Temporal and spatial occurrence of jellyfish species along the coastal area of the United Arab Emirates

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ABSTRACT: Dramatic spatial and temporal shifts in jellyfish distributions have been reported worldwide over the past few decades. The coastal region of the United Arab Emirates (UAE) has experienced a number of blooms and the negative economic impacts associated with them. The present study aims to identify the diversity in jellyfish species along the coast of the UAE during a study period that extended from December 2019 until August 2022. Six genera belonging to two cnidarian classes (i.e., Scyphozoa and Cubozoa) have been identified. These include five scyphozoans i.e., *Catostylus mosaicus, Cassiopea andromeda, Aurelia* spp., *Chrysaora quinquecirrha, Cephea cephea* and one cubozoan i.e., *Copula sivickisi*. The spatial and temporal occurrence of all identified species are discussed in relation to monthly water temperature variations during the study period. Although the present study provides the first available information about jellyfish diversity along the UAE coast, further studies are still needed, with a special focus on the reproductive biology of the bloom-forming jellyfish.

KEYWORDS: Jellyfish outbreak; Cnidaria; diversity; Indian Ocean; seasonality

1 INTRODUCTION

Jellyfish are cosmopolitan gelatinous macro zooplankters which belong to the phylum Cnidaria (Arai, 1997). In recent years, frequent out-breaks have been experienced worldwide in a number of coastal areas, whereby the ecology and economy of these blooming locations have been seriously affected (Hays et al., 2018). Jellyfish are known to directly impact tourism, the fishing industry, and aquaculture. What is more, blooms have caused several power plant outages when they started to clog the pump filters of the water inlets of coastal power and de-salination plants (Tinta et al., 2021). Besides these direct negative effects, there are many other indirect consequences on fisheries, in that these species feed on ichthyoplankton and can act as strong predators as well as potential competitors of fish (Han et al., 2022). Jellyfish can cope with a large spectrum of harsh environmental conditions and are considered powerful players in several coastal, estuarine, and other open-water ecosystems (Mills, 1995; J. Purcell et al., 2007; Richardson et al., 2009; J. E. Purcell, 2012). Over-fishing, eutrophication, species invasion and climate change have been highlighted as the potential causes of jellyfish blooms (J. Purcell, 2005; Briggs, 2007; Schnedler-Meyer et al., 2018; Goldstein & Steiner, 2020).

The Arabian/Persian Gulf is a shallow and geologically young coastal basin located in the southwest of the Asian continent, bordered by eight fast-developing countries including the United Arab Emirates (UAE) (Vaughan et al., 2018). Water mass exchange and circulation in the Gulf is controlled primarily by the combined action of winds, heat flux, freshwater flux and river discharge, tides, and the limited exchange with the open ocean through the Strait of Hormuz (Al Azhar et al., 2016). Surface waters enter the Gulf through the Strait of Hormuz and move northwest along the Iranian coast before turning to south near the Kuwait/Saudi Arabia border. Prior to its outflow from the Gulf, the water

travels along the western and southern coastline of the UAE, with different physical and chemical features compared with the in-flow water (Vaughan et al., 2018). The Gulf is considered the hottest sea on the planet during summer, when surface water temperatures exceed 35°C. Indeed, the water can reach up to 38°C in the coastal region of the UAE in summer and drop down to 15°C in winter (Alsharhan & Kendall, 2003; Hamza & Munawar, 2009). The average salinity of nearshore waters ranges from 42.7 to 44.5 ppt, whereas that of lagoonal waters and the central part of the Gulf can be as high as 53.6–66.9 ppt and 37–40 ppt, respectively (Alsharhan & Kendall, 2003). The UAE coastal region receives an average rainfall of less than 40 mm per year, primarily during the seasons of winter, autumn, and spring (Hamza & Munawar, 2009). While recent studies have shown an increase in the number of jellyfish populations world-wide, the latest available information indicates that their abundance fluctuates with climatic cycles (Richardson et al., 2009). However, few data are available from the tropics, an area that features great scyphozoan diversity (R. Daryanabard & Dawson, 2008). The main objective of our study was to identify jellyfish species collected within two consecutive years together with their spatial and temporal occurrence in the coastal area of the UAE as monthly water temperatures changed.

