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## Revealing Hidden Pelagic BioDiversity: Confirmed Records of Holoplanktonic Molluscs in Lebanese Waters (Eastern Levantine Mediterranean Sea)

Ali Badreddine<sup>1,2\*</sup>, Laura Khatib Lakiss<sup>3</sup>, Samer Lakiss<sup>3,4</sup>, Samer Fatfat<sup>5</sup>, Ricardo Aguilar<sup>6</sup>

<sup>1</sup> Tyre Coast Nature Reserve-Department of Biology-Tyre, South Lebanon

<sup>2</sup> Lebanese University-Faculty of Sciences-Hadath-Lebanon

<sup>3</sup> Guardians of the Blue, Byblos, Lebanon

<sup>4</sup> Xiphias Diving Center, Byblos, Lebanon

<sup>5</sup> Palm Island Nature Reserve-Tripoli, North Lebanon

<sup>6</sup> OCEANA, Gran Via 62, 7, 28013, Madrid, Spain

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\*Corresponding author: Ali Badreddine

### Abstract

*This study provides the first confirmed records of two holoplanktonic molluscs, the sea elephant *Pterotrachea coronata* Forsskål, 1775, and the pelagic nudibranch *Phylliroe bucephala* Lamarck, 1816, in Lebanese waters (eastern Levantine Mediterranean Sea), based on photographic and video evidence collected during marine biodiversity monitoring surveys off Byblos (Jbeil), northern Lebanon, within an area of interest for future designation as a Marine Protected Area in Lebanon. In addition, an unidentified pelagic Mollusca larva was documented, along with important new observational data on hydromedusae of the genus *Aequorea* Péron & Lesueur, 1810.*

*These findings validate previously unconfirmed reports and highlight the presence of specialized and elusive holoplanktonic Mollusca in the region. Their occurrence reflects the ecological richness of Lebanese pelagic ecosystems, the availability of gelatinous zooplankton prey, and the complexity of marine trophic interactions.*

*This work further underscores the importance of sustained marine monitoring and the growing role of citizen science as an effective tool for documenting marine biodiversity. It also emphasizes the need for strengthened conservation efforts, including the expansion of Marine Protected Areas, to enhance knowledge and protection of understudied pelagic biodiversity in the Levantine basin.*

## Introduction

Holoplanktonic molluscs constitute an important component of zooplankton communities, which comprise a highly diverse assemblage of organisms occupying multiple trophic levels and linking primary production to higher consumers (Lalli & Gilmer, 1989; van der Spoel et al., 2023). In addition, complex biological interactions within the pelagic realm, including parasitic and symbiotic relationships, further highlight their ecological significance (Laval, 1980; Lalli & Gilmer, 1989; Maggioni et al., 2023).

Among them, the heteropod *Pterotrachea coronata* Forsskål, 1775, commonly known as the “sea elephant”, and the pelagic nudibranch *Phylliroe bucephala* Lamarck, 1816 are highly specialized holoplanktonic molluscs that play key roles in pelagic ecosystems, functioning both as predators and prey and contributing to energy transfer within marine food webs (Thiriou-Quievreux, 1973; Seapy, 1985; Lalli & Gilmer, 1989; van der Spoel et al., 2023; Jerez-Guerrero et al., 2024). Furthermore, the bioluminescent capabilities of *Pterotrachea coronata* and *Phylliroe bucephala* have been documented, highlighting their functional role within pelagic ecosystems (Brown, 2023). This trait is closely linked to key ecological processes such as predator avoidance, prey attraction, and intraspecific communication, and is often associated with diel vertical migration patterns—an important behavior also observed in *Pterotrachea coronata* (Brown, 2023). Despite their ecological importance and wide global distribution, both species, as well as holoplanktonic molluscs in general, remain poorly documented in the Mediterranean Sea (Petrescu & Petrescu, 2016), particularly in the Eastern Levantine basin (Lalli & Gilmer, 1989), including Lebanese waters, where available data remain scarce (Lakkis, 2013).

This apparent rarity is likely not due to their absence, but rather to the strong temporal variability and patchy distribution of planktonic communities, coupled with the lack of sustained long-term monitoring programs, which together contribute to their underrepresentation in regional datasets (Boero et al., 2008; Petrescu & Petrescu, 2016; van der Spoel et al., 2023). It may also be related to their biological and ecological characteristics.

