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RESEARCH ARTICLE

Bridging knowledge and conservation in Pichavaram mangroves: A multi-stakeholder study

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Abstract

Mangrove ecosystems play a vital role in coastal protection, climate regulation and supporting livelihoods, yet they remain among the most threatened ecosystems globally. This study assesses the awareness levels and perceptions of primary stakeholder groups-namely residents, fishermen and visitors-regarding the ecological significance, prevailing status and key determinants affecting the Pichavaram mangrove ecosystem in Tamil Nadu, India. Using a structured questionnaire, data were collected from 360 respondents across two panchayats adjacent to the mangrove forest. Statistical and descriptive analyses indicated that provisioning services, such as food and fuelwood, were widely recognized-especially among fishermen and residents-whereas awareness of supporting and regulating services, including nutrient cycling and climate change mitigation, was comparatively limited. Perceptions of the ecosystem varied, with many recognizing degradation, while others noted post-cyclone improvements linked to community conservation initiatives. Climate change impacts, including prolonged saline water intrusion and seedling mortality, were acknowledged by only a minority of respondents, reflecting limited awareness. Nevertheless, a large majority across all stakeholder groups recognized the broader ecological and societal consequences of mangrove loss. The findings highlight the critical need for participatory conservation strategies that integrate local knowledge and address awareness gaps to enhance the sustainable management of mangrove ecosystems. The study offers valuable insights for policymakers, conservationists and development planners seeking to align community engagement with ecological restoration efforts.

Keywords: climate change impacts; ecosystem services; management policy; mangrove status; social impacts

Introduction

In the intertidal zone of tropical, subtropical and mild temperate waters, mangrove forests are the most prevalent forest type. Mangroves are a woody vegetation that grows in brackish and marine environments (1). Mangrove trees can be found on mudflats, the banks of tropical and subtropical rivers and along coastlines worldwide. They are frequently impacted by tides and stand with their roots in saltwater (2). They also serve as a boundary between two distinct environments. Mangroves have developed a range of reproductive and survival techniques to cope with their harsh habitat, which includes muddy and highly saline water (3–5).

According to India Water Portal (IWP), approximately 6.8 % of the world's mangroves are found in South Asia, with 48.53 % of these occurring in India. People have always been drawn to coastal areas because they offer a wealth of readily available resources that require no effort to be exploited, especially since the massive migration and cultural developments that took place in the mid-Holocene. The mangrove ecosystem typically dominates the coastal areas found in tropical and subtropical climates. Because of its capacity for adaptation and the significant influence of the environment, this ecosystem can be regarded as the dominant ecosystem in the coastal area when compared to other types of vegetation (6).

Coastal and marine habitats are made up of salt marshes, seagrass meadows and mangrove forests (7). Due to their critical role in mitigating the effects of climate change, mangroves, seagrass beds and tidal marshes need to be better managed, which gave rise to the idea of blue carbon ecosystems (8). Through a process known as carbon sequestration, blue carbon ecosystems regulate climate by allowing plants to directly absorb CO_2 from the atmosphere and surface waters, which is then stored in their biological and soil material (9, 10). Additionally, mangrove forests offer regulatory protection (to differing degrees and with constraints) from typhoon-driven storm surges and other natural threats (11, 12). Mangroves are among the most endangered ecosystems, despite being, extremely productive by offering a variety of ecosystem services that benefit and sustain regional and national economies (8, 11).

In the twenty-first century, dynamic anthropogenic activities, including aquaculture, shrimp farming, land expansion, human settlement and agriculture, appear to be major threats contributing to the near-extinction of mangroves (13, 14). The loss of these ecosystems has led to a reduction in the beneficial services they offer, including protection from storm surges, food provision, climate management and cultural and spiritual values (15-17). Mangroves were recognised after the devastating 2011 cyclone for their resilience and effectiveness in protecting coastal areas from the effects of the storm. The mangrove environment, once thought to be a wasteland, is now highly valued for its ability to protect against coastal threats. Conservation efforts for mangroves and their environment have significantly increased on a global scale. Given the significance of ecosystem services for human well-being, the scientific community has recently shown a great deal of interest in integrating these services into decision-making processes (18, 19). Governments have made efforts to guarantee sustainable management of mangroves and numerous laws and policies have been put into place to protect and sustain them.

Achieving sustainable management of mangroves requires more than just enforcing laws and policies; local communities must be involved in the framework to guarantee consistent yields and a higher success rate (20). Responsible authorities should give due consideration to this strategy, as it holds the potential to inform more sustainable mangrove management policies. To ensure effective mangrove planning and management for future sustainability, it is imperative to assess local people's awareness and understanding of the significance of mangrove services and their current status in the area. Understanding local people's attitudes and perceptions related to their natural resources is crucial for promoting their commitment.

