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High occurrence of Jellyfish (*Catostylus perezi*, Ranson 1945) in proximity to industrial development, Gulf of Kutch/ Kachchh, India

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Here, the mass occurrence of Jellyfish, *Catostylus perezi*, Ranson 1945 is reported from the coastal waters of Gulf of Kutch/ Kachchh, Gujarat, India. Although high productivity is a possible reason the presence of man-made infrastructures like thermal power plants and ports are further highlighted. A further assessment of the effects of these structures on marine life is suggested in this article.

[**Key words**: High productivity, Port, Power plant, Scyphozoa]

Introduction

The gelatinous zooplanktons mysteriously appear (and disappear) at unpredictable times and are usually considered the dark side of ecology[1-3]. Their large size, rapid growth, transparency, and buoyancy, together with the absence of hard structures, set these animals apart as a distinct ecological category based on predation-protection strategies[4]. Jellyfish form amazing population blooms, and there is undeniable evidence that jellyfish blooms are becoming more frequent and widespread, and their swarms have enormous ecological, economic and social impacts[3]. For example, they have been associated with the decline of commercial fisheries; disturbances in the cooling water intakes of coastal industries and ships and reduce the amenity of coastal waters for tourists[5-7]. Jellyfish outbursts are now related to many anthropogenic activities such as climate change, eutrophication, and overfishing[6,8,9]. Sometimes regarded as trophic dead-ends due to the few obligate predators, there lies a need for regular monitoring.

Within the Indian sub-continent, twelve species of scyphozoan jellyfish have been reported[10], while information within the Gulf of Kutch/ Kachchh (GoK; Gujarat) region remains limited with just one report as per a recent review[11] (Table 1). New studies have, however, filled in significant knowledge gaps indicating an increased number of jellyfish swarming in the area[12-14]. In the present study, the high occurrence of *Catostylus perezi*, Ranson 1945 (Cnidaria: Scyphozoa) in the Gulf of Kutch region in proximity to a thermal power plant is discussed along with information on the jellyfish blooms along the coast of India. It is vital to note that species within this genus are known to be medically important[15] and have applications in biomaterial science[16]. *C. perezi* is also a commercially exploited species in the nearby regions[17].

Materials and Methods

During regular field visits to coastal places of the northern GoK, particularly in the third and last week of December 2018, plenty of jellyfishes were lying stranded on the beaches near Kathada, (Figs. 1, 2). Several specimens were collected and preserved in 5 % formaldehyde for further assessment and were identified following Riyas *et al.*[12]. The observation was photographed with a digital camera (Samsung SM-960F). Jellyfishes were further observed to be moving along with the water current. In Kathada, 10 (1×1 m) quadrats were laid, and the abundance data was calculated. Linear regression was done from the collected specimens to find a correlation between bell diameter and oral arm length. Fishermen further reported entanglements as a bycatch in the region and on the beaches near Nanalayza, Panchotiya and Sanghi Jetty in Kaharo creek water (Fig. 1). The study area lies ~ 35 km from a

