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Original Article

A triangulated DPSIR assessment of fisheries sustainability and marine conservation in Pulicat region, India: integrating interview schedule and participatory rural appraisal

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Abstract
Pulicat Lagoon, India's second-largest brackish water lagoon, supports diverse fisheries and coastal livelihoods but has experienced increasing environmental degradation and resource-use pressures. This study assesses the status of marine conservation and fisheries sustainability in Pulicat Lagoon using the Driver–Pressure–State–Impact–Response framework integrated with Participatory Rural Appraisal. A mixed-method sequential explanatory design was adopted. Quantitative data were collected from 213 fisheries-dependent respondents through a structured interview schedule, while qualitative information was obtained using participatory mapping, seasonal calendar analysis, and problem matrix scoring with three community focus groups. Descriptive statistics and Spearman's rank-order correlation were used for quantitative analysis, and findings from the participatory tools were triangulated with the interview schedule results. The findings indicated that high dependence on fisheries, climate variability, and increasing fishing pressure acted as major drivers of environmental change. Pollution, lagoon-mouth closure, and sedimentation emerged as the principal pressures, resulting in reduced fish availability, reduced juvenile fish observations, lower catch per unit effort, income reduction, and increased livelihood vulnerability. Although most respondents expressed willingness to adopt sustainable fishing practices, weak institutional trust and inadequate enforcement constrained effective fisheries management. The participatory tools validated the quantitative findings while providing additional insights into community priorities and seasonal livelihood dynamics. This study integrating the Driver–Pressure–State–Impact–Response framework with participatory approaches provides a comprehensive understanding of the interactions between environmental degradation, governance, and fisheries livelihoods, supporting the need for integrated, ecosystem-based, and participatory management of Pulicat region.

Keywords: Driver–Pressure–State–Impact–Response; fisheries management; marine conservation; participatory rural appraisal; Pulicat Lagoon; sustainable fisheries

1 | INTRODUCTION

Coastal lagoons are among the most productive and threatened ecosystems in the world, sustaining diverse fauna and the livelihoods of millions of coastal inhabitants globally (Gari *et al*. 2015). Global capture fisheries production has remained largely static for decades, holding within an 86–94 million tonne range since the late 1980s, even as aquaculture has grown to become the sector's primary source of new production and total aquatic food output has reached record levels (FAO 2026). This plateau in capture fisheries places sustained pressure on small-scale, capture-based systems, such as Pulicat Lagoon, to meet livelihood and food security needs from an effectively fixed resource base.

The Pulicat Lagoon is India's second-largest brackish water lagoon, located along the border of Tamil Nadu and Andhra Pradesh at latitudes 13°18′–13°46′N and longitudes 80°08′–80°19′E. It has been gazetted as a wildlife sanctuary and, as of May 2026, has also been designated as wetland of international importance under the Ramsar Convention. The lagoon supports a rich diversity of fish and shellfish species, large populations of migratory waterfowl, and other bird populations and is home to one of India's most ancient artisanal fishing traditions, the Paadu system, in which fishing rights are rotated among community members to promote equitable, sustainable use of the resource. This reflects a broader pattern recognized internationally: wetlands worldwide function not only as biodiversity reservoirs but also as living cultural landscapes, shaped by generations of community knowledge and practice (UNESCO World Heritage Centre 2026). Tens of thousands of fishermen across numerous villages surrounding the lagoon depend on it for food security, livelihood, and socio-cultural identity, and their patterns of adaptation to environmental shocks have been shown to vary systematically by livelihood specialization, with the most specialized fishermen, not the poorest, often the least able to adapt (Coulthard 2008). The lagoon environment has nonetheless been increasingly degraded over recent decades; a pattern consistent with the global trend of continuing wetland decline despite growing conservation attention worldwide (UNESCO 2026).

This study aims to document these issues through the Driver–Pressure–State–Impact–Response (DPSIR) framework, developed by the European Environment Agency (EEA 1999) and widely used in coastal and marine studies to integrate social, economic, and administrative drivers of change with ecological conditions and impacts (Gari *et al*. 2015; Elliott *et al*. 2017). This analytical framework is combined here with local ecological knowledge generated through Participatory Rural Appraisal (PRA) tools such as participatory mapping, seasonal calendars, and problem-ranking matrices, an approach that draws on community-generated, rather than researcher-imposed, knowledge (Chambers 1994). The specific objectives of this study were to assess the status of marine conservation and fisheries sustainability in Pulicat region using the Driver–Pressure–State–Impact–Response (DPSIR) framework; to triangulate interview schedule findings with Participatory Rural Appraisal (PRA) tools to strengthen the validity of the identified environmental and socioeconomic challenges; and to identify feedback loops and priority intervention points within the DPSIR chain to guide fisheries management and governance responses in Pulicat region. By integrating the DPSIR framework with community-generated evidence from participatory approaches, this study contributes a triangulated socio-ecological assessment of fisheries sustainability in the Pulicat region and identifies priority intervention points relevant to ecosystem-based and participatory fisheries management.

2 | METHODOLOGY

2.1 Study area

The research was carried out in and near Pulicat Lagoon (Pulicat Lake), situated on the southeastern coast of India at the Tamil Nadu-Andhra Pradesh border, roughly 60 km north of Chennai. Data were collected in various fishing villages in Pulicat such as Thirumalai Nagar, Jamilabad, S.P. Kuppam, Gunakuppam, and Thonirevu, where households rely on both lagoon-based and marine-based fishing areas. GPS coordinates captured during fieldwork position the main interview and Participatory Rural Appraisal (PRA) locations at approximately 13.42° N, 80.32° E (WGS-84), aligning with Pulicat township and nearby Fisheries Department sites where multiple PRA sessions took place. The selected localities represented fisheries-dependent communities across the Pulicat region, including villages located around the lagoon and Pulicat town. These localities were selected to ensure representation of communities primarily dependent on lagoon fisheries, marine fisheries, and both lagoon and marine fisheries, thereby capturing the different patterns of fisheries dependence present within the study area.

2.2 Research design

This research used a mixed-method sequential explanatory design, starting with the collection and analysis of quantitative data, followed by participatory rural appraisal (PRA) tools to clarify, confirm, and contextualize the quantitative results. The combination of quantitative and qualitative evidence allowed for a thorough understanding of the ecological and socioeconomic challenges faced by communities that depend on fisheries. Ultimately, both datasets were triangulated to improve the validity and reliability of the results (Creswell and Clark 2017).

Figure 1 illustrates the overall methodological framework of this study.

2.3 Sampling

A total of 213 respondents were interviewed from six sampling localities within the Pulicat region, comprising five fisheries-dependent villages, namely Thirumalai Nagar (*n* = 50), Jamilabad (*n* = 67), S.P. Kuppam (*n* = 17), Gunakuppam (*n* = 24), and Thonirevu (*n* = 21), and Pulicat town (*n* = 34). The sampling localities were selected to represent fisheries-dependent communities with different patterns of dependence on lagoon and marine fisheries. Within each selected locality, individuals who met the eligibility criteria were identified through the local fishing community and field visits. Among eligible individuals who were available during the field visits and provided informed consent, respondents were selected using a simple random approach.

