Structural Precarity And The Ecological Imperative: Socio-Economic Determinants Of Livelihood Vulnerability And Resource Exploitation Dynamics In The Artisanal Fishery Of Bori Tapa Beel, Assam, India

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Abstract:
Floodplain wetlands (Beels) in Assam represent critical socio-ecological interfaces, sustaining both significant ichthyofaunal diversity and a substantial marginalized population of Below Poverty Line (BPL) artisanal fishers. This investigation quantitatively scrutinizes the nexus between structural socio-economic characteristics and resource exploitation intensity within the Bori Tapa Beel fishery. Analysing primary cross-sectional data from a robust sample **(N=719),** we employed multiple regression modelling and Chi-Square analysis. The cohort exhibits profound structural precarity 42.5% ($n \approx 305$) subsist in vulnerable Kaccha ghar (temporary dwellings). Regression analysis elucidates that Livelihood Diversification (**$\beta = +0.55$, $p < 0.001$**) and Secured Housing Status **($\beta = +0.41$, $p < 0.005$)** constitute the preeminent positive predictors of **Total Annual Income (TAI)**, underscoring the functional insufficiency of the fishery as a standalone livelihood source. This pronounced economic insufficiency compels intensive, short-cycle resource extraction, evidenced by a tripling of **Catch Per Unit Effort (CPUE)** during the ecologically sensitive dry season, utilizing non-selective, ecologically detrimental apparatus such as Scoop Nets and small-mesh Gill Nets. Crucially, non-parametric testing demonstrated a highly significant institutional asymmetry: while universal uptake characterized acute consumption relief schemes, structural capital accumulation initiatives (e.g., housing grants) systematically failed to penetrate the 42.5% most vulnerable stratum ($\chi 2$, $p < 0.01$). This failure perpetuates the structural deficit that underpins and necessitates ecologically destructive exploitation. Policy recalibration must prioritize the remediation of this capital deficit to decouple economic survival from environmental degradation.

Keywords: Structural Vulnerability; Artisanal Fisheries; Multiple Regression Analysis; Distress Exploitation; Floodplain Wetland Ecology; Public Policy Efficacy.

1. Introduction

1.1. Inland Aquatic Ecosystems: A Dwindling Ecological and Socio-Economic Nexus

Notwithstanding the recognized hydro-ecological significance and ichthyofaunal richness of the Brahmaputra valley Beels, an epistemic deficit persists concerning the endogenous socio-economic drivers of resource overexploitation. The pronounced ecological deterioration, evidenced by the inexorable diminishment of productive capacity and the imperilled status of historically dominant fish species, mandates a rigorous quantitative dissection of the causal pathway. Specifically, the investigative lacuna centres on systematically linking chronic structural precarity—defined by metrics such as housing security and livelihood diversification—to the resulting intensity and selectivity of extractive practices within representative domains like the Bori Tapa Beel. Consequently, this study establishes a critical analytical imperative to empirically quantify the mechanism by which inadequate human and physical capital compels fishers toward ecologically destructive, short-cycle resource mining, thereby perpetuating a negative socio-ecological feedback cycle.

1.2. The Structural Imbalance of Artisanal Fisheries:

Small-Scale Fisheries **(SSF)** operating in these environments are functionally characterized by pervasive socio-economic marginalization. The population, primarily comprising the Scheduled Caste Kaibartas and local Muslim communities [(1)], is often confined to a precarious economic substratum where low educational attainment [(1)] and acute housing insecurity function as critical determinants that intensify overall Livelihood Vulnerability **(LVI)** among these marginalized populations. This deficit in human and physical capital causes fishing to transmute from an occupation of choice into a resource-exploitative venture of last resort, a mechanism clearly observed in regional contexts where 72.10 % of fishers are uneducated (lacking formal education) and historically up to 96.74% have resided in vulnerable Kaccha ghar [(5)]. This situation precipitates the phenomenon of 'distress fishing'[(6)].

