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RESEARCH PAPER

Deterioration of Wetland Ecology and Livelihood Crisis: A Study from Loktak Wetland, Manipur, India

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Abstract: Loktak Lake, a Ramsar wetland of international importance, is vital to the livelihoods of people in Manipur. The wetland's ecology has been degrading for various reasons, particularly anthropogenic activities. Hence, it was listed in the Montreux Record in 1993. This study investigates risks associated with fishing and farming livelihoods in the area and identifies the factors that drive them. It is based on a field investigation of 600 households from 12 villages in the wetland. The study employed a mixed-methods approach, incorporating participatory risk mapping, various indices such as the Standard Livestock Unit Index, Policy Index, Wealth Index, and Simpson Diversity Index, and, finally, Ordinal Logistic Regression (OLR) model to identify significant predictors. The findings show that the extinction and decline of fish species, the proliferation of *phumdis*, water pollution, siltation, and submergence are major concerns that severely impact fishing. Non-ecological stressors, such as lack of irrigation infrastructure, market risks, and input costs, severely affect farmers. The OLR model indicates that household size, age range of the household members, sex ratio, migration, religion, and livestock ownership are significant predictors of ecological risks. Conserving wetland ecology is a prerequisite for ensuring sustainable livelihoods in Loktak; accordingly, an integrated natural resource management strategy is urgently needed.

Keywords: Wetland Ecology, Livelihood Issues, Participatory Risk Mapping, Fishing, Farming.

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1. INTRODUCTION

Wetlands play a significant role in maintaining the ecological balance and supporting human livelihoods. They offer several environmental benefits, including freshwater for domestic use and irrigation, food security, wildlife habitats, and carbon sequestration. In addition, they also contribute to flood control, help manage groundwater recharge and discharge, and reduce nutrient contamination. There is a strong, inseparable connection between wetlands and communities, particularly in developing countries, where people are reliant on wetland ecosystems for their livelihoods (Wondie 2018). Globally, one in eight people depends on wetlands for activities such as fishing, farming, ecotourism, and handicrafts (Convention on Wetlands n.d.). Globally, wetlands support rice production that feeds 3.4 billion people and meet more than 40% of fish demand through aquaculture (Convention on Wetlands n.d.).

However, wetlands in different parts of the world are increasingly being degraded by various human activities (Sica *et al.* 2016; Oberholster *et al.* 2014; Wang *et al.* 2012). Between 1990 and 2015, the average annual loss rate of wetlands (–0.78%) was estimated to be three times that of natural forests (–0.24%) (FAO 2015). Approximately 35% of marine, coastal, and inland natural wetlands were lost between 1970 and 2015, with regional losses ranging from 12% in Oceania to 59% in Latin America (Convention on Wetlands 2018). Some of the impacts of wetland degradation include loss of biodiversity, decline in water quality and water shortages, increased vulnerability to flooding, and reduced carbon sequestration (Zedler and Kercher 2005).

According to the *Millennium Ecosystem Assessment* (2005), various anthropogenic factors are the primary drivers of changes in wetland ecologies, which in turn affect the livelihoods of households engaged in fishing and farming in the area. Since the communities dependent on wetlands are usually the poorest and most directly affected by them, they are among the most affected by the changing ecology of the wetland (Kundu *et al.* 2024; Huq *et al.* 2020). As a result, diversifying livelihood activities—whether *in situ* or through migration—has become a crucial strategy for sustaining livelihoods. Studies on coastal mangrove swamps, the Sundarbans wetland (Mistri and Das 2020), inland freshwater wetlands, and the Loktak wetland complex show that people are migrating in large numbers from wetlands to either nearby cities or distant metropolitan areas outside their states in search of employment (Mistri *et al.* 2025a; Singh and Mistri 2025). For instance, in the Nijhum Dwip coastal wetland of Bangladesh, fishing communities have shifted from fishing to alternative income sources, including livestock rearing, farming, daily labour, and handicraft activities (Rahman *et al.* 2012).

This study focuses on Loktak Lake, a Ramsar wetland (designated in March 1990) in the Northeast (NE) Indian state of Manipur. Loktak Lake, spanning about 260 sq km, is the largest freshwater lake in NE India, and along with 19 freshwater marshes, forms the Loktak wetland complex. The Loktak wetland supports rich biodiversity, including 54 fish species, 68 reptiles and amphibians, 22 mammals, 116 bird species, and more than 200 plant species (MoEFCC 2025). Approximately 3 lakh people residing in 55 rural and urban settlements in and around the wetland depend directly or indirectly on it for their sustenance (LDA n.d.; Bharati *et al.* 2017).

According to the *Ramsar Sites of India Factbook* (2025), approximately 5,000 fishers depend on Loktak Lake for their livelihoods (MoEFCC 2025). It is a major source of fish throughout Manipur. Fishing in the wetland includes two types: open-water fishing and aquaculture along the lakeshore. Three types of farming activities are practised along the periphery of the wetland: aquaculture cum paddy cultivation; intensive subsistence farming, primarily rice cultivation; and commercial farming, primarily horticulture. The wetland also provides various edible and medicinal plants as well as raw materials for handicrafts, which constitute an important source of income for many households (LDA n.d.). Owing to its immense importance to Manipur's economy, the lake is known as the "Lifeline of Manipur" (LDA n.d.).

Three years after its Ramsar designation, Loktak Lake was listed in the Montreux Record in June 1993 due to ecological issues. According to the Ramsar Sites Information Service (23 March 1990), "deforestation in the catchment area, water hyacinth infestation, and pollution" were identified as primary causes of ecological degradation of the Loktak Lake (Ramsar Convention 1990). The commissioning of the Ithai Barrage (in 1983) on the Manipur River under the Loktak Hydro Electric Project (LHEP), which blocked the wetland's outlet, was the turning point for the rapid deterioration of the lake's ecology. The cofferdam has "caused the local extinction of several native fish species" (Ramsar n.d.). Before the construction of the barrage, many fish species would migrate from the Chindwin–Irrawaddy River system through the Manipur River into the lake. However, with the barrage blocking their migratory pathway, the number of fish species and their population in the lake have declined or disappeared altogether (Singh 2018). Because the lake water was maintained above the flood level, the lake's periphery, including residential and agricultural land, became submerged, resulting in displacement and loss of economic activities (Thakur 2020).