In particular, their fully pelagic lifestyle, high transparency, and relatively small size—especially in *Phylliroe bucephala*, which rarely exceeds 30–40 mm, compared to *Pterotrachea coronata*, which can reach 200–300 mm (Lalli & Gilmer, 1989)—make them inherently difficult to detect, photograph, and sample, even for experienced divers and marine researchers, resulting in rare and largely chance-based encounters.

However, in recent years, the development of citizen-science initiatives and marine biodiversity monitoring programs has improved the detection and reporting of elusive marine organisms, particularly in coastal and surface waters of the Mediterranean Sea (Boero et al., 2016; Micaroni et al., 2022; Badreddine et al., 2025; Zampardi et al., 2025). In Lebanon, despite increasing efforts in marine biodiversity research led by marine protected areas, research centers, and universities, holoplanktonic molluscs remain poorly studied and are only rarely documented (Lakkis, 2013; Badreddine et al., 2025). Recent collaborative marine biodiversity monitoring initiatives, focusing on indigenous/ non-indigenous species in the Lebanese waters, involving fishers, divers, and other marine stakeholders have begun to address this gap, facilitating the

detection of rare and previously overlooked species (Badreddine et al., 2022, 2023, 2024, 2025).

In Lebanese waters, *Pterotrachea coronata* was only briefly mentioned by Lakkis (2013), who noted that “two species are present in our Levantine waters” (“2 sont présentes dans nos eaux levantines”, p. 258), without providing clear documentation or confirmation. In the same work, *Phylliroe bucephala* was also reported under the name *Phylliroë bucephalum* Péron & Lesueur, but likewise without supporting photographic or specimen-based evidence (Lakkis, 2013).

The present study aims to confirm the occurrence of the sea elephant *Pterotrachea coronata* and the pelagic nudibranch *Phylliroe bucephala* in Lebanese waters (eastern Levantine Mediterranean Sea) based on photographic and video evidence, thereby contributing to improved knowledge of the distribution of holoplanktonic molluscs in the Levantine basin.

## Materials and Methods

The species were observed and documented as part of a regular marine biodiversity monitoring program conducted in the coastal and offshore waters of Byblos (Jbeil), northern Lebanon. This program aims to assess marine habitats and biodiversity in an area of interest for potential designation as a future Marine Protected Area. Surveys were regularly carried out by a team of divers and marine experts.

Unusual or noteworthy species were systematically documented through in situ photography and videography, and, when possible, specimens were collected for further investigation and identification.

All photographic and video records were shared among specialists for verification. Species identification was based on distinctive morphological characteristics described in the literature. In addition, observational data (including date, location, and observer/photographer) were recorded. Information on species distribution, morphology, and ecology was also considered to support accurate identification and to contextualize their occurrence in Lebanese waters (Figure 1).



**Figure 1.** Schema illustrating the marine biodiversity monitoring protocol: in situ observation and documentation (photos, videos, field notes including depth, habitat, and species), followed by data sharing and expert verification for species identification ©Ali BADREDDINE.

## Results and Discussion

Table 1. Records of holoplanktonic molluscs observed in Lebanese waters (eastern Levantine Mediterranean Sea). The table presents

Species	Date	Number of individuals	Location / Area	Depth (m)	Observers and Data Verification Details	Photos / Videos
<i>Pterotrachea coronata</i>	28 April 2023	1	Byblos (Jbeil), 2.2 km offshore, North Lebanon	12	Observed and photographed by Sahar Lakkis; identification verified based on morphological characteristics and literature comparison and expert consultation (RA)	Video and photos
Unidentified Pelagic Mollusca	2 September 2023	1	Offshore waters of Byblos (Jbeil), North Lebanon	10	Observed and photographed by Sahar Lakkis; identification limited due to larval stage	Video and photos
<i>Phylliroe bucephala</i>	25 January 2024	1	Byblos (Jbeil), 2.8 km offshore, North Lebanon	6	Observed and photographed by Sahar Lakkis; identification confirmed based on morphological traits and literature comparison and expert consultation (RA)	Video and photos

Three taxa were recorded in Lebanese waters (eastern Levantine Mediterranean Sea): the heteropod *Pterotrachea coronata* (sea elephant) and the pelagic nudibranch *Phylliroe bucephala*, both confirmed through photographic and video evidence, along with an unidentified pelagic veliger (Mollusca larva) at an early developmental stage (Table 1).

