Social-ecological system change and adaptation: A case of Chilika lagoon small-scale fishery, India

by

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Author's Declaration

"I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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ABSTRACT

Coastal lagoons are highly productive ecosystems and many fisher communities depend on the ecosystem services for their livelihoods. Unfortunately, due to anthropogenic stressors these lagoons are undergoing severe environmental changes that are impacting local fisher communities. To cope and adapt to with the changes in lagoon social-ecological systems, fisher communities are using their local knowledge. Using Chilika lagoon on the east coast of India near the Bay of Bengal as a case, I examined a range of drivers that have caused changes in the social-ecological system of the lagoon and the various adaptation options fishers consider when faced with extreme environmental and social changes. In particular, I analyse the role of local fishers' knowledge in crafting various adaptation strategies.

Semi-structured and focus-group interviews were used to collect data in the field over a three month period. Analysis of qualitative data showed that the major drivers of changes in the lagoon are: a) opening of new sea mouth; b) change in fishing techniques; and c) increase in shrimp aquaculture. Results showed that there are no long term adaptation strategies in the fisher community, and the adaptation strategies themselves act as drivers of change in the social-ecological system. Communication gaps and conflict between the fisher communities is further limiting adaptation in the fisher community.

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Ashok Selvaraj

Waterloo, Ontario

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DEDICATION

To my parents

Mr. & Mrs. Selvaraj & Bavani Selvaraj

and

To my siblings

Anandaraja, Prabhu and Ezhil Akka

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CHAPTER 1: INTRODUCTION

1.1.Background

Coastal lagoons are "dynamic ecosystems dominated by physical characteristics, such as shallowness, relative isolation and the presence of boundaries with strong physical and ecological gradients" (Ruzafa et al., 2006; Pg: 107). The water exchange between the sea and the lagoon through the sea mouth determines whether the lagoon is a salt water or a fresh water lagoon. If the sea mouth is bigger, lagoons tend to be primarily marine, or if the lagoon sea mouth is smaller the lagoon will be a fresh water lagoon. Coastal lagoons support diverse aquatic organisms by providing them a favourable environment for survival.

The natural productivity of coastal ecosystems depends on regional land cover and basin land use patterns. Changes in these could modify the hydrology of lagoons, strongly influencing water catchment and storage, drainage rates and biodiversity maintenance (Pérez et al., 2003). In recent decades, coastal ecosystems have suffered a serious decline worldwide due to human influence (Pérez et al., 2003). Declining water quality, drainage, eutrophication and catchment disturbances such as development, loss of natural vegetation and poor agricultural practices are changing the fundamental ecology of lagoon systems in much of the world (Pérez et al., 2003). Among these aquatic ecosystems, coastal wetlands have been subject to significant environmental degradation and habitat destruction worldwide (Pérez et al., 2003).

Several regions across the world have suffered large landscape transformations, including the loss of around 25 ha of wetland per minute in the US from 1780 to the mid-1990s, and the rapid, wide-ranging changes in land cover currently occurring throughout the tropics. For example,

more than 50% of the original area of coastal wetlands that existed in 1900 have been lost in most countries of Western Europe (Pérez et al., 2003; Garrido et al., 2011).

The main drivers for these changes to lagoon and wetland ecosystems are not a result of climate change, but other more direct anthropogenic activities. Factors like land-use change, freshwater withdrawal from ground and surface water sources, sedimentation, point and nonpoint water pollution, shoreline hardening, and overfishing are examples of anthropogenic stressors that can have profound and sudden impacts on coastal ecosystems (Anthony et al., 2009). For example, salinity change and ecological degradation have occurred in the Chelem lagoon, Mexico because of anthropogenic activities like construction of roads, creation of artificial connection with the sea, the presence of an old municipal dump and urban waste water discharge (Herrera-Silveria & Morales-ojeda, 2010). Other examples include the degradation of sea grasses (submerged aquatic vegetation) due to high levels of tourism in the Nichupte and Bojorquez lagoons in Mexico (Herrera-Silveria & Morales-ojeda, 2010), and the degradation of the Pulicat lagoon in India because of industrial pollution (Coulthard, 2008).

Among the different anthropogenic stressors, aquaculture is a significant driver of change in many coastal lagoons of the world (Osuna, 2001). Aquaculture has been a particular challenge since the 1970s, when capture fisheries in many locations did not meet the growing demand for fish in local and global markets (Nayak & Berkes, 2011). This decline in the capture fishery brought aquaculture development to the forefront (Nayak & Berkes, 2011). Aquaculture has historically degraded estuarine water quality in many regions of the world. Farmed shrimp, for example, contributed 27% of worlds total shrimp production in 1995 with a volume of 712000 tonnes. Around 80% of that total came from Asia (Primavera, 1997).

It is estimated that 1-1.5 million ha of coastal lowlands have been converted into shrimp farms, mainly in China, Thailand, India, Indonesia, Philippines, Malaysia, Ecuador, Mexico, Honduras, Panama, and Nicaragua (Osuna, 2001). Undoubtedly, the shrimp culture industry earns value in the foreign market for developing countries and generates jobs across the industry from fry gatherers to growers and processors. However, grave socio-economic consequences – including conversion, expropriation and privatization of mangroves and other lands; salinization of water and soil; decline in local food security; marginalization of coastal communities, unemployment and urban migration; and social conflicts – have followed in the wake of shrimp farm development (Osuna, 2001; Primavera, 1997).

India holds a wetland area cover of about 58.2 MHa (UNICEF et al., 2013). Natural wetlands in India include the high-altitude Himalayan lakes; wetlands situated on the flood plains of the major river systems; saline and temporary wetlands of the arid and semi-arid regions; and coastal wetlands such as lagoons (Chilika Lagoon), backwaters and estuaries; mangrove swamps; coral reefs; and marine wetlands (UNICEF et al., 2013). However in the last decades, India has lost 38 per cent of its wetlands with the loss rate being as high as 88 per cent in some districts (UNICEF et al., 2013).

The biophysical changes in the ecological sub-system that are mentioned earlier in this section may not affect the population in the urban areas. But certainly those changes impact the local communities that depend on the ecological sub-system for their livelihoods. For local fishing communities, a reduction in ecosystem services from lagoons means a reduction in the fish production in the ecosystem that they depend on. As a result, those communities face livelihood crises, as is the case in Chilika lagoon. To conclude, local communities that depend on the

ecosystem for their livelihood suffer when there are even a minor changes in the social-ecological system (i.e., lagoons) on which they depend on.

1.2.Research context

The Chilika Lagoon is the largest brackish water lagoon of Asia, which is situated on the east coast of India, in the state of Orissa (Rajawat et al., 2007). Unfortunately, like most lagoons of the world, Chilika lagoon is also facing a series of problems, which by the 1990s impaired many of its uses. Major problems are related to a decreased salinity in the lagoon, caused by a narrowing of the lagoon mouth. The gradual choking of this outlet to the sea was a result of the accumulation of sediment entering the lagoon from the drainage basin. There is also a general increase in pollution from agriculture in the Chilika lagoon (Nayak, 2011). Traditional fisher folks were particularly hard hit by these problems. In addition, there is a decline in fish production that has led many fishers to change their fishing techniques. New fishing techniques consist of nets with small mesh size capable of catching juvenile fish and shrimp, thereby putting even greater pressure on the fisheries and further complicating the problems. Compounding the difficult situation was the change in government policy regarding: a) the lease of fishing grounds, which resulted in the loss of access of traditional fishing grounds in the fisher community to the non-fisher community; and b) the associated promotion of commercial shrimp aquaculture. As a consequence of these changes there have been some violent clashes and several deaths in communities in the Chilika lagoon (Ghosh & Pattnaik, 2006).

In Chilika, fishing communities rely completely on the lagoon for their livelihood. This relation between the fishers and the lagoon forms a linked 'social-ecological system' (Nayak & Berkes, 2012). Social-ecological systems are interconnected systems in which the human system is recognized as an integral part of the natural system (Anderies et al., 2004). Both the social and

ecological sub-systems and their feedbacks play a crucial role in the stability of the system. In other words, human actions affect biophysical systems, and biophysical factors affect human well-being, which signifies their interconnected nature (Anderies et al., 2004; Nayak, 2011). In Chilika lagoon, changes in the ecological sub-system negatively impacted the fishing communities that rely on it for their daily livelihood (Nayak & Berkes, 2012). As a result, communities must continuously adapt to changing social-ecological conditions.

Adaptation is the ability to learn and adjust to changing conditions. Denevan, (1983, pg. 401) define the process of adaptation as "one by which groups of people add new and improved methods of coping with the environment to their cultural repertoire". There is a not a single driver but multiple drivers in the process of adaptation, and they include social, economic, cultural, political and environmental drivers (Smit & Wandel, 2006). These drivers are intertwined, which means communities must adapt reactively to changes or proactively before projected changes occur (Smit & Wandel, 2006). To analyse the adaptation strategies used by the fisher communities it is necessary to analyse both the social and the ecological sub-system. Moreover, to analyse this constantly changing social-ecological systems we need local knowledge because that knowledge is influenced by and reflects environmental, social and economic realities.

The term 'local knowledge' can be defined as "dynamic and complex bodies of know-how, practices and skills that are developed and sustained by peoples/communities with shared histories and experiences" (Beckford & Barker, 2007, Pg. 118). Most of the practical skills and wisdom of local knowledge is developed through experience in and earning livelihoods from the environment (Brook & McLachlan, 2008). To analyze the recent ecological changes, their consequences and the adaptation strategies used by fisher communities, local knowledge is essential because it is developed through this lived experience.

1.3.Purpose and objectives of the study

Over the past several decades, the link between the human system and the natural system has been degraded drastically by the influence of multiple anthropogenic stressors. The most impacted population as the result of changes in social-ecological systems are the communities that directly depend on the natural system for their livelihoods. As a result, communities that are directly dependent on the natural system must adapt to changing conditions. Hence, the purpose of my research is to understand how a fisher community (*Nohlia,* in the village Khirishai) in the Chilika lagoon is able to understand and adapt to the social and ecological changes they confront. Three objectives further guide my research:

1. To examine the key social and environmental changes in Chilika Lagoon and their driving forces. In regards to this objective, I seek to analyse the key social and environmental changes occurring in the lagoon and their drivers, to provide a broad perspective of what are the root causes of the social-ecological degradation in the Khirishai lagoon system.
2. To analyze how fisher communities in Chilika Lagoon perceive major social and environmental changes. Here I draw on the local ecological knowledge of fishers to understand the ongoing process of change in the lagoon system.
3. To analyze the strategies used by fisher communities to cope and adapt to the social and environmental changes. This objective involves examining the adaptation strategies used by the fisher communities, and to determine which adaptation strategies may be successful and which are not.

1.4. Organization of thesis

This thesis is organized in a total of six chapters as follows:

Chapter 2 discusses the literature on which this thesis is based on, with a particular focus on environmental change, social-ecological system, and adaptation.

Chapter 3 outlines the study area and the methodology. This chapter introduces the research village that is the focus of the thesis. The chapter discusses the research methods that have been used to collect the data for this research and sampling methods used to recruit the participants. It further discusses the difficulties with community-based research.

Chapter 4 discusses the social-ecological changes and drivers influencing the research village. This chapter includes a discussion of the different change in the physical and the chemical properties of the lagoon and the drivers behind the changes.

Chapter 5 outlines the key outcomes of the changes and the adaptation strategies being used by the fishers to adapt to the changes.

Chapter 6 offers discussion and conclusion. This chapter summarizes the current situation of the social-ecological system of the lagoon and the research village. The chapter also offers recommendations from the fisher themselves on ways to improve the social-ecological system and their well-being.

CHAPTER 2: LITERATURE REVIEW

This chapter discusses the theories and concepts on which this thesis is based. Specifically, I discuss about the concepts of environmental change, social-ecological system, local knowledge and adaptation.

2.1. Ecosystem structure and function

Ecosystems are defined as the places on earth that consists of biotic components (living organisms) and abiotic or physical components (climate, geology, soil) (Frances et al., 2001; Hooper et al., 2005). These components of ecosystems interact with each other to produce a dynamic set of processes and structures. Ecosystems may have a wide range of scales; they can be as small as a pond or extend thousands of kilometers (e.g., the boreal forest) (Frances et al., 2001). Characteristics and interactions of the abiotic and biotic components of ecosystems vary according to the type of ecosystem and their spatial and temporal scale (Frances et al., 2001). Hooper et al., (2005) discuss the general functioning of ecosystems as including: ecosystem properties; ecosystem goods; and ecosystem Services.

Ecosystem properties are the processes in the ecosystem. Such as decomposition, maintenance of biological diversity, biological productivity, biogeochemical cycling and storage, etc. (Christensen et al., 1996; Hooper et al., 2005). Ecosystem goods are parts of ecosystems that provide economic values, including for example food, construction material, animal breeding, medicines, tourism and recreation, etc. (Christensen et al., 1996; Hooper et al., 2005). Ecosystem Services are the benefits that are derived from ecosystem, include provisioning (e.g., food, water), regulation (e.g., climate regulation), cultural (e.g., spiritual, aesthetic) and supporting (e.g.,

primary production) (Frances al., 2001; Hooper et al., 2005; Millennium Ecosystem Assessment, 2005). For example, lagoons are a major providers of ecosystem services (Chapman, 2012).

2.1.1. Environmental change

A variety of organisms in an ecosystem play a crucial role in ecosystem functioning. Biodiversity of the ecosystem determines the ecosystem functioning of a particular ecosystem. Christensen et al., (1996, pg. 671) defines biodiversity as "Biological diversity is the variety of life and its process including the variety of living organisms and the genetic differences among them, as well as the variety of habitats, communities, ecosystem and landscapes in which they occur". Some roles of biodiversity in ecosystem functioning, includes: 1) essential processes 2) ecosystem resistance to and recovery from disturbances and 3) adaptability to long term changes in environmental conditions (Christensen et al., 1996). Christensen et al., (1996, pg. 675) defines that "Ecosystem stability is the rate of return after perturbation and the ability of an ecosystem to resist the forces of change acting on it". When faced by any disturbances (internal or external factor) biodiversity aids in stability against disturbances and helps recovering from the disturbance, hence preventing disturbance on ecosystem functioning. That is biodiversity (variety of species) makes ecosystems resilient to disturbances Christensen et al., (1996).

Slight fluctuations are normal in an ecosystem. However, now extreme fluctuations have become normal in ecosystems. But changes that are occurring today in the earths' ecosystems is something different that has not occurred before (Christensen et al., 1996). These fluctuations or changes are not caused by some other living organisms but primarily by human beings. Human beings interact with the ecosystem to get benefits from the goods that are produced by the ecosystem by various processes. But human beings utilize the ecosystem in an unsustainable manner, which is degrading the quality and quantity of the ecosystem. Devaluation and

overexploitation of ecosystem is one of the negative outcomes in the process of development which generated enormous benefits to the human society. The rate of degradation of ecosystems by human beings is significant and increasing every day. Human domination over the ecosystems coupled with the increase in human population has pushed the ecosystems to a state of desperation (Acevedo-Whitehouse & Duffus, 2009; Liu et al., 2007; Loreau et al., 2001; Vitousek et al., 1997).

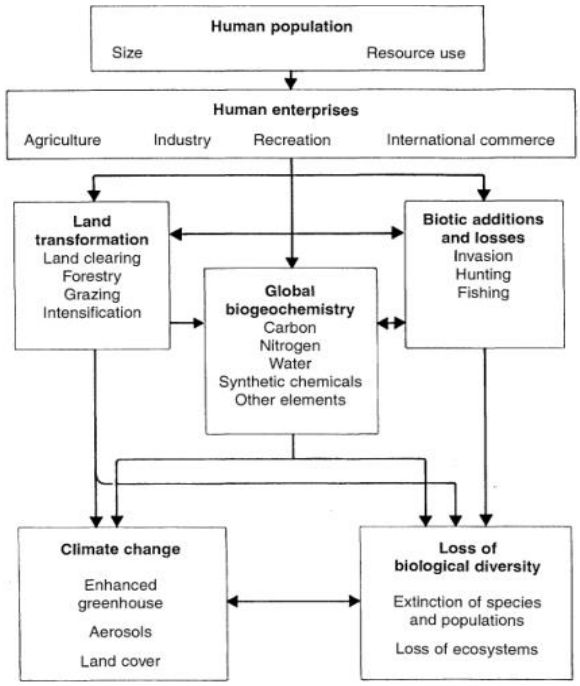

Figure 2.1: A conceptual model illustrating humanity's direct and indirect effect on the earth ecosystem; Source: Vitousek et al., (1997), Pg: 494.

"Environmental change is the human induced decline in the quality or quantity of a renewable resource that occurs faster than it is renewed by the natural processes" (Homer Dixon, 1994, Pg. 8). Vitousek et al., (1997) illustrated through a conceptual model (Fig. 2.1) how humanity directly or indirectly impacts the ecosystem. Human population grows and the demand for the resources increases for the food and shelter and other purposes. These resources are provided to humanity by various types of human enterprises by using the suitable ecosystem for agriculture, fishing and industry. Some of the resources are the biotic properties of ecosystem, like fishing. But activities like agriculture involve transformation of land. So ecosystems like forests are cleared and replaced with cropland, hence producing the desired resource for the humans. These change in the land use and biotic losses or addition of ecosystem alters the global biogeochemical cycles. These change influence climate change and loss of biological diversity. One of the best example of human impact on ecosystem is the marine ecosystem which was once thought to be inexhaustible is now under

severe threat because of human activities (Christensen et al., 1996). 60% of the human population is located within 100 km near coasts (Vitousek et al., 1997). It is estimated that 50% of the mangroves of the coastal ecosystem has destroyed by human activity (Vitousek et al., 1997).

Many changes in ecosystems in turn make ecosystems vulnerable to change. When an ecosystem is vulnerable they are prone to more changes, even when a slight disturbance is made whether it is an internal factor or an external factor. Global changes affects important functions of the ecosystem like the ecosystem properties, ecosystem goods and ecosystem services (Luque et al., 2013). Huntington et al., (2009) explains that" vulnerability is often defined as a function of the sensitivity of a system to change, its exposure to change and its adaptability to change".