Siltation is another major issue, as rivers and canals deposit sediment in the lake. This results in the lake bed filling and blocking water flow at the Ithai Barrage (Singh 2018). According to the *Ramsar Sites of India Factbook*, "water regime alteration by Ithai barrage" is identified as a "high threat" in the Loktak wetland; other medium-level threats are the proliferation of *phumdis* (heterogeneous floating masses of vegetation, soil, and organic matter), siltation, water pollution, unsustainable water abstraction for Loktak hydropower, and fragmentation by road construction on the wetland (MoEFCC 2025, 82).

The "Wetland Health Card" prepared by the Ministry of Environment, Forest and Climate Change (MoEFCC 2021), which is based on information collected in 2019 on nine parameters[1] across four broad categories—area, hydrology and catchment, biodiversity, and governance—paints a gloomy picture of the Loktak wetland's health. Invasive macrophytes cover approximately 21–30% of Loktak Lake, and since 2000, 1–5% of the wetland has been converted to non-wetland uses. The ratios of the number of natural inlets choked and diverted to the total number of natural inlets, and of the number of natural outlets choked and diverted to the total number of natural outlets, were estimated at 0.4–0.6 for each; i.e., evaluated as "B category", whereas the "desired value" is <0.2 for each parameter. Notably, data on annual waterbird counts as a proportion of the five-year average are unavailable, constraining biodiversity assessment. In short, Loktak's degraded ecology threatens biodiversity, natural resources, and the livelihoods of wetland-dependent communities.

Several studies have focused on ecological issues and their impacts. Yet, economic issues and their impact on the livelihoods of communities dependent on the Loktak wetland are rarely explored with empirical rigour. A handful of studies (Mistri *et al.* 2025a, 2025b; Singh and Mistri 2025; Paonam and Chatterjee 2023; Oinam and Khoiyangbam 2017) have examined the status of and challenges to livelihoods in and around Loktak Lake. However, these are small-scale studies, limited to one or two villages, blocks, or islands, with a narrow scope, focusing only on fishing issues or on fishers' health. Moreover, research on the impact of ecological changes

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[1] The nine parameters in the "Wetland Health Card" are the percentage of wetland converted to non-wetland use since 2000; the ratio of the number of natural inlets choked and diverted to the total number of natural inlets; the ratio of the number of natural outlets choked and diverted to the total number of natural outlets; the percentage of samples conforming to desired biochemical oxygen demand/ dissolved oxygen/ chemical oxygen demand levels; the percentage of wetland area covered by invasive macrophytes; annual water bird count as a proportion of average count of last five years; clearly demarcated wetlands map; wetland management plan; and wetland notification.

on the livelihoods of island and lakeshore communities—particularly in relation to fishing, aquaculture, and farming, as well as their adaptation to these adverse conditions—has remained empirically underexplored. Therefore, the present study aims to bridge this gap by assessing the perceived risks associated with the principal means of livelihood generation—fishing and farming—in and around Loktak, given the wetland's deteriorating ecological conditions. The study also examines how demographic, social, and economic factors influence ecological risk perception among individuals engaged in fishing and farming.

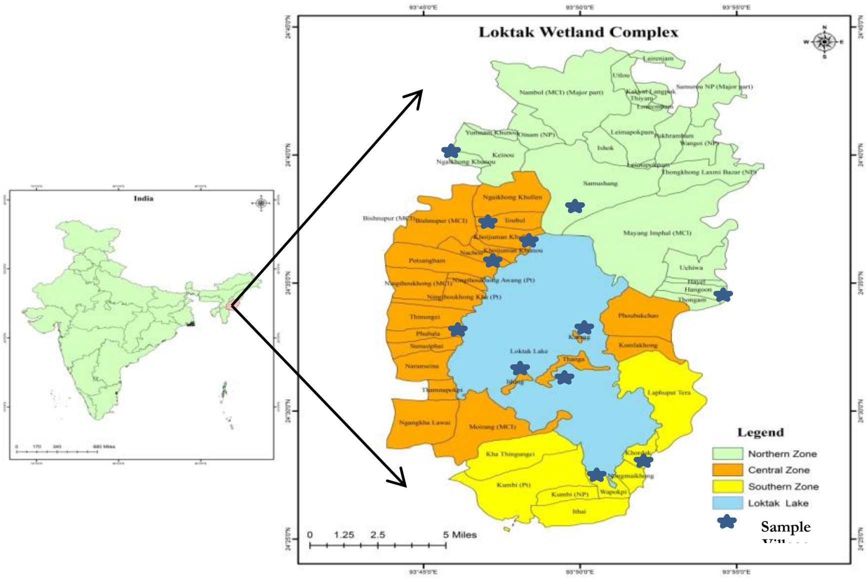
2. METHODOLOGY

In order to fulfil the objectives of the study, primary data pertaining to livelihood risks and socio-economic conditions were collected. The data were analysed using a mixed-methods approach that combined descriptive and inferential techniques. The detailed methodology adopted in this study is described in the following sections.

2.1 Data Sources and Sample

This study is primarily based on a field survey conducted in 12 census villages in the 55 settlements in and around the Loktak wetland (Census of India 2011). A census village is the smallest geographical unit, while the household is the smallest social unit for sampling. The study area, along with the sampled villages, is illustrated in Figure 1. Multistage sampling was employed to select villages with the highest share of households dependent on farming and fishing in the 2011 Census. The Loktak Development Authority (LDA) divides the Loktak wetland into three distinct zones—Northern, Central, and Southern—based on factors such as vegetation type, density of *phumdis*, drainage system, location of open water areas, and human activities. In the Northern Zone, three villages—Samusang, Hangoon, and Ngaikhong Khunou—were selected; these had the highest share of households practising fish farming combined with agriculture. Similarly, in the Southern Zone, two villages—Wapokpi and Khordak—were chosen for their predominant reliance on fishing. In the Central Zone, three islands—Ithing, Thanga, and Karang—were purposively selected to observe the effects of capture fishing in the lake's open waters. Additionally, four lakeshore villages in the Central Zone—Phubala, Nachou, Toubul, and Khoijuman Khullen—were included, as fishing and farming are their primary economic activities.

