



Aggregation of *Acromitus flagellatus* in a Tropical Tidal Creek: First Record From Gopalpur Creek, India

Suchismita Srichandan¹ · Baisakhi Pattnaik¹ · Sumit Kumar Mohanty¹ · Susmita Raulo² · Sanjiba Kumar Baliarsingh²

Received: 10 February 2026 / Revised: 27 July 2026 / Accepted: 25 September 2026
© The Author(s), under exclusive licence to Springer Nature Switzerland AG 2026

Abstract

Estuarine ecosystems, particularly those located near urbanized coasts, are increasingly affected by eutrophication, pollution, and hydrological alterations, creating favourable conditions for opportunistic species such as jellyfish. The present study reports, for the first time, the occurrence and ecological characteristics of an *Acromitus flagellatus* aggregation in Gopalpur Creek along the Odisha coast, India, during August 2024. Hydrographic and biological parameters were measured at two stations (S1 and S2) to assess environmental variability associated with the aggregation event. Salinity ranged between 9.1 and 10.1, and temperature varied from 29.9 to 30.8 °C. Marked differences were recorded between stations in turbidity (0.9 to 10.2 NTU), dissolved oxygen (0.48 to 6.9 mg/L), and total chlorophyll-*a* (5.8 to 11.1 µg/L), with near-hypoxic conditions (0.48 to 1.29 mg/L) confined to the inner station (S1). The aggregation, comprising a visually estimated density of approximately two individuals per square meter of water surface, was recorded only during low tide, coinciding with higher turbidity and elevated chlorophyll-*a* levels dominated by pico- and nanophytoplankton. The zooplankton samples contained rotifers, especially *Brachionus*, together with copepods, taxa that are associated with nutrient-rich and low-oxygen conditions. The occurrence of *A. flagellatus* under low salinity and hypoxic conditions contrasts with earlier reports from Indian estuaries and may indicate ecological plasticity and tolerance, although these physiological traits were not directly assessed in the present study. These findings provide critical baseline information on the ecology of gelatinous zooplankton in Gopalpur Creek, underscoring the need for continued monitoring of anthropogenic and climatic influences that may drive jellyfish proliferation in tropical estuarine systems.

Keywords Jellyfish · Anthropogenic influence · Bay of Bengal · Water quality · Hypoxia

Introduction

Estuaries are characterized by high productivity and complex, dynamic ecosystems. However, the water quality and ecological integrity of estuarine systems, particularly those in urbanized areas, are significantly compromised by rapid population growth and uncontrolled coastal development worldwide (Kennish 2019). Activities such as nutrient overloading from agricultural runoff, organic matter from

industrial effluents, pathogens from domestic sewage, and heavy metal accumulation have profoundly impacted biotic communities and jeopardized ecosystem health (Padhiary and Kumar 2024; Baliarsingh et al. 2010). In contrast to many marine invertebrates, jellyfish exhibit a wide tolerance to environmental fluctuations caused by anthropogenic activities and display synanthropic behaviour (Richardson et al. 2009). This resilience is attributed to their dual-phase mode of life, which allows them to alternate between a benthic (bottom-dwelling polyp) and a pelagic (open-water medusa) existence, and can even synchronize their reproductive cycles with seasonal shifts in environmental variables, such as temperature and salinity (Miglietta et al. 2008). Jellyfish with high tolerance to environmental fluctuations can take advantage of ecological imbalances and proliferate into swarms in warm, high-salinity, turbid, and eutrophic waters (Purcell 2012). Although jellyfish aggregation is a natural feature of marine ecosystems, it has been

✉ Suchismita Srichandan
suchismita.sima@gmail.com

¹ Department of Marine Sciences, Berhampur University,
Bhanja Bihar 760007, India

² Indian National Centre for Ocean Information Services,
Ministry of Earth Sciences, Govt. of India,
Hyderabad 500090, India

increasingly reported along the east coast of India (western Bay of Bengal), including the Odisha coast, in recent decades (Sahu and Panigrahy 2013; Baliarsingh et al. 2016; Barik et al. 2025). These gelatinous organisms, being opportunistic feeders, prey upon zooplankton and ichthyoplankton, thereby disrupting the pelagic food web and competing with fish larvae for common food resources (Bilio and Niermann 2004). The Gopalpur Creek, located in southern Odisha (Fig. 1), is characterized by a dynamic estuarine environment that supports rich biodiversity and sustains local fisheries and aquaculture activities. In recent years, increased coastal development, the expansion of shrimp farms, and the discharge of nutrient-rich effluents into the creek have made the system more susceptible to opportunistic species.

Despite the potential ecological and economic implications, studies focusing on the occurrence, composition, and ecological drivers of jellyfish in Gopalpur coastal and creek waters are limited. While previous research along the Gopalpur Creek has addressed plankton (phytoplankton and zooplankton) dynamics, fishery patterns, and water quality (Baliarsingh et al. 2013; Sahu et al. 2013; Sial et al. 2019), systematic investigations on jellyfish, particularly Scyphozoa, remain scarce. This knowledge gap is particularly significant, given that jellyfish serve as important indicators of ecosystem health and anthropogenic stress in tropical estuaries (Samarweera and Dissanayake 2025; Doyle et al. 2013). The present study documents the first report of *Acromitus flagellatus* aggregation in Gopalpur Creek, a significant finding that extends the known distributional range and temporal occurrence patterns of this species in Indian waters. This documentation is accompanied by a

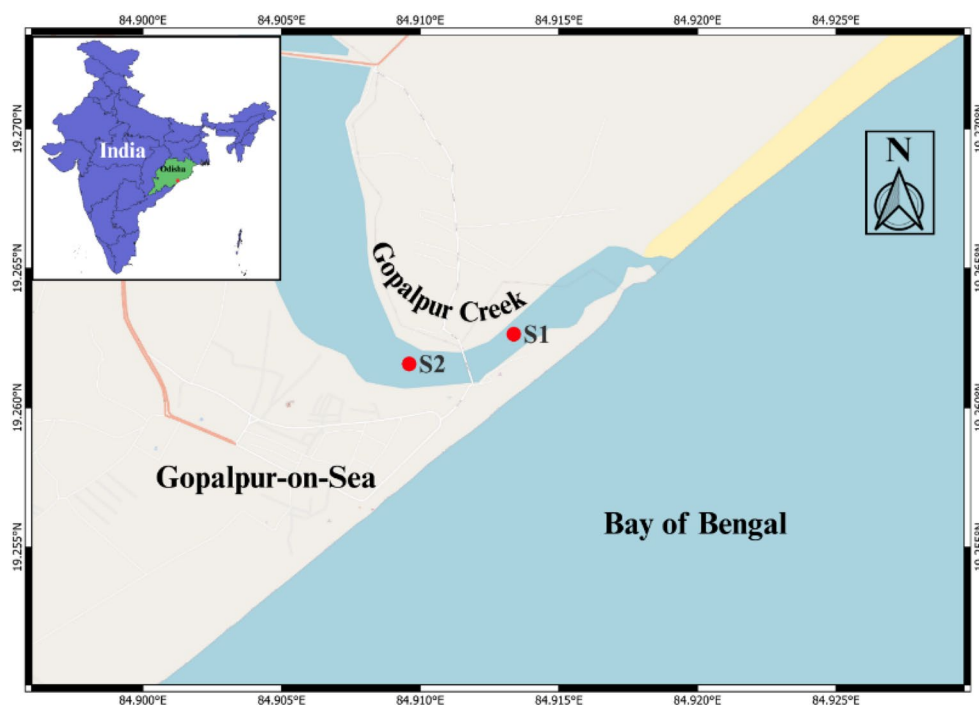
comprehensive assessment of the environmental and biological parameters that may influence distribution patterns, thereby justifying the emphasis on this first record and its ecological implications. This baseline information is crucial for understanding the ecological responses of the creek ecosystem to anthropogenic pressures and for developing management strategies to mitigate the impacts of future jellyfish swarming events.

Materials and Methods

Study Area

Gopalpur Creek is a dynamic, semi-enclosed estuarine system located along the southern Odisha coast of the Bay of Bengal (Fig. 1). The creek originates from a network of small drainage channels that collect runoff from the hinterland and discharge into the Bay near Gopalpur-on-Sea (Baliarsingh et al. 2013). The region experiences a tropical monsoonal climate, characterized by heavy rainfall from June to September, moderate temperatures from October to February, and elevated sea surface temperatures during the pre-monsoon (March to May) months. Hydrologically, the system is shaped by tidal exchange and monsoon-driven freshwater inflow, resulting in pronounced seasonal variations in salinity, turbidity, and nutrient concentrations (Khadanga et al. 2025a; b). The creek has a mean depth of approximately 1.2 m, increasing to 1.5 to 2.0 m during the monsoon season. Its bar-built mouth frequently closes from June to September due to sediment deposition and littoral

Fig. 1 Location of the study area showing Gopalpur Creek and the sampling stations (S1 and S2) along the eastern Indian coast



drift, reopening manually around October or November to restore tidal exchange. This cyclic closure-opening process creates two distinct hydrographic regimes: a closed phase characterized by restricted seawater exchange, elevated nutrient and organic matter loads, reduced dissolved oxygen, and lower pH; and an open phase marked by enhanced tidal mixing, higher salinity, and improved water quality. The substrate is predominantly muddy-sandy, supporting diverse benthic and planktonic communities, and the area serves as a nursery ground for finfish, shellfish, and other invertebrates (Sahu et al. 2013).

Ecologically, Gopalpur Creek sustains seagrass meadows and oyster beds, functioning as a critical blue carbon ecosystem. However, ecological integrity is increasingly threatened by anthropogenic pressures, including aquaculture effluents, agricultural runoff, and the expansion of industrial activities near Gopalpur Port and the proposed industrial park. These stressors contribute to nutrient enrichment, eutrophication, hypoxia, and acidification, making the system a sensitive indicator of coastal environmental change. Earlier work in this creek has documented external nutrient inputs from surrounding hatcheries and elevated organic and suspended loads (Baliarsingh et al. 2013; Khadanga et al. 2025b), providing context for the eutrophic conditions inferred in the present study. Overall, Gopalpur Creek exemplifies a monsoon-influenced tropical estuary, providing valuable insights into the interactions between hydrology, nutrient dynamics, carbonate chemistry, and habitat conservation along the Indian east coast.

Methodology

A field survey was conducted on August 8, 2024, at Gopalpur Creek to investigate the conducive conditions for jellyfish aggregation. Two sampling stations were studied in the creek: S1 and S2 (Fig. 1). The present observation was opportunistic, made during a routine rapid survey of tidal biogeochemistry; the two stations were positioned to capture the inner/upstream (S1) to lower/near-mouth (S2) gradient of the creek, which also represents the principal salinity and water-quality gradient of the system. The restricted number of stations limits spatial inference and is acknowledged as a constraint of this short-term documentation; broader spatial coverage, including additional upstream and near-coastal stations, is recommended for future surveys. Physical parameters of water were measured using a CTD (Conductivity-Temperature-Depth) profiler (make: Sea-Bird Scientific, model: SBE 19Plus V2). The CTD measures conductivity, temperature, and pressure with high accuracy and resolution. Turbidity is measured simultaneously by detecting the scattered light.