Environmental change is an important factor to study because environmental change impacts both the ecosystem and the human depending on it, as humans depends in the ecosystem services provided by the ecosystem. Environmental change acts as a driver for change in the ecological sub-system and social-subsystem. So to study the change in the social-ecological system, environmental change has to be researched. To study the social-ecological system both systems have to be studied, and environmental change is an important factor that helps to analyse the ecological system. Hence, it also leads to the analysis of social sub-system which depend on the ecological system. Especially lagoons around the world and lagoons like Chilika are facing severe environmental changes that are caused by the anthropogenic stressors, which are affecting the basic ecosystem functions like ecosystem properties, ecosystem goods and ecosystem service. By studying the environmental changes it will lead us to find the drivers. And also studying the changes will help us analyse the changes impact on the ecosystem function which the social system depends. This requires us to analyse both the ecological system and the social system in an integrated manner.

2.2. Social-ecological system

When talking about the impact of environmental changes on the ecosystem, we cannot exclude the human society that benefits from the ecosystem. Human beings are integral part of the ecosystem, which is called social-ecological system. These systems are not individual systems, but they function as a coupled, interdependent, and co-evolutionary systems that are equally important (Berkes, 2011). Berkes, (2011; Pg: 9) defines that "social-ecological system as an integrated complex system that includes social (human) and ecological (biophysical) system in a two-way feedback relationship". Social-ecological systems are complex, which exhibit different levels of linkages at different levels of a scale. Scale refers to the spatial and temporal dimension of a pattern or a process in the ecological system (Cumming et al., 2006). Both the system act dependent of each other, so ecosystem cannot be properly understood by excluding the human component that shapes nature and in turn shaped by nature because social and ecological components are intertwined and evolving across the spatial and temporal scale (Folke, 2006; Zurlini et al., 2006). Perry et al., (2010) in their research used marine ecosystems to explain how difficult it is to understand the driving forces that are causing changes in the marine ecosystem without considering both the human and environment system.

In the social-ecological system, the human component dominates the ecological system. Society plays an important role for the changes in the ecosystem component of the social-ecological systems. Human dominance over the ecosystem has altered the natural ecosystem process. Anthropogenic activities have profoundly altered the ecosystem that they are interacting with (Zurlini et al., 2006). The changes are global in spatial scale and far-reaching in extent. The changes range from modifications of the atmosphere and the climate to the degradation of habitats through vast exploitation of lands and seas, and the massive introduction of non-native species and

chemical contaminants around the world (Luque et al., 2013). Humans have pushed the planetary support beyond the bound of what is observable in the paleo-climate record. Young et al., (2006; Pg. 306) states "Survival of the social-ecological system has become increasingly dependent on the resilience of their social dynamics in contrast to their purely biophysical dynamics". This is because social actor's decisions are crucial for the survival of the ecosystem as environments were homogenised by humans to bring the environment under their control.

Nelson et al., (2007) elaborates that whatever the nature of the change like social, biological or physical, it will affect the feedback and relationships within the social-ecological system. Some systems shows resilience towards the disturbances. Resilience is the ability of a system to absorb the disturbances and still stay in the position where it was before the disturbances (Walker and Meyers, 2004).

Usually a system tends to be in an equilibrium position. When a system is disturbed internally or externally, the system losses or move to a reduced equilibrium state (Walker and Meyers, 2004). So when the equilibrium of the system is lost the system changes (For example: Conversion of forest into a grassland after a forest fire, when the equilibrium of the forest ecosystem in disturbed by the forest fire. During the forest fire the biodiversity of the forest is lost, making it to unable to retain the equilibrium in the forest ecosystem. But the system moves towards the basin of attraction where the system can become a stable grassland ecosystem) (Walker et al., 2004). Homer Dixon, (1994) extensively discussed the changes that are caused by the anthropogenic stressors. He mentioned some of the main changes: depletion of fisheries, degradation and loss of forests to agriculture land, depletion and pollution of water supplies. Homer Dixon, (1994) also talks about the environmental scarcities that results from the environmental change. He classified environmental scarcities in three dimensions, they are: 1.

Supply induced scarcity; 2. Demand induced scarcity; 3. Structural scarcity. Madrid et al., (2013) says that an element becomes resource when it is useful or provide service to a specified end user (E.g.: Water). An acute consequence brought by resource scarcity is conflict. The diagrammatic illustration (fig. 1.2) by Homer Dixon, (1994) explains the casual pathway to conflict.

In figure 1.2, Homer Dixon, (1994) mentioned three pathways to environmental scarcities. Decrease in quality and quantity of the renewable resource (fish, water, etc.) occurs because of the destruction of the ecosystem. When the ecosystems are disturbed their functions are disrupted which leads to the decrease in ecosystem service. This category comes under the supply-induced scarcity which is promoted when the resources are extracted and degraded more than they are renewed.

Population growth is another major aspects in environmental scarcity. Increasing population increase the demand on ecosystem services which creates the demand-induced scarcity. When the resources are controlled by handful of people, while remaining population suffer from

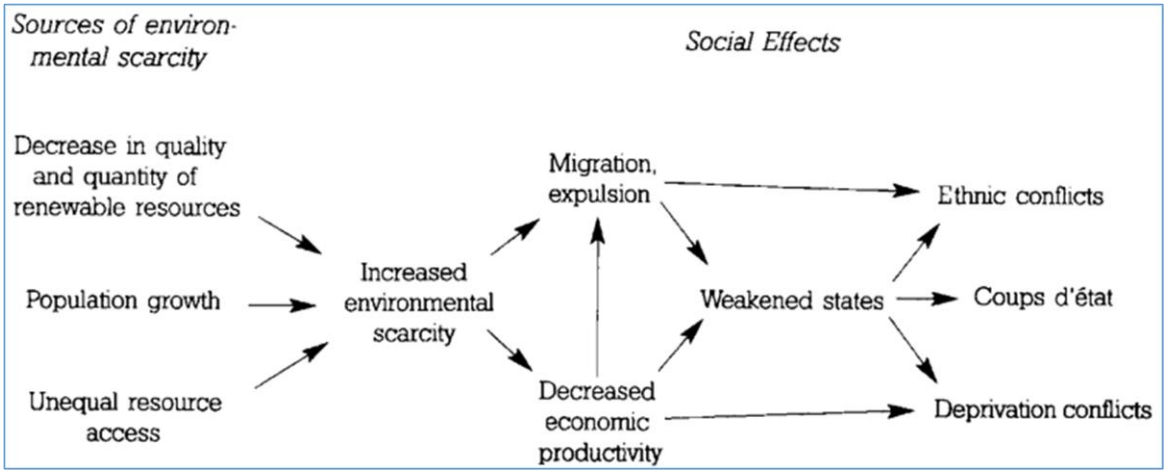

Figure 2.2: Some Source and Consequences of Environmental Scarcity; Source: Homer-Dixon (1994), Pg: 31

resource shortage causes unequal resource access. There is an alarming increase in the unequal resources access because of the ecosystem degradation and other factors. These changes create

pressure in the indigenous communities depending directly on the ecosystem for their livelihood. When the resource becomes scare these communities face economic crisis, for example, as is the case often with indigenous fisher communities. Communities are marginalised, lose their livelihood, which may push them to a weakened state that might cause ethnic conflict (Homer Dixon, 1994).

Chilika lagoon has a strong social-ecological factor that is embedded into their fishing system. It is important to study both the social and ecological sub-systems, as each of them is influenced by the other. To analyse the social sub-system of the Chilika fisher community it is important to understand the ecological sub-system (lagoon) which they depend on for their daily livelihood. As the ecological sub-system is dominated and controlled by the social sub-system, any change in the ecological sub-system is due to the change in the social sub-system and vice versa. Also the way the ecological sub-system is being maintained by the social sub-system can explain the status of the social sub-systems. So in the case of Chilika lagoon, social and ecological sub-systems are intertwined in a complex manner that makes it difficult to separate the system (figure 2.3). To study the changes and the adaptation strategies it is necessary to study the social-ecological system of the fisher community. Also to study the conflict it is important to study both the sub-systems as

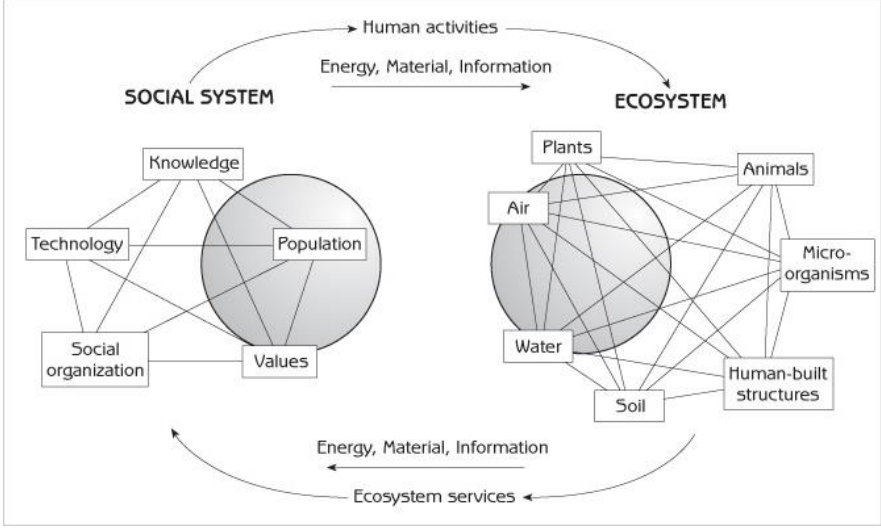

Figure 2.3: Interaction of human social system with the ecosystem; Source: Marten, 2001; Pg. 2

the root cause of conflict is mainly because of the scarcity in the ecological sub-system caused by the sub-social system.

2.3. Adaptation

Communities when faced with social-ecological changes tend to adapt. Stringer et al., (2009, Pg: 749) defines adaptation as *"Adaptation is a process of deliberate change, often in response to multiple pressure and changes that affects people's life"*. When there is a change in the social, economic or ecological change, people take actions either long term or short term actions to adapt, so that they can live. Before adapting communities try to cope with the changes, which allows them to quickly respond to the changes in the system and prevent the system from moving to a new state or condition. Coping can be adjustments that are short term and reactive in nature (Nelson et al., 2007). But when the frequency of change in the system is increased it will erode the coping ability of the system. As a result, system moves to a new state or is unlikely to return to its previous state, communities respond by adapting to the changes (Nelson et al., 2007; R. I. Perry et al., 2011). The actions or outcomes in a system to adapt or cope can come from household, community, group, sector, region and country (Smit & Wandel, 2006; Smit et al., 2000). Grafton (2010; Pg: 609) defines social adaptation in the context of fisher community "social adaptation is how communities and networks of fishers and stakeholders collaborate to respond to change". He also explained the importance of social adaptation: 1. it integrates and brings together different knowledge sets and experience; 2. sharing of risk across stakeholders; 3. helps in the collective decision making. There are two main types of adaptation (Adger et al., 2005). First is unintentional adaptation which takes place without any strategies, second one is the purposeful adaptation. Unintentional adaptation helps in the delay of purposeful adaptation by reducing the change in the system. In the context of fishing unintentional adaptation may consists of fishing for

longer time which can prevent the change in the fishing technique, or it may be loans which will reduce the economic crisis faced by the fisher because of the changes. Both purposeful and unintentional adaptation has short term and long term benefits. Bryant et al., (2000) identifies four components of adaptation, they are:

- Characteristics of stress: the kind of stress, impacting the community (e.g. environmental factors, economic conditions, government policies, etc.).
- System characteristics: facts that influence the adaptive capacity of the system which include local biophysical, cultural, technological, economic, political and institutional factors.
- Scales of system vulnerabilities and responsibilities: How big is the system, so that adaptive responses can be taken at different scales.
- Adaptive responses: what are the strategies used to respond to the changes.

Perry et al., (2011) discussed the two types of strategies that are used to adapt to the change regardless of stress on the system. So he and his colleagues used the marine social-ecological system case study to illustrate the strategies.

- Fast short term respond
- Slow but persistent long term response

In fisheries, some fast short term responses of the ecological system are migration and distribution, species composition, change in diet, growth conditions (R. I. Perry et al., 2011). Long term responses in the ecological system are change in life history characteristics and restructuring. In the social sub-system of the fisheries short term responses are intensification of effort, diversification, migration and riding out the storm (R. I. Perry et al., 2011). Some long term

responses identified by Perry et al., (2011) among fisher communities are capacity building, community closure and political reforms (R. I. Perry et al., 2011).

But not all the strategies are beneficial to the community. Intensification of efforts will increase the pressure on the remaining resources, which ultimately reduces the resource for the future. These kinds of adaptation strategies which are short term tend to create unintentional impacts on the other natural and social system (Adger et al., 2005). Adger et al., (2005) discussed the effectiveness of adaptation. Effectiveness of adaptation is always changing because the actions may depend upon the future social, economic condition and also on the ecological conditions. But there are two indicators that helps to identify the effectiveness of adaptation strategies, they are:

- Robustness to uncertainty and
- Flexibility or ability to change in response to change in response to altered circumstances

When there is a change in social-ecological system adaptation becomes an integral part of the system to maintain the system. However, not all successful adaptation strategies used by a particular community will produce similar results when used by another community. Adaptation strategies can increase the vulnerability of a community instead of helping them to deal with ongoing change processes, which is referred to as maladaptation (Barnett & O'Neill, 2010; Scheraga & Grambsch, 1998). Maladaptation is often termed as "the problem of increasing risk from adaptation" (Barnett & O'Neill, 2010; Pg: 211). Maladaptation occurs because of the avoidant reaction (e.g., denial of the threat, wishful thinking, fatalism), which leads to the increased vulnerability of the system (Grothmann & Patt, 2005). As a result of maladaptation, communities become more vulnerable to changes in the social-ecological system.

The type of strategy that a community is using to adapt to changes in the social-ecological system is important because of the possibilities of maladaptation that can make the system more vulnerable to changes. If the adaptation strategy is maladaptive then the social-ecological system of the community will become vulnerable and even a slight change will impact the system profoundly. In this research I have focused on the adaptation strategies used by the fisher community and analysed what worked and what did not, thereby leading to maladaptation.

2.4 Summary

In the following chapters, I draw on this literature to guide my analysis of environmental changes and their drivers that affect the social-ecological system from a village level perspective. I use local knowledge to analyse fishers' perceptions of the ongoing social-ecological changes in Chilika Lagoon. I also analysed the strategies used by the fisher of Khirishai to adapt to the changes, and which strategy worked and not through the lens of local knowledge.

CHAPTER 3: STUDY AREA AND METHODOLOGY

3.1. Introduction

This chapter discusses the study area and the methods used to collect the data during the three-month field visit to Chilika lagoon. The first section of the chapter discusses the general geographical features, demographics and the biodiversity of the Chilika lagoon, and further discusses the research village and criteria for choosing that particular village for this research.

The second section discusses the methods employed to collect the data. Utmost care was taken to choose the right methodology for collecting the data from the fisher and the non-fisher villages. Also the chapter discusses the benefits of using a participatory approach and how the researcher aimed to reduce bias (e.g., ideology, preconceived notions, and predetermined research objectives) while conducting semi-structured and focus-group interviews. Further, I discuss the sampling methods and the challenges faced in the while doing community-based research in Chilika lagoon.

3.2. Study area

Chilika Lagoon, (19°28’-19°54’ N latitude and 85°05’-85°38’ E longitude) located on the east coast of the state of Odisha, India, is the largest lagoon in Asia (Ghosh & Pattnaik, 2006; Iwasaki & Shaw, 2008). Its size fluctuates substantially within the course of a year, with a maximum area of 1,165 km^2 during the monsoon season and a minimum area of 906 km^2 during the dry season (Sekhar, 2004). The catchment has a tropical climate, with average maximum and minimum annual temperature of 39° C and 14° C (Ghosh & Pattnaik, 2006). The southwest monsoon brings much rain during June-September, while the northeast monsoon brings some rain during November-December. December-February is the winter season, and March-May is the hot season. The lagoon is a well-known wintering site for migrating birds; approximately half of the

over 211 species recorded are intercontinental migrants from various parts of Asia, including the Caspian Sea, Lake Baikal and Siberia. The lagoon is the one of two lagoons in the world that is home to the Irrawady dolphin (Ghosh & Pattnaik, 2006). Its rich biodiversity, along with the beautiful scenery of the area, attracts many bird watchers and Eco tourists. Chilika lagoon supports around 337 fisher and non-fisher villages. Among the 337 villages, 150 of the villages are fisher villages. More than 400,000 fishers, belonging to specific caste groups, customarily depend upon the lagoon for their livelihoods (Nayak & Berkes, 2010, 2012). The four major fisher castes in the Chilika lagoon are *Kaibartya, Khatia, Kandra and Tiara* (Nayak & Berkes, 2010). The Chilika lagoon ecosystem also supports nearly 800,000 non-fisher villagers (Nayak & Berkes, 2010, 2012). The lagoon is also extremely important for the local population especially for the fisher communities as a source of livelihood (mainly through its fisheries) and also as a focus for cultural, religious and spiritual activities.

As my research is a village-level study, I choose the fisher village of Khirishai, which is on the island of Khirishai, and located in the central sector of the lagoon close to the sand bar which separates the Chilika lagoon from the Bay of Bengal (Figure 3.1).

Figure 1.1: Chilika lagoon basin with different sectors; Source: Ghosh and Pattnaik, 6002; Pg. 1

The island of Khirishai has two villages: Khirishai and Banabaspur. However, because the village of Khirishai is the more highly populated village on the Island, it is called as Khirishai. Khirishai is a fishing village, and the fishers of Khirishai belong to the *Nohlia* caste. Fishers of Khirishai migrated to Chilika Lagoon some two hundred years ago.