Figure 1: Map of the Study Area with Sample Villages Marked



Source*:* Authors' compilation

A total of 600 households—on average, 50 per village—were selected from the 12 sample villages. The sample size was decided based on Cochran's sampling formula (1977). At a 4% margin of error, 95% confidence level, and population variance of 0.5, the required sample size is approximately 600 for an unknown study population. A census village comprises different wards, locally called *leikai*. From each *leikai*, roughly an equal number of households that engaged in either fishing or farming were selected randomly. A household survey was conducted using a structured questionnaire. The survey was conducted after obtaining the respondents' informed consent. Only adult fishers or farmers were chosen as respondents.

2.2 Study Design

The study employed a mixed-methods approach. It incorporated descriptive statistics, such as mean, median, mode, and standard deviation, as well as other inferential statistics. Indices such as the Standard Livestock Unit Index, Policy Index, Wealth Index, and Simpson Diversity Index were constructed. The study included participatory risk mapping (Smith *et al.* 2000), a method used to assess risk perception in fishing and farming activities in Loktak. Participatory risk mapping is a subjective approach based on the perceptions of respondents. In this method, respondents are first asked to identify risks associated with fishing or farming that they have experienced in the last five years. If they do not remember or struggle to articulate these, they are provided with a predefined list of risks derived from the existing literature (Paonam and Chatterjee 2023; Singh 2018; Oinam and Khoiyangbam 2017) and pilot surveys. After identifying the risks, respondents are asked to rank them from most severe to least severe. Based on these perceived risks and their ranking, three indices—Incident Index (I_j), Severity Index (S_j), and Risk Index (R_{ij})—were constructed. The I_j and S_j were constructed for the entire sample and graphically represented using quadrant mapping (risk mapping). Risk perception at the household level was assessed using the Risk Index (R_{ij}).

2.3 Incident Index

The Incident Index quantifies the proportion of respondents who identified a specific risk, indicating its prevalence in the population (Smith *et al.* 2000). The index ranges from 0 (no households are affected) to 1 (all households are affected). The formula for the Incident Index is given as:

$$I_j = \frac{n_j}{s} \qquad \text{(i)}$$

Where I_j is the Incident Index for the risk j, n_j is the total number of households identifying a particular risk j, and s is the total number of households in the study.

2.4 Severity Index

The Severity Index assesses the severity of each risk on a scale from 0 (least severe) to 1 (most severe). The index is based on the respondents' ordinal rankings. In the study, the Severity Index (vide formula ii) for a particular risk (j) perceived by a household (i) was computed using the formula adopted by Bunting et al. (2013), modified from Smith et al. (2000):

$$S_j = \left[\frac{r-1}{n-1}\right] \text{x} \, (-1) + 1 \qquad \text{(ii)}$$

Where S_j is the Severity Index of a particular risk j identified by a household, r is the ordinal rank of risk j, and n is the total number of risks identified by a household. The mean of all S_j values for the whole sample is the Severity Index for risk j.

2.5 Risk Mapping

Risk mapping with quadrants provides a graphical representation of risk combining I_j and S_{ij}. Since the Incidence and Severity indices range from 0 to 1, 0.5 is used as the midpoint for both the x-axis and y-axis, dividing the figure into four quadrants: upper-right quadrant (+, +), upper-left quadrant (–, +), lower-right quadrant (+, –), and lower-left quadrant (–, –). Risks in the upper-right quadrant are characterized by high prevalence and severity, while those in the lower-left quadrant have low prevalence and severity. The lower-right quadrant has high severity and low prevalence, while the upper-left quadrant has low prevalence but high severity.

2.6 Risk Assessment at the Household Level

Doss *et al.* (2008) and Nnaji *et al.* (2023) developed the Risk Index, based on Smith *et al.* (2000), to assess risk at the household or unit level. The formula is given as:

$$R_{ij} = 1 - \left[\frac{(r_{ij}-1)}{n_i}\right] \qquad \text{(iii)}$$

Where R_{ij} is the risk index for household i for the risk j, r_{ij} is the ordinal rank of risk *j* for the household *i*, and n_i is the total number of risks identified and ranked by household *i*.

2.7 Simpson Diversification Index

Livelihood diversification was assessed to examine household income diversity in the wetland beyond fishing and farming. The livelihood diversification index was constructed based on the Simpson Diversification Index (SDI) (Simpson 1949), which is calculated using the number of sources and the proportion of income from each source. The formula for SDI is as follows:

$$SDI = 1 - \sum_{i=1}^{n} P_i^2 \qquad \text{(iv)}$$

Where n is the total number of income sources, and Pi is the proportion of income from the *i*-th income source. The SDI value ranges from 0 to 1, where 0 indicates no diversification—meaning the household relies on a single wetland-dependent activity, either fishing or farming. As the SDI value increases and approaches 1, it indicates an increase in the number of income sources and a more even distribution of income across those sources. Based on this value, the SDI is categorized into four categories of diversification: no diversification, low, medium, and high. When a household engages in a single activity, such as fishing or farming, it is tagged as "no diversification". These households do not generate income from any economic activities other than wetland-based fishing or farming, or farming combined with fish farming. A low diversification household is engaged in two economic activities, with one activity (e.g., fishing or farming) contributing the predominant share of income. A medium-diversification household engages in two or three activities, with income distributed more or less equally; one of these activities is dependent on the wetland, such as fishing or farming. A high diversification indicates a household with income from four or more sources that are evenly distributed, one of which is a wetland-based activity.

