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Traditional knowledge of seagrass distribution and phenology in the northern Palk Bay, Tamil Nadu, India

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Original Article

Abstract

Seagrass ecosystems, throughout the world, possess one of the world's most productive zones and serve as crucial carbon sinks. The seagrass meadows harbour a vast spectrum of ecological services, including stabilisation of sediments, habitat provision and breeding and feeding grounds for a variety of organisms. Compared to coral reefs and mangroves, seagrass habitats in the northern Indian Ocean are still poorly understood, which limits our knowledge of how they contribute to biodiversity in regions like Palk Bay. Though it is challenging to monitor these submerged habitats, benchmark studies on their distribution and phenology are essential to evaluating ecosystem responses. Thus, the current study employs a community approach, using questionnaire-based surveys in fishing villages of two districts, Thanjavur and Pudukkottai, northern Palk Bay region, Tamil Nadu, India, to document traditional ecological knowledge on seagrass. Notable findings were the widespread occurrence of *Cymodocea serrulata* and frequent seasonal flowering of *Enhalus acoroides* in the study sites. The results also witnessed the correlation of increased fishery resources with higher seagrass diversity. Species-specific associations were also observed with fish like *Hemirampus* sp. and *Siganus* sp. more commonly reported in the areas with high seagrass diversity. The insights acquired during the survey regarding spatial distribution, seasonal patterns and threats from local communities aim to fill critical data gaps and contribute to sustainable management practices.

Keywords: *Palk Bay, phenology, sea grass, spatial distribution, seasonal flowering, Tamil Nadu*

Introduction

Seagrasses are unique among marine angiosperms, being the only fully submerged plants that possess rhizomes and fixed roots for anchorage and nutrient uptake (Short *et al.*, 2007). With the spectrum of coastal marine ecosystems, seagrass meadows are recognised as some of the most productive systems and serve as a significant carbon sink (Gullström *et al.*, 2002; Patro *et al.*, 2017). Studies have been conducted focusing on a wider spectrum of the sustainability of the seagrass beds to improve biodiversity in the Tamil Nadu and nationwide coastal waters (Kaladharan *et al.*, 2020; Kaladharan *et al.*, 2021; Akhand *et al.*, 2023). These habitats support a variety of array of biota, ranging from microalgae to large marine vertebrates, thereby playing a crucial role in ecosystem productivity and energy transfer through various trophic levels.

Seagrass ecosystems provide a multitude of ecological and biological functions, including nursery grounds for various juvenile organisms, refuge from predation, foraging habitats for a variety of organisms, and sediment stabilisation, which directly benefits commercial and recreational fisheries (Gullström *et al.*, 2002).

Geographically, seagrasses are distributed extensively, across shallow coastal regions in the tropics, including the northern Indian Ocean coasts of India, Sri Lanka, the Maldives and Pakistan (Patro *et al.*, 2017). Reports suggest there have been a total of 16 recorded seagrass species in the south-east region, and all of them are found in Indian waters (Kannan *et al.*, 1999). Compared to the neighbouring waters of Sri Lanka and the Maldives, where 15 and two species of seagrass were recorded respectively (De Silva and Amarasinghe, 2007; Payre *et al.*, 2012), Indian waters harbour additional species and dependent diversity. Despite growing recognition of their ecological significance, seagrass ecosystems remain

comparatively underexplored relative to the adjacent coastal systems, such as corals and mangroves (Patro *et al.*, 2017). Comprehensive ecological assessments are constrained by the lack of baseline data across many regions. Increasing interest in their study is critical, not only for ecosystem conservation, but also for the protection of associated threatened species such as the dugongs (*Dugong dugon*) and various species of sea turtles. However, participatory research efforts have demonstrated the value of local community engagement in documenting the structure, functions and cultural relevance of seagrass ecosystems (Wyllie-Echeverria and Cox, 1999; Rönnbäck *et al.*, 2007; Newmaster *et al.*, 2011).