"Our forefathers migrated to Chilika some 100 to 200 years ago"

- *Focus group Interview (Fisher, Khirishai; August)*

Because people migrated to the village in different time periods, there is no specific knowledge about when they migrated to Chilika lagoon. *Nohlia* caste fisher is from the State of Andhra Pradesh, which is situated to the south of the state of Odisha. *Nohlia* people are sea going fishers, but when they migrated to Chilika, they started lagoon fishing. Nevertheless, unlike other fisher communities in Chilika they only fish during particular months in the lagoon and spend the rest of their time sea fishing, see section 4.1.1.

My criteria for choosing Khirishai as my field site are as follows:

- Nohila is a minority community than compared with other fishing communities in Chilika lagoon, this means they are considered less among the other fisher villages during decision making.
- Khirishai is impacted by both aquaculture and opening of the new sea mouth and therefore the magnitude of impact on the village is higher.
- People in Khirishai practice both sea and lagoon fishing. As a sea going fisher community it was possible to understand changes taking place in the sea in addition to the lagoon.
- This village is under studied.

3.3. Methodology

3.3.1. Qualitative and participatory research approach

I used qualitative approach in my research, because my research is solely based on how the local fisher community understands and adapts to the changes they are facing in their daily life. In order to understand the perception of the fisher community in the Chilika lagoon, a qualitative technique is one of the best approaches. However, a qualitative approach has its own disadvantages because the results can be biased according to the researches personnel influence. But apart from this drawback, Cresswell (2014) outlined several advantages which make the qualitative approach the preferred methodological approach for my research. Some of the advantages are:

1. ***Natural setting:*** Data is collected in the field at the site where participants experience the issue or problem under study. Working in a natural setting makes the participants feel comfortable when answering researcher questions, hence generating more information about the current situation of the lagoon.
2. ***Researcher as key instrument:*** Collecting data themselves through examining documents, observing behavior, or interviewing participants. Thus gives the researcher a more realistic experience of what is the real situation in the field, apart from listening to the informants.
3. ***Multiple sources of data:*** Researchers gather multiple forms of data, through interviews, observations, documents, and audiovisual information, rather than rely on a single data source. Generating information from different sources includes observing the activities undertaken by the fishers, and being involved in other social activities in the villages (festivals).

4. ***Data analysis:*** Both inductive and deductive data analysis can be done. In this research I tried to relate my observations with the theory which helped me to understand the theory itself and on the other hand theory helped me to understand the changes.
5. ***Holistic account:*** Qualitative researchers try to develop a complex picture of the problem or issue under study. This helps to provide a clear picture of the current issues and how complex the issues are.

My research also employed participatory techniques in the context of a qualitative approach. What made my research participatory is the depth of involvement of participants in the research process (Bagnoli & Clark, 2010). The participatory aspects involved two types of interview 1) semi-structured interviews and 2) focus group interviews. All the information were collected from interviewing diverse fishermen and non-fishers. The amount of fisher involvement and the information gathered from them made this research more community-based and participatory. Data was collected from research participants and was categorised according to the research questions presented in Figure 3.2.

My research is a case study. Case study is a relevant method for my research because it focused on the contemporary phenomenon within some real-life context which involved the questions of "how" and "why" (Yin, 2014). The case study method is 'an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident' (Yin, 2003, pg: 13). My research question revolves around how the changes are occurring, what has caused these changes, and how the fisher community is adapting to the changes.

As discussed earlier in this section, qualitative techniques have many advantages which make it useful for community based research. However, qualitative techniques have some disadvantages (Choy, 2014):

- Qualitative research requires a skilled interviewer to successfully carry out the data collection because as interviews have to be carried in a manner that will reduce the bias and keep the participants in track of the research objective, as the semi-structured and focus-group interview are open-ended interviews. For the interview to be efficient and informative I used a guide during the interview which helped me to direct the conversation towards the research objective.
- Another limitation is the influence of researcher's knowledge and experience on observations and conclusions. Sometimes, researchers make conclusion about a situation according to their own observation in the field, which might not be right in participants view. In order to eliminate this type of bias I verified all the observation and conclusion with the help of data collected during the semi-structured and focus-group interviews.
- Another potential problem with qualitative technique is that some problems or issues may be left unnoticed. As some interviews last for longer time durations the researcher may leave some issues unnoticed in the interest of time. If explored further and more time is allocated more information about the topic can be generated. To eliminate this bias in this particular research, all the interviews were recorded, and the researcher listened to the recorded interview before proceeding to another interview so that missing elements can be addressed in the next interview.

3.3.2. Research Framework & Analysis

In this section I discuss a framework that has been used to design this research (See Figure: 3.2). The framework is adapted from (Smit et al., 2008) and it helped me to outline my research objectives as my research is based on changes in both the social sub-system and the ecological sub-system and related responses and adaptation measures in the fisher community. I considered this framework as a two-step research objective. The first step is the current vulnerability, which helped me to focus on the ongoing changes in the social-ecological system and led me to the analysis of the drivers which impacted the social-ecological system. The second step of the framework helped me to analyse future changes in the system. The framework also helped to find the key elements that are needed to accomplish this research (e.g., local knowledge, stakeholder involvement (fishers)) and arranging the findings in order. It provided guidance in selecting the relevant literature for this research. It also showed the connection between environmental change and social-ecological system and their relation with adaptation.

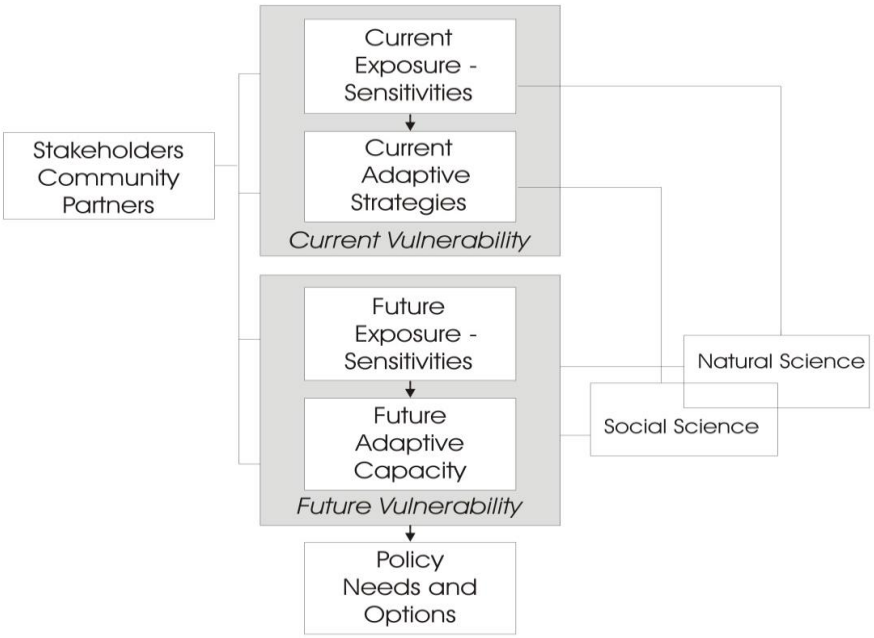

Figure3.2: Key elements (Source: adapted from: Smith et al., 2008. Pg.6)

3.3.3. Data collection

I used multiple data collection methods which were carried out in two phases. The first phase of the data collection was through the review of secondary sources. The second phase was the participatory approach, which included semi-structured interviews and focus group interviews. Two participatory approaches were employed in the second phase to minimize bias and to increase the credibility of the information's collected. Further, focus group interviews also helped in the triangulation to confirm and verify the results. Table. 3.1, provides an overview of each research objective, the associated sub-questions and the data sources for each.

Table 3.1: Research Objectives, Sub-questions and data sources

Objectives	**Sub questions**	**Data type**
To examine the key social and environmental changes in Chilika Lagoon and their driving forces	• What are the key social and ecological changes in the lagoon? • What are the driving forces for the social and ecological changes in the lagoon? • How does the environmental change affect the social system of the lagoon? • How does the changes affects the lagoon system	Secondary data, Semi structured interview
To analyze how fisher communities in Chilika Lagoon perceive major social and environmental changes.	• What are their perception about the social and ecological changes? • How the changes affects their day to day life? • How does the environmental change affect their connection with the lagoon	Semi structured interview, focus group discussion
To analyze the strategies used by fisher communities to cope and adapt to the social and environmental changes	• What strategies are used adapt to the changes? • What are the problem faced in the process of adaptation? • How does adaptation help them	Semi structured interview and Focus group discussion

3.3.3.1. Semi structured interview

In a semi-structured interview, a guide is used with questions, which cover the topics that are being researched (See Figure 3.2). It also gives interviewer or researcher some discretion about the order in which questions are asked. Nevertheless, the questions are standardized, and probes may be provided to ensure that the researcher covers the correct material. This kind of interview collects detailed information in a style that is somewhat conversational. However, semi-structured interview help the researcher to delve deeply into a topic and to understand thoroughly the answers provided (Harrell & Bradley, 2009). Semi-structured interviews are well-suited for the exploration of the perceptions and opinions of respondents regarding complex and sometimes sensitive issues and enable probing for more information and clarification of answers (Barriball & While, 1994).

In my research, I used semi-structured interviews to collect data from the fisher and non-fisher community members based on a predetermined set of questions (Annexure I). Given the different communities, the predetermined questions were changed for non-fisher community. An interview guide was used to start the discussion with some open-ended questions. The open-ended questions made the interviewee feel comfortable during the interview and provoked some useful information. I used a snowball sampling technique to recruit participants for my research. Potential participants for the study were listed from the people that I interviewed who provided names of people that I could approach for additional interviews. One of the disadvantages in this method is the reduction in the quality of data and selection bias because of problems of representativeness and sampling principle as the elements are dependent on the respondent and are not randomly drawn (Atkinson & Flint, 2001). In this research this bias was addressed by interviewing fishers from different villages and also some participants were randomly selected to reduce the bias.

The study involved diverse fisher and non-fisher respondents. All the participants were male and were chosen randomly without any predetermined condition like age. This allowed me

to access the perception of people of different ages from 25 to 70. Some 50 semi-structured interviews were conducted in distinct fisher and non-fisher villages, but the majority of the interviews were conducted in the research village of Khirishai, with some interviews in different fisher villages, including Berhampur, Banabaspur, Biripathar, Banamalipur, Badukul and Balugaon, and the non-fisher villages of Jarakatta (Table.3.2). Interviewing fishers from different part of Chilika lagoon helped to cross-check the information gained through semi-structured interviews and focus group discussions from different fisher villages, and hence, triangulating my information from different villages, which also helped in finding bias in the information gathered. Information gained from the semi-structured interviews gave clear insight how to conduct the focus group discussions.

Table 3.2: Number of semi-structured interview conducted and the different villages for the study

Name of the village	**Number of semi-structured interviews**
Fisher Village	
Khirishai	42
Banabaspur	1
Berhampur	2
Banamalipur	2
Biripadar	2
Non-fisher Village	
Jharakata	1

3.3.3.2. Focus group discussion

With the information gained from the semi-structured interviews I proceeded towards the focus group interview. Focus group discussions are a powerful research tool for collecting qualitative information across many contexts. Focus groups are structured or semi-structured meetings with a small group of individuals (i.e., ‘‘informants’’ or ‘‘participants’’) that allow for the exchange of information, opinions, and feedback related to a single topic (Harrell & Bradley,

2009). The focus group is uniquely suited to helping members of specific groups articulate their beliefs, values, desires, concerns, aspirations, and needs in ways that produce richer insight, and with greater community representation than is often achieved via other common assessments of group perceptions, needs, and knowledge (Harrell & Bradley, 2009). The results focus groups generate provide insight into past, present, or future actions; the why of those actions; and the meaning individuals assign to them. Information from focus groups also complements quantitative research by illuminating existing data or by generating ideas for new inquiry (Harrell & Bradley, 2009).

Focus group discussions are a very effective method for research in the fisher communities that are characterized by caste and class. Interviewing a group of people with different caste and gender will create bias in the information. Women may sometimes not speak in the presence of men which shows the hierarchy of men and women. If the interview group consists of people from higher caste and lower caste, the voices of the lower caste will be less during the interview because of the hierarchical social system. In the context of a gender and caste-based system, different gender and caste groups have different perceptions about environmental, economic and social changes. The fishing communities which are the lower caste will have different perception about the lagoon system because their life is dependent on the resources of the lagoon. The higher caste people who are engaged in shrimp aquaculture will have different perceptions of the lagoon system. The same difference prevails with respect to gender.

Keeping this disadvantage in mind, I moved forward and conducted focus group interviews in the fisher village. To reduce the bias and associated hierarchy that is prevalent among people in Chilika lagoon, care were taken to not conduct the focus group interviews in a mixed caste group environment. Only the fishermen belonging to the same caste were included in the focus group

interview. Six focus groups were conducted with fishermen belonging to different castes in different fishing villages like Banabaspur, Biripathar, Badukul and Khirishai (See Table.3.3). Some of the participants of the focus-group interview were the participants of the semi-structure interviews. The other participants were recruited using the snowball method.

Table 3.3: Name of the village and the number of focus-group interview conducted for the study

Name of the Village	**Number of focus group interview**
Khirishai	3
Banabaspur	1
Biripathar	1
Badukul	1

Data about the ecological sub-system was collected using semi-structured and focus groups interviews. The interviews started with the question of "what are the changes that you are experiencing in the lagoon". This allowed the fishers to talk about the ecological changes that are happening in the lagoon. This also led to discussions about the social sub-system as people frequently shifted to talk about social changes that directly or indirectly resulted from the ecological changes. Field observation made during three months of field research gave me additional clarity on the ecological changes.

I used the framework (See Figure 3.2) to analyse my data. It offers an outline of how to arrange the information. I used focus group interviews to both validate information gained from semi-structured interviews and to get new information about the changes in the social-ecological system. Field observation helped me to analyse both the social sub-system and ecological sub-system of Khirishai and Chilika lagoon.

3.4. Local knowledge

When analysing the social-ecological system of a community it is important to get the perspective from people who are involved or part of the social-ecological system. When communities face changes in the social-ecological system they tend to respond and/or adapt by using their local knowledge. Local knowledge is a "dynamic and complex bodies of know-how, practices and skills that are developed and sustained by peoples/communities with shared histories and experiences" (Beckford & Barker, 2007, pg. 118). Failing et al., (2007) explained three characteristics of local knowledge:

- Local knowledge is typically experience-based, relying more (but not exclusively) on personal observation than on quantitative data and controlled experimentation.
- Local knowledge tends to be expressed in ways that are more holistic (often reflecting eco systemic properties) and less reductionist than that of western science.
- Local knowledge is usually anchored firmly in the experience of place, and as such it tends to deal with particular things rather than categories of things, and time and context specific observations and conclusions rather than fixed or generalizable rules.

Local knowledge varies between communities in different ecosystem. For example, in coastal lagoons, the traditional communities have knowledge about lagoon ecological system and fishing and in forest ecosystem the traditional community knowledge pertains to the forest. Local knowledge helps in decision-making when the community is in the midst of a changing social-ecological system. Local knowledge helps in identifying the indirect and direct impacts that can be caused by a proposed action. This property of local knowledge is essential for adapting to the changing social-ecological system. As it is experience based, communities can clearly sort out the

necessary action for the management of the social-ecological system (Failing et al., 2007). Berkes & Folke (2001) further clarify that for the management and sustainable use of resources and ecosystem, ecological knowledge and understanding of how the ecosystem works are essential for responding to the changes that are impacting the system. The book "Voices of the poor crying out for change by Narayan et. al., (2000) shows how useful it is to incorporate people's perception of change. They have used perceptions to analyze the wellbeing of different communities from different countries. Their research shows how local knowledge can be useful in finding the degradation of social-ecological system and the drivers causing the changes.

Local knowledge is one of the best ways to analyse the change in social-ecological system. As traditional fisher community of Chilika lagoon, the knowledge held by the fishers about the lagoon is of immense value. As my research is mainly based on the fisher perception of the changes in the lagoon, use of local knowledge is essential. As local knowledge is gained through experience it is easy to identify the past and the current changes that are happening in the social-ecological system.

CHAPTER 4: KHIRISHAI'S CHANGING SOCIAL-ECOLOGICAL SYSTEM

Fishing is an activity which involves both social and ecological sub-systems. In the context of Khirishai's social-ecological system created by fishing. This chapter discusses the drivers that are causing changes in the social-ecological system of Khirishai.

4.1. Social-ecological system of Khirishai

Social and ecological systems are interconnected, complex in nature and cannot be studied separately (Folke, 2007; Holling, 2001). A social-ecological system is the two-way interaction between social sub-system and sub-ecological system. Any change in one of the sub-systems will impact the other sub-system. The level of interaction between the systems changes according to spatial and temporal factors (Berkes, 2011; Cumming et al., 2006; Folke, 2007).

For centuries, people of Khirishai have depended upon their lagoon for their livelihoods. Their day-to-day activities revolved around the lagoon and its resources. This created an interaction between the social sub-system and the ecological sub-system in Khirishai. The traditional fishing technique used by the people of Khirishai is called "*Kadijala*". The fishing nets that they used were made of cotton, which is a biodegradable material, causing no damage to the environment. *Kadijala* also creates positive economic growth in the community. As the fishers know how to fix their own nets, they do not have to buy new ones, thus rendering it more cost effective. The mesh size of the nets is quite large (3-4 cm), allowing only the matured fish to be caught, and leaving behind the juvenile fish for the future. Besides this, their fishing norms (see Section 4.1.3) include catch & release methods, which involves the release of small fish and other aquatic organism back into the lagoon that are caught in the net while fishing. The community of

Khirishai's historical interaction with the lagoon is largely sustainable, and it has prevented the collapse or degradation by avoiding negative feedback in the social-ecological system. The sections below discuss three factors that highlights the interaction between the social sub-system and the sub-ecological system in Khrishai: 1) fishing technique, 2) fishing equipment, and 3) social norms.