Table 1 — List of Jellyfish blooms across Indian coastal waters

Jellyfish species*	Locality	Year of occurrence	Potential cause	References
Pelagia noctiluca	Rushikulya estuary (19º23'43" N; 85º05'23" E) (Odisha, ECI)	November, 2012 – February, 2013	Wind-current tide action, water pollution, climate change	Baliarsingh *et al.*[11,37]
Crambionella stuhlmanni	Visakhapatnam (17° 42' 46.62" N; 83°19' 23.2" E) (Andhra Pradesh, WCI)	February, 2015	Tropical cyclone Hudhud	Deccan Chronicle[39]; Baliarsingh *et al.*[11]
Physalia physalis+	Goa (15°15'1.15" N; 73°55'12.9" E) (WCI)	October, 2015	--	Baliarsingh *et al.*[11]
Rhizotomatidae	Jakhau (23°14'3.12" N; 68°34'5.02" E) (Gujarat, WCI)	November – December; April – May	--	Cadalmin[32]; Baliarsingh *et al.*[11]
Physalia physalis+	Mumbai (19°6'34.45" N; 72°49'24.1" E) (Maharashtra, WCI)	July – August, 2018	--	Baliarsingh *et al.*[11]
Crambionella orsini; Cyanea sp., *Chrysaora caliparea*; *Netrostoma coerulescens*	Kollam coast (8º45'& 9º07' N; 76º29' & 77º17' E) (Kerala, WCI)	--	Eutrophication, overfishing, artificial structure creation, climate change	Biju Kumar *et al.*[34]; Biju Kumar & Anitha[41]
Crambionella stuhlmanni; *Chrysaora quinquecirrha*	Chennai coast (Tamil Nadu, ECI)	June – August (1981-1985)	--	James *et al.*[36]
Crambionella stuhlmanni; *Crambionella buitendijki***; *Chrysaora quinquecirrha*	Madras Atomic Power Station (12°33' N and 80°11' E) (Chennai, Tamil Nadu, ECI)	October, 1996 (Maximum quantity)	Reversal of coastal water currents during monsoon seasons	Masilamoni *et al.*[35]
Crambionella orsini; *Lychnorhiza malayensis*; *Chrysaora caliparea*; *Netrostoma coerulescens*; *Cyanea nozakii*	Kerala coast: Neendakara (8°56′ N; 76°32′ E), Kochi (9°58′ N; 76°12′ E), Puthiyappa (11°19′ N; 75°44′ E), Thaikadapuram (12°11′ N; 75°06′ E). (South-eastern Arabian Sea, WCI)	*C. orsini*: Beginning of monsoon to non-monsoon, 2016/2017. *L. malayensis*, *N. coerulescens*: August – October 2016/2017.	Positive correlation with nutrient parameters *viz*. phosphate, silicate, and Chl-*a*	Riyas *et al.*[25]
Pelagica noctiluca	Gulf of Mannar: Hare Island (09°11.779′ N, 079°04.420′ E); Manoli Island (09°13.15′ N, 079°07.33′ E).	October, 2018	Rise in SST; low salinity due to precipitation	Ramesh *et al.*[38]
Porpita porpita+	Puri (19°47'50.53" N; 85°50'7.12" E) (Odisha, ECI)	May, 2018	--	Baliarsingh *et al.*[11]
Porpita porpita+	Kavaratti island (N 10°34.6333′ and E 72°38.4418′) (Lakshadweep, atolls)	December, 2021	High SST (climate change), wind driven	Marimuthu *et al.*[42]
Porpita porpita+	Konark-Astaranga coastline (19°57'10.66" N; 86°21'35.1" E) (Odisha, ECI)	April – May, 2016	Climate change	Baliarsingh *et al.*[11]; Sahu *et al.*[43]
Porpita porpita+	Windfarm beach, Mandvi, Kutch (22°49'23.34" N; 69°20'28.57" E), WCI.	August, 2021	--	Shah & Shah[13]
Catostylus perezi	Veraval coast, Gujarat (20°55′19.3" N, 70°19'59.9" E), WCI.	April, 2017	--	Riyas *et al.*[12]
Catostylus perezi	Kathada Beach, Gulf of Kutch, WCI.	December, 2018	High productivity, anthropogenic factors?	Current study

+Not a true Jellyfish; *Species names updated from WoRMS; **Information not available on WoRMS; ECI: East Coast of India; WCI: West Coast of India; List may be non-exhaustive; Reports without identification not shown

thermal power plant (Fig. 1). Chlorophyll maps were created through Sentinel Applications Platform (SNAP Ver. 7). Level 1 full resolution products secured by Sentinel 3 Ocean and Land Color Instrument (OLCI) were downloaded from the Copernicus Online Data Access (CODA) and atmospheric correction was done through the Case 2 Regional Coast-Color (C2RCC) algorithm[18]. Clouds were masked and uncertainty values were incorporated through polychromatic blending. The created image was downloaded as KMZ and superimposed on Google earth engine (Fig. 3). For Sea

