Seasonal dynamics of the jellyfish *Rhizostoma pulmo* between the two estuaries of Oued Ghis and Oued Nekkour, Al Hoceima Bay (Moroccan Mediterranean coast)

**Bouchra Benyoubi**¹, **Omar Benamari**², **Sofiane Hasni**³, **Asmae Aknaf**⁴, **Said Benyoussef**⁵, **Omar Kada**⁵, **Hossain El Ouarghi**¹,²

¹Environmental Management and Civil Engineering Research Team (GEC), Laboratory of Applied Sciences (LSA). ENSAH, Abdelmalek Essaadi University, Tetouan, Morocco.
²Applied Chemistry Research Unit, FSTH, Abdelmalek Essaadi University, Tetouan, Morocco.
³Biology Department, Faculty of Sciences and Technology - Tangier, Abdelmalek Essaadi University, Tetouan, Morocco.
⁴Laboratory of Biology, Geosciences, Physics and Environment (OLMAN-LBGPE) Multidisciplinary Faculty, Mohammed the First University, Nador, Morocco.
⁵Laboratory of Halieutic Resources of the Institut des Recherches Halieutiques of Nador, Morocco.

**Abstract.** In recent decades, the global environmental balance has been disrupted due to new environmental conditions and increasing anthropogenic pressure. In this context, the increase in frequency and magnitude of jellyfish proliferation in the Mediterranean Sea can be examined as an indicator closely associated with potential impacts of global changes. Despite their importance in ecosystem function and services, current knowledge of jellyfish diversity and phenology is largely lacking in the southern Mediterranean Sea, particularly along the Moroccan Mediterranean coast. *Rhizostoma pulmo* is a large scyphozoan jellyfish endemic to the Mediterranean. It is the second dominant scyphozoan species in the jellyfish community of Al Hoceima Bay. In this article, we explore the seasonal dynamics of the jellyfish *R. pulmo* between the estuaries of Oued Ghis and Nekkour at Souani Beach. Due to the disparity between the visual abundance of jellyfish and their rare beaching along the shores of Al Hoceima Bay, we implemented a specific method for collecting *R. pulmo*. This approach involves the use of a coastal trawl, a fishing net 200 meters long with a mesh size of 5 cm, deployed 80 meters from the shore and pulled from both sides by fishermen. Sampling missions conducted throughout the year 2022 revealed that *R. pulmo* reaches its maximum abundance in summer. The results indicate a maximum abundance of 0.28 ind/m² in July 2022, with a maximum umbrella diameter reaching 26 cm in August 2022. Under the jellyfish umbrellas, fry of two fish species and one crustacean species were observed, adding an ecological dimension to this study. **Keywords:** Jellyfish blooms, Scyphomedusae, *Rhizostoma pulmo*, Moroccan Mediterranean coast.

**1 Introduction**

In recent decades, the global environmental balance has been disrupted due to global changes closely linked to increasing anthropogenic pressure [1]. Thus, the Mediterranean Sea can serve as a significant example of increasing anthropogenic pressure [1]. The Mediterranean Sea can serve as a significant example of increasing anthropogenic pressure [1]. The Mediterranean Sea can serve as a significant example of increasing anthropogenic pressure [1]. The Mediterranean Sea can serve as a significant example of increasing anthropogenic pressure [1]. The Mediterranean Sea can serve as a significant example of increasing anthropogenic pressure [1].