- Fishing activity is a direct interaction between the social sub-system and the ecological sub-system.
- Fishing technique can help to understand whether the interaction between the sub-systems is positive (For example, traditional techniques may promote sustainability which creates a positive interaction in the social-ecological system).
- Any change fishing techniques can help in analysing the changes in the social or the ecological sub-systems that leads to a subsequent change (e.g., in the fishing techniques, and also highlights the impact on the social-ecological system after the change in the technique
- The type of the fishing equipment used for fishing can explain the interaction in the social-ecological system (for example, traditional fishing techniques of fishers in Khirishai consist of fishing nets made of cotton, which is eco-friendly. However, new fishing techniques consist of nets made of nylon which is non-biodegradable and more expensive)
- In Khirishai norms and rules were created for the well-being of the ecological sub-system and social-subsystem. A breach in social norms can be detrimental to the social-ecological system of Khirishai and encourage adverse changes in the system.

4.1.1. Positive interaction of social system with the ecological system by different fishing techniques

People from the *Nohlia* community are predominantly from the state of Andhra Pradesh (see section 3.2). They were historically sea going fishers. However, when they migrated to Chilika lagoon they started practising lagoon fishing. After some years of migration lagoon fishing became a part of their custom.

"Before coming to Chilika we were doing sea fishing, but we started lagoon fishing after we migrated to Chilika lagoon some two to three centuries ago from Andhra Pradesh"

- *Focus Group interview (Fisher, Khirishai; August)*

As their island is located near the sand bar that separates the lagoon from the Bay of Bengal, they gained easy access to the sea. Their sea fishing is a group activity where it involves more than four fishers per boat. As their boats are not like trawlers or other fishing boats used for commercial fishing, they don't perform deep sea fishing. They only perform fishing along the coast. Around 80% of the semi-structured interviews I did with the Nohlia community fishermen revealed that usually they have been sea fishing during October to February months, and engaged in lagoon fishing during March to the end of September.

"We don't fish in the deep sea. We only go to a distance of about 100-300 metres into the sea for fishing"

- *Khalu Behera (Fisher, Khirishai; June)*

Even though they are sea going fishers, the Nolia community of Khirishai do not fish in the deep sea. As it has been mentioned by a fisher in the above quote, they only fish within a distance of about 100-300 metres from the shore. The fishing space is near the coastline, which prevents the conflict with the commercial trawlers. Sea fishing has not only benefited the

fishermen economically but it also has created a positive feed-back on the ecological system of the lagoon.

Studies have showed that in Chilika lagoon during the month of November and December, the fresh water and the saline waters retreat and becomes favourable for photosynthesis (Jeong et al., 2008). High photosynthetic activity promotes the growth of macrophytes in the lagoon. Macrophytes act as a bio-indicator of wetland ecosystems (Chilika Development Authority, 2001). Not only are macrophytes an excellent bio-indicator but also they provide ecological service such as:

- shelter to fish
- shelter to aquatic invertebrates and
- Breeding grounds to the water birds.

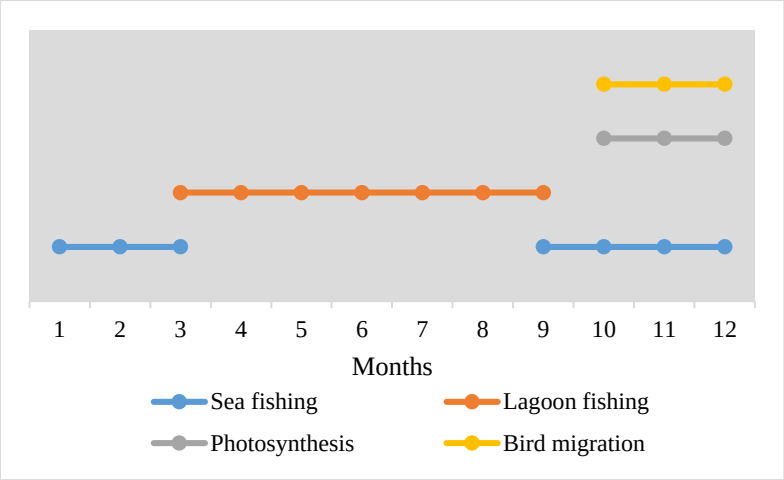

Figure 4.1: Relation between Khirishai's fisher community fishing technique and photosynthesis and migration of birds

The limnological character of the lagoon, migration of birds and photosynthesis are related to Khirishai fisher fishing calendar (See Figure 4.1). Migratory birds come to Chilika during the month of November and December to breed and evade the winter in Siberia. The seasonal fishing calendar of Khirishai's fishermen is unique, creating a positive feed-back in the social-ecological system because they don't fish in the lagoon during the months of November till February (Source: 10 semi-structured interviews). This strategy by the fishermen in Khirishai reduces the negative feedback in the ecological sub-system during a time of recovery in

the lagoon. Similar practices have been noticed in other fisher villages in the study area (Nayak, (2011). But Khirishai is distinct as they are not a traditional lagoon fisher caste but they changed their fishing practices after migrating to Chilika. Studies done by Nayak, (2011) showed that other fisher villages in Chilika undertake crab fishing instead of catching fish during the fish breeding season. Such practices promote sustainability and preservation of future stock. These two stages of fishing season practised by Khirishai's fisher shows a mutually beneficial feedback cooperation between the social sub-system and the ecological sub-system. As a process it creates a 'positive' feedback within the social-ecological system, hence promoting sustainability through their local knowledge. The implications of practising combined sea fishing and the lagoon fishing on the social-ecological system is presented in the table. 4.1.

Table 4.1: Implication of different activities on the social and the ecological system

Social and the ecological sub-systems activity	**Months**	**Implication on the social sub-system**	**Implication on the ecological sub-system**
Sea Fishing	October to February	Regain their sea fishing skills	Reduces pressure the lagoon ecosystem from being overfished.
Lagoon fishing	March to September	Regaining their lagoon fishing skills	Reduces pressure the sea ecosystem
Migratory birds	November and December		Improves the ecological system of the lagoon
Period of high photosynthesis	November to December	Increase in help in the rejuvenation of macrophytes which	Provides favourable condition for the reproduction of fishes in the lagoon

		promotes the reproduction of fishes	
Fish Breeding	High during the period when there are more macrophytes	Livelihood of fishermen is fish. More fish, more potential for income for fishermen	The higher the fish production, stronger the food chain in the lagoon.

**Source: Semi-structure, focus group interview and secondary sources*

4.1.2. Fishing equipment as a social-ecological system indicator

Another good example of how people of Khirishai interact with the ecological system and how positive feed-back is created on the ecological system by the Khirishai's social system is the use of traditional fishing boats for fishing. Oil pollution is now an emerging issue in Chilika which is primarily caused by the motorised boats. Fishers in Khirishai use the traditional fishing boats made of wood. The boat is specifically built for lagoon fishing. Even though many fishermen in other fishing villages are using diesel driven motors to move their boats during fishing in lagoon, fishers of Khirishai are maintaining their traditional technique. They use a long bamboo stick to move the boat which does not produce any noise, and there is also no oil spills or other toxic material released from the traditional boats. On the other hand, the motorized boats make noise and leave oil spillage which is harmful to the environment.

There are around 2259 motorized boats in Chilika (Baliarsingh et al., 2014). These motorized boats are predominantly used for fishing with a smaller number used for tourism purposes. The benefits of using traditional boats and motorized boats are presented in Table. 2. When compared with the motorized boats these boats are eco-friendly and sustainable (Table. 4.2).

Table 4.2: Impacts of using motorized and non-motorized boats in Chilika lagoon

Factors	Boats used in Khirishai	Motorized Boats
Chemicals	No harmful chemicals are released during fishing because bamboo sticks are used to move the boats	Oil and diesel are released from the motor. The oil has polycyclic aromatic hydrocarbons which can affect the aquatic organism in the lagoon (Baliarsingh et al., 2014).
Impact on migratory and other birds	Traditional boats do not create noise like the motorised boats which scares the birds	Oil spilled from the motor may impact the birds by creating problems in the insulation. Hence preventing them from flight (Baliarsingh et al., 2014).
Impact on Irrawaddy dolphins	Zero noise pollution from the traditional boats and it does not lead to any oil spill.	Oil may block the blowhole of the dolphin and also it might enter the lungs (Baliarsingh et al., 2014).
Photosynthesis of phytoplankton's	No fishing during the period of high photosynthesis in the lagoon (November-December)	The spilled oil residue form a thick layer on the water preventing the light to penetrate through the water that reduces the photosynthesis activity of phytoplankton which serves as the lifeline of the lagoon (Vazquez-Duhalt, 1989)
Heavy Metals	No heavy metals	Oil contains heavy metals like Pb, Zn, Cu, Cr, Ni and Cd (Vazquez-Duhalt, 1989).
Toxic Effect	No toxic effect on the environment	*"the diesel goes into the pregnant fish mouth and affects the small fishes inside its stomach"* - *Jambu Behera (Fisher, Khirishai)*

Noise Pollution	No noise is created during fishing	Noise is created while fishing as the fisher quotes: *"The noise from the motor scares the fishes, and they will move to some other place"* - *Chandra Behera (Fisher, Khirishai)*
Impact on fish	No negative impacts on the fishes	Impact on the fish due to oil spill (Baliarsingh et al., 2014).

**Source: Semi-structure, focus group interview and secondary source*s

As discussed in the table. 4.2, traditional fishing technique benefits the ecological system, hence creating a positive loop in the social-ecological system.

4.1.3. Social norms promoting positive feedback on the ecological system

Most fisher communities in Chilika lagoon, including Khirishai, have rules and norms that govern life in the villages and people's interaction with ecosystems. The Khirishai community has a set of rules to govern both the social sub-system and the ecological sub-system. The community established set of rules to guide the fishing group's behaviour and fishing activity. Some of the community rules and their implication are listed in Table. 4.3. The first two rules in Table. 2 (no fishing in the lagoon channel and no fishing near the sea mouth) might seems like it only benefit ecosystems. However they also serve to prevent the conflict with other community fishers. As noticed by Iwasaki & Shaw (2009), traditional rules and norms are put in place to prevent the occupational competition between other caste fishers in the lagoon. This is because fishing near the sea mouth or in the lagoon channel may prevent the movement of fishes, shrimp and other aquatic species to other fisher's traditional fish landing sites. By not fishing there, the rules allow the free flow and proper distribution of fish and other organisms to other parts of the lagoon, which are the livelihood for other fisher communities. The third rule is known as 'catch and release'

which helps in sustaining the fish production in the lagoon by not killing the juvenile fish and other aquatic organisms. The fourth rule (equal sharing), promotes strong social relationships among the community members. Ultimately, these rules and norms creates a positive feedback between the social-ecological systems.

Table 4.3: Community rules and their implications

Rules	**Implications**
No fishing in the lagoon Channel	Lagoon channels act as a highway for the fish, shrimp and other aquatic organisms to enter the lagoon. Usually, fish moves through the channel either to reach the sea or to enter the lagoon for reproduction. By not fishing in the lagoon channel, these promote the reproduction of fish and other aquatic organisms, and hence promote sustainability.
No fishing near the sea mouth	Sea mouth is the door for the entry of fish and other aquatic organism into the lagoon. If fishing activity is performed near the sea mouth, it reduces the fish, shrimp and other organisms entering the lagoon.
Catch & release fishing	Fish, shrimps and other organism which are caught in the nets are analysed. If they are small, they are released back into the lagoon hence preserving future fish and shrimp stocks.
Equal share	*Kadijala* is a group activity where four or more fishers join together and fish. There is no hierarchy in fishing. Resources that are caught while fishing are equally shared

	among the fishers who went together for fishing.
No stealing	Stealing or damaging other fishermen's fishing equipment is prohibited in the village.
Sea fishing	Sea fishing should be carried out during the months of October till the end of February
Community fund	Each fisher family of the village has to contribute to the community fund which is used for conducting community festivals and other ceremonies.

**Source: Semi-Structure & focus group interview*

In recent decades, the social-ecological system of this village has been increasingly threatened and degraded by several environmental changes. The forthcoming sections will discuss what those drivers of change are and how they are influence the social-ecological system of Khirishai.

4.2. Drivers of Changes

The Millennium Ecosystem Assessment, (2005: 64) defines drivers as *"Natural or human-induced factors that directly or indirectly cause a change in an ecosystem"*. Ecosystems are affected by the drivers which negatively impact the ecosystem services, on which the human beings depend (Millennium Ecosystem Assessment, 2005). The divers can be global or local, but drivers have the capacity to change ecosystems (Nayak & Berkes, 2012). This section of the thesis discusses the drivers that have caused social-ecological system degradation in Khirishai. Most of the drivers are human-induced factors. The drivers of change in Khirishai are discussed in the following section, and include: opening of new sea mouth; shrimp aquaculture; changes in the fishing techniques; commercial trawlers; road construction; and population growth and policy.

4.2.1. Influence of new sea mouth on Khirishai's lagoon

Coastal lagoons are connected to the sea by an opening which are commonly known as a sea mouth. A sea mouth maintains the inflow and outflow of marine and fresh water, which in turn balances or maintains salinity and other physical, chemical, biological properties of the lagoon. The sea mouth in a lagoon is of great importance as it is the life line of the coastal lagoon. Any disruption or alteration in the sea mouth affects the physical, chemical and biological properties of the lagoon. The prosperity of the lagoon fisheries also depend in large part on the sea mouth (Reddy, 1977). In Chilika, the inner channel that serves to connect the outer channel to the lagoon is called '*mugger mukh'* (Dujovny, 2009). Dujovny (2009) explained how the old sea mouth worked. The old sea mouth was strategically located with sharp turns in the channel, which slowed down the sea water while entering the lagoon hence maintaining the properties of the lagoon. But in the 1990s the old sea mouth started to close because of some natural factors (Dujovny, 2009). As a result of the choking of the lagoon sea mouth, the salinity of the lagoon changed, and eutrophication and fresh water weed infestation increased.

Because of these factors the fishers in the lagoon faced a decline in the fish stock. To stop the crisis among the fisher and to save the lagoon, the government intervened with the help of the Chilika Development Authority (CDA) and planned to open a new artificial sea mouth. On September 23, 2000, a new sea mouth was dredged with an effective width of 240 metres and a depth of 5.5 metres (Dujovny, 2009; Mohapatra et al., 2007). Apart from the opening of new sea mouth they also extended the prevailing lagoon channel *mugermukh* about 22.5 km for better salinity and flushing out of sediments (Mohapatra et al., 2007). As a result of the new sea mouth, the distance between the core part of Chilika lagoon and Bay of Bengal was reduced by 18 km (Dujovny, 2009). The new sea mouth helped in solving salinity and other issues in some parts of

Chilika lagoon. However, it brought forth other new issues and compounded the prevailing issues in the Chilika lagoon. Interviews with the fishers of Khirishai showed that their lagoon has been impacted by the opening of the new sea mouth. Some of the drivers for the impacts are discussed sections below.

4.2.1.1. Geographical location

Chilika Lagoon is divided into four sectors according to a varying salinity gradient, including a northern, central, southern and outer channel (Dujovny, 2009). Khirishai is located in the central part of Chilika near the sand bar, which separates the lagoon from the Bay of Bengal. Before the opening of new sea mouth, Khirishai was situated around 25 km from the old sea mouth (Fig. 4.2). After the new sea mouth was opened, conditions changes significantly, because the distance between Khirishai and the sea mouth was reduced, and it became exposed to the sea water, and tides more than before. Research by Dujovny (2009) showed that the distance between the core part of lagoon and the outer channel was reduced by 18 km. Data collected through interviews highlights that the change in the geographical location has caused three major problems in their lagoon. These problems are 1) change in salinity; 2) change in tidal influx; and 3) change in the lagoon channel. The section below discusses these drivers of change and their impacts on the biodiversity and the fisher community of Khirishai. Interviews with the fishers of

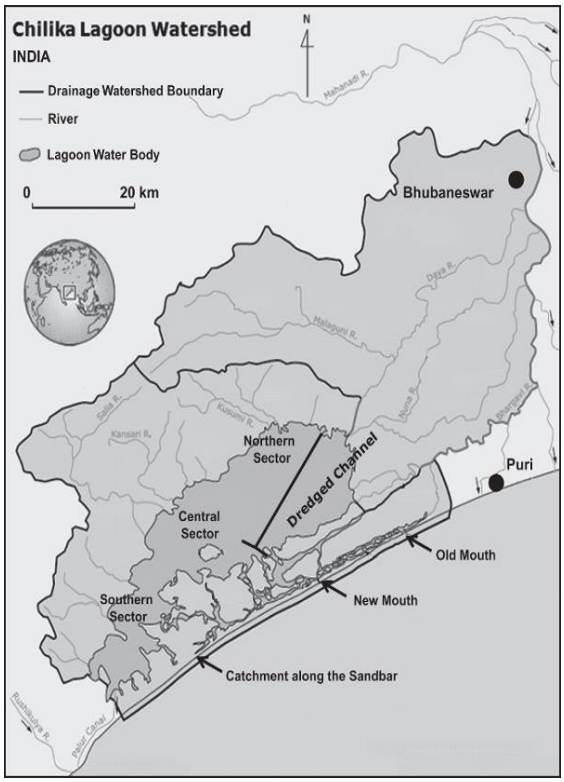

Figure 4.2: Map of Chilika lagoon showing the new sea mouth and the dredged lagoon channel; Source: Ghosh and Pattnaik, 2005, Pg. 1

Khirishai reveal that the government did not consult or include them in the decision making process for the opening of a new sea mouth.

4.2.1.2. Change in salinity

"Opening new sea mouth has created many problems in Chilika"

- *Ragunath Behera (fisher, Khirishai; July)*

For a lagoon to be brackish, the salinity should be between 5-20 parts per thousand (Dujovny, 2009). The salinity of a particular location depends upon the location of the place. The other main factor that determines salinity of a particular area is its distance from the sea mouth and fresh water flow (Panda et al, 2013). Locations near the sea mouth are usually highly saline because of the sea water inflow from the sea mouth. Further into the lagoon the salinity decreases because of the fresh water inflow from the river tributaries. Researches have shown that the sea entrance of the lagoon plays a major role in the salinity maintenance of the lagoon (Panda et al., 2013), and that salinity regime changes according to the type of lagoon.