One key process for advancing seagrass research lies in the study of phenology, the timing and cycles of biological events such as flowering, seed production, and leaf turnover. Phenological data can provide insights into responses to climate change, environmental stresses and denote the timing of seed collection for restoration purposes. Understanding temporal variations in phenology can thus enhance predictions related to ecological stress (Peirano *et al.*, 2010) and aid in the development of effective conservation strategies.

However, monitoring seagrass phenology is often hindered by logistical challenges, especially in regions with limited accessibility. In such contexts, integrating traditional ecological knowledge from local fishing communities offers a valuable alternative for acquiring baseline phenological data. This is particularly relevant to regions like the Palk Bay, where seagrass meadows contribute substantially to primary productivity.

The present study aims to document the phenology of seagrass ecosystems through participatory methods, specifically questionnaire-based surveys conducted in fishing villages along the coast of northern Palk Bay, Tamil Nadu, India. The research focuses on local ecological knowledge to assess seasonal patterns, spatial distribution and perceived threats to seagrass meadows. The findings are expected to inform the sustainable management and restoration of seagrass habitats, particularly within the Dugong Conservation Reserve.

Material and methods

Study area

The study area was along the Palk Bay coastal villages across the Thanjavur and Pudukkottai districts, which are designated as part of the Dugong Conservation Reserve (DCR) project. Sampling for the traditional mapping of seagrass was done within 21 rural fishing villages (Fig. 1). These villages were chosen as they represent DCR coastal villages closely linked to seagrass meadows and marine ecosystems (Seagrass-Watch, 2023).

Sampling methods

In each village, 2 to 3 individuals were selected to share their knowledge of seagrass ecosystems. Respondents were chosen based on their experience and regular engagement with marine habitats. Cross-confirmation of information was conducted by consulting women who clean fishing nets, providing an additional layer of validation. This selective and purposive sampling approach ensured the collection of reliable and comprehensive data.

Phenological survey

The data were collected in a series of mixed interviews of structured, semi-structured and unstructured questionnaires, gathering insights into seagrass phenology, including seasonal changes, flowering and fruiting patterns, and the impact of anthropogenic activities. To ensure specificity, visual cues (coloured photos, plants, along with their flowers and seeds of available seagrass species) were used to recall the insight memories or data during interviews to aid in species identification. Data were collected through in-person interviews conducted in the local/native language (Tamil) to ensure clarity and accuracy in responses. (Berg, 2004, Newmaster *et al.*, 2011)

Data analysis

The data collected were analysed to identify patterns in seagrass phenology, including flowering periods, seed viability duration, and approximate locations or distances of seagrass meadows from the shore. Responses were categorised and cross-referenced to ensure consistency and reliability.

Fig. 1. Study area

Comparisons were made across villages to understand regional similarities and variations in seagrass dynamics.

Participants were informed about the purpose of the study, and informed consent was obtained before interviews. Ethical considerations include ensuring the anonymity and confidentiality of the respondents, with all data used exclusively for research purposes. While the study provides valuable insights, certain limitations, such as subjective bias in traditional knowledge and weather-related accessibility challenges, were acknowledged and mitigated through cross-validation.

Results and discussion

Species distribution and richness

The survey revealed the presence of key seagrass species (Fig. 2), including *Cymodocea serrulate, Halophila ovalis, Halophila decipiens, Halodule pinifolia, Syringodium isoetifolium, Enhalus acoroides,* across the 21 villages (Fig. 3). *Cymodocea serrulata* was reported in all villages, while *Halophila* sp. were reported in 19 villages, except for Pillaiyarthidal and Velivayal. The species *C. serrulata* is widely distributed in many seagrass ecosystems, including the northern Indian Ocean and is a highly resilient species in shallow waters (Fortes *et al.*, 2018). *Halodule* species were recorded in 17 villages except Pillaiyarthidal, Manora, Velivayal, and Kollukadu in Thanjavur district, and *Enhalus acoroides* were recorded in 17 villages, except Pillaiyarthidal, Velivayal, Kollukadu (Thanjavur district) (Table 1), and Anthoniyarpuram (Pudukkottai district) (Table 2). *Syringodium isoetifolium* was recorded in 10 villages, including Pillaiyarthidal, Manora, Velivayal, Keezhathottam, Adaikkathevan and Kazhumanguda in Thanjavur district and Vadakku Ammapattinam, Alaganvayal, Kattumavadi Meenavartheru, and Mudukkuvayal in Pudukkottai district. The species was restricted to fewer locations compared to any other species, consistent with its known preference for clearer waters (Waycott *et al.*, 2004).