To measure various chemical and biological parameters of surface water, samples were collected using a Niskin sampler at both high tide and low tide, capturing tidal variability. The Dissolved Oxygen (DO) samples were fixed immediately using Winkler's reagents, and the analysis was performed by Winkler's titration method as described by Grasshoff et al. (1999). The Total Suspended Matter (TSM) concentration was measured by filtering 1 L of water through pre-weighed 0.45 μm membrane filter paper and reweighing after oven drying (Strickland and Parsons 1972). The phytoplankton biomass in terms of total chlorophyll-*a* (chl-*a*) was measured by filtration of a known volume of water sample through glass fibre filter paper following the spectrophotometric method (Strickland and Parsons 1972). The phytoplankton size class in terms of chl-*a* concentration was measured through sequential filtration of the water sample through different pore size filter papers (20 μm for micro, 2 μm for nano, and 0.2 μm for picophytoplankton), following the analysis using the spectrophotometric method. For the taxonomic analysis of phytoplankton, 1 L of the water sample was fixed with Lugol's iodine-formalin solution. To assess phytoplankton abundance, a compound light microscope (make: Labomed, model: Lx400) was used, following standard identification keys (Tomas 1997).

Jellyfish individuals were observed floating within the water column. Abundance was estimated semi-quantitatively through direct visual (eye-count) observations of medusae aggregating at and immediately below the water surface, an approach commonly applied to surface-aggregating gelatinous zooplankton that cannot be sampled with fixed substrate plots (Houghton et al. 2006; Baliarsingh et al. 2015; Padate et al. 2020; Ramesh et al. 2021). At each observation point along the S1–S2 stretch of the creek during low tide, when individuals were most abundant and surface visibility was greatest, all clearly visible medusae were counted within a visually delineated 1 m^2 area of the water surface. Counts were made at ten independent observation points distributed along the creek, covering an estimated total water-surface area of approximately 10 m^2 . Density was then expressed as the mean number of individuals per square metre of water surface (ind. m^{-2}). Because counts were obtained by direct visual observation within visually delineated areas rather than by enumeration of physically sampled volumes, the reported values should be regarded as semi-quantitative visual estimates rather than precise density measurements. This approach detects only those individuals present at or immediately below the water surface; medusae distributed deeper in the water column would not have been registered, and detectability therefore varies with water depth and tidal stage. Jellyfish specimens were collected manually during field observations (Fig. 2a), and morphometric measurements, including bell diameter, oral

arm length, and body features, were recorded (Fig. 2b). Specimens were photographed in vivo and preserved in 5% formaldehyde for detailed taxonomic examination following standard protocols for scyphozoan identification (Kramp 1961; Gershwin 2006).

Zooplankton was collected by duplicate horizontal surface hauls per station using the flow-meter-equipped net (120 μm nylon mesh plankton net); the volume of water filtered was computed from flow-meter revolutions and net-mouth area. Subsequently, samples were preserved with 5% formaldehyde, and in the laboratory, taxa were identified and expressed on a relative (qualitative) basis. Quantitative

cells L^{-1} or individual-density enumeration was not undertaken during this rapid opportunistic assessment.

Results and Discussion

Field Observations and Jellyfish Occurrence

During a routine field observation in Gopalpur Creek in August 2024, an unusual aggregation of jellyfish was recorded, marking one of the few documented aggregation events in this tropical estuarine environment. The aggregation consisted predominantly of *Acromitus flagellatus*

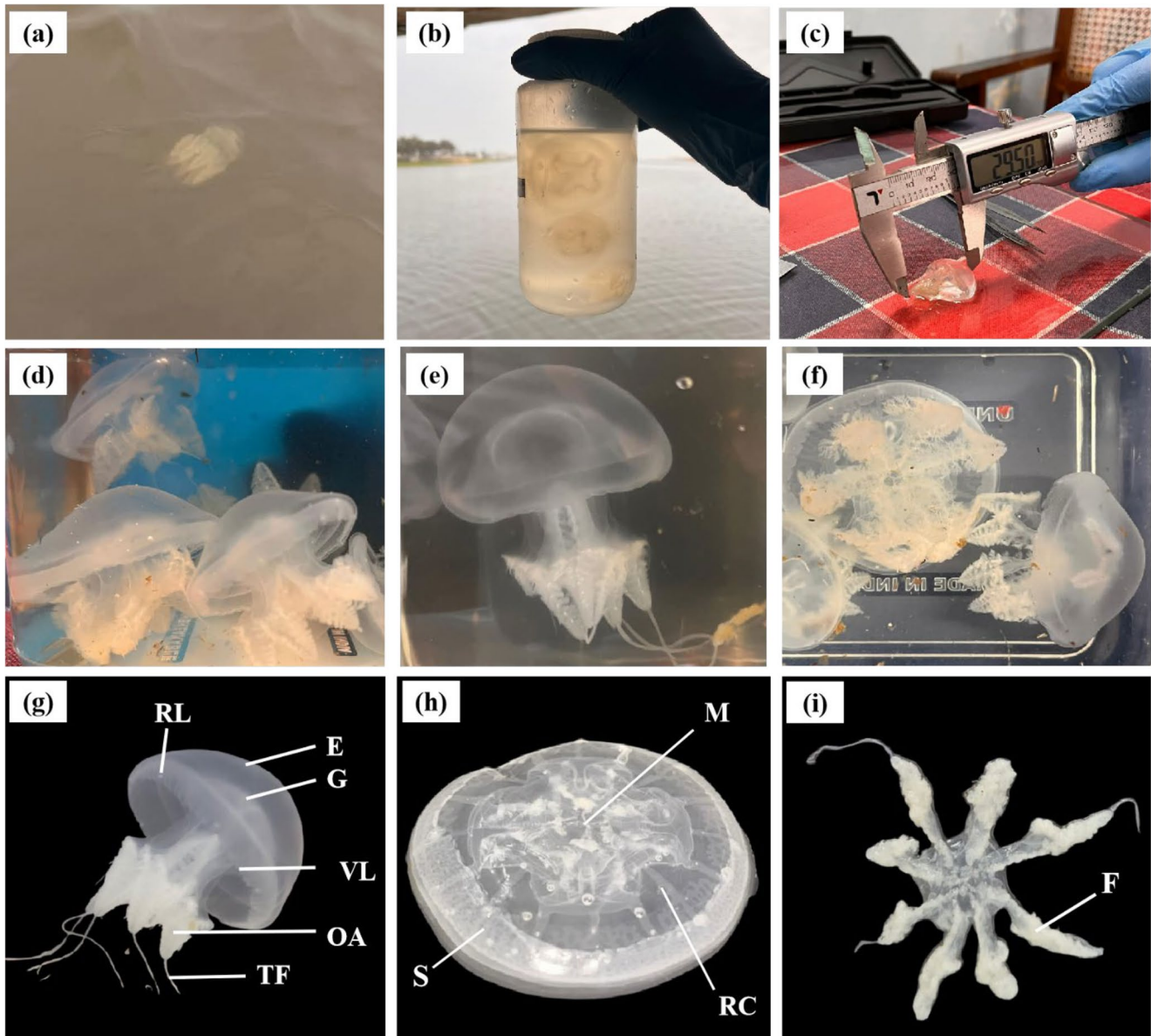


Fig. 2 (a) *Acromitus flagellatus* observed in the Gopalpur Creek; (b) On-site collection; (c) Body length measurement; (d) Whole medusa of *A. flagellatus*; (e) lateral view; (f) oral and aboral view; (g) Lateral

view, E- exumbrella, VL- velar lappet, RL- rhopalar lappet, OA- oral arm, TF- terminal filament, G- gonad; (h) Ventral view, RC- radial canal, S- subumbrella, M- manubrium; (i) F- filaments on oral arms

(Fig. 2c), confirmed through morphological and taxonomic identification following standard zooplankton protocols. The individuals were observed forming dense, sporadic patches across the upper and lower reaches of the creek, with many adhering to the banks, while stranded and decomposing specimens were found along the intertidal sands.

Field observations revealed highly variable swarm densities, with individuals forming dense, pulsating clusters in the mid and lower reaches of the creek, particularly near seagrass patches and semi-enclosed embayments, where water movement was minimal. Several medusae were observed entangled among filamentous algae and floating debris, suggesting that aggregation may have been facilitated by weak current regimes and high organic loads. Similar accumulation patterns have been documented in other tropical estuarine systems where hydrodynamic retention zones promote jellyfish congregation (Vandendriessche 2007). In the upstream section, a smaller number of jellyfish were observed drifting passively in turbid waters, while the downstream zone near the creek mouth showed evidence of strandings and carcass accumulation along the intertidal sands. Many individuals adhered to the muddy banks, their tentacles extended and motionless, which may indicate stress or senescence, although physiological condition was not assessed. Surface films of mucus and fragmented tissues were noted during late-afternoon surveys, coinciding with higher temperature and reduced tidal exchange. These combined visual and environmental indicators suggest that the aggregation represented a transient swarming event, consistent with the ephemeral nature of scyphozoan aggregations in dynamic estuarine environments.

Morphological Characteristics and Taxonomic Identification

The detailed morphological examination of collected specimens (Fig. 2d) confirmed the identification as *A. flagellatus*. The species is taxonomically identified within its genus by a specific set of morphological traits. The bell-shaped medusae exhibited hemispherical morphology with a central thickening and a thinner margin (Fig. 2e). Specimens possessed eight oral arms (Fig. 2f), pyramidal in shape, approximately 1 to 2 times the body diameter, with distinctive whip-like terminal appendages, and four horse-shoe-shaped gonads (Fig. 2g) positioned interradially. The exumbrella was smooth in most specimens, though some exhibited brown-pigmented spots. The bell-shaped medusae were predominantly transparent to pale bluish-grey in colouration.

Eight rhopalia were clearly visible around the bell margin, each bordered by two-pointed, triangular-shaped lappets (Fig. 2g). Eight velar lappets were present per octant,

noticeably shorter than rhopalial lappets. The species is further characterized by sixteen radial canals, comprising eight rhopalar and eight interrhopalar canals that extend from the gastric cavity to a ring canal positioned one-third of the radius inward from the edge, eventually transitioning into a richly branched, anastomosing canal system that forms a fine network at the umbrella margin. Four interradial spaces between the arm-disc pillars were observed in the subumbrellar view (Fig. 2h). The manubrium and filaments on the oral arms were well-developed (Fig. 2i). These morphological characteristics are consistent with previous descriptions of *A. flagellatus* from Indian waters and Southeast Asian estuaries (Siddique et al. 2022a; Kitamura and Omori 2010).

Tidal Variation in Environmental Parameters

Distinct tidal variations were observed at the sampling stations (Fig. 3). The hydrographic parameters exhibited noticeable changes between high tide (H) and low tide (L), reflecting the dynamic nature of this creek system. Water temperature showed marginal (29.9 to 30.8 °C) variation between the stations and tides. Salinity patterns showed nearly identical values, ranging from 9.1 (L) to 10.1 (H), with both stations showing higher salinity during high tide, likely due to reduced freshwater dilution and marine water influence during ebb conditions.