Lagoons are of three types, namely: 1) choked, 2) leaky and3) restricted (Bjourn Kjerfve, 1994). This categorization is based upon the lagoon entrance, apart from other factors like wind, tidal influx and the rate of fresh water inflow (Bjourn Kjerfve, 1994). The lagoon barriers are formed by the process of sedimentation by the sea and by the sediments of the river. However, these lagoon barriers are breached by storm waves or flooding water trying to escape the lagoon (Bird, 1994). Bird (1982) explained that cutting or enlarging of an entrance to a lagoon can have geomorphological and as well as ecological consequences.

About 90% of the fishers interviewed in Khirishai stated that the salinity of the water has changed in their lagoon after the opening of new sea mouth. Fisher knowledge about the lagoon is

strong and they can detect small changes in the properties of the lagoon water. The quotes below from the villagers highlight, their perception about change in salinity in the lagoon.

"In the past when we are fishing the water tastes somewhat normal, but now water in the lagoon tastes too much of salt"

- *Jagannath Behera (Fisher, Khirishai; June)*

"Now-a-days fishing in the lagoon has become uncomfortable because high salt in the water is causing itchiness on our body"

- *Nachia Behera (Fisher, Khirishai; August)*

When I asked them about the possible reason for the change in the salinity, they pointed out the location of the new sea mouth, and the reduction in the distance between their island and the new sea mouth as the driver for the change in salinity.

"Before the opening of new sea mouth our island is far from the sea mouth. But after the opening of the new sea mouth our village got closer to the sea mouth. Which made our lagoon salty"

- *Khasinath Behera (Fisher, Khirishai; June)*

Not only did the new sea mouth affect the chemical properties of the lagoon, but it also negatively affected the aquatic organisms in the lagoon. Changes in salinity has decreased the fish population in their lagoon according to fishers in Khirishai. Indeed, salinity is an important factor for the survival of fish. After the increase in salinity in Khirishai's lagoon, the population of fish species that are vulnerable to salinity reduced.

"After the salinity was increased the fish were not able to live in our lagoon, so they went in search of new places to live in the lagoon"

- *Sarath Behera (Fisher, khirishai; July)*

"The fish feel uncomfortable after the salt increased in the lagoon water and sometimes fish and crab die because of the high salt in the water"

- *Nachia Behera (Fisher, Khirishai; August)*

The statement by the villager's shows how important salinity is to the survival of the fish. Fish are the main source of livelihood for the fishers.

4.2.1.3. Change in the tidal flux

A sea mouth is formed by sea tidal waves or by the flood water coming from the river (Bird, 1994). The sea mouth or the lagoon entrances are so important that changes in the entrance to the lagoon can change the tidal ventilation and also the salinity of the water. The higher the tide, the larger the amount of sea water entering into the lagoon and increasing the salinity of the water (Bird, 1994). When asked about any particular change that happened after the opening of new sea mouth that resulted in the increase in the salinity, most of the fishers pointed the increase in the tidal flux.

"Before the new sea mouth we are far from the sea and the tide are not big. But after the new sea mouth the tides got bigger and the speed of the tide has increased. This caused more sea water entering into the lagoon daily causing the change in the salinity"

- *Focus group interview, (Fisher Khirishai; August)*

Because they are working in the lagoon, they experience the increase in the tidal velocity after the opening of new sea mouth. Scientifically it has been proven, that in Chilika lagoon the central sector near the lagoon channel has shown a higher velocity range of about 5-15 cm/s (centimeters per second) (Jayaraman, Rao, Dube, & Mohanty, 2007). The increase in the tidal velocity coupled with the increasing size of the new sea mouth has changed the salinity regime of the lagoon (Jayaraman et al., 2007; Panda et al., 2013).

"When the new mouth was opened it was small but when days passed by it started expanding and started moving towards the old sea mouth"

- *Mukhundha Jally (Fisher, Banamalipur; June)*

The natural expansion of new sea mouth is documented by Panda et al., (2013). When dredged in September 2000, the new sea mouth was 80 m but it widened about 680 m by 2004 (Panda et al., 2013). The new mouth is still expanding and moving in a northeast direction (Panda et al., 2013). Interviews with the fishers of Banamalipur which is near the sea mouth revealed that the sea mouth is expanding and moving.

"When the new sea mouth was opened it was around 100 metres but after sometime the size of the sea mouth increased and is still increasing. Now it is more than a kilometre long and it is moving to its right side (North east) towards the old sea mouth. In few years it might reach the old sea mouth which was opened naturally"

- *Jagannath Jena (Fisher, Banamalipur; July)*

When asked about how the new sea mouth is expanding and moving towards the old sea mouth, they highlighted the increase in the tide.

"The tides form a circle of water which erodes the sand in the right side which make it to expand and move towards the old sea mouth"

- *Jagannath Jena (Fisher, Banamalipur; July)*

The quote by the fisher shows that the sea mouth is maintained by the tidal waves. As a consequence of the heavy tidal influx, the salinity of Khirishai lagoon was changed and also brought about other damages, like 1) reduction in the shrimp and fish seeds; and 2) movement of fish and shrimp seeds to deeper areas of Chilika.

4.2.1.4. Reduction in the fish and shrimp seeds

As per the Chilika Development Authority (CDA) report, the amount of fish and shrimp landing in the lagoon has increased. However, various studies showed that fish and shrimp production has reduced in the lagoon due to changes in the ecological system (Dujovny, 2009; Nayak et al., 2014; Nayak & Berkes, 2010). Interviews with fishers show that fish and shrimp seed landing has been reduced in their lagoon, and also in the Chilika more generally. The prime reason for this change is the alteration in the tidal velocity.

"Fish and shrimp seeds are coming through the new sea mouth but they are pushed back into the sea by the high tide"

- *Kandha Behera (Fisher, Khirishai; August)*

Tide plays a vital role in the dispersion of the seeds. The velocity of the tide increased the amount of fish, shrimp and other aquatic organism's seeds come into the lagoon, yet at the same time they are pushed back into the sea. This has resulted in the reduction of fish and shrimp seeds in the whole lagoon and also in Khirishai lagoon, because they are located closer to the sea mouth and the tidal velocity is higher in that area.

Another impact of the increase in the velocity of tide is the poor distribution of fish and shrimp seeds in the lagoon. Because of the increased velocity, the fish and shrimp seeds are pushed to deeper area of Chilika. This reduces the landing of fish and shrimp seeds in the Khirishai are of the lagoon because they are located near the sea mouth.

"Fast tides are pushing the fish and shrimp seeds into deeper Chilika"

- *Siba Behera (Fisher, Khirishai; June)*

4.2.1.5. Sand infestation

Another major concern for the villagers is the sand infestation of their lagoon. Main driver of sand infestation is the increase in the tidal velocity which has resulted because of the opening and widening of a new sea mouth. As the tidal velocity has increased, it promotes more sea sand to enter into the lagoon. With the old sea mouth they did not experience this change because the velocity of the tide was decreased gradually by the outer channel. As the new sea mouth nullified the function of the outer channel, the lagoon has become directly exposed to the sea water and tide. Khirishai is situated near the sea mouth and their lagoon is getting infested by the sand from the sea. This has impacted the Khirishai lagoon adversely.

"Now-a-days our lagoon is filled with sand instead of clay because of the new sea mouth and the high tide. Also our lagoon depth has reduced"

- *Focus group interview (Fisher, Khirishai; August)*

Clay and sand composition are very important in the lagoon. A proper proportion of sand and clay provide favourable conditions for the distribution of the fish and other aquatic organisms (Franco et al ., 2006). In Khirishai, as the fishers mentioned, the proportion has changed after the opening of new sea mouth. Once dominated by clay, the lagoon floor is now dominated by sand. As a consequence of the sand infestation, the depth of lagoon has been reduced drastically, and many parts of their lagoon have become shallow in the past years because of sand infestation. Sand infestation has also caused improper depth in the lagoon. The lagoon which was once deep is now shallow, and the shallow parts are now becoming deeper.

Sand infestation has reduced the fish, crab and other organism population in their lagoon because their lagoon has become unfavourable for their survival. Fishes and other organisms need deep water and proper clay composition for their survival and reproduction. As one fisher said:

"The fishes are not coming to our lagoon for playing because the depth of our lagoon has reduced and they don't have any good place for playing. They are moving to other parts of Chilika"

- *Gurunath Behera (Fisher, Khirishai; July)*

In the above quote, "not playing" means they are not reproducing in their lagoon. This shows that their lagoon has lost the qualities that fish and other aquatic organisms need for reproduction and surviving. The change in depth has also changed the fish movement in the lagoon.

"When fish see the change in depth in the lagoon they think they are going towards the land. So they move to some other place which is deeper than our lagoon"

- *Dushana Behera (fisher, Khirishai; June)*

4.2.1.6. Impact of lagoon channel

Apart from geographical location, dredging of lagoon channel has also impacted Khirishai adversely. Lagoon channels act as a highway for fish to enter and exit the lagoon through the sea mouth (Jones and Sujansingani, 1950). The channel helps the fish to navigate towards the lagoon. During the dredging of the new sea mouth, the government also increased the length of the prevailing *muggermukh* by dredging it for another 22.5 km. However, the channel is so long and it does not pass near Khirishai, preventing the movement of the fish to Khirishai lagoon. Fish and other aquatic organism use the lagoon channel and bypass Khirishai by reaching directly to the central part of the lagoon.

"Fish and shrimp are coming through the sea mouth to the lagoon but because of the channel they are directly going to the deeper Chilika"

- *Sarath Behera (fisher, Khirishai; July)*

The channel promoted fishing near the sea mouth and also in the channel. Usually, according to the customary rights, fisher are not allowed to practise fishing in the lagoon channel.

But after the opening of new sea mouth, fisher and non-fisher villages near the sea mouth were motivated by the potential economic gain and started fishing in the lagoon channel, which has drastically reduced the landing of fish to other parts of Chilika. Khirishai as a village near the sea mouth and not being connected by the lagoon channel is affected by the fishing in the lagoon channel.

4.2.2. Implications for the Khirishai's social-ecological system

Major environmental changes and their consequences in Khirishai are outlined in the Table. 4.4. One of the problems that has emerged as a result of these different drivers of change is the lack of fishing space in Khirishai.

Table 4.4: Key changes and their consequences being experienced in Khirishai's lagoon after the opening of new sea mouth

Opening of New Sea Mouth		
Key Changes	**Consequences**	**Results**
Increase in tidal velocity	-Pushes the fish and shrimp seeds into deeper Chilika -Reduction in the landing of fish and shrimp seeds in the lagoon -Reduction in the food for fish and other aquatic organism	Loss of livelihood, reduction in the available fishing space, intensification of fishing
Increase in Salinity	-Water became unfavourable for the survival of fish and other aquatic organisms	
Sand infestation	-Change in the depth of the lagoon -Lagoon clay floor is dominated by sand	

	-No place for the fish reproduction	
Dredging of Lagoon Channel		
Fish and shrimp seeds are landing directly in the deeper Chilika	-Reduction of fish landing in Khirishai	Loss of livelihood, intensification of fishing
Promoted fishing in the lagoon channel		

**Source: Semi-structure & focus group interview*

- Reduction in the depth of the lagoon has made parts of Khirishai lagoon shallow which is unfavourable for casting the nets and also it is an unfavourable environment for the survival of fish and other aquatic organisms
- Increase in salinity have made some parts of the lagoon uninhabitable for the fish and other aquatic organisms. This has made some parts of Khirishai lagoon unusable for fishing.
- Lagoon clay is important for the survival of fish and crab. Though sand infestation, lagoon clay is lost which is preventing the migration of fish into their lagoon.

As a coping strategy to these changes, fishers have started intensifying the catch by increasing the number of nets. In turn, this has created competition among the fishers in the village for the remaining available fishing space. Ultimately, all the actions are leading to further decline in the social ecological system of Khirishai.

4.2.3. Dual role of shrimp aquaculture

Coastal lagoon are a hotspot for aquaculture. Shrimp aquaculture has changed land use patterns and created socio-economic crisis, lead to degradation of mangroves, increased food insecurity and exacerbated the marginalisation of fisher communities (Datta et al, 2010; Nayak & Berkes, 2010; Primavera, 1997). Shrimp aquaculture has played a dual role in Khirishai. Shrimp

aquaculture, which was once started for economic benefit has now become a driver for changes that are taking place in Khirishai. Interviews with fishers revealed that the prime reason for starting aquaculture was to cope with the changing environment in the lagoon, especially after the reduction in the fish production. As one fisher says:

"When the fish production in the lagoon was reduced we started aquaculture in our lagoon area"

- *Chandra Behera (Fisher, Khirishai; June)*

As discussed in earlier section (4.2.1), the reduction in the fish production occurred after the opening of new sea mouth in 2000 which changed the geomorphological, salinity, tidal influx and other properties of the lagoon. When incomes were reduced, they changed their livelihood to aquaculture. Aquaculture was first started by a fisher Gangadhar Jena from a nearby island.

"First Gangadhar Jena started aquaculture and he gained more money, so we followed him and started aquaculture. But now we are feeling that we don't have enough space for fishing"

- *Kandha Behera (Fisher, Khirishai; July)*

Aquaculture come up with a cost. Khirishai is facing a lack of fishing space. Among the 836 acres (338.31 Hectares) of lagoon space allotted to Khirishai for fishing, around 350 acres (141.64 Hectares) is now under shrimp aquaculture and it is increasing each year. Aquaculture has also reduced the natural shrimp and fish productivity of their lagoon. First, before introducing the shrimp fry into the aquaculture field they clean the aquaculture field by applying chemicals to kill other aquatic organisms. After unwanted aquatic organisms and pests are dead, they flush the contaminated water into the lagoon by opening the sand dykes. As the contaminated water mixes with the lagoon water, it kills the fish, shrimp and other aquatic organism living adjacent to the aquaculture field which reduces the productivity of the lagoon.

"Poison used for the cleaning the aquaculture field when released into lagoon it kills the fish, shrimp and crab of the lagoon."

- *Khasinath Behera (Fisher, Khirishai; June)*

The live shrimp fry culture for the aquaculture is obtained from the lagoon. Each year at the start of the aquaculture season fish farmers scoop out the lagoon floor to access live shrimp fry. This process has reduced the naturally occurring shrimp in the lagoon with implications for future stocks in the lagoon.

Contamination has reduced the natural productivity of the lagoon. Along with the aquaculture dykes and shrimp fry being taken from the lagoon as culture, a loss of lagoon space has resulted. Increasingly, unproductive areas cannot be used for fishing and fishers move to other spots for fishing which is creating congestion and competition among the fishers for fishing grounds. This has created an environment which is unsuitable for the fish and other organisms. As one fisher has said:

"Aquaculture has reduced the lagoon space and the fisher does not have enough space to live so they are moving to some other place, which reduced the fish production in our lagoon"

- *Nachia Behera (Fisher, Khirishai; August)*

Moreover, not all the lagoon under aquaculture are used by fishers. Some of the aquaculture fields are leased to non-fishers for aquaculture. When asked for the reason for leasing their lagoon to non-fisher, a fisher answered:

"Both fishers and non-fishers do aquaculture in our lagoon. The main reason for leasing our lagoon to non-fishers is the misunderstanding between the villages"

- *Shanka Benera (Fisher, Khirishai, July)*

As the social-ecological system collapsed fishers changed their traditional techniques to new techniques (See Section 4.2.4). This change in the fishing technique led to the collapse of the social sub-system of the community as fishing became an individual activity. As a result social relations between the fishers of Khirishai deteriorated. Consequently, this led the fishers to lease their lagoon to non-fishers for shrimp aquaculture.

As the ecological sub-system continues to be impacted by anthropogenic stressors it has also created a negative feedback in the social-ecological system, which in turn is leading to a collapse in the social sub-system of Khirishai. When asked why fishers are doing aquaculture, even though they know the consequences of it, a fisher from Khirishai said that

"All the people know that it is dangerous for their lagoon, but because there is no other way for income they do it"

- *Kurmaya Behera (Fisher, Khirishai; July)*

As a consequence of the collapse in fish population, people of Khirishai have faced a reduction in their daily incomes, and the degradation of social relations among the community members which has led to the leasing of their lagoon space for shrimp aquaculture to non-fishers. The shift which started in the ecological sub-system, driven by changes in the social sub-system has resulted shifts in both the social and the ecological sub-systems. Aquaculture which was thought to be helpful for the community as a way to increase incomes has become another driver of social-ecological system degradation in Khirishai.

4.2.4. Technology drives practice

As a response to the environmental changes and economic crisis emerged because of the changes in the lagoon, fishers of Khirishai have adopted new fishing technology (i. e., replacement of traditional fishing *Kadijala* technique with new fishing technique *Kondhajala*). When fishers

changed fishing techniques it compounded the prevailing issues and further degraded the social-ecological system. Technology is not always beneficial, as Frances et al., (2001) note: "Technology is a mixed blessing, societies do not always choose to avail themselves of technological solutions; technological complexification is not the same as good in a moral sense and may even lead to destruction". This is the case in Chilika, and especially in Khirishai, because changes in fishing technique has severely degraded the lagoon. The main reasons for changes in technology and their consequences are listed in table 4.5. Interviews revealed that the main motive behind the change in fishing techniques is the economic factor.

"When the fish production started reducing in the lagoon we lost our income. So we thought that the new technique Kondhajala will help us to gain more money by capturing more fish. So we left our traditional technique"

- *Danei Behera (Fisher, Khirishai; June)*

Table 4.5: Consequences and the reasons for changing the fishing technique in Khirishai

Reason for changing fishing technique	**Consequences of changing the fishing technique**
-Traditional nets were removed from the market -Reduction in the income -Reduction in the landing of fish and shrimp on Khirishai because of the new sea mouth	-Reduction in the fish production -Killing of Juvenile fish and shrimp -Lack of fishing space -Fear of fishing alone -Hard labour -Further reduction in the income

**Source: Semi-structure & focus group interview*

However, it is not only the fishers who make the decision to change techniques, but also the companies that sold the new equipment. Companies stopped selling the traditional cotton nets which forced fishers to adapt to other available equipment in the market. One of the main reasons for companies to switch to the new equipment is the increase in demand from non-fishers. Because

the non-fishers lack traditional knowledge about fishing, they adapted the new fishing techniques which are user friendly for people without knowledge in fishing. However, this new technique is increasing being adopted by the fishers of Chilika mainly because it is convenient from the point of price, ease of fishing, and so on. As a result, the demand for new equipment increased in the market, which pushed the traditional equipment out of the market. As the fishers are slowly changing their fishing technique from traditional to the new technique the market has responded by not selling traditional fishing equipment's anymore.