Some jellyfish species can generate significant accumulations of biomass, a phenomenon known as "jellyfish blooms." These proliferations pose a major obstacle to various economic activities, including fishing, aquaculture, coastal industry infrastructure, and tourism, leading to significant economic losses [4]. Research has shown that certain coastal areas experience a more pronounced increase in these populations than others [5,6]. As ecosystem components, jellyfish play a crucial role in the food web, renowned for their predation ability on various prey, including copepods, fish eggs and larvae, small fish, and other gelatinous planktonic taxa [7]. They are also preyed upon by several fish species, seabirds, and sea turtles [8, 9]. Jellyfish hosts provide shelter for developing larvae and juvenile fish while simultaneously serving as a vital food source for associated fish species [10]. This contributes to enhancing the survival and recruitment of fish larvae.
Rhizostoma pulmo [11] is an endemic species of the Mediterranean [12], being a large Scyphomedusa (approximately 40 cm in diameter). It is one of the six species considered as a nuisance [13]. Its presence in bloom density has been reported in the bay of Al Hoceima in two recent studies related to jellyfish biodiversity [14,15]. Due to the scarcity of knowledge about this species along the Moroccan Mediterranean coast and its invasive abundance, we launched a field study to analyze the seasonal dynamics of the jellyfish R. pulmo between the two estuaries of the Oued Ghis and the Oued Nekkour, in the bay of Al Hoceima, which is also an important tourist destination. This analysis is based on parameters such as jellyfish abundance per m², diameter of their umbrella, water temperature (°C), and salinity (g/l) of surface waters.

2 Materials and methods

2.1 Sampling Strategy and Area

Due to the significant gap between the visually observed abundance of jellyfish and their rare stranding along the coasts of Al Hoceima, a specific method for collecting R. pulmo was implemented. This method involved the use of nets with dimensions of 200 meters in length, equipped with a 5 cm mesh size. Sampling missions were conducted throughout the year 2022, covering all four seasons. A monthly frequency was maintained during the autumn, winter, and spring seasons. However, during the summer season, sampling was conducted bi-weekly, i.e., every two weeks. Horizontal trawls were conducted using the same type of fishing net (mesh size, 5 cm; length, 200 m). Horizontal sampling was performed using the net deployed horizontally along the coast (Figure 1), precisely at Souani Beach (35°11'53.74"N / 3°51'24.73"W) (Figure 2), to facilitate targeted jellyfish collection.

During each net retrieval, when catches were significant, sub-sampling was carried out to examine and measure the diameter of individual jellyfish umbrellas using a measuring board. Jellyfish abundance was estimated per square meter by dividing the number of jellyfish counted on the swept surface by the fishing net (at 80 m from the coast), as well as through visual observations. In parallel, measurements of the temperature (°C) and salinity (g/l) of surface waters were carried out during each sampling mission using a multi-parameter device.

3 Results

Temperature results show seasonal variations in the environmental conditions of the study area. Water temperatures rise gradually from January (15.4°C) to August (25.1°C), peaking in August, and then gradually decreasing to 17.8°C in December. (Figure 3). This increase in water temperature is a characteristic of the summer season in the region. Salinity appears relatively stable throughout the year, with slight fluctuations.

The R. pulmo jellyfish were spotted along the coasts of the central part of Al Hoceima Bay, reaching their maximum abundance during the summer season. In the sampling station at Souani beach (35°11'53.74"N / 3°51'24.73" W) located between the estuaries of the Oued Ghis (35°12'7.19" N / 3°52'11.45" W) and the Oued Nekkour (35°11'55.78" N / 3°49'34.45" W), the actual observation of R. pulmo extends over a period of seven months during the year 2022 (Figure 4). In contrast, other areas of the bay show limited abundance, characterized by sporadic observations of only a few specimens. During the year 2022, no jellyfish were observed in January, February, March, November, and December. However, the first sightings occurred in April, with a low abundance of only a few specimens (7 to 15 individuals) caught, followed by a slight increase in May and June. The month of July marked a significant increase in the number of R. pulmo caught, with a total of 543 individuals captured. In August, although the number of individuals caught decreased, it remained relatively high, with 35 individuals.
The diameter of the umbrella of examined *R. pulmo* individuals varied in April from 7 to 11 cm (Figure 5). Individuals ranged in size from a minimum of 5 cm to a maximum of 25 cm during the month of July. The maximum umbrella diameter, 26 cm, was observed in August, where umbrella diameters ranged between 15 and 26 cm. The analysis of the maximum abundance of *R. pulmo* jellyfish per square meter in the sampling area revealed significant seasonal variations. The first appearance was in April, with a low maximum abundance of 0.003 ind/m² recorded, followed by a slight increase in May to 0.006 ind/m² and 0.05 ind/m² in June. In July, a considerable increase in maximum abundance, reached 0.28 ind/m², while in August, it maintained a relatively high abundance at 0.13 ind/m². In September and October, there was a significant decrease in maximum abundance to 0.02 ind/m² (Figure 6).

