International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Distribution and Ecological Impacts of Carybdea Marsupialis along Moroccan Coasts: A Comprehensive Analysis

Idrissi Farah Hounaida[1], Baibai Tareq[2]

Institut National de Recherche Halieutique (INRH), Boulevard Sidi Abderrahmane, Ould Jmel- Casablanca, Morocco
Corresponding Author Email: *hounaidafarahidrissi[at]inrh.ma*

Abstract: ***This research investigates the presence and ecological dynamics of Carybdea marsupialis along the Moroccan Mediterranean and North Atlantic coasts from 2017 to 2023. An analysis of 101 specimens revealed significant seasonal and spatial variability linked to environmental parameters. Observations underscored the species' impact on local ecosystems and potential risks to human activities. These findings emphasize the necessity for continuous monitoring and further research to understand the proliferation of this species and mitigate its ecological and economic impacts.***

Keywords: *Carybdea marsupialis*, jellyfish ecology, Moroccan coasts, environmental monitoring, trophic analysis

1. Introduction

The box jellyfish *Carybdea marsupialis* is known to inhabit the tropical and subtropical waters of the Atlantic Ocean and the Mediterranean Sea [1,2,3,4]. It has also been observed sporadically in mass aggregations in the Adriatic Sea [5,6,7] as well as has been recorded in Portuguese waters [8]. Massive numbers of the box jellyfish *C. marsupialis* were already recorded at some beaches at Denia (Alicante, Spain) in 2008 [9]. Local scientists expressed significant concern about the massive increase in box jellyfish populations on beaches, as this could jeopardize the health of swimmers and divers owing to their neurotoxic and hemolytic properties, which adversely affect red blood cells.

The pelagic box jellyfish colonizes the shallow depths, often between the surface and the first two meters. It mainly favors ports, marina environments and also sandy beaches. [9] located this medusa species in Denia (East Spain) at depths between 0.5 and 1.2m, whilst [3] observe did at 1.3- 2 depth on the coast of Tunisia. This box jellyfish complex eyes that provide advanced visual capabilities. Some of its eyes are oriented upwards, while others face downwards to observe underwater structures and objects. This vision aids in locating prey and partners, and its swimming skills enable it to follow and approach detected targets [7]. The species is nearly invisible during daylight due to its small size and the high transparency of its bell. *C. marsupialis* is an oviparous, gonochoric species with a two-phase life cycle: 1- Benthic polyp: attached to the substrate and reproducing asexually. 2- Pelagic jellyfish: free-swimming and reproducing sexually [9, 10]. *C. marsupialis* holds an important role in marine food chains in specific localized areas, acting as a top-down predator of zooplankton and ichthyoplankton [11, 12]. However, a large-scale proliferation of this species could have adverse effects on both the ecosystem and the economies of coastal regions that are highly dependent on tourism [3].

In Morocco, the first record was reported by [13], where two specimens about twenty centimeters high were fished near El Jadida in February 1954, above depths of 20 m, at a water temperature of 15.8°C. the third specimen was collected at the beach of Casablanca (Ain Diab) above depths of 25 m and a water temperature around 14.8°C. Over the last few years, an unusual presence of box jellyfish has been recorded in observations conducted by the National Institute of Fisheries Research (INRH) at the Moroccan Mediterranean and Atlantic shores. Indeed, more than a hundred individuals were sampled between July 2017 and April 2023. This rise in the occurrence of these species prompts questions regarding the reasons for their emergence and the biological cycle that governs their survival in the environment. It is then reasonable to be concerned about the potential threats they pose to both humans and the ecosystem. The box jellyfish observed recently on the Moroccan coasts, has been identified as *Carybdea marsupialis* (Linnaeus, 1758).

The first aim of this paper is to report in more details the detection sites of *Carybdea marsupialis* along both coasts, in western Mediterranea and Atlantic, highlighting the occurrences of their presence at each site. In some locations, parameters collected from the surrounding environment are also described. Results of the biological analyses conducted on the collected samples, specifically size distribution, morphometric relationships, percet of the developpemnt stages and the gut contents are also provided to study their biological parameters and feeding habits.