Finally, an Ordinary Logistic Regression (OLR) model was constructed to examine how 13 predictors influence perceived ecological risks in fishing and farming. The formula for the OLR model (Cameron and Trivedi 2005) is:

$$\Pr(Yi > j) = \frac{\exp(\alpha j + Xi\beta j)}{1 + [\exp(\alpha j + Xi\beta j)]} \; j = 0 - 2 \qquad \text{(v)}$$

Where Y_i is the dependent variable of three categories of ecological risks (low, moderate, and high) (see Section 2.8), *aj* is the intercept, and *βj* is the vector of the parameter to be estimated. *Xi* denotes independent variables.

2.8 Variables Used in the Study

This section presents the dependent and independent variables, including their categories, descriptions, and the techniques used for deriving them. These variables are incorporated into the OLR model to examine the demographic and socio-economic determinants of the perception of ecological risk.

2.8.1 Dependent variable

The dependent variable of the study is ecological risk. Ecological risk is estimated by summing the *Risk Indices* for all the ecological and climatic risks that a household experiences in relation to fishing and farming. The risk perception score is divided into three categories: low risk (< 0.94), moderate (0.94–3.64), and high (> 3.64), based on the mean ± standard deviation.

2.8.2 Independent variable

The influence of 14 independent variables on the perception of ecological risks was assessed. These are (1) household size, which includes the total number of household members; (2) age group, which comprises the age range of household members (15–29 years, 30–59 years, and 60 years and above); (3) educational level, which refers to the highest level of education—primary, secondary, or higher—attained by any household member; (4) sex ratio, i.e., number of females per 1,000 males living in a household (calculated by dividing the total number of female household members by total number of male household members and multiplying by 1000), based on which households are categorized as male-dominated, balanced, and female-dominated; (5) household migration status, conceptualized in the study as the migration of any household member for at least a month at a stretch for work or employment purposes within the last two years; (6) social group, which includes Scheduled Caste (SC), Other Backward Classes (OBC), and General (Gen) (i.e., non-SC/OBC/Scheduled Tribe (ST)); (7) religion, comprising Sanamahism, Christianity, and Hinduism; (8) household type, defined by the household's principal activities—fishing, farming, and both; (9) income, measured by the household monthly income in Rupees (□); (10) landholding, referring to the total land held by households in hectares; (11) SDI, which was used to measure the level of livelihood diversity among wetland communities; (12) the Standard Livestock Unit Index, which is a summary index of livestock possession computed by multiplying the coefficients/weights proposed by the Food and Agriculture Organization (2011) by the number of livestock reared in a household; (13) the Wealth Index, comprising 24 indicators that capture housing, basic amenities, and household assets, which is derived using principal component analysis with varimax rotation, yielding four components that explain 60% of the variance; and (14) the Policy Index, a summation of benefits or facilities obtained by households in the last five years from policies/schemes, which is constructed using the equal-weighted standardization technique.

3. RESULTS

This section presents the findings of the study based on the primary data collected through the field survey. The analysis begins with the perceived risks associated with fishing and farming, the ecological conditions of the Loktak Lake wetland, the background characteristics of the households, and the determinants of perceived ecological risk. The detailed findings are discussed in the following subsections.

3.1 Perceived Risk in Farming

The farmers identified 11 farming risks (Table 1). These are categorized under five heads. Ecological and climatic risks in farming include the submergence of agricultural fields, irregular rainfall patterns, and the sudden onset of climatic events. Highly reported non-ecological risks include the rising cost of agricultural inputs, market price fluctuations, lack of credit and financial support, and health issues. The rising cost of farm inputs, such as fertilizers, tillage costs, and machinery, are the most often cited farming risk reported by 90% of households. However, since its intensity is not severe (S_j = 0.484), it is placed in the lower-right quadrant of the risk map (Figure 2). The unavailability of irrigation is the second-most prevalent concern, affecting 86% of households; its effects are also intense (S_j = 0.810). Irregular rainfall is also the most prevalent and severe farming risk,

Table 1: Farming Risks in the Loktak Wetland

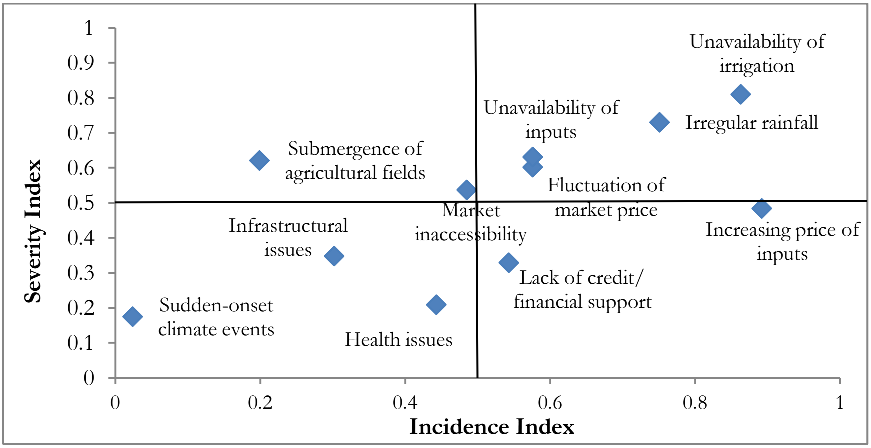
Category	**Risks**	**Incidence (I_j)**		**Severity (S_j)**	
		Value	Rank	Value	Rank
Ecology and climate	Submergence of agricultural fields	0.199	9	0.621	4
	Irregular rainfall	0.751	3	0.73	2
	Sudden-onset climatic events	0.024	10	0.175	11
Agricul-tural input	Unavailability of irrigation	0.863	2	0.81	1
	Unavailability of l inputs	0.576	4	0.602	5
	Increasing price of inputs	0.892	1	0.484	7
Market	Fluctuation of market price	0.576	4	0.631	3
	Market inaccessibility	0.485	6	0.537	6
Institu-tional	Lack of credit/financial support	0.543	5	0.329	9
	Infrastructural issues	0.302	8	0.348	8
Personal	Health issues	0.443	7	0.209	10

Note: n = 241.
Source: Computed from field survey data

affecting 75% of households and carrying a severity index of 0.73, placing it in the upper-right quadrant of the risk map (Figure 2).

