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Brief Report

Expanding the Zooplankton Inventory of the Levantine Basin: Novel Taxa and First Records from South Lebanon

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Abstract

The Levantine Basin is the first region of the Mediterranean Sea to be impacted by climate warming and the arrival of non-indigenous species (NIS) via the Suez Canal. Although Levantine zooplankton has been studied previously, recent datasets capable of detecting the occurrence of new taxa, or shifts in community composition, especially in the eastern-most part of the basin, are lacking. The present study provides updated information on zooplankton composition from Tyre (South Lebanon). In this study, the occurrence of two copepod families (Canuellidae, Longipediidae) and the first regional record of Facetotecta (Y-nauplii) are reported for the first time in the Levantine Basin. Additionally, although six Calanoida species were recorded as new to the Lebanese fauna, none can be attributed to Lessepsian NIS.

Keywords: biodiversity; Levant sea; Mediterranean basin; plankton; Tyre; *Canuella*; *Longipedia*; Facetotecta

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1. Introduction

The increasing anthropic pressure [1–6], the ongoing climate warming [7,8], the continuous arrival of species from outside the Mediterranean, and biological invasions [9–11] make the Mediterranean basin one of the most rapidly changing bioregions worldwide [12,13]. The introduction and invasiveness of non-indigenous species (NIS) are manifested by their establishment and expansion into new ecological niches following their arrival, often at the expense of indigenous species [14]. This process has been intensified since the opening of the Suez Canal in 1869 and the damming of the Nile in 1964, making the Levant basin a sentinel zone for newcomer species [9,15] in the frame of the so-called Lessepsian migration [16]. The Levantine Basin is characterized by distinct oceanographic features [17], primarily influenced by its distance from the nutrient-rich Atlantic inflow. It also experiences a negative freshwater balance, with evaporation exceeding the input from

rivers and precipitation [18,19]. For these reasons, along with habitat degradation, and fishing pressure, the Levantine Basin is the most sensitive region of the Mediterranean to climate change. Therefore, the increasing sea temperature favors the establishment of new thermophilic species coming from the Red Sea and the Indo-Pacific region [20–27]. The Lebanese coastal waters are characterized by a narrow continental shelf that hosts a variety of marine habitats [28–31] and a high number of NIS [32–36]. This well-known situation, however, is typical of benthic environments, whereas pelagic communities have not been considered as potentially diverging from this pattern. In fact, the last comprehensive zooplankton lists date back to 2013 (with samples collected in 2007) [37], with most surveys conducted before 2000 [38–42]. No updated datasets have been produced since then, leaving a significant gap in knowledge. Planktonic communities do not always conform to the patterns established from benthic studies. In fact, unlike benthic taxa, some zooplankton groups such as Calanoida show an increase in species richness from west to east across the Mediterranean basin (compare [43] with [44]), as well as a tendency to migrate southwards, contrary to the expected routes imposed by climate warming, even with the transit in the Suez Canal as so-called anti-Lessepsian migrants [16,45,46]. Such atypical behavior, together with the rarity of Lessepsian migrants in planktonic assemblages, highlights the necessity of a dedicated study focused on planktonic communities in the Levantine Basin of the Mediterranean Sea.

Based on material collected within the framework of "Blue Tyre Local Partnership for Sustainable Marine and Coastal Development" (AID 012314/01/6), and in line with previously published results on benthic material [47–49], the aim of the present study is to update the zooplankton composition in Lebanese waters, with the focus on the taxon Calanoida (Copepoda), the most important component of the zooplankton across all latitudes in terms of both species richness and abundance [43].

2. Materials and Methods

Sample collection was carried out in November 2022, June 2023, and April 2024, within the framework of the Blue Tyre project, at three stations (a, b, c) off the coast of Tyre (south Lebanon) (Figure 1).

At each station, three vertical tows (each tow representing a replicate) were conducted over a 0–50 m depth interval. The used plankton net was characterized by a 42 cm net mouth diameter and a 200 µm mesh size. The vertical tows were performed by hand without the aid of a winch, taking care of filtering at a speed not lower than 0.5 $m \cdot s^{-1}$. The filtered volume was calculated by using a flowmeter (digital flowmeter HYDRO-BIOS model 438115, Holtenau-Kiel, Germany). Given the impossibility of using the same instrument throughout the whole duration of the project, environmental parameters such as surface temperature and salinity have been retrieved from the Copernicus Marine Environment Monitoring Service (CMEMS) [50].

Each sample was fixed in situ with 80% ethanol and stored in the Blue Tyre Project inventory at the Department of Biological and Environmental Sciences and Technologies (DiSTeBA) of the University of Salento (Lecce, Italy). Samples were sorted under a Zeiss compound microscope, and specimens underwent preliminary morphological identification to the LPT level (lowest possible taxon). Due to their general dominance in species richness and abundance within zooplankton [43], Calanoida (Copepoda) were studied in detail, with species-level identifications made using available identification guides [51,52].

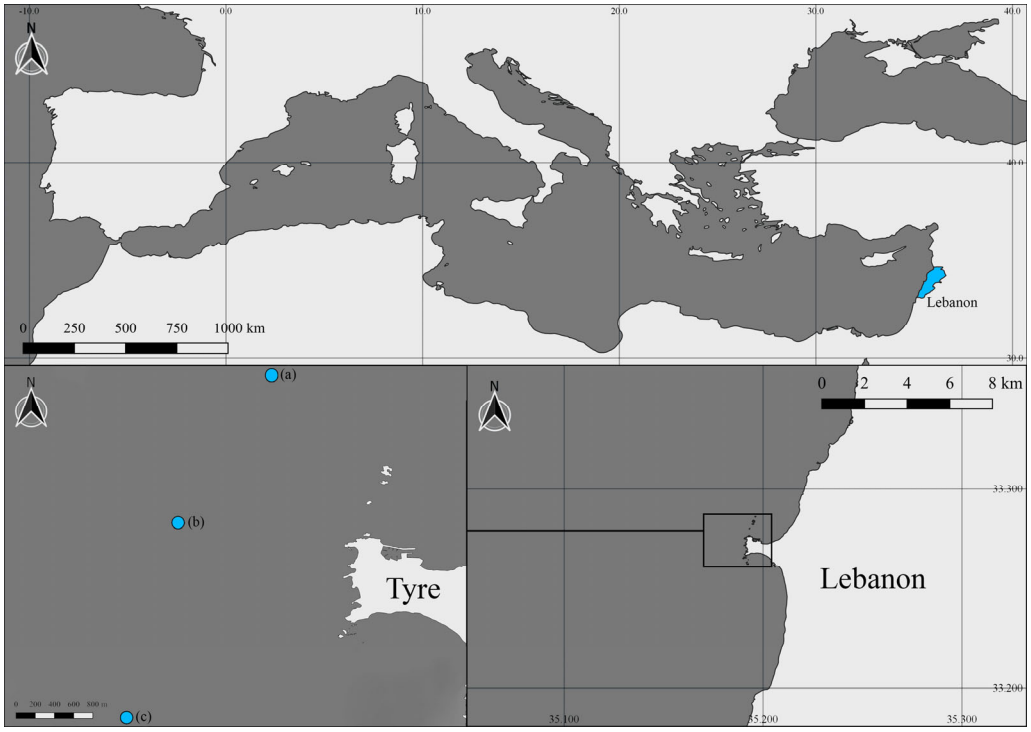

Figure 1. Map of the geographic area where sampling has been carried out. (**a**) 33°17′15.8634″ N, 35°8′24.648″ E, (**b**) 33°16′25.14″ N, 35°8′15.6114″ E, (**c**) 33°15′42.2994″ N, 35°8′13.38″ E, sampling stations.