Turbidity measurements showed contrasting patterns between stations. S1 exhibited higher turbidity during high tide (1.8 NTU), which decreased to 0.9 NTU during low tide, whereas S2 demonstrated the opposite trend, with turbidity increasing from 6.3 NTU (H) to 10.2 NTU (L). This inverse relationship suggests that different sediment dynamics operate at the two locations, with S2 experiencing stronger tidal resuspension during ebb flow. TSM concentrations displayed similar contrasting patterns: at S1, TSM increased marginally from 52 mg/L (H) to 54 mg/L (L), while at S2, TSM increased from 23 mg/L (H) to 46 mg/L (L). Although turbidity generally increases with TSM, the relationship was not uniform across stations. At S2, turbidity and TSM increased concurrently during low tide, consistent with tidal resuspension of fine sediment. At S1, the two measures diverged; this most likely reflects the fact that nephelometric turbidity and gravimetric TSM respond differently to changes in particle size, shape, and organic-versus-mineral composition, such that finer or more organic particles can elevate the gravimetric load with comparatively little increase in light scattering (Bright et al. 2018, 2020). The overall elevated concentration of TSM during the study period (August) could be attributed to the suspended load brought through monsoon-driven riverine/terrestrial influx (Srichandan et al. 2019). Furthermore, earlier studies from Gopalpur Creek have also observed higher TSM due to a

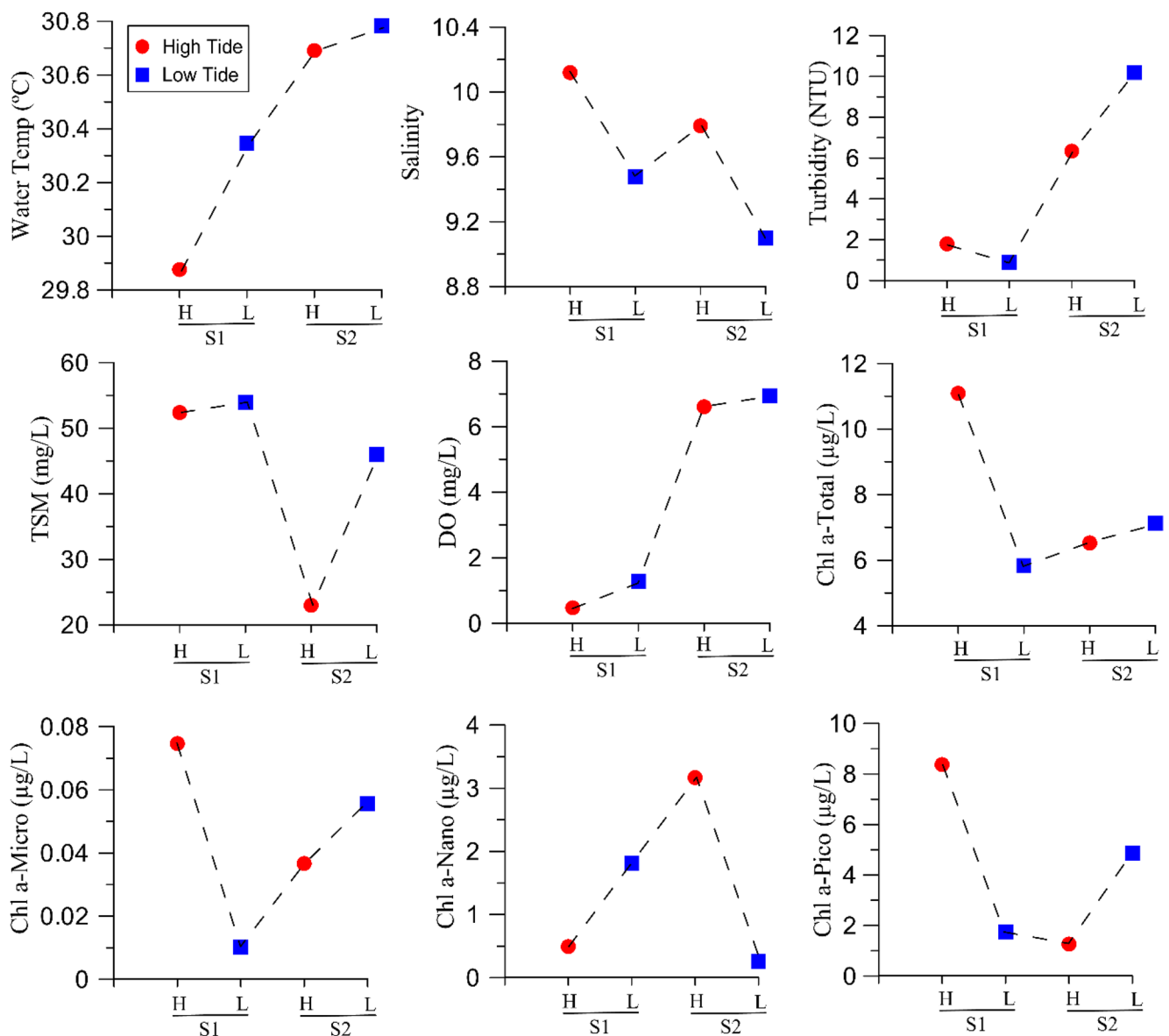


Fig. 3 Tidal variation of major biogeochemical parameters in Gopalpur Creek. Variations in water temperature, salinity, turbidity, Total Suspended Matter (TSM), Dissolved Oxygen (DO), Chlorophyll-a

(Chl-a; total, micro-, nano-, and pico-fractions) are shown during high tide (H) and low tide (L)

high anthropogenic load from upstream and discharge of surrounding industrial and hatchery wastewater (Khadanga et al. 2025b).

DO concentrations exhibited the most striking spatial variability across the creek. At S1, critically low DO levels (0.48 mg/L) were recorded during high tide, improving moderately to 1.29 mg/L during low tide, but remaining in the near-hypoxic range ($\text{DO} < 2$ mg/L). In contrast, S2 maintained substantially higher DO concentrations (6.7 mg/L at H, 6.9 mg/L at L) throughout the tidal cycle. This pronounced oxygen gradient within the creek likely reflects spatial differences in water residence time, organic matter decomposition rates, degree of tidal flushing, and proximity

to marine water sources. Similar near-hypoxic levels during the monsoon season have been previously reported from this creek (Khadanga et al. 2025a). The hypoxia or near-hypoxia in estuarine ecosystems can be ascribed to increased respiration and microbial decomposition of organic matter (Srichandan et al. 2015).

Chl-*a* concentrations were elevated throughout the creek, indicating high phytoplankton biomass characteristic of eutrophic conditions. Total chl-*a* at S1 was highest during high tide (11.1 µg/L), decreasing substantially to 5.8 µg/L during low tide. At S2, total chl-*a* concentrations remained relatively stable across tidal phases (6.5 µg/L at H, 7.1 µg/L at L). The phytoplankton size class biomass exhibited

complex tidal and spatial patterns. Microphytoplankton (greater than 20 μm) showed the highest concentrations at S1 during high tide (0.075 $\mu\text{g/L}$), dramatically declining to 0.01 $\mu\text{g/L}$ during low tide, while at S2, concentrations increased from 0.038 $\mu\text{g/L}$ (H) to 0.056 $\mu\text{g/L}$ (L). Nanophytoplankton (2 to 20 μm) displayed variable patterns, with S1 showing an increase from 0.5 $\mu\text{g/L}$ (H) to 1.8 $\mu\text{g/L}$ (L), while S2 exhibited a decrease from 3.2 $\mu\text{g/L}$ (H) to 0.3 $\mu\text{g/L}$ (L). Picophytoplankton (less than 2 μm) dominated the phytoplankton biomass at several sampling points, particularly at S1 during high tide (8.3 $\mu\text{g/L}$) and at S2 during low tide (4.9 $\mu\text{g/L}$), though showing considerable variability.

The dominance of picophytoplankton, particularly at S1 during high tide, coinciding with hypoxic conditions and high total chl-*a*, suggests a phytoplankton community adapted to nutrient-rich but oxygen-limited environments. Such tidal-driven shifts in phytoplankton size classes are characteristic of shallow tropical estuaries where mixing regimes influence nutrient availability and light conditions (Cloern 1996; Muylaert et al. 2009). A similar pattern of elevated chl-*a* values due to adequate nutrient availability has been reported earlier from this creek (Baliarsingh et al. 2013). The dominance of small-celled phytoplankton under nutrient-replete but oxygen-limited conditions has been reported from other eutrophic Indian estuaries (Gauns et al. 2020). Studies on phytoplankton in the oxygen-deficient waters of the western continental shelf of India found that such conditions markedly alter community structure, with the bulk of the biomass occurring in the smaller (picophytoplankton) size range (Gauns et al. 2020). The shift from picophytoplankton dominance during high tide to increased nanophytoplankton contribution during low tide at S1 may reflect tidal advection of different water masses or changes in grazing pressure and nutrient dynamics associated with tidal cycling. However, proliferation of nanophytoplankton community during the monsoon season has also been reported from other Indian estuarine ecosystems such as Cochin estuary, Thane creek, Mahanadi estuary, and Chilika lagoon (Madhu et al. 2010; Srichandan et al. 2019; Hardikar et al. 2021).

Tidal and Spatial Patterns of Jellyfish Aggregation

Although the initial objective was to examine tidal variation in biogeochemical parameters in Gopalpur Creek during August 2024, an aggregation of *A. flagellatus* was documented, representing a finding of ecological significance given the limited documentation of this species from the Odisha coast. According to established classification criteria in the literature, jellyfish swarming can be classified as low abundance when less than 10 ind./m², medium abundance when 10 to 15 ind./m², and high abundance when 15 to 25

ind./m² (Raghavan et al. 2025). Observations revealed *A. flagellatus* only during low tide along the stretch from S1 to the S2 region, with a semi-quantitative, visually estimated density of approximately 2 individuals per square meter of water surface, categorizing this event as a low-abundance aggregation. However, this represents the first documented report of *A. flagellatus* from both Gopalpur Creek specifically and the broader Odisha coast, thereby extending the known geographic distribution of this species along India's eastern coastline. A summary of *Acromitus* and other jellyfish aggregation event records from Indian and Asian coastal and estuarine systems, including reported abundance and associated environmental conditions, is presented in Table 1.

The temporal restriction of jellyfish occurrence to low tide periods merits discussion and is most parsimoniously attributed to the limitations of the observational method rather than to an active ecological response. Because medusae were enumerated exclusively by surface visual census, detectability was itself tide-dependent. At high tide, the greater water depth and volume within the creek would have distributed individuals through a deeper water column, diluting surface densities and placing an unknown fraction of the population below the layer visible from above. Although turbidity remained comparatively low during the survey, the principal constraint on detection was therefore not water clarity but the inability of a surface-restricted visual census to register submerged or passively drifting individuals. The apparent absence of *A. flagellatus* at high tide is consequently better interpreted as reduced detectability combined with spatial dilution than as a genuine removal of the population from the creek. A behavioural contribution cannot be excluded, and downward displacement towards near-bottom zones during ebb currents has been proposed for scyphozoans elsewhere (Syazwan et al. 2025). Such an explanation is, however, difficult to reconcile with the physical condition of many of the individuals recorded here, which were motionless, adhered to the muddy banks, or showed signs of senescence and decomposition; animals in that state are unlikely to have been performing controlled, directed vertical migrations. Any behavioural component would therefore have been restricted to the fraction of the population that remained actively swimming. Passive transport may also have contributed, in that *A. flagellatus* specimens with smaller body sizes (100 to 200 mm bell diameter) could have been swept seaward by strong ebb currents more readily than larger individuals. Distinguishing among reduced detectability, passive advection, and active behaviour would require depth-stratified net sampling or acoustic survey across a complete tidal cycle, which was beyond the scope of this opportunistic observation.