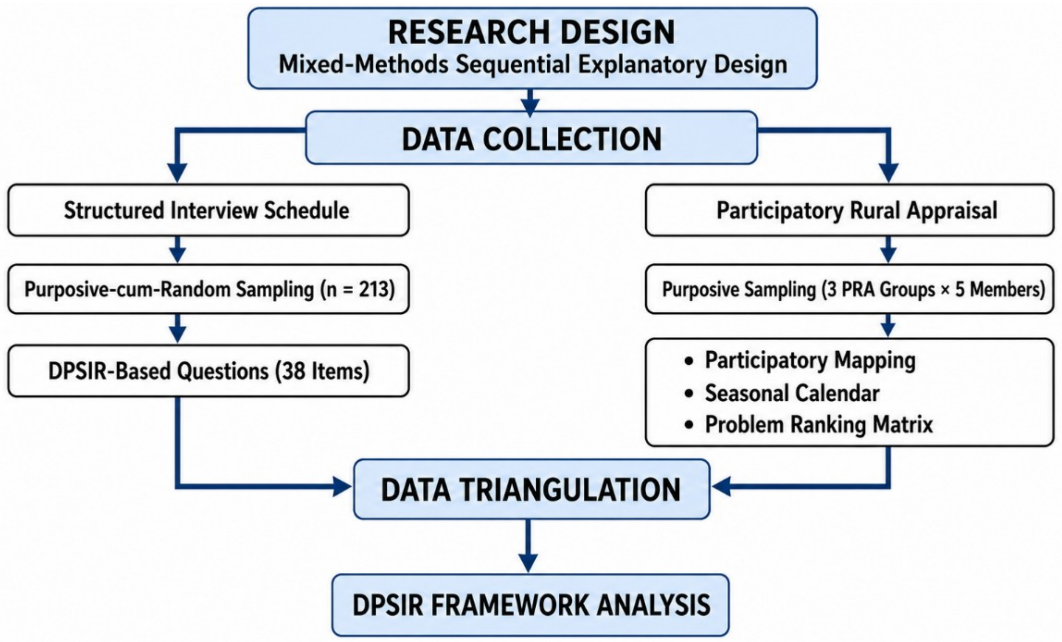

FIGURE 1 Mixed-method sequential explanatory research design used in the study.

2.4 Data collection

2.4.1 Interview schedule: Primary data were collected using a structured interview schedule. The indicators for the interview schedule were initially drawn from established fisheries and environmental assessment frameworks and published guidelines on small-scale fisheries, coastal livelihoods, and environmental sustainability (Cheshire *et al*. 2009; FAO 2015, 2021; UNEP 2021). This candidate list was then refined and shortlisted through the Delphi technique with a panel of ten subject-matter experts across three rounds of anonymous rating and re-rating, an iterative consensus-building process in which panelists independently score candidate items and revise their ratings in light of aggregated group feedback until a stable, agreed set of indicators emerges, minimizing the influence of dominant individuals or groupthink that can occur in face-to-face expert panels (Dalkey and Helmer 1963). Following the Delphi process, the finalized interview schedule was pre-tested with 12 fishermen from the study area to assess the clarity, relevance, sequence, and comprehensibility of the questions. Based on the feedback received during the pre-test, necessary modifications were made to the wording and presentation of the questions before the final schedule was used for the data collection. The finalized 38-question interview schedule, developed based on the Drivers-Pressures-State-Impact-Responses (DPSIR) framework, was structured into six sections: (i) respondent and household profile, (ii) drivers, (iii) pressures, (iv) state, (v) impacts, and (vi) responses.

It was used to collect information on respondents' demographic and socio-economic characteristics, dependence on fisheries, environmental pressures (such as pollution, mangrove degradation, lagoon mouth closure, and sedimentation), ecological changes in the lagoon, livelihood impacts, and awareness of fisheries management.

2.4.2 Participatory rural appraisal (PRA): Following completion of the interview schedule, qualitative data were collected using PRA– an established participatory approach that facilitates local knowledge generation and community-based resource assessment (Chambers 1994). Three participatory tools namely participatory mapping, seasonal calendar analysis, and problem matrix scoring were applied with three community focus groups (*n* = 15 fishers total; 5 participants per group), in which local people themselves elicit, rank, and map their own knowledge rather than having it extracted by outside researchers. The categories used across the three PRA tools were selected based on the purpose of each method.

Participatory mapping: Community members collaboratively annotated printed satellite imagery to identify fishing grounds, pollution hotspots, sedimentation zones, and fishing paths. Four feature categories were pre-selected to align with the study objectives, while the mapped locations were identified entirely by the community based on their spatial knowledge of the lagoon (Nunes *et al*. 2021).

Seasonal calendar: Participants jointly prepared monthly calendars depicting seasonal variations in fish catch, fishing effort, market prices, lagoon-mouth conditions, and fishing income using a standardized scoring system. These five livelihood indicators were predefined to ensure comparability across focus groups and relevance to the DPSIR framework. The monthly scores were generated entirely by the community based on their lived experiences.

Problem ranking matrix: Community members identified major fisheries-related problems, including pollution, declining fish catch, lagoon-mouth closure, sedimentation, resource-use conflicts, and declining income. These issues were subsequently prioritized using paired-comparison and token allocation techniques. The problems were identified directly by the focus groups, following the PRA principle that issues of local concern should emerge from the community rather than be predetermined by researchers (Chambers 1994).

2.5 Triangulation

The primary analytical strategy used in this study was methodological triangulation. The results of interview schedule were methodically contrasted with data from problem-ranking matrices, seasonal calendars, and participatory maps. While inconsistencies were subject to additional interpretation during data analysis, agreement between multiple data sources was seen as evidence supporting the validity and reliability of the conclusions (Carter *et al*. 2014). Triangulation strengthened the validity of the assessment by reducing respondent bias associated with structured interview schedule while simultaneously incorporating community-level ecological knowledge.

2.6 Drivers-Pressures-State-Impact-Responses (DPSIR) framework

The DPSIR framework was used to organize and interpret the study's findings (EEA 1999; Elliott *et al*. 2017). Interview schedule questions were grouped into five components: drivers, covering livelihood dependence on fisheries and fishing effort; pressures, covering pollution, destructive fishing practices, lagoon-mouth closure, and sedimentation; state, covering changes in fish availability, biodiversity, and mangrove cover; impacts, covering effects on catch, income, and livelihoods; and responses, covering awareness, management, and sustainable fishing practices. This structure gave the study a systematic basis for linking environmental change to its socio-economic consequences in Pulicat Lagoon.

2.7 Data analysis

The quantitative data were coded and analysed using IBM SPSS Statistics (version 26). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise respondents' demographic characteristics and responses to the structured interview schedule. Interview schedule variables were analysed according to the five DPSIR components: Drivers, Pressures, State, Impacts, and Responses. The seasonal calendar data were analysed using Spearman's rank-order correlation coefficient (ρ) to examine the relationships among the five livelihood indicators (fish catch, fishing effort, market price, fishing income, and lagoon-mouth condition) within each focus group. Spearman's correlation was selected because the seasonal calendar scores were ordinal in nature. Findings from the PRA tools were triangulated with the quantitative results to provide an integrated assessment of marine conservation in the Pulicat region.

3 | RESULTS AND DISCUSSION

3.1 Demographic profile

Among the 213 respondents, most belonged to the economically active age groups, with 41.3% aged 30–44 years and 32.4% aged 45–59 years (Table 1). This age distribution is consistent with the socioeconomic characteristics commonly observed in small-scale fishing communities (Reis-Filho *et al*. 2026). The respondents were predominantly male (89.7%), reflecting the traditional division of labour in fisheries, although women also contribute to fish processing, marketing, and other shore-based activities (Basurto *et al*. 2025; Cavole *et al*. 2025). Educational attainment was generally low, with 45.1% having no formal or only primary education, a pattern also reported in small-scale fishing communities (Reis-Filho *et al*. 2026). Most respondents (85.4%) had lived in their villages for more than 20 years, indicating strong local familiarity with fisheries and environmental changes. Fishing was the primary livelihood for 77.0% of respondents, while 8.5% were engaged in fishing-related activities and 14.6% had multiple livelihoods (Etongo and Arrisol 2021; Roscher *et al*. 2022). Dependence on fishing grounds was distributed across marine waters (39.4%), both marine and lagoon areas (32.4%), and mainly lagoon areas (28.2%). Overall, the demographic profile indicates substantial dependence on fisheries resources and provides important socioeconomic context for interpreting the subsequent findings on environmental pressures, livelihood impacts, and fisheries management.