Taxonomic abundances per sample were counted and then normalized to volume (ind.·m^{-3}). For each sampling site and time, mean abundances and standard deviations were calculated to LPT and family level. Statistical analyses included ANOVA carried out on abundance values of 103 zooplankton taxa recorded in 27 samples, and on 5 environmental descriptors (temperature, salinity, Chl-*a* concentration, photoperiod, and moon phase) related to the three different stations and times of the study. The SIMPER procedure has been used to individuate taxa mainly responsible for similarities inside each time, and each station or dissimilarities between times and stations. Zooplankton diversity was assessed on a subset of the 103 taxa, including only those identified at the species level (59). Species richness (S), Margalef's index (D), and Pielou's evenness (J′) were computed using the DIVERSE routine implemented in the software PRIMER-E. To evaluate the effects of sampling time (November 2022, June 2023, April 2024) and station (A, B, C) on community diversity, PERMANOVA analyses were performed on univariate indices using Euclidean distance. Each PERMANOVA included time, station as fixed factors, with 9999 permutations. Abundance data were fourth-root transformed prior to analysis to reduce the influence of dominant taxa, and temporal or spatial differences were considered significant at P(perm) < 0.05 (significance level = 95%). All statistical tests were performed using the software package PRIMER-E v6 [53].

Both the hand towing of the plankton net, the fragmentariness of sampling times, and the impossibility of collecting complete datasets of environmental parameters must be considered as limiting factors for ecological assessments, including seasonality and quantitative comparisons with previous studies [37].

This research complies with restrictions regarding collected sample size and environmental surveys of the collection sites, as well as with local, regional, national, and international rules and regulations on biodiversity access, sustainable use, and benefit-sharing (Convention on Biological Diversity and its Nagoya Protocol, national regulations).

3. Results

The extrapolation of environmental parameters from CMEMS at the three stations at the three sampling times allowed the obtaining of environmental data adjusted in Table 1. At each sampling time, data from the satellite did show differences in values between the stations only for Chl-*a* concentrations.

Table 1. Water parameters (temperature, salinity, and Chl-*a*, from Copernicus satellite data) and season characteristics (photoperiod and moon phase) of sampling sites at time of zooplankton collections. Moon phase is calculated for full moon = 100.

	Nov22A	Nov22B	Nov22C	Jun23A	Jun23B	Jun23C	Apr24A	Apr24B	Apr24C
Temp (°C)	23.8	23.8	23.8	24.5	24.5	24.5	22.2	22.2	22.2
Sal (psu)	40.0	40.0	40.0	38.4	38.4	38.4	37.7	37.7	37.7
Chl-*a* (mg/m^3)	0.1349	0.1349	0.1330	0.0724	0.0706	0.0852	0.1116	0.1134	0.1191
photoper. (h)	10.2	10.2	10.2	14.4	14.4	14.4	13	13	13
moon	0.0	0.0	0.0	100.0	100.0	100.0	50	50	50

The analysis of 27 zooplankton samples yielded a total of 103 taxa (Table 2). The most represented group was Copepoda (Crustacea), comprising 53 taxa, most of which were identified to the species level, with Calanoida being particularly dominant (41 species) and the most abundant taxon overall, ranging from an average of 14.5 individuals per m^{-3} (ind.·m^{-3}) at station B (April 2024) to 1751.7 ind.·m^{-3} at station A (November 2022). Among other Crustacea, the most common were Corycaeidae, Oithonidae, and Oncaeidae, each found in more than 25 of the 27 samples (Figure 2). Taxa with the highest abundances were *Clausocalanus furcatus*, *Temora stylifera* (Copepoda, Calanoida), Oithonidae (Copepoda, Cyclopoida), *Evadne* spp. (Branchiopoda, Onchyopoda). The most abundant "non-Crustacea" taxa were Polychaeta larvae, Chaetognatha, Gastropoda veligers, and *Oikopleura* sp. (Appendicularia) (Figure 3).

Table 2. List of all the zooplankton taxa recorded in Lebanon, with their mean abundances and standard deviation at each sampling period. Taxa marked in bold are reported for the first time in Lebanon. Taxa marked with an asterisk (*) are the first record for the entire Levantine Basin.

		LPT	Nov-2022		Jun-2023		Apr-2024	
CALANOIDA		indet.	276.6	±117.2	61.7	±27.5	139.3	±98.7
	ACARTIIDAE	*Acartia clausi* Giesbrecht, 1892					9.0	±6.0
		Acartia negligens Dana, 1849–1852	1.1	±1.8	3.9	±2.5	2.2	±2.0
	AETIDAEIDAE	*Aetideus* sp.	0.1	±0.3	0.2	±0.7		
	AUGAPTILIDAE	*Haloptilus longicornis* (Claus, 1863)	0.1	±0.3	2.5	±1.6	1.1	±1.2
	CALANIDAE	*Calanus helgolandicus* (Claus, 1863)			0.3	±0.5		
		***Mesocalanus tenuicornis* (Dana, 1849–1852)**	0.1	±0.3	0.4	±1.1	0.5	±1.3
		Nannocalanus minor (Claus, 1863)	1.8	±2.1	1.6	±1.3	2.5	±3.1

Table 2. *Cont.*

		LPT	Nov-2022		Jun-2023		Apr-2024	
CALANOIDA	CANDACIIDAE	*Candacia bispinosa* Claus, 1863			0.4	±0.8		
		Candacia simplex (Giesbrecht, 1889)	1.9	±4.1	0.6	±1.1		
	CENTROPAGIDAE	***Centropages bradyi* Wheeler, 1900**	0.6	±0.8	0.4	±1.1		
		Centropages furcatus (Dana, 1849–1852)	4.0	±7.2	0.2	±0.8		
	CLAUSOCALANIDAE	*Clausocalanus arcuicornis* (Dana, 1849–1852)	20.3	±30.9	1.6	±2.0	1.5	±2.8
		Clausocalanus furcatus (Brady, 1883)	51.9	±54.4	0.8	±0.8	1.8	±1.9
		***Clausocalanus jobei* Frost & Fleminger, 1968**			0.8	±1.1		
		Clausocalanus mastigophorus (Claus, 1863)	5.5	±4.9	1.1	±1.3	3.7	±4.1
		Clausocalanus paululus Farran, 1926	10.4	±16.8			6.1	±5.9
	EUCALANIDAE	*Eucalanus* sp.	0.2	±0.7				
		Pareucalanus sp.					0.1	±0.4
	EUCHAETIDAE	*Euchaeta marina* (Prestandrea, 1833)			0.6	±0.7	1.0	±1.3
	HETERORHABDITAE	*Heterorhabdus spinifrons* (Claus, 1863)			0.2	±0.7	0.1	±0.4
	LUCICUTIIDAE	*Lucicutia flavicornis* (Claus, 1863)	2.3	±3.8	6.4	±6.6	2.3	±1.6
	METRIDIIDAE	*Metridia* sp.			0.2	±0.5		
		Pleuromamma abdominalis (Lubbock, 1856)			1.0	±1.3	0.1	±0.4
	PARACALANIDAE	*Calocalanus* sp.	2.3	±4.4	2.9	±3.4	4.6	±6.6
		***Calocalanus neptunus* Shmeleva, 1965**	0.7	±2.1				
		Calocalanus pavo (Dana, 1849–1852)	0.3	±0.8	2.6	±3.8	0.1	±0.4
		Calocalanus styliremis Giesbrecht, 1888	2.7	±8.2				
		Mecynocera clausi Thompson I.C., 1888	2.3	±4.3	2.3	±2.4	1.1	±1.3
		***Paracalanus denudatus* Sewell, 1929**	0.1	±0.3			3.8	±6.6
		Paracalanus nanus Sars G.O., 1925	0.6	±1.8	0.2	±0.7	3.2	±2.4
		Paracalanus parvus (Claus, 1863)	2.2	±2.9	2.0	±2.4	2.0	±1.8
		Parvocalanus crassirostris (Dahl F., 1894)	4.3	±8.9			0.3	±0.7
	PHAENNIDAE	*Phaenna* sp.			0.4	±1.0		
		Xanthocalanus sp.			0.4	±1.2		
	PONTELLIDAE	*Calanopia elliptica* (Dana, 1849–1852)	2.6	±2.6				
		Pontella sp.	1.4	±1.4			0.2	±0.5

