



## Scyphozoan jellyfish diversity and distribution along the north-eastern Arabian Sea off Gujarat coast, India

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### ABSTRACT

Swarming of Scyphomedusae in large numbers in the Indian Ocean and specifically in the north-eastern Arabian Sea has been found to impact fishing operations; however, information on the diversity and distribution of these enigmatic jellyfishes are scanty. Hence, a study was carried out along the Gujarat coast, India during 2017-2020. Field surveys were conducted to identify the areas where jellyfish landings or swarming were regularly reported and locations viz. Jakhau, Okha, Porbandar, Veraval and Navabandar emerged as jellyfish focal stations. Fisher-assisted onboard surveys were conducted from the jellyfish focal stations. The results revealed the occurrence of six Scyphozoan jellyfish species viz, *Catostylus* cf. *perezi*, *Rhopilema hispidum*, *Cassiopea* cf. *andromeda*, *Cyanea* cf. *nozakii*, *Chrysaora* cf. *chinensis* and *Chrysaora* cf. *caliparea*, identified based on morphological characteristics. This study also mapped the diversity of these jellyfishes to understand the species-specific occurrences along the Gujarat coast which would form a baseline for further monitoring of potential changes in the swarming of jellyfishes.

Keywords: Gujarat coast, Jellyfish, North-eastern Arabian Sea, Scyphomedusae

### Introduction

The true jellyfish refers to the pelagic phase of the members of the Class Scyphozoa in the Phylum Cnidaria. Mass swarmings of jellyfish have been reported with multiple negative impacts on fisheries, aquaculture, tourism and other associated sectors (Richardson *et al.*, 2009; Dong *et al.*, 2010; Lucas *et al.*, 2014). With the growing consumption and utilisation of jellyfish as food, the global landings recently exceeded one million tonnes through fishing of 38 species by more than 19 countries (Omori and Nakano, 2001; Brotz, 2016; Brotz *et al.*, 2017). Citing evidence of ecological and economic consequences, continuous monitoring of the ecosystem is a must and should be a mandate to collect baseline information on medusae composition and distribution (Brodeur *et al.*, 2016; Schiariti *et al.*, 2018).

The diversity of jellyfish worldwide is unclear and is typically underestimated, due in part to the confusion in taxonomy of jellyfishes. The complications involved in their identification have led to a paucity of information about their distribution (Omori and Kitamura, 2004; Morandini and Marques, 2010; Jarms and Morandini, 2019). The diversity of the Scyphozoan jellyfish was largely ignored in India. The historical records of Menon (1930, 1936) and Nair (1951) were considered as the pioneering works. Thirty-four species of Scyphomedusae have been reported from India (Chakrapany, 1984).

Jellyfish are categorised as lesser-known animals in India (Venkataraman *et al.*, 2015); but assessments have shown increasing trends in the Indian large marine ecosystems (Brotz *et al.*, 2012). There were only a few reports on jellyfishes from the Indian region but the response has increased in such reportings recently (Baliarsingh, 2020; Behera *et al.*, 2020; Karunarathne and de Croos, 2020; Mondal and Devi, 2020). Reports on the Scyphozoan jellyfish diversity are increasing in the Indian Ocean region (Pourjomeh *et al.*, 2018). Mass deposition of jellyfish in the bottom has supported the mass swarming in the Arabian Sea (Billett *et al.*, 2006). The Scyphomedusae swarming in large numbers in the Indian Ocean and specifically in the north-eastern Arabian Sea impacted fishing operations (Kumawat *et al.*, 2021), but the diversity of these enigmatic jellyfishes is poorly known. Hence, a study on the diversity and distribution of the Scyphozoan jellyfish along the north-eastern Arabian Sea, off Gujarat coast, India was carried out which may serve as an inventory of jellyfish, supporting new investigations in this field.