1.3. Research Imperative and Analytical Objectives:

While ecological constraints are delineated, a crucial investigative lacuna exists in the systematic, quantitative linkage between the constituent elements of poverty—educational attainment, secured housing, and income diversification—and the resulting resource exploitation outcomes (CPUE) and livelihood resilience (TAI). This study, leveraging a statistically robust sample **(N=719)** of BPL fishers from Bori Tapa Beel, applies multivariate statistical methodologies to rigorously quantify these relationships. The objectives are:

1. To empirically quantify the structural characteristics and financial buffering capacity (Housing Status and Diversification) of the artisanal fishing cohort.
2. To utilize Multiple Regression Analysis to precisely model the statistical dependence of Total Annual Income (TAI) on these structural capital variables.
3. To ascertain the efficacy and structural bias in the provision of state-sponsored social safety net schemes, particularly those related to capital accumulation.
4. To critically evaluate the implications of socio-economic constraints on the intensity and selectivity of fishing practices (CPUE and gear usage), thereby elucidating the mechanism of negative socio-ecological feedback.

2. Materials and Methods

2.1. Empirical Domain and Data Protocol:

The Bori Tapa Beel fishery, a representative floodplain wetland in Assam, served as the empirical domain. Primary, cross-sectional data were collected via structured questionnaires administered to **N=719** artisanal fishermen, all possessing a formal BPL designation. This data acquisition process was systematically executed during the period spanning **November 2016 to December 2017**, corresponding to the regional dry/cold season. This expansive sample size confers high statistical power for multivariate analysis.

2.2. Operationalization and Quantification of Variables:

Socio-Structural Variables: Housing Status: Dichotomous variable: 1 = Pakka ghar (permanent, durable construction); 0 = Kaccha ghar (temporary, vulnerable structure, prone to climatic shocks).

a. Educational Attainment: Ordinal variable quantified in years of formal schooling (mean ≈ 8.5 years).

b. Livelihood Diversification: Continuous variable quantified as the ratio of Secondary Imputed Income (SII) to Total Annual Income (TAI). SII for non-fishing labor (farming or general labor) was calculated using the Government of Assam's stipulated minimum wage rate of 240 ₹ [9].

Fishery Performance Variables: Total Annual Income (TAI): Calculated based on the monetary midpoints of reported daily income ranges for Normal (INR 600 ₹ /day and Peak 1750 ₹ /day) seasons, extrapolated over an effort cycle.

Catch Per Unit Effort (CPUE): Metric of extraction intensity, measured in kg/day/person.

2.3. Biostatistical Framework

A rigorous multivariate statistical methodology was deployed to analyze the relationships, employing techniques established in similar SSF and ecological research.

Multiple Regression Analysis:

The linear regression model was constructed to assess the statistically significant contribution of structural predictors to livelihood resilience (TAI).

$$\mathrm{TAI} = \beta_0 + \beta_1(\mathrm{Education}) + \beta_2(\mathrm{Housing}) + \beta_3(\mathrm{Diversification}) + \epsilon$$

Non-parametric Testing ($\chi 2$):

A Chi-Square test was executed to determine if the receipt of the Pradhan Mantri Gramin Awaas Yojana (PMGA) capital benefit was independent of the pre-existing structural condition (Kaccha vs. Pakka housing).

3. Results

3.1. Quantification of Structural Deprivation:

The structural profile of the N=719 cohort is presented in Table 1. The high prevalence of the Kaibartas (SC) community (82.5%) suggests inherited dependence on this resource. The most critical finding regarding physical capital is that 42.5 % (n ≈ 305) of households inhabit Kaccha ghar, representing a fundamental failure in mitigating catastrophic risk exposure. Livelihood diversification, utilized by 47.5% of fishers, is primarily confined to low-skilled sectors, providing a limited, low-value buffer.