### Systematics

1. *Pterotrachea coronata* Forsskål, 1775

Phylum Mollusca Linnaeus, 1758

Class Gastropoda Cuvier, 1795

Clade Heterobranchia Burmeister, 1837

Order Pterotracheoidea Rafinesque, 1814

Family Pterotracheidae Rafinesque, 1814

Genus *Pterotrachea* Forsskål, 1775

Species *Pterotrachea coronata* Forsskål, 1775

### Distribution of the species

The sea elephant *Pterotrachea coronata* Forsskål, 1775 is a holoplanktonic heteropod gastropod belonging to the family Pterotracheidae Rafinesque, 1814. This family comprises two genera and five currently accepted species, four of which are assigned to the genus *Pterotrachea* Forsskål, 1775 (MolluscaBase eds., 2026). *P. coronata* has a broad circumglobal distribution (Jerez-Guerrero et al., 2024, and references therein) and is considered cosmopolitan in tropical and subtropical waters (Aravindakshan, 1973; Thiriote-Quievreux, 1973).

The species has been reported from the Indo-Pacific region (Aravindakshan, 1969, 1973; Thiriote-Quievreux, 1973), the Atlantic Ocean (Thiriote-Quievreux, 1973; de Vera et al., 2006; Clark et al., 2021; López-Cabello et al., 2025), and the Red Sea (Janssen, 2007). In the Mediterranean Sea, *P. coronata* has been sporadically recorded across several sub-basins (Aravindakshan, 1969; Thiriote-Quievreux, 1973), including the central Mediterranean (e.g., the Tyrrhenian Sea: Koutsoubas et al., 1997; the Ionian Sea: Montesanto et al., 2022; and Malta, based on online video observations ©Marine Life Guide Malta, non-peer-reviewed source), the western Mediterranean (e.g., Villefranche-sur-Mer:

details of the identified taxa, including date of observation, number of individuals recorded, location and area, depth of occurrence, observer and data verification details, and the type of photographic or video evidence provided.

Olivier et al., 2015; Koutsoubas et al., 1997), and the eastern Mediterranean, including the Aegean Sea (Koutsoubas et al., 1997) and Greek waters (based on online video observations ©EastMediterraneanLife, non-peer-reviewed).

In the Levantine basin, the species appears to be rarely encountered, with confirmed records mainly restricted to Turkish waters (Çevik et al., 2006; Mutaf et al., 2008; Janssen & Peijnenburg, 2013). Its occurrence in Lebanese waters has only been briefly mentioned (Lakkis, 2013), but remains unconfirmed, as no specimen-based or well-documented photographic evidence has been available to date.

### Morphology and Ecology

*Pterotrachea coronata* is characterized by a highly transparent, elongated, and streamlined body, with visible internal organs and a complete loss of the shell, reduced to a small visceral nucleus (Figure 2). It possesses prominent cylindrical paired eyes, a long and mobile proboscis, and a well-developed ventral swimming fin used for propulsion, as well as a laterally flattened tail adapted for efficient locomotion in the water column (Seapy, 1985). The examined specimen exhibited a relatively compact morphology and lacked a fully developed tail, suggesting a juvenile stage. This observation is consistent with previous descriptions of early developmental stages reported from the eastern Mediterranean, including Turkish waters (Mutaf et al., 2008) and the Ionian Sea (Montesanto et al., 2022), as well as earlier accounts by Thiriote-Quievreux (1973).



Figure 2. The sea elephant *Pterotrachea coronata* observed in the waters of Byblos (Lebanon). Image extracted from video footage provided by S. Lakkis.

Ecologically, *Pterotrachea coronata* is an active pelagic predator, feeding on a wide range of zooplanktonic organisms, including copepods, fish larvae, and gelatinous plankton (Aravindakshan, 1973; Thiriou-Quievreux, 1973; Seapy, 1985). The species exhibits pronounced diel vertical migration, typically moving from mesopelagic depths (200–600 m) during the day to surface waters (0–200 m) at night (Clark et al., 2021; Brown, 2023). This behavior plays a significant ecological role by contributing to vertical energy transfer within the water column and facilitating the biological carbon pump, thereby linking surface productivity with deeper ocean layers (Brown, 2023; López-Cabello et al., 2025).