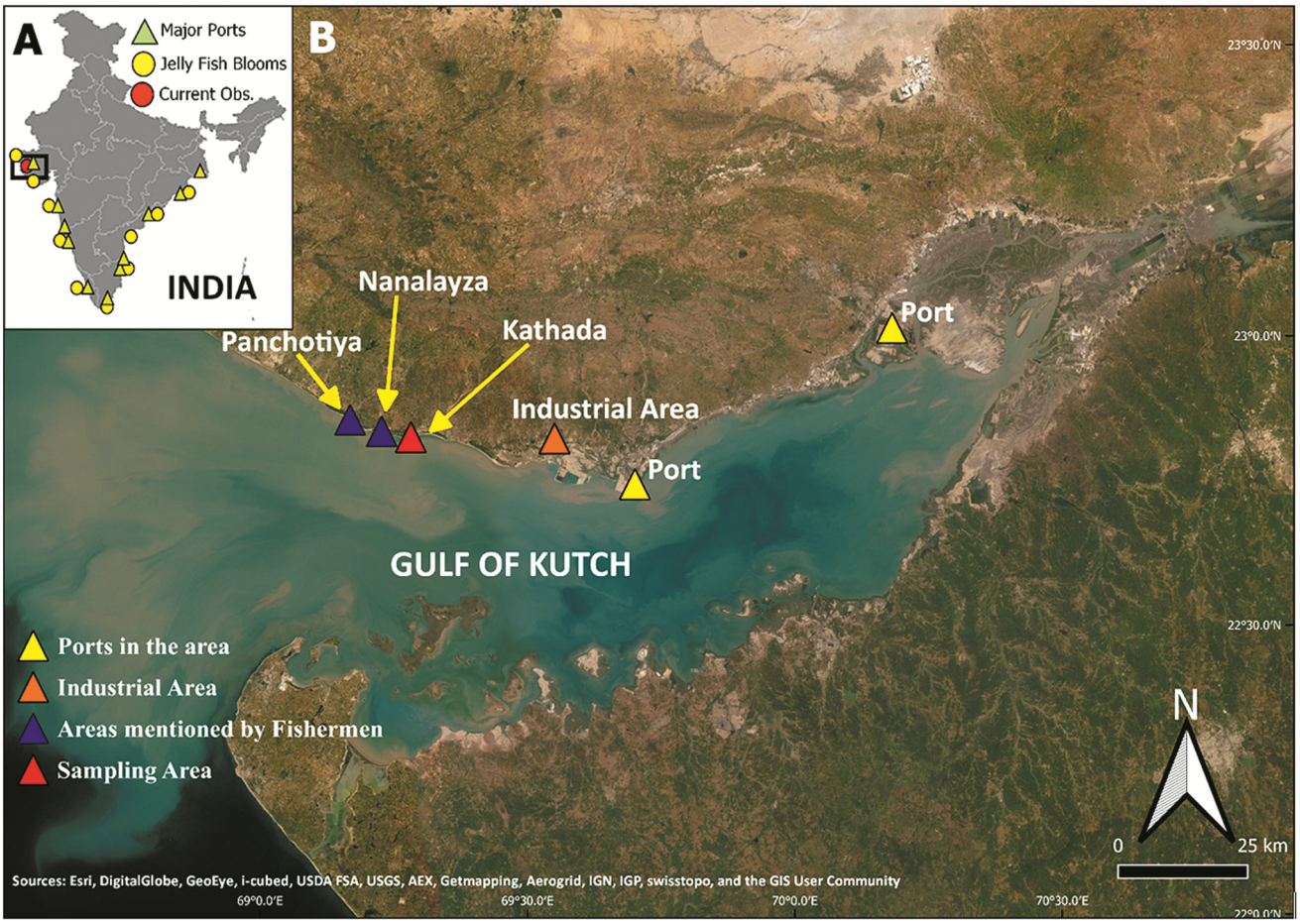

Fig. 1 — A) India map showing other areas with reports of jellyfish blooms (Yellow circles). Yellow triangles: Major ports across the Indian coast; Black box: Gulf of Kutch. B) Current Study area – Gulf of Kutch/ Kachchh (GOK): a) Red Triangle: Location of data collection; b) Blue Triangle: Location where fishermen mentioned the presence of species; c) Orange triangles: Industrial area; d) Yellow Triangles: Port (Abbv. MAH: Maharashtra; KAR: Karnataka; KER: Kerala; TN: Tamil Nadu; AP: Andhra Pradesh; OD: Odisha; WB: West Bengal)

Surface Temperature (SST) analysis, level three monthly averaged nighttime SST data were obtained from MODIS satellite (4 km resolution) in NetCDF format, directly uploaded and visualized in QGIS[19] (Ver. 3.18) (Fig. 4). The colour pattern was manually modified for clarity.

Results and Discussion

Morphological details revealed the species as *Catostylus perezi*, Ranson 1945 (Cnidaria: Scyphozoa) (Fig. 2) which has a general distribution in the Arabian Peninsula extending up to the Arabian sea[12]. Abundance data indicated a mean presence of > 4 jellyfish per meter square with a maximum of 9 and a total of 45 (10 quadrats pooled) (Figs. 5, 6). The species