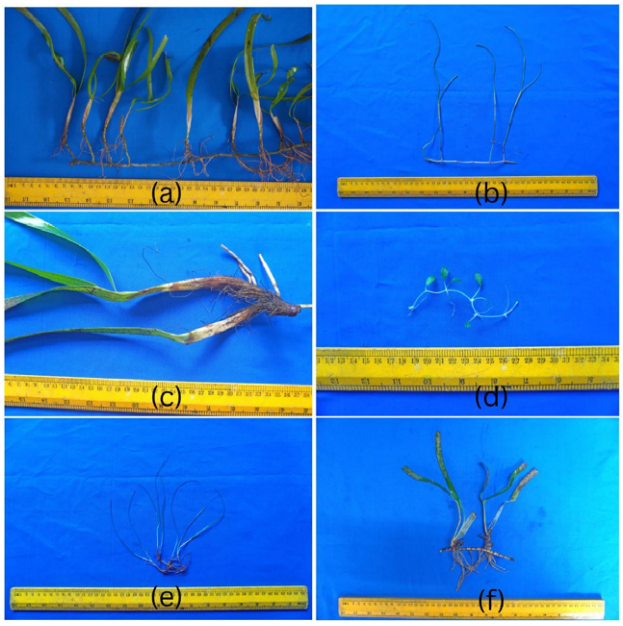

Fig 2. Key seagrass species available in the study sites (a) *Cymodocea Serrulata*; (b) *Syringodium isoetifolium*; (c) *Enhalus acoroides*; (d) *Halophila ovalis*; (e) *Halophila pinifolia*; (f) *Thalassia hemprichii*

Villages such as Keezhathottam, Adaikkathevan and Kazhumankuda exhibit high species richness, with the co-existence of all five species having been recorded. Average species richness is higher in the villages of Thanjavur district than in Pudukkottai district, which denotes the pattern of diversity. *Cymodocea sp.* It is the most commonly recorded species throughout the study, while *Syringodium sp.* remains to be in the least common section.

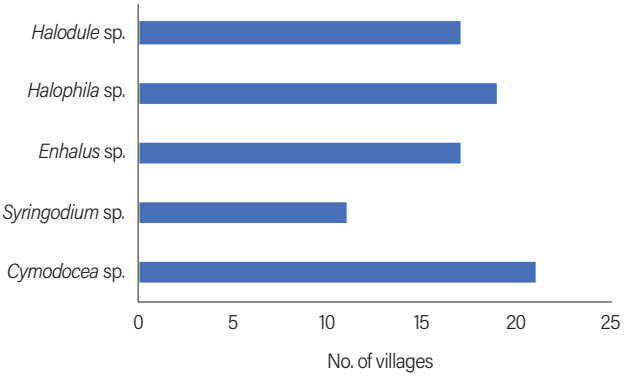

Fig 3. The number of villages where seagrass were recorded

Table 1. Villages and recorded species

No	Species	Villages reported
1	*Cymodocea* sp.	All
2	*Syringodium* sp.	Velivayal, Pillaiyarthidal, Manora, Adaikkathevan, Keezhathottam, Kazhumankuda, Vadakku Ammapattinam, Alaganvayal, Kattumavadi, Mudukkuvayal, South Pudukkudi
3	*Enhalus* sp.	All except Kollukadu, Velivayal, Anthoniyarpuram
4	*Halophila* sp.	All except in Velivayal, Pillaiyarthidal
5	*Halodule* sp.	All except in Kollukadu, Velivayal, Pillayarthidal, Manora