### Materials and methods

Rapid field surveys were conducted along the coast of Gujarat to identify the areas where jellyfish swarming or landing was regularly reported which later emerged as the jellyfish focal stations (Jakhau,

Okha, Porbandar, Veraval and Navabandar) (Fig. 1). An enumeration-based survey schedule was used in the fisher-assisted random sampling (Uye *et al.*, 2017). Scoop nets were used onboard fishing vessels (gillnetters, bagnetters and trawlers) to collect jellyfishes from the focal stations during the study period from November 2017 to February 2020. Important points of observation were recorded for morphological and taxonomic characters (Table 1). The specimens were identified using original descriptions and available literature (Martellos *et al.* 2016; Jarms and Morandini, 2019) and classified as per the World Register of Marine Species (WoRMS, 2020). The collected specimens were preserved in a solution of 4% formalin in seawater with appropriate label and it was renewed after two weeks to ensure successful fixation. Representative samples were preserved and maintained at the Marine Biodiversity Museum of Veraval Regional Station of ICAR-Central Marine Fisheries Research Institute, Gujarat. The maps of the study locations were generated using QGIS 3.16 (QGIS, 2021).

## Results and discussion

The initial rapid field surveys along the coast of Gujarat revealed that the fishers have either witnessed swarming of jellyfishes or caught jellyfishes in various fishing gears as by-catch or for commercial purposes. Based on our preliminary observations, the fishing harbours *viz.* Jakhau, Okha, Porbandar, Veraval and Navabandar were considered as jellyfish focal stations (Fig. 1). The species encountered during the surveys revealed that Gujarat coastal waters are inhabited with swarming of six Scyphozoan species *viz.* *Catostylus cf. perezii* Ranson, 1945 (Fig. 2); *Rhopilema hispidum* (Vanhoffen, 1888) (Fig. 3); *Cassiopea cf. andromeda* (Forsk., 1775) (Fig. 4); *Cyanea cf. nozakii* Kishinouye, 1891 (Fig. 5); *Chrysaora cf. chinensis* Vanhoffen, 1888 (Fig. 6) and *Chrysaora cf. caliparea* (Reynaud, 1830) (Fig. 7)

Table 1. Morphological features and points of observations used for jellyfish identification

| Morphological feature | Points of observation                          |
|-----------------------|------------------------------------------------|
| Bell                  | Bell diameter; surface (rough/smooth); pattern |
| Lappet                | Rhopalial and velar (number); shape            |
| Rhopalia              | Number                                         |
| Tentacles             | Present/absent; number                         |
| Manubrium             | Pattern; mouth opening; oral pillars           |
| Oral arms             | Length; number; gross morphology; shape        |
| Scapulae              | Number; pattern                                |
| Terminal clubs        | Shape and size                                 |
| Filaments             | Density and length                             |
| Gastrovascular cavity | Pouch shape; number                            |
| Sub-genital ostia     | Shape and number                               |
| Papillae              | Shape and number                               |
| Canal network         | Pattern; connections                           |
| Muscles               | Coronal and radial (pattern)                   |
| Gonads                | Shape; colour                                  |

belonging to five different genera under five different families, identified based on their morphological characteristics. The distribution of Scyphozoan jellyfishes along the Gujarat coast is illustrated in Fig. 8.

*Catostylus cf. perezii* Ranson, 1945

### Systematics

Phylum: Cnidaria Hatschek, 1888

Class: Scyphozoa Goette, 1887

Subclass: Discomedusae Haeckel, 1880

Order: Rhizostomeae Cuvier, 1800

Suborder: Daktyliophorae Stiasny, 1920

Family: Catostylidae Claus, 1883

Genus: *Catostylus* Agassiz, 1862

Species: *Catostylus cf. perezii* Ranson, 1945 (Fig. 2).

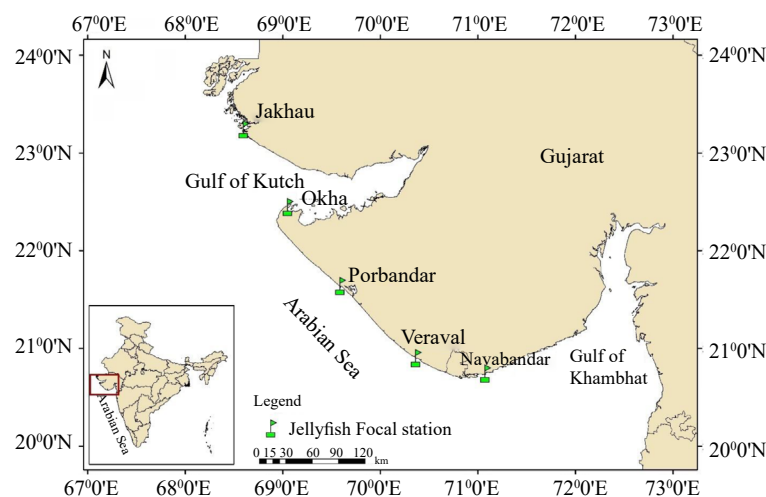


Fig. 1. Map showing the study location



Fig. 2. *C. cf. perezii* Ranson, 1945. (a) Dorso-lateral view and (b) Ventral view