appears from January to August on the coast of Pakistan and in the nearby region of Balochistan[17,20] and in general is seasonal, forming large congregations, appearing, and disappearing with an annual cycle[21]. However, observations made during the present study of large congregations might be due to several factors. Firstly, the proximity to the thermal power plant could be one reason. Earlier studies have shown that some marine species residing near nuclear power plants, *viz*. corals, either cope or die due to long-term exposure to increased SST[22]. Scyphozoans globally have been shown to benefit due to climate change-induced SST rise, pollution and eutrophication[6,7,23,24]. Secondly, most of the previous factors being interlinked, a decrease in SST can also trigger blooms[23]. SST in GoK ranges between 24 – 30 °C[26] and current observation being the winter months of December 2018, satellite imagery clearly shows water temperature much lower compared to the outer ocean (Fig. 3). Thirdly, the highly productive nature of the Arabian Sea is another factor which can

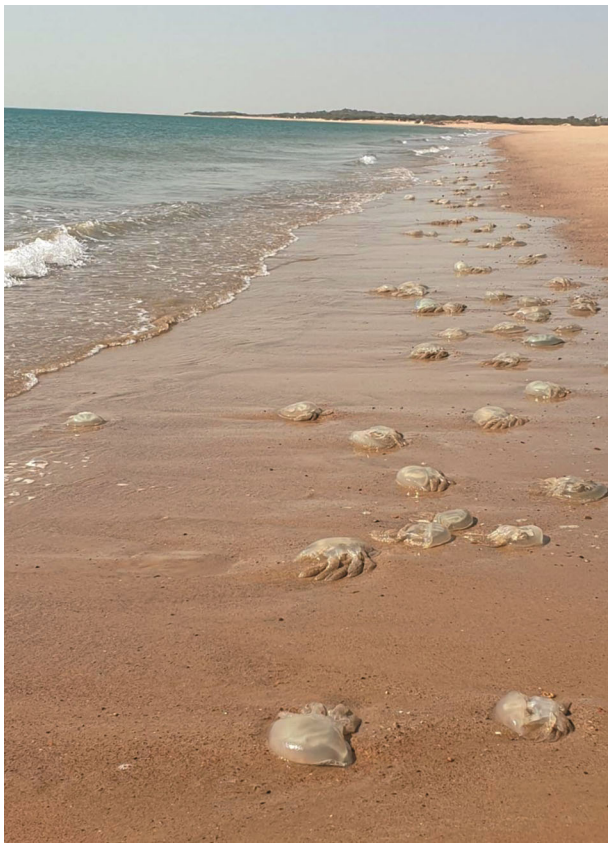

Fig. 2 — Stranding of jellyfishes (Catostylus perezi, Ranson 1945) on the Kathada beach along GoK, west coast of India