Agricultural fields getting submerged due to the construction of the Ithai Barrage emerged as the most severe risk (S_j = 0.621). However, it is also among the least prevalent, affecting only 20% of households. The risk of sudden onset of a climatic event is the least prevalent risk reported by 2.5% of households and the least severe (S_j = 0.175). Personal health hazards and infrastructure issues are also among the least prevalent and severe risk categories.

Figure 2: Farming Risk Map Overview



Source: Computed from field survey data

Table 2: Fishing Risks in the Loktak Wetland

Category	Risks	Risk Index (I_j)		Severity Index (S_j)	
		Value	Rank	Value	Rank
Ecological and environmental	Water pollution	0.574	5	0.638	3
	Phumdis proliferation	0.618	4	0.685	1
	Decrease in depth of water	0.417	10	0.482	9
	Decrease in fishing areas	0.507	8	0.599	7
	Sudden-onset climatic events	0.49	9	0.616	6
	Flooding/submergence of fishponds/ farms	0.385	12	0.619	5
	Seasonality in fish availability/ production	0.404	11	0.635	4
	Decrease in fish species and availability	0.674	2	0.671	2
Fishing input	High price of fishing equipment	0.716	1	0.581	8
	Low availability of inputs	0.206	15	0.453	10
Market	Market inaccessibility	0.517	7	0.424	11
	Fluctuation of fish price	0.287	14	0.346	15
Institutional	Fishing regulations	0.098	16	0.409	12
	Lack of infrastructure in fishing	0.321	13	0.357	14
	Unavailability of credit/ financial support/in fishing	0.625	3	0.379	13
Personal	Health hazard	0.566	6	0.24	16

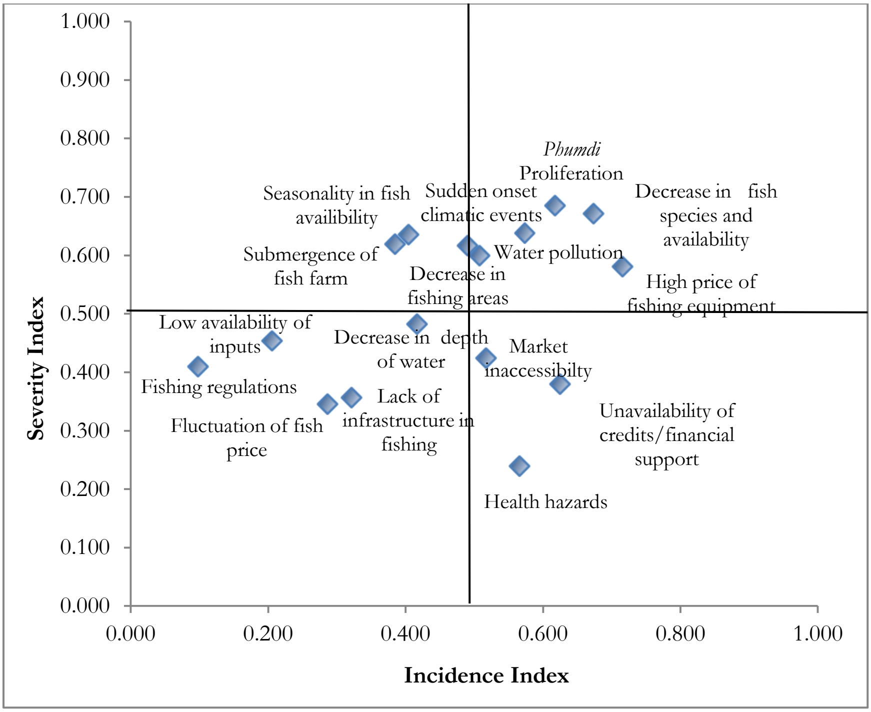
Note: n = 408.

Source*:* Computed from field survey data

3.2 Perceived Risk in Fishing

Fishers reported facing 16 risks associated with fishing, disaggregated into five categories (Table 2). The analysis showed that ecological or environmental risks in fishing are more severe than non-ecological risks. Proliferation of *phumdis* is a severe livelihood concern reported by most fisherfolk (I_j = 62; S_j = 0.69). This is followed by a decrease in fish species and their availability. *Phumdis* proliferation, decrease in fishing species and production, and water pollution are placed in the upper-right quadrant of the risk map (Figure 3), indicating a high prevalence and high severity of risk in fishing. Seasonality in fish availability is the most severe risk (S_j = 0.635), but its prevalence is low, reported by 40% of fishing households. A similar trend (severe risk, low prevalence) is also observed in risks associated with sudden-onset climatic events, such as rainfall, gusty winds, and storms.

Figure 3: Fishing Risk Map Overview



Source*:* Computed from field survey data

About 62% of fishing households reported the unavailability of credit facilities, mainly from the government sector, although the severity is relatively lower (S_j = 0.379). This risk is therefore placed in the lower-right quadrant. Health issues resulting from fishing are also placed in the same quadrant, indicating high prevalence but low severity. Price issues, such as volatility in the price of fish products, rules and regulations governing fishing issued by the LDA and other government agencies, and limited availability of fishing inputs, are among the least prevalent and least severe fishing risks faced by fishers (Figure 3).

