

# Detection of an unusual presence of the cubozoan *Carybdea marsupialis* at shallow beaches located near Denia, Spain (south-western Mediterranean)

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*An unusual bloom of the cubozoan Carybdea marsupialis occurred at some beaches located near Denia (south-western Mediterranean Sea, south-eastern Spain) during the summer of 2008. The bloom was first detected and recorded by the local Red Cross first aid services. Densities of C. marsupialis in the area were characterized by quantitative sampling. The number of bathers stung totalled 3330 during the three months of summer. Sampling at shallow beaches from 15 September to 21 November 2008 gave insights into cubozoan density in the area, estimated at 265.9 individuals per 100 m<sup>2</sup> as the highest value. These densities have never been recorded previously in the Mediterranean where the species was considered to be rare. Mean density along the 17 km of coastline which was sampled reached 5.4 ± 3.8 ind/100 m<sup>2</sup>. Data on size distribution are also given. This paper analyses the reasons behind these unusually high abundances of C. marsupialis in the north-western Mediterranean Sea and provides guidelines for future studies to elucidate the causes of this bloom.*

**Keywords:** Cubomedusae, *Carybdea marsupialis*, jellyfish blooms, western Mediterranean, jellyfish stings

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## INTRODUCTION

*Carybdea marsupialis* (Linnaeus, 1758) is a venomous box jellyfish widely distributed in tropical waters of the Atlantic Ocean. It is also found in large aggregations in the Caribbean Sea (Kramp, 1961; Sánchez-Rodríguez *et al.*, 2006) where the species is present all year around in bays, harbours and mangrove channels. Moreover, ripe specimens may be found in any season in Puerto Rico (Cutress & Studebaker, 1973).

In the Mediterranean basin and adjacent areas, this carybdeid is the only known cubomedusa species. It is frequently found in the Adriatic Sea (Boero & Minelli, 1986; Di Camillo *et al.*, 2006), where massive aggregations have sporadically been observed (Giampiero *et al.*, 1997). In the western Mediterranean, adult individuals of *C. marsupialis* have been spotted in summer along the south-east coastline of Spain by SCUBA divers, but to the best of our knowledge, these

observations have never been reported in the scientific literature. In some of the Spanish Mediterranean diving guides this species is shown as rare, consequently very few divers have seen it.

*Carybdea marsupialis* has a bi-partite life cycle, is oviparous and settlement of planulae occurs about two days after fertilization of ova. The polyp stage has been found only once on dead bivalve shells on the bottom of mangrove channels (Cutress & Studebaker, 1973). Moreover, there is evidence from experimental work of the capacity of the polyps to develop in cysts when the conditions are not adequate (Straehler-Pohl, personal communication). The cubopolyp reproduces asexually through lateral budding and by transforming the polyp into a cubomedusa. Budding rate is positively correlated with feeding frequency, in contrast to conditions leading to the medusa formation, and increases in darkness. Furthermore, the polyp seems to have a high regeneration potential (Fischer & Hofmann, 2004). A second type of metamorphosis, leaving a regenerative remnant, is also frequent and can reach up to 45% of the total number of metamorphosis. This mode of medusa formation seems to be derived from the strobilation process common to scyphozoans (Straehler-Pohl & Jarms, 2005).

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Nevertheless, considering the importance of benthic stages for jellyfish outbreak formations (Boero *et al.*, 2008) there exists a lack of information about other important topics such as: substrate choice; food limitation; predators; and competitors.

The nematocysts and the venom of *Carybdea marsupialis* have been widely studied (Golz, 1993; Avian *et al.*, 1997; Di Camilo *et al.*, 2006; Sánchez-Rodríguez *et al.*, 2006). The contact between human skin and *Carybdea* tentacles causes severe pain, burning sensation, erythematous-vesicular eruption and local oedema (Kokelj *et al.*, 1992; Milla *et al.*, 2000; Sánchez-Rodríguez *et al.*, 2006).

