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Short Communication

A scientific study on mass mortality of Indian mackerel (*Rastrelliger kanagurta* (Cuvier, 1816)) along the lower stretches of river Godavari

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A mass mortality event of Indian mackerel (*Rastrelliger kanagurta* (Cuvier, 1816)) was observed on 5th July 2024 along the lower stretch of the Godavari River estuary, where the species is known to enter periodically. Water samples collected from Masakapalli, Brahmapuri, and Yanam showed markedly low salinity levels of 1–6 psu, pH values of 8.07–8.23 and ammonia concentration ranging 0.01–0.13 mg/L. The substantially reduced salinity likely imposed osmotic stress on this predominantly marine species. While the relatively high pH, in combination with the measured ammonia concentrations may have increased the toxicity of un-ionised ammonia (NH_3), compounding physiological stress in the fish and potentially contributing to the observed mortality. Oceanic parameters in nearby coastal waters, including sea surface temperature (28.7 °C), salinity (33.2 psu), chlorophyll-*a* concentration (1.8 mg/m³), and sea level anomaly (3.3 cm), remained within normal ranges, indicating no significant anomalies in adjacent coastal waters. These observations suggest that the mortality event was most likely linked with the conditions of pronounced freshwater dilution, associated osmotic stress, and enhanced ammonia toxicity prevailed along the lower stretch of the Godavari River estuary.

[**Keywords**: Estuary, Godavari river, Indian mackerel, Mass mortality, NH_3 toxicity]

Introduction

Mass fish mortality events have been reported from various regions of the Indian Ocean attributed to a range of environmental and anthropogenic factors[1-6]. However, incidents specifically involving the Indian mackerel (*Rastrelliger kanagurta* (Cuvier, 1816)), particularly in estuarine ecosystems, have not been documented to date. A first-of-its-kind, mass mortality event of Indian mackerel was reported along the lower stretch of the Godavari River estuary on 5th July 2024, raising concerns about sudden ecological disturbances in such transitional habitats.

Indian mackerel is a commercially important pelagic species widely distributed along the east and west coasts of India, with the west coast alone contributes more than 80 % of India's total mackerel catch[7]. On the east coast, particularly in Andhra Pradesh, the species has become increasingly important in marine landings, ranking among the top contributors and emerging as the most landed species in 2023, with a reported catch of 0.18 lakh tonnes[7].

Fish mortality events have historically been linked to diverse causative factors such as anoxic conditions triggered by anthropogenic activities[2], heavy metal contamination[6], harmful algal blooms[1,8,9], and abrupt temperature shifts due to cyclonic storms[4]. More recently, climate change has been increasingly recognised as a compounding stressor that alters temperature regimes, promoting hypoxia, and shifting biogeochemical balances[10] and thereby intensifying the severity and frequency of such events.

Furthermore, alterations to riverine hydrology resulting from dam construction, barrage operations, and water diversion projects changes natural freshwater discharge patterns and disrupt ecological functioning of estuaries[11], often creating stressful conditions for both freshwater and marine biota.

In this context, the sudden and localised mortality of Indian mackerel in the Godavari estuary prompted an urgent investigation. This study therefore aims to identify the potential oceanic and estuarine causative factors associated with the mortality event, and to provide critical ecological insights into estuarine fish health, water quality dynamics, and habitat vulnerability. Understanding the environmental drivers underlying such events is essential for the effective conservation and management of this economically important fishery resource, as well as for developing early-warning and mitigation strategies to minimise the risk of similar events in the future.

Material and Methods

The Godavari River, one of India's largest river systems, has a drainage basin area of approximately 312,812 km² and an average yearly runoff of 105 km³, with 25 tributaries feeding into it[12,13]. Near Rajahmundry, the river's flow is regulated by the