2 MATERIALS AND METHODS

2.1 *Study area*

The study was conducted along the coastal area of the UAE in the Arabian/Persian Gulf and the Sea of Oman, which are connected through the Strait of Hormuz (Figure 1). The samples were collected from the shoreline out to a seaward extension of approximately 5 km over a period ranging from December 2019 until August 2022,

2.2 *Sampling*

Monthly jellyfish samples were collected during opportunistic encounters using a 1-mm-mesh hand net primarily from the coastal waters of Abu Dhabi (24°06′27.8″N 53°28′07.4″E), Dubai (25°23′53.7″N 55°07′48.6″E), Ras Al Khaimah (25°89′05.1″N 56°02′06.8″E), Fujairah (25°07′36.1″N 56°23′05.3″E), Ba Al Ghaylam Island (24°32′00.8″N 54°34′28.8″E), and Sir Bu Nair Island (25°13′51.8″N 54°14′47.0″E) (Figure 1). All above-mentioned locations had previously experienced jellyfish aggregations. Opportunistic or emergent sampling performed during the study period was also based on information provided by local fishermen. Each site, consisting of semi-enclosed areas (such as harbors, bays, and coastal lagoons) whose domain ranged from two to five square kilometers, was sampled every four to six hours. Surface-water jellyfish sampling was carried out by a long hand (2 meters) net, measuring 50 cm in diameter and with a mesh size of 2 mm. Sometimes, snorkeling was necessary to collect individuals at depths exceeding 2 meters. Local fishermen and residents also aided in sample collection, as they granted access to their available sampling equipment. During this activity, specimen collectors used a digital aqua thermometer to measure the water temperature of each sampling location to the nearest 0.1°. Photographs of the specimen were taken during collection. Later, the collected samples were transferred to the laboratory in ice boxes for further processing.

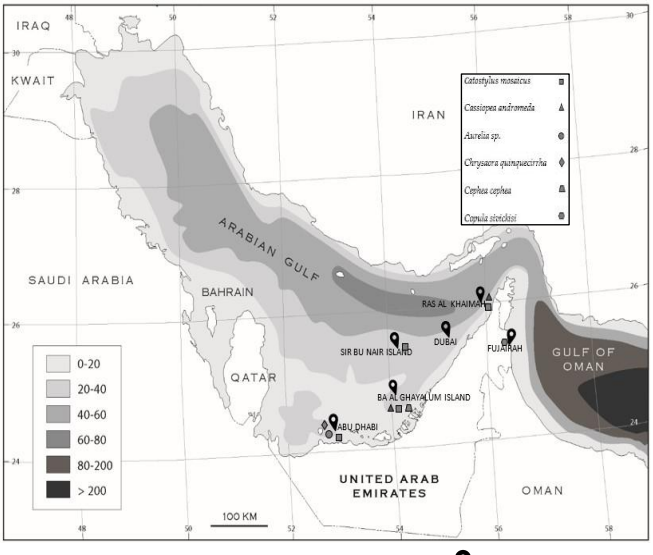

Figure1: Map of sampling locations ( ) and species distribution along the study coastal area. (Adapted from Hamza and Munawar, 2009)

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2.3 *Morphological identification*

A flexible measuring tape was used to measure the bell diameter of each specimen. Color patterns on the bell, gonad, and tentacles of the sample were noted. To identify which species the specimen belonged to, reference was made to the morphological characteristics described in the World Atlas of jellyfish and the jelly-watch project (CIESM 2014; Jarms & Morandini, 2019). Correlation between temperature and bell diameter was investigated in each species by estimating the Spearman's rank correlation coefficient since the size cluster showed a non-parametric correlation against the abundance.

3 RESULTS

Based on the morphological analysis, six genera from two Cnidarian classes were encountered over the course of study (Table 1). Barring one exception, there was a single species within each genus. However, in the case of Aurelia, it was not possible to determine exactly whether one or more species were represented.

Occurrence of jellyfish species fluctuated during the study period (Figure 2). *Catostylus mosaicus* was the most encountered species year in the study area all year round (Figure 3b). Different color morphs of *C. mosaicus* such as light blue, and creamy white were encountered during the study period (Figure 4). However, the most abundant color was light-blue, a variety primarily found on the coasts of Ras Al Khaimah and Abu Dhabi and in Ba Al Ghayalam Island. An aggregation of hundreds of instances of this variant was reported in the port of Ras Al Khaimah and on the coast of Al Jazirah Al Hamra during the latter half of March 2020. In September, another collection of the white color morph was observed in Sir Bu Niar Island.