This study contributes critical insights into the population dynamics of Carybdea marsupialis, highlighting its ecological roles and potential impacts on marine biodiversity and coastal economies.

2. Materiel and Methods

2.1 Study site

Six beaches were smepled along the moroccan coasts; Two in the Western Mediterranean and four in north Atlantic. These beaches were respectively: Kabila marina (KM) (35°43'17.6"N, 5°20'11.4"W), M'diq Port (MP) (35°40'59.0"N, 5°18'56.8"W), Skhirat (SK) (33°52'10.7"N, 7°03'26.2"W), Casablanca (CA) (33°35'06.4"N, 7°41'23.4"W), Sidi Rahel (SR) (33°28'45.4"N, 7°57'47.1"W)

and El Jadida (EJ) (33°15'04.8"N, 8°29'57.2"W) (Fig 1). The specimens were collected in three differentes sampling periods, in fin July- August 2017 for mediterrane coasts, September 2018, April and September 2021,2022 and 2023 for Atlantic coasts. Following these occasional and sporadic appearances, the collection of live or stranded specimens on adjacent beaches was carried out by INRH scientists together with fishermen and surfers. GPS coordinates, water temperature (T°C), and the number of individual *C. marsupialis* collected were all recorded in spread sheets.

2.2 Biological parameters

All specimens were preserved in 70% ethanol. As all individuals were preserved in the same manner, the hypothetic loss of water content would be standardized across all. Measurements were taken of bell height (BH), horizontal bell width (BW), and total weight (TW), subsequent to being preserved. The analysis focused on the description of the size distributions of individuals according to BH. Developmental stages of individuals were determined according to umbrella width (Recently detached DBW < or equal 2mm; Small 2mm<DBW<or equal 5mm; Juveniles 5mm<DBW<15mm; Adult DBW> 15mm).

Subsequently, the specimens were dissected at different levels, the gastro-vascular cavities are exposed and observed under the tri-ocular magnifying glass. Ingested elements were separated and identified to the lowest possible taxonomic level. The gastro-vascular cavities collected was carefully examined and immediately placed in a bag corresponding to the size of the individual, with a solution of filtered seawater and alcohol to reduce the risk of escape of intestinal contents regarding living specimens from the Atlantic Ocean in North Morocco.

3. Results

3.1 Occurence spatiale

In this study, 101 individuals of *Carybdea marsupialis* (box jellyfish) were analyzed across five sampling periods, with specimens appearing exclusively in summer in the western Mediterranean and in early autumn in the North Atlantic. Of these, 60% were found alive, swimming at shallow depths near port quays, while the remaining 40% had recently washed up on nearby beaches. All specimens observed were located in shallow coastal waters, ranging from approximately 0.5 to 10 meters deep, along the surveyed beaches. Notably, in 2018, on the beaches of Casablanca, Sidi Rahal, and Skhirat, and again in 2023 in El Jadida, sightings included jellyfish actively swimming at night under the illumination of a full moon (Table 1).

In the Mediterranean Sea, 14 live box jellyfish were reported and collected in July and August 2017. In the North Atlantic, according to in situ observations and reports from fishermen and surfers, these organisms appeared suddenly in coastal areas, particularly on the beaches of Skhirat, Casablanca, Sidi Rahal, and El Jadida. They were observed in varying sizes, with low to medium abundance, displaying a cyclical pattern of reappearance each year in April and September (Table 1). A total of 87 specimens were studied, 49 of which were alive while 38 were recently stranded on nearby beaches. The highest number of sightings was recorded in 2022, with 31 individuals observed. Species identification was based on the studies of [14, 3, 7] (Fig 2).

In September 2018, a significant number of box jellyfish were observed in a single month, particularly in Casablanca, with 22 individuals reported. This seasonal concentration indicates a notable presence of these jellyfish during the autumn period (2021 and 2022). The phenomenon was further documented in other areas like Mediterranean beaches, with lower occurrences saw14 specimens during the summer months of July and August 2017.