Table 1 Selected records of *Acromitus* spp. and other jellyfish from coastal and estuarine systems of India and nearby regions, with reported abundance/density and associated environmental conditions

Species	Region/system	Reported abundance/density	Associated salinity/conditions	Date/Year	Reference
<i>Acromitus flagellatus</i>	Gopalpur Creek, Odisha, India (present study)	~2 ind. m ⁻² (low-abundance aggregation)	Salinity 9.1–10.1; near-hypoxic to oxie; turbid; peak monsoon (August)	August 2024	Present study
<i>Crambionella stuhlmanni</i> ; <i>Chrysaora quinquecirrha</i>	Chennai coast, Bay of Bengal	Aggregation (not quantified)	Seasonal coastal circulation and advection concentrating medusae nearshore	1981–1985 (February, March, June, July, August, September)	James et al. (1985)
<i>Crambionella stuhlmanni</i> ; <i>Crambionella buitendijki</i> ; <i>Dactylometra quinquecirrha</i>	Off Kalpakkam, Bay of Bengal	Up to 17.54 t per month entering intake systems	Reversal of coastal currents	1995–1996	Masilamoni et al. (2000)
<i>Rhizostome scyphozoan</i>	Off Goa, Arabian Sea	Aggregation (not quantified)	Not Mentioned	2006	Purcell et al. (2007)
<i>Porpita porpita</i> , <i>Velella velella</i> , <i>Physalia physalis</i>	Saurashtra Coast, Gujarat	20 individuals in 20 m ²	Coast-ward waves, SSC, and wind	Pre-monsoon	Pandya et al. (2015)
<i>Lobonema smithii</i>	Gulf of Mannar, Bay of Bengal	Swarm (not quantified)	environmental and physical factors	July–October	Murugan and Durgekar (2008)
<i>Porpita porpita</i>	Adri beach, Gujarat, Arabian Sea	Not quantified	Monsoon conditions	Monsoon 2010	CMFRI (2010a)
<i>Porpita porpita</i>	Off Jakhau, Arabian Sea	~800 t seasonal production	Seasonal bloom fishery	Nov–Dec and Apr–May 2010	CMFRI (2010b)
Not specified	Off Kochi, Mangalore, Goa, Mumbai and Okha, Arabian Sea	Swarm (not quantified)	Green Noctiluca scintillans bloom, enhanced prey availability	2010–2017	Thomas et al. (2020)
Not specified	Sindhudurg coast of Maharashtra, Arabian Sea	1000 kg of jellyfish were landed in two shore seine fishing	Not Mentioned	Oct–Nov 2012	Shiledar (2013)
<i>Acromitus hardenbergi</i>	Perak River estuary, Malaysia	Swarming/ fishery aggregation	Low salinity; high sediment load; fast currents	3–4 October 2012, 20–21 September 2013, 27–28 December 2014, 13–16 June 2015 and 8–11 January 2016	Miyake et al. (2021)
<i>Pelagia noctiluca</i>	Rushikulya, Bay of Bengal	1–7 nos./10m ²	hydrodynamic forcing, eutrophication, salinity variability	Nov 2012–Feb 2013	Baliarsingh et al. (2015)
Not specified	Dhalabali and Gopalpur, Bay of Bengal	80–100 nos	Coastal circulation, wind-driven transport,	Dec 2012	Sahu and Panigrahy (2013)
<i>Porpita porpita</i>	Pulicat lagoon	Beach stranding (not quantified)	Reproductive period	Dec-13	Ramanibai et al. (2014)
Not specified	Gopalpur, Bay of Bengal	Swarm (not quantified)	Prey availability	Apr 2014	Baliarsingh et al. (2016)
<i>Pelagia noctiluca</i> ; <i>Anemonia viridis</i>	Shivrajpur, Gujarat coast, Arabian Sea	<i>Pelagia noctiluca</i> – 14.37 ± 0.49 individuals m ⁻² ; 26.45 ± 2.82 individuals per rock pool <i>Anemonia viridis</i> – 6.15 ± 1.07 individuals per rock pool	Salinity 36.7–36.8	Jan 2016	Padate et al. (2020)
<i>Porpita porpita</i>	Northern Arabian Sea	Swarm (not quantified)	Food availability (swarming within thick green Noctiluca scintillans bloom)	February to March 2016	Baliarsingh et al. (2018)

Table 1 (continued)

Species	Region/system	Reported abundance/density	Associated salinity/conditions	Date/Year	Reference
<i>Porpita porpita</i>	Astaranga to Puri, Bay of Bengal	> 100,000 nos (mass beach stranding)	Abundant food, higher temperature, shore-ward SSC, and wind	May 2016	Sahu et al. (2020)
<i>Crambionella orsini</i> ; <i>Lychnorhiza malayensis</i> ; <i>Chrysaora caliparea</i> ; <i>Netrostoma coeruleescens</i> ; <i>Cyanea nozakii</i>	Kerala coast, Arabian Sea	<i>Lychnorhiza malayensis</i> and <i>Chrysaora caliparea</i> (> 71 ind/100/m ²) – 2016 <i>Lychnorhiza malayensis</i> and <i>Chrysaora caliparea</i> (> 65 ind/100/m ²) – 2017 <i>Netrostoma coeruleescens</i> (> 18 ind/100/m ²) – 2016 <i>Netrostoma coeruleescens</i> (> 29 ind/100/m ²) – 2017 <i>Cyanea nozakii</i> (> 25 ind/100/m ²) – 2016 <i>Netrostoma coeruleescens</i> (> 29 ind/100/m ²) – 2017	Salinity ~ 32.45–33.7	2016–2017	Riyas et al. (2021a)
<i>Acromitus flagellatus</i>	Kerala coast, Arabian Sea	> 300 ind/100 m ² in pre-monsoon and > 210 ind/100 m ² in post-monsoon	Salinity ~ 21.01 to 25.51	2016–2019	Riyas et al. (2025)
<i>Chrysaora caliparea</i> ; <i>Cyanea nozakii</i> ; <i>Lychnorhiza malayensis</i>	Off Kerala, Arabian Sea	Bloom (not quantified)	Not Mentioned	2017–2018	Riyas et al. (2021b)
<i>Crambionella annandalei</i>	Off Andhra Pradesh, Bay of Bengal	Bloom (not quantified)	Seasonal fishery period	Mar–Jul 2018	Behera et al. (2020)
<i>Blackfordia virginica</i> , <i>Acromitus flagellatus</i> , <i>Pleurobrachia</i> sp.	Cochin estuary	0.35 ± 0.35 ind. m ⁻³ (early pre-monsoon) 0.73 ± 0.43 ind. m ⁻³ (late pre-monsoon)	Salinity ~ 20.17	May-18	Vineetha et al. (2022)
<i>Pelagia noctiluca</i>	Southern Hare Island and Manoli Island, Gulf of Mannar, Bay of Bengal	> 100/m ² approximately	Decrease in seawater salinity	16 Oct 2018	Ramesh et al. (2021)
<i>Pelagia</i> cf. <i>noctiluca</i>	Ratnagiri, Arabian Sea	7550 ± 576 ind. m ⁻³	Salinity 36 psu	Dec 2018	Hari Praved et al. (2021)
<i>Acromitus flagellatus</i> <i>Acromitus maculosus</i>	Cochin backwaters, India	Bloom/swarm (not quantified)	Salinity < 19; pre-monsoon	2019 to 2023	Raghavan et al. (2025)
<i>Porpita porpita</i>	Vadakadu to Olai-kuda Coastline, Rameswaram Island, Gulf of Mannar, Bay of Bengal	Beach stranding (not quantified)	shoreward currents and wind-driven drift due to Cyclone Nivar	7–14 Dec 2020	Tharik et al. (2021)
<i>Acromitus flagellatus</i>	Sundarbans (Saptamukhi channel), India	5200 ± 440 individuals m ⁻³	Salinity ~ 24.5; turbid; low DO, nutrient-rich estuarine waters	Feb-21	Siddique et al. (2022a)
<i>Porpita porpita</i>	Visakhapatnam	Beach stranding (not quantified)	Salinity ~ 32.1	16-03-2021	Pattnayak et al. (2023)
<i>Porpita porpita</i>	Coast of Mandv, Gujarat	Beach stranding (not quantified)	South-westerly monsoon winds, higher water temperature, and salinity	Aug-21	Shah and Shah (2021)
<i>Porpita porpita</i>	Kavaratti Island, Lakshadweep	Beach stranding (not quantified)	Strong winds, Climate change-mediated rise in water temperature and a northward shift of plankton assemblages	Dec-21	Marimuthu et al. (2022)
<i>Acromitus flagellatus</i>	Negombo estuary, Sri Lanka	Swarm (not quantified)	Salinity ~ 20	May 2022 - April 2024	Samarweera and Dissanayake (2025)

Table 1 (continued)

Species	Region/system	Reported abundance/density	Associated salinity/conditions	Date/Year	Reference
<i>Physalia physalis</i> , <i>Velella velella</i> , <i>Porpita porpita</i> ,	Mandvi, Dwarka, Harsid dhi, Mangrol, Adri, Veraval, Sutra- pada, and Kodinar	<i>Physalia physalis</i> (142–218 ind. per 100 m shoreline) <i>Porpita porpita</i> (5–24 ind. per 100 m shoreline) <i>Velella velella</i> (1–3 ind. per 100 m shoreline)	Wind pattern and direction, warmer temperatures	July - August 2022	Sabapara et al. (2022)
<i>Porpita porpita</i> , <i>Physalia physalis</i> , <i>Aurelia sp.</i> , <i>Salpa</i> <i>sp.</i>	Mangrol shore, Gujarat	Beach stranding (not quantified)	Post-monsoon nutrient enrich- ment, plankton blooms, and wind-driven transport	Sep-22	Aghera et al. (2025)
<i>Lobonemoides</i> <i>gracilis</i>	Gahirmatha	200–700 individuals per bloom patch; bloom area ~20 km ²	Salinity ~14.48	27–28 Septem- ber 2022	Mahapatro et al. (2025)
<i>Porpita porpita</i>	Southeastern Bangladesh	1.3 individuals m ⁻²	Salinity ~30 ppt, NW onshore winds (~19kmh ⁻¹), monsoon- current transport	April 10, 2024	Bhowmik et al. (2025)
<i>Pelagia noctiluca</i>	Off Visakhapatnam	150 ind./m ³	Salinity ~33.61	27-Jun-24	Siddique et al. (2026)
<i>Porpita porpita</i>	Astaranga, the east coast of India	Beach stranding (not quantified)	High SST, Coastward currents & winds	5th September 2024	Barik et al. (2025)
<i>Chrysaora cali- parea</i> , <i>Chrysaora</i> <i>chinensis</i>	Tarkarli, Sindhudurg	67% of the total November Fish catch	Salinity ~32.0	Nov-24	Dhale et al. (2026)

The timing of the *A. flagellatus* aggregation observed in this study presents an interesting departure from previously documented patterns in Indian estuaries. Most reports indicate that swarming of *A. flagellatus* occurs predominantly between November and May, corresponding to post-monsoon and pre-monsoon seasons. For instance, swarming of *A. flagellatus* was observed between November and May from 2016 to 2019 in the backwaters of Kerala (Riyas and Biju Kumar 2019). Further, blooms of *A. flagellatus* have also been noticed during March 2017 in Cochin backwaters (Peter et al. 2018). Another study documented swarms of *A. flagellatus* in Cochin Backwater during late pre-monsoon, specifically April and May 2019 and 2020 (Raghavan et al. 2025). Furthermore, blooms of *A. flagellatus* have been observed in January and February in other regions of India (Hemavathi 2017; Siddique et al. 2022a; Bhowal et al. 2023).

In contrast, the observation of *A. flagellatus* aggregation during the peak monsoon season (August) differs from earlier reports from Indian estuarine waters. This temporal discrepancy raises important ecological questions about the environmental triggers and physiological tolerances of this species. Recent investigations suggest that climate-driven shifts in monsoon patterns and anthropogenic modifications to estuarine hydrology may be altering the seasonal windows favourable for jellyfish proliferation in the Bay of Bengal region (Baliarsingh et al. 2020; Siddique et al. 2023), although such drivers were not evaluated in the present study. The monsoon occurrence documented here may tentatively indicate either: (1) increasing ecological

plasticity and adaptation of *A. flagellatus* populations to variable environmental conditions, (2) localized environmental conditions in Gopalpur Creek that differ substantially from other Indian estuaries, or (3) an emerging shift in swarming phenology potentially linked to anthropogenic alterations of the system. Because the present study is based on a single observational event, these explanations are advanced as hypotheses requiring further testing rather than as conclusions supported by the current data. Further long-term monitoring is necessary to determine whether this represents an anomalous event or an emerging trend in jellyfish ecology along the Odisha coast.