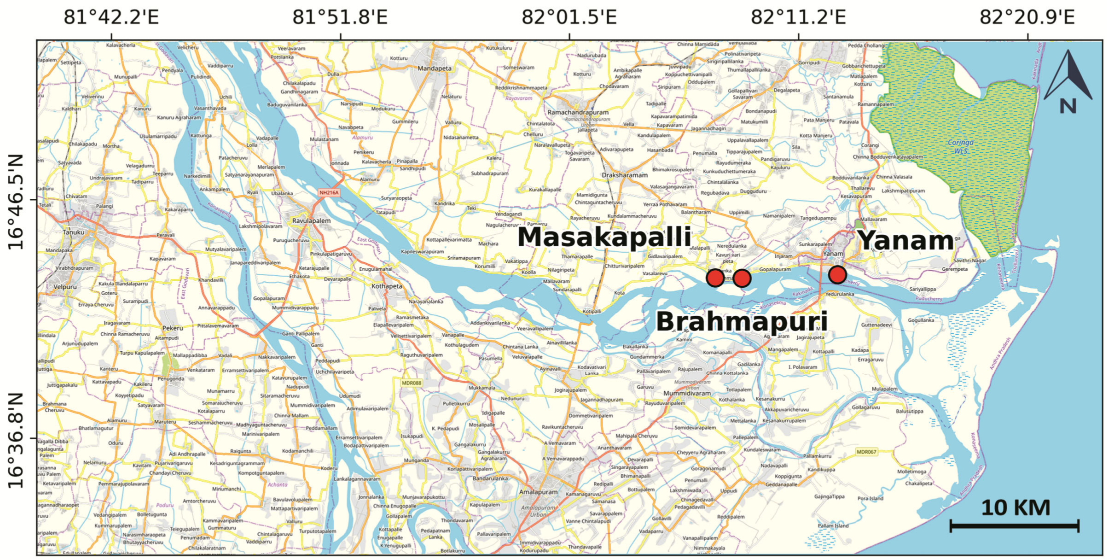

Fig. 1 — Map showing the mass mortality locations and sampling locations

Fig. 2 — Dead Indian mackerel fishes along the shores of river Godavari

Dowleswaram Barrage, beyond which the river splits into two main distributaries: the Gautami-Godavari (eastward) and the Vasista-Godavari (southward) estuaries. The mass mortality event of Indian mackerel was reported in the Gautami-Godavari estuary on 5th July 2024 (Fig. 1).

Field observations and sampling

Upon receiving reports of fish mortality, the second author (KC) and team conducted a rapid field survey on 6th July 2024, covering three locations along the lower estuarine stretch: Masakapalli (16°43'20.22" N, 82°07'39.47" E), Brahmapuri (16°43'19.33" N, 82°08'47.32" E), and Yanam (16°43'27.83" N, 82°12'48.91" E). At all three sites, dead Indian mackerel (*R. kanagurta*) were observed both floating in the river and washed ashore. Notably, no other fish species were found among the mortalities (Fig. 2). Informal interviews with local fishermen provided additional qualitative insights regarding the timing, spatial extent, and potential environmental triggers of the event.

Water samples were collected from each site on the same day, transported under controlled conditions to the laboratory, and analysed for key physicochemical parameters to assess estuarine water quality. Parameters measured included pH, salinity (psu), alkalinity (mg/L), total hardness (mg/L), calcium (mg/L), magnesium (mg/L), Dissolved Oxygen (DO, mg/L), ammonia (mg/L), nitrite (mg/L), and chlorine (mg/L), following standard procedures outlined by the American Public Health Association (APHA)[14].

Satellite and oceanographic data analysis

To examine the oceanographic and meteorological conditions associated with the mortality event, Sea Surface Temperature (SST) obtained from the OSTIA product, at a 0.05°×0.05° resolution, and gap-free multi-sensor blended chlorophyll data (Chl-102, 4 km resolution) were utilised to detect any abnormal chlorophyll near the estuary. Sea Surface Salinity (SSS) data (1/8° resolution) were derived from multi-observation global product integrating satellite and *in situ* measurements. Sea Level Anomaly (SLA) and surface currents (Currents-046) at 0.25° resolution products were used to evaluate physical oceanographic variability during the event period. Daily rainfall data were extracted from the ERA5 reanalysis dataset. All satellite datasets were accessed and downloaded from the Copernicus Marine Service and Copernicus Climate Data Store.

Results and Discussion

A mass mortality event involving Indian mackerel (*R. kanagurta*) was observed in the Godavari River estuary on 5th July 2024. The affected fish were uniform in size (17–19 cm; 72–78 g), with thousands of carcasses observed floating and stranded along the riverbanks near Yanam, Masakapalli, and Brahmapuri.