Table 2. *Cont.*

		LPT	Nov-2022		Jun-2023		Apr-2024	
CALANOIDA	SCOLECITRICHIDAE	***Pseudoamallothrix profunda* * (Brodsky, 1950)**					0.4	±1.2
		Scolecithricella dentata (Giesbrecht, 1893)	0.1	±0.3	0.8	±1.0		
		Scolecithrix bradyi Giesbrecht, 1888	0.6	±1.8				
	TEMORIDAE	*Temora stylifera* (Dana, 1853–1855)	5.9	±5.8	42.2	±17.8	0.9	±1.2
CANUELL-OIDA	CANUELLIDAE	***Canuella* sp. ***	1.5	±2.1				
	LONGIPEDIIDAE	***Longipedia* sp. ***	0.2	±0.6			0.2	±0.5
CYCLOPOIDA	CORYCAEIDAE	indet.	21.7	±11.5	21.0	±9.5	22.5	±13.7
	OITHONIDAE	indet.	108.6	±74.8	30.9	±16.9	9.7	±9.3
	ONCAEIDAE	indet.	13.3	±7.5	1.1	±9.5	11.8	±6.0
	SAPPHIRINIDAE	indet.	2.0	±3.6	2.7	±3.5		
		Copilia sp.	0.3	±0.7	1.4	±1.1	0.1	±0.4
HARPACTIC-OIDA		indet.	1.4	±3.3	0.2	±0.5	0.5	±0.7
	CLYTEMNESTRIDAE	indet.	0.6	±1.9			1.0	±1.5
	ECTINOSOMATIDAE	*Microsetella* sp.	0.2	±0.6	0.1	±0.4	0.2	±0.4
	MIRACIIDAE	*Macrosetella* sp.	0.1	±0.4			0.1	±0.4
	TACHIDIIDAE	*Euterpina* sp.	2.4	±1.3			2.3	±2.0
DECAPODA	indet.	larvae	3.4	±1.6	8.7	±7.9	5.9	±3.2
	BRACHYURA	larvae	3.5	±2.5	4.0	±3.0	1.0	±0.9
	LUCIFERIDAE	larvae					0.4	±0.8
MYSIDA		indet.	0.8	±1.7	0.2	±0.5		
AMPHIPODA		indet.	0.1	±0.3				
	CAPRELLIDAE	indet.			0.2	±0.6		
	HYPERIIDAE	indet.			0.1	±0.4	0.8	±1.3
	VIBILIIDAE	indet.					0.1	±0.4
ISOPODA	GNATHIIDAE	*Gnathia* sp.					0.1	±0.4
EUPHAU-SIACEA		larvae	0.1	±0.4				
DIPLOSTRACA		*Evadne* sp.	48.4	±22.0	1.3	±2.3	0.2	±0.7
		Penilia avirostris Dana, 1849			1.0	±1.9		
FACETOTE-CTA		***Hansenocaris* sp. ***	0.5	±0.8			0.3	±1.0
OSTRACODA		indet.	3.2	±4.3	8.4	±5.4	6.0	±4.9
CIRRIPEDIA	LEPADOMORPHA	larvae	2.0	±3.7	4.1	±3.7	6.3	±10.0
	BALANOMORPHA	larvae			0.5	±0.9	0.2	±0.7
DINOPHYTA		*Ceratium* sp.	22.0	±17.5	2.0	±1.7	23.4	±33.5
		Noctiluca sp.	2.3	±1.8	5.6	±3.9	5.7	±5.1
PHAEOPHY-CEAE		*Sphacelaria* sp.			0.2	±0.7	0.3	±0.7

Table 2. *Cont.*

		LPT	Nov-2022		Jun-2023		Apr-2024	
RADIOLARIA		indet.	52.6	±50.8	5.0	±4.8	44.5	±27.0
	COLLODARIA	indet.	38.3	±115.0	9.3	±26.3	75.5	±197.7
	SPONGODISCIDAE	indet.	0.8	±1.5				
ACANTHARIA		indet.	9.7	±7.9	5.3	±5.0	17.7	±18.4
		Lithoptera sp.	0.4	±1.3				
	PHYLLOSTAURIDAE	indet.	2.4	±2.2				
FORAMINIFERA	GLOBIGERINOIDEA	*Globigerina* sp.	5.8	±5.2	2.7	±2.3	1.5	±0.7
	GLOBOROTALIOIDEA	indet.	2.4	±3.1	0.7	±1.6	2.1	±1.8
	MILIOLIOIDEA	indet.	1.2	±3.3			0.2	±0.6
	ROTALIOIDEA	indet.	0.7	±2.2			0.5	±1.0
	TEXTULARIOIDEA	indet.	0.2	±0.6				
CILIOPHORA	TINTINNINA	indet.	0.2	±0.6				
PORIFERA		***Alectona* sp.**	0.1	±0.3				
HYDROZOA		medusae and polyps	0.3	±0.7	0.5	±1.3	0.1	±0.4
	SIPHONOPHORA	indet.	1.3	±1.7	4.4	±4.5	0.5	±1.4
NEMATODA		indet.	0.2	±0.6				
POLYCHAETA		larvae	15.8	±6.9	0.4	±0.8	0.4	±0.8
	TOMOPTERIDAE	indet.	0.2	±0.7	3.6	±2.8	0.2	±0.4
BRYOZOA		statoblasts	0.8	±0.9				
CHAETOGNATHA		indet.	7.4	±5.8	14.4	±5.1	10.9	±9.6
BIVALVIA		veliger	4.1	±3.0			5.7	±3.7
GASTROPODA		veliger	7.9	±3.6	1.4	±1.6	10.1	±5.6
	EUTECHOSOMATA	indet.	0.5	±0.7	2.4	±2.3	0.7	±0.6
ECHINODERMATA		brachiolaria/auricolaria	1.5	±1.8	2.2	±2.7	0.4	±0.8
		ophiopluteus	0.3	±0.7	1.4	±1.9	0.2	±0.6
		echinopluteus					0.2	±0.7
APPENDICULARIA		*Oikopleura* sp.	37.1	±14.2	61.2	±39.1	1.4	±1.7
		Fritillaria sp.			1.0	±2.0		
THALIACEA		indet.	16.1	±20.0	0.8	±0.9	1.8	±2.9
ASCIDIACEA			0.1	±0.4				
VERTEBRATA	OSTEICHTHYES	larvae/eggs	0.4	±0.8	1.4	±2.1	2.6	±2.5