Plankton Community Composition During the Aggregation of *Acromitus flagellatus*

The phytoplankton community during the aggregation event was composed of three major groups: diatoms, dinoflagellates, and cyanobacteria. The observed taxa were largely represented by *Cylindrospermum* sp., *Synedra ulna*, *Proocentrum minimum*, *Pyrophacus steinii*, *Scenedesmus quadricauda*, *Phormidium* sp., *Merismopedia glauca*, *Coscinodiscus* sp., *Anabaena* sp., *Proocentrum micans*, and *Trichodesmium erythraeum*. The dinoflagellate communities described above have been reported to be mixotrophic (Jeong et al. 2005; Badylak and Phlips 2004). It has also been shown that mixotrophic dinoflagellates can survive longer without light than strict autotrophs because they can acquire carbon and energy heterotrophically (Jeong 2011; Keller et al. 2014). The presence of small-celled cyanobacteria and

dinoflagellates in the samples is characteristic of eutrophic tropical estuaries experiencing high nutrient loads and reduced water clarity (Lueangthuwapranit et al. 2011; Srichandan et al. 2015). The presence of *Trichodesmium erythraeum*, typically associated with nitrogen fixation in oligotrophic waters, alongside eutrophic indicators, suggests complex nutrient dynamics and possible marine influence even during the monsoon.

Qualitative taxonomic examination of the zooplankton samples collected during the aggregation showed that the samples contained *Brachionus* sp., represented by *Brachionus calyciflorus*, *Brachionus bidentatus*, *Brachionus rubens*, and *Brachionus plicatilis*. The occurrence of these rotifer species is noteworthy, as they are recognized as indicators of eutrophic conditions and organic pollution in estuarine systems. The genus *Brachionus* thrives in environments with high organic matter, low DO, and elevated nutrient concentrations, and its occurrence has been consistently associated with deteriorated water quality in Indian estuaries (Varghese and Krishnan 2013; Arora and Mehra 2003). The literature also suggests that natural populations of *Brachionus* adapt to low-oxygen environments by lowering their metabolic rate, which alters their reproductive schedule and extends generation times (Esparcia et al. 1989; Snell et al. 2019). The samples also included copepods namely, including *Acartia danae*, *Acartia erythraea*, *Acartia spinicauda*, *Acartia centrura*, *Subeucalanus subcrassus*, *Microsetella rosea*, *Centropages furcatus*, *Acrocalanus longicornis*, *Acrocalanus gibber*, as well as *Sagitta enflata*, copepod nauplii, gastropod veliger, and barnacle nauplii. The co-occurrence of *Acartia* species, which are euryhaline copepods tolerant of variable salinity conditions, alongside rotifers and chaetognaths, suggests a taxonomically varied but stress-tolerant zooplankton assemblage. The co-occurrence of *Brachionus* and *Acartia*, has similarly been reported during jellyfish swarming events in other tropical Asian estuaries, suggesting common trophic conditions that favour both rotifers and gelatinous predators (Vineetha et al. 2022). A prevalence of microzooplankton has also been reported in another estuarine ecosystem, such as the Sundarban estuary (India), although the species composition differed (Bhowal et al. 2023), likely reflecting regional differences in environmental conditions and anthropogenic pressures. Because both the phytoplankton and zooplankton were examined qualitatively rather than by quantitative enumeration, the descriptions above refer only to the presence of taxa in the samples and carry no implication regarding their relative abundance; quantitative cell- and individual-density data would be required to characterize community structure or to establish patterns of dominance during the aggregation.

Environmental Conditions Associated with the Aggregation Event

Salinity is an important factor in controlling the spatial distribution of gelatinous zooplankton in tropical coastal and estuarine ecosystems (Balqis et al. 2019; Syazwan et al. 2020; Nogueira Jr et al. 2018; Karati et al. 2021). In particular, *A. flagellatus*, commonly called the “River jellyfish,” is known to occur in seas, estuaries, and low-salinity waters along the Indian coast (Panikkar and Aiyar 1939). For instance, salinity ranges of less than 17 PSU and greater than 21 PSU in Kochi Backwater (India) and salinity of 24.5 PSU in the Sundarban estuarine area (India) were noted as potentially reducing the density and distribution of *A. flagellatus* (Raghavan et al. 2025; Siddique et al. 2022a). Furthermore, studies from other tropical estuaries, such as the Matang mangrove estuary (Malaysia), have also shown a higher abundance of *A. flagellatus* during moderately low salinity conditions (Syazwan et al. 2020). Another tropical study reported that jellyfish abundance in the Negombo estuary (Sri Lanka) peaked at approximately 20 PSU with swarming of *A. flagellatus* (Samarweera and Dissanayake 2025). Similarly, investigation in the Pearl River estuary, China, have documented optimal salinity ranges of 15 to 25 PSU for scyphozoan aggregations in monsoon-influenced systems (Lee et al. 2017).

However, these earlier reports contrast with the present investigation, where the recorded salinity was exceptionally low at 9.1 to 10.1, substantially lower than previously reported ranges for *A. flagellatus* aggregations. This finding is particularly significant as it demonstrates the species' presence and aggregation capability under extreme oligohaline conditions rarely documented in previous studies. The occurrence of *A. flagellatus* at such low salinities may be related to the euryhaline nature and osmoregulatory capacity reported for the species (Samarweera and Dissanayake 2025); however, these capacities were not measured here, and the observation should be regarded as a field record rather than direct evidence of physiological tolerance. Recent physiological studies on scyphozoans have revealed sophisticated ion regulation mechanisms and adaptive strategies that enable survival across wide salinity gradients, including upregulation of osmoregulatory genes and modifications in mesoglea water content (Giovagnoli 2023; Wright and Purcell 1997). Although a congeneric species, *A. hardenbergi*, has been reported abundantly in estuaries of the Perak River with relatively lower salinity (Yusoff et al. 2006; Nursuhayati et al. 2013), the salinity at which *A. flagellatus* was observed in this study is lower than the ranges previously documented for the species. Additionally, it has been suggested that *A. hardenbergi* has adapted to estuarine environments characterized by drastic salinity changes,

abundant sediment loads, and fast currents (Miyake et al. 2021), traits that may also apply to *A. flagellatus* populations in monsoon-dominated systems like Gopalpur Creek.

In addition to salinity tolerance, DO availability represents another critical environmental factor influencing jellyfish distribution. Literature suggests that deterioration of water quality, higher turbidity, and lower DO concentrations can lead to patchy aggregation and swarms (Purcell et al. 2007). Many studies have also reported that jellyfish can thrive at low DO concentrations, even in hypoxic conditions ($\text{DO} < 2 \text{ mg L}^{-1}$), due to lower metabolic oxygen requirements and the ability to store oxygen in the intragel matrix of the mesoglea (Purcell and Arai 2001; Vineetha et al. 2022). The gelatinous body structure of scyphozoans, composed primarily of water (greater than 95%), confers significant advantages in oxygen-depleted environments by minimizing metabolic demands and maximizing oxygen diffusion efficiency (Thuesen et al. 2005; Purcell et al. 2001). In this study, *A. flagellatus* appeared across the creek under variable oxygen regimes, ranging from severely hypoxic conditions (0.48 to 1.29 mg/L at S-1) to well-oxygenated conditions (6.7 to 6.9 mg/L at S-2). The occurrence of *A. flagellatus* across this oxygen gradient is consistent with the broad tolerance reported for scyphozoans elsewhere; however, oxygen tolerance was not directly tested in the present study, and these field observations should not be interpreted as evidence of physiological tolerance limits. The apparent ability to occur under both hypoxic and normoxic conditions suggests that oxygen availability, while potentially influencing distribution patterns, may not represent a primary limiting factor for *A. flagellatus* in this system. Broad hypoxia tolerance has been documented in other scyphozoan species from tropical estuaries, where jellyfish can exploit oxygen-depleted zones that exclude competing predators and reduce predation pressure (Miller and Graham 2012; Breitburg et al. 2018). Further, this hypoxic condition may benefit jellyfish feeding rates as prey mobility and escaping ability are hampered by low oxygen levels (Purcell et al. 2001; Decker et al. 2004; Shoji et al. 2005). For instance, studies have shown that the ingestion rate of fish larvae by moon jellyfish (*Aurelia aurita*) doubled as DO decreased (Shoji et al. 2005).

A question left open by the framing of this study concerns the potential predatory impact of *A. flagellatus* on the plankton assemblage of a creek that functions as a nursery ground for finfish and shellfish. Rhizostome medusae such as *Acromitus* bear fused oral arms with numerous small mouth openings and are generally regarded as opportunistic suspension feeders on small particles and microzooplankton rather than as visual predators on larger prey (Kitamura and Omori 2010; Siddique et al. 2022a). The reported ecological outcomes are, however, inconsistent: reduced chlorophyll-*a*

during an *A. flagellatus* swarm in the Sundarbans has been attributed to this feeding mode (Siddique et al. 2022a), whereas in the Cochin estuary, elevated jellyfish abundance coincided with increased chlorophyll-*a*, interpreted as an indirect consequence of nutrient regeneration through excretion (Vineetha et al. 2022). The net effect on plankton assemblages therefore, appears to be context-dependent and governed by medusa density, prey composition, and system residence time. It should be emphasised that, to our knowledge, no species-specific ingestion or clearance rates have been published for *A. flagellatus*, and no study has tested whether its feeding rates are enhanced under hypoxia; the ingestion data cited above for *Aurelia aurita* (Shoji et al. 2005) are presented only as an illustration of a mechanism reported for scyphozoans generally and are not extrapolated to the present species. In the case documented here, the aggregation was of low abundance (approximately 2 ind. m^{-2} , semi-quantitative visual estimate) and was observed on a single occasion, so a measurable predatory impact on the plankton community or on the nursery function of Gopalpur Creek is unlikely to have arisen from this particular event. Densities reported elsewhere for the species are nevertheless orders of magnitude higher (for example, $5200 \pm 440 \text{ ind. m}^{-3}$ in the Saptamukhi channel of the Sundarbans; Siddique et al. 2022a), and at such concentrations predation on microzooplankton and ichthyoplankton, together with dietary overlap with fish larvae, could plausibly become ecologically significant. Resolving this will require gut-content analysis, laboratory clearance-rate experiments across oxygen and salinity gradients, and stable-isotope characterisation of trophic position; these measurements were not undertaken here and are identified as priorities for subsequent work in this system.

The relationship between phytoplankton biomass and jellyfish occurrence also warrants examination. Chl-*a* concentrations throughout the creek were elevated, ranging from 5.8 to 11.1 $\mu\text{g/L}$, indicating high phytoplankton biomass typical of eutrophic conditions. The size structure analysis revealed variable contributions from different phytoplankton size classes, with nanophytoplankton and picophytoplankton dominating at different tidal phases and locations. The increased total chl-*a* concentration during this study could be related to increased nutrient levels in the system. However, previous studies in this creek have reported chl-*a* of 0.54 to 1.11 $\mu\text{g/L}$ during the monsoon season (Baliarsingh et al. 2013), suggesting that the current study captured a period of exceptionally high phytoplankton biomass. Some recent studies have reported low chl-*a* values, while others have reported increased chl-*a* concentrations during *A. flagellatus* blooms. For instance, low chl-*a* levels due to the non-specific opportunistic feeding behaviour of *A. flagellatus* have been reported from the estuarine waters of the

Saptamukhi River channel in the Sundarbans deltaic region, India (Siddique et al. 2022a). Another study has reported that higher jellyfish abundances and their ammonia excretion may have contributed to increasing nutrient levels and, consequently, a rise in chl-*a* concentration in the Cochin estuary, India (Vineetha et al. 2022). Furthermore, the variation in biomass of nano-, pico-, and micro-phytoplankton may be related to the non-specific opportunistic feeding behaviour of *A. flagellatus*. The complex interactions between jellyfish grazing, nutrient regeneration through excretion, and phytoplankton dynamics have been increasingly recognized as important feedback mechanisms in eutrophic estuarine systems (Pitt et al. 2009; Condon et al. 2010).