### Observations

Total number of collected individuals: 6096; bell diameter range: 2.6-29.8 cm (mean 20.5 cm); wet weight range: 4-1822 g (mean 1120 g); gear used: scoop net; distribution: off Jakhau and Gulf of Kutch (GoK) (Fig. 8). Local name: Banana *jhar* (the term *jhar* used for jellyfish in Gujarati).

Umbrella hemispherical in shape. Exumbrella smooth at central but rough on marginal lappets with many small papillae outspread in rows; 96-128 pointed marginal lappets (12-16 per octant) (velar lappets coupled with a thin membrane and very small rhopaliar lappets without papillae). Eight rhopalia in the exumbrellar groove. The gastrovascular system comprises of 16 radial canals (eight rhopaliar and eight inter-rhopaliar). The intra-circular anastomosing canal network is linked to the ring canal and with rhopaliar and inter-rhopaliar radial canals. No primary mouth opening. Medusae with three-winged eight mouth arms, adradial triangular shaped and without any appendages which are longer or equal to the bell radius. One sub-genital cavity has four widespread sub-genital ostia consisting of white-creamy grey clouded cruciform gonads. Bluish white to cloudy white coloured medusa in life.

### Remarks

The family Catostylidae includes non-scapulate medusae of the Daktyliophorae (refers to circular, ring-shaped typical primordial ring canal), holds three-winged triangular mouth arms. The *Catostylus* genus is known for three-winged eight mouth arms without any appendages and rough marginal lappets on exumbrella (Martellos *et al.*, 2016; Jarms and Morandini, 2019). The *Catostylus* genus contains 10 accepted species at present and the distinguishing morphological features of *C. cf. perezii* medusae collected during the present study were in agreement with literature reports (Ranson, 1945; Kramp, 1956; Gul and Morandini, 2013; Jarms and Morandini, 2019). The distribution of the species has been documented along the south-coast of the Arabian Peninsula/Persian Gulf (Ranson, 1945); the Persian Gulf, the coast of Iran (Kramp, 1956), and the Pakistan coast (Gul and Morandini, 2013; Waryani *et al.*, 2015). The presence of catostylid medusae

in the northern Arabian Sea was also reported by Pourjomeh *et al.* (2018) and Riyas *et al.* (2019) recently. The present study revealed that *C. cf. perezii* is distributed off Jakhau and the GoK along the Gujarat coast, India.

*Rhopilema hispidum* (Vanhoffen, 1888)

### Systematics

Suborder: Daktyliophorae Stiasny, 1920

Superfamily: Rhizostomatoidea Cuvier, 1800

Family: Rhizostomatidae Cuvier, 1800

Genus: *Rhopilema* Haeckel, 1880

Species: *Rhopilema hispidum* (Vanhoffen, 1888) (Fig. 3).

### Observations

Total number of collected individuals: 1610; bell diameter range: 11.2-95 cm (mean 60.8 cm); wet weight range: 87-7950 g (mean 3580 g); gear used: scoop net; distribution: in and around the GoK (Fig. 8). Local name: Flower *jhar*.

Very large scapulate; hemispherical/dome-shaped medusa; less thick mesoglea at the central part. Well developed subumbrellar circular muscles. Rough surfaced exumbrella consists of two types of warts: small (colourless with rounded tips) and large (brownish with pointed tips) abundant near the margin and gradually less towards the bell top. Eighty marginal lappets (eight large rounded adjoined velar lappets and two pointed small rhopaliar lappets per octant) with tiny uneven vertical lines on the surface. Eight rhopalia. No primary mouth opening. The three-winged J-shaped eight-mouth arms fused up to half of the length in an adradial position with 16 scapulets without spaces. The length of mouth arms was 2/3 long of bell diameter consisting of plentiful digitate and club-shaped appendages and long whip strands at the arm disk. The gastrovascular system comprises of 16 radial canals. Ring canal absent. The anastomosing canals are connected only with rhopaliar canals. Four subgenital ostia with one large and two small papillae. Sandy-white coloured medusa with inflated brownish rough acnes on top and margin of exumbrella.