Among the rare or occasional occurrences, *Alectona* sp. (Porifera), *Canuella* sp. (Canuelloida), and *Longipedia* sp. (Canuelloida) were collected as larvae and/or juveniles. Finally, the report of Nauplii "Y" (*Hansenocaris* sp., Facetotecta), although by very few specimens, added an entire subclass of Crustacea to the fauna of the whole Levantine Basin, with a morphology distinct from any previously described Mediterranean species [54].

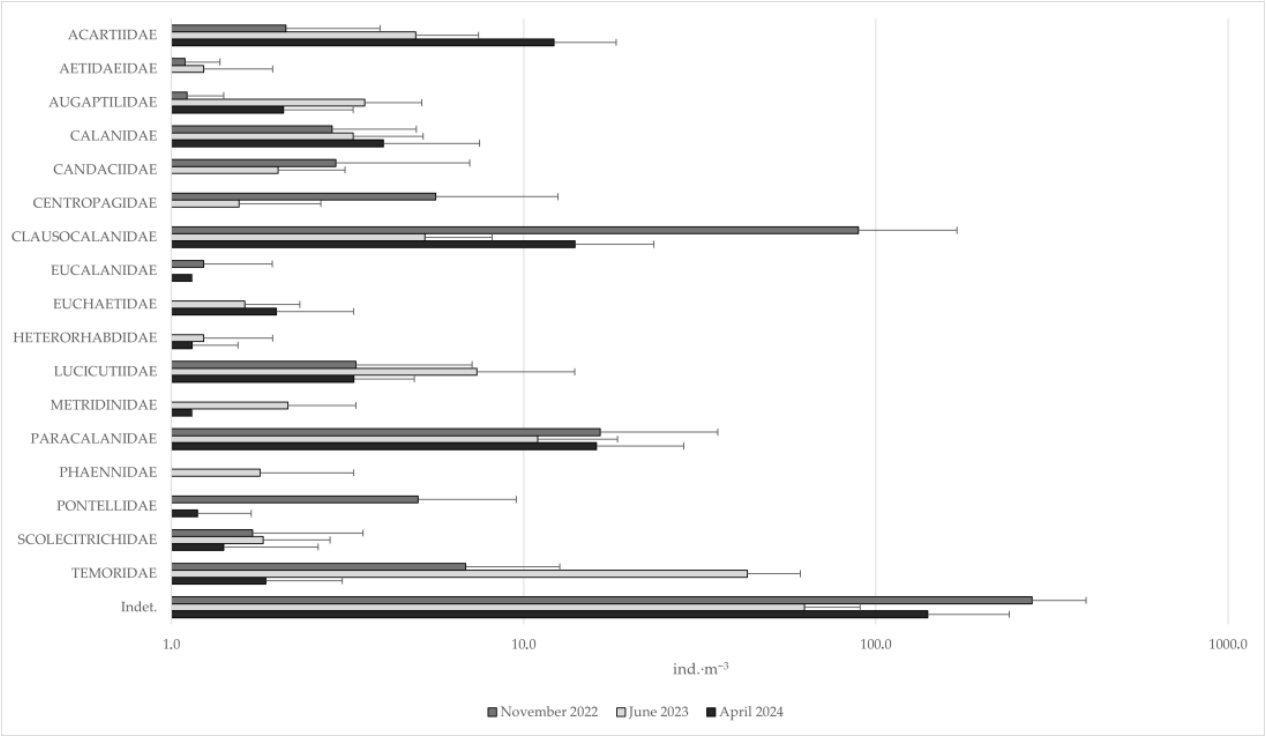

Figure 2. Mean abundances of the identified Calanoida families at the three sampling times (each time deriving from three sites and a total of 9 replicates), expressed as ind.·m^{-3}. Abundances are represented on a logarithmic scale (base 10). Error bars represent the standard deviation between all replicates.

The detailed analysis of the Calanoida assemblage led to the discovery of six species new to the Lebanese fauna, including *Pseudoamallothrix profunda* (Brodsky, 1950), which is also new to the entire Mediterranean Sea. The other five species, recently reported only from the Turkish coast (from 1991 onwards), represent additions to Lebanese zooplankton records. In none of the cases can the faunistic novelties be associated with a recent arrival from the Red Sea via the Suez Canal. *P. profunda*, in detail, was reported, before the present study, only from the southern Atlantic and northern Pacific [52].

The analysis of the zooplankton diversity indices (S, D, and J′), showed a relatively uniform distribution of species abundances across samples. Mean values of S ranged between 17.5 and 19.4, while Margalef's index varied from 5.25 to 5.75 across stations and sampling times, with evenness values consistently high between 0.98 and 0.99 (Figure 4). PERMANOVA analyses revealed no significant differences in S or D among sampling times or stations ($p > 0.05$). In contrast, Pielou's evenness (J′) showed a highly significant temporal effect (Pseudo-$F_{(2,16)} = 11.83$, $p = 0.001$), with the highest evenness recorded in April 2024 (0.992 ± 0.005). No spatial or interaction effects were detected for any diversity index. These findings suggest that, while overall species richness and diversity remained stable across the study area, zooplankton communities exhibited greater evenness in April 2024, possibly reflecting a more balanced distribution among taxa during this period.