This research aimed to assess the awareness and understanding of the local community regarding the importance and current condition of mangrove resources in the Pichavaram Mangrove Forest. It also sought to identify key factors affecting the survival of mangroves in the region. The findings of this study can serve as a valuable baseline for stakeholders and agencies involved in mangrove conservation, helping to inform resource planning and support the formulation of effective management strategies for mangrove ecosystems.

Materials and Methods

Study area

The study was conducted in and around the Pichavaram mangrove ecosystem, located between latitude 11°23’ to 11°30’ N and longitude 79°45’ to 79°50’ E in the Chidambaram Taluk of Cuddalore District, Tamil Nadu, India. The geographical hierarchy of the study area is illustrated in Fig. 1. Pichavaram, situated between the Coleroon and Vellar estuary systems, is one of India's most notable and ecologically vital mangrove forests. It forms part of the Pichavaram Reserve Forest, managed by the Tamil Nadu Forest Department. The forest area is rich in biodiversity and provides multiple ecosystem services, broadly classified as provisioning, supporting, cultural and regulating services.

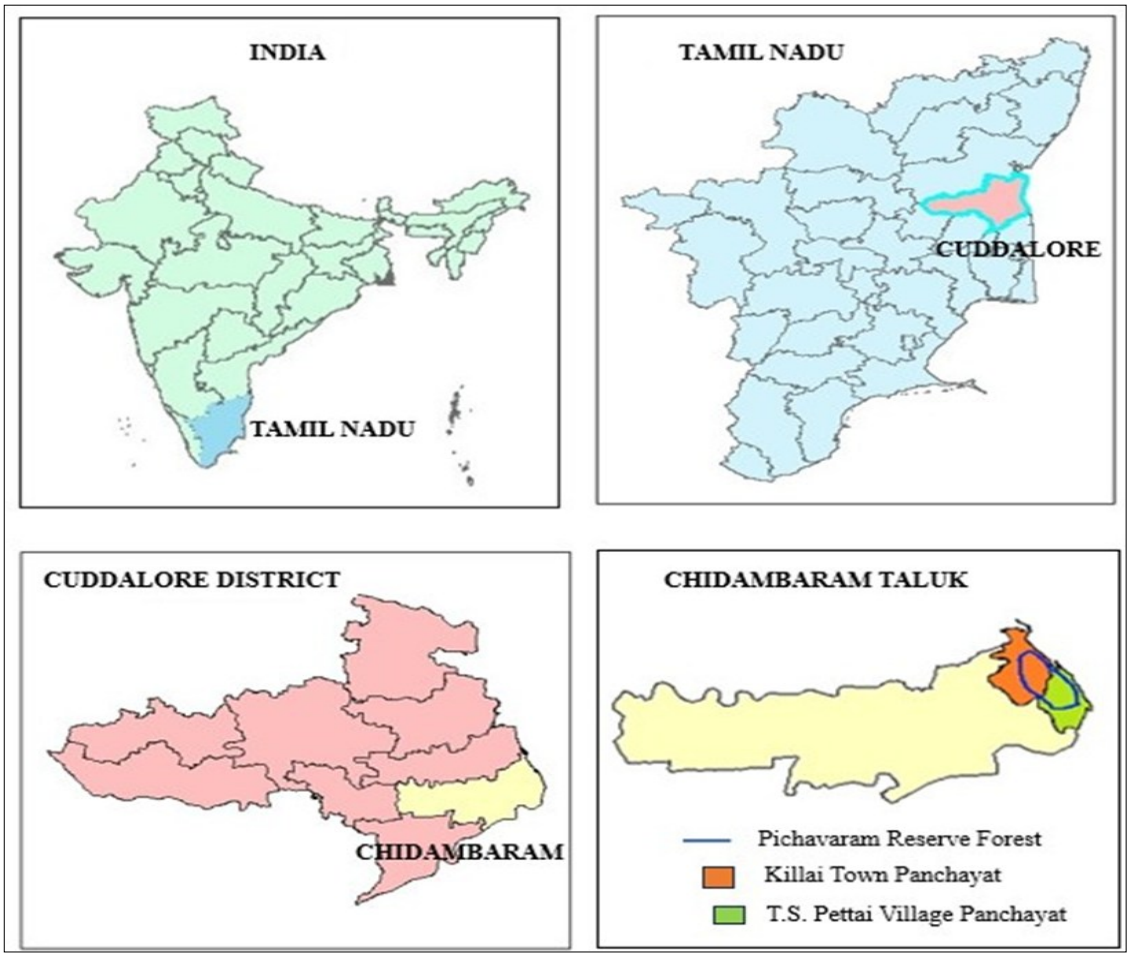

Fig. 1. Study area map.