Turbidity and suspended matter also appear to play important roles in creating favourable conditions for jellyfish aggregations. Literature suggests that high turbidity (increased TSM) of estuarine ecosystems favour jellyfish (Purcell et al. 2007). The elevated TSM concentrations throughout the creek and variable turbidity appear to have provided suitable conditions for *A. flagellatus* aggregation. Similar to this study's findings, a recent study in the Cochin estuary (India) also found a positive relationship between *A. flagellatus* and TSM, supporting their preference for turbid water (Vineetha et al. 2022). High turbidity may benefit jellyfish by reducing visual predation pressure, providing refuge from UV radiation, and supporting elevated densities of their zooplankton prey (Eiane et al. 1999; Purcell and Sturdevant 2001).

Finally, the role of anthropogenic nutrient enrichment may be a relevant contextual factor when considering the environmental context of this jellyfish occurrence. As inorganic nutrients (e.g., ammonium, nitrate, phosphate, and silicate) were not measured in the present study, eutrophication is inferred indirectly from elevated chlorophyll-*a*, the prevalence of small-celled phytoplankton, and the occurrence of eutrophication-tolerant zooplankton; previously reported nutrient enrichment in this creek (Baliarsingh et al. 2013; Khadanga et al. 2025b) provides supporting context. Studies by Baliarsingh et al. (2013) in Gopalpur Creek reported an external nutrient source from the surrounding area due to anthropogenic influence from nearby hatcheries. According to Samarweera and Dissanayake (2025), anthropogenic nutrient inputs resulting from wastewater discharges associated with fishing and aquaculture practices can stimulate phytoplankton productivity, thus indirectly supporting jellyfish population growth. Similar conditions in the study area may enhance the retention of jellyfish and zooplankton prey. Accordingly, the associations between *A. flagellatus* and eutrophication, aquaculture effluents, and altered hydrology are presented here as potential contributing factors rather than demonstrated causes. The synergistic effects of nutrient enrichment, altered hydrology, and habitat modification

have been implicated in jellyfish proliferation across multiple Indian estuarine systems (Purcell 2012; Baliarsingh et al. 2020; Siddique et al. 2022b). Taken together, the conditions observed during this study are consistent with the broad environmental tolerance attributed to *A. flagellatus* in the literature; direct physiological assessment would be required to confirm the plasticity inferred here.

Conclusion

The present study provides the first documented evidence of *Acromitus flagellatus* aggregation in the Gopalpur Creek along the Odisha coast, India, during the peak monsoon season. The occurrence of this species under low-salinity (9.1 to 10.1), moderately turbid, and apparently nutrient-enriched conditions is consistent with broad ecological tolerance, although physiological tolerance was not directly assessed. The observed association between increased turbidity, higher chlorophyll-*a* concentrations, and jellyfish presence suggests that eutrophic and low-oxygen environments may favour *A. flagellatus* aggregation. Contrary to earlier studies from other Indian estuaries reporting *A. flagellatus* swarms during post- and pre-monsoon periods, the present findings lead us to hypothesize that monsoonal hydrological fluctuations and nutrient influx may act as additional triggers for aggregation formation in this system; given that this inference rests on a single observational event, it requires confirmation through further investigation. Anthropogenic inputs from aquaculture effluents and land-based discharges may represent potential contributing factors rather than demonstrated drivers. The principal contribution of this study is the first documented record of *A. flagellatus* in Gopalpur Creek and a description of the environmental conditions observed during the aggregation; broader inferences regarding physiological tolerance, eutrophication, and anthropogenic influence require direct measurement and longer-term monitoring.

This baseline study contributes to understanding the ecological responses of tropical estuaries to environmental stress and highlights the need for long-term monitoring of gelatinous zooplankton as indicators of ecosystem health. Future investigations integrating molecular, trophic, and biogeochemical analyses, including direct measurement of inorganic nutrients and quantitative plankton enumeration, and quantification of medusa feeding and clearance rates, are essential to elucidate the mechanisms underlying jellyfish swarming, to evaluate the predatory impact of *A. flagellatus* on the plankton assemblage and nursery function of the creek and to establish implications for fisheries and coastal management in the Bay of Bengal region.

Acknowledgements The authors express their gratitude to the authorities of their respective institutions for their support and encouragement throughout this research. The authors sincerely thank the anonymous reviewers for their constructive comments, which substantially improved the manuscript. Sanjiba and Susmita thank INCOIS for assigning publication contribution number 731 to this work.

Author Contributions SS: Conceptualization, Formal analysis, Investigation, Writing - original draft; BP: Investigation, Data curation, Formal analysis, Visualization, Writing - original draft; SKM: Investigation, Data curation, Formal analysis, Visualization, Writing - original draft; SR: Formal analysis, Writing - original draft; SKB: Writing - original draft. All authors read and approved the final manuscript.

Funding This study was undertaken with financial assistance from the Berhampur University Seed Fund Grant (Sanction Order No. L.N. 1836/R&DC/BU/25, dated 12 March 2025) awarded to the first author.

Data Availability The datasets will be made available upon reasonable request.

Declarations

Competing Interest The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Generative AI and AI-assisted technologies in the writing process During the preparation of this work, the authors utilized Grammarly to enhance readability and language. After using this tool, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

References

- Aghera DS, Gajera NK, Kundu RS (2025) Massive stranding of gelatinous zooplankton on the west coast of India. *J Mar Biol Association India* 67(2). <https://doi.org/10.6024/jmbai.2025.67.2.2628-06>
- Arora J, Mehra NK (2003) Seasonal dynamics of rotifers in relation to physical and chemical conditions of the river Yamuna (Delhi), India. *Hydrobiologia* 491(1):101–109. <https://doi.org/10.1023/A:1024490805310>
- Badylak S, Philips EJ (2004) Spatial and temporal patterns of phytoplankton composition in subtropical coastal lagoon, the Indian River Lagoon, Florida, USA. *J Plankton Res* 26(10):1229–1247. <https://doi.org/10.1093/plankt/fbh114>
- Baliarsingh SK, Srichandan S, Padmavati T, Naik S, Sahu KC (2010), November Accumulation of heavy metals by freshwater zooplankton-a toxicological study. In *Recent Advances in Space Technology Services and Climate Change 2010 (RSTS & CC-2010)* (pp. 7–14). IEEE. <https://doi.org/10.1109/RSTSCC.2010.5712789>
- Baliarsingh SK, Biraja S, Srichandan S, Sahu KC, Lotliker AA, Kumar TS (2013) Seasonal variation of phytoplankton community in Gopalpur Creek: a tropical tidal backwater ecosystem, East Coast of India. *Indian J Geo-Mar Sci* 44(4):508–526
- Baliarsingh SK, Srichandan S, Sahu KC, Lotliker AA (2015) Occurrence of a new species of toxic Cnidaria (*Pelagia noctiluca* Forskål, 1775) from estuarine waters of Rushikulya River, Western Bay of Bengal. *Indian J Geo Mar Sci* 44(4):580–582
- Baliarsingh SK, Lotliker AA, Trainer VL, Wells ML, Parida C, Sahu BK, Srichandan S, Sahoo S, Sahu KC, Kumar TS (2016) Environmental dynamics of red *Noctiluca scintillans* bloom in tropical coastal waters. *Mar Pollut Bull* 111(1–2):277–286. <https://doi.org/10.1016/j.marpolbul.2016.06.103>
- Baliarsingh SK, Lotliker AA, Sudheesh V, Samanta A, Das S, Vijayan AK (2018a) Response of phytoplankton community and size classes to green *Noctiluca* bloom in the Northern Arabian Sea. *Mar Pollut Bull* 129(1):222–230. <https://doi.org/10.1016/j.marpolbul.2018.02.031>
- Baliarsingh SK, Srichandan S, Lotliker AA, Kumar TS, Sahu KC (2018b) Zooplankton distribution in coastal water off Gopalpur, north-western Bay of Bengal. *J Ocean Univ China* 17:879–889. <https://doi.org/10.1007/s11802-018-3414-0>
- Baliarsingh SK, Lotliker AA, Srichandan S, Samanta A, Kumar N, Nair TB (2020) A review of jellyfish aggregations, focusing on India's coastal waters. *Ecol Processes* 9(1):58. <https://doi.org/10.1186/s13717-020-00268-z>
- Balqis SA, Yusoff FM, Nishikawa J, Lindsay D, Nishida S (2019) Influence of environmental parameters on habitat preference of gelatinous zooplankton in various coastal ecosystems, the Straits of Malacca. *Reg Stud Mar Sci* 30:100712. <https://doi.org/10.1016/j.rsma.2019.100712>
- Barik KK, Jena AK, Mohanty SK, Srichandan S, Baliarsingh SK, Samanta A, Chhotaray PK, Joseph S, Nair B, T. M (2025) Probing a Blue Button Jellies Beach Stranding Event on the East Coast of India. *J Indian Soc Remote Sens* 1–11. <https://doi.org/10.1007/s12524-025-02214-y>
- Behera PR, Raju SS, Jishnudev MA, Ghosh S, Saravanan R (2020) Emerging jellyfish fisheries along Central South East coast of India. *Ocean Coastal Manage* 191:105183. <https://doi.org/10.1016/j.ocecoaman.2020.105183>
- Bhowal A, Siddique A, Prasad H, Purushothaman J, Banerjee D (2023) Comparison of microzooplankton community structure before and during *Acromitus flagellatus* swarm in the estuarine waters of northern Bay of Bengal. *Reg Stud Mar Sci* 61:102864. <https://doi.org/10.1016/j.rsma.2023.102864>
- Bhowmik P, Datta S, Hasan MN, Khan MSR (2025) Latitudinal Range Shift of the Blue Button Jelly (*Porpita porpita*) in the Bay of Bengal: A Signal of Ecological Imbalance in Coastal Bangladesh. *Mar Ecol* 46(6):e70069. <https://doi.org/10.1111/maec.70069>
- Bilio M, Niermann U (2004) Is the comb jelly really to blame for it all? *Mnemiopsis leidyi* and the ecological concerns about the Caspian Sea. *Mar Ecol Prog Ser* 269:173–183. <https://doi.org/10.3354/meps269173>
- Breitburg D, Levin LA, Oschlies A, Grégoire M, Chavez FP, Conley DJ, Garçon V, Gilbert D, Gutiérrez D, Isensee K, Zhang J (2018) Declining oxygen in the global ocean and coastal waters. *Science* 359(6371):eaam7240. <https://doi.org/10.1126/science.aam7240>
- Bright CE, Mager SM, Horton SL (2018) Predicting suspended sediment concentration from nephelometric turbidity in organic-rich waters. *River Res Appl* 34(7):640–648. <https://doi.org/10.1002/rra.3305>
- Bright C, Mager S, Horton S (2020) Response of nephelometric turbidity to hydrodynamic particle size of fine suspended sediment. *Int J Sedim Res* 35(5):444–454. <https://doi.org/10.1016/j.ijsrc.2020.03.006>
- Cloern JE (1996) Phytoplankton bloom dynamics in coastal ecosystems: a review with some general lessons from sustained investigation of San Francisco Bay, California. *Rev Geophys* 34(2):127–168. <https://doi.org/10.1029/96RG00986>
- CMFRI Kochi (2010a) Unusual occurrence of *Porpita porpita* in Aadri beach. *Gujarat CMFRI Newsl* 126(July–September):1–23
- CMFRI Kochi (2010b) Seasonal jellyfish fishery in Jakhau, Gujarat. *CMFRI Newsl* 127(October–December):19
- Condon RH, Steinberg DK, Bronk DA (2010) Production of dissolved organic matter and inorganic nutrients by gelatinous zooplankton in the York River estuary, Chesapeake Bay. *J Plankton Res* 32(2):153–170. <https://doi.org/10.1093/plankt/fbp109>