### Systematics

2. *Phylliroe bucephala* Lamarck, 1816

Phylum Mollusca Linnaeus, 1758

Class Gastropoda Cuvier, 1795

Clade Heterobranchia Burmeister, 1837

Order Nudibranchia Cuvier, 1817

Suborder Cladobranchia Willan & Morton, 1984

Family Phylliroidae Menke, 1830

Genus *Phylliroe* Péron & Lesueur, 1810

Species *Phylliroe bucephala* Lamarck, 1816

### Distribution of the species

*Phylliroe bucephala* Lamarck, 1816 is a holoplanktonic nudibranch belonging to the family Phylliroidae Menke, 1830, which comprises two confirmed genera and three currently accepted species. It is one of only two recognized species within the genus *Phylliroe* F. Péron & Lesueur, 1810 (Jerez-Guerrero et al., 2024; MolluscaBase eds., 2026). The species exhibits a circumtropical distribution (Lalli & Gilmer, 1989; Salvador et al., 2022; Jerez-Guerrero et al., 2024), occurring in both the Atlantic Ocean (Cervera et al., 2004; Borges et al., 2010; Jerez-Guerrero et al., 2024) and the Indo-Pacific region (Geyzner et al., 2017, and references therein; van der Spoel et al., 2023; Jerez-Guerrero et al., 2024; Santiago-Valentín et al., 2025).

In the Mediterranean Sea, *P. bucephala* has been only rarely reported from several regions (Jerez-Guerrero et al., 2024), including the western basin (Salvador et al., 2022), the central Mediterranean (Pruvot-Fol, 1954; Janssen et al., 2020), including the French waters at Villefranche-sur-Mer, where the earliest documented specimen dates back to 1899 and is housed in the Grigore Antipa National Museum of Natural History (Petrescu & Petrescu, 2016, and references therein). In the Levantine Sea, confirmed records are limited to Syrian waters (Durgham & Ikhtiyar, 2020) and the most southeastern Mediterranean (Geyzner et al., 2017). In Lebanese waters, the species has been previously reported by Lakkis (2013) under the name *Phylliroë bucephalum*; however, this record has remained unconfirmed to date, with no photographic or video evidence available prior to the present study.

### Morphology and Ecology

*Phylliroe bucephala* is characterized by a highly transparent, laterally compressed body and a fish-like appearance, making it one of the most specialized and visually distinctive pelagic opisthobranchs (Pruvot-Fol, 1954; Goodheart & Wägele, 2020; Salvador et al., 2022; Jerez-Guerrero et al., 2024). This

morphology is clearly illustrated in the examined specimens, particularly the lateral compression and overall body outline (Figure 3. 1B, D). Locomotion is achieved through undulatory movements of lateral body expansions that function as fins, enhancing hydrodynamic efficiency in the open ocean (Fernández-Alamo, 1997), as observed during swimming sequences (Figure 3C, D). The species possesses two well-developed rhinophores that serve as chemosensory organs, visible in the anterior region (Figure 3C). Its conspicuous digestive glands are clearly visible through the transparent body, typically exhibiting orange to reddish-brown pigmentation (Figure 3A, B, D), while other major internal structures are also discernible, reflecting its advanced adaptation to a fully pelagic lifestyle (Hernández & de Vera, 2010; Goodheart & Wägele, 2020; Jerez-Guerrero et al., 2024). The observed specimen (Figure 3A, B, C, D) is consistent with previous descriptions of *Phylliroe bucephala* (Lalli & Gilmer, 1989; Salvador et al., 2022), including records from the Mediterranean Sea, particularly the Levantine basin (Geyzner et al., 2017; Durgham & Ikhtiyar, 2020).

Ecologically, *Phylliroe bucephala* is a specialized pelagic predator that feeds primarily on gelatinous zooplankton, including cnidarians and salps (Pruvot-Fol, 1954; Lalli & Gilmer, 1989; Jerez-Guerrero et al., 2024).

Its life cycle includes a parasitic larval stage (Lalli & Gilmer, 1989; Maggioni et al., 2023), during which larvae develop within the bell of hydromedusae, particularly *Zanclaea costata* Gegenbaur, 1857, as well as other hydrozoans such as species of the genus *Aequorea* Péron & Lesueur, 1810. Observational evidence, including photographs and field notes, has documented parasitic interactions and feeding behavior on *Aequorea*-type jellyfish (e.g., online visual record: <https://shellmuseum.org/blog/fish-or-mollusk/>; non-peer-reviewed source).