3.3 Background Characteristics of Households

Table 3 presents the background characteristics of households. On average, there are six individuals in each household. Approximately 67% of households have members aged 30–59 years, while 29% have members aged 15–29 years. This indicates that the study area is in a more favourable stage of the demographic dividend, characterized by a larger share of economically productive people and a lower dependency ratio. About 54%

Table 3: Background Characteristics of Households

Characteristics	Frequency	(%)	Mean	Standard Deviation
Demographic Characteristics				
Household members	600		5.72	1.944
Age group				
15–29 years	77	12.8		
30–59 years	406	67.7		
60 years and above	117	19.5		
Educational level				
Primary	34	5.7		
Secondary	242	40.3		
Higher	324	54		
Sex ratio				
Male dominated	243	40.5		
Balanced	156	26		
Female dominated	198	33		
Migration				
No	293	48.8		
Yes	307	51.2		
Social Characteristics				
Social category				
SC	230	38.3		
OBC	289	48.2		
GEN	81	13.5		
Religion				
Sanamahism	269	44.8		
Christianity	12	2		
Hinduism	319	53.2		
Economic Characteristics				
Livestock possession				
No	233	38.8		
Yes	377	62.2		
Income	600		Rs. 27,643	Rs. 24,187
Landholding	600		0.49 ha	0.81ha
Household type				
Farming	192	32		
Fishing	359	59.8		
Both	49	8.2		
Location of village				
Northern zone	146	24.3		
Central zone	355	59.2		
Southern zone	99	16.5		

Contd...

Characteristics	Frequency	(%)	Mean	Standard Deviation
Livelihood diversification				
No diversification	163	27.2		
Low diversification	75	12.5		
Medium diversification	300	50		
High diversification	62	10.3		

Source*:* Field survey data

of households have at least one member with higher education; only 5.7% have only members with primary education. Households are predominantly male-dominated (40%), while the share of female-dominated households is 33%. Approximately 51% of households reported that one or more members experienced migration due to work and employment purposes in the last two years. The population in the study area was predominantly constituted by low-income OBC communities. A significant number of SC households reside in three islands—Thanga, Karang, and Ithing. Hinduism (53%) is the most followed religion, followed by Sanamahism (45%), a traditional religion of the Meitei community. Christianity (2%) is the least followed of the major religions.

Among the sampled households, approximately 60% are engaged in fishing, 32% in farming, and 8.2% in both. About 40% of households rear livestock. Intensive and commercial rearing are negligible. Nearly 27% of households depend solely on the wetland for their livelihood, while 73% engage in other non-wetland-dependent activities as well as wetland-dependent activities. The average monthly household income is Rs. 27,643, which is above the average monthly income (Rs. 12,698) of rural households in India as per the National Bank for Agriculture and Rural Development (NABARD 2022). The mean landholding is about 0.50 hectares, which is below the average landholding size (0.74 hectares) in rural India (NABARD 2022).

3.4 Factors Affecting Ecological Risks in Fishing and Farming

Table 4 presents the results of the OLR model, which predicts the likelihood of households reporting ecological risks. Of the 14 predictors, 7 significantly account for variations in the response variable, i.e., the ordinal category of ecological risk perception in fishing and farming. For each additional household member, the odds of being in a high ecological risk category increase by 14%. The households with members aged 30–59 are two times more likely to experience high ecological risk than those with members aged 60 and above. Male-dominated households are 48% more likely to perceive high ecological risk than female-dominated households.

Table 4: OLR Model of the Likelihood of Ecological Risk Perception in the Loktak Wetland

Response Variable: Ordinal Category of Ecological Risk (Low: 1, Medium: 2, High: 3)					
Independent Variables	**Estimate**	**Odds Ratio (OR)**	***p***	**95% Confidence Interval**	
				Lower Bound	Upper Bound
Demographic Characteristics					
Household members	0.130	1.139	0.023	0.018	0.242
Age group					
15–29 years	0.521	1.683	0.128	–0.150	1.191
30–59 years	0.690	1.994	0.007	0.191	1.189
60 years and above (ref)					
Education level					
Primary	–0.313	0.731	0.508	–1.239	0.613
Secondary	–0.038	0.963	0.854	–0.440	0.364
Higher (ref)					
Sex ratio					
Male dominated	0.394	1.482	0.025	–0.039	0.827
Balance ratio	0.274	1.315	0.266	–0.209	0.757
Female dominated (ref)					
Migration					
Yes	0.192	1.212	0.041	–0.203	0.587
No (ref)					
Social Characteristics					
Social category					
SC	–0.363	0.696	0.265	–1.001	0.275
OBC	–0.288	0.749	0.318	–0.855	0.278
GEN (ref)					
Religion					
Sanamahism	–0.395	0.674	0.045	–0.781	–0.009
Christianity	–2.333	0.097	0.001	–3.708	–0.958
Hinduism (ref)					
Economic Characteristics					
Household type					
Both	–1.865	0.155	0.124	–2.689	–1.041
Fishing	1.138	3.120	0.003	0.386	1.890
Farming (ref)					
Income	1.02	5.590	3.78	4.91	1.290
Livelihood diversification					
No diversification	0.015	1.015	0.969	–0.761	0.791
Low diversification	0.207	1.230	0.621	–0.615	1.029
Medium diversification	0.354	1.425	0.300	–0.316	1.024
High diversification (ref)					

Contd...

Landholding	–0.063	0.938	0.629	–0.321	0.194
Livestock	–0.342	0.711	0.045	–0.677	–0.007
Policy Index	–0.039	0.962	0.326	–0.116	0.039
Wealth Index	–0.301	0.740	0.352	–0.933	0.332

Note: Model fitting information: $X^2 = 190.034$, $p = 0.000$; $n = 600$; Cox & Snell $R^2 = 0.296$.

Source: Computed from field survey data

Migrant households have higher odds (OR = 1.21) of reporting high ecological risk compared to non-migrant households.

In the social category, religion is a significant factor. Compared with households following Hinduism, those following Sanamahism or Christianity have lower odds of experiencing high ecological risk (OR = 0.674 and OR = 0.097, respectively). Fishing households have a higher likelihood—by three times—of experiencing high ecological risk compared with farming households. Livestock rearing has a negative impact on the likelihood of experiencing ecological risk; for every one-unit increase in livestock, the likelihood of experiencing high ecological risk decreases by 29%.