The study area includes Killai town Panchayat and Thandavarayansozhagan Pettai (T.S. Pettai) village Panchayat, both of which are located near the mangrove forest and are inhabited by communities whose livelihoods are closely linked to the ecosystem. These locations serve as key stakeholder zones for data collection, representing a diverse set of respondents, including residents, fishermen and visitors who directly or indirectly interact with the mangrove ecosystem. The livelihoods of local residents, particularly fishermen and their families are highly dependent on the provisioning and regulating services offered by the mangroves. In addition, the region attracts a substantial number of visitors, contributing to ecotourism and cultural services. The selected study region provides a unique blend of ecological richness and socio-economic diversity, making it an ideal site for assessing stakeholder awareness and perceptions of the mangrove landscape.

Data collection

The primary data collection was conducted in the villages of Killai and T.S. Pettai panchayats. The stakeholders of the Pichavaram mangroves were identified, namely residents, fishermen and visitors. A sample of 360 respondents was interviewed (120 of each stakeholder group) using a pre-tested and structured questionnaire. The respondents residing within a 1 km radius of the mangrove forest boundary were considered residents in this study. The fishermen sample of 120 was further stratified into two groups: 60 fishermen and 60 Irulars (tribal fishermen). Likewise, the 120 visitors interviewed were stratified into two groups of each 60, based on the department through which they accessed recreational services, as both the Tamil Nadu Tourism Department and the Tamil Nadu Forest Department operated boat services. Data collection was carried out over a period of two months, from February 2025 to March 2025.

The questionnaire was structured into three sections:

a) questions on respondents' background and demographic characteristics.

b) items assessing respondents' awareness of the different types of ecosystem services provided by mangroves.

c) questions evaluating respondents' perceptions of the current condition of mangroves and the factors influencing their present state.

Statistical analysis

To analyse stakeholders' awareness and perception on the significance, current status and influencing factors of the Pichavaram mangrove ecosystem, a combination of descriptive statistics and percentage analysis was conducted using Microsoft Excel. The raw responses collected through the pre-tested questionnaire were first cleaned and entered into a spreadsheet. Responses related to awareness were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to capture the degree of agreement. Categorical variables (e.g. gender and marginalized communities) and continuous variables (e.g. age, years of education, family size, etc.) were also captured to examine the socio- economic characteristics of the sample groups.

Descriptive analyses such as frequency distribution, mean scores and percentage analysis were computed to summarize responses across the three stakeholder groups: residents, fishermen and visitors. This approach helped in understanding general trends in awareness and perception while identifying areas of agreement or divergence. To present comparative awareness across stakeholder groups, Likert-scale plots were generated using Excel. These plots provided a clear idea of agreement/disagreement patterns related to different types of ecosystem benefits. This analytical framework allowed for both a comprehensive summary of stakeholder perceptions and a statistically valid interpretation of the factors influencing the status of mangroves. The insights derived from the analysis served as a foundation for evaluating the gaps in awareness and perception, thereby informing the design of targeted conservation interventions.

Table 1. General characteristics of sample respondents

S. No.	Category	Residents (N= 120)	Fishermen (N= 120)	Visitors (N= 120)
I	**Average age**	41.25	38.51	42
II	**Educational status**			
1	Illiterate	11 (9.17)	37 (30.83)	1 (0.83)
2	Primary education	24 (20.00)	26 (21.67)	6 (5.00)
3	Middle school	33 (27.50)	23 (19.17)	29 (24.17)
4	Secondary education	29 (24.17)	19 (15.83)	31 (25.83)
5	Higher secondary education	15 (12.50)	12 (10.00)	16 (13.33)
6	Graduate	8 (6.67)	3 (2.50)	37 (30.83)
III	**Average family size**	4.16	3.82	4.23
IV	**Average no. of earners**	1.88	1.68	1.13
V	**Primary occupation**			
	Fishermen	37 (30.83)	120 (100)	-
	Farm workers	9 (7.50)	-	6 (5.00)
	Non- farm workers	56 (46.67)	-	91 (75.83)
	Students	-	-	17 (14.17)
	Housewife	17 (14.17)	-	2 (1.67)
	Unemployed	1 (0.83)	-	4 (3.33)
VI	**No. of SC/ST households**	33 (27.50)	75 (62.50)	12 (10.00)
VII	**No. of landowners**	37 (30.83)	14 (11.67)	86 (71.67)
VIII	**Average farm size (ha)**	0.34	0.11	1.12
IX	**Average livestock possession (no.)**	0.82	0.43	0.14

(Figures in parentheses denotes the % to total)

Results and Discussions

Socio-economic characteristics

The socio-economic characteristics of the sample respondents, categorized into residents, fishermen and visitors, revealed notable demographic and livelihood variations among the groups (Table 1). The average age of the respondents ranged from 41.25 years among residents, to 38.51 years among fishermen and 42 years among visitors, indicating a mature respondent base across all categories. Educational attainment varied significantly: fishermen had the highest proportion of illiterate individuals (30.83 %) and the lowest graduate representation (2.50 %), whereas visitors showed the highest educational levels, with 30.83 % holding a graduate degree. Household characteristics also differed, with average family size being highest among visitors (4.23), followed by residents (4.16) and fishermen (3.82). Residents reported the highest number of earning members per household (1.88), while visitors had the least (1.13), reflecting their limited economic dependence on local livelihoods.