TABLE 1 Demographic characteristics of respondent fishermen (*n* = 213) in Pulicat region, India.

Variable	Category	*n*	%
Age group	18-29 years	34	16.0
	30-44 years	88	41.3
	45-59 years	69	32.4
	≥60 years	22	10.3
Gender	Male	191	89.7
	Female	22	10.3
Education	No formal education	46	21.6
	Primary (Class 1-5)	50	23.5
	Secondary (Class 6-10)	76	35.7
	Higher secondary (class 11–12)	24	11.3
	Graduate or above	17	8.0
Duration of residence	<5 years	9	4.2
	5-10 years	5	2.3
	11-20 years	17	8.0
	>20 years	182	85.4
Primary livelihood	Fishing	164	77.0
	Fishing-related activity	18	8.5
	Multiple livelihoods	31	14.6
Fishing area dependence	Lagoon-dominated	60	28.2
	Marine-dominated	84	39.4
	Both lagoon and marine	69	32.4

3.2 Drivers

Dependence on fisheries for income was high, with 59.1% of respondents earning more than half of their income from fishing, including 41.3% who earned more than 75% from fisheries. Only 12.7% reported low dependence (Table 2). This is consistent with global small-scale fisheries, where fishing is the main source of livelihood for many households (Basurto *et al*. 2025).

Fishing effort was high, with 54.9% of respondents fishing for more than 15 days per month (Table 2), indicating a strong dependence on fishing for their livelihood. Most respondents (92.5%) also experienced climate-related disruptions during the past five years, including 13.1% who reported severe impacts (Table 2). This is similar to findings from India's west coast, where climate variability has been shown to alter fishing effort, trip duration, and yields (Rai and Bera 2025).

The main reasons for increased fishing pressure as per the respondents of the present study were declining fish availability (39.9%), an increase in the number of fishers (32.9%), and limited alternative livelihoods (21.6%) (Table 2). Similar patterns have been reported in fisheries, where declining fish stocks lead to greater competition and increased pressure on the remaining resources (Dolbeth *et al*. 2016). Consistent with this, 57.3% of respondents reported that their own fishing effort had decreased over the past 10 years, mainly because fewer fish were available to catch (Table 2).

TABLE 2 Drivers influencing fishing pressure in Pulicat Lagoon as perceived by respondents (*n* = 213).

Variable	Category	*n*	%
Income dependence on fisheries	≤25% (low)	27	12.7
	26-50% (moderate)	60	28.2
	51-75% (high)	38	17.8
	>75% (very high)	88	41.3
Fishing days per month	≤10 days	22	10.3
	11-15 days	74	34.7
	16-20 days	61	28.6
	>20 days	56	26.3
Climate variability impact (5 years)	No noticeable impact	16	7.5
	Occasional disruption	119	55.9
	Regular disruption	50	23.5
	Severe disruption	28	13.1
Main reason for fishing pressure	Declining fish availability	85	39.9
	Increase in number of fishers	70	32.9
	Limited alternative livelihoods	46	21.6
	Increased market demand	12	5.6
Change in fishing effort (10 years)	Decreased	122	57.3
	Increased	71	33.3
	Remained similar	20	9.4

3.3 Pressures

Plastic and solid waste was the pressure fishers noticed most: 79.8% reported observing it at some level - occasionally, frequently, or persistently, while only 20.2% said they never see it. This matches FAO's own findings that plastic debris causes direct economic damage to small-scale fisheries worldwide through gear damage, reduced catches, and lost operating time (Macfadyen *et al*. 2009). Sewage and wastewater were reported less frequently. About 45.5% of respondents had observed sewage pollution at some level, most commonly seasonally (33.3%), with smaller shares reporting regular (8.9%) or continuous (3.3%) occurrence, whereas 54.5% had not noticed it (Table 3). This suggests that fishers are more likely to notice visible solid waste than less obvious forms of water pollution. Industrial pollution was also widely reported, with 59.1% of fishers reporting some degree of impact (minor, moderate, or severe), while 13.1% perceived the impact as severe. Although its perceived impact was lower than that of plastic waste, these findings suggest that industrial and other anthropogenic pollution sources continue to affect the lagoon ecosystem and fisheries, highlighting the need for effective pollution control and environmental management (Kwadzo *et al*. 2022).

Mangrove cutting was the least reported environmental pressure, with 58.7% of respondents stating that it had no impact (Table 3). However, this does not necessarily mean that mangroves are free from ecological threats. Mangroves provide important breeding and nursery habitats for many fish species, and even small losses can affect fish populations over time. Studies have shown that mangrove degradation can reduce fish stocks and biodiversity, even when the impacts are not immediately noticed by local fishers (Reis-Filho *et al*. 2019; zu Ermgassen *et al*. 2020). Therefore, the low level of reported mangrove cutting should not be interpreted as a low ecological risk.

TABLE 3 Environmental pressures affecting Pulicat Lagoon as perceived by respondents (*n* = 213).

Variable	Category	*n*	%
Plastic/solid waste	Not observed	43	20.2
	Observed occasionally	99	46.5
	Observed frequently	49	23.0
	Observed persistently	22	10.3
Sewage/wastewater	Not observed	116	54.5
	Occurs seasonally	71	33.3
	Occurs regularly	19	8.9
	Occurs continuously	7	3.3
Industrial pollution impact	No noticeable impact	87	40.8
	Minor impact	52	24.4
	Moderate impact	46	21.6
	Severe impact	28	13.1
Mangrove cutting/degradation	Not observed	125	58.7
	Localized	55	25.8
	Widespread	24	11.3
	Extensive	9	4.2
Lagoon-mouth closure effect	No effect	20	9.4
	Occasional disruption	95	44.6
	Frequent disruption	37	17.4
	Severe disruption	61	28.6
Sedimentation/siltation effect	No impact	54	25.4
	Reduces fishing efficiency	95	44.6
	Restricts access to areas	37	17.4
	Makes fishing difficult	27	12.7

Lagoon-mouth closure was identified as the most serious environmental pressure affecting fishing. About 90.6% of respondents reported that lagoon-mouth closure disrupted their fishing activities, with 46.0% describing the impact as frequent or severe (Table 3). Previous studies have also shown that lagoon-mouth closure is a recurring event in Pulicat and can interrupt the movement of juvenile fish between the sea and the lagoon, reducing fish production (Nagalaksmi *et al*. 2017; Stein *et al*. 2021).

Sedimentation was another major concern. About 44.6% of respondents reported that it reduced their fishing efficiency, 17.4% said it restricted access to fishing grounds, and 12.7% reported that it made fishing very difficult. Only 25.4% reported no impact (Table 3). These findings indicate that sedimentation is reducing access to fishing areas and affecting fishing productivity, highlighting the need for effective lagoon management.

3.4 State

Fish availability declined over the past decade according to 87.8% of respondents, while only 1.4% reported an improvement (Table 4). Species diversity also declined, with 49.8% describing it as low and only 11.3% as high. Similar studies have shown that the loss of species reduces the productivity of lagoon ecosystems and the livelihoods they support (Rodrigues-Filho *et al*. 2023).

TABLE 4 Ecological state as perceived by respondent fishermen (*n* = 213).