Table 1: Identified species and their taxonomic rankings.

Species	Class	References
Catostylus mosaicus	Scyphozoa	Forskål, 1775
Cassiopea andromeda	Scyphozoa	Quoy & Gaimard, 1824
Aurelia spp.	Scyphozoa	Linnaeus, 1758
Chrysaora quinquecirrha	Scyphozoa	Desor, 1848
Cephea cephea	Scyphozoa	Forskål, 1775
Copula sivickisi	Cubozoa	Stiasny, 1926

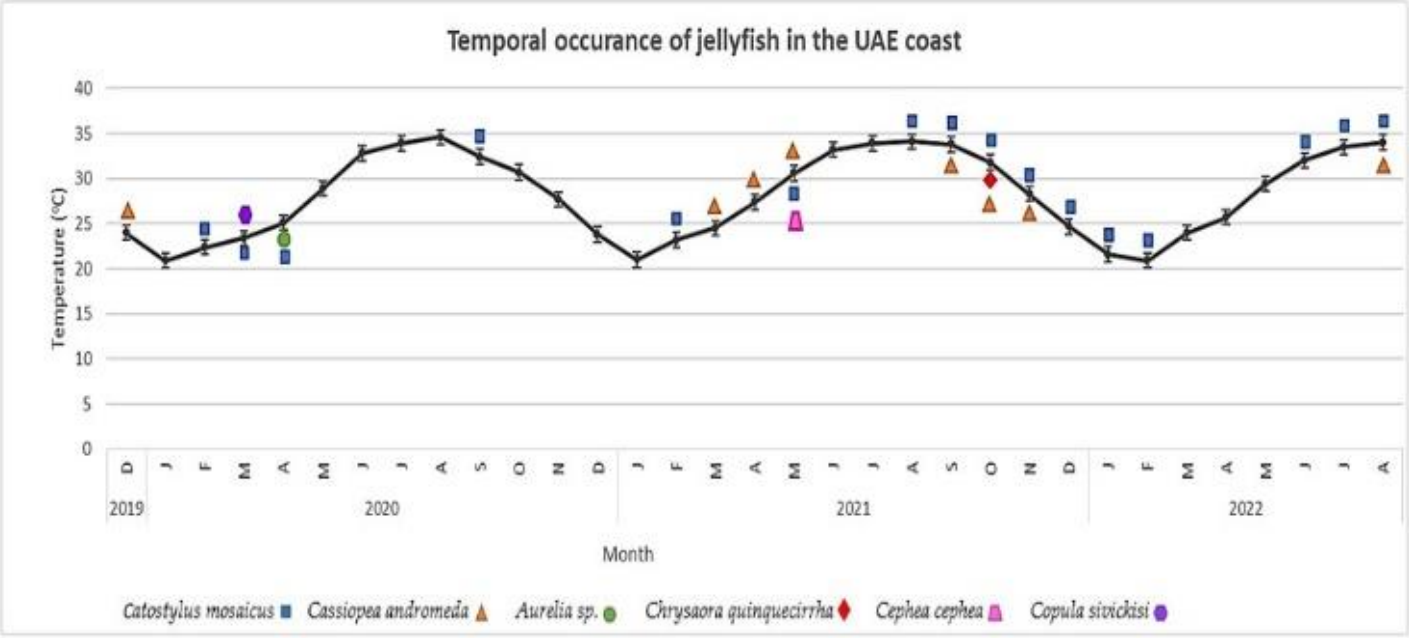

Figure 2: Water temperature measured and temporal occurrence of jellyfish species along the UAE coast during the study period from December 2019 to August 2022.

Figure 3: Jellyfish species identified along the UAE coastal area (a) *Cassiopea andromeda* (b) *Catostylus mosaicus* (c) *Aurelia* spp.(d) *Chrysaora quinquecirrha*, (e) *Cephea cephea*, and (f) *Copula sivickisi*.