Primary occupation patterns revealed complete reliance on fishing among the fishermen group (100 %). In contrast, residents were engaged in fishing (30.83 %), farm activities (7.50 %) and non-farm activities (46.67 %). Most visitors were non-farm workers (75.83 %) or students (14.17 %), suggesting an indirect or recreational association with the mangroves. A marked difference was observed in social group representation, with 62.50 % of fishermen belonging to SC/ST categories, compared to 27.50 % among residents and only 10 % among visitors. Land ownership was most prevalent among visitors (71.67 %) and lowest among fishermen (11.67 %) as half of the fishermen sample comprised tribal households without any landholdings. Similarly, average farm size was highest for visitors (1.12 ha), compared to residents (0.34 ha) and fishermen (0.11 ha). Livestock possession followed a similar trend, with residents owning the most (0.82 per household) and visitors the least (0.14).

Awareness of ecosystem services

The mangrove ecosystems are known to provide diverse benefits that directly or indirectly play a major role in human well-being (21). The study assessed the sample respondents' awareness of different ecosystem services. The results presented in Fig. 2, reveal significant variation in awareness across provisioning, supporting, cultural and regulating services. Among the benefits that the respondents were aware of, provisioning services like food and fuelwood ranked the highest (22, 23). Over 70 % of fishermen and 68.34 % of residents recognized mangroves as crucial sources of food, while more than 50 % of both groups valued fuelwood, highlighting their continued dependence on mangrove biomass for domestic energy. However, services like fodder and materials for thatching or basket-making were undervalued, particularly among visitors, suggesting a decline in traditional resource use and a shift toward modern substitutes. Supporting services such as nutrient cycling were met with largely neutral responses, implying lower visibility or awareness of ecological processes.

Cultural services like bird roosting were moderately valued, with visitors showing the highest appreciation, likely due to tourism exposure and biodiversity interest. Regulating services such as carbon sequestration and climate regulation received mixed responses. While a majority of residents and visitors remained neutral regarding carbon sequestration, approximately 35 % of fishermen agreed or strongly agreed with its value, highlighting slightly greater awareness among resource-dependent groups. Shoreline protection was more widely acknowledged, especially by fishermen (59.17 %), underscoring its direct influence on coastal stability and occupational safety (24). However, the role of mangroves in mitigating climate change remained less well-known, with over 45 % of fishermen and 41.67 % of residents expressing disagreement or neutrality, reflecting the intangible and long-term nature of this service. Conversely, protection against tsunamis and cyclones was strongly recognized across all groups, particularly by visitors and fishermen, echoing global findings that communities with prior disaster exposure place higher value on such regulatory functions.

Mangroves significance, status and influencing factors

Mangroves along the coastal belt of the state have long served as a vital source of livelihood for a large section of the rural population. Hence, traditional knowledge and local customs are closely linked to these ecosystems (25). The local population has perceived the merits and demerits of mangrove destruction, either through observation or through experience. This section analyses micro-level attributes, assessments on mangrove status and factors influencing its wealth, primarily based on respondents' perception. To gather information on the perceived significance of mangrove ecosystems, direct benefits and indirect benefits were considered individually and in combination (Fig. 3).

The respondents in all three groups assigned the highest importance to combined benefits. More than 50 % of the residents and fishermen and about 48 % of the other group positively responded to this statement. Less than 15 % of the respondents perceived only direct benefits. About one third of residents and fishermen and 43 % visitors attributed more significance to indirect benefits. Among the sample respondents, residents and fishermen demonstrated greater awareness and experience regarding the indirect benefits of the mangroves, as these groups directly interact with mangroves in one way or another. Fishermen and a section of residents depend on mangroves for fish resources. Respondents in these groups have recognized the significance mangroves as a coastal shield since the Thane cyclone of 2011. In contrast, the majority of the general public had only heard or read about such indirect benefits.

Mangrove ecosystems worldwide have faced a range of biotic and abiotic stresses, contributing to their decline. Factors such as demographic changes, socio-economic developments, institutional dynamics and climatic variations have, both individually and collectively, led to the degradation of these ecosystems (26, 27). In Tamil Nadu, existing data suggests a gradual increase in mangrove cover over the years (28). However, due to the lack of detailed data at the micro level, this study aimed to evaluate stakeholder perceptions concerning this trend. The study also explored the factors responsible for fluctuations in mangrove resources. Table 2 presents the respondents' views on the current condition of mangroves. Around 45 % of them felt that mangrove resources have declined over time. About one-third of residents and fishermen, along with over half of the visitors, believed that mangroves are experiencing degradation. Although there is widespread concern about the deteriorating health of mangrove ecosystems, some stakeholders believe there has been little change at the local level. Approximately 10 % of residents and fishermen stated that the mangrove condition has remained stable over the years, whereas only 1.67 % of visitors shared this view.