During this parasitic phase, larvae attach to the interior of the host medusa's bell and feed on its ring canal, radial canals, and manubrium, supporting their development within the host. Juveniles maintain this association until reaching maturity, after which they transition into free-swimming adults (Pruvot-Fol, 1954; Lalli & Gilmer, 1989).

In adulthood, *P. bucephala* adopts an active predatory lifestyle, feeding on gelatinous zooplankton such as hydromedusae and siphonophores (Lalli & Gilmer, 1989; Jerez-Guerrero et al., 2024). This trophic behavior highlights its ecological role within pelagic food webs, particularly in gelatinous-based trophic interactions (Pruvot-Fol, 1954; Lalli & Gilmer, 1989; Jerez-Guerrero et al., 2024).

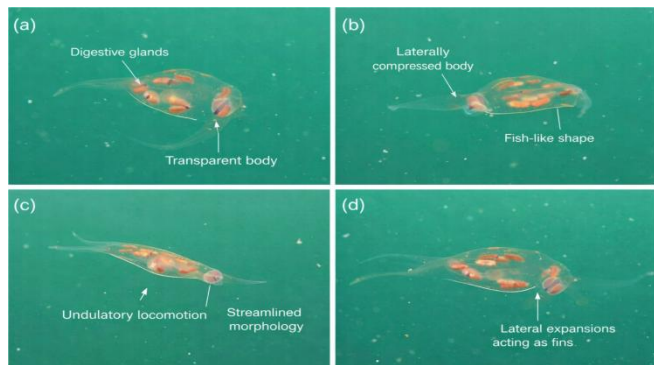
In Lebanese waters, *Zanclaea costata* has been reported, although its current occurrence requires confirmation (Lakkis, 2013). Hydrozoans of the genus *Aequorea*, including *Aequorea forskalea* Péron & Lesueur, 1810 (Figure 4A, B, H), *Aequorea conica* Browne, 1905 (Lakkis, 1988, 2013), and *Aequorea* spp. (Figure 4E–G, I), are widely distributed and frequently observed along the Lebanese coast, and waters (Lakkis, 1988, 2013; Badreddine, pers. obs.). Seasonal blooms of *Aequorea* spp. and other gelatinous organisms have been repeatedly recorded along the Lebanese coastline, particularly in April (Badreddine, pers. obs. since 2016), including in the Byblos area where *P. bucephala* was observed, may suggesting favorable conditions for its occurrence.

Siphonophores (Badreddine et al., 2025) and salps (Figure 4C, D) are also present in Lebanese waters (Badreddine et al., 2025).

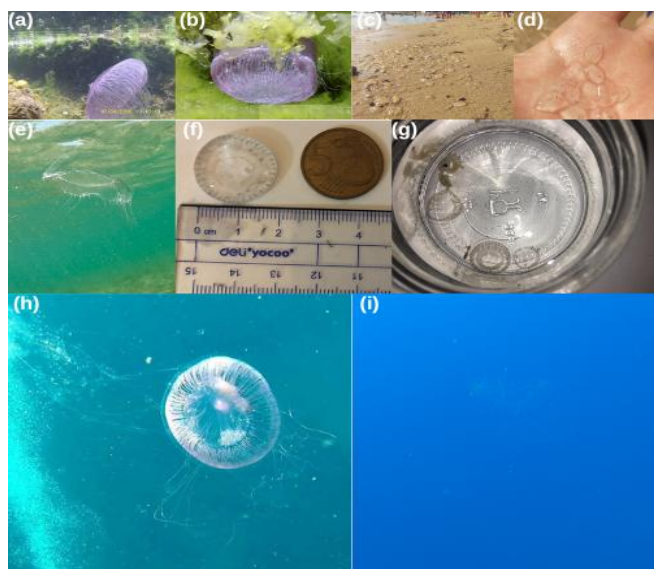
These gelatinous organisms have been observed in the same area where the species was recorded, particularly in the Byblos region, where seasonal blooms are frequently documented (Lakkis, 2013; Badreddine et al., 2025; pers. obs.). Such local prey availability and aggregations likely facilitate the occurrence and observation of *P. bucephala*.

This trophic behavior highlights the ecological role of *P. bucephala* within pelagic food webs, particularly in gelatinous and medusa-based trophic interactions (Pruvot-Fol, 1954; Lalli & Gilmer, 1989; Jerez-Guerrero et al., 2024).