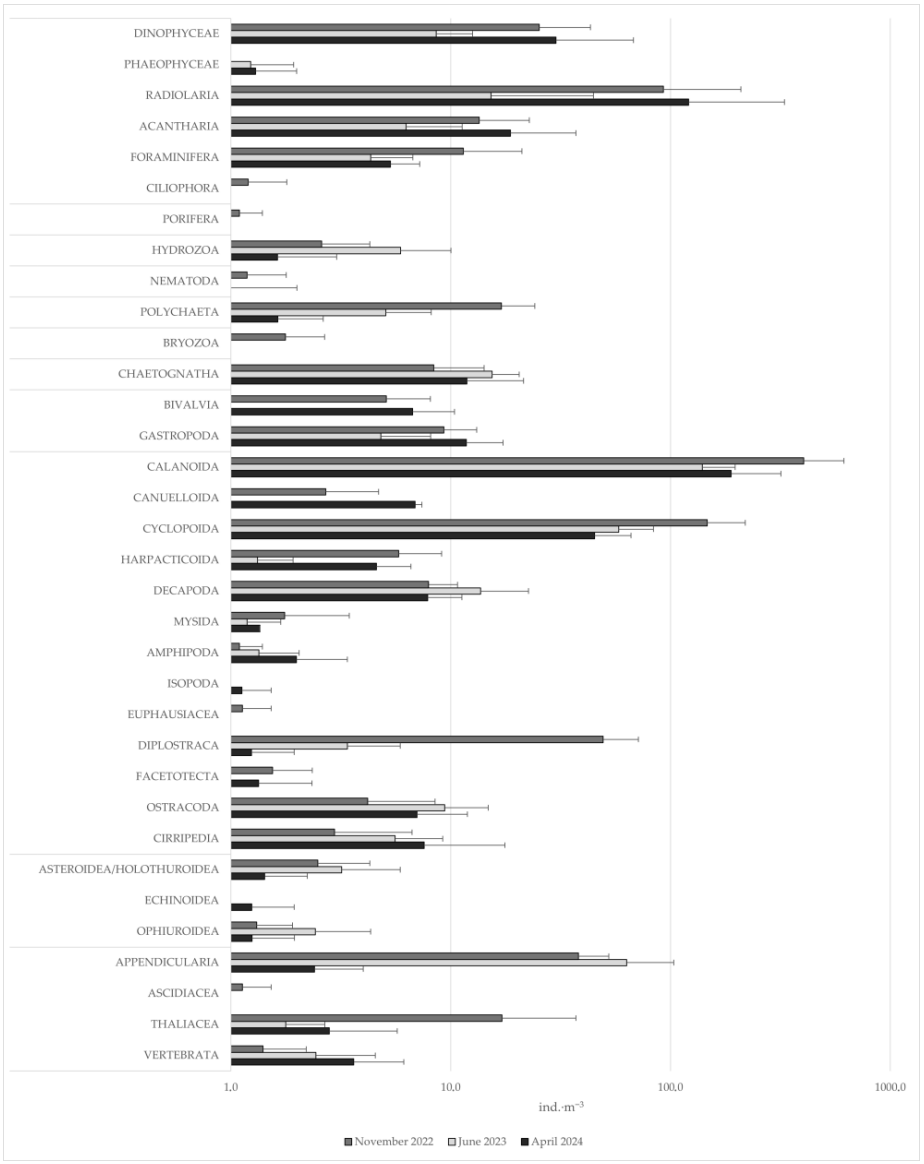

Figure 3. Mean abundances of the identified taxa, other than Calanoida, at the three sampling times (each time deriving from three sites and a total of 9 replicates), expressed as ind.·m^{-3}. Abundances are presented on a logarithmic scale (base 10). Error bars represent the standard deviation between all replicates.

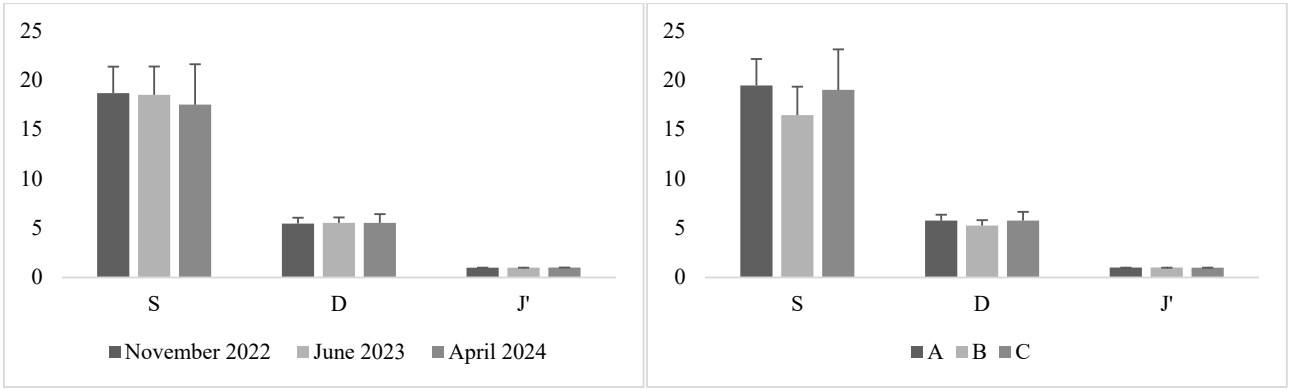

Figure 4. Diversity index values (species richness, S; Margalef's index; D; and Pielou's evenness, J') across sampling times (November 2022, June 2023, and April 2024; (**left**)) and stations (A, B, and C; (**right**)). Error bars represent standard deviations.

3.1. *Hansenocaris* sp.

The genus is currently the only recognized taxon of the subclass Facetotecta (Crustacea), created by Grygier [55] to collocate a series of nauplii, long referred to as "Y" nauplii, with a morphology not corresponding to any known crustacean taxon. Such nauplii have been reported from Japan, the Arctic, the Atlantic, and the Mediterranean Sea, with a total of five species proposed [54,56] (Figure 5a–e).