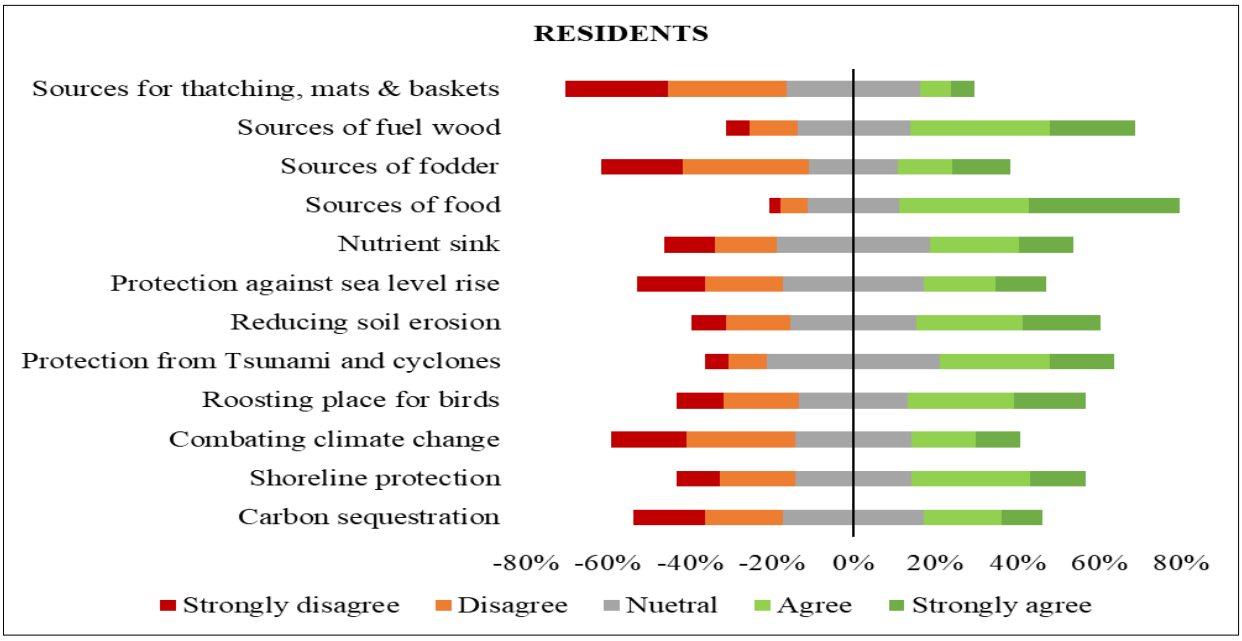

Fig. 2a. Percentage distribution of the residents in each level of awareness.