Table 2. Villages and recorded species

No	Species	Villages flowerings are reported
1	*Cymodocea* sp.	Adaikkathevan, Vadakku Ammapattinam, Alaganvayal, Kattumavadi, Ponnagaram, Pattangadu, Anthoniyarpuram, South Pudukkudi
2	*Syringodium* sp.	Adaikkathevan, Vadakku Ammapattinam, Alaganvayal, Kattumavadi, South Pudukkudi
3	*Enhalus* sp.	Adaikkathevan, Somanathanpattinam, Keezhathottam, Puthutheru, Vallavanpattinam, Mandhiripattinam, Kazhumankuda, Vadakku Ammapattinam, Alaganvayal, Kattumavadi, Ponnagaram, Pattangadu, Mudukkuvayal, South Pudukkudi
4	*Halophila* sp.	Vadakku Ammapattinam, Alaganvayal, Kattumavadi, Ponnagaram, Pattangadu, Anthoniyarpuram, South Pudukkudi
5	*Halodule* sp.	Vadakku Ammapattinam, Alaganvayal, Kattumavadi, Ponnagaram, Pattangadu, Anthoniyarpuram, South Pudukkudi

Flowering report

The acquired seagrass flowering records remained sparse in the villages of Thanjavur district, with most villages reporting no flowering activity across any of the species. The residents of Adaikkathevan village reported flowering of three species, *Cymodocea* sp., *Syringodium* sp., and *Enhalus* sp., standing out from six other villages, where recorded exclusively with *Enhalus* sp. In Pudukkottai, villages such as Vadakku Ammapattinam, Alaganvayal, Kattumavadi and South Pudukkudi reported flowering of all five surveyed genera. Other villages, including Ponnagaram and Pattangadu, reported flowering in four of five species except *Syringodium isoetifolium*. A few villages, including Keelakkudiyiruppu, reported no flowerings, while the residents of Mudukkuvayal reported only one flowering pattern in *Enhalus* sp.

Enhalus acoroides, remains the prominently reported flowering species, with 13 out of 22 villages reporting its occurrence (Fig. 4). This was followed by *Cymodocea* sp., which was