Cassiopea andromeda was the second most common species during the study (Figure 3a). It appeared as a group of hundreds, in Al Marjan Island, Ras Al Khaimah, between April and May both in 2020 and 2021. In Ba Al Ghayalam Island, individuals of same species were spotted in late October 2021.

The remaining taxa (*Aurelia* spp., *Chrysaora quinquecirrha, Cephea cephea* and *Copula sivickisi*) were encountered sporadically. An aggregation of *Aurelia* spp. was observed in Abu Dhabi in April 2020 (Figure 3c) whereas *Chrysaora quinquecirrha* was spotted as a single specimen from the port of Abu Dhabi in October 2021 (Figure 3d). An individual of *Cephea cephea* was found in Ba Al Ghayalam Island in May 2021 (Figure 3e). The venomous box jelly *Copula sivickisi* was encountered during a dive in the coastal waters of Fujairah (Sea of Oman) in March 2020 (Figure 3f).

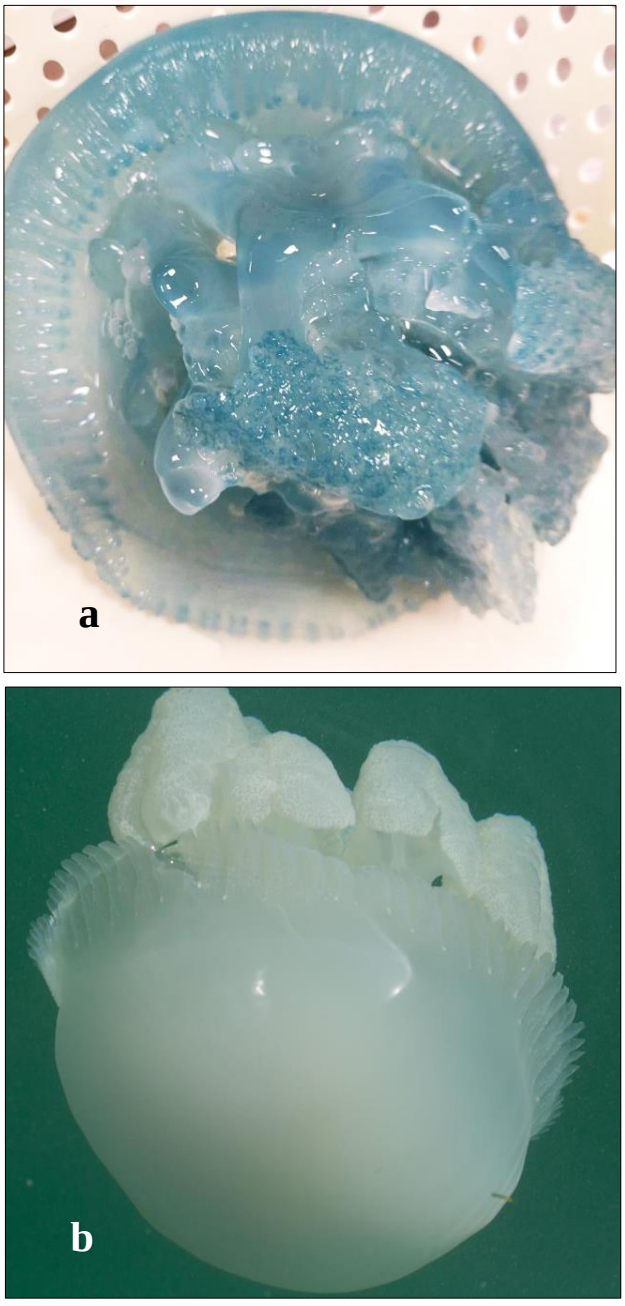

Figure 4: Two different colour morphs of *C. mosaicus* encountered during the study period. (a) Light blue, (b) Creamy white

Table 2 and figure 5 show the bell diameter of specimens measured in the two most encountered species along with average monthly temperature during the study period.

No correlation was found between bell diameter and average monthly temperature in the case of *C. mosaicus* (Spearman rank correlation, $n = 130$, $p > 0.05$). However, a strongly significant correlation was found in the case of *C. andromeda* (Spearman rank correlation, $n = 90$, $p < 0.01$). In fact, during cool months it exhibited a decreased diameter, followed by an increase in warmer months.