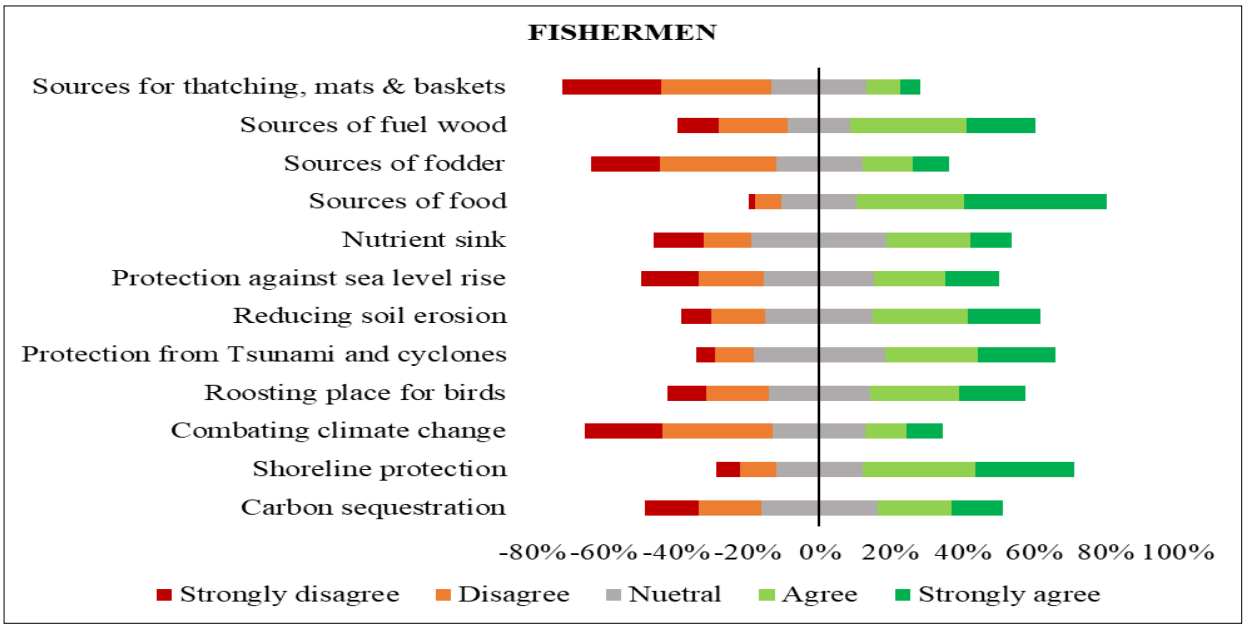

Fig. 2b. Percentage distribution of the fishermen in each level of awareness.

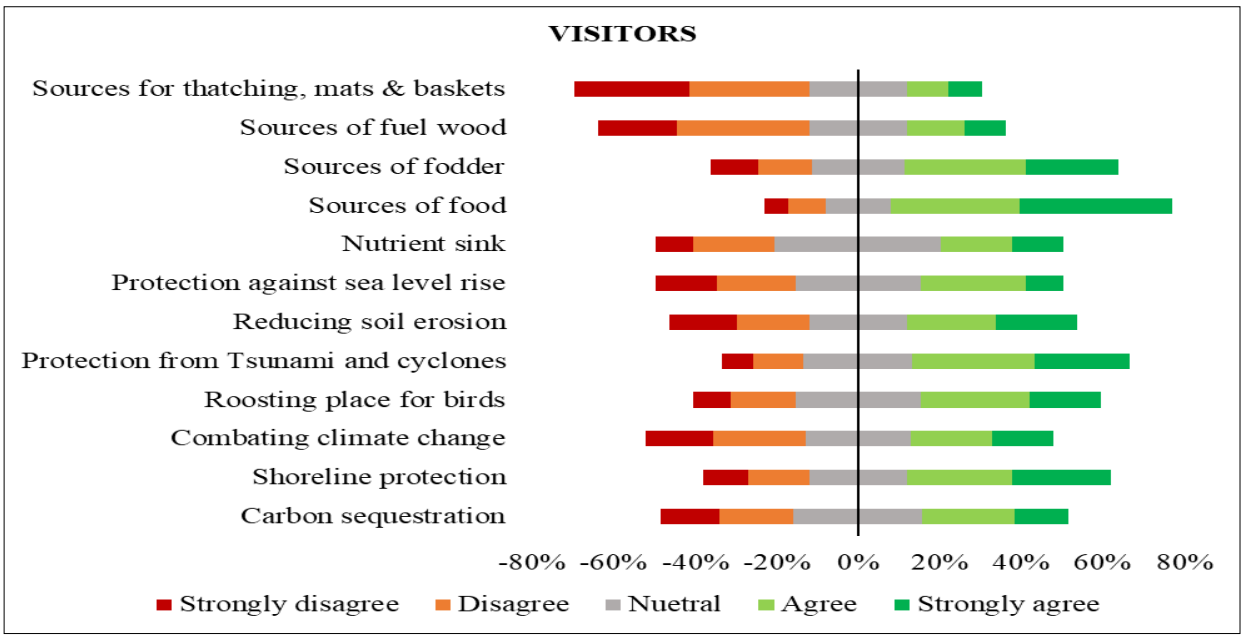

Fig. 2c. Percentage distribution of the visitors in each level of awareness.

Table 2. Perception of sample respondents about the status of mangroves

Sl. No.	Particulars	Residents	Fishermen	Visitors	Average
1.	There are destruction and degradation of mangroves	43 (35.83)	46 (38.33)	66 (55.00)	51 (42.50)
a.	Developmental activities	38	43	52	44
b.	Tourism	4	-	8	4
c.	Collection of fuel wood	1	3	6	3
2.	Maintaining status quo position	14 (11.67)	11 (9.17)	2 (1.67)	9 (7.50)
3.	Improvement in the mangrove status	56 (46.67)	63 (52.50)	30 (25.00)	50 (41.67)
a.	Government's initiative	13	33	11	19
b.	People participation	17	12	-	10
c.	Planting along borders	2	16	16	11
d.	Natural regeneration	24	2	3	10
4.	Not aware	7 (5.83)	-	22 (18.33)	10 (8.33)
	Total	120 (100)	120 (100)	120 (100)	120 (100)

(Figures in the parenthesis indicate % to total)