Variable	Category	*n*	%
Fish availability (catch volume, 10 years)	Declined	187	87.8
	Remained stable	23	10.8
	Improved	3	1.4
Fish species diversity	Low	106	49.8
	Moderate	83	39.0
	High	24	11.3
Juvenile fish/fingerlings observed	Rarely	87	40.8
	Sometimes	94	44.1
	Regularly	32	15.0
Seasonal fish availability	No major change	50	23.5
	Seasons have shifted	108	50.7
	Seasons unpredictable	55	25.8
Mangrove cover change	Decreased	92	43.2
	No change	64	30.0
	Increased	57	26.8
Invasive/alien species	Not observed/not known	179	84.0
	Observed occasionally	32	15.0
	Observed frequently	2	0.9
Migratory birds	Decreased	85	39.9
	No change	38	17.8
	Increased	90	42.3

Juvenile fish and fingerlings were observed only rarely or sometimes by 84.9% of respondents, while just 15.0% reported seeing them regularly (Table 4). Since juvenile fish represent future fish stocks, their low abundance may indicate reduced juvenile fish observations. This is consistent with studies showing that the loss of nursery habitats and overfishing can reduce fish populations over time (Reis-Filho *et al*. 2019). Perceptions of mangrove cover change were mixed with about 43.2% of respondents reported a decrease, 30.0% reported no change, and 26.8% reported an increase (Table 4). However, even localized mangrove loss can negatively affect fish stocks and biodiversity (zu Ermgassen *et al*. 2020).

Most respondents (84.0%) had not observed invasive or alien species or were unaware of them (Table 4). This may reflect limited awareness rather than the absence of invasive species, as fishers often recognize new invasive species only after they become established (Bwalya *et al*. 2026). Responses on migratory bird sightings were mixed, with 42.3% reporting an increase and 39.9% reporting a decrease (Table 4). This may be because birds move to areas with greater food availability. In Pulicat, flamingos are known to gather where fish and invertebrates are abundant (Ramesh and Ramachandran 2005). This supports earlier findings that changes in biodiversity are not always the same across different groups of species (Rodrigues-Filho *et al*. 2023).

3.5 Impacts

Most respondents (78.9%) reported that their catch per unit effort (CPUE) had declined over the past 10 years, while only 11.3% reported an increase (Table 5). A similar trend was observed for fishing income, with 74.6% reporting a decline and only 8.0% reporting an increase (Table 5). This suggests that lower fish catches are directly affecting fishers' income. Similar findings have been reported in the Mozambique Channel, where increasing numbers of motorized fishing vessels led to a major decline in CPUE over time, highlighting the risk of overexploitation when fishing effort continues to increase without proper management (Zeller *et al*. 2021).

Fishing days lost due to lagoon mouth closure, pollution, and siltation were high. Only 11.3% of respondents reported no loss of fishing days, while 37.1% lost 6–10 days per month and 25.4% lost more than 10 days (Table 5). This reflects the impact of lagoon mouth closure and other environmental problems reported in Section 3.3, which reduced fishing opportunities. More than half of the respondents (54.5%) experienced occasional or frequent resource conflicts, mainly due to territorial disputes with outsider fishers and competition over fishing gears (Table 5). This is likely linked to the increasing number of fishers, identified by 32.9% of respondents in Section 3.2 as a major cause of higher fishing pressure.

Most respondents (65.3%) reported economic losses due to pollution events, while 34.7% reported no such losses (Table 5). These losses are consistent with the pollution problems described in Section 3.3, where plastic waste and industrial pollution were widely reported, showing that environmental degradation is directly affecting fishers' livelihoods. About 78.0% of respondents eating fish on four or more days each week, suggests that fish continues to be an important source of food even when fishing income declines. This supports previous findings that subsistence fishing helps maintain household food security (Virdin *et al*. 2023).

Livelihood diversification was limited, with only 14.6% of respondents having more than one source of income. Studies have shown that fishers with diversified livelihoods generally experience more stable incomes than those who depend only on fishing (White and Scheld 2024). As a result, most respondents remained highly vulnerable to the environmental and economic challenges reported in this study.

TABLE 5 Livelihood impacts perceived by fishers (n = 213) in Pulicat Lagoon of India.

Variable	Category	*n*	%
CPUE change (10 years)	Decreased	168	78.9
	No change	21	9.9
	Increased	24	11.3
Fishing income change	Decreased	159	74.6
	No change	37	17.4
	Increased	17	8.0
Fishing days lost per month due to various problems (e.g. mouth closure, pollution, or siltation)	None	24	11.3
	1-5 days (minor)	56	26.3
	6-10 days (moderate)	79	37.1
	>10 days (severe)	54	25.4
Fish consumption days per week	0-1 day	1	0.5
	2-3 days	46	21.6
	4-5 days	90	42.3
	6-7 days	76	35.7
Resource conflicts experienced	Not experienced	97	45.5
	Occasional	95	44.6
	Frequent	21	9.9
Economic loss from pollution events	None	74	34.7
	Low	61	28.6
	Moderate	54	25.4
	High	24	11.3

3.6 Responses

Awareness of fisheries regulations was moderate among respondents. About 44.6% were partially aware, 38.0% were fully aware, and 17.4% were not aware of the regulations (Table 6). However, enforcement was perceived to be weaker, with 39.4% reporting that regulations were rarely enforced, while only 25.4% believed they were mostly enforced. This suggests that the main challenge lies in implementing fisheries regulations rather than creating awareness. Trust in fisheries authorities was also moderate, with 44.1% reporting moderate trust, 33.3% low trust, and only 22.5% high trust (Table 6). Previous studies have shown that weak enforcement often reduces trust in fisheries management and encourages communities to rely on informal local enforcement (Turner *et al*. 2016; Castillo *et al*. 2024).

Participation in fisheries and coastal management meetings was relatively high, with 71.8% attending at least one meeting during the previous year (Table 6). However, moderate trust and weak perceptions of enforcement persisted despite this participation. This suggests that simply organizing meetings is not enough to improve trust. Studies have shown that fishers are more supportive of management when they have meaningful involvement in decision-making rather than simply attending meetings (Pita *et al*. 2010). Therefore, strengthening genuine participation through co-management may help improve trust and fisheries governance in the Pulicat Lagoon (Smallhorn-West *et al*. 2022).

Most respondents (67.2%) were willing to adopt sustainable fishing practices, with 53.1% willing only with institutional support and 14.1% willing without support (Table 6). This suggests that institutional support is important for promoting sustainable fishing practices, consistent with studies highlighting the role of trust and legitimacy in fisheries governance (Turner *et al*. 2016; Castillo *et al*. 2024). However, 32.9% of respondents were unwilling to adopt sustainable practices. This may be linked to the moderate trust in fisheries authorities and weak enforcement reported in this study, emphasizing the need to strengthen governance and co-management (Smallhorn-West *et al*. 2022).

TABLE 6 Governance responses and community perceptions related to fisheries management (*n* = 213).

Variable	Category	*n*	%
Awareness of regulations	Not aware	37	17.4
	Partially aware	95	44.6
	Fully aware	81	38.0
Perceived enforcement	Rarely enforced	84	39.4
	Sometimes enforced	75	35.2
	Mostly enforced	54	25.4
Participation in meetings (past year)	None	60	28.2
	1–2 times	76	35.7
	3+ times	77	36.2
Trust in fisheries authorities	Low	71	33.3
	Moderate	94	44.1
	High	48	22.5
Willingness to adopt sustainable practices	Not willing	70	32.9
	Willing with institutional support	113	53.1
	Willing even without support	30	14.1

3.7 Participatory rural appraisal findings

3.7.1 Sample characteristics: The three focus groups were reasonably balanced across age (mean 38–45 years), reducing the likelihood that the results reflect a single fishing practice or generational perspective.