Table 2: Monthly average bell diameter of *C. mosaicus and C. andromeda* (2 dominant species) and average water temperature along the UAE coast during the study period

Month	Average water temperature	Average bell diameter of *C.mosaicus*	Sample size of *C.mosaicus*	Average bell diameter of *C .andromeda*	Sample size of *C. andromeda*
January	20.8	14.3	9	-	-
February	22.1	13.9	14	5.6	12
March	24	11.3	12	10.9	10
April	26.1	12.4	11	13.6	14
May	29.6	14.1	14	14.4	8
June	32.7	15.9	9	-	-
July	33.7	14.9	11	-	-
August	34.2	10.7	8	13.3	9
September	33.1	10.1	12	10.3	8
October	31.3	6.5	13	8.6	11
November	28	11.8	10	6.7	9
December	24.1	18.3	8	4.5	8

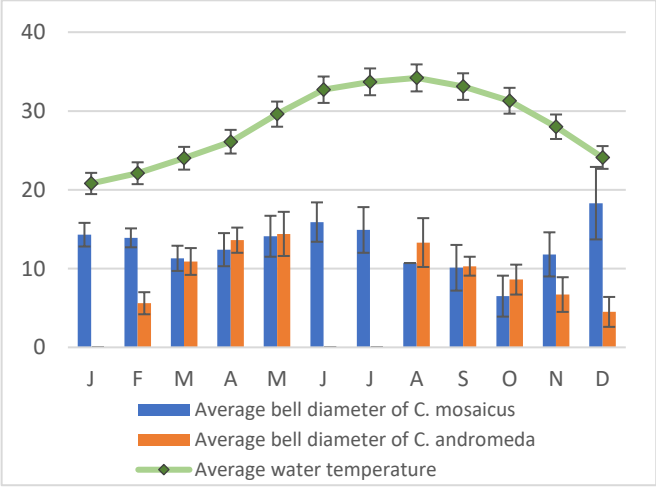

Figure 5: Monthly average bell diameter of *C. mosaicus* and *C. andromeda* and average water temperature along the UAE coast during the study period

4 DISCUSSION

The present study provides the first record of jellyfish species encountered along the UAE coastal area in the Arabian/Persian Gulf and Sea of Oman. The six identified taxa included five scyphozoans (i.e., *Catostylus mosaicus, Cassiopea andromeda, Aurelia* spp., *Chrysaora quinquecirrha,* and *Cephea cephea*) and one cubozoan (i.e., *Copula sivickisi*). Of these, three (i.e., *Chrysaora quinquecirrha, Cephea cephea*, and *Copula sivickisi*) were encountered only once as a single individual. Hamza (2006) documented the presence of non-native zooplankters including planula at the ballast water tanks of a gas tanker in the coastal area of the UAE (Hamza, 2006). The bipartite life-histories of scyphozoans support this mode of transportation because it includes the sessile polypoid stage, which can easily attach to the hulls of ships (Arai, 1997) (Mills, 2001). However, *Crambionella orsini* is the most encountered species in the Oman sea (Kramp, 1961; R. Daryanabard, 2003; R. Daryanabard & Dawson, 2008) though, quite surprisingly, it never appeared in the study area during our study period.

The most abundant bloom-forming jellyfish species along the UAE coast during the study, were *Catostylus mosaicus* and *Cassiopea andromeda*. Both scyphozoans have a free-swimming medusa and sessile polyp forms in their lifecycle (Agassiz, 1857; Ceh et al., 2015; Morandini et al., 2016). Therefore, the oil platforms, marinas, harbors, and other artificial structures placed in the water column can provide enough space for the polyp to settle on, thereby helping these species to form blooms. Considering that the UAE is a fast-developing country, such coastal development structures are frequent in the waters, thereby providing jellyfish a suitable environment to form blooms. Moreover, *C. mosaicus* prefer water with a temperature ranging from 20°C to 35°C, which can also cause blooms in February and March in Ras Al Khaimah Emirate (RAK), port and in October and November in the Abu Dhabi coast, where the water temperatures at these months are within the above-mentioned range. By contrast, *C. andromeda* formed blooms in April and May in RAK port, as well as in January until March in Ba Al Ghayalam Island. This variation may be due to the influence of the circulation of the water respectively from the Sea of Oman and the Arabian Gulf in Ras Al Khaimah and Abu Dhabi. Higher water temperatures in the Sea of Oman compared with the Arabian Gulf during the cold months of January–March has been reported in a recent study (Hamza et al., 2020). However, its absence in the pelagic zone does not imply that it has vanished from the water column. It may be