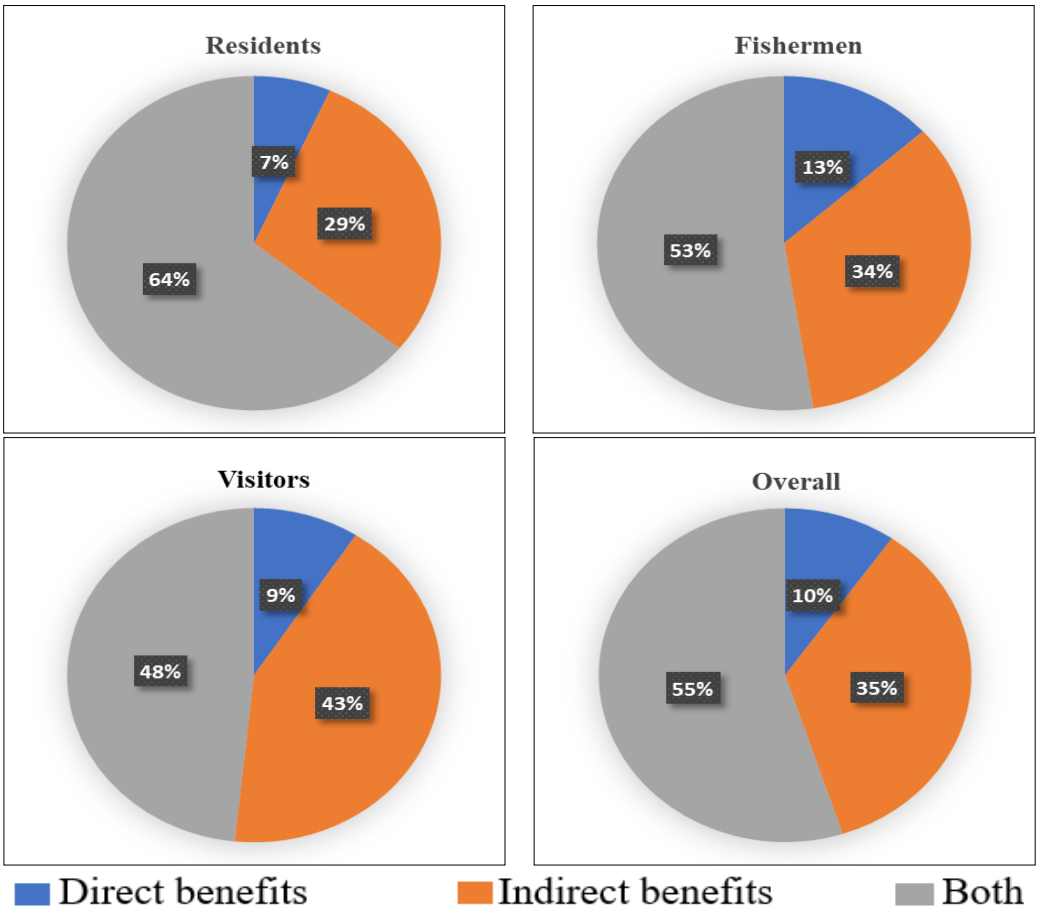

Fig. 3. Perception of sample respondents on significance of mangrove ecosystems.

About 46.67 % of residents, 52.50 % of fishermen and 25 % of visitors expressed the opinion that the mangrove area has improved over the years. Residents and fishermen acknowledge government initiative promoting mangrove conservation through community participation. Awareness programmes on the significance of mangroves have also contributed to this understanding. Since the Thane cyclone of 2011, people have become more aware of the storm-protection function of mangrove. Consequently, a larger number of people are participating in conservation drives and planting mangroves along the boundary of the homesteads to reduce soil and embankment erosion (29). Natural regeneration in the less disturbed pockets contributes to an increase in the area. On average, about 42 % of respondents perceived that mangrove area is expanding, whereas 5.83 % of residents and 18.33 % of visitors reported being unaware of its current status. Visitors' responses differed notably from those of residents and fishermen, likely because visitors tend to rely on mass media for information, where instances of environmental destruction are frequently emphasized. Among the various reasons cited for mangrove degradation, developmental activities emerged as the most significant (30). Climatic and social factors were also identified as key influences on the changing condition of mangroves.

Climate change impacts are typically gradual and public awareness of these effects remains limited. Table 3 presents the relevant responses, indicating that a majority of respondents (72.50 % to 82.50 %) were uncertain about how climate change might affect mangroves. Around 20 % believed that climate change has a negative influence. Observations included the drying of mangroves during summer months and widespread loss of mangrove seedlings due to prolonged stagnation of saltwater. Elderly respondents noted that such occurrences appear to be a recent development. Mangroves thrive on a regular alternation between fresh and saline water. However, with declining annual rainfall in recent years, the duration of freshwater availability has shortened, resulting in mangrove seedlings being exposed to saline conditions for extended periods, leading to significant mortality (31). Normally occurring

Table 3. Perception of sample respondents about the climatic impacts on mangroves