"The net companies stopped selling the cotton nets, so we started buying other nets which are predominantly used by the non-fisher community in the lagoon"

- *Shanka Behera (Fisher, Khirishai; July)*

Figure 4.3: Researcher showing the mesh size of Kondhajala; Source: Picture taken during the field research by the researcher

However, soon after techniques were changed, fishers started experiencing ecological consequences. The first change that fishers experienced was a reduction in the fish and shrimp production in the lagoon. Mesh size of *Kondhajala* is small and it catches even juvenile fish and shrimp, which are the future stock of the lagoon (See figure. 4.3). Previously, the traditional technique also included a catch & release policy, which prevented the killing of juvenile fish and shrimp. However, *Kondhajala* is a more destructive fishing approach. The traditional fishing technique *Khadijala*, which is based on cooperation, reciprocity and human relations was replaced with a less healthy competition between the fishers. Table. 4.6 offers a comparison between the traditional and new techniques. For instance, one of the major impact in the social sub-system is the fear of fishing alone. As the villager said

"Before I go for fishing as a group, if I get tired my friend will help me. If the tide is high I don't get frightened because many people are there who can help me. But now a days I am afraid of fishing because I had to do it alone in the lagoon"

- *Khasinath Behera (Fisher, Khirishai; June)*

Once considered a comfortable occupation, fishing is now a life threatening occupation for the fishers. The traditional technique also helped to build a strong community. After the change in technique, people started competing for the best fishing grounds, which undermined the relation among the fishers as fishing became an individual activity.

Fishers are also concerned about their deterioration of their health because of the *Kondhajala*. In the Kondhajala fishing technique, the nets are tied with many small bamboo sticks. During the time of fishing these bamboo sticks are placed in the lagoon by piercing the lagoon floor. Each fisher has to place more than 75 bamboo sticks into the lagoon floor every day. This caused some health issues among the fishers like chest pain, arm pain, full body pain, and even paralysis. They are also required to stay in the water for a considerably long time. The technique has not only reduced their income but also reduced their capacity to work by reducing their health, which increase the economic crisis in the family and pushes them to poverty.

Table 4.6: Comparison between Kadijala and Kondhajala fishing technique

***Kadijala* (Traditional Technique)**	***Kondhajala***	**Implication on the social-ecological system**
Group activity (involves four to six fishers)	Individual Activity	Deterioration in the social-ecological system of Chilika. Created competition among fishers which degraded the social sub-system.
When a member is tired during fishing the other will take over the nets	No one is available for help	
No fear of fishing because it is a group activity	Fear of fishing alone in the lagoon	

Builds trust in other fisher while fishing	No interaction	
Sustainable fishing (nets are made of cotton and the mesh size is large, so that only larger fish are caught in the net and small fish can escape the net or released back into the lagoon to preserve future production)	Destructive fishing (Nets are made of polyester and the mesh size is small that it catches big fish to juvenile fish and shrimp. Juvenile fish and shrimp are not released back into the lagoon, hence impacting the future production)	Fishing is not sustainable anymore because of the change in technique Created an uncertain fish production in the lagoon
High profit and less labour	Low profit and high labour	Deteriorating the health of the fishers

**Source: Semi-structure & focus group interview with the fishers of Khirishai*

4.2.5. Encroachment of fishing area in sea by trawlers

Another serious issue that has a direct impact on the lagoon is the encroachment of sea trawlers into Khirishai fisher grounds. As it was discussed in section 4.1.1, Khirishai fishers fish during the months of October to February in the sea. In recent years, the number of fishers going to for sea fishing has reduced drastically because of competition with the trawlers. 50 % of the semi-structured interview respondents mentioned that the trawlers have occupied their fishing space.

"Now-a-days not many people are going for sea fishing because the trawlers have occupied our fishing space"

- *Jagannath Behera (Fisher, Khirishai; June)*

Trawlers are commercial fishing boats that fish in the sea. Trawlers usually fish one or two km far from the sea shore. However, trawlers are increasingly fishing near the coastline. Fishers mentioned that the trawlers use drag nets which scoop all aquatic organisms from the sea floor.

These nets are capable of capturing juvenile fish and other organisms. When asked about the reason for not fishing in the sea, 20% of the respondent responded by quoting that they are afraid of the trawlers.

"We are afraid of doing sea fishing, because when we asked the trawler's fisher not to fish in our area, they threatened to kill us by weapons"

"Trawlers has broken our nets many times by driving their boats over our nets in the sea"

-Focus group interview (Fisher, Khirishai; August)

Not only are they afraid of sea fishing, but the fish production has also reduced because of over fishing by trawlers.

"Everyday lots of trawlers are fishing near the sea shore which has reduced the fish production in the sea"

- *Ladu Kishore Behera (Fisher, Khirishai; June)*

As a consequence of these changes, fishers have started relying fully on the lagoon for their livelihood. This creates an imbalance and more pressure on the lagoon ecosystem (See Section 4.1.1)

4.2.6. Connection of island by road

Khirishai was historically an island in the Chilika lagoon. The only mode of transportation from Khirishai was by fishing boat, because there was no proper ferry service. The people relied on fishing boats for their transport and they were only able to travel twice a day. Once when fishers

went to the lagoon to cast their nets, and second when they went to take back their nets from the lagoon. During the summer season when parts of their lagoon become shallow, they walk through the lagoon to reach the nearby village. During of emergencies they pay the fisher to take them to other village by boat. With these difficulties in mind, in the early 2014 the government started constructing a road that connects Khirishai with the adjacent land, but without the knowledge of the fishers.

Khirishai was an island before the road was constructed. After the construction of road the whole scenario changed (See table. 4.7). For Example, not only did it provide better transportation for them, but also it provided them with economic growth. Usually before the construction of road, they sold their daily catch to buyers for a low price. The buyers would come by boat to the island every morning to collect fish, shrimp and crabs and they would sell them in the market with a higher price. Now, with the road construction fishers have direct access to the market where they can sell directly without having to go through middleman. This makes them the seller in the market. Some villager discussed the benefit from the construction of road:

"We get transport facility to the other places. Also it is east to buy stuffs that we need daily. Instead of paying more money to the local grocery shop, now we have direct access to the market. Also we can sell our daily fishing catch directly to the market for more money"

- *Dushana Behere (fisher, Khirishai; June)*

"Road construction will allow other buyers to come to them directly and buy their daily catch for higher price than they sell now. It also help for transportation during the time of emergency"

- *Khasinath Behera (fisher, Khirishai; June)*

Road construction has benefits, but it has impacted the ecosystem of the lagoon. Cumming et al., (2006) discuss how providing infrastructure is a subsidy to group of people that will benefit

from the infrastructure. The improvement of infrastructure has created an unfavourable social-ecological driver. More than half of the people interviewed identified the benefits that they gain from road construction. This economic benefit has masked the ecological impacts of road construction on the lagoon. Only a few people analysed the consequences of the road construction on their lagoon as outline in table 4.7.

Table 4.7: Economic gains and ecosystem loss because of road construction in Khirishai's lagoon

Gains from the road construction	Ecological impact of road construction
-Direct access to the market -Fast transport facility -Better transport in the time of emergency	-Natural movement of the water is restricted -Movement of fish is reduced -Loss of essential fishing ground -Promotes aquaculture -Creates competition among the fisher for the remaining fishing space

**Source: Semi-structure and focus group interviews*

"The road construction will reduce the fish and shrimp landing in our lagoon because it is built on the small lagoon channel that once brought the fish and shrimp to our lagoon from the bigger channel"

- *Kandha Behera (Fisher, Khirishai; July)*

The road is built straight across the small lagoon channel that brings the fish and shrimp to their lagoon. This road has thus reduced the fish and shrimp landing in their lagoon. During road construction, the plan included construction of concrete tunnels that help to connect both sides of the lagoon, which helps in the movement of fish, shrimp and other aquatic organisms, as well as for the tidal ventilation on the other side of the road. However, the plan proved impossible for the movement of fish and the tidal ventilation. Figure 4.4 shows the concrete tunnel that is used to connect both sides of the lagoon across the road/ Figure 4.5 shows the peak summer seaeson which

clearly depicts the impact of the road construction on the lagoon. The picture shows that there is no water movement to the left side even though they are connected by the concrete tunnel (See figure 4.4 & 4.5). A shift in the system (i.e., from a lagoon system to a marshland system) is also evident. Figure 4.6 was taken during the monsoon season when the lagoon reached its high water level, but there is no tidal influence. The reason is that the concrete tunnel is not wide enough for the tidal influence, which also prevents the movement of fish and other organisms landing in their lagoon.

Another major consequence of the road construction is the reduction in the available fishing space. Already around one-third of their lagoon is under shrimp aquaculture. Now, after the road construction, it turned more fishing places into marshland. This has compounded the prevailing issue of a lack of fishing space in the village, and also provoked competition among the villagers for the remaining fishing ground. This marshland will also be turned to shrimp aquaculture field in the future.

Figure 4.4: Concrete tunnels used to connect the lagoon; Source: Picture taken during the field research

Figure 4.5: Systems shift from lagoon to marshland (left side of the road); Source: Picture taken during the field research

Figure 4.6: Zero tidal influence in the lagoon left side of the road; Source: Picture taken during the field research

4.2.7. Role of population and policy

One of the reasons that came up in the interview for the lack of fishing area is the lease policy in Chilika. The state government of Orissa formulated a guideline in 1991 (Iwasaki & Shaw, 2009) that officially allowed non-fishers to fish in the lagoon. This impacted the fishers of Khirishai immensely because the majority of population around their village consists of non-fishers. Fisher of Khirishai leased 836 acre of lagoon surrounding their island from the government. Before the lease policy they had access to most areas of the lagoon. This further restricted the fisher of Khirishai to a small space for fishing.

Population growth is another factor that causes a lack of fishing space in the lagoon and includes population growth in the village non-fisher population, as the number of non-fisher practising fishing is increasing every day. As Kurmaya Behera a fisher from Khirishai says

"In the past days people are so little and the catch was high, now so many people and the catch is small".

- *Kurmaya Behera (Fisher, Khirishai; July)*

The statement illustrates how population growth influence livelihoods. It is not only because of the increase in fisher population but also the number of non-fishers depending on the lagoon for their livelihood which increased after the lease policy of 1991.

Khirishai is surrounded by non-fisher villages of Jarakatta, Jannikudha and Nuvapada. The non-fisher population in the surrounding villages out-numbers the fishers in Khirishai. The non-fisher community also practices aquaculture in the lagoon.

"If we go to some other place like a Balugaon (Deeper Chilika), our nets will be taken by the non-fisher"

- *Ragunath Behera (Fisher, Khirishai; July)*

Population growth coupled with the lease policy has caused three types of scarcity in Khirishai:

1) **Supply Induced Scarcity** which occurs when the available resources are degraded by environmental change sooner than their renewal capacity by environmental change (Hauge & Ellingsen, 2001). In the case of Khirishai, because of anthropogenic stressors like the opening of new sea mouth and other factors, the natural productivity of the lagoon has declined which in turn is accelerated by the population growth in Khirishai, and increases in the number of non-fishers practising destructive fishing and shrimp aquaculture.
2) **Demand Induced Scarcity** occurs when demand for resources exceeds the supply because of population growth (Hauge & Ellingsen, 2001). In Khirishai, involvement of non-fishers in shrimp aquaculture and capture fishing has created demand induced scarcity. This is evident in the reduction of the Khirishai fish production, but the population is still growing and more people are dependent on a depleting resource base.
3) **Structural Scarcity** usually occurs in the society when there is unequal access to the resources (Hauge & Ellingsen, 2001). The lease policy of 1991, started structural scarcity

in Chilika, where 40% of the lagoon was given to non-fishers for fishing by the government. As a consequence, lots of fisher communities lost their traditional fishing grounds. Fishers in Khirishai were restricted because of this government policy.

As a result of the human induced drivers like new sea mouth, changes in the fishing technique, increased shrimp aquaculture, encroachment of sea fishing space by trawlers, policy and population, the social-ecological system of Khirishai has deteriorated. As discussed above some of the major ecological changes in Khirishai lagoon caused by the drivers are changes in the salinity, reduction in the lagoon depth, sand infestation, and reduction in the fish and shrimp seeds. This chapter addressed the objective to analyse the changes and the drivers that are causing the changes. As an outcome of these changes, the fishers of Khirishai are experiencing difficulties in the social-ecological which are discussed in the following chapter.

CHAPTER 5: KEY OUTCOMES AND ADAPTATION

This chapter focuses on objective two and three of this research. It examines the key outcomes of the changes discussed in the previous chapter (See Chapter 4). This chapter outlines the key impacts of the changes in the social-ecological system and also the strategies being used by Khirishai fishers to adapt to the changing social-ecological system.

5.1. Key outcomes

This section discusses the issues emerging from the social-ecological changes that are caused by the drivers mentioned in section 4.2. Initially observed as small threats, these issues have now become a concern in Khirishai because they threaten the social-ecological system, which is already in the state of collapse. This section also consists of the adaptation strategies the fisher communities use to respond to the changing social-ecological system. It addresses the research objectives of analysing the key outcomes of changes and the successful and unsuccessful adaptation strategies. The main reasons for discussing the four key changes (reduction in fishing space, connection of island by road, out-migration and conflict between the villages) are: a) they create negative feed-back in the social-ecological system, b) they reduce the chances of adaptation in the community, and c) the changes have the potential to completely displace the community of Khirishai.

5.1.1. Reduction in the fishing space

Reduction in the fishing space is the prominent issue that appeared in the interviews with the fishers of Khirishai. All the drivers previously discussed (see section 4.2) have contributed to a reduction in the fishing space in the lagoon (see Table. 5.1). The new sea mouth has ignited the issue of the lack of fishing space in Khirishai. A summary of the caused and the implications is

provided in Table 5.1. A key point is that the reduction in fishing space is exacerbated by and are a catalyst for several other pressures, including increasing poor communication among fishing villages, conflict between villages and out-migration. These issues are discussed below

Table 5.1: Drivers and the changes that caused the reduction in the quality and the quantity of fishing space in Khirishai's lagoon

Drivers	**Causes for the reduction in the quality of the lagoon fishing space**	**Causes for the reduction in the quantity of the lagoon fishing space**
New sea mouth	Change in the salinity and change of lagoon clay into sand made the lagoon unfavourable for the survival of aquatic species.	Sand infestation reduced the lagoon depth by making it shallower, which is unsuitable for casting nets.
Aquaculture	Lagoon clay is removed to build the aquaculture dykes. This changes the lagoon clay and sand composition. Also shrimp fry are removed from the lagoon for aquaculture field. This leads to reduction of the lagoon quality because of the reduced shrimp production in the lagoon.	Around 350 acres of lagoon fishing space is under aquaculture creating a lack of fishing space.
Fishing technique	Reduced the natural productivity of the lagoon by depleting the juvenile fish and shrimp fry leading to the intensification of fishing.	As fishing intensifies, so does the number of nets used for fishing. Thus, congestion in the lagoon is created.
Road Construction	Constructing road on the channel prevents the fish migration to the lagoon causing the fishers to intensify fishing.	Changed a large part of the lagoon to marsh land, which pushed fishers to compete for the remaining fishing space.
Population	As the population increased, amount of fish and shrimp extracted from the lagoon also increased and with no by catch law the juvenile fish and shrimp which sustains the future production is also reduced.	Population is increasing in the village but the available fishing space for fishing remains constant or decreases because of the other factors.

**Source: Semi-structure & Focus group interview*

5.1.2. Communication gaps between fishing villages

Social systems consisting of people often create a shared set of norms, understandings or routines to integrate their actions, and to establish patterns of dominance and resource allocation by interacting with each other (Frances at al., 2001). In order for a social sub-system to be healthy, the people in that system have to share their knowledge with others. Communication helps in assisting collective decision making, which can facilitate the social processes needed for adaptation in communities facing change.

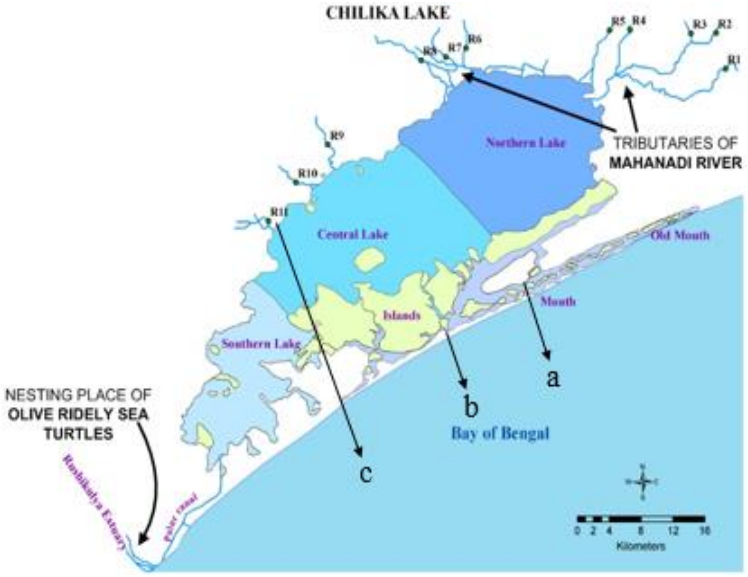

Figure 5.1: Map of Chilika showing the location of different villages that are studied for analysing the communication gap with the fisher villages; Source: Source: http://valueofdissent.blogspot.mx/2013/02/wetlands-chilika-lake-ecosystem-health.html

This section discusses the factors that have caused the communication gaps between the fisher villages in Chilika. Interviews conducted in three villages from different sectors of the Chilika lagoon showed that there is communication gap between the fishing villages. The three villages are: a) Banamalipur, near the new sea mouth; b) Khirishai, research village; c) Balugaon, Deeper Chilika (see figure. 5.1). All the people who were interviewed are fishermen. Responses from the fisher of different villages are:

"*People in the deeper Chilika are fishing more because the heavy tide is pushing the fishes and shrimp to deeper Chilika"*

- *Banamalipur fishing village, Near New sea mouth*

"People near the sea mouth are fishing more because they are putting nets in the lagoon channel and people in the deeper Chilika are fishing more because the heavy tide is pushing the fishes and shrimp to deeper Chilika"

- *Khirishai fishing village, Research village*

"People near the sea mouth are fishing more because they are putting nets in the lagoon channel"

- *Balugaon fisher, Deeper Chilika*

The quotes above from fishers of Khirishai, Balugaon and Banamalipur have different perceptions on changes that are happening in the lagoon. The fishers from deeper Chilika are blaming the fishers near the sea mouth for the reduction in fish production. They think that the fishers near the sea mouth are overfishing in the lagoon channel thereby restricting movement of fish to their part of the lagoon. Fishers near the sea mouth are also complaining that the fishers near the deeper Chilika are engaged in unsustainable fishing as they continue to deplete all the fish resources that are pushed into the deeper Chilika by the high tides near the sea mouth. However, fishers of Khirishai are blaming both the fishers in the deeper Chilika and near the sea mouth saying that both these groups of fishers are engaged in unsustainable fishing. These statements clearly show a communication gap between the fisher villages, i.e., there is an inconsistency in communication between the fisher villages in Chilika. Upon further analysis I found that all these three regions of the lagoon have been impacted negatively by the environmental changes that are taking place. But instead of communicating and sharing information among themselves on their commons problems the fishers are blaming each other for the reduction in fish production in the lagoon.