- Decker MB, Breitburg DL, Purcell JE (2004) Effects of low dissolved oxygen on zooplankton predation by the ctenophore *Mnemiopsis leidyi*. *Mar Ecol Prog Ser* 280:163–172. <https://doi.org/10.3354/meps280163>
- Dhale SN, Adsul AD, Pawase AS, Ade PJ, Pawar VV, Jadhav VV, Nimabrt PV (2026) The Catch Composition of Beach Seine Fishery along Tarkarli Beach, Malvan, West Coast of India. *Thalassas: Int J Mar Sci* 42(2):69. <https://doi.org/10.1007/s41208-026-01079-3>
- Doyle TK, Hays GC, Harrod C, Houghton JD (2013) Ecological and societal benefits of jellyfish. *Jellyfish Blooms*. Springer Netherlands, Dordrecht, pp 105–127. https://doi.org/10.1007/978-94-007-7015-7_5
- Eiane K, Aksnes DL, BagØien E, Kaartvedt S (1999) Fish or jellies—a question of visibility? *Limnol Oceanogr* 44(5):1352–1357. <https://doi.org/10.4319/lo.1999.44.5.1352>
- Esparcia A, Miracle MR, Serra M (1989) *Brachionus plicatilis* tolerance to low oxygen concentrations. *Hydrobiologia* 186(1):331–337. <https://doi.org/10.1007/BF00048929>
- Gauns M, Mochemadkar S, Pratihary A, Shirodkar G, Narvekar PV, Naqvi SWA (2020) Phytoplankton associated with seasonal oxygen depletion in waters of the western continental shelf of India. *J Mar Syst* 204:103308. <https://doi.org/10.1016/j.jmarsys.2020.103308>
- Gershwin LA (2006) Nematocysts of the Cubozoa. *Zootaxa* 1232(157):30
- Giovagnoli A (2023) Proteomic insights into osmoregulation and salinity-induced thermotolerance in the cnidarian-dinoflagellate symbiosis (Doctoral dissertation, Te Herenga Waka-Victoria University of Wellington). <https://doi.org/10.26686/wgtn.24466396>
- Grasshoff K, Kremling K, Ehrhardt M (1999) *Methods of seawater analysis*, 3rd edn. Wiley-VCH, New York
- Hardikar R, Haridevi CK, Ram A, Parthipan V (2021) Distribution of size-fractionated phytoplankton biomass from the anthropogenically stressed tropical creek (Thane creek, India). *Reg Stud Mar Sci* 41:101577. <https://doi.org/10.1016/j.rsma.2020.101577>
- Hari Praved P, Morandini AC, Maronna MM, Suhaana MN, Jima M, Aneesh BP, Nandan B, S., Jayachandran PR (2021) Report of Mauve Stinger *Pelagia cf. noctiluca* (Cnidaria: Scyphozoa) Bloom from Northeastern Arabian Sea (NEAS). *Thalassas. Int J Mar Sci* 37(2):569–576. <https://doi.org/10.1007/s41208-021-00304-5>
- Hemavathi M (2017) Studies on the Isolation, Purification, Characterization and Biomedical Applications of Nematocyst Venom Protein from the Jellyfish *Acromitus flagellatus*. Ph.D. Thesis. University of Madras
- Houghton JDR, Doyle TK, Davenport J, Hays GC (2006) Developing a simple, rapid method for identifying and monitoring jellyfish aggregations from the air. *Mar Ecol Prog Ser* 314:159–170. <https://doi.org/10.3354/meps314159>
- James DB, Vivekanandan E, Srinivasarengan S (1985) Menace from medusae off Madras with notes on their utility and toxicity. *J Mar Biol Association India* 27(1):170–174
- Jeong HJ (2011) Mixotrophy in red tide algae raphidophytes 1. *J Eukaryot Microbiol* 58(3):215–222. <https://doi.org/10.1111/j.1550-7408.2011.00550.x>
- Jeong HJ, Park JY, Nho JH, Park MO, Ha JH, Seong KA, Jeng C, Seong CN, Lee KY, Yih WH (2005) Feeding by red-tide dinoflagellates on the cyanobacterium *Synechococcus*. *Aquat Microb Ecol* 41(2):131–143. <https://doi.org/10.3354/ame041131>
- Karati KK, Ashadevi CR, Harikrishnachari NV, Valliyodan S, Kumaraswami M, Naidu SA, Ramanamurthy MV (2021) Hydrodynamic variability and nutrient status structuring the mesozooplankton community of the estuaries along the west coast of India. *Environ Sci Pollut Res* 28(31):42477–42495. <https://doi.org/10.1007/s11356-021-13634-x>
- Keller DP, Lee DY, Hood RR (2014) Turbidity maximum entrapment of phytoplankton in the Chesapeake Bay. *Estuaries Coasts* 37(2):279–298. <https://doi.org/10.1007/s12237-013-9692-2>
- Kennish MJ (2019) Estuaries: anthropogenic impacts. In: Finkl CW, Makowski C (eds) *Encyclopedia of Coastal Science*. Encyclopedia of Earth Sciences Series. Springer, Cham, pp 803–811. https://doi.org/10.1007/978-3-319-93806-6_140
- Khadanga MK, Mishra RK, Swain GK, Jena BK, Mohanty PK (2025a) Monsoon-driven biogeochemical shifts and acidification risk in tropical estuarine ecosystems: A case study from the Indian coast. *Mar Environ Res* 107697. <https://doi.org/10.1016/j.marenvres.2025.107697>
- Khadanga MK, Mishra RK, Sahoo RK, Dora DP, Behera AK, Panda US, Mohanty PK, Mishra P (2025b) Seagrass conservation in a dynamic tidal creek system: Balancing creek stability and nutrient loads for sustainable management. *Sci Total Environ* 1001:180462. <https://doi.org/10.1016/j.scitotenv.2025.180462>
- Kitamura M, Omori M (2010) Synopsis of edible jellyfishes collected from Southeast Asia, with notes on jellyfish fisheries. *Plankton Benthos Res* 5(3):106–118. <https://doi.org/10.3800/pbr.5.106>
- Kramp PL (1961) Synopsis of the medusae of the world. *J Mar Biol Association United Kingdom* 40:7–382. <https://doi.org/10.1017/S0025315400007347>
- Lee HE, Han CH, Kim B, Yoon WD (2017) Effects of temperature and salinity on the asexual reproduction of *Nemopilema nomurai* (Scyphozoa: Rhizostomeae). *Ocean Sci J* 52(4):573–579. <https://doi.org/10.1007/s12601-017-0040-5>
- Lueangthuwapranit C, Sampantarak U, Wongsai S (2011) Distribution and abundance of phytoplankton: influence of salinity and turbidity gradients in the Na Thap River, Songkhla Province, Thailand. *J Coastal Res* 27(3):585–594. <https://doi.org/10.2112/JCOASTRES-D-10-00123.1>
- Madhu NV, Jyothibabu R, Balachandran KK (2010) Monsoon-induced changes in the size-fractionated phytoplankton biomass and production rate in the estuarine and coastal waters of southwest coast of India. *Environ Monit Assess* 166(1):521–528. <https://doi.org/10.1007/s10661-009-1020-8>
- Mahapatro D, Mishra S, Pati SS, Behera R, Das Sharma S, Mallick N, Murugesan K (2025) First Occurrence Record of *Lobonemoides gracilis* Light, 1914 Jellyfish Bloom in the Coastal Waters of World's Largest Sea Turtle Rookery—The Gahirmatha, Northwestern Bay of Bengal, India. *Natl Acad Sci Lett* 1–7. <https://doi.org/10.1007/s40009-025-01666-7>
- Marimuthu N, Kandasamy SV, Raheem CN, Idreesbabu KK (2022) Mass occurrence of blue button hydrozoan fauna in the Lakshadweep Archipelago, India. *Curr Sci* 122(4):369–370
- Masilamoni JG, Jesudoss KS, Nandakumar K, Satpathy KK, Nair KVK, Azariah J (2000) Jellyfish ingress: a threat to the smooth operation of coastal power plants. *Curr Sci* 79(5):567–569
- Miglietta MP, Rossi M, Collin R (2008) Hydromedusa blooms and upwelling events in the Bay of Panama, Tropical East Pacific. *J Plankton Res* 30(7):783–793. <https://doi.org/10.1093/plankt/fbn038>
- Miller MEC, Graham WM (2012) Environmental evidence that seasonal hypoxia enhances survival and success of jellyfish polyps in the northern Gulf of Mexico. *J Exp Mar Biol Ecol* 432:113–120. <https://doi.org/10.1016/j.jembe.2012.07.015>
- Miyake H, Honda S, Nishikawa J, Yusoff FM (2021) Life cycle of edible jellyfish *Acromitus hardenbergeri* Stiasny, 1934 (Scyphozoa: Rhizostomeae) inhabiting a brackish-water environment. *Animals* 11(7):2138. <https://doi.org/10.3390/ani11072138>
- Murugan A, Durgekar R (2008) Beyond the Tsunami: Status of Fisheries in Tamil Nadu, India: A Snapshot of Present and Long-Term Trends. UNDP/UNTRS, Chennai and ATREE, Bangalore, India, p 75