3.7.2 Participatory mapping: The consolidated resource map was digitised using QGIS and geo-referenced against the map's coordinate grid to quantify spatial relationships between fishing activity and identified hazards (Table 7 and 8, Figure 2 and 3). One fishing ground was located immediately adjacent (0 m) to a siltation zone near the bridge crossing, while three southern fishing grounds were situated within 55–230 m of pollution hotspots. The geo-referenced participatory maps provided spatially explicit information on fishing grounds and environmental stressors, demonstrating the value of fishers' local ecological knowledge for fisheries management and environmental planning (Nunes *et al*. 2021). Approximately 27% of fishing grounds were located within 300 m of siltation zones, and 27% were within 100 m of pollution hotspots, indicating considerable spatial overlap between fishing activities and environmental pressures. In addition, the bridge crossing appeared to act as a partial barrier, with fishing routes converging and diverging around it, consistent with studies reporting that coastal infrastructure can alter water flow and fish movement (Lennox *et al*. 2025).

TABLE 7 Summary statistics from digitised participatory resource map.

Feature type	Count	Notes
Fishing grounds	11	Concentrated north of the bridge; two clusters south
Pollution hotspots	5	Scattered across western channel and southern zone
Siltation zones	3	Clustered near the bridge crossing
Total fishing-path length	~3.8 km	Meander-adjusted estimate from digitised paths

TABLE 8 Spatial proximity analysis between fishing grounds and hazard zones (digitised coordinates).

Proximity metric	Mean distance (m)	Range (m)	Grounds within threshold
Fishing ground → nearest siltation zone	447	0–747	3 of 11 within 300 m (27%)
Fishing ground → nearest pollution hotspot	379	54–818	3 of 11 within 100 m (27%)

3.7.3 Seasonal calendar analysis: Seasonal calendars were completed independently by three focus groups, each scoring five livelihood indicators across twelve months on a 0–3 ordinal scale. The three groups showed different seasonal peaks for catch, income, and effort rather than a single shared pattern, and their Spearman correlations (Table 9) diverged sharply in structure as well as strength. The Spearman rank-order correlation for seasonal calendar analysis was based on monthly scores generated by three focus groups, resulting in only 12 observations per group for the correlation analysis. Therefore, the statistical relationships should be interpreted as exploratory rather than conclusive. Nevertheless, the seasonal calendar provided valuable insights into livelihood dynamics and complemented the quantitative interview schedule by identifying temporal patterns that would not have been evident from the interview data alone.

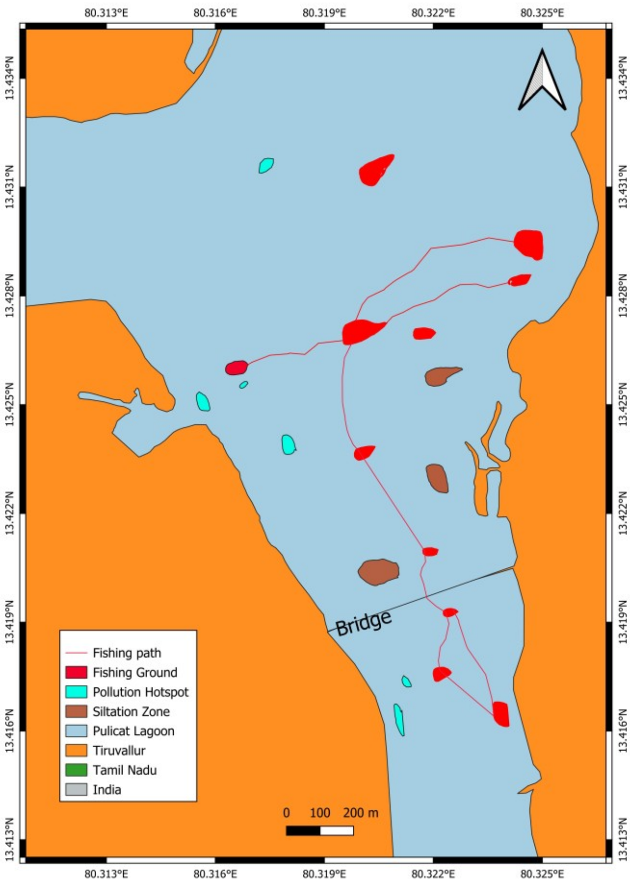

FIGURE 2 Consolidated participatory resource map of Pulicat Lagoon, digitised in QGIS.

The three focus groups identified different seasonal patterns rather than a common livelihood calendar. Group 1 showed a strong positive relationship between fishing days and catch (ρ = 0.95, $p < 0.001$), indicating that catch was mainly influenced by fishing effort. In Group 2, catch was significantly associated with market price (ρ = 0.70, $p = 0.011$), suggesting greater market influence. Group 3 exhibited the most complex pattern, with catch significantly related to both price and income (ρ = 0.66, $p = 0.019$), while price and income showed a perfect positive correlation (ρ = 1.00, $p < 0.001$). Lagoon-mouth condition was also negatively associated with fishing days in Group 3 (ρ = −0.69, $p = 0.012$), indicating that mouth closure directly reduced fishing activity (Table 9).

FIGURE 3 Fishers annotating base imagery during a Participatory mapping session (Pulicat Lagoon, 28 Jan 2026; photo by Deepak B.).

FIGURE 4 Fishers completing the seasonal calendar during a PRA session, Pulicat (28 Jan 2026; photo by Deepak B.).

Overall, only six significant relationships were observed across the three groups, and none were common to all groups. This indicates that Pulicat's fishing community comprises diverse livelihood strategies rather than a single homogeneous system, consistent with previous studies on livelihood diversification in small-scale fisheries (Roscher *et al*. 2022; White and Scheld 2024). The negative association between lagoon-mouth condition and fishing activity also supports earlier evidence that recurring mouth closure disrupts lagoon connectivity and fishing livelihoods (Nagalaksmi *et al*. 2017; Stein *et al*. 2021).

TABLE 9 Spearman rank-order correlations across twelve monthly observations.

Relationship	Group 1 ρ (*p*)	Group 2 ρ (*p*)	Group 3 ρ (*p*)
Catch × Price	−0.50 (0.097)	0.70 (0.011)*	0.66 (0.019)*
Catch × Income	0.50 (0.095)	0.18 (0.565)	0.66 (0.019)*
Catch × Days	0.95 (<0.001)*	0.35 (0.270)	0.48 (0.111)
Catch × Mouth condition	−0.02 (0.941)	−0.01 (0.975)	−0.36 (0.254)
Price × Income	0.13 (0.689)	0.25 (0.434)	1.00 (<0.001)*
Price × Days	−0.45 (0.141)	0.25 (0.440)	0.16 (0.618)
Price × Mouth condition	0.17 (0.593)	−0.01 (0.965)	−0.32 (0.313)
Income × Days	0.51 (0.089)	−0.38 (0.218)	0.16 (0.618)
Income × Mouth condition	−0.56 (0.061)	0.22 (0.496)	−0.32 (0.313)
Days × Mouth condition	−0.05 (0.870)	−0.25 (0.436)	−0.69 (0.012)*

Note: ρ = Spearman's rank correlation coefficient; values in parentheses are *p*-values. All 10 possible pairwise relationships among the five livelihood indicators are reported.

3.7.4 Problem prioritisation (matrix scoring)

Each group allocated 10 tokens across five community-identified problems, ranking them by perceived severity a direct matrix ranking exercise in which fishers themselves generate and weigh the criteria, rather than responding to categories imposed by researchers (Mulugeta *et al*. 2025). Consolidated scores here (Table 10, Figure 5) show pollution/waste and declining fish catch as the dominant concerns, jointly accounting for 53% of all tokens allocated across groups direct, independently generated evidence that water quality and resource depletion, rather than social conflict, are perceived as the primary threats to fisheries livelihoods.