The presence of fish fry and crustaceans may indicate that the area serves as an essential nursery for several fish species. The diet of *R. pulmo* includes various species, including copepods, calanoids, ciliates, and fish larvae [18]. Proliferations of *R. pulmo* could first threaten the recruitment of zooplanktivorous fish larvae through competition or by controlling their population in the planktonic community, and then have repercussions on higher trophic levels. Commercial categorization of edible jellyfish typically relies on measuring the diameter of their bells [21]. If the bell diameter of the jellyfish exported to China is approximately 33 cm, it is classified as Class A; between 25 and 33 cm, as Class B; between 17 and 25 cm, as Class C and if the diameter is less than 17 cm, as Class D [21]. The maximum bell diameter of the *R. pulmo* individuals obtained in this study reached 26 cm. In this study, *R. pulmo* is classified in Class C.

### 4 Discussion

There is limited research on the distribution of *R. pulmo* along the Moroccan Mediterranean coast. A study conducted in northwest Morocco reported a low number of *R. pulmo* strandings on the beaches [16]. Two recent studies conducted in the Bay of Al Hoceima on jellyfish biodiversity revealed that *R. pulmo* is the second dominant species in the scyphomedusa community of the bay, with abundance ranging from isolated individuals to moderate aggregations (a single proliferation reported in July 2022). These species exhibit significant seasonal variation, with the highest densities observed during the summer months of July and August and a complete absence during the winter months. On July 22nd, 2022, the number of *R. pulmo* reached bloom densities in the study area, with an abundance of 0.5 ind/m² [14,15]. The seasonal variations in *R. pulmo* abundance dynamics in the region can be interpreted as the outcomes of environmental conditions. Specifically, the average winter temperature serves as a key trigger for the onset of sexual reproduction and strobilation [17]. In the winter of 2022 in the Bay of Al Hoceima, the average surface water temperature ranged between 15.4 and 15.8°C. Spring temperatures also influence phenological changes, promoting an earlier onset and a longer jellyfish season [18]. There is evidence that water temperature changes trigger strobilation in many Rhizostome spp cases. The relationship between warmer winters and an early season for *R. pulmo* has been highlighted by Leoni et al. [18]. A higher temperature not only induces an earlier jellyfish bloom but also stimulates the abundance of the *R. pulmo* population. In experimental settings, the number of buds generated per *R. pulmo* polyp increases with temperature, rising from 2.5 ± 1 at 21°C to 8.8 ± 5.6 at 28°C [20].
5 Conclusion

Overall, this study sheds light on the seasonal distribution and abundance of *Rhizostoma pulmo* in the region of the Moroccan Mediterranean coast, a relatively understudied area in this context. The results highlight a significant variation in the abundance of *R. pulmo*, with maximum densities observed during the summer months, particularly in July and August, and a complete absence during winter. Warmer winter temperatures appear to trigger strobilation and promote an early onset of the jellyfish season. Additionally, the study reveals the presence of fish fry and crustaceans, suggesting a crucial role of this area as a nursery for several fish species. Lastly, *R. pulmo* proliferations could have significant implications for higher trophic levels, initially threatening the recruitment of zooplanktivorous fish larvae through competition or top-down control of the planktonic community, and subsequently, on marine ecosystems as a whole.

References

11. S. Macri, Nuove Osservazioni Intorno La Storia Naturale Del Polmone Marino (1778)