The juvenile stage of the box jellyfish *C. marsupialis* shows significant spatial variability in Moroccan waters. In the Western Mediterranean, juveniles dominate in the Tetouan region, accounting for 60% of individuals at Marina Kabila Beach and 100% at M'diq Port (Fig 3). By contrast, in the northern Moroccan Atlantic, populations display a mix of developmental stages, with adults and juveniles observed across surveyed beaches. El Jadida Beach exhibits an equal distribution of adults and juveniles, each representing 50% of the population. Skhirat Beach is characterized by a predominance of adults, comprising 82% of the observed individuals. Sidi Rahal and Casablanca Beaches have adult proportions of 62% and 58%, respectively, while juveniles account for 43% at Casablanca and 50% at El Jadida (Fig 3). The notable presence of juveniles suggests these waters may provide suitable habitats for settlement and development.

3.2 Biological parameters

The size of *Carybdea marsupialis* varied between 5 - 55 mm in height. The size class distribution (Fig 4) is clearly bimodal. The mode representing 40 mm accounted for 23.30% of the total specimens. while the second mode 10 mm represented 18.45%.

We established a global equation for all the specimens treated in different periods without distinction of sex. The results obtained revealed that the slope b is significantly different from 3. the growth allometry is therefore lower. this shows a weight increase of the box jellyfish proportionally slower than the size (Fig 5).

3.3 Trophic spectrum in the Western Mediterranean and North Atlantic

In the Tétouan region, a total of 14 individuals of Carybdea marsupialis were analyzed, including 5 cubomedusa specimens with empty stomachs, accounting for 35.7% of the sample. The detailed quantification of this species' diet composition in the Mediterranean could not be furthered due to these limitations. However, among the three analyzed stomach contents, fish remains (opercula, scales, and vertebrae) were identified, along with biological forms of algae and nematodes, which were the most frequent and abundant components (Table 2).

A total of 49 cubomedusae specimens were analyzed to assess their diet and feeding intensity. Among them, 5 specimens had empty stomachs, resulting in a vacuity coefficient of 11.4%.

The trophic composition of the intestinal contents was predominantly crustaceans, particularly amphipods (IRI% = 35.6%), represented by the families Caprellidae and Gammaridae. Fish constituted the primary secondary prey category (18.57%), while algae (5.38%), annelids (7.75%), and bryozoans (3.08%) were classified as supplementary dietary components (Table 3).

3.4 Influence of temperature on the abundance of *Carybdea marsupialis*

The data collected between 2017 and 2023 highlight the thermal preferences of *Carybdea marsupialis*. In 2017, the first observations recorded 14 individuals at a temperature of 21.2°C during the summer in the Tétouan region. In 2018, the highest abundance was observed in September, with 22 individuals at a temperature of 22.9°C.

In 2022, a peak abundance of 31 individuals was recorded, with 12 observed in April at a temperature of 21.6°C, and detected in September at 22.5°C. In 2023, 12 individuals were reported in April at a temperature of 21.1°C.

It is important to note that strandings data, while providing information on the presence of *Carybdea* marsupialis along the coasts, do not allow for a direct correlation between water temperature and the abundance of this cubomedusa.

4. Discussion

This study provides the first comprehensive documentation of *Carybdea marsupialis* aggregations of varying sizes in the western Mediterranean, as well as their significant and unusual reappearances in the North Atlantic. Recent research highlights the increasing presence and proliferation of this species along the Spanish Mediterranean coast, with high-density blooms reported since 2008, particularly on beaches in Denia, Spain. Historically, *C. marsupialis* was not known to form blooms, but these events reflect a notable increase in abundance and ecological impact, potentially disrupting local marine ecosystems by altering biodiversity and ecosystem function [7]. The mass proliferation of *C. marsupialis* poses serious risks to both marine ecosystems and coastal economies [3]. The species' neurotoxic and hemolytic effects can harm human red blood cells, posing significant dangers to swimmers and divers and often leading to temporary beach closures [15, 16]. Such disruptions negatively affect tourism-dependent coastal areas like Denia, Spain. Additionally, its ability to alter prey populations and compete with native predators creates imbalances within marine food webs, with cascading consequences for ecosystem stability. Similar risks have been observed with *Chironex fleckeri* in Australia, where authorities issue swimming bans during jellyfish bloom events. Their recent appearance along the Moroccan coasts, particularly in the western editerranean, may be attributed to several factors, including climate change, shifts in ocean currents, and the degradation of coastal habitats [17]. The geographical spread of this species has already been documented in other parts of the Mediterranean, underscoring their ability to colonize new habitats [17].