The tie between the top two problems (8/30 tokens each) is resolved decisively not by token count, but by where each group placed its single highest-priority problem. Pollution and waste were independently ranked #1 by two of the three groups, meaning two separate community groups, working without knowledge of each other's sessions, converged on the same top concern. Declining fish catch, by contrast, accumulated an equal number of tokens overall but was rarely any individual group's first choice it was distributed across the second and third positions rather than concentrated at the top. This is a materially stronger form of evidence than token volume alone: a problem that several groups agree is the most urgent issue is a more actionable management signal than one that is broadly acknowledged but rarely prioritised first. This has a direct practical implication. Management effort at Pulicat should not treat "declining fish catch" as the entry point for engaging the community, since it is not what fishers themselves reach for first when asked to prioritise. Pollution and waste management is the intervention most likely to be recognised by fishers as addressing their own stated top concern, making it the more strategic starting point for building trust and cooperation before tackling harder, slower-moving problems such as catch decline or mouth-closure management.

TABLE 10 Consolidated matrix scoring results across three focus groups (30 tokens total).

Problem	Token				Rank
	G1	G2	G3	Total	
Pollution & waste	3	3	2	8	1
Declining fish catch	2	3	3	8	2
Mouth closure & siltation	2	1	2	5	3
Low income	2	2	1	5	4
Conflicts in fishing	1	1	2	4	5

FIGURE 5 Group 1's completed matrix scoring board with rankings 1–5 (Pulicat, 28 January 2026; photo by Deepak B.).

3.8 Triangulation of interview schedule and PRA findings

The structured interview schedule and the three-tool participatory rural appraisal were designed and analysed independently, using different elicitation logics and different susceptibility to bias: individual interview responses are prone to recall and social-desirability effects at the person level, while group-based ranking and calendar exercises are prone to different, group-level dynamics. Convergence across data sources that carry different bias structures is precisely the condition under which triangulation strengthens, rather than merely repeats, a finding, because agreement across independently collected sources reduces the likelihood that any single result reflects one source's peculiar bias (Carter *et al*. 2014). This logic is formalised in mixed-methods design as the deliberate use of qualitative and quantitative strands to confirm and extend one another's conclusions (Creswell and Clark 2017), and is operationalised here using the triangulation typology of Farmer *et al*. (2006), who classify triangulation outcomes as convergence, partial convergence, complementarity, or dissonance. All five problems identified through PRA matrix scoring were triangulated against the interview schedule and are presented in Table 11.

TABLE 11 Cross-method triangulation of major problems: interview schedule vs. PRA evidence.

Major problem	Interview schedule evidence	PRA evidence	Classification
Pollution & solid waste	Observed by 79.8% of respondents	Ranked #1 by 2 of 3 groups in matrix scoring	Convergence
Lagoon-mouth closure	Disrupts fishing for 90.6% of respondents, 28.6% severely	Ranked #3 of 5 in matrix scoring by token count, but rarely chosen as any single group's top priority. Significantly correlated with fishing days in Group 3 ($\rho = -0.69$, $p = 0.012$)	Partial convergence
Declining fish catch (CPUE)	78.9% reported CPUE decline; 87.8% reported declining catch volume over the past 10 years	Ranked #2 of 5 in matrix scoring, but rarely any group's top-ranked concern; catch significantly correlated with income ($\rho = 0.66$, $p = 0.019$) in the seasonal calendar	Partial convergence
Declining income	74.6% report declining fishing income	Ranked only 4th of 5 in matrix scoring; income tracked market price more strongly than catch volume in Group 3 specifically ($\rho = 1.00$ vs. 0.66), though this pattern was not consistent across all three groups	Complementarity
Resource conflicts	Reported by 54.5% of respondents	Ranked lowest (5th of 5) in matrix scoring	Convergence

Note: Convergence = both methods independently identify the same priority and rank. Partial convergence = both methods confirm the problem, but rank order or statistical significance differs. Complementarity = PRA evidence adds explanatory depth or spatial specificity not captured by the interview schedule alone Dissonance = the two methods produce contradictory findings on the same problem (Farmer *et al.* 2006).

Two problems show full convergence pollution/solid waste and resource conflicts meaning two structurally different instruments, applied to non-overlapping respondents, independently arrived at the same conclusion about both the leading concern and the least urgent one. This is the strongest form of evidence a mixed-methods design can offer, since it reflects two different instruments agreeing rather than two measurements from the same instrument (Carter *et al*. 2014). Two further problems mouth closure and declining catch show partial convergence: both are confirmed as serious by the interview schedule, but the PRA data qualify rather than simply repeat this finding.

The triangulation of the interview schedule and PRA findings showed strong agreement across the two methods. Pollution/solid waste and resource conflicts demonstrated complete convergence, with both the interview schedule and matrix ranking identifying them as the highest and lowest priority issues, respectively. Such agreement between two independent methods strengthens confidence in these findings (Carter *et al*. 2014).

Mouth closure and declining fish catch showed partial convergence. Both were identified as important issues in the interview schedule, while the PRA findings provided additional insights into their relative importance. Although declining catch received a high overall score in the matrix ranking, it was not consistently ranked as the highest priority by the focus groups, suggesting that fishers view it as a serious but secondary concern. Similarly, lagoon-mouth condition showed a significant negative relationship with fishing days in Group 3 ($\rho = -0.69$, $p = 0.012$), indicating that mouth closure was associated with reduced fishing activity. Together with the participatory mapping results, this provides consistent evidence that mouth closure is a major environmental pressure in Pulicat (Nagalaksmi *et al*. 2017; Stein *et al*. 2021).

Declining income showed complementarity rather than direct convergence. While the interview schedule confirmed that income had declined for most respondents, the seasonal calendar indicated that market price was a stronger driver of income than catch volume in Group 3, where price and income were perfectly correlated ($\rho = 1.00$, $p < 0.001$). This illustrates how combining the interview schedule with PRA tools can generate insights that neither method could provide independently (Creswell and Clark 2017).

Overall, no contradictions were observed between the interview schedule and PRA findings. Instead, the two approaches complemented each other, strengthening confidence in the results. Pollution and lagoon-mouth closure emerged as the most consistent management concerns across methods, while declining catch and income appeared to be associated with these underlying environmental pressures rather than being identified as the primary drivers of fisheries decline.

3.9 DPSIR synthesis

Sections 3.2–3.8 presented the drivers, pressures, state, impacts, and responses as separate components of the DPSIR framework, each supported by interview schedule findings and, where applicable, complemented by independent PRA evidence (Figure 6). Rather than repeating those results, this section integrates them into a DPSIR pathway, illustrating the perceived relationships among the different components and the feedbacks linking management responses to the system. This interpretation follows the mosaic-DPSIR approach proposed by Dolbeth *et al*. (2016) and the DAPSI(W)R(M) framework of Elliott *et al*. (2017), and is consistent with the interactive DPSIR cycle applied by Delgado *et al*. (2021) in a small-scale coastal fishery. Figure 6 illustrates this integrated framework, with the left panel presenting the Pulicat-specific causal pathway and the right panel showing the generalized feedback cycle.