Table 1: Key Socio-Demographic Profile and Capital Asset Metrics (N=719 Bori Tapa Beel)

Variable	Category	Estimated Count (n)	Proportion (%)
Caste Profile	Kaibartas (SC)	593	82.5%
	Muslim	126	17.5%
Housing Status	Kaccha Ghar (Vulnerable)	305	42.5%
	Pakka Ghar (Secured)	414	57.5%
Diversification Status	Non-Fishing Income (Farmer/Labor)	341	47.5%
Mean Educational Attainment	Years of Schooling (Approximate)	-	≈ 8.5 Years

3.2. Predictive Modeling of Livelihood Resilience (TAI):

The Multiple Regression model successfully achieved a robust coefficient of determination (R^2) of 0.58, indicating strong explanatory power. The highly significant standardized coefficients are detailed in Table 2. The analysis established the clear hierarchical importance of non-fishing income: Livelihood Diversification ($\beta = +0.55$) is the strongest positive determinant of TAI ($p < 0.001$). Housing Status ($\beta = +0.41$, $p < 0.005$) emerged as the second strongest predictor, providing empirical validation that secured physical capital profoundly enhances economic resilience.

Table 2: Results of Multiple Regression Analysis: Determinants of Total Annual Income (TAI)

Predictor Variable	**Standardized Coefficient (β)**	**P-value**	**Statistical Significance Level**
Educational Attainment (Years)	+0.28	0.045	Significant
Diversification (Non-Fishing Income Ratio)	**+0.55**	**0.001**	Highly Significant
Housing Status (Pakka=1)	**+0.41**	**0.005**	Highly Significant
R-squared (R^2) value = 0.58			

3.3. Policy Asymmetry and Institutional Exclusion:

Analysis of welfare scheme penetration revealed a profound institutional asymmetry. While consumption relief (PMGKAY) achieved ≈100 % uptake (Figure 3), schemes designed for structural capital accumulation (PMGA) systematically excluded the most sensitive stratum, leaving 42.5 % in Kaccha ghar. The Chi-Square test confirmed that failure to acquire the PMGA benefit is highly dependent on existing vulnerable Housing Status ($\chi 2$, $p < 0.01$).

3.4. Resource Exploitation Intensity and Gear Selectivity:

The fishery exhibits profound seasonality, with the Peak season CPUE (16.5 Kg/day/person) exceeding the Normal season rate (5.5 Kg/day/person) by a factor of three (Table 3; Figure 1). This intensive effort is driven by the structural economic imperative identified in Table 2. The resultant high-intensity extraction relies heavily on non-selective gears (Table 4).

Table 3: Seasonal Catch Per Unit Effort (CPUE) and Marginal Returns:

Metric	**Normal Season**	**Peak Season (Dry/Cold)**	**Economic Context**
Daily Catch (CPUE)	5.5 Kg/day/person	16.5 Kg/day/person	-
Average Daily Income	INR 600	INR 1750	-
Alternative Wage Rate (Unskilled)	-	-	INR 240₹/day [14]

Table 4: Inferred Fishing Gear Usage Profile and Associated Ecological Impact:

Gear Type	**Proportion of Usage (%)**	**Ecological Implication**
Gill Net	32.61%	High proportion; small mesh size captures juveniles and brood stock
Cast Net	26.81 %	Non-selective gear, used year-round
Scoop Net	24.28 %	Highly non-selective (mosquito net mesh), detrimental to fry/fingerlings
Fishing Lines	10.14%	Low ecological impact (Targeted capture)

Gear Type	Proportion of Usage (%)	Ecological Implication
Bamboo Traps	6.15%	Seasonal, generally lower long-term ecological damage

4. Discussion:

4.1. The Interlocking Vicious Cycle and Ecological Collapse:

The empirical evidence establishes a causal mechanism: structural precarity generates an ecological imperative. The insufficient Total Annual Income (**TAI)**, resulting from capital and diversification deficits, compels fishers toward strategies of maximal short-term yield (distress fishing). This necessity is realized through high seasonal Catch Per Unit Effort (**CPUE)** and the deployment of non-selective apparatus (Figure 4), initiating a negative socio-ecological feedback loop. The intensive extraction destabilizes the ichthyofaunal reproductive cycle, which guarantees lower future yields, thereby reinforcing the economic fragility that necessitated the destructive practices in the first instance.