4. DISCUSSION

Fishing risks related to ecological changes, such as the decline of fish species, the proliferation of *phumdis*, water pollution, and seasonality in fishing, are the most severe. Before the construction of the Ithai Barrage in 1983, seasonal fluctuations in water levels and dry periods limited the growth of *phumdis* (LDA and WISA 2010). However, following the operation of the barrage, between 1989 and 2002, the area occupied by *phumdis* increased from 116.4 sq km to 134.6 sq km (Singh and Moirangleima 2009). The proliferation of *phumdis* is also aggravated by blockage of the wetland's water by the Ithai barrage. Before the construction of the barrage, *phumdis* were used to remove from the wetland through the Manipur River. Chemical fertilizers, pesticides, and insecticides used in the surrounding catchment areas are carried into the wetland by rivers, leading to eutrophication and the proliferation of *phumdis* (LDA 2011). The proliferation of *phumdis* negatively impacts fishing by obstructing the navigation of fishing boats, reducing open-water fishing areas, disrupting fish breeding, increasing water pollution through *phumdis* decomposition, and contributing to Lake Siltation (Singh and Khundrakpam 2011). The risk of *phumdis* proliferation is more pronounced in villages in the Northern and Southern Zones, such as Hanggon, Shamushang, Wapokpi, and Khordak.

Water pollution in Loktak mainly results from the rivers that drain into the wetland (Kangabam and Govindaraju 2019). The Nambul River, which flows through Imphal city, drains directly into the Loktak wetland. It significantly pollutes the wetland because of the discharge of silt, sediment, and urban waste, leading to a reduction in fish species (Meinam et al. 2025). A study by Borah *et al.* (2024) found microplastics in 91% of fish samples from the wetland, underscoring the severity of pollution and potential health risks to humans. The sediments in the wetlands have a high iron concentration. The probable reason for this is the diffusion of iron-rich soils from surrounding catchment areas and other human influences (Laishram *et al.* 2025)

Before 1950, fish from the wetland accounted for more than 60% of Manipur's total fish production, with fish from the Chindwin–Irrawaddy system accounting for 40% of the wetland's production. However, fish production in the wetland has now dropped to 11% (Meinam *et al.* 2025). This decline in fish species and their populations is, therefore, among the most widespread and serious risks facing the Loktak wetland. The Ithai Barrage slows the water current, leading to extensive deposition of debris on riverbeds and in Loktak Lake (Singh 2018). According to local fishers, this sedimentation makes the lake's bottom shallower, making it difficult for them to use their fishing gear and reducing fish breeding, as reported by local fishers.

Windy weather on the lake also poses a serious risk, causing the loss of fishing gear, injuries, and even fatalities. For instance, a fisherman died in the lake when strong winds capsized his boat in 2024 (The Sangai Express 2024). Fishers also experience seasonal fluctuations in fishing activity. From December to April, fish catches are minimal due to a low breeding rate, slower metabolism, and fish migrating to deeper waters. This minimal fish catch makes it difficult for fishers to support their families. Hence, they switch to other occupations, mainly working as construction labourers in their villages or nearby areas, or temporarily migrate elsewhere.

Health risks among fishers in the Loktak wetland are a serious concern. Musculoskeletal issues caused by holding awkward positions for long durations during fishing, skin problems, and infections from cuts and wounds due to exposure to polluted wetland water are becoming increasingly common. Fishing equipment, such as nets and canoes, are also becoming more expensive. For instance, fishers reported that they need approximately Rs. 50,000 to start fishing. With nearly 63% of fishers unable to access credit, the lack of credit facilities further aggravates their challenges.

Irregular rainfall due to the vagaries of the monsoons, as well as flooding of agricultural fields, poses severe environmental and ecological risks for farmers in the wetlands. Due to variations in topography, rainfall in Manipur varies significantly. Imphal Valley, where the Loktak wetland is located, is a rain shadow area with an average annual rainfall of 1,412 mm (Dikshit and Dikshit 2014). An increase in temperature and changes in rainfall patterns have affected Manipur's agricultural sector (Feroze *et al.* 2014). The same effect was reported by farmers in the wetland, who said that irregular rainfall was reducing their agricultural yields. The construction of the barrage submerged approximately 80,000 acres of the lakeshore, resulting in an annual financial loss of Rs. 300 crore, including losses from crops, fishing, and other seasonal vegetable harvests (Singh 2018; Singh 2017). The lack of irrigation facilities poses the greatest risk in the study areas. The Loktak lakeshore area was to be irrigated through the Loktak Lift Irrigation Canal, which was one of the primary purposes of constructing the Ithai Dam under LHEP. The project was estimated to generate an irrigation potential of 24,000 ha in the Bishnupur and Imphal West districts. However, it has failed to irrigate the fields efficiently due to the lack of proper maintenance. A large proportion of the area under canal command does not receive adequate irrigation.

Rice is the predominant crop during the kharif season, and its cultivation remains highly dependent on monsoon rainfall. After the kharif season, most of the fields on the periphery of the wetland have been left uncultivated due to the unavailability of irrigation. The problem of inadequate irrigation facilities is more pronounced for horticultural crops, as these are usually planted after the Kharif season. Some villages in the Central Zone, such as Toubul, Khoijuman, and Kwaksiphai, are famous for horticulture crops in Manipur. Farmers from these villages reported purchasing water through water tankers due to the lack of irrigation facilities. Village farms in this area are facing a severe crisis due to insufficient rainfall and inadequate support from irrigation projects; production remains low despite significant investment and manual labour (Singh 2021).

The lack of agricultural inputs and high prices, especially of fertilizers, are amongst the most severe and prevalent risks farmers face in the wetland's periphery. Farmers reported that fertilizers are very expensive here compared with other parts of India, because they rarely receive them at subsidized rates. Delayed allocation of subsidized urea is a major problem in Manipur, and demonstrations are often staged to demand its timely distribution. Due to distribution delays, farmers often buy from the black market at substantial prices (Takhel 2023).