It is noteworthy that an unidentified pelagic veliger (Mollusca larva) was also observed and photographed during this study; however, identification to a lower taxonomic level was not possible due to its very early developmental stage (Figure 5).

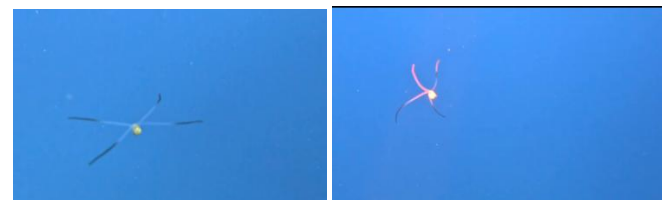


**Figure 3.** *Phylliroe bucephala* Lamarck, 1816 observed in Lebanese waters (eastern Levantine Mediterranean Sea). (A) Dorsolateral view showing the highly transparent body and conspicuous orange digestive glands; (B) Lateral view illustrating the laterally compressed, fish-like body shape; (C) Elongated swimming posture highlighting undulatory locomotion and streamlined morphology; (D) General view showing lateral body expansions functioning as fins and overall pelagic adaptations. Image extracted from video footage provided by S. Lakkis.



**Figure 4.** Gelatinous zooplankton observed in Lebanese coastal waters. (a–b) *Aequorea forskalea* observed in a tidal pool of the vermetid reef in Beirut (Raoucheh) on 7 April 2016. © A. Badreddine. (c–d) Bloom of salps (*Salpida*) observed along the Byblos coast on 7 May 2019 (© Lebanese Facebook page “Marine Life and

Biodiversity in Lebanon”): (c) stranded individuals along the shoreline of Byblos beach (same area where *Pterotrachea coronata* and *Phylliroe bucephala* were observed and photographed); (d) freshly collected specimens. (e) *Aequorea* sp. observed in Tripoli waters (34°29'28.38"N, 35°46'5.41"E) on 19 May 2019. © H. Safarjal. (f–g) *Aequorea* spp. observed in Beirut waters on 13 February 2020: (f) collected specimen showing radial canal structure; (g) specimens in a container highlighting internal morphology. © A. Badreddine. (h) *Aequorea forskalea* observed in Tyre waters (April 2021). © H. Ezzedine. (i) *Aequorea* sp. observed in Byblos waters on 28 November 2025, in the same area where *Pterotrachea coronata* and *Phylliroe bucephala* were recorded. © S. Lakkis.



**Figure 5.** The unidentified pelagic veliger (Mollusca larva) observed and photographed in Byblos waters. Image extracted from video footage provided by S. Lakkis.

## Conclusion

The occurrence of *Pterotrachea coronata* and *Phylliroe bucephala* in Lebanese waters is not unexpected, as the eastern Levantine Mediterranean is characterized by relatively high productivity and supports diverse planktonic communities, including zooplankton, phytoplankton, tintinnids, and dinoflagellates (Abboud-Abi Saab, 2012; Ouba et al., 2016; Abboud-Abi Saab et al., 2022). The availability of such prey resources likely facilitates the presence of pelagic predators such as *P. coronata* and *P. bucephala*. Their apparent rarity in the region is therefore more likely related to limited observation and monitoring rather than true absence.

The confirmed presence of *P. coronata* and *P. bucephala* in Lebanese waters significantly improves current knowledge of the distribution of these rarely reported holoplanktonic molluscs in the Levantine basin and the Mediterranean Sea, helping to fill an important biogeographic gap.

From an ecological perspective, these findings highlight the richness of pelagic biodiversity in Lebanese waters and emphasize the importance of sustained monitoring and continued investigation of marine habitats and their associated communities.

These results are consistent with the increasing number of marine biodiversity records reported in recent years along the Lebanese coast, including both native and non-indigenous species, likely reflecting improved monitoring efforts and growing research capacity (Aguilar et al., 2018; Badreddine et al., 2022, 2023, 2024, 2025).

Furthermore, this study highlights the importance of expanding Marine Protected Areas in Lebanese waters to safeguard pelagic habitats and associated biodiversity, strengthening long-term marine biodiversity monitoring programs, and promoting citizen science initiatives as effective tools for detecting and documenting rare and elusive species.

Overall, further research focusing on holoplanktonic organisms remains essential to better understand their distribution, ecology,

and functional role within Mediterranean marine ecosystems, particularly in the still understudied Levantine region.

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