Moreover, the potential proliferation of this species as a gelatinous predator represents a threat to the ecosystem due to its ecological effects. Cubozoans consume zooplankton, as well as ichthyoplankton (Larson, 1976; Nogueira Jr & Haddad, 2008); therefore, zooplankton populations and the juvenile fish community could potentially be reduced and modified. Such situations can cause a direct or an indirect cascade effect in marine food webs and natural populations.

During summer 2008, a high number of stings caused by the unusual and abundant presence of *Carybdea marsupialis* were reported along 17 km of the coastline near Denia (south-eastern Spain, north-western Mediterranean). Because this was such an unusual event, a sampling strategy was developed to quantify stung bathers, and evaluate abundance, as well as size distribution of *C. marsupialis*.

## MATERIALS AND METHODS

The study area extends to include coastline to the north of Denia, which consists of long sandy beaches with a gentle slope where *Posidonia oceanica* meadows coexist with rocky and sandy bottoms. The northern and southern limits of the study area are the Racons-Molinell River ( $38^{\circ}53'09''\text{N}$   $0^{\circ}02'14''\text{E}$ ) and 2 km south from Denia harbour ( $38^{\circ}50'55''\text{N}$   $0^{\circ}02'14''\text{E}$ ) respectively (Figure 1). The area absorbs river run-off which contains high levels of nitrate and other crop fertilizers. There are 4 perpendicular dykes (from 100 to 230 m long), 3 at L'Almadrava beach and 1 at Les Marines. Both beaches have been replenished with sand: Les Marines beach, in 1987, and L'Almadrava beach, in 2005. The region is a popular tourist spot in this part of

Spain where bathing, yachting and other aquatic activities take place during summer months.

In order to conduct the sampling programme, 17 km of the coastline was divided into 8 beaches (from north to south): Racons, Deveses, Almadrava, Molins, Marines, Raset, Marineta and Rotes (Figure 1). Quantitative sampling commenced on 15 September, just two months after a high number of stings had been detected by the Red Cross at Raset beach. Sampling was completed on 21 November, two weeks after the last organism of *Carybdea marsupialis* was found. Since the animals were detected in a very shallow area, samples were taken using a hand net (5 mm mesh size) of 949 cm<sup>2</sup> of filtering surface ( $30.9 \times 30.8$  cm) and by walking in a parallel direction to the coastline. While walking, the net was kept 0 to 5 cm off the bottom and a total distance of 100 m was covered in each transect. Each sampling point consisted of 4 transects, each of them parallel to the other at a distance of 1.5 m, covering approximately from 0.5 to 1.2 m depth. The distance between sampling points was 50 m (Figure 2). All data were collected in spreadsheets, including GPS coordinates, individual references for starting and finishing points, water temperature ( $T$  data logger  $\pm 0.1^{\circ}\text{C}$ ) and the number of individual *C. marsupialis* collected. Density data are calculated using individuals per square metre (to obtain densities in cubic metres, multiplied by net height, 0.308 m). We randomly chose 150 individuals to measure (umbrella height and width) and a linear correlation was undertaken between both measures, obtaining correlation coefficient  $R^2$ .

All *Carybdea marsupialis* individuals collected were preserved in 4% formalin for further analysis.

The other set of data used for this study was based on the information supplied by the Red Cross emergency services who kindly gave us permission to use official information related to the number of people stung by jellyfish and the total number of incidences at the beaches located along the Denia coastline. The Red Cross beach service commences each year on 1 July and finishes at the end of August; hence no data on stung people can be obtained after this date.

To assess if 2008 was an exceptional year in relation to jellyfish stings, data from previous years were also analysed and compared with the years 1996 to 2007.