Fig. 3. *R. hispidum* (Vanhoffen, 1888). (a) Dorso-lateral view and (b) Ventral view

### Remarks

The family Rhizostomatidae includes scapulate medusae (refers to elongate areas of dense mouthlets near the base of the mouth arms) of the Daktyliophorae, holds three-winged mouth arms fused at the basal portion. The family contains four accepted genera and the *Rhopilema* genus is known by scapulate medusae with terminal fusiform and/or filamentous appendages at mouth arms (Martellos *et al.*, 2016; Jarms and Morandini, 2019). The *Rhopilema* genus contains six accepted species at present. The distinguishing morphological features of *R. hispidum* medusae corresponded with that of available reports (Vanhoffen, 1888; Kishinouye, 1899; Light, 1914; Jarms and Morandini, 2019). Distribution of the species has been documented from Hong Kong (Vanhoffen, 1888); Nagasaki (Kishinouye, 1899); Philippines (Light, 1914); South-east coast of India (Menon, 1936; Panikkar and Prasad, 1952); Red Sea (Vine, 1986) and Pakistan waters (Gul and Morandini, 2015). The species reported in the by-catch study off Veraval by Panda and Madhu (2009) is likely to be *R. hispidum*. The present study revealed that *R. hispidum* is distributed in the GoK along the Gujarat coast, India.

*Cassiopea* cf. *andromeda* (Forsk., 1775)

### Systematics

Suborder: Kolpophorae Stiasny, 1920

Infraorder: Kamyliomyaria Stiasny, 1920

Family: Cassiopeidae Tilesius, 1831

Genus: *Cassiopea* Peron and Lesueur, 1810

Species: *Cassiopea* cf. *andromeda* (Forsk., 1775) (Fig. 4).

### Observations

Total number of collected individuals: 2090; bell diameter range: 1.1-13 cm (mean 8.9 cm); wet weight range: 0.44-88 g (mean 56.2 g); gear used: scoop net; distribution: restricted to Arambhada and Okha (Fig. 8). Local name: *Taliyo jhar* (due to upside-down position).

Disk-shaped flat umbrella; Short and rounded 1-11 marginal lappets between rhopalia; 11-22 (usually 16)

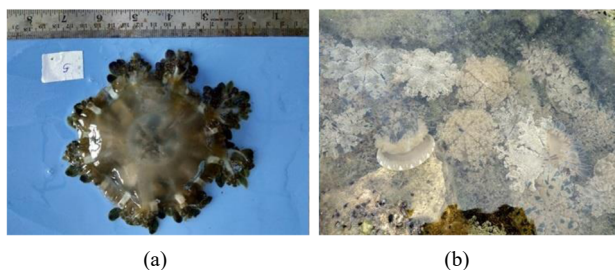


Fig. 4. *C. cf. andromeda* (Forsk., 1775). (a) Dorsal view and (b) Ventral view

rhopalia vary in number. Eight flat-wide mouth arms in adradial linear position, tree-like branching at edges. Several minor and few large club-shaped vesicles on each arm. No primary mouth opening but visible in ephyra; Gastrovascular system containing 16 radial rhopaliar canals and 16 inter-rhopaliar canals (may vary due to the number of rhopalia) having typical anastomosing network linked with side branches. No clear ring canal. Four subgenital ostia; gonads have four tissue clouds. Medusa colour brownish or bluish-green with white spots at the margin and dark radial belts and the colour forms enormously changeable due to presence of zooxanthellae.