propel outbreaks. Being a highly productive region due to upwelling and convective mixing[27], an increase in phytoplankton blooms in the region[28] might lead to high jellyfish and ctenophores presence as they are chief consumers of zooplankton, including fish larvae, hence, a potential competitor of fish[28]. Sentinel 3 OLCI imagery has clearly shown the high chlorophyll content in the entire Gulf region, ranging from 0.05 – 33 mg m^{-3} (Uncertainty: 0.025 – 3.5 mg m^{-3}), and to our knowledge is the first known study to use 300 m resolution Sentinel 3 data in this region (Fig. 3). Even within the Southeastern Arabian Sea, increase in chlorophyll-*a* content has accounted for an increase in jellyfish abundance[25]. Lastly, ballast water discharge from the nearby ports may enhance the invasion of jellyfish in this area as two major ports are in a vicinity of 50 – 100 km (Fig. 1).

Along the coastal water of India (Table 1), jellyfishes are the prominent and less studied faunal group. However, the literature related to jellyfish blooms is increasing slowly. The first incident of such bloom was reported in Mumbai (Arabian Sea), where the outburst of ctenophores and medusa was observed coinciding with the enhancement of Pomfret catch[29] during October – December of 1959. Panda & Madhu[30] studied landing patterns of jellyfish in different trawling units on the Veraval coast