Sl. No.	Particulars	Residents	Fishermen	Visitors	Average
1.	Climatic change impact the mangrove wealth	28 (23.33)	31 (25.83)	13 (10.83)	24 (20.00)
a.	Drying of mangroves in summer	14	16	12	14
b.	Destruction of mangrove seedlings due to prolonged water stagnation	9	6	1	5
c.	a+b	5	9	-	5
2.	No impacts	-	2 (1.67)	8 (6.67)	3 (2.50)
3.	Not aware	92 (76.67)	87 (72.50)	99 (82.50)	93 (77.50)
	Total	120 (100)	120 (100)	120 (100)	120 (100)

(Figures in the parenthesis indicate % to total)

in November-December, saltwater intrusion into rivers and backwaters has recently begun as early as September, increasing risks to mangrove health. Interestingly, 2.50 % of respondents stated that there were no climatic impacts on the mangrove ecosystem.

The consequences of mangrove destruction as perceived by the respondents are presented in Table 4. On average 85 % of respondents perceived negative impacts. The proportion was the highest among residents (92.50 %), who are closely associated with mangroves in their daily lives. They associate with the main indirect benefit as protection to their life and property by preventing the furious waves and high velocity winds along with unidentified ecological services (32, 33). The fishermen group (84.17 %), associate the ecological benefits with their livelihood option (income from fishing). Meanwhile, 78.33 % of the visitors perceived that mangrove destruction might create a negative impact on the society as a whole.

Mangroves provide shelter to several avian fauna, which feed on their fruits and nest in the branches. Rare and endangered birds, including migratory birds, have been reported along the mangrove tracts. Migratory birds roost for about eight months each year. The destruction of mangroves leads to the loss of roosting locations for birds and results in a decline in the number of the winged creatures in the coastal tracts. The most significant creatures found in mangroves are otters. These animals are nearly endangered; therefore, their numbers are declining as a result of mangrove damage (34).

A total of 8.34 % of the respondents believed that the reduction of mangroves from existing levels would not cause any impact and 5.83 % were not sure about the consequences. The analysis highlights the micro-level situation; the ecosystem is under great threat of destruction and the local population is aware and concerned about the potential threats. This situation reflects the necessity for scientific conservation efforts that ensure people's participation. The necessity for micro-level area assessment and the identification of areas for conservation based on participatory approaches is underlined.

Conclusion

The study highlights the critical role of the Pichavaram mangrove ecosystem in supporting coastal livelihoods, biodiversity and climate regulation. Residents and fishermen readily recognized direct benefits like fishing and fuelwood, whereas visitors showed lower awareness of indirect services such as nutrient cycling and carbon sequestration. Perceptions of mangrove status varied: nearly half of the respondents reported signs of degradation due to development pressures, while others observed improvements, mainly due to post-cyclone conservation efforts and community involvement. Despite these positive efforts, knowledge gaps regarding the ecological impacts of climate change remain a concern, with most respondents unaware of how changes in salinity and rainfall patterns affect mangrove health. Importantly, residents and fishermen recognized the serious consequences of mangrove degradation, including coastal vulnerability, biodiversity loss and reduced livelihood options. These findings emphasize that effective mangrove conservation cannot depend solely on policies or enforcement mechanisms but must include local knowledge and participation. To address this, the study recommends the establishment of a community-based mangrove stewardship program (CBMSP) aimed at empowering local stakeholders as active participants in mangrove conservation. This program should focus on environmental education, hands-on training in ecosystem services and the creation of local eco-monitoring committees within panchayats. By recognizing and incentivizing community efforts through government schemes and partnerships, the initiative would foster a sense of ownership and responsibility. This participatory approach can bridge existing awareness gaps, strengthen ecological resilience and ensure the long-term sustainability of mangrove ecosystems like Pichavaram. It also provides a scalable model for integrated coastal zone management across similar regions globally.

Table 4. Perception of sample respondents on social impacts of mangrove destruction

Sl. No.	Particulars	Residents	Fishermen	Visitors	Average
1.	There is negative impact	111 (92.50)	101 (84.17)	94 (78.33)	102 (85.00)
a.	Affects livelihood	74	60	63	66
b.	House/ property damage	18	7	-	8
c.	Loss of employment	17	33	19	23
d.	Loss of biodiversity	2	1	12	5
2.	There is positive impact	3 (2.50)	-	-	1 (0.83)
3.	No impacts	6 (5.00)	15 (12.50)	9 (7.50)	10 (8.34)
4.	Not aware	-	4 (3.33)	17 (14.17)	7 (5.83)
	Total	120 (100)	120 (100)	120 (100)	120 (100)

(Figures in the parenthesis indicate % to total)

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Authors' contributions

HB is responsible for designing the study, data collection, data analysis and drafting the initial manuscript. SKD, SV, UK, BK and SD contributed their insights and helped in revising the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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