found in benthos, or it can be metamorphosized into some resting stages such as spores or cysts to overcome the extreme changes in temperature and salinity (Schiariti et al., 2014). On the contrary, *C. mosaicus* regularly formed blooms along the Australian coast at 20°C to 27.5°C, which corresponds with early spring and autumn temperatures in the UAE coastal waters (Murad et al., 2007; Dawson et al., 2015) (Figure 2). Changes in color and variations in bell diameter could be attributed to the effect habitat, food quality, and harsh environmental conditions, particularly high water salinity and temperatures have on these species (Dawson, 2005).

Copula sivickisi is a nocturnal species which prefers water temperatures between 18°C and 25°C, thereby leading to its presence in March 2020 in the Fujairah coast (Sea of Oman), where the recorded temperature was 23.2°C. During the daytime, they prefer to be near the benthos to avoid exposure to hotter surface water (Lewis Ames & Long, 2005; Lewis et al., 2008; Bentlage et al., 2010). They were found once in the Indian ocean for the first time in the west coast of Sumatra in 1929 (UCHIDA, 1929). However, the photographed individual in the Fujairah coast during the study period is the first recorded instance of *C. sivickisi* in the Sea of Oman. Apart from temperature, other environmental parameters including food availability and water circulation patterns in the Arabian Gulf and Sea of Oman may lead to the presence of this jellyfish species in this location.

The occurrence of *Cephea cephea* has never been reported in the study area probably because they prefer a temperature range of 24°C–28°C and tend to remain in deeper water layers (Sugiura, 1963). The presence of this species in late May in the coastal water of Abu Dhabi where the average temperature was 29.6°C suggests their ability to tolerate this temperature range. *Chrysaora quinquecirrha* has been observed several times along the UAE coast but not as an aggregation, particularly in Dubai in September and October 2012, 2014, and 2018 (Crane, 2014). However, during this study, it appeared only twice in Abu Dhabi in the first week of October 2021 and 2022 when the average temperature was 29.6°C. This could be due to the water circulation pattern of the Gulf, which circulates anti-clockwise at the middle of the Gulf close to the coast of Qatar before continuing along the west coast of the UAE (Abu Dhabi coastal area) (Vaughan et al., 2018).

Although *Aurelia* spp. have a worldwide distribution, they formed aggregations only three times on the coast of the UAE. In March 2008 and 2014, hundreds of this genus washed upon beaches in Dubai. During the current study, it appeared as a group in Abu Dhabi in April 2020, at a water temperature of 26.1°C. This phenomenon could be due to the fact that *Aurelia* spp. thrive in epipelagic water with a salinity greater than 38 ppt and temperature above 17°C (Browne, 1901; FitzGeorge-Balfour et al., 2013; Schiariti et al., 2015).

Pitt and Kingsford identified a negative correlation between temperature and bell diameter in *Catostylus mosaics* (Pitt & Kingsford, 2000). When studying the life history and settlement preferences of the *C. mosaicus*, Pitt pointed out the considerable impact of temperature on growth rate, maturity, and movement of *C. mosaicus* (Pitt, 2000). However, this contradicts with the results of present study as no correlation between bell diameter and water temperature was verified during the present study. The reason may be the adaptability of this species with the subtropical temperature range of the Arabian/ Persian Gulf. In *Cassiopea andromeda*, temperature exhibited a significant correlation with bell diameter throughout our study period. This corroborates findings by Rowe et. al (2022) on the physiological responses of upside-down jellyfish (Rowe et al., 2022). Many publications on scyphozoans species, such as *Aurelia aurita, Aurelia labiata, Pelagia noctiluca, Nemopilema nomurai*, have highlighted the impact of temperature on size and growth rate (Malej, 1989; Widmer, 2005; Iguchi et al., 2010; Wang & Li, 2015).

5 CONCLUSIONS

This study provides the first available information about jellyfish diversity along the coast of the

UAE. However, a detailed insight into the main factors initiating blooms calls for further studies, especially on the reproductive biology of bloom-forming jellyfish.

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