### Remarks

The family Cassiopeidae includes Kolpophorae (refers to bulges of the primordial gastric sinus) medusae in Kamyliomyaria (refers to curved muscle strands that traverse the umbrella in feather-like arcs). The family contains only one accepted genus *Cassiopea* Peron and Lesueur, 1810; which is known by the typical network of gastrovascular anastomosing canals (Martellos *et al.*, 2016; Jarms and Morandini, 2019). *Cassiopea* genus contains 10 accepted species presently. *C. andromeda* (Forsk., 1775) was originally named *Medusa andromeda* Forskal, 1775. The distinguishing morphological features of the observed medusae were in agreement with literature reports (Forsk., 1775; Vanhoffen, 1888; Maas, 1903; Richmond, 1997; Zenetos *et al.*, 2010; Prasade *et al.*, 2016; Jarms and Morandini, 2019). The species has been reported from Suez Canal, Egypt and the Red Sea (Vanhoffen, 1888; Vine, 1986); India (Rao, 1931); the Mediterranean Sea and Indo-West Pacific (Morandini *et al.*, 2017). Similar to a previous report (Prasade *et al.*, 2016), the species is found to have a very restricted distribution in Arambhada and Okha shallow coastal waters off Gujarat, India.

*Cyanea* cf. *nozakii* Kishinouye, 1891

### Systematics

Order: Semaestomeae Agassiz, 1862

Family: Cyaneidae L. Agassiz, 1862

Genus: *Cyanea* Peron and Lesueur, 1810

Species: *Cyanea* cf. *nozakii* Kishinouye, 1891 (Fig. 5).



Fig. 5. *C. cf. nozakii* Kishinouye, 1891. (a) Dorso-lateral view and (b) Dorsal view

### Observations

Total number of collected individuals: 1867; bell diameter range: 7.3-49.1 cm (mean 36.7 cm); wet weight range: 190-4950 g (mean 1890 g); gear used: scoop net; distribution: majority off Navabandar and few in the GoK (Fig. 8). Local name: *Safed jhar* (White jellyfish).

Medium-large flat-wide whitish medusa, with consistently smooth exumbrella. Sixteen round marginal lappets; Eight rhopalia without ocellus. Numerous (110-150) tentacles beyond bell diameter are organised in eight horseshoe-shaped long wide parallel clusters in the subumbrella. Folded curtain-like fragile oral arms somewhat longer than bell diameter. The gastrovascular cavity is separated into 16 rectangular stomach pockets by raised radial septa. Radial septa are repeatedly interrupted along their length. The anastomosing canals are dense at the margin. Well-developed musculature, with 16 proximal and 16 distal radial fields. Four folded gonads in the subumbrella.

### Remarks

The family Cyaneidae includes semaeostome (refers to four bundled mouth arms) medusae. Central stomach raised to 16 radiating pouches separated by septae and tentacles arising in rows. Family Cyaneidae contains only two accepted genera. The genus *Cyanea* is known by tentacles arising from horseshoe-shaped clusters on the subumbrellar surface and gastrovascular cavity divided by radial septa forming 16 gastric pouches and radial muscles in the subumbrella (Martellos *et al.*, 2016; Jarms and Morandini, 2019). Genus *Cyanea* contains 17 accepted species. The distinguishing morphological features of the observed medusae corresponded with literature reports (Kishinouye, 1891; Chen, 1982; Jarms and Morandini, 2019). Distribution of the species has been recorded from the Inland Sea, Japan (Kishinouye, 1891); India (Rao, 1931) and a recent report from Iran (Pourjomah *et al.*, 2018). The present study revealed that the species has patchy distribution off Navabandar and a few locations in the GoK along the Gujarat coast with majority coming in bag nets.

*Chrysaora cf. chinensis* Vanhoffen, 1888

### Systematics

Order: Semaestomeae Agassiz, 1862

Family: Pelagiidae Gegenbaur, 1856

Genus: *Chrysaora* Peron and Lesueur, 1810

Species: *Chrysaora cf. chinensis* Vanhoffen, 1888 (Fig. 6).