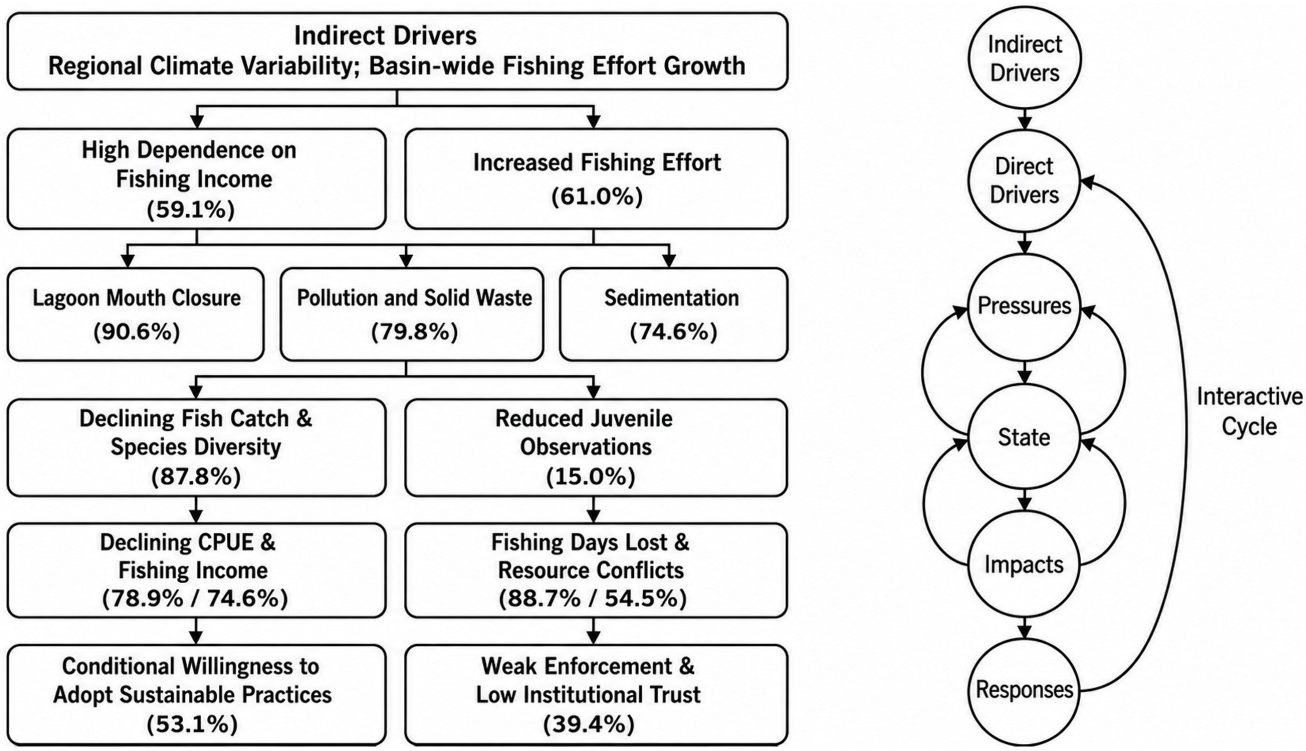

FIGURE 6 DPSIR-based synthesis of fisheries sustainability and marine conservation in the Pulicat region.

High dependence on fisheries, climate variability, and increasing fishing pressure constituted the principal drivers of change in Pulicat Lagoon. These drivers generated multiple environmental pressures, particularly lagoon-mouth closure, pollution, and sedimentation, which were consistently identified through both the interview schedule and PRA findings. These pressures were reflected in the declining ecological condition of the lagoon through reduced fish availability, lower juvenile observations, and changes in biodiversity. Comparable studies have shown that pollution, habitat degradation, and disrupted lagoon connectivity reduce nursery functions and fish productivity in coastal lagoons (Reis-Filho *et al*. 2019; zu Ermgassen *et al*. 2020; Stein *et al*. 2021). The seasonal calendar provided additional evidence by showing that poor lagoon-mouth conditions significantly reduced fishing activity in one focus group, highlighting the direct influence of hydrological changes on fishing livelihoods. The ecological degradation subsequently translated into declining catch, reduced income, and loss of fishing days, consistent with previous studies demonstrating the close relationship between ecosystem condition and livelihood security in small-scale fisheries (Etongo and Arrisol 2021; Zeller *et al*. 2021).

Although most respondents expressed willingness to adopt sustainable fishing practices, their willingness was largely conditional on institutional support, while weak enforcement and moderate trust in fisheries authorities remained important constraints. Similar findings have been reported in co-managed fisheries, where effective governance, institutional trust, and stakeholder participation are critical for improving compliance with fisheries management measures (Turner *et al*. 2016; Smallhorn-West *et al*. 2022; Castillo *et al*. 2024).

The findings further demonstrate that the DPSIR framework operates as a dynamic feedback system rather than a linear sequence. Weak governance allows environmental pressures to persist, while declining catches may encourage greater fishing effort, reinforcing ecological degradation and livelihood vulnerability. This interpretation supports the mosaic-DPSIR framework proposed by Dolbeth *et al*. (2016), which emphasizes feedbacks among ecological, social, and governance components rather than simple cause-and-effect relationships.

Overall, the synthesis indicates that sustainable management of Pulicat Lagoon should focus on reducing the underlying environmental pressures, particularly pollution, lagoon-mouth closure, and sedimentation, while simultaneously strengthening governance, institutional trust, and participatory co-management. Addressing these interconnected components is more likely to improve both ecosystem health and fisheries livelihoods than interventions targeting declining catch or income alone.

4 | CONCLUSIONS

This study applied the Driver–Pressure–State–Impact–Response (DPSIR) framework to assess fisheries sustainability and marine conservation in the Pulicat region by integrating interview schedule data with participatory rural appraisal approaches. The findings indicate that high dependence on fisheries, climate variability, and fishing pressure were important drivers, while pollution, lagoon-mouth closure, and sedimentation were major environmental pressures perceived by the fishing communities. These pressures were associated with declining fish availability, reduced catch and income, and increased livelihood vulnerability. Although many respondents expressed willingness to adopt sustainable fishing practices, weak enforcement and limited trust in fisheries authorities remained important challenges.

The integration of interview schedule findings with participatory mapping, seasonal calendars, and problem-ranking matrices provided complementary insights into the environmental and livelihood challenges of the Pulicat region. The triangulated findings highlight the need for improved pollution control, effective management of lagoon-mouth conditions and sedimentation, stronger institutional trust, and meaningful community participation in fisheries governance. The combined DPSIR and participatory approach therefore provides a useful framework for understanding the interconnected environmental, livelihood, and governance challenges affecting fisheries sustainability in the Pulicat region.

Overall, the Pulicat fishery functions as an interconnected socio-ecological system in which environmental degradation, livelihood dependence, and governance challenges influence one another. Therefore, addressing individual environmental problems in isolation may not be sufficient to achieve sustainable improvements. An integrated ecosystem-based approach that reduces environmental pressures, strengthens governance and enforcement, and promotes meaningful participation of local fishing communities is essential for improving the ecological resilience of Pulicat Lagoon and supporting the long-term sustainability of fisheries and associated livelihoods

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTION

Deepak B.: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing - original draft. Agnes Daney Angela S.: Supervision; Writing - review & editing; Project administration; Lloyd Chrispin C: Supervision. Sudhan C: Supervision. Arunachalam R: Writing - review & editing. Kanmani S: Writing - review & editing. Sarabes NJ: Writing - review & editing. All authors read and approved the final manuscript.

AI-USE STATEMENT

Grammarly was used for grammar, and language correction. The authors reviewed the corrections and take responsibility for the final manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