The Gulf of Cádiz is a favorable area for jellyfish development, characterized by higher temperatures and elevated primary production levels. The surface current system connects this region with the northern Moroccan coastal fringe, causing warm water masses to particularly impact areas such as Mehdia, Casablanca, and El Jadida [18]. Also, the presence of juvenile *Carybdea marsupialis* indicates that environmental conditions, such as temperature and prey availability, are favorable for their growth and development. This phenomenon may also suggest an expansion of the species' habitat, indicating that it could colonize new areas and establish itself in previously inhospitable environments.

Temperature plays a critical role in the distribution and survival of *C. marsupialis*, which thrives within a narrow thermal range. Observations suggest its optimal sea surface temperatures fall between 19°C and 25°C, with peak abundances recorded at 22.1°C and 24.2°C. Laboratory experiments confirm increased mortality rates below 19°C, establishing this temperature as a critical threshold for survival. Data collected from Moroccan coasts in 2017 and 2023 support these findings, emphasizing the strong correlation between thermal conditions and the species' proliferation. As an opportunistic predator, *C. marsupialis* has a varied diet dominated by small crustaceans such as amphipods and copepods, as well as juvenile fish [19]. Studies on Moroccan populations reveal a predominance of crustaceans from the families Caprellidae and Gammaridae, while fish, algae, and annelids serve as supplementary food sources. The species exhibits nocturnal feeding behavior, using powerful digestive enzymes to rapidly break down prey. This behavior is shared by other cubomedusae, such as *Alatina alata* [20], although some species, like *Chironex fleckeri* [21], primarily feed during the day. The dietary flexibility of *C. marsupialis* highlights its adaptability and significant role within marine ecosystems as both a predator and a competitor.

Although stranding records provide valuable information on the presence of *C. marsupialis* along coastlines, they are not reliable indicators of population densities in marine environments. Strandings are often influenced by ocean currents, extreme weather events, or population dynamics, rather than reflecting the actual abundance of active marine populations. To establish stronger correlations between environmental parameters, such as temperature, and jellyfish distribution, in-situ marine sampling is required. Such studies must consider both environmental conditions and jellyfish behavior in their natural habitats to provide more accurate insights.

5. Conclusion

The appearance and establishment of *Carybdea marsupialis* along the Moroccan coasts call for increased monitoring due to their potential impacts on local ecosystems and human activities, particularly fishing and tourism. A better understanding of their trophic interactions, combined with ecological models that incorporate climatic variables, would allow for predicting their future distribution and mitigating associated risks. In addition, comprehensive research on their life cycle, ecology, and the environmental factors influencing their proliferation is crucial for developing effective management strategies. International collaboration within

regional programs would be a valuable asset in understanding cubozoan dynamics in the western Mediterranean and beyond.

Acknowledgment
The authors would like to thank the artisanal fishermen, the surfers and Mrs. Moutaki B. for their efforts in sampling the cubomedusae and for the data related to the surveys conducted on the adjacent beaches.