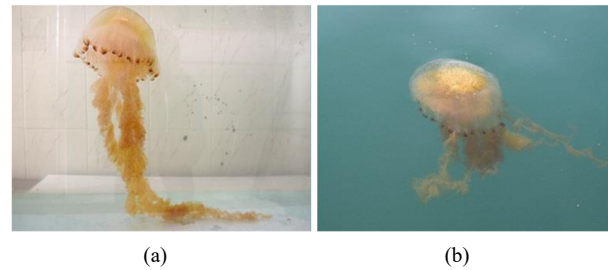


Fig. 6. *C. cf. chinensis* Vanhoffen, 1888. (a) Dorso-lateral view and (b) Dorsal view

### Observations

Total number of collected individuals: 190; bell diameter range: 9.7-32 cm (mean 24.3 cm); wet weight range: 350-1950 g (mean 1450 g); gear used: scoop net; distribution: rare to occasionally distributed off Veraval, Porbandar and in the GoK (Fig. 8). Local name: *Soneri jhar* (due to the golden-yellowish colour of the umbrella).

Medium-sized dome-shaped medusa; exceptionally granulated light yellow/golden-reddish exumbrella surface with numerous nematocyst warts. Thick mesoglea at the centre. Reddish/brownish spots spread evenly on the arms. Four elongated studded frilled mouth arms 2-4 times longer than the bell diameter, making curtain-like spirals/folds at edges. Four to six stretched marginal lappets per octant arising from clefts between marginal lappets with reddish-brown coloured edges; 3-5 tentacles per octant. Eight rhopalia. The gastrovascular system contains 16 pouches (large tentacular and narrow rhopalar pouches). Papillae and network of canal absent. No ring canal. Four folded semi-circular gonads.

### Remarks

The family Pelagiidae includes semaeostome medusae that hold four mouth arms and the central stomach connected with radial pouches separated by radial septae. Other distinguishing characteristics include exumbrella covered with numerous nematocyst warts, no canal system and no ring canal. Family Pelagiidae contains four accepted genera and the *Chrysaora* genus is known for 16 gastric pouches of different sizes, rhopalar pouches narrower near margin than the tentacular pouches, bending radial septae and more than 24 tentacles and eight rhopalia (Martellos *et al.*, 2016; Jarms and Morandini, 2019). The *Chrysaora* genus contains 17 accepted species presently and the distinguishing morphological features of *C. cf. chinensis* medusae recorded during the present study corresponded with literature reports (Vanhoffen, 1888; Morandini and Marques, 2010; Nicholas and Yong, 2012; Jarms and Morandini, 2019; Low *et al.*, 2019). The distribution has been recorded from the South China Sea, Indo-Pacific (Vanhoffen, 1911; Morandini and

Marques, 2010) and a recent report in Chabahar Bay, Iran (Pourjomah *et al.*, 2018). The present study revealed that the species is distributed off Veraval, Porbandar and some parts of the GoK along the Gujarat coast, India.

*Chrysaora* cf. *caliparea* (Reynaud, 1830)

#### Systematics

Species: *Chrysaora* cf. *caliparea* (Reynaud, 1830) (Fig. 7).

#### Observations

Total number of individuals collected: 506; bell diameter range: 6.5-27 cm (mean 21.6 cm); wet weight range: 220-1600 g (mean 1290 g); gear used: scoop net; distribution: rare to occasionally distributed off Veraval, Porbandar and in the GoK (Fig. 8). Local name: *Bhuri chhattri* (due to prominent brown radiating bands on the umbrella).

Medium-sized brownish medusa; 32 prominent dark-brownish rounded marginal lappets (four per octant). 3-5 tentacles per octant. Eight rhopalia. Remarkably granulated brown-reddish exumbrella surface with numerous nematocyst warts and 16 prominent radiating

dark brown bands slightly faded near marginal and at the top. Brownish spots spread evenly on the arms. Four elongated studded frilled mouth arms 6-7 times longer than the bell diameter, making curtain-like spirals/folds at edges. The gastrovascular system contains 16 pouches (large tentacular and narrow rhopalar pouches). Papillae and network of canals absent. No ring canal. Four folded semi-circular gonads.