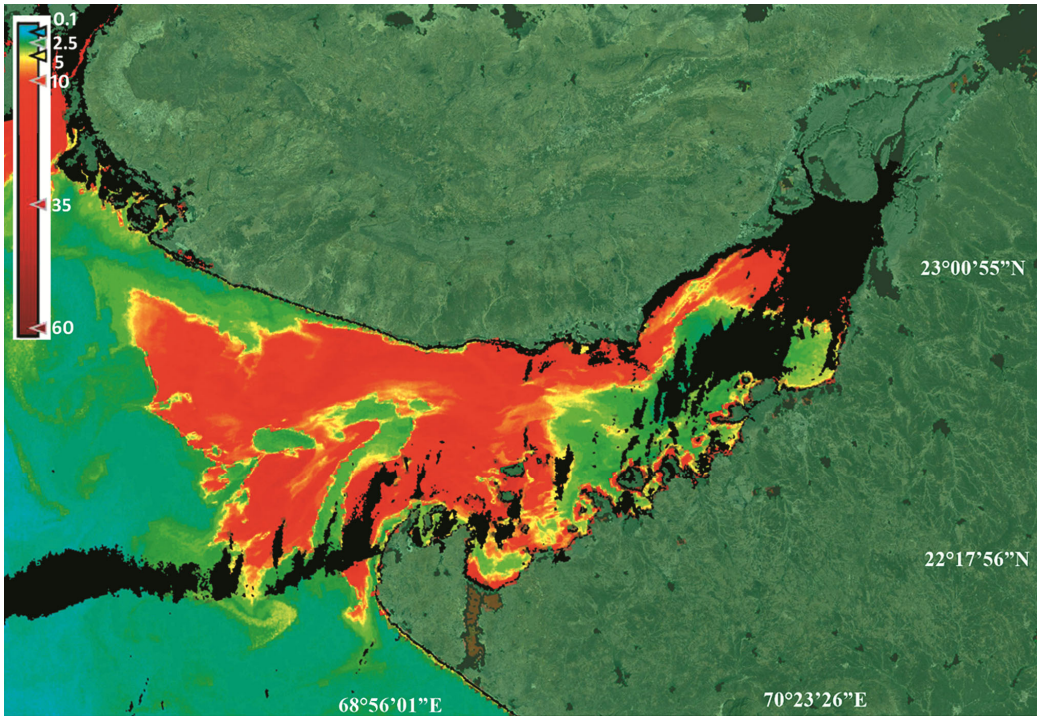

Fig. 3 — Chlorophyll concentration (mg m^{-3}, top left) as of December 30, 2018, indicating high productivity in the Gulf of Kutch region. Black regions: cloud cover

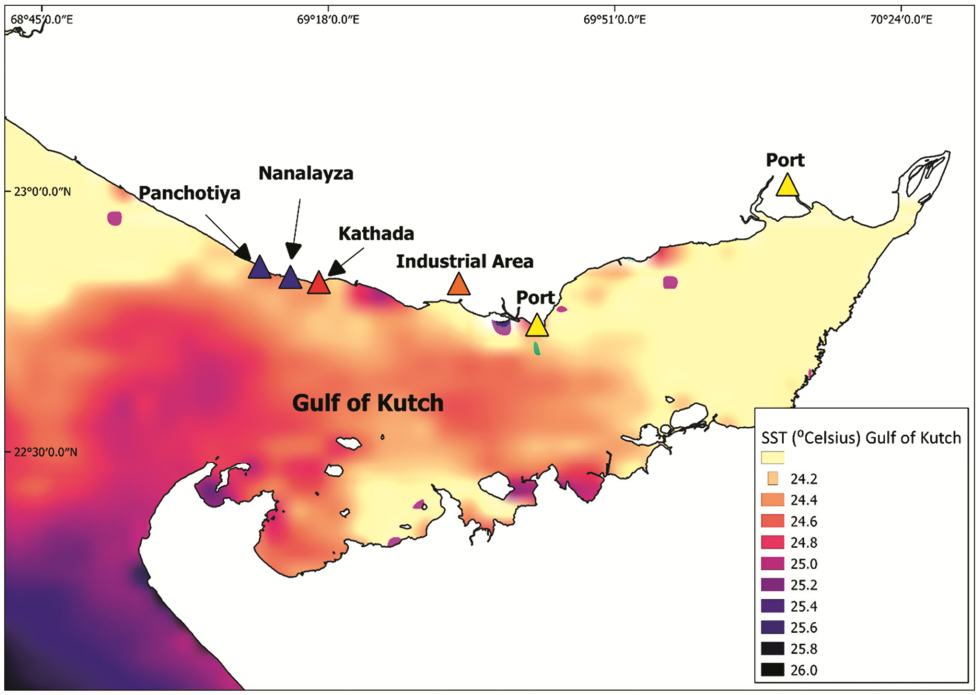

Fig. 4 — Sea surface temperature maps using AQUA-MODIS satellite imagery (Monthly Mean, December 2018)