Individuals who have been stung by the *Carybdea marsupialis* are easily recognized because they suffer a burning

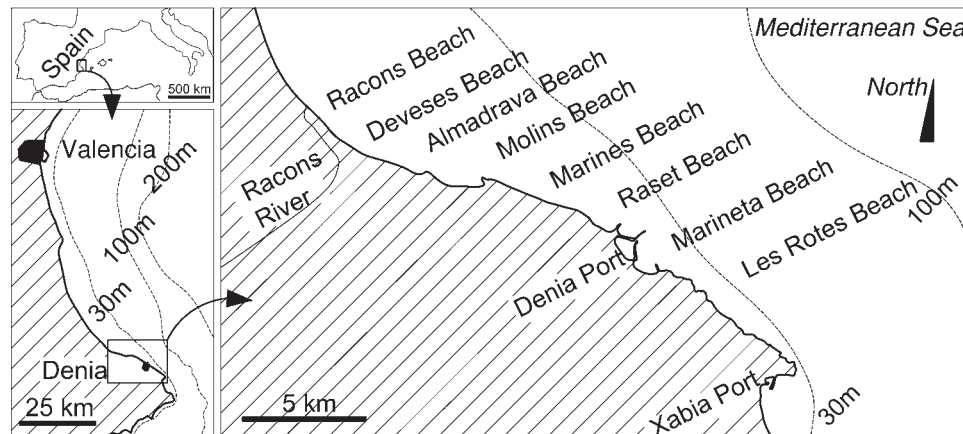


Fig. 1. Studied area in the south-western Mediterranean. Coast of the municipality of Denia (Spain).

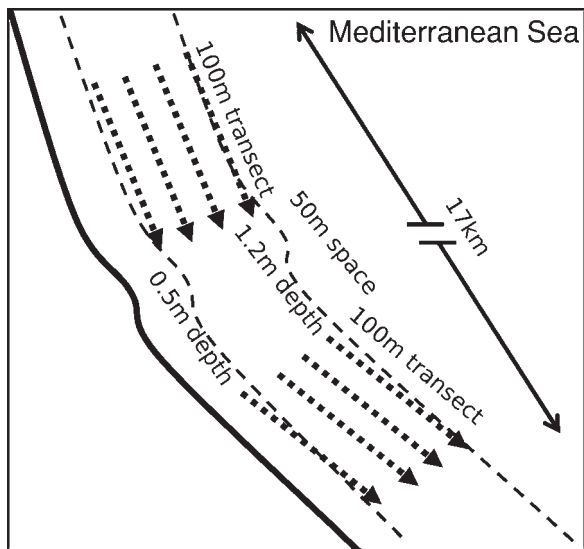


Fig. 2. Sampling procedure.

pain which lasts for several hours, accompanied by a self-limiting (1–2 days) localized erythematous eruption. Small vesicles and hives can also appear in the affected area.

## RESULTS

### *Carybdea marsupialis* abundance and distribution

As shown in Figure 5, *Carybdea marsupialis* density was measured from 15 September until 21 November 2008, and during this period, a total of 476 *C. marsupialis* were collected. No cubozoans were found in the area after 10 November. Some adults of *C. marsupialis* were captured in the second week of August, 5 weeks prior to the quantitative sampling period. Density of *C. marsupialis* decreased from a maximum of  $5.4 \pm 3.8$  ind  $100 \text{ m}^2$  (Figure 5) at the end of September to zero on 10 November.

The highest number of stinging incidences was recorded during the first week of August (Figure 3). The peak water temperature ( $25 \pm 0.5^\circ\text{C}$ ; Figure 5) occurred during the fourth week of September which was when *C. marsupialis* was abundant ( $5.4 \pm 3.8$  ind  $100 \text{ m}^2$ ; Figure 5). Temperatures fell from  $25 \pm 0.5^\circ\text{C}$  at the end of September to  $16.8 \pm 0.5^\circ\text{C}$  on 17 November.

When data are analysed from each of the beaches sampled (Figure 6), it can be observed that the highest average abundances were found in L'Almadrava and Deveses beach ( $3.85 \pm 1.1$  ind  $100 \text{ m}^2$  and  $2.73 \pm 1.8$  ind  $100 \text{ m}^2$ , respectively). In contrast, no organisms were captured in Les Rotes, neither at Marineta beach. Despite the fact that the maximum number of stinging incidences was recorded at Raset beach, the highest densities of *Carybdea marsupialis* were recorded at L'Almadrava and Deveses beach. Records for highest abundances ranged from 0 organisms in Marineta and Les Rotes beaches to 265 per  $100 \text{ m}^2$  in Deveses beach. Scaling was clearly different between both beaches (Figures 7 & 8), where average abundances ranged from 0 to 3.85 ind per  $100 \text{ m}^2$ , while the highest abundance ranged from 0 up to more than 250 ind per  $100 \text{ m}^2$ . Figure 6 shows the abundances at each sampling beach between 15 September and 20 October. We found that average abundances were constant during different weeks, with the exception of Deveses and L'Almadrava, where a decrease, as well as an increase, of this parameter was recorded respectively.