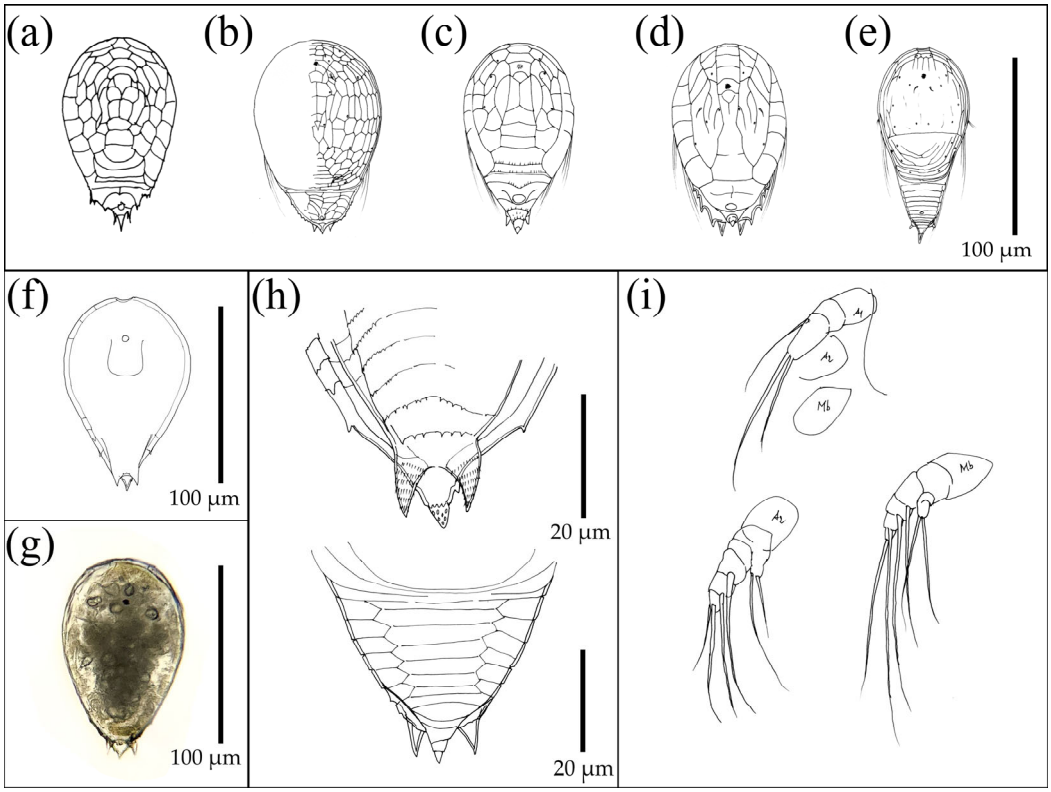

Figure 5. Nauplius of Facetotecta found in Tyre zooplankton and reference existing species, included for visual comparison with the sampled organisms. (**a**) *Proteolepas* sp. (from [56]). (**b**) *Hansenocaris leucadea* Belmonte, 2005 (from [54]). (**c**) *H. salentina* Belmonte, 2005 (from [54]). (**d**) *H. corvinae* Belmonte, 2005 (from [54]). (**e**) *H. mediterranea* Belmonte, 2005 (from [54]). (**f**) Drawing of the Facetotecta found in Lebanon. (**g**) Microscope photography of the Facetotecta found in Lebanon. (**h**) Drawing details of ventral (up) and dorsal (down) terminal spines of Facetotecta found in Lebanon. (**i**) Drawing details of appendices A1, A2, and Mb (antennulae, antennae, and mandibles, respectively) of Facetotecta found in Lebanon.

Adults of Facetotecta, after more than 100 years of scientific research, are still unknown and probably extremely modified endoparasites in some marine organisms [57]. Even under laboratory conditions, Facetotecta nauplii only produced a successive larval stage (a "cypris") that never underwent the final metamorphosis to the adult stage [58–60]. By administering crustacean growth hormone to y-cypris at Okinawa, Glenner et al. [61] induced them to molt into a minute, sluglike "ypsilon" stage, which they interpreted as a juvenile, very likely a parasite, but in any case, not the adult. All described Y nauplii were assigned to the genus *Hansenocaris*, though it is evident that morphological differences at the larval stage are probably enough to justify differences above the species level. The *Hansenocaris* nauplii found in the Tyre plankton (Figure 5f–i) shared the general shape with *Hansenocaris salentina* Belmonte, 2005 (Figure 5c), but with some marked differences, including more pronounced cuticle partitioning in the posterior part of the body, and the absence (or inconspicuous presence) of the rounded cuticular area in the middle of the

dorsal part of the rear body. These differences probably justify the recognition of a new species. However, the low abundance of specimens prevented a full diagnostic examination and a formal species description, which will be undertaken in the future.

3.2. *Canuella* sp.

The nauplii were recognizable by their short antennulae, typical of Canuelloida, and by two prominent, semi parallel spines at the extremity of the abdomen, characteristic of family Canuellidae. This family contains several genera, and *Canuella* species were reported already by Por [62] from the benthos of the Israeli coast, even from Haifa, a site very close to Tyre. However, that report of Canuellidae did not include nauplii, which are typical and well recognizable [63] (Figure 5a–d). In fact, nauplii are common in the plankton of coastal and brackish environments, whereas adults are benthic and rarely encountered in plankton samples.

3.3. *Longipedia* sp.

The nauplii are characterized by short antennulae, typical of Canuelloida, and a single prominent, elongated spine at the extremity of the abdomen, characteristic of Longipediidae [63] (Figure 6e–h). The family Longipediidae contains a single genus *Longipedia*, whose adults are characterized by an extremely long terminal article of the P2 (second thoracic leg) and have been reported by Por [62] in coastal benthos of Israel since 1964. Nauplii, along with the first two copepodite instars, are common in coastal plankton and brackish lakes, whereas adults are benthic and rarely found in plankton samples. Although the genus is widespread in the Mediterranean benthos, it has not previously been reported from Lebanese zooplankton.

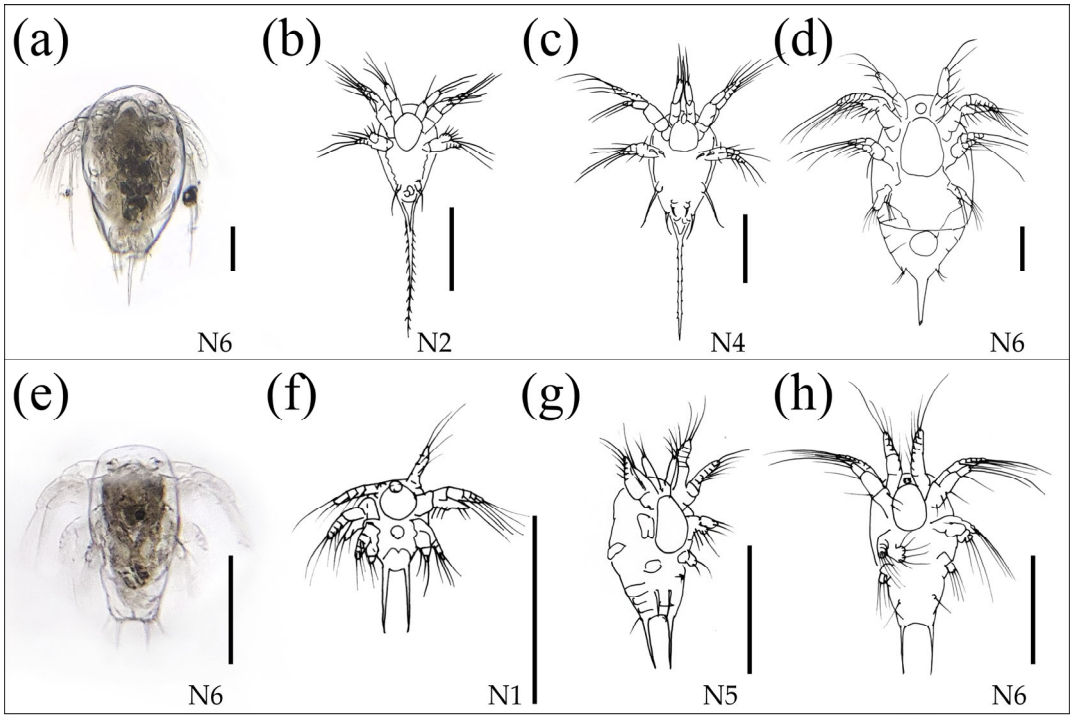

Figure 6. (**a**) Microscope photography of one of the *Longipedia* nauplii found in Lebanon. (**b**–**d**) Drawings of various stages of *Longipedia* nauplii found in Lebanon. (**e**) Microscope photography of one of the *Canuella* nauplii found in Lebanon. (**f**–**h**) Drawings of various stages of *Canuella* nauplii found in Lebanon. All the scale bars measure 100 µm.

As regards the statistical treatment of data, two Bray–Curtis [64] similarity matrices were obtained to realize a cluster plot of samples (and the relative MDS plot) either for zooplankton or for environmental data (only clusters of samples are reported, Figure 7). In both the plots it is evident that the samples cluster mainly according to the time, than to the space.