Table 5.2 illustrates changes that are happening in different parts of the lagoon. It shows fish production has reduced drastically in all parts of Chilika because of the ecological changes. The quotes also show existing power dynamics amongst the fisher communities of Chilika. It has created a cause and effect relationship among the fisher communities, i.e., the more power dynamics among fisher communities, the higher the gap in communication between them and vice versa.

Another factor that came up during the field visit is that the fishers of different villages do meet each other at some common places (eg., market, social gatherings) and communicate with each other. However, their interactions do not focus much on the social-ecological crisis their villages are facing. One factor that influences the communication gap between fishers is the degradation in the ecological system. As the ecological system degraded so does the communication between the fisher communities. Other factors that may have influenced the communication gap between fisher communities are caste differences because fisher communities in Chilika belong to different group.

Table 5.2: Comparison of problems in different sectors of the Chilika lagoon

Problems	**Banamalipur (Near Sea mouth)**	**Khirishai (Research Village)**	**Balugaon (Deeper Chilika)**
Fish Production	Reduced	Reduced	Reduced
Opening of new sea mouth	Negative impact	Negative impact	Negative impact
Depth	Reduced	Reduced	Reduced
Invasive Species	High	Low	Low
Aquaculture	Low	High	High
Non fisher	High	High	High

**Source: Semi-structured and Focus group interview from villages of Banamalipur, Khirishai and Balugaon*

Another cause that stood up in the research is that ecological change plays a major role in communication. There is a declining trend in communication with the decline in the ecosystem. Three month field observation showed that fishers from different parts of Chilika meet and communicate, but environmental communication is lacking.

5.1.3. Out-migration

Out-Migration is the short term adaptive strategy used by the fisher community when they face social-ecological degradation. Out-migration is not the best adaptation strategy because it degrades the social sub-system of the village. This section discusses out-migration in Khirishai and how the community becomes stuck in vicious cycle of socio-economic crisis.

Out migration in Khirishai was began approximately 12 years ago. Nayak, (2014) showed that out-migration in Chilika was higher during the period since 2002, which is after the opening of the new sea mouth. Khirishai's out-migration pattern is similar to the pattern that Nayak, (2014) identified. This clearly shows that the change in the ecological sub-system by anthropogenic intervention has created a negative feedback in the social sub-system of Chilika, and Khirishai specifically. Interviews with the fisher revealed that approximately 30% of the villagers are out-migrants and the percentage is increasing every year because of the reduction in income.

"Our catch has reduced to 10% from 100% in the last 10-15 years"

- *Dushana Behera (Fisher, Khirishai; June)*

Most of the fishers that out-migrated are youths who leave their family behind in the village. The type of jobs performed by the fisher in out-migration are a) fishing in other area (e.g., trawler fishing in Goa, Tamil Nadu, and other place); b) construction worker; c) textile industries; and other industries. But not all the fishers that out-migrate are successful in sending money to

their family. Three different types of out-migration were noticed in Khirishai which is discussed in Table. 5.3.

But when it comes to adaptation, out-migration is not always an effective strategy and it comes with a socio-economic cost. An interview with a fisher who just came back to Khirishai after a year labouring in the state of Tamil Nadu said

"We have to pay an amount of Rs.10000 ($ 188 CAD) for the contractor and we train for 3 months, during the training period they don't pay us and we spend money from our pocket"

- *Ravi Behera (Fisher, Khirishai; July)*

Out-migration has uncertainty embedded in it. Figure 5.2, explains the uncertainty and the cost of out-migration. The process of out-migration can be divided into two stages. The first stage is the preliminary preparation stage for out-migration. As stated by one fisher, sometimes they need to pay contractors to get a job and they lend money to pay the contractor, which increases debt. The second stage comes after out-migration. Being unskilled labour, they are trained for several months depending upon the job. The interview with the same fisher revealed that during the training period, the fishers have to support themselves financially. In the absence of the men, women and children do labour in the village in order to repay debts. In certain circumstances, the fishers get cheated by the contractors and return to their village empty handed. This places their family in severe debt forcing them into a cycle of socio-economic crisis as shown in the Figure 5.2. A process which started as an ecological crisis has now impacted all the systems - namely ecological and the social sub-system.

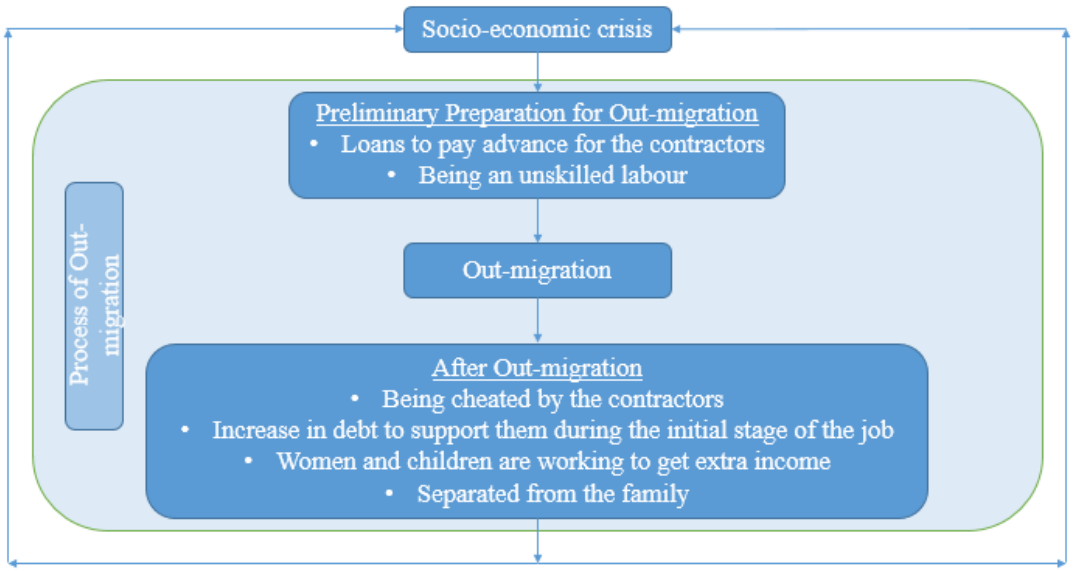

Figure 5.2: Socio-economic crisis trap that is created by out-migration

5.1.4. Conflict between fisher villages

Environmental scarcity is the root cause for the conflict in Khirishai. This section discusses the pathway of conflict between the two fisher villages of Khirishai and Banabaspur. As discussed by Wenche (2001), environmental scarcity leads to the conflict in Khirishai. The island of Khirishai has two villages; Khirishai and Banabaspur. Fishers in Khirishai belong to Nohlia caste and the fishers in Banabaspur belong to *Kondra* caste. The island is predominantly occupied by Nohlia fisher caste. The main reasons for the environmental scarcity are the changes in salinity, sand infestation, increase in tidal influx that occurred in Khirishai lagoon because of the drivers like opening of new sea mouth, shrimp aquaculture, change in fishing technique, construction of road and population and policy. This issues has been discussed in the previous chapter (See also Figure 5.3). As a result of the changes, the fisher's faces lack of fishing space in their lagoon. The problem started when the fishers in Banabaspur used the *Kondhajala technique* for fishing. Fish *Kondhajala* is predominantly used for catching fish rather than shrimp or crab. But the important drawback of using fish *kondhajala* is that it requires a lot of fishing space. On the other hand

fishers in Khirishai use shrimp *Kondhaja*, which requires less space but it also catches fishes and other organisms.

With lack of fishing space becoming a problem among the fishers, the fishers of Khirishai insisted the fishers of Banabaspur change their fishing equipment from 'fish kondhajala' to 'shrimp kondhajala'. As the fishers of Banabaspur did not comply with their order, the fishers of Khirishai took advantage of their high population as compared to Banabaspur, and started fighting with Banabaspur, eventually capturing their fishing nets as a punishment. As they took their nets, the fishers of Khirishai asked the fishers of Banabaspur to do sea fishing with them. However, fishers belonging to the caste *Kondra* are traditional fishers of Chilika Lagoon and they only do fishing in the lagoon. They don't have any knowledge of fishing in the sea. Because the number of fishers in Khirishai is large, they are forcing the fishers of Banabaspur to practise sea fishing which they have never practised before in their life. When interviewed, the one fisher in Banabaspur said:

"Because the fisher in Khirishai are huge in number we could not do anything against them"

- *Gangadhar Behera (Fisher, Banabaspur; July)*

This statement shows the power dynamics that is prevailing in the fisher village. The future of Banabaspur village people is uncertain.

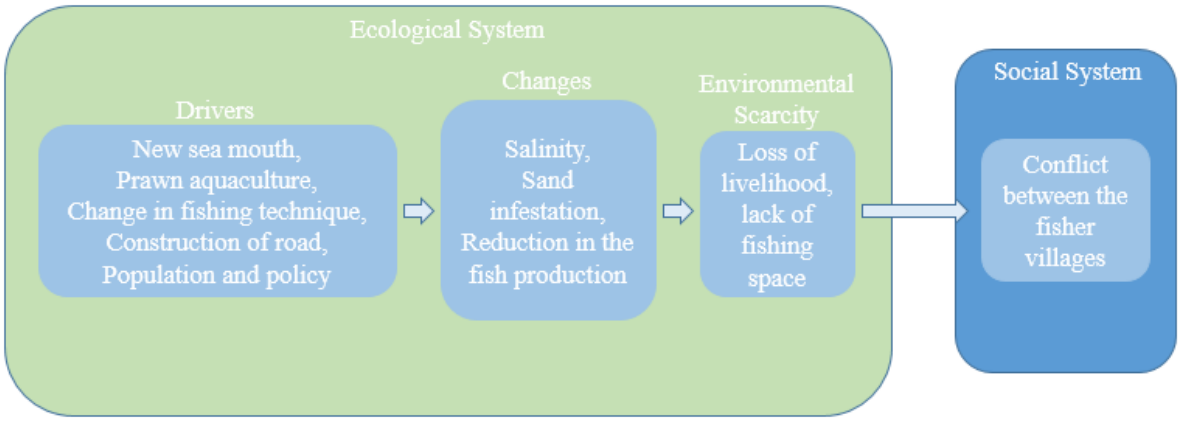

Figure 5.3: Pathway of conflict in Khirishai caused by environmental scarcity

5.2. Adaptation

This section discusses the third research objective on adaptation. The chapter discusses specifically the adaptation strategies being used by the fishers of Khirishai to respond to the changing social-ecological system crisis. It also examines the type of adaptation strategy being used by the fishers of Khirishai (i.e., short term or long term).

In the context of fisher community, adaptation is a process of change in the community that occurs when there is a change in the social-ecological system of the community. This section discusses strategies that are being used by the *Nohlia* fishers of Khirishai to adapt to the changing social-ecological system. It also considers which strategies were successful and which are unsuccessful. As a response to the changes that are discussed in chapter 4, the fisher of Khirishai are using multiple strategies to adapt to the changes. These strategies include: 1) change in the fishing technique from Kadijala to Kondhajala; 2) aquaculture; 3) out-migration; 4) loans.

5.5.1. Change in the fishing technique

One of the strategies used by the fishers of Khirishai to adapt to the changes in the social-ecological system is changing the fishing technique from *kadijala* to *kondhajala*. Information about the fishing technique is discussed in Section 4.2.4. Changes in the fishing technique, which was started as an adaptation strategy by the fishers to escape the crisis caused by the changes in the social-ecological system, has emerged as a maladaptation which in turn has increased the vulnerability of the social-ecological system. Change in the fishing technique from *kadijala* to *kondhajala* was adapted as a short-term adaptation strategy by the fisher community of Khirishai. As discussed in section 4.2.4, this lead to the reduction in the lagoon's natural productivity, resulting in the intensification of fishing to catch the remaining available fish and shrimp from the

lagoon. It also impacted the social sub-system by changing the fishing activity from a cooperative, group activity to an individual fishing activity. This resulted in the collapse of the village norms.

5.5.2. Shrimp aquaculture

Shrimp aquaculture is another adaptation strategy adapted by the fishers of Khirishai. Aquaculture is practised in the lagoon by non-fishers and fishers in response to the lease policy of the government of Odisha. One of the main factors behind starting aquaculture is the economic motive. The fishers of Khirishai started aquaculture to increase their families living quality and to decrease the economic burden that was created by the changes in the social-ecological system of the lagoon. Shrimp aquaculture also falls under the category of short-term adaptation strategy. First, it was started as a minor source of income for some of the fishers in Khirishai. But after a year or so, shrimp aquaculture has become one of the main source of livelihood along with fishing. Aquaculture started to support the community activities like festivals, temple ceremonies, as the income from fishing reduced. However, shrimp aquaculture turned out to be a maladaptation for the fisher community of Khirishai. Impacts caused by the shrimp aquaculture outweighed the benefits initially obtained from shrimp aquaculture. Shrimp aquaculture has caused severe ecological and social degradation which is discussed in section 4.2.3. The shrimp aquaculture adaptation strategy acted like a double-edge sword, which on one hand benefited the fishers of Khirishai in the short term, but on the other hand debased the social-ecological system of Khirishai in the long term.

5.5.3. Out-migration

Before the out-migration strategy, the fishers of Khirishai stayed in the village and adapted strategies like changing fishing techniques and emerging shrimp aquaculture to cope with the

changes. However, when the magnitude of social-ecological system degradation increased, the fishers of Khirishai used the adaptation strategy of out-migration.

Most of the fishers that out-migrated are youths who leave their family behind in the village. The type of jobs performed by the fishers while on out-migration are a) fishing in other areas (e.g., trawler fishing in Goa, Tamil Nadu, and other place); b) construction worker; c) textile industries; and other industries. But not all the fishers that out-migrate are successful in either finding a suitable job or sending money to their family. Three different types of out-migration were noticed in Khirishai which is discussed in Table. 5.3.

Table 5.3: Different types of out-migration observed in Khirishai

Type of out-migration	**Description of out-migration**	**Period of out-migration**
Seasonal out-migration	This type of out-migration is predominantly carried out by fishermen	The fishermen come back for fishing during the time of high season for fish and shrimp production in the lagoon
Short term out-migration	Mainly carried out by women in the fisher community to support the family financially	Visit the family every four or three months
Long term out-migration	The fisher family migrates out of their village	Out-migration is for more than 4-5 years

**Source: Focus group interview, Khirishai.*

Out-migration also falls under the category of short-term migration, which gives a short relief from the prevailing social-ecological crisis. Different patterns of out-migration are discussed in section 5.3. Eventually out-migration has led to the degradation of social relationship in

Khirishai families and in the entire community. As mentioned earlier (Section 5.3) the process of out-migration is complex, and it further degrades the social sub-system.

5.5.4. Loans

Getting loans from other fishers of non-fisher communities is an adaptation used by the fishers of Khirishai to reduce the household economic crisis caused by the social-ecological system degradation. Focus group interviews with the fishers of Khirishai revealed that almost 80% of the households of Khirishai have loans. Fishers mortgage their house, gold ornaments and lands to get money and some fishers have even sold their fishing gears to support their family. But a loan is not a better adaptation strategy because as interviews revealed the fishers are mentally stressed after getting loans.

"We are mentally stressed after getting the loans, because we don't know what will happen tomorrow as the fish production is reducing in the lagoon"

- *Focus group interview (Fisher, Khirishai, August)*

Another impact is the intensification of fishing in the lagoon. The fishers are working more in the lagoon by increasing the number of nets used for fishing to repay the loan amount with interest included. As a result of getting loans, trust among the fishers has reduced because of failing to repay the loans in the due date. Also fish production is further reduced because of intensification.

5.5.5. Chapter Summary

Adaptation as a process has been discussed in the literature section (See Chapter 2). Before using the adaptation strategies fishers opted to use a variety of coping strategies which helped them to deal with some of the initial impacts from the social-ecological crisis. One of the coping strategies used by the fishers were loans. Fishers borrow money for short-term purposes and they

mortgage their land and gold jewellery to cope with the change before engaging in any long-term adaptation. In the case of Chilika, there is no known effective long-term adaptation strategy. All the strategies that are being used by the fishers are short-term strategies which have in effect led to maladaptation and further degraded the social-ecological system of Khirishai. There is not a single adaptation strategy used by the fishers of Khirishai that have benefited the social-ecological system (see table: 5.4). Each of the adaptation strategies gives short-term relief only. In Khirishai, each adaptation strategy is also a driver that is impacting the ecosystem upon which fishers depend for their livelihoods. The fishers are trying to cope with the prevailing social-ecological system degradation but the past decisions have trapped them in a cycle of livelihood and other social and economic crisis.