A total of 150 individuals were measured from the 476 samples that were collected. There was a clear dominance of mid-class sizes in September (18 to 33 mm width and 25 to 33 mm length; Figure 7). However, big-sized classes were dominant in October and individuals smaller than 18 mm were not detected (Figure 7). A linear relationship was detected between length and width (Figure 8), which reveals a high correlation value ( $R^2 = 0.788$ ).

During the third week of August 2009, we randomly sampled approximately  $10 \text{ m}^3$  of water in three different localities (Fonts, Raset and L'Almadrava beaches) to test whether *Carybdea marsupialis* populations were the same as in 2008. We sampled a total of 33 organisms of *C. marsupialis* (5, 2 and 26 individuals respectively) which seems to

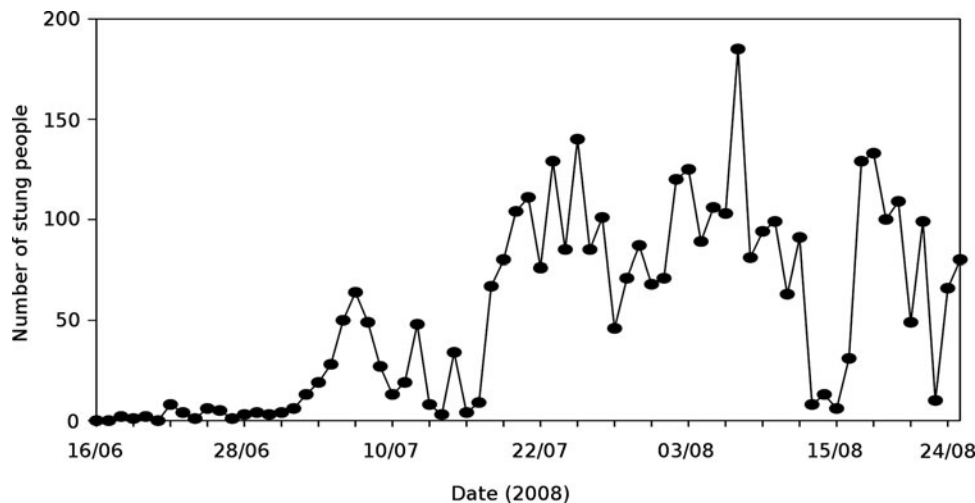


Fig. 3. Red Cross records of people stung from 16 June to 25 August 2008 in all stations in Denia's beaches. Raset, Marines and Molins beach had altogether 88% of the stings (58%, 25% and 5% of stings respectively).

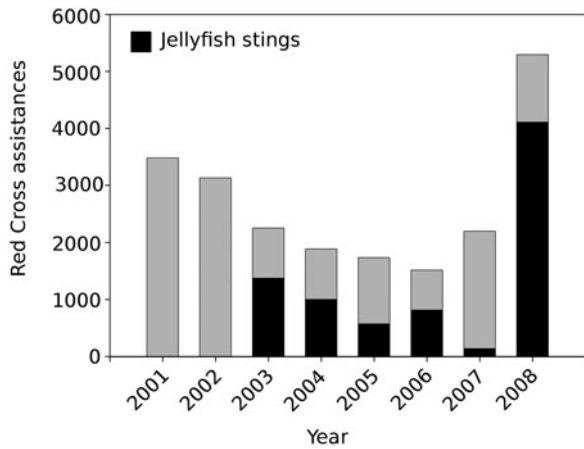


Fig. 4. Red Cross records of total assistances in beaches, differentiating people stung by jellyfish (dark bar) in Denia's beaches from 1996 to 2008. Stung people data in 2001 and 2002 are not known.

infer that a population may be permanently established in the area.