Figures and Tables

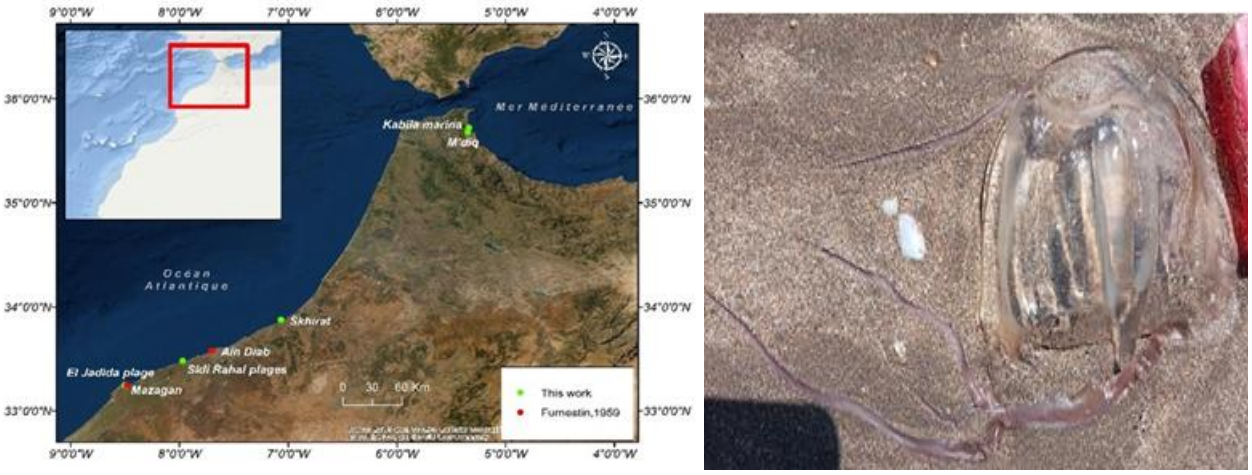

Figure 1: (**a)** Distribution of published records of *C. marsupialis* in the Atlantic North, including observations made in the Mediterranean and the Atlantic moroccains coasts. (**b)** *C. marsupialis* captured in El Jadida on April 16 2022

Table 1: Spatial and Temporal Distribution of *C. MARSUPIALIS*: Occurrences Across Moroccan Coasts by Status and Location: Kabila Marina (KM), M'DIQ Port (MP), Casablanca AIN DIAB (CA), Sidi Rahal (SR), El Jadida (EJ), and Skhirat (SK), Classified by Status: Living (L) Or Stranded (S)

Period/ Beach Western Mediterranean	KM	MP	SK	CA	SR	EJ	Year Total
July 2017	5 (L)						14
August 2017		9 (L)					
North Atlantic							
September 2018				10 (S)	12 (L)		22
April 2021				2 (L)		1 (S)	22
September 2021			6 (L)	3 (L)		10 (S)	
April 2022			2 (L)	5 (L)		5 (S)	31
September 2022			5 (L)	5 (L)	1 (S)	8 (S)	
April 2023				4 (L)	3 (S)	5 (L)	12
Total Specimens Traited 101							

Figure 2: Samples from *C. marsupialis* captured in Skhirat on September 01, 2021 and preserved in 70% ethanol and manipulated

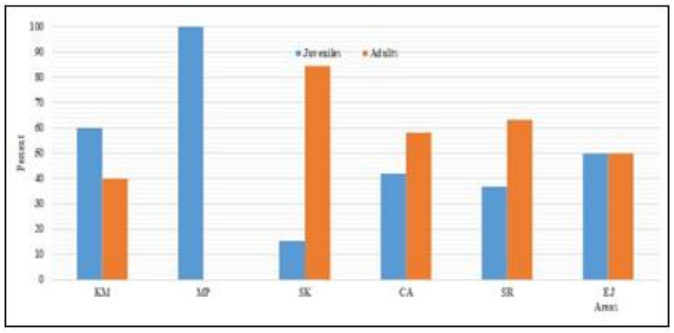

Figure 3: Spatial occurrence of different development stages in percent the *C. marsupialis*