Table 5.4: Adaptation strategies adapted by the fisher of Khirishai and their impact on the social-ecological system

Adaptation Strategy	**Type of Strategy**	**Description of the adaptation strategy**	**Impacts on the social-ecological system**
Change in the fishing technique	Short term	Fishing technique was changed from the traditional fishing technique kadijala to the new fishing technique Kondhajala, due to the reduction in the fish and shrimp production in the lagoon as a consequence of the degrading ecological sub-system caused by the human activities	New technique further reduced natural productivity of lagoon by capturing juvenile fish and shrimp, which are the lifeline for the sustainability of the lagoon. It also created lack of fishing space and degraded the fishing norms.
Shrimp Aquaculture	Short term	Shrimp aquaculture was started to support the community activity, which was funded by the income from fishing. But because of the ecosystem degradation and income from fishing reduced, they started shrimp aquaculture in their lagoon. detailed description of aquaculture is the section 4.2.3	Degraded the social sub-system, which caused the leasing out of lagoon for shrimp aquaculture to non-fishers. Reduced the available fishing space, natural productivity of the lagoon.
Out-migration	Short-term/ Long term	When the social-ecological system crisis increased and survival based on fishing as livelihood was uncertain, people started out-migrating to different parts of Odisha and to other states like Tamil Nada, Goa etc. in India. Mostly the men of the fisher community migrated	Collapsed the social structure in both the family and community level, prominently as the men are out-migrating from the community. Loss of knowledge about fishing and the lagoon. Fishers are mentally stressed after out-migration.

Loans	Short/term	To cope with the economic crisis, the fishers are mortgaging their house, gold ornaments, lands to get loans.	Fishers are mentally stressed, again taking loans from other people to repay the previous loan, thereby trapped in debt forever. To repay the loans, fishers are intensifying fishing, which is causing future degrading the social-ecological system.

**Source: Semi-structure and focus group interview*

All the adaptation strategies used by the fishers of Khirishai led to maladaptation, which has made them more vulnerable to change. What can be done to change this maladaptation to a successful adaptation strategy? Perhaps one of the ways is to bridge the communication gap that is prevailing amongst the fisher communities and preventing social adaptation among them.

CHAPTER 6: CONCLUSION

This chapter summarises the overall findings of this case study. It also elaborates the current situation of the social-ecological system of Khirishai, and offers some recommendations for research and practice.

6.1. Current Situation of Khirishai

Local communities around the world that are depending on the ecological system for livelihoods. This is the case in Khirishai. For centuries, this fragile Khirishai social-ecological system was managed by local communities with their local knowledge, which was gained through experience. When the delicate relations between the human and the natural systems are disturbed by external or internal factors, local communities depending on the system suffer the most. Changes in the sub-systems, which initially occurs as a small issue (aquaculture & opening of new sea mouth) will become a larger issue through time. As well, the issue will give rise to other factors that will further impact the social-ecological system. It will create a chain of actions that further exacerbate the social-ecological system degradation.

The role of local knowledge diminishes and local communities must take grave short-term adaptation strategies to cope with the changes— even though they know the impact of the strategy on the social-ecological system may be negative. The changes and the consequences of changes becomes a cycle where the local communities are trapped.

In Khirishai, the drivers of changes are both external and internal. External factors include the change in the lease policy (which gave access to non-fishers to fish in the lagoon), aquaculture (started by the non-fishers), opening of new sea mouth, and construction of road. Internal factors include the change in the traditional fishing technique, and alternate livelihood (aquaculture). Both

the internal and external factors are linked and a result of these changes, the people of Khirishai are facing livelihood crisis. In the context of Khirishai, external factors are the changes that are brought about by others (e.g., Government and non-fishers) which did not involve the knowledge of fishers of Khirishai. On the other hand, internal factors are changes that are brought by the Khirishai fishers themselves.

The livelihood crisis and resource scarcity has led to conflict between the fisher villages of Khirishai and Banabaspur. Thus is a barrier for the process of adaptation as *"social adaptation is how communities and networks of fishers and stakeholders collaborate to respond to change"* (Grafton, 2010; Pg. 609). As a result of the conflict, the communication between the fisher villages is degrading. Moreover, the adaptation strategies used by the fisher of Khirishai have worsened the situation. Changes in fishing technique, aquaculture and out-migration gave the fisher a short relief from issues but in the long term, the strategies negatively impact the social-ecological system of Khirishai.

The present state of Khirishai's social-ecological system is has crossed a threshold where it can no longer support people as it could. One of the changes occurring as a consequence of all the drivers (synergistic effect of multiple drivers) is the reduction in fishing space for the fishers of Khirishai. Figure 6.1, explains the spatial and the temporal changes in the social-ecological system of Khirishai. It also expresses the present state of the social-ecological system of Khirishai. As shown in figure 6.1, changes started appearing slowly in the social-ecological system but as time went on, changes became more significant and they have created a cycle of livelihood crisis in Khirishai. The magnitude of change in the lagoon is increasing, and doing so in an unpredictable manner. All adaptation strategies taken by the fisher of Khirishai to cope with the changes in the social-ecological system have contributed to the cycle of livelihood crisis.

As a consequence of changing social-ecological system, the potential of the system to generate benefits to people has reduced drastically. As the potential decreases, the range of future adaptation options for the system decrease. However systems situation can be improved or fishers can build a capacity to cope. Some of the recommendations made by the fishers of Khirishai during the semi- structured interview and focus group interviews address the challenges they face are discussed.

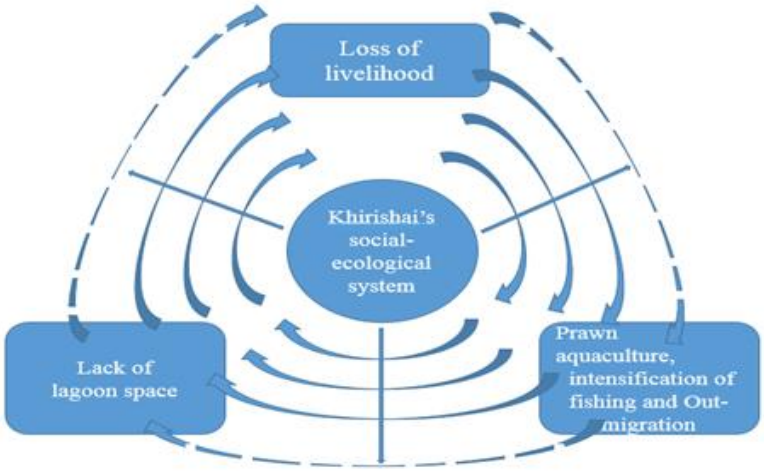

Figure 6.1: Spatial and temporal change in social-ecological system of Khirishai

6.2. Recommendations by the fishers of Khirishai

This section discusses the recommendations suggested by the fishers of Khirishai to reduce the anthropogenic stressors on the social-ecological system:

- No shrimp aquaculture in the lagoon

  Shrimp aquaculture is a serious issue in Khirishai and other villages in Chilika because it requires a great deal of lagoon fishing space, and also allows non-fishers to use the lagoon. By restricting shrimp aquaculture in the lagoon, the lagoon space

is reclaimed for other types of fishing and fishing grounds, conflicts between fishers and non-fishers will reduce.

- Changes to fishing techniques:

  Changing the fishing technique from current technique (*Kondhajala* to *Kadijala*) to their traditional technique. Changing the technique will increase the lagoon fish and shrimp production and also improve the social sub-system of the community as the traditional fishing technique is a group activity, and also supports other ecological benefits (e.g., cotton nets)

- Restricting non-fisher community from using the lagoon:

  Non-fisher communities are a huge issue because they occupy a large part of the lagoon for fishing and shrimp aquaculture. By restricting non-fisher communities from practising fishing, the lagoon will be more accessible for the fishers of Khirishai.

- No fishing in the lagoon channel:

  The Lagoon channel acts as a path for the fish to enter and exit the lagoon. Fishing in the lagoon channel prevents the movement of fish and other aquatic organism into the lagoon. Restricting fishing in the lagoon channel, will improve catch in Khirishai and other lagoon fisher villages.

- No trawlers fishing near the sea mouth and the sea

  Trawlers catch a quiet deal of fish and shrimp near the sea mouth, and from the sea near the lagoon. As a result of that, the fish production in the lagoon has been reduced in the recent years. If the trawlers are restricted to the deep sea, the natural productivity of the lagoon will increase.

Despite the recommendations given by the fishers of Khirishai it is impossible to say whether these recommendations, if implemented, will be helpful for Chilika fishers because there are many other stakeholders whom need to be considered. Active social-ecological changes in Chilika have been happening since the last two or more decades and restoring the social-ecological system to its previous position (if that is even possible) will take time and innovation. One of the recommendations pertains to key policy changes that can make provisions for actively restoring the social-ecological system of the lagoon by addressing each of the impacts it has received in the previous decades.

6.3. Future uncertainty

One of the future uncertainties in the lagoon relates to Climate change. About 25% of the semi-structured interview participants noted that the temperature is rising every year in the lagoon and the lagoon is nowadays drying rapidly. However, fishers are not concerned about the changes that are happening because of the climate change. A news report (See Annexure II) outlined the raising sea level in Puri a coastal city, which is not far from Chilika lagoon. This increase in the sea level certainly impacts the lagoon by promoting an increase in the amount of sea water entering into the lagoon.

6.4. Information for policy making

Change is inevitable in this era. But when it comes to policy making or decision making, all the stakeholders have to be included in the process. This is especially the case for indigenous communities who directly depend on ecosystems for their livelihoods. Policies that are made for the broader population sometimes exclude the interests of minority communities like Khirishai. Chilika lagoon is an example of what will happen to indigenous stakeholders (traditional fisher communities) are excluded in decision making (opening of new sea mouth and lease policy).

6.5. Conclusion

As discussed in the literature section of this thesis (See Chapter 2), Khirishai is an example of how humans dominate the ecosystem and how their decisions shape the ecosystem and its functions. Adaptation is an important factor to be considered when analysing social-ecological system changes. In the context of Khirishai, analysing the social-ecological system might have been ineffectual without analysing the adaptation strategies used by fishers. We can see a clear link between the social-ecological system and the adaptation strategies. Social-ecological system change pushed the fishers to use adaptation strategies which increased the vulnerability of the system instead of stabilising the social sub-system and ecological sub-system. Also the adaptation strategies used in the fisher community of Khirishai can be used to predict the future of the system. If the adaptation strategy being used was successful the social-ecological system could have recovered, but as a consequence of maladaptation, it further degraded the system leading the community towards social-ecological crisis and socio-economic crisis. Maladaptation in the case of Khirishai also resulted from other external factors like the practice of fishing by non-fishers, replacement of traditional cotton nets, and changes in policies which changed the social-ecological system of the lagoon. All of these factors pushed the fishers of Khirishai to take measures which emerged as internal factors that are degrading the social-ecological system. Figure 3.2 gave a framework for this thesis. The framework helped to analysis the past, present and future of social-ecological system changes and how the fisher community is responding to the changes.

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ANNEXURE I

Questionnaire for semi-structure and focus group interview

1. Are you experiencing any change in the Chilika Lagoon? If yes, what are the changes you experiencing in the Chilika lagoon? In your opinion what causes this changes?
2. What are the impact of opening of sea mouth on Chilika and Fishers?
3. Are you experiencing any difference in the impact of new mouth opening in the beginning and now?
4. Are you experiencing any disconnection to the lagoon because of the new sea mouth?
5. What are the impacts of aquaculture on Chilika and the Fishers?
6. What effects did you experienced in the past and now in the present?
7. Are there any minor changes other than opening of the new mouth and aquaculture that affects the Chilika? If yes please explain the changes and their impact on Chilika and the fishers.
8. What are the action do you take cope with this condition in Chilika?
9. What do you think about other natural calamities like cyclones?
10. In your opinion how these changes can be solved in the Chilika lagoon?

ANNEXURE II

Introductory letter and Invitation

Ashok Selvaraj

School of Environment, Enterprise and Development

University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1

Email: a5selvar@uwaterloo.ca

Re: Role of Local Knowledge and Adaptation to Environmental Change: A Case of Chilika Lagoon Small-scale Fishery, India

To Whom It May Concern:

My name is Ashok Selvaraj and I am conducting research on the local knowledge and adaptation strategies you have taken to cope with the environmental and social changes.

Three objectives guide this research program: 1) To examine the key social and environmental changes in Chilika Lagoon and their driving forces 2) How fisher communities perceive major environmental and social changes 3) The different strategies used by fishing communities to cope and adapt to the social and environmental changes.

The research will take place in Chilika Lagoon area, Odisha, India. The research approximately include 100-110, participants such as government authorities in local, district level, national levels, resource users and harvesters, and officials from relevant development and non-governmental organizations. I expect our discussions to take (approximately 45 minutes to three hours depending on whether invitation is for interview or focus group)

The outcomes associated with this study could benefit communities, local, provincial, and national government, NGOs and development agencies, and the general public as the environmental and social on the lagoon system and its related resources are a key concern. While this research focus on social-ecological changes, adaptation and local knowledge, the result could be applicable in other areas of the world where pressure on the social-ecological system are being addressed.

A summary report of this research will be provided to participating organizations, and results returned in summary report form to local community government representatives (fisher federation commune councils) within six months of the completion of the research project" I intend to publish the results of the research and make presentation as appropriate. I will also make available to all interested participants a brief summary of research results.

Please note that individual interview results will be kept strictly confidential and your comments will not be attributed by name or your organization, unless you ask for that to be done. I will seek your permission to audio tape the interview, and for the use of any quotations in the reports, publications or presentation.

I will transcribe any audio tapes, and only my research assistant and I will have access to interview notes. All of the results will remain in my possession and will be maintained on a password protected computer or in a locked cabinet and will be kept indefinitely to facilitate future comparative research.

Your participation is voluntary and you have the right to refuse to answer any questions or end the conversation at any time. There are no consequences for choosing not to answer questions or withdrawing from the interview process entirely. There are no anticipated risks associated with participation in this research. Data collection activities will proceed only when you feel comfortable doing so.

Given the group format of this session we will ask you to keep in confidence information that identifies or could potentially identify another person and/or his/her comments.

This project has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. However, the final decision about participation is yours. Participants who have concerns or questions about their involvement in the project may contact the Chief Ethics Officer, Office of Research Ethics at 001-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca. Collect calls will be accepted.

If you have any questions about the study you may please get in touch with my faculty supervisor Prof. Prateep Nayak at 001-519-888-4567 x33112 or pnayak@uwaterloo.ca

I would like to extend an invitation to you to participate in this (interview/focus group) as a part of the project titled 'Role of Local Knowledge and Adaptation to Environmental Change: A Case of Chilika Lagoon Small-scale Fishery, India'. Please indicate if you: a) agree to proceed with this interview / focus group; agree to having the interview / focus group audio-taped; and 3) if you agree to the use of direct quotation from your responses.

Yours Truly,

Ashok Selvaraj

Telephone: 01-519-781-4413

Email: a5selvar@uwaterloo.ca

ANNEXURE III

Letter of Appreciation

(To be modified to reflect either an individual interview or focus group meeting)

Dear (Name to be added)

I am writing to thank you for a stimulating meeting last week. Information provided by you during the meeting is really useful in understanding the issue, current activities and future requirements to deal social-ecological challenges for lagoon resource management. It was indeed a pleasure meeting you.

My project, Role of local knowledge and adaptation to environmental change: A case of Chilika Lagoon small-scale fishery, India, is proceeding according to design, and I plan to meet other resource person including government representatives in the coming week / months. Thank you for suggesting (name of contact) as a potential source.

I hope you will get in touch with me in further thoughts occurs to you about subject of our conversation, particularly if you decide in retrospect that you will like to designate some of it for non-attribution. Should you have any comment or concerns you could also contact Dr. Maureen Nummelin, the Director, Office of Research Ethics, at 001-519-888-4567 x36005 or Maureen.nummelin@uwaterloo.ca .

This project was reviewed by, and received ethics clearance through, the office of research Ethics at the University of Waterloo.

If you have any questions about the study you may please get in touch with my faculty supervisor Prof. Prateep Nayak at 001-519-888-4567 x 33112 or pnayak@uwaterloo.ca

I shall as promised, be sending draft documents, for your criticism and comments. I expect it to be ready for your review by (date to be added).

Sincerely,

Ashok Selvaraj/Student Researcher

Telephone: 001-519-781-4413

Email: a5selvar@uwaterloo.ca

Address:

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Environment 3

Ring Rd

Waterloo, Ontario, Canada N2L 3G1

ANNEXURE IV

Participants Feedback Letter

University of Waterloo

Date

Dear ***(Insert Name of Participant),***

I would like to thank you for your participation in this study entitled *"Role of local knowledge and adaptation to environmental change: A case of Chilika Lagoon small-scale fishery, India"*. As a reminder, the purpose of this study is to identify, how the fisher communities in Chilika understand and adapt to the social and environmental changes in the Chilika Lagoon.

The data collected during interviews will contribute to a better understanding of change processes experienced by fisher communities particularly in Chilika Lagoon but also elsewhere in the world.

Please remember that any data pertaining to you as an individual participant will be kept confidential. Once all the data are collected and analyzed for this project, I plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please provide your email address, and when the study is completed, I will send you the information. In the meantime, if you have any questions about the study, please do not hesitate to contact me by email or telephone as noted below. As with all University of Waterloo projects involving human participants, this project has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. Participants who have concerns or questions about their involvement in the project may contact the Chief Ethics Officer, Office of Research Ethics at 001-519-888-4567, Ext. 36005 ormaureen.nummelin@uwaterloo.ca. Collect calls will be accepted.

If you have any question about the study you may please get in contact with my faculty supervisor Prof. Prateep Nayak at 001-519-888-4567 x33112 or pnayak@uwaterloo.ca

Yours Truly,

Ashok Selvaraj/Student Researcher

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ANNEXURE V

Newspaper article stating the sea level rise in Puri, Odisha, India