### Red Cross records of stinging incidences

Between 18 July and 25 August 2008, an unusually high number of stinging incidences were registered at the beaches that surround Denia. During this period, more than 3330 jellyfish stings were recorded by the Red Cross. Figure 3 shows the number of people with jellyfish stings treated at the Red Cross facilities on a daily basis, which illustrates that between 18 July and 13 August there had been a significant increase in the number of bathers affected compared to other years. The average number of stinging incidences increased from less than 50 a day to more than 100, with the highest occurrence on 7 August when 185 people were stung. This pattern was not common at all of the beaches that are included in the study or in other coastal cities, and such an increase in the number of people affected was due, almost exclusively, to the number of bathers stung at Raset beach. Visits to Red Cross facilities were almost constant

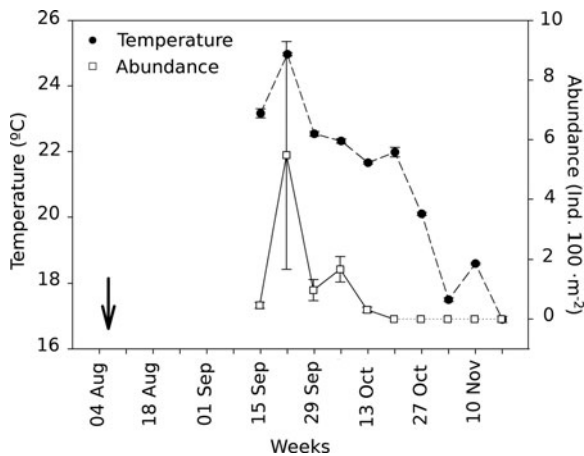


Fig. 5. Abundance of *Carybdea marsupialis* and water temperature during the sampling period (4 August to 21 November). Values are shown as averages  $\pm$  standard error. The arrow indicates the occurrence of the first stinging events in mid-August.

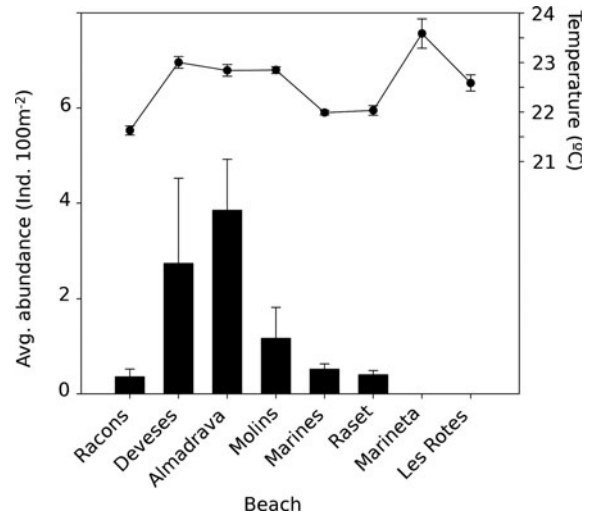


Fig. 6. Abundance of *Carybdea marsupialis* in the different beaches along Denia's coast. Values are shown as averages  $\pm$  standard error. Avg, average.

during the study period at Molins and Marines Beaches, however, at Raset, more than 100 people were treated on a daily basis compared to less than 20 in previous years.

Between 2003 and 2007, the total number of people treated for jellyfish stings ranged from 138 (2007) to 1378 (2003) (Figure 4). However, the total number of stings rose to 4116 in 2008, indicating an unusually exceptional year, not only for a single event, but also for an extended period during the summer. Moreover, the amount of assistance given by the Red Cross for stings other than jellyfish in 2008 was similar to previous years. These data point to the fact that 2008 was characterized mainly by a high number of people stung (Figure 4). No data were located for 2000, or for 2002 (Figure 4).