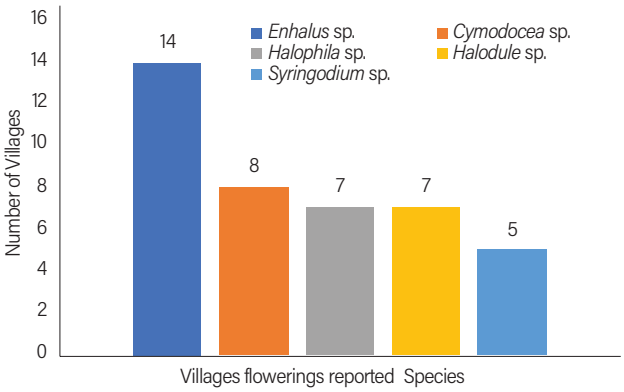

Fig 4. Number of villages with flowering reports of each species

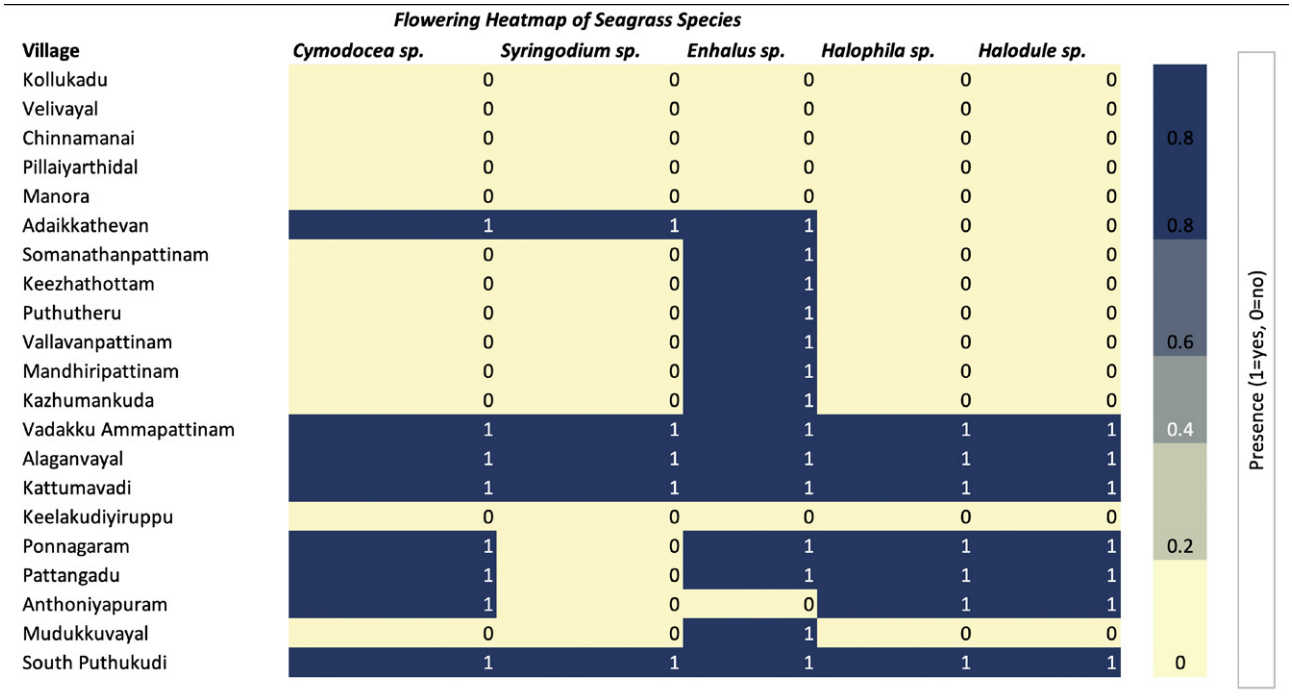

Fig 5. Village-wise occurrence of flowering of each species

reported in nine villages. Flowering in both *Halophila* sp. and *Halodule* sp., reported in seven villages. Flowering of all five surveyed species recorded higher counts in Pudukkottai than in Thanjavur (Fig. 5).

Seed observation cycles and interaction with fishing gears

In Thanjavur, most villages, including Kollukkadu, Velivayal, Chinnamanai, Pillaiyarthidal and Manora, reported no seagrass flowering patterns, no observed seeds and no incidents of seeds attaching to the fishing gears (Table 3). According to the residents of Adaikkathevan village, flowering lasts more than four weeks, with seeds observed (Fig. 6) within 10 and 20m distance from the shore. Fishers frequently reported seeds attached to their gears, with occurrences exceeding five times in a quarter (Table 4). Vallavanpattinam recorded an extended flowering period exceeding four weeks and frequent seed gear

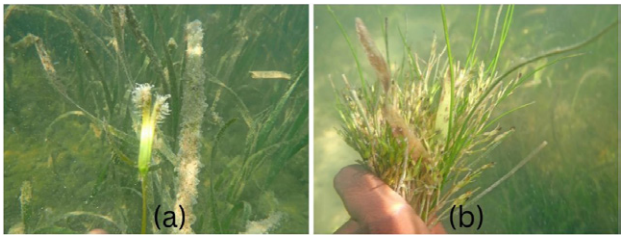

Fig 6. Observed flowers and seeds of two seagrass species (a) Flower of *E. acoroides*; (b) Seeds of *S. isoetifolium*

interactions, similar to Adaikkathevan. Similarly, villages including Somanathanpattinam, Keezhathottam, Puthutheru, Vallavanpattinam, Mandhiripattinam and Kazhumankuda reported varying degrees of flowering and seed disposal. Somanathanpattinam and Keezhathottam noted a short flowering period of less than one week, but seeds were found at distances up to 1000m from the shoreline, with frequent entanglements in the gear. The residents of villages Puthutheru, Mandhiripattinam and Kazhumankuda stated