Hydrographic conditions outside the estuary mouth revealed stable SST and salinity before the mass die off event, while chlorophyll concentration burgeoned and SLA gradually declined till the day of event onset. On the day of mass mortality, average values were SST: 28.7 °C, Salinity: 33.2 psu, SLA: 3.3 cm, and Chlorophyll-*a*: 1.8 mg/m³. A cold SST patch was formed off the estuary mouth from 4th July (Fig. 3),

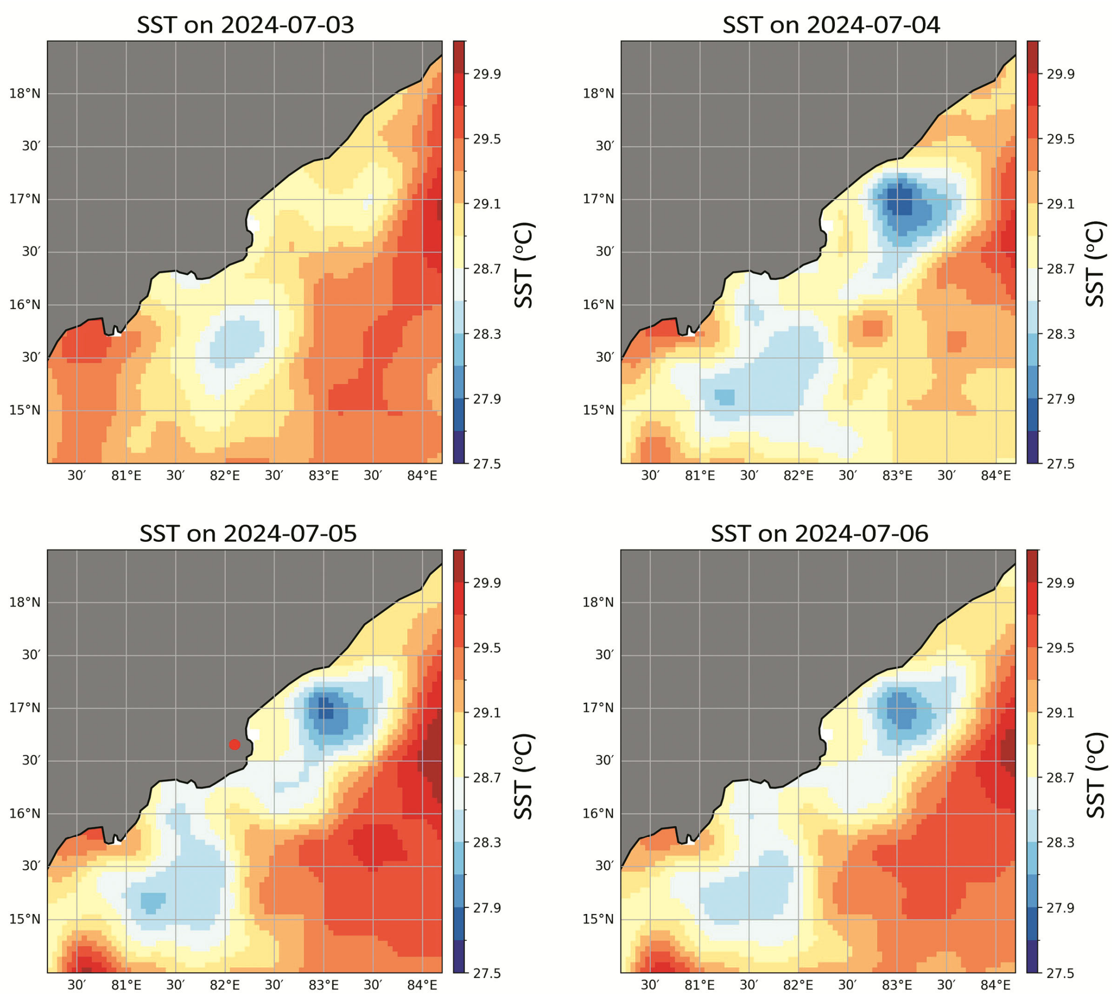

Fig. 3 — SST maps on 3 to 6 July 2024, red dot indicates the location of mass die-off on 5th July 2024