### DISCUSSION

Prior to this study, *Carybdea marsupialis* had never been detected in such high abundance in the Spanish Mediterranean. In Italy similar abundances of *C. marsupialis*

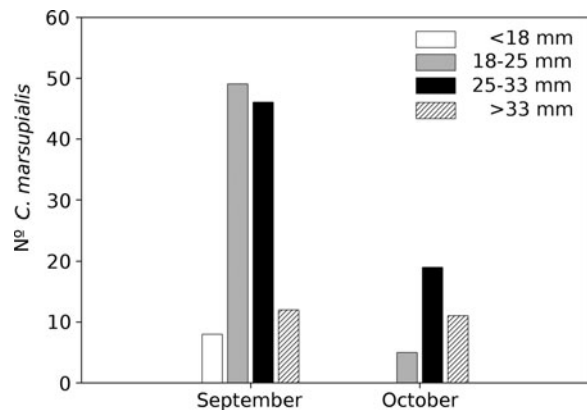


Fig. 7. Size distribution of *Carybdea marsupialis* during September and October 2008.



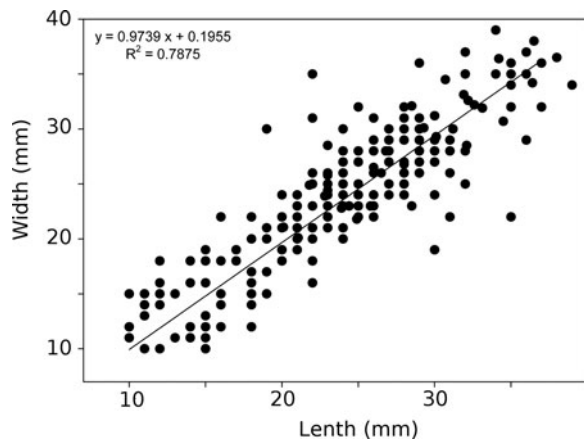


Fig. 8. Relationship between length and width of *Carybdea marsupialis*.

have been found in Tuscany, as well as Liguria (western Italian coast) and along the northern Adriatic coastline (Boero, personal communication; unpublished data). Many factors may have been responsible for this atypical abundance. It is therefore necessary to carry out long-term monitoring surveys of several variables that would have boosted the studied population, such as available food, salinity, temperature or rainfall as was done for the scyphozoan *Pelagia noctiluca* (Goy *et al.*, 1989). *Carybdea marsupialis* presents a benthic polyp stage, consequently, availability of suitable settling surface and adequate conditions for polyps survival must be key factors contributing to the proliferation of this species in 2008 (and possibly, in the following years).

*Carybdea marsupialis* has been mainly reported in shallow waters such as slow bays that have low water movement (Bigelow, 1918; Larson, 1976). However, in this study the highest abundances were found at a turbulent beach (L'Almadrava) with a slope of 15° to 20° (6.5 m horizontal from 0 m to -3 m depth). In addition, the limitations of the sampling methodology limits spatial observations from 0.5 to 1.2 m deep, therefore we currently cannot offer conclusions regarding distribution of *C. marsupialis* across the water column.

Three stone breakwaters (200 to 230 m long, perpendicular to the coast) were built in 2004 in L'Almadrava beach and they may have favoured settlement of the benthic stage of *C. marsupialis*, increasing substrate availability for polyps to settle and develop.

Measures of the size of *Carybdea marsupialis* matched those taken by Kramp (1961), who reported body lengths, as well as widths of 40 and 30 mm respectively, but these numbers seem to be small when compared with the large-sized cubozoans (up to 190 mm bell length) reported in Pakistan waters (Kazmi & Sultana, 2007).

Several jellyfish species such as *Chrysaora melanaster*, *Chironex fleckeri*, *Carukia barnesi* and *Pelagia noctiluca* can severely affect local socio-economies because bathers are stung and fishing, aquaculture, as well as power plant operations can be interfered with (Purcell *et al.*, 2007).

The coastal bloom of *Carybdea marsupialis* located around Denia can be related to a combination of coastal features (currents, temperature, available substrates for polyps, predation, etc.) and more likely than not, anthropogenic causes (artificial substrates, eutrophication, fishing, etc). However, the influence of all these factors on this *Carybdea*

*marsupialis* bloom still remains unclear and requires further investigation.

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