#### Remarks

*Chrysaora* cf. *caliparea* (Reynaud, 1830) was originally named *Medusa (Cyanea) caliparea* Reynaud, 1830. The morphological features of observed medusae were in agreement with literature reports described as *Medusa (Cyanea) caliparea* Reynaud, 1830; *Chrysaorae reynodii* Brandt, 1835; *Cyanea caliparea* Lesson, 1843; *Stenoptycha caliparea* L. Agassiz, 1862; *C. calliparea* Haeckel, 1880; *C. helvola* var. *calliparea* Mayer, 1910; *C. callipara* Vannucci, 1954; *C. caliparea* Morandini and Marques, 2010 (Jarms and Morandini, 2019; WoRMS, 2020). Predation and prey selectivity of this species has been reported from the South-east Indian waters (Kanagaraj *et al.*, 2011). Though, there is taxonomical confusion about *Chrysaora* species due to the complex mix of morphological features which make the distinction between some species difficult as specified by Morandini and Marques (2010) which needs to be confirmed with further investigations with the support of molecular data. The geographical distribution was primarily contained in Pondicherry coast, India. Though it was stated that the species is present in the Indian Ocean (Jarms and Morandini, 2019), no detailed reports are available from the Red Sea and Arabian Gulf (Morandini and Marques, 2010).

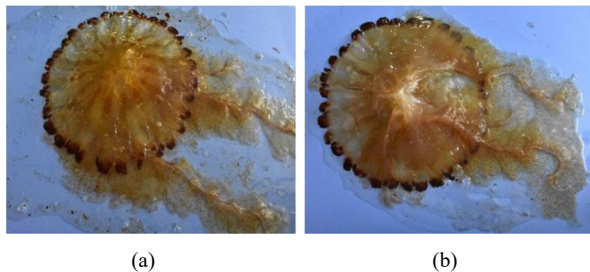


Fig. 7. *C. cf. caliparea* (Reynaud, 1830). (a) Dorsal view and (b) Ventral view

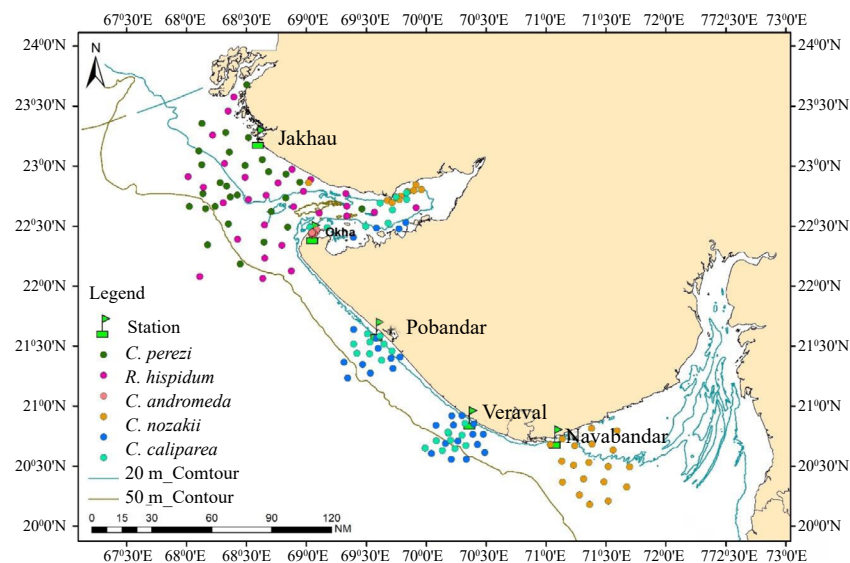


Fig. 8. Distribution map of Scyphozoan jellyfish species along the north-eastern Arabian Sea off Gujarat coast, India

The distribution pattern of species may change based on the new data, previous misidentifications, revisions of taxa, or, quite naturally, on invasions by natural or anthropogenic means (Jarms and Morandini, 2019). The study with taxonomic documentation of these diverse enigmatic species may serve as a baseline for jellyfish research, supporting new investigations in this field. The diversity and distribution of Scyphozoan jellyfishes illustrated through the map may further support to study the swarming dynamics and their interactions with fishing.

### Acknowledgements

Authors express their sincere thanks to the Director, ICAR-CMFRI, Kochi and Scientist-in-Charge, Veraval Regional Station of ICAR-CMFRI for providing facilities and support for research work, and to the Director, ICAR-CIFE, Mumbai for permitting Ph. D. studies of the first author. The work was funded by ICAR-CMFRI (Project Code: MBD/JLY/32). Authors also thank the fishers for their help during the research work.

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