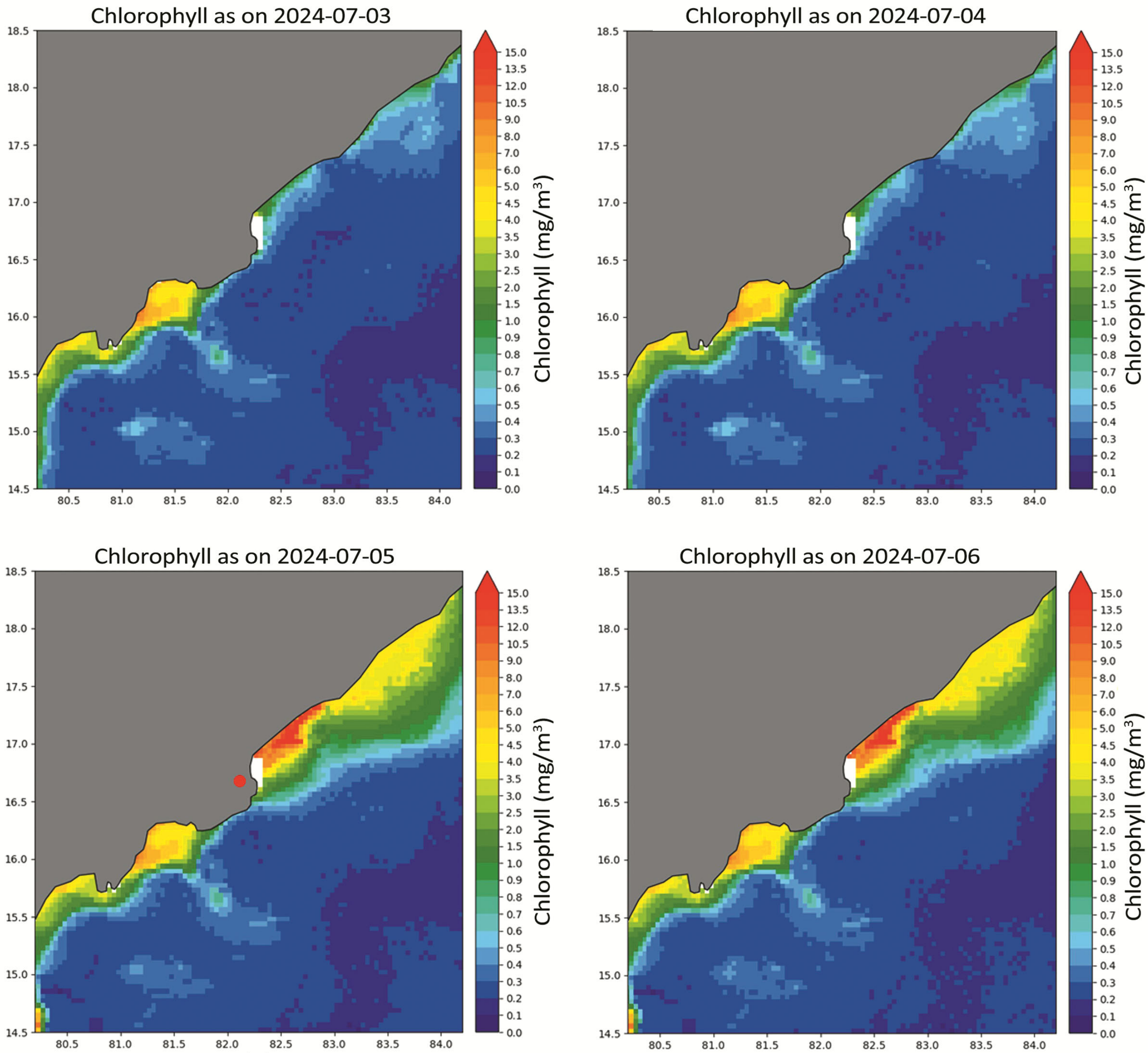

Fig. 4 — Chlorophyll maps, red dot indicates the location of mass die-off on 5th July 2024