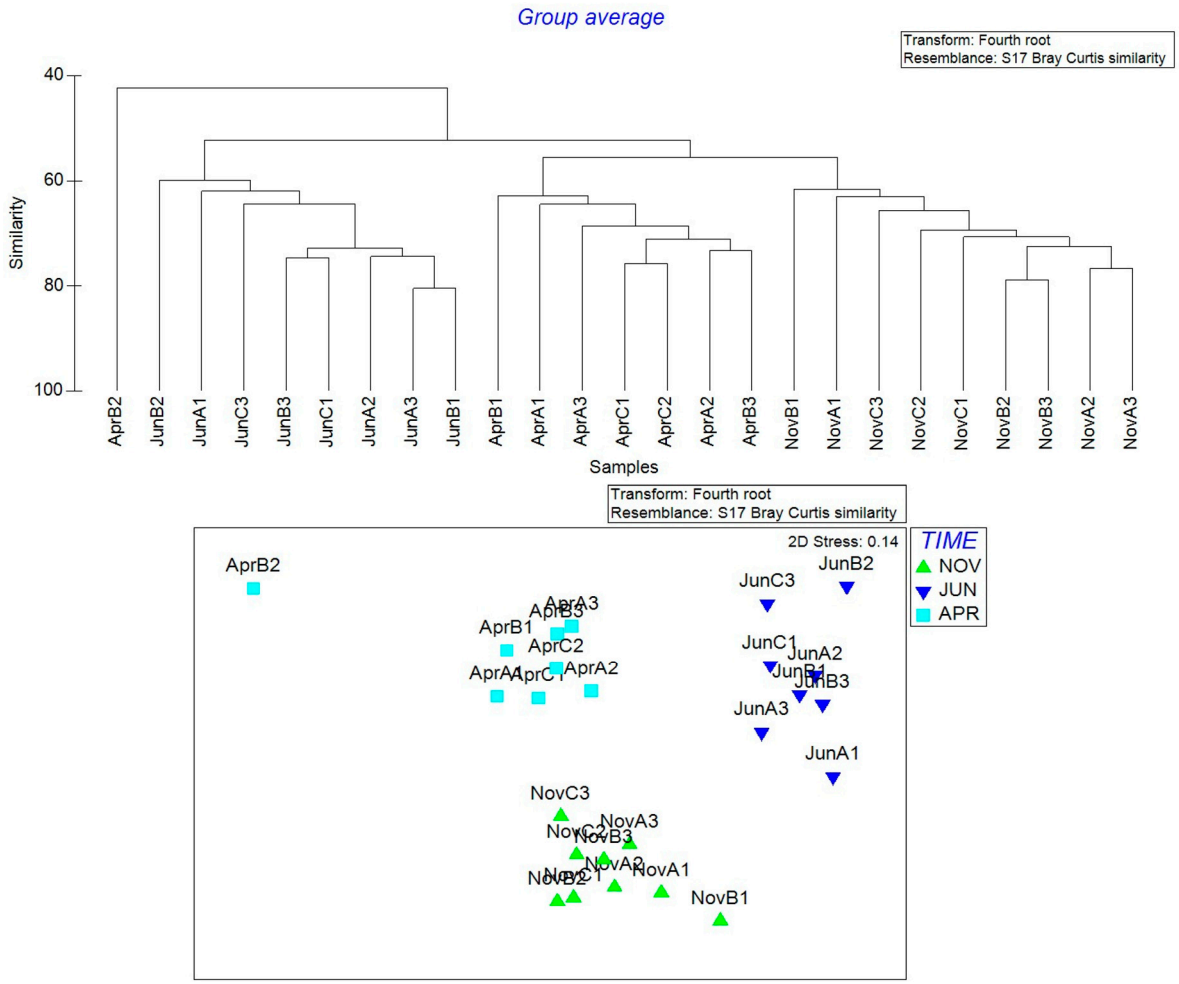

Figure 7. (**Up**), the cluster graph of samples. All the samples, except AprilB2, of the same time (November 2022, June 2023, April 2024) cluster together at the minimum similarity level of 60%. (**Below**), the MDS plot representation.

The SIMPER procedure (PRIMER package) allowed us to establish the taxa mainly responsible for similarities inside data groups from different times and stations, and dissimilarities between times and stations in paired comparisons (Table 3). Calanoida indet. (nauplii and juveniles) were always the most important taxon, in terms of abundance (ind. m^{-3}) and consequently the taxon mainly responsible for similarities. The statistical treatment also allowed us to establish the taxa more important for the dissimilarity between times (all the stations) and stations (all the times). Dissimilarity between different times (November 2022, June 2023, April 2024) resulted in more important differences than that between stations (a, b, c) (Table 4). In this case, the taxa responsible for dissimilarities between times were mainly single species (Table 4), and the total dissimilarity was higher for the comparison between distant times (November 2022 vs. April 2024).

Table 3. The five most important (in terms of abundance and presence) taxa (among 103) in each time (November 2022, June 2023, April 2024), and in each station (A, B, C) in affecting similarities of samples inside times (all the stations) and/or stations (all the times). Av., Average; Ab., abundance; Sim., similarity; SD, standard deviation; Contr., contribution; Cum., cumulative CAL, Calanoida indet.; CORY, Corycaeidae indet.; EVA, *Evadne* sp.; GAS, Gastropoda veliger; OIKO, *Oikopleura*; OITH, Oithonidae indet.; ONC, Oncaeidae indet.; RADIO, Radiolaria indet.; TES, *Temora stylifera*.

Group Nov 2022					
Average similarity: 70.20					
Species	Av. Ab.	Av. Sim.	Sim./SD	Contr.%	Cum. Contr.%
CAL	3.48	5.99	14.63	8.53	8.53
OITH	2.69	4.67	3.78	6.65	15.18
EVA	2.22	3.67	3.69	5.24	20.41
OIKO	2.11	3.54	9.28	5.04	25.45
RADIO	2.15	3.30	7.83	4.71	30.16
Group Jun 2023					
Average similarity: 66.19					
CAL	2.21	4.67	8.61	7.06	7.06
OIKO	2.17	4.56	6.42	6.89	13.95
TES	2.03	4.39	17.05	6.64	20.59
OITH	1.85	3.75	9.38	5.66	26.25
CORY	1.70	3.54	11.62	5.35	31.60
Group Apr 2024					
Average similarity: 63.64					
CAL	2.79	5.55	14.74	8.72	8.72
CORY	1.81	3.98	4.11	6.26	14.97
RADIO	1.98	3.23	1.43	5.08	20.06
GASTR	1.49	3.18	4.01	5.00	25.06
ONC	1.47	3.03	2.28	4.76	29.82

Table 4. The five taxa (among 103) mainly responsible for dissimilarities (in terms of abundance and presence) between times (all the stations). Av., average; Ab., abundance; Diss, dissimilarity; SD, standard deviation; Contr., contribution; Cum., cumulative. ACL, *Acartia clausi*; BIVA, Bivalvia veliger; CAL, Calanoida indet.; CLF, Ciliofora indet.; EVA, *Evadne* sp.; OIKO, *Oikopleura* sp.; POLY, Polychaeta larvae; RADIO, Radiolaria indet.; TES, *Temora stylifera*.