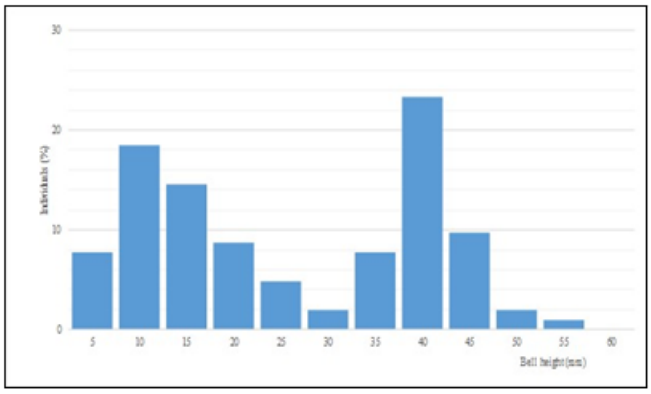

Figure 4: Size distribution of individuals collected throughout the Period

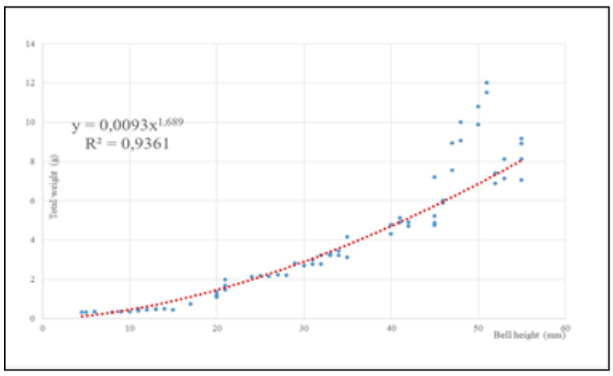

Figure 5: Relationship between Bell height and total weight of the individuals captured

Table 2: Prey Composition Found in the Intestinal Cavities of C. Masupialis Collected in the Tetouan Region

Preys	Fr	Cn	Cp
Algae	7.14	5.25	0.1
Nematodes	78.5	93.8	9.4
Fish Und.	7.2	0.95	90.5

Table 3: Prey Composition Found in the Intestinal Cavities of *C. Marsupialis* Collected in the North Atlantic

Preys	Fr	Cn	Cp	IRI	%IRI
Algae	11.36	7.30	8.79	182.82	5.38
Amphipods	22.73	18.25	10.24	647.53	19.07
Annelids	11.36	7.30	15.86	263.18	7.75
Brachyura larvea	9.09	8.76	19.97	261.18	7.69
Bryozoans	6.82	7.30	8.06	104.74	3.08
Caprellidae	20.45	8.75	2.18	223.77	6.59
Crustaceans Und.	34.09	10.95	6.81	605.31	17.82
Gammaridae	18.18	11.68	7.07	340.91	10.04
Mollusks Und.	11.36	3.65	7.67	128.59	3.79
Fish larvea Ind.	22.73	14.60	13.15	630.67	18.57
Shrimps	4.55	1.46	0.20	7.54	0.22
Fishing nets (green. Bleu) Und.					

References

[1] P.L. Kramp, "Synopsis of the Medusae of the world. Cubomedusae," Marine Biological Association of the United Kingdom, 40. 304–310, 1992.

[2] H. C. Bordehore, Studies on the Ecology of *Carybdea marsupialis* (Cubozoa) and Jellyfish Sting Risk Management, Universidad de Alicante- Instituto de Ciencias del Mar, CSIC, 2014.

[3] S.K.M. Gueroun, M.J. Acevedo, O. Kéfi-Daly Yahia, A. Deidun, V.L. Fuentes, S. Piraino, M.N. Daly Yahia," First records of *Carybdea marsupialis* proliferation (Cnidaria : Cubozoa) along the eastern Tunisian coast (Central Mediterranean)," Italian Journal of Zoology, 82. 430–435, 2015. [Online]. Available: http://dx.doi.org/10.1080/11250003.2015.1045945.

[4] K. Pulis, Genetic characterisation of the Mediterranean Box Jellyfish (*Carybdea marsupialis*), University of Malta, Msida, 2015.

[5] N. Bettoso," First record of *Carybdea marsupialis* (L. 1758) (Cnidaria : Cubozoa) in the Gulf of Trieste," Periodicum Biologorum, 104. 233, 2002.