and high chlorophyll-*a* from 2–6 July (Fig. 4), which could have enhanced coastal productivity, attracting planktivorous Indian mackerel coastward. Simultaneously, SLA gradually decreased from ~12 cm (26 June) to 3.3 cm (5 July), indicating an upwelling process in the area. Current analyses revealed a large cold-core eddy approaching the estuary since 20 June, along with two small warm-core eddies. These hydrodynamic features likely facilitated fish aggregation and movement into the estuarine region. Rainfall on 4–5 July in the upstream catchment resulted in a strong influx of freshwater into the estuary. North-easterly winds prevailed during the event. Water samples collected on 6 July showed significantly reduced salinity levels (Table 1), reaching values as low as ~1 psu while most physicochemical parameters (DO, nitrite, calcium, magnesium, alkalinity, and hardness) remained within tolerable limits. Salinity levels were extremely low for a marine species such as the Indian mackerel, which is not well-adapted to abrupt salinity declines.

Ammonia concentrations (0.01–0.13 mg/L) were below lethal thresholds but could intensify physiological stress under low-salinity conditions[15]. Higher pH (8.07–8.23) during the event favours the toxic un-ionised form of ammonia (NH_3)[16,17], especially at

Table 1 — Values of physicochemical variables for the collected water samples on 6th July 2024 a day after the mass mortality

Parameters	Masakapalli	Brahammapuri	Yanam
pH	8.23	8.07	8.14
Salinity (psu)	1	2	6
Alkalinity (mg/L)	110	80	130
Hardness (mg/L)	200	320	1300
Calcium (mg/L)	24	40	120
Magnesium (mg/L)	34.02	53.46	243
DO (mg/L)	7.7	7.4	7.0
Ammonia (mg/L)	0.01	0.04	0.13
Nitrite (mg/L)	0.06	0.05	0.08
Chlorine (mg/L)	Nil	Nil	Nil

Yanam, where both ammonia and pH were highest. Reduced salinity further increases ammonia sensitivity in marine fishes, potentially impacting osmoregulation. Microscopic histological analysis was beyond the scope of this study, but could be considered for future detailed investigations.

Thus, the combined effects of sudden freshwater intrusion, low salinity, alkaline pH, and moderate ammonia levels likely created physiological distress, resulting in mass mortality. The absence of common causes of fish kills, such as abnormal dissolved oxygen, chlorine, foam, odour, and multi-species mortality[1,6,11,18], rules out hypoxia, algal bloom, or point-source pollution as primary causes. Indian mackerel are known to occasionally enter estuaries[19-21], possibly following tidal currents and entering estuaries to evade predators, or may have been attracted to eddy-concentrated planktonic prey[22]; however, a die-off of this magnitude is unusual.

The lack of freshwater or estuarine species mortality further supports the notion that marine fish are disproportionately affected by salinity-pH-ammonia interactions. Mass mortality events have been reported in various Indian estuaries[2,3,5,6,23,24], underscoring vulnerabilities of estuarine ecosystems to both natural and anthropogenic stressors; however, a global study found that the majority are linked to anthropogenic causes[25]. Given increasing climatic variability and extreme weather events, continuous monitoring of key environmental variables including salinity, pH, and ammonia is essential for early warning and mitigating future fish kill events.

Conclusion

The mass mortality of Indian mackerel in the Godavari estuary is most likely due to a combination of environmental stressors triggered by a sudden influx of freshwater from upstream rainfall. While low salinity alone may not directly cause mortality; it can increase the physiological stress in marine fish and elevate their sensitivity to other toxicants. The marine species are highly sensitive to NH_3 toxicity due to changes in osmoregulatory function and gill permeability. In this case, although ammonia concentrations were moderate (0.01 to 0.13 mg/L), the high pH (8.07 to 8.23), combined with low salinity, likely enhanced ammonia toxicity, potentially causing gill damage and mortality. This incident underscores the need to understand the other potential factors in mass mortality among coastal shoaling fishes.

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Conflict of Interest

The authors declare that they have no known competing financial interests that could have appeared to influence the work reported in this paper. The authors declare no conflict of interest.

Ethical Statement

Authors declare that the research does not involve human or animal requiring ethical approval. Dead fish were handled for length measurements; no live fish were captured.

Author Contributions

CS: Conceptualization, data analysis, preparation of the first draft, and editing and review; KC: Field data collection, water sample analysis, and writing of the manuscript; SK, Ha, SJh, DML, SKB & AS: formal analysis and writing of the manuscript; SJ & TMBN: Manuscript editing and supervision.

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