

BIODIVERSITY AND ABUNDANCE OF GELATINOUS ZOOPLANKTON ALONG THE ALGERIAN COAST

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RÉSUMÉ.— *Biodiversité et abondance du zooplancton gélatineux le long de la côte algérienne.*— La distribution du zooplancton gélatineux (*Siphonophorae*, *Salpidae*, *Doliolidae*, *Appendicularia*, *Chaetognatha* et *Mollusca*) a été étudiée durant les quatre saisons sur un ensemble de stations le long de la côte algérienne. Sur 56 espèces reconnues, la diversité a été plus grande au printemps et l'abondance a été plus importante au printemps et en été. La composition taxinomique a varié selon les saisons : les assemblages printaniers ont été plus diversifiés, comprenant essentiellement des espèces de *Thaliacea* ; les assemblages d'été ont été dominés par *Doliolum nationalis* et *Flaccisagitta enflata* ; les assemblages d'automne ont été caractérisés par les deux espèces gélatineuses les plus abondantes et les plus fréquentes (*F. enflata* et *Oikopleura longicauda*) ; et les assemblages d'hiver ont été caractérisés par des espèces carnivores.

SUMMARY.— Gelatinous zooplankton (*Siphonophorae*, *Salpidae*, *Doliolidae*, *Appendicularia*, *Chaetognatha*, and *Mollusca*) distribution was investigated over four seasons at several stations along the Algerian coast. Of 56 species recognized, diversity was greatest during spring, and abundance greatest during spring and summer. Taxonomic composition varied among seasons: spring assemblages were most diverse, essentially comprising species of *Thaliacea*; summer assemblages were dominated by *Doliolum nationalis* and *Flaccisagitta enflata*; autumn assemblages were characterized by two most abundant and frequently found gelatinous species (*F. enflata* and *Oikopleura longicauda*); and winter assemblages were characterized by carnivorous species.

Gelatinous zooplankton forms a taxonomically diverse group of macroplankton with varied and significant roles in pelagic communities (Madin & Harbiso, 2001; Robison, 2004). There has been limited exploration of its diversity, and the density of the species is frequently over- or underestimated due to their fragility (Raskoff *et al.*, 2003; Bouillon *et al.*, 2006). Although often similar in their morphology (typically being fragile, and transparent, or with a translucent body) and ecology (planktonic lifestyle), these species are taxonomically and phylogenetically distant (Olenycz, 2015).

In recent years, strong and sustained blooms of gelatinous populations have been recorded in different geographic marine areas (Mills, 2001; Brodeur *et al.*, 2002). These blooms have often been related to global warming, which can be particularly important in temperate zones. Combined with eutrophication, it can generate a rapid increase in the abundance of phytoplankton, which in turn can lead to an increase of mesozooplankton abundance (Mills, 2001; Lynam *et al.*, 2004; Attrill *et al.*, 2007). Some gelatinous species can bloom in very high densities and seriously affect prey populations, and fish eggs production (Purcell, 1997; Richardson *et al.*, 2009).

Previous studies of zooplankton communities in the Algerian basin and Alboran Sea have tended to focus on copepods, the major zooplankton component, providing considerable qualitative and quantitative data (Seridji & Hafferssas, 2000; Youssara & Gaudy, 2001; Andersen *et al.*, 2004; Riandey *et al.*, 2005; Hafferssas & Seridji, 2010). However, other groups, like the *Siphonophorae* and *Appendicularia*, have been regarded as being of secondary importance in terms

of numerical abundance, and have not been described in detail. Despite the ecological importance of gelatinous marine zooplankton in the marine food chain (Jaspers *et al.*, 2015), knowledge of this fauna off the Algerian coast was incomplete. To part-compensate for this deficiency, we describe the richness, and spatial and seasonal distribution of gelatinous zooplankton in the southwestern Mediterranean Sea off Algeria. This work is not only a study of gelatinous zooplankton along the Algerian coast, but it also contributes to new knowledge on the distribution of gelatinous zooplankton in the Western Mediterranean Sea.

MATERIAL AND METHODS

STUDY AREA

Sampling was undertaken along the Algerian coast from the Habibas Islands (36°39'9"N, 2°39'8"E) to Skikda (37°03'06"N, 6°34'45"E) (Fig. 1, Tab. I). Biological samples and environmental parameters were collected and measured every three months off Sidi Fredj from November 2012 to July 2013, and off the Habibas Islands from May 2012 to July 2012. Sampling off Tipaza, Algiers Bay, Tizi-Ouzou, Jijel, and Skikda was undertaken in September 2014, and that off Tenes in July and August 2015.