Table 3. Data record of the seed cycle and interaction with fishing gears

No	Village	Flowering period	Distance from where the seeds occurred	Seeds attached to fishing gear	Frequency	Number of times in a quarter
1	Kollukadu	No	No	No	NIL	NIL
2	Velivayal	No	No	No	NIL	NIL
3	Chinnamanai	No	No	No	NIL	NIL
4	Pillaiyarthidal	No	No	No	NIL	NIL
5	Manora	No	No	No	NIL	NIL
6	Adaikkathevan	>4 weeks	10 to 20m	Yes	Frequently	>5 times
7	Somanathanpattinam	<1 week	50 to 100m	Yes	Frequently	>5 times
8	Keezhathottam	<1 week	500 to 1000m	Yes	Frequently	>5 times
9	Puthutheru	<1 week	within 100m	Yes	Occasionally	3 to 5 times
10	Vallavanpattinam	>4 weeks	50 to 100m	Yes	Frequently	>5 times
11	Mandhiripattinam	<1 week	within 100m	Yes	Occasionally	3 to 5 times
12	Kazhumankuda	<1 week	Within 300m	Yes	Occasionally	3 to 5 times
13	Vadakku Ammapattinam	>4 weeks	within 100m	No		
14	Alaganvayal	2 to 4 weeks	500 to 1000m	Yes	Rarely	1 to 2 times
15	Kattumavadi	>4 weeks	within 100m	Yes	Frequently	>5 times
16	Keelakudiyiruppu	No	No	Yes	Occasionally	3 to 5 times
17	Ponnagaram	<1 week	2000 to 4000m	Yes	Frequently	>5 times
18	Pattangadu	<1 week	within 100m	Yes	Rarely	1 to 2 times
19	Anthoniyarpuram	>4 weeks	within 100m	No	Rarely	1 to 2 times
20	Mudukkuvayal	>4 weeks	within 50m	Yes	Rarely	1 to 2 times
21	South Pudukkudi	<1 week	within 50m	Yes	Rarely	1 to 2 times

Table 4. Flowering seasons of dominant seagrass species

No.	Species	Flowering season
1	*Enhalus acoroides*	Vaadai season (November-April)
2	*Cymodocea serrulata*	Vaadai season (November-April)
3	*Syringodium isoetifolium*	Sola season (May-October)

occasional seed attachment to the fishing gears, with reported incidents ranging between three to five times per quarter.

In Pudukkottai, the pattern of flowering and seed dispersal showed notable diversity. The residents of Vadakku Ammapattinam reported flowering lasting more than four weeks, but no seeds were observed attached to the fishing gears. Alaganvayal reported with flowerings spanning two to four weeks, with seeds found between 500 to 1000 metres from shore, though gear attachment was rare, occurring once or twice per quarter. Kattumavadi was reported with prolonged flowering beyond four weeks and frequent seed attachments to the fishing gears, reported more than five times in a quarter. Keelakudiyiruppu, although reporting no flowering, still noted occasional seed entanglements. Ponnagaram exhibited a unique pattern where seeds were found at considerable distances, between 2000 m to 4000 m from shore, with frequent incidents of seeds entangled in fishing gears despite the short flowering duration of less than a week. Villages such as Pattangadu, Anthoniyarpuram, Mudukkuvayal and South Pudukkudi showed limited flowering durations with seeds often found within 50 to 100m from the shore, and seed entanglement events were occurring once or twice in a quarter. Extended flowering durations and frequent seed entanglement in fishing gears in the studied villages suggest the potential of natural seed disposal and expansion of meadows along with the reproductive vigour (McMahon *et al*., 2014). While seed observations can be considered as a passive monitoring technique (Unsworth *et al*., 2018), it also states the necessity to manage the localised fishing habits on interacting with seeds and dispersal pathways.

Seasonality of flowering

Most fishermen observed *Enhalus acoroides* flowers and seeds between October and December (Vaadai season). This corroborates the previous studies, which report seasonal flowerings influenced by monsoonal cycles and photoperiod changes (Tongkok *et al*., 2020). The frequency of observations varied, with 5 villages reporting rare occurrences (1–2 times per quarter), 10 villages observing occasional sightings (3–5 times per quarter), and 6 villages reporting frequent observations (more than 5 times per quarter).