Groups Nov 2022 and Jun 2023						
Average dissimilarity = 48.96						
Species	Av. Ab.	Av. Ab.	Av. Diss	Diss/SD	Contr.%	Cum. Contr.%
EVA	2.22	0.38	1.91	2.40	3.91	3.91
CLF	2.01	0.54	1.52	2.32	3.10	7.01
POLY	1.70	0.25	1.48	2.78	3.03	10.04
CAL	3.48	2.21	1.27	3.11	2.60	12.64
RADIO	2.15	0.98	1.19	1.54	2.43	15.07
Groups Nov 2022 and Apr 2024						
Average dissimilarity = 45.60						
EVA	2.22	0.13	2.13	2.96	4.68	4.68
OIKO	2.11	0.57	1.61	2.16	3.52	8.20
CLF	2.01	0.57	1.51	1.68	3.32	11.52
POLY	1.70	0.26	1.43	2.80	3.15	14.67
OITH	2.69	1.45	1.38	1.57	3.04	17.71

Table 4. *Cont.*

Groups Jun 2023 and Apr 2024						
Average dissimilarity = 47.89						
OIKO	2.17	0.57	1.95	1.89	4.07	4.07
TES	2.03	0.50	1.65	2.75	3.45	7.52
BIVA	0.00	1.28	1.47	6.27	3.06	10.58
RADIO	0.98	1.98	1.42	2.22	2.96	13.54
ACL	0.00	1.30	1.40	2.31	2.93	16.47

4. Discussion

Although the sampling plan did not consider a complete annual cycle, and its ecological information could not be considered strong, some differences emerged from previous research in both abundances and taxonomic composition of Lebanese zooplankton. This is particularly evident when compared with the datasets provided by [39], who sampled in a nearby area but not in southern Lebanon, and those of [37,40], who provided most of the available data on Lebanese zooplankton. Lakkis [37,40] described the zooplankton composition of 1969–1972 as being dominated by Copepoda, reaching abundances of up to 3000 ind. m^{-3}, whereas in the present study values never were so high, with a mean abundance of 525.5 ± 210.3 ind. m^{-3} (Figures 2 and 3). Variations in this size cannot be reliably attributed to ongoing environmental changes, because the possibility of not having collected samples in a "rich" period of the year is real (only one date per year has been considered, and differences in times are probably more affected by interannual variability than by seasonality). The present study is more informative from the point of view of taxa presence. Lakkis published a revised checklist of Lebanese plankton in 2013 [37], also describing seasonal trends in community composition. However, in that study, regarding plankton seasonality in Lebanese waters, only a general overview is provided, without any statistical data on abundance fluctuation. Consequently, comparisons with the data obtained in the present study will be only qualitative. Autumnal plankton was reported showing remarkable abundances of Hydrozoa medusae, Siphonophora, Polychaeta larvae, Appendicularia, Cirripedia larvae, and Radiolaria, together with the presence of Luciferidae larvae (annual peak) and dense macroscopic aggregations of Ctenophora that span over the whole winter period. In the present study, the only autumn date of November 2022 gave all these taxa in the samples; however, only Polychaeta, Appendicularia, Cirripedia, and Radiolaria abundances and the presence of Luciferidae larvae reflected the patterns described by Lakkis [37]. Hydrozoa, Siphonophora, and Cirripedia were found only occasionally in 2022 samples, while Ctenophora were almost absent, with just two individuals at the larval stage recorded in a single sample. During spring, plankton communities are typically characterized by demographic increases, especially in herbivorous and filter-feeding copepods, with higher densities of the predatory Chaetognatha. The data collected in April 2024 reflected these community characteristics. In summer data of [37], the presence of a thermocline between 35 and 75 m coincided with the annual peak of zooplankton biomass, followed by the decline of the phytoplankton. Samples collected in June 2023 did not reflect such a seasonal pattern, showing higher biomass than spring samples but considerably lower than autumn values. Lack of a complete seasonal survey in the present work, however, could justify this difference. In any cases, Lakkis described how June and July typically exhibit very high abundances of Cladocera, particularly *Evadne* spp., whereas in our samples this taxon showed the lowest density in June. A similar trend was observed for Hydrozoa and Siphonophora, which reached their highest abundances in spring rather than in summer.

These observed deviations from past seasonal patterns could be influenced by ongoing climate change and the warming of Mediterranean waters, which may alter the timing, abundance, and distribution of zooplankton in Lebanese coastal waters. Lakkis [37], however, already highlighted that interannual fluctuations in plankton abundance can exceed twofold increases or decreases relative to the previous year, indicating that our data should be viewed as descriptive snapshots of zooplankton during specific study periods, rather than as definitive ecological comparisons of seasonal dynamics. If the abundance variation in community and single taxa cannot be satisfactorily compared with data of the past, the qualitative composition remains the main result.

Among species new for Lebanese waters, *Pseudoamallothrix profunda* (Calanoida) was reported before from the South Atlantic and North Pacific [52], in any case far from the entrance area of the Suez Canal, which represents the most important access of faunal novelties in the eastern Mediterranean [9,10]. Also, Canuellidae and Longipediidae were recorded for the first time in the zooplankton of the Levant Basin, as the nauplius stage of unidentified species. Non-adult Copepoda are often left unidentified due to the absence of diagnostic characteristics that are present only in adult stages. However, these two families exhibit morphological features already detectable in nauplii, allowing the first record of Canuelloida families (Canuellidae and Longipediidae) in Lebanese zooplankton, although Canuelloida have already been reported from the benthos of the Levant Basin [62]. Moreover, the present study shows figures to help the identification of naupliar stages of Canuellidae and Longipediidae, that switch to benthic environment when passing to the better studied adult stage. In contrast, Y-Nauplii (Facetotecta), also reported for the first time in the Levent Mediterranean Sea, have unknown adult stages, and only a few authors have provided taxonomic information [60,65–67], with only two studies interesting a site of the Mediterranean basin [54,56]. Their morphology, described in the present study, does not correspond to currently known Mediterranean species (see [54]) for a comparison (Figure 4), or to any other species described in the world's seas [59], and this fact suggests that it could be a species new to science. Future collection (more material) will be resolutive in helping the correct morphological description other than a molecular biology characterization of the possible new taxon, before a definitive addition to the world biodiversity checklist. As in other circumstances, the rarity, and the habit of students to skip the systematics of nauplii in the absence of adults, propose an existence of such a taxon in the area, and not a new arrival. Consequently, for different reasons (species already present in other parts of the Mediterranean, species not present in the Red Sea or the Indian Ocean, and taxa here recognized from the nauplius stage), the faunal novelties here communicated for the Lebanese zooplankton, should not be attributed to the Lessepsian invasion, which is the main responsible for faunal new arrivals in the Levantine Basin of the Mediterranean.

5. Conclusions

The study of zooplankton collected at the marine coast off Tyre (South Lebanon) between 2022 and 2024 has been an occasion to update the knowledge on zooplankton composition in a Mediterranean sector particularly subject to habitat alteration due to climate change, and to biological invasion from the Suez Canal. The analysis of zooplankton composition allowed the addition of six Calanoida species new to the Lebanese zooplankton, including one species new to the entire Mediterranean basin. In addition, two new Copepoda families (Canuellidae, and Longipediidae) and a new subclass of Crustacea (Facetotecta) were also reported for the first time in the zooplankton, as nauplii. None of these faunal novelties appear to certainly derive from Lessepsian invasion (sensu Por [16]). Future studies will take into consideration this particular aspect of Copepoda biogeographic

distribution, which, as with other distributional patterns, does not seem to be influenced by the general trends affecting the non-planktonic fauna [43].

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