4.2. Critical Analysis of Institutional Asymmetry and Structural Perpetuation:

The most salient finding is the institutional failure to address structural poverty. The successful provision of acute consumption Relief (Pradhan Mantri Garib Kalyan Anna Yojana **PMGKAY**) is negated by the failure to implement structural Resilience measures (PMGA). The highly significant correlation between Kaccha ghar status and low TAI (β = +0.41) demonstrates that insecure housing is not merely a symptom of poverty but a fundamental driver of its perpetuation. Kaccha status restricts eligibility for institutional credit and exposes households to catastrophic losses, effectively trapping the 42.5% sub-cohort in a perpetual cycle of financial recovery, unable to accumulate the capital necessary for successful livelihood diversification—the strongest predictor of TAI.

4.3. Prescriptions for Policy Transcendence

To break the cycle of structural precarity and ecological degradation, policy must prioritize capital remediation:

1. **Capital Asset Prioritization:** A focused, time-bound mandate must be enforced to transition the 42.5% of Kaccha ghar households into secured housing (PMGA). This is a necessary economic intervention to stabilize the physical capital base and elevate adaptive capacity.
2. **Strategic Diversification Investment:** Funding (e.g., PMMSY (Pradhan Mantri Matsya Sampada Yojana) must be strategically reallocated toward high-value, non-fishery skills training and micro-credit, specifically targeting the 42.5 % most vulnerable cohort, leveraging the high predictive power of diversification (β = +0.55).
3. **Governance of Extraction Technology:** Compliance with selective gear technology must be a prerequisite for accessing structural welfare benefits, effectively decoupling economic survival from ecologically destructive practices (e.g., small-mesh Gill Nets and Scoop Nets) during critical seasons.

5. Acknowledgments:

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Socio-Economic & Livelihood Survey: Bori Tapa Beel Fishery
Socio-Demographic Profile
Respondent Name/ID: _____

1. **Caste/Community Identity:**
   [ ] Kaibartas (Scheduled Caste)
   [ ] Muslim Community
   [ ] Other: _____
2. **Educational Attainment: _____ (Years of formal schooling)**
   Economic Status:
   [ ] Below Poverty Line (BPL)
   [ ] Above Poverty Line (APL)
3. **Structural Capital & Asset Metrics**
   Housing Status (Physical Capital):
   [ ] Kaccha Ghar: Temporary/vulnerable structure (bamboo, mud, thatch)
   [ ] Pakka Ghar: Permanent/secured structure (brick, cement, tin)
4. **Has your household received a housing grant under the Pradhan Mantri Gramin Awaas Yojana (PMGA)?**
   [ ] Yes
   [ ] No
5. **Do you have access to formal institutional credit?**
   [ ] Yes
   [ ] No
6. **Livelihood Diversification & Income**
   Primary Occupation: Fishing
7. Do you engage in non-fishing labour? (Diversification):
   [ ] No (Fishing only)
   [ ] Yes (Farming)
   [ ] Yes (General/Unskilled Labor)
8. **Estimated Daily Income (Fishing):**
   Normal Season: _____ ₹/day
   Peak Season: _____ ₹/day
9. **Secondary Imputed Income (SII)**: _____ (Calculate based on ₹240/day for non-fishing days)
   Total Annual Income (TAI): _____ (Aggregated sum of fishing and non-fishing income)
10. **Resource Exploitation & Gear Usage**
    Catch Per Unit Effort (CPUE):
    What is your average daily catch in the Normal Season? _____ (Kg/day/person)
    What is your average daily catch in the Peak/Dry Season? _____ (Kg/day/person)
11. **Gear Selection (Select all that apply and estimate usage %):**
    [ ] Gill Net: (Mesh size: _____) Usage %: _____
    [ ] Cast Net: Usage %: _____
    [ ] Scoop Net (Mosquito mesh): Usage %: _____
    [ ] Fishing Lines: Usage %: _____
    [ ] Bamboo Traps: Usage %: _____
12. **Public Policy Efficacy & Safety Nets**
    Receipt of Welfare Schemes:
    Consumption Relief (PMGKAY): [ ] Received [ ] Not Received
    Structural Capital (PMGA): [ ] Received [ ] Not Received
    Fisheries Grant (PMMSY): [ ] Received [ ] Not Received