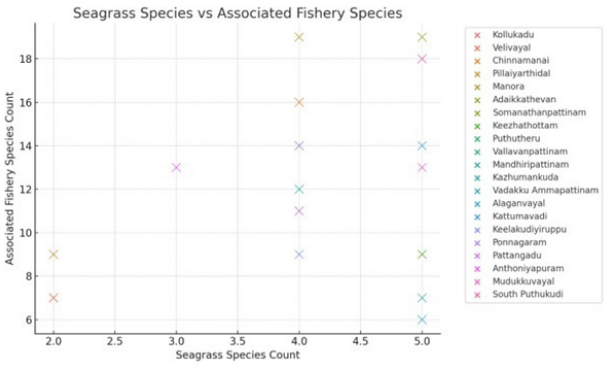

Fig. 7. Seagrass and associated fishery species

Associated fishery resources

The survey revealed that the diversity of fishery resources increased with the increase in the number of seagrass groups per village (Fig. 7). Villages with higher seagrass richness, particularly those with five genera, such as Adaikkathevan, Kazhumankuda, Kattumavadi, and South Pudukkudi, show the most diverse fishery assemblages. These locations were recorded with a variety of economically and ecologically important fishes, including *Lates* sp. (Barramundi), *Nemipterus* sp., *Rastrelliger sp.* (Mackerels), *Siganus* sp. (Rabbitfish), *Sphyraena* sp. (Barracuda), *Gerres* sp. (Mojarra) (Azeez *et al*., 2016). The positive correlation between the seagrass species richness and associated fishery resources supports that the structurally diverse seagrass habitats support associated biodiversity (Duffy *et al*., 2015; Nordlund *et al*., 2016). In the same way, Adaikkathevan and Manora hold the highest fishery diversity with 19 genera (Table 5), also recorded with

Table 5. Villages with both high seagrass and fish species richness

No.	Villages	Sea grass species	Fish species
1	Manora	4	19
2	Adaikkathevan	5	19
3	Kazhumankuda	5	18
4	South Pudukkudi	5	18

the highest numbers of seagrass species. Some villages, including Manora and Chinnamanai, despite being reported with four species of seagrass, recorded high fish diversity. Some villages, including Kollukadu, Velivayal and Pillayarthidal, recorded only two seagrass species, also recorded with a few fishery diversity.

Crustacean diversity, including *Scylla serrata* (Mud crab), *Portunus pelagicus* (Blue swimming crab), and *Portunus sanguinolentus* (Three-spotted crab) was consistently

recorded in many villages, even where seagrass diversity is moderate. Molluscs' representations, including *Loligo* sp. (Squids), *Sepia* sp. (Cuttlefish) and *Octopus sp.*, were recorded across almost all the surveyed villages.

Conclusion

The survey documented the distribution and phenology of seagrasses in Thanjavur and Pudukkottai, with widespread reports of *Cymodocea serrulata* and notable flowering of *Enhalus acoroides* during the Vaadai season (October–December). Fishery resources were generally higher in areas with greater seagrass genus diversity, as seen in villages such as Adaikkathevan, Manora, Kattumavadi and Kazhumankuda, though exceptions indicate the role of factors like habitat connectivity and water quality. Species such as *Hemiramphus* sp. and *Siganus* sp. showed stronger associations with high-diversity seagrass zones, reflecting species-specific habitat preferences. Future work should emphasize direct field validation, particularly in biodiversity-rich villages, and combine community observations with scientific assessment to build a robust phenological map and strengthen conservation and restoration strategies.

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Author contributions

Conceptualisation: BV; Methodology: SSA, ONFJ, AC, MG; Data Collection: SSA, BV; Data Analysis: SSA; Writing Original Draft: SSA; Writing Review and Editing: UU, BV, PA Supervision: BV

Data availability

The data are available and can be requested from the corresponding author

Conflict of interest

The authors declared that they have no conflict of interest

Ethical statement

Participants were briefed about the study objectives, and informed consent was obtained before interviews. Anonymity and confidentiality of the respondents were maintained, and their insights were used solely for research purposes.

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Publisher's note

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