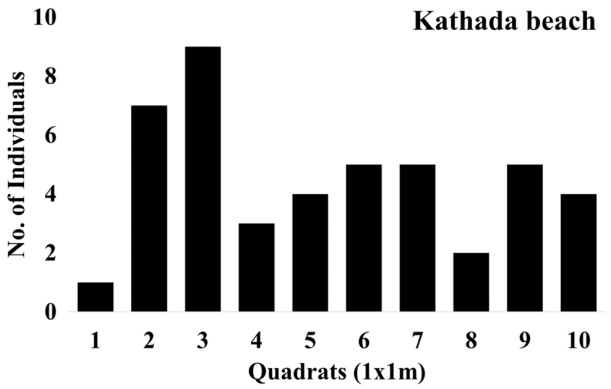

Fig. 5 — Abundance of Jellyfish in Kathada beach, GoK

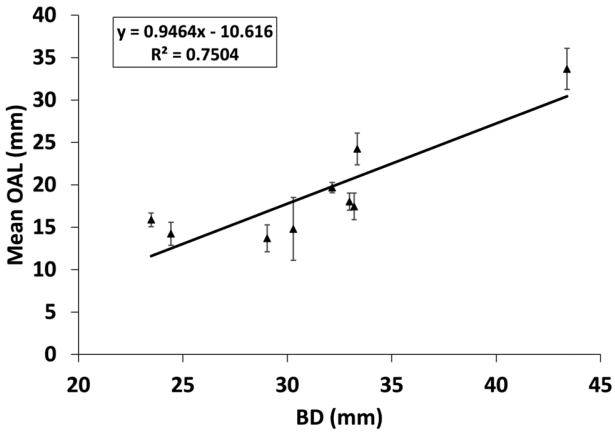

Fig. 6 — Linear regression showing a positive correlation between bell diameter and mean oral arm length (OAL)

(Gujarat). They observed the higher landing of jellyfish's post-monsoon. In Jakhau (Gujarat), there are seasonal blooms that led to harvesting[31]. Bottom trawling had high jellyfish occurrence than pelagic trawling. Some pelagic trawling has given 91 % of jellyfish of the total catch. They opined that heavy fishing pressure may ascend the jellyfish population. During December on the Kerala coast, an increasing number of jellyfish species *Cyanea* spp. was observed[32]. According to the report, the species was observed during November – December, however, now it is observed from August onwards. Bijukumar *et al.*[33,34] described jellyfish blooms encountered by fishermen of the Kerala coast of different types (Table 1).

Although not discussed in detail (Table 1), the east coast of India has also seen several outbreaks *viz*., in Kalpakkam coastal waters, where *Dactylometra quinquecirrha* Agassiz, 1862 (accepted as *Chrysaora quinquevir* (Desor, 1848)); *Crambionella stuhlmanni* (Chun, 1896); *Chiropsalmus buitendijki* van der Horst, 1907 (accepted as *Chiropsoides buitendijki* (van der Horst, 1907)) blooms have created considerable problems in powerplants[5,35]. Year-round occurrence of *C. stuhlmanni*, *D. quinquecirrha* (accepted as *C. quinquecirrha*), is noted in the Chennai coastal waters[11,36]. It is imperative to

highlight the presence of toxic *Pelagia noctiluca* (Forsskål, 1775) in the Rushikulya estuary (Odisha), which is known to create problems in tourism[37]. The same toxic species has also been recently reported from Hare & Manoli Island (Gulf of Mannar Marine National park, GMMNP, South India)[38]. Recently, off the coast of Visakhapatnam (Andhra Pradesh), the collection of 500 kg of *C. stuhlmanni* in a single haul created speculation that a tropical cyclone (Hudhud) might be responsible for its occurrence[39] as reported in the case of other organisms[40].

Conclusion

Although it becomes essential to understand the role of climate-driven jellyfish blooms globally, our regional observation highlights the need to assess the anthropogenic developments within the vicinity. Discharge from the nearby power plant might need to be evaluated in detail through water quality assessments to monitor the physio-chemical parameters. The need to determine invasive species through the nearby ports remains a priority. Additionally, more specimens should be analyzed for creating a more robust linear relationship in future studies. Finally, we suggest organizing citizen science programs to report blooms, which will significantly increase our knowledge on the topic within the Indian Ocean.

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Conflict of Interest

The authors declare that this work was done without any financial or competing interest.

Ethical Statement

This is to certify that the manuscript is original and has not been submitted elsewhere. This submission has been approved by all co-authors and has contributed sufficiently to share collective accountability for the results.

Author Contributions

DPB: Observation, data collection, conceptualization and writing – original draft. GT: Writing – reviewing and editing and funding acquisition. BKS: Writing – reviewing and editing. RRD: Writing – original draft, reviewing and editing, SST and chlorophyll maps and formal analysis.

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