REFERENCES

Basurto X, Gutierrez NL, Franz N, Mancha-Cisneros MDM, Gorelli G, … Tilley A (2025) Illuminating the multidimensional contributions of small-scale fisheries. Na-

ture 637(8047): 875–884.
Bwalya P, Bwalya H, Mbewe G, Ndhlovu I, Mbewe J, … Muzungaire A (2026) Redclaw crayfish: challenge or resource? Voices of fishers in Zambia. Aquatic Conservation Marine and Freshwater Ecosystems 36(2): e70333.
Carter N, Bryant-Lukosius D, DiCenso A, Blythe J, Neville AJ (2014) The use of triangulation in qualitative research. Oncology Nursing Forum 41(5): 545–547.
Castillo LS, Wilson JR, Aceves-Bueno E, Quintana AC, Gaines S (2024) Enforcement, deterrence, and compliance in co-managed small-scale fisheries. Ecology and Society 29(4).
Cavole LM, Gragnolati M, Matoso Silva RV, Lopes PF, Giarrizzo T, Reis-Filho JA (2025) Unveiling gender disparities: the role of women in transforming small-scale fisheries. Fish and Fisheries 26(6): 1146–1163.
Chambers R (1994) The origins and practice of participatory rural appraisal. World Development 22(7): 953–969.
Cheshire AC, Adler E, Barbière J, Cohen Y, Evans S, … Westphalen G (2009) UNEP/IOC guidelines on survey and monitoring of marine litter. UNEP Regional Seas Reports and Studies, No. 186; IOC Technical Series No. 83, 120 p.
Coulthard S (2008) Adapting to environmental change in artisanal fisheries—insights from a South Indian Lagoon. Global Environmental Change 18(3): 479–489.
Creswell JW, Clark VLP (2017) Designing and conducting mixed methods research. Sage publications.
Dalkey N, Helmer O (1963) An experimental application of the Delphi method to the use of experts. Management science 9(3): 458–467.
Delgado LE, Zúñiga CC, Asún RA, Castro-Díaz R, Natenzon CE, … Olivares GR (2021) Toward social-ecological coastal zone governance of Chiloé Island (Chile) based on the DPSIR framework. Science of The Total Environment 758: 143999.
Dolbeth M, Stålnacke P, Alves FL, Sousa LP, Gooch GD, … Soares JA (2016) An integrated Pan-European perspective on coastal lagoons management through a mosaic-DPSIR approach. Scientific Reports 6(1): 19400.
EEA (1999) Environmental indicators: typology and overview (available at: https://www.eea.europa.eu/publications/ TEC25)
Elliott M, Burdon D, Atkins JP, Borja A, Cormier R, … Turner RK (2017) “And DPSIR begat DAPSI (W) R (M)!”-a unifying framework for marine environmental management. Marine Pollution Bulletin 118(1–2): 27–40.
Etongo D, Arrisol L (2021) Vulnerability of fishery-based livelihoods to climate variability and change in a tropical island: insights from small-scale fishers in Seychelles. Discover Sustainability 2(1): 48.
FAO (2015) Voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication. Food and Agriculture Organization of the United Nations, Rome.
FAO (2021) Guidelines to enhance small-scale fisheries and aquaculture statistics. Food and Agriculture Organization of the United Nations, Rome.
FAO (2026) The state of world fisheries and aquaculture 2026 – blue transformation: turning vision into impact. Food and Agriculture Organization of the United Nations, Rome.
Farmer T, Robinson K, Elliott SJ, Eyles J (2006) Developing and implementing a triangulation protocol for qualitative health research. Qualitative Health Research 16(3): 377–394.
Gari SR, Newton A, Icely JD (2015) A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems. Ocean and coastal management 103: 63–77.
Kwadzo M, Miyittah MK, Dovie DB, Kosivi RK, Owusu R (2022) Pollution and climate change impacts on livelihood outcomes of lagoon fishermen in Central Region, Ghana. Current Research in Environmental Sustainability 4(4): 100137.
Lennox RJ, Birnie-Gauvin K, Bate C, Cooke SJ, Haraldstad T, … Piczak ML (2025) Marine fish passage—underappreciated threats to connectivity within the marine environment. Marine Ecology 46(1): e12859.
Macfadyen G, Huntington T, Cappel R (2009). Abandoned, lost or otherwise discarded fishing gear. Co-publication UNEP Regional Seas Report and Studies/FAO Fisheries and Aquaculture Technical Paper.
Mulugeta Y, Hordofa D, Elias D, Ortega-Pacheco A (2025) Participatory epidemiological study of endemic bovine diseases among gnyangatom and dasenech pastoralists, South Omo Zone, Ethiopia. Veterinary Medicine International 2025: 2726225.
Nagalaksmi K, Kumar MP, Jayaraju N, Prasad TL, Lakshmanna B, Sreenivasulu G (2017) Dynamics of Pulicat Lake mouth analysis using geospatial data, east coast of India: implications to socio-economic scenarios. Data in Brief 15: 142–147.
Nunes MUS, Cardoso OR, Silvano RAM, Favaro LF (2021) Participatory mapping and fishers’ knowledge about fish and shrimp migration in a subtropical coastal ecosystem. Estuarine, Coastal and Shelf Science 258(11–12): 107412.
Pita C, Pierce GJ, Theodossiou I (2010) Stakeholders’ participation in the fisheries management decision-making process: fishers’ perceptions of participation. Marine Policy 34(5): 1093–1102.
Rai S, Bera S (2025) Impact of climate variability on fishermen livelihood: evidence from the western coast of India. In: Communication, Science, Technology, and Innovation in Disaster Risk Management: Recent

Trends and Approaches in South Asia (pp. 41–48). Cham: Springer Nature Switzerland.

Ramesh DA, Ramachandran S (2005) Factors influencing flamingo (*Phoenicopterus roseuis*) distribution in the Pulicat Lagoon ecosystem, India. Wetlands Ecology and Management 13(1): 69–72.

Reis-Filho JA, Fogliarini CO, Giglio VJ, De Souza GBG, Noleto-Filho EM (2026) Eroding lineages: age structure and intergenerational risks in small-scale fisheries. Reviews in Fish Biology and Fisheries 36(1): 24.

Reis-Filho JA, Harvey ES, Giarrizzo T (2019) Impacts of small-scale fisheries on mangrove fish assemblages. ICES Journal of Marine Science 76(1): 153–164.

Rodrigues-Filho JL, Macêdo RL, Sarmento H, Pimenta VR, Alonso C, … Rocha O (2023) From ecological functions to ecosystem services: linking coastal lagoons biodiversity with human well-being. Hydrobiologia 850(12–13): 2611–2653.

Roscher MB, Allison EH, Mills DJ, Eriksson H, Hellebrandt D, Andrew NL (2022) Sustainable development outcomes of livelihood diversification in small-scale fisheries. Fish and Fisheries 23(4): 910–925.

Smallhorn-West P, Cohen PJ, Phillips M, Jupiter SD, Govan H, Pressey RL (2022) Linking small-scale fisheries co-management to UN sustainable development goals. Conservation Biology 36(6): e13977.

Stein ED, Gee EM, Adams JB, Irving K, Van Niekerk L (2021) Advancing the science of environmental flow management for protection of temporarily closed estuaries and coastal lagoons. Water 13(5): 595.

Turner RA, Addison J, Arias A, Bergseth BJ, Marshall NA, … Tobin RC (2016) Trust, confidence, and equity affect the legitimacy of natural resource governance. Ecology and Society 21(3): 18.

UNEP (2021) Understanding the state of the ocean: a global manual on measuring SDG 14.1.1, SDG 14.2.1 and SDG 14.5.1. Nairobi: UNEP.

UNESCO (2026) Convention on wetlands of international importance especially as waterfowl habitat.

UNESCO World Heritage Centre (2026) World Wetlands Day 2026: celebrating cultural heritage through wetlands.

Virdin J, Basurto X, Nico G, Harper S, del Mar Mancha-Cisneros M, … Mills DJ (2023) Fishing for subsistence constitutes a livelihood safety net for populations dependent on aquatic foods around the world. Nature Food 4(10): 874–885.

White SB, Scheld AM (2024) Assessing diversification behavior of small-scale commercial fishers. ICES Journal of Marine Science 81(3): 480–490.

Zeller D, Vianna GM, Ansell M, Coulter A, Derrick B, … Pauly D (2021) Fishing effort and associated catch per unit effort for small-scale fisheries in the Mozambique Channel region: 1950–2016. Frontiers in Marine Science 8: 707999.

zu Ermgassen PS, Mukherjee N, Worthington TA, Acosta A, da Rocha Araujo AR, … Parrett CL (2020) Fishers who rely on mangroves: modelling and mapping the global intensity of mangrove-associated fisheries. Estuarine, Coastal and Shelf Science 248: 106975.

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