[6] C. Di Camillo, M. Bo, S. Puce, S. Tazioli, G. Bavestrello," The cnidome of *Carybdea marsupialis* (Cnidaria : Cubomedusae) from the Adriatic Sea," J. Mar. Biol. Assoc. UK, 86. 705–709, 2006.

[7] M. J. Acevedo Dudley, Biology. ecology and ecophysiology of the box jellyfish *Carybdea marsupialis* (Cnidaria: Cubozoa), Institut de Ciències del Mar CSIC, 2016.

[8] C. Rodríguez-García, V. Sanz-Fernández, R. Muñoz-Lechuga, M. Gutiérrez-Martínez, R. Cabrera-Castro," First records and presence over time of the cubozoan *Carybdea marsupialis* (Linnaeus. 1758) on the southwestern Spanish coast (Northeast Atlantic)," Regional Studies in Marine Science, 44. 101712, 2021.

[9] C. Bordehore, V.L. Fuentes, D. Atienza, C. Barberá, D. Fernandez-Jover, M. Roig, M.J. Acevedo-Dudley, A. J. Canepa, J. M. Gili," Detection of an unusual presence of the cubozoan *Carybdea marsupialis* at shallow beaches located near Denia Spain (south-western Mediterranean)," Marine Biodiversity Records, 22. 61–63, 2011. [Online]. Available: http://dx.doi.org/10.1017/S1755267211000650

[10] C.E. Cutress, J.P. Studebaker, "Development of the Cubomedusae. *Carybdea marsupialis*." In Proceedings of the Association of the Islands Marine Laboratories of the Caribbean, pp. Vol. 9, 1973.

[11] R.J. Larson," Cubomedusae : Feeding — Functional morphology. Behavior and phylogenetic position,"In : Mackie. G.O. (Ed.). Coelenterate Ecology and Behavior. Springer. Boston. MA. 1976. [Online]. Available: http://dx.doi.org/10.1007/978-1-4757-9724-4_25.

[12] M. Nogueira-Junior, M.A. Haddad, "The diet of cubomedusae (Cnidaria. Cubozoa) in southern Brazil," Brazilian Journal of Oceanography, 56. 157- 164, 2008. [Online]. Available: http://dx.doi.org/10.1590/S1679-87592008000300001.

[13] M.L. Furnestin, "Méduses du plancton Marocain" Revue des travaux de l'Institut des pêches maritimes, 23 (1), 105- 124, 1956.

[14] C.Claus, "Ueber *Charybdea Marsupialis*," Vol. 1. Arbeitenaus dem Zoologischen. Instituten der Universität Wien, pp. 1–56, 1878.

[15] G. Rottini, L. Gusmani, E. Paravoel, M. Avian, P. Patrarca, « Purification and properties of a cytolytic toxin in venom of the jellyfish *Carybdea marsupialis* »Toxicon, 33, 315–326, 1995.

[16] J. Sánchez-Rodríguez, E. Torrens, L. Segura-Puertas," Partial purification and characterization of a novel neurotoxin and three cytolysins from box jellyfish

(*Carybdea marsupialis*) nematocyst venom," Arch. Toxicol, 80, 163–168, 2006.

[17] J.E. Purcell, S.I. Uye, W.T. Lo, « Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review. » Mar. Ecol. Prog. Ser, 350, 153–174, 2007. [Online]. Available: http://dx.doi.org/10.3354/meps07093

[18] INRH," Report of the Appearance of the Cubomedusa on Moroccan Coasts in 2021, INRH, 8p, 2021.

[19] P. A. Arneson, C. E. Cutress, "Feeding behavior of Alatina alata (Cubomedusae, Coelenterata) in the laboratory, Marine Biology, 36 (1), 1-7, 1976. [Online]. Available:https://doi.org/10.1007/BF00390473

[20] J.E. Seymour, T.J. Carrette, P.A. Sutherland," Do box jellyfi sh sleep at night? "Med J Aust, 181: 707—707, 2004.