- Muyllaert K, Sabbe K, Vyverman W (2009) Changes in phytoplankton diversity and community composition along the salinity gradient of the Schelde estuary (Belgium/The Netherlands). *Estuar Coast Shelf Sci* 82(2):335–340. <https://doi.org/10.1016/j.ecss.2009.01.024>
- Nogueira Jr M, Nascimento do, Maciel LS, Tilbert PV, S., Oliveira LD (2018) Diversity, species composition and assemblage dynamics of estuarine gelatinous and semi-gelatinous zooplankton from Brazil. Plankton ecology of the southwestern atlantic: from the subtropical to the subantarctic realm. Springer International Publishing, Cham, pp 375–412. https://doi.org/10.1007/978-3-319-77869-3_18
- Nursuhayati AS, Yusoff FM, Shariff M (2013) Spatial and temporal distribution of phytoplankton in Perak estuary, Malaysia, during monsoon season. *J Fish Aquat Sci* 8(4):480. <https://doi.org/10.3923/jfas.2013.480.493>
- Padate G, Mirza R, Viradiya A, Salunke S (2020) Scyphozoa *Pelagia noctiluca* (Forsskal, 1775): blooming on the coast of Gujarat, India and its predation by *Anemonia viridis* (Forsskal, 1775). *Zool Ecol* 30(2):157–164. <https://doi.org/10.35513/21658005.2020.2.9>
- Padhiary M, Kumar R (2024) Assessing the environmental impacts of agriculture, industrial operations, and mining on agro-ecosystems. Smart internet of things for environment and healthcare. Springer, Cham, pp 107–126. https://doi.org/10.1007/978-3-031-70102-3_8 Nature Switzerland
- Pandya KM, Parikh KV, Dave CS, Mankodi PC (2015) Occurrence of hydrozoans from the Saurashtra Coast of Gujarat, India. *Res J Mar Sci ISSN* 2321:1296
- Panikkar NK, Aiyar RG (1939) Observations on breeding in brackish-water animals of Madras. In *Proceedings/Indian Academy of Sciences*. New Delhi: Springer India (Vol. 9, No. 6, pp. 343–364) June 1939
- Pattnayak SK, Silambarasan K, Kar AB, Das P, Prasad GVA (2023) Stranding of blue button jelly *Porpita porpita* on the beaches of Visakhapatnam, India (Western Bay of Bengal). *Mar Fish Sci* 36(2):197–202. <https://doi.org/10.47193/mafis.3622023010505>
- Peter S, Manojkumar B, Pillai D (2018) First record of Eutonina indicans (Romanes, 1876) from Kerala waters, India. *Indian J Geo-Mar Sci* 47(08):1636–1639
- Pitt KA, Welsh DT, Condon RH (2009) Influence of jellyfish blooms on carbon, nitrogen and phosphorus cycling and plankton production. *Hydrobiologia* 616(1):133–149. <https://doi.org/10.1007/s10750-008-9584-9>
- Purcell JE (2012) Jellyfish and ctenophore blooms coincide with human proliferations and environmental perturbations. *Annual Rev Mar Sci* 4(1):209–235. <https://doi.org/10.1146/annurev-marine-120709-142751>
- Purcell JE, Arai MN (2001) Interactions of pelagic cnidarians and ctenophores with fish: a review. *Hydrobiologia* 451(1):27–44. <https://doi.org/10.1023/A:1011883905394>
- Purcell JE, Sturdevant MV (2001) Prey selection and dietary overlap among zooplanktivorous jellyfish and juvenile fishes in Prince William Sound, Alaska. *Mar Ecol Prog Ser* 210:67–83. <https://doi.org/10.3354/meps>
- Purcell JE, Breitburg DL, Decker MB, Graham WM, Youngbluth MJ, Raskoff KA (2001) Pelagic cnidarians and ctenophores in low dissolved oxygen environments: a review. Coastal hypoxia: consequences living Resour Ecosyst 58:77–100. <https://doi.org/10.1029/CE058p0077>
- Purcell JE, Uye SI, Lo WT (2007) Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. *Mar Ecol Prog Ser* 350:153–174. <https://doi.org/10.3354/meps>
- Raghavan G, Gokulan NC, Matilda MV, Narayana SV (2025) Stabilized Length-Weight Relationship and Pre-Monsoon Ascendancy of Jellyfish, *Acromitus maculosus* and *Acromitus flagellatus* in Kochi-Backwaters, India. *Thalassas: Int J Mar Sci* 41(2):126. <https://doi.org/10.1007/s41208-025-00865-9>
- Ramanibai R, Govindan S, Balakrishnan T (2014) Notes on the occurrence of *Porpita porpita* (Blue button) from Pulicat Lagoon. *J Res Biology* 4(7):1487–1490
- Ramesh CH, Koushik S, Shunmugaraj T, Murthy MV (2021) Occurrence of a Scyphozoan jellyfish, *Pelagia noctiluca* (Forskål, 1775) bloom in the Gulf of Mannar Marine National Park, Southern India. *Indian J Geo Mar Sci* 50(02):161–164
- Richardson AJ, Bakun A, Hays GC, Gibbons MJ (2009) The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. *Trends Ecol Evol* 24(6):312–322. <https://doi.org/10.1016/j.tree.2009.01.010>
- Riyas A, Biju Kumar A (2019) Jellyfish blooms along the southwest coast of India: current status and trends. In *6th International Jellyfish Bloom Symposium*
- Riyas A, Dahanukar N, Krishnan KA, Kumar AB (2021a) Scyphozoan jellyfish blooms and their relationship with environmental factors along the South-eastern Arabian Sea. *Mar Biol Res* 17(2):185–199. <https://doi.org/10.1080/17451000.2021.1916034>
- Riyas A, Kumar A, Chandran M, Jaleel A, Kumar AB (2021b) The venom proteome of three common scyphozoan jellyfishes (*Chrysaora caliparea*, *Cyanea nozakii* and *Lychnorhiza malayensis*) (Cnidaria: Scyphozoa) from the coastal waters of India. *Toxicon* 195:93–103. <https://doi.org/10.1016/j.toxicon.2021.03.005>
- Riyas A, Krishnan KA, Kumar AB (2025) Evaluating environmental influence on *Acromitus flagellatus* Maas, 1903 (Cnidaria: Scyphozoa) blooms in the tropical estuaries and backwaters along southwest India. *J Mar Biol Association India* 67(2). <https://doi.org/10.6024/jmbai.2025.67.2.2627-08>
- Sabapara Z, Baroliya H, Poriya P (2022) Mass stranding of pleustonic cnidarians on Gujarat coastline, India. *Species* 23(72):504–508
- Sahu BK, Panigrahy RC (2013) Jellyfish bloom along the south Odisha coast, Bay of Bengal. *Curr Sci* 104(4):410–411
- Sahu BK, Baliarsingh SK, Srichandan S, Sahu KC (2013) Seasonal variation of zooplankton abundance and composition in Gopalpur creek: a tropical tidal backwater, east coast of India. *J Mar Biol Association India* 55(1):59–64. <https://doi.org/10.6024/JMBAI.2013.55.1.01715-10>
- Sahu BK, Baliarsingh SK, Samanta A, Srichandan S, Singh S (2020) Mass beach stranding of blue button jellies (*Porpita porpita*, Linnaeus, 1758) along Odisha coast during summer season. *Indian J Geo Mar Sci* 49(06):1093–1096
- Samarweera VD, Dissanayake DCT (2025) Influence of physicochemical parameters on jellyfish abundance and community structure in tropical estuarine and marine waters: A case study from Sri Lanka. *Reg Stud Mar Sci* 104607. <https://doi.org/10.1016/j.rsm.2025.104607>
- Shah N, Shah Y (2021) Mass beach stranding of blue button jellyfishes, *Porpita porpita* (Linnaeus, 1758) from the Coast of Mandvi, Kutch, India during August, 2021. *J Mar Sci* 3(4). <https://doi.org/10.30564/jms.v3i4.3851>
- Shiledar BAA (2013) Fishing activity affected by swarming of jellyfish along the Sindhudurg coast of Maharashtra. *Mar Fisheries Inform Service; Tech Ext Ser* 215:39–39
- Shoji J, Masuda R, Yamashita Y, Tanaka M (2005) Predation on fish larvae by moon jellyfish *Aurelia aurita* under low dissolved oxygen concentrations. *Fish Sci* 71(4):748–753. <https://doi.org/10.1111/j.1444-2906.2005.01024.x>
- Sial NK, Satapathy D, Kund GC, Patra SK, Nanda S, Misra SK (2019) Seasonal abundance and distribution of plankton in relation to water qualities in Gopalpur creek, east coast of India. *J Appl Zool Res* 30(1):83–90
- Siddique A, Bhowal A, Purushothaman J, Azeez A (2022a) First record of *Acromitus flagellatus* (Maas, 1903) (Cnidaria: Scyphozoa) swarm from the world's largest deltaic ecosystem, the

- Sundarbans, India. Reg Stud Mar Sci 55:102555. <https://doi.org/10.1016/j.rsma.2022.102555>
- Siddique A, Purushothaman J, Madhusoodhanan R, Raghunathan C (2022b) The rising swarms of jellyfish in Indian waters: the environmental drivers, ecological, and socio-economic impacts. J Water Clim Change 13(10):3747–3759. <https://doi.org/10.2166/wcc.2022.245>
- Siddique A, Bhowal A, Purushothaman J, Madhusoodhanan R, Banerjee D (2023) Environmental drivers and ecological implications of a ctenophore swarm: a case study from the Bay of Bengal, northern Indian Ocean. J Water Clim Change 14(8):2885–2901. <https://doi.org/10.2166/wcc.2023.266>
- Siddique A, Garbhapu NS, Sarma VVSS (2026) Jellyfish diversity and niche partitioning during a scyphozoan swarm in the coastal Bay of Bengal: interactions and environmental factors associated with coexistence. Marine Biodivers 56(3):49. <https://doi.org/10.1007/s12526-026-01654-0>
- Snell TW, Johnston RK, Jones BL (2019) Hypoxia extends lifespan of *Brachionus manjavacas* (Rotifera). Limnetica 38(1):159–166. <https://doi.org/10.23818/limn.38.04>
- Srichandan S, Kim JY, Kumar A, Mishra DR, Bhadury P, Muduli PR, Pattnaik AK, Rastogi G (2015) Interannual and cyclone-driven variability in phytoplankton communities of a tropical coastal lagoon. Mar Pollut Bull 101(1):39–52. <https://doi.org/10.1016/j.marpolbul.2015.11.030>
- Srichandan S, Baliarsingh SK, Prakash S, Lotliker AA, Parida C, Sahu KC (2019) Seasonal dynamics of phytoplankton in response to environmental variables in contrasting coastal ecosystems. Environ Sci Pollut Res 26(12):12025–12041. <https://doi.org/10.1007/s11356-019-04569-5>
- Strickland JDH, Parsons TR (1972) A practical handbook of seawater analysis (2nd ed.). *Bulletin of Fisheries Research Board of Canada*, 167. Queen's Printer, Ottawa
- Syazwan WM, Low LB, Rizman-Idid M (2020) First record in Peninsular Malaysia and morphological redescription of *Lychnorhiza malayensis* (Scyphozoa: Rhizostomeae: Lychnorhizidae). Raffles Bull Zool 68. <https://doi.org/10.26107/RBZ-2020-0004>
- Syazwan WM, Then AYH, Chong VC, Rizman-Idid M (2025) Temporal drivers of abundance and community structure of scyphozoan jellyfish in tropical coastal waters. PeerJ 13:e18483. <https://doi.org/10.7717/peerj.18483>
- Tharik M, Saraswathi S, Arumugam K (2021) Uncommon mass beaching of *Porpita porpita* (Linnaeus, 1758) in the Gulf of Mannar, Tamil Nadu, India. Nat Eng Sci 6(3):256–260. <https://doi.org/10.28978/nesciences.1036855>
- Thomas LC, Nandan SB, Padmakumar KB (2020) Understanding the dietary relationship between extensive Noctiluca bloom outbreaks and Jellyfish swarms along the eastern Arabian Sea (West coast of India). Indian J Geo Mar Sci 49(8):1389–1394
- Thuesen EV, Rutherford LD, Brommer PL (2005) The role of aerobic metabolism and intragel oxygen in hypoxia tolerance of three ctenophores: *Pleurobrachia bachei*, *Bolinopsis infundibulum* and *Mnemiopsis leidyi*. J Mar Biol Association United Kingdom 85(3):627–633. <https://doi.org/10.1017/S0025315405011550>
- Tomas CR (ed) (1997) Identifying marine phytoplankton. Elsevier
- Vandendriessche S (2007) Floating seaweed as ephemeral neustonic habitat (Doctoral dissertation, PhD Thesis. Universiteit Gent, Faculteit Wetenschappen: Gent, Belgium. X, 145 pp. details). <https://doi.org/10.1016/j.seares.2005.09.002>
- Varghese M, Krishnan L (2013) Brachionus species distribution in relation to environmental characteristics in Cochin backwaters, Kerala, South India. Indian J Fisheries 60(1):133–138
- Vineetha G, Kripa V, Karati KK, Madhu NV, Anil P, Nair MV (2022) Surge in the jellyfish population of a tropical monsoonal estuary: A boon or bane to its plankton community dynamics? Mar Pollut Bull 182:113951. <https://doi.org/10.1016/j.marpolbul.2022.113951>
- Wright DA, Purcell JE (1997) Effect of salinity on ionic shifts in mesohaline scyphomedusae, *Chrysaora quinquecirrha*. Biol Bull 192(2):332–339. <https://doi.org/10.2307/1542726>
- Yusoff FM, Shariff M, Gopinath N (2006) Diversity of Malaysian aquatic ecosystems and resources. Aquat Ecosyst Health Manag 9(2):119–135. <https://doi.org/10.1080/14634980600713315>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.