Fluctuations in market prices and market inaccessibility are a significant concern in the area. A farmer from Phubala who cultivates watermelons reported that the price of one kilogram of watermelon sometimes fell below Rs. 5. The main reason is the import of cheap produce from other states. Due to the state's strategic geographical location, many farm products cannot be exported outside the state. Farmers have demanded the introduction of Minimum Support Prices (MSP) for agricultural produce. Bandhs, strikes, and economic blockades that continue for over a week or a month are very common in Manipur. As a result, farmers are unable to sell their produce on time, leading to the vegetables rotting and incurring substantial losses.

The Meitei–Kuki ethnic conflict, which began on 3 May 2023, has had a severe impact on farmers. Before the conflict, they sold farm produce in hill markets such as Churchandpur and Moreh. Now, they can only sell in the valley area. A farmer from Toubul mentioned that there is no proper venue to sell vegetables in Imphal City. Farmers rely heavily on brokers and intermediaries, who profit from the lack of market mechanisms for direct sales (Thangjam and Jha 2020).

In the wetland, households with many members are more likely to face higher ecological risk. Larger households require more essential materials for their survival. To meet their needs, they depend heavily on the wetland, leading to greater exposure to ecological risks. Male-dominated households in the wetland are more likely to engage in open-water fishing and commercial agriculture and are directly exposed to ecological and non-ecological risks. Migration is a common strategy for sustaining livelihoods amid ecological change (Mistri *et al.* 2025a). Households send one or more members to other places, mainly urban areas, for work and employment purposes. Households that reported experiencing high ecological risk were more likely to have a migrant member; migration increased overall income, stabilizing household income.

Diversification of livelihood activities without migrating to other places or engaging in non-wetland-dependent activities is also an adaptive strategy adopted by fishing and farming households to sustain their livelihoods (Singh and Mistri 2025). Compared to farming households, fishing households face greater ecological and environmental risks, such as *phumdis* proliferation, water pollution, declines in fish species, and sudden onset of climatic events. Thus, the impact of ecological changes on fishing households is more pronounced. In the wetland, livestock provides an alternative source of income for fishing and farming households. This alternative income reduces dependency on the wetland, thereby lowering the risk of ecological impacts.

The LDA was established in 1986 to oversee and mitigate the wetland's deterioration. The main activities carried out by LDA include survey and demarcation, procurement of equipment for de-siltation and de-weeding, removal of silt, removal of *phumdis*, control of water hyacinth by releasing weevils, construction of silt detention structures, afforestation of critical catchment areas by planting appropriate species of plants and fruit-bearing trees, and soil conservation. To improve the livelihoods of people living on the wetlands' periphery, the Government of Manipur initiated the Loktak Livelihood Mission Project, aiming to increase the income of fish farmers who use the wetland's ecosystem without harming it. Periodically, the Government of Manipur also releases thousands of fish fingerlings into the wetland to increase the fish population. Recently, the government implemented measures to irrigate agricultural land near the wetlands. Sometimes, the LDA undertakes coercive measures, such as evicting floating fishing huts, displacing fishers, banning *phumdis* hut homestay tourism, and prohibiting *athaphum* fishing (a traditional circular fishing method), severely harming fisherfolk and hampering their livelihoods. Despite various government efforts, ecological health and people's livelihoods in the Loktak wetland have emerged as serious concerns.

5. LIMITATIONS OF THE STUDY

The study has certain limitations. It adopted a cross-sectional design that involved collecting information at a single point in time. A longitudinal design would improve the study by allowing the examination of how certain phenomena and livelihood activities change over time across the study area. The study employed a subjective approach to assess climatic and non-climatic risks in traditional agriculture, which contains certain limitations. An objective approach to risk measurement could be complementary to the subjective approach, but there is a dearth of secondary data on (physical) parameters. The data void can be minimized by using remote sensing data alongside geographic information systems. In addition, gender plays an important role in livelihood diversification. In NE states, women are comparatively more empowered in traditional parameters—sex ratio, labour force participation rate, and education. Within the limited scope of the present study, the gender dimension could not be captured separately.

6. CONCLUSION

This study examined the livelihood risks associated with ecological change alongside non-ecological stressors for the principal means of living—fishing and farming—in and around the Loktak wetland and identified the factors that affect ecological risk. The findings of the study indicate that fishing in the Loktak wetland is affected by changes in the lake's ecology, such as *phumdis* proliferation, water pollution, and siltation, which contribute to the decline of fish species and their stocks. The submergence of vast, low-lying, and fertile agricultural fields along the lakeshore due to the construction of the Ithai Barrage is directly related to changes in the wetland's ecology. Apart from ecological issues, the lack of irrigation facilities, rising agricultural input costs, and market issues significantly affect farmers and pose severe threats to farming. The ecological risks associated with their work in the wetland are influenced by multiple factors, including demographic, social, and economic factors, as well as governmental policies. In the study, household size, age group, dependency ratio, migration, and livestock rearing were found to significantly predict the likelihood of experiencing ecological risks in fishing and farming.

Based on the findings, the study advocates inclusive economic policies focusing on sustainable development in the wetland. To maintain the long-term sustainability of livelihoods in and around the Loktak wetland, ecological degradation must be addressed with earnest care, and the sustainable use of natural resources must be encouraged. To reduce livelihood risks in fishing and farming, it is necessary to promote the adoption of multiple income sources through skill development, improve market accessibility and linkages, and enhance financial inclusion and access to credit to support sustainable farming. Within the limited scope of the present study, it was not possible to delve deeper into livelihood diversification and migration. Hence, future research is suggested to explore alternative livelihood options and diversification strategies, including labour migration from the region.

Author Contribution: OKS: conceptualization, first draft and final version; AM: review, editing, quality control and final revision.

Ethics Statement: We hereby confirm that this study complies with requirements of ethical approvals from the institutional ethics committee for the conduct of this research.

Consent to Participate: Informed consent from the respondents was obtained before the survey to ensure their willingness to participate. Assurances of anonymity and confidentiality of the information, and consent to publication, were part of the informed consent.

Consent for Publication: The participants in this research had consented to the publication of the findings in a journal.

Data Availability Statement: Data are available from the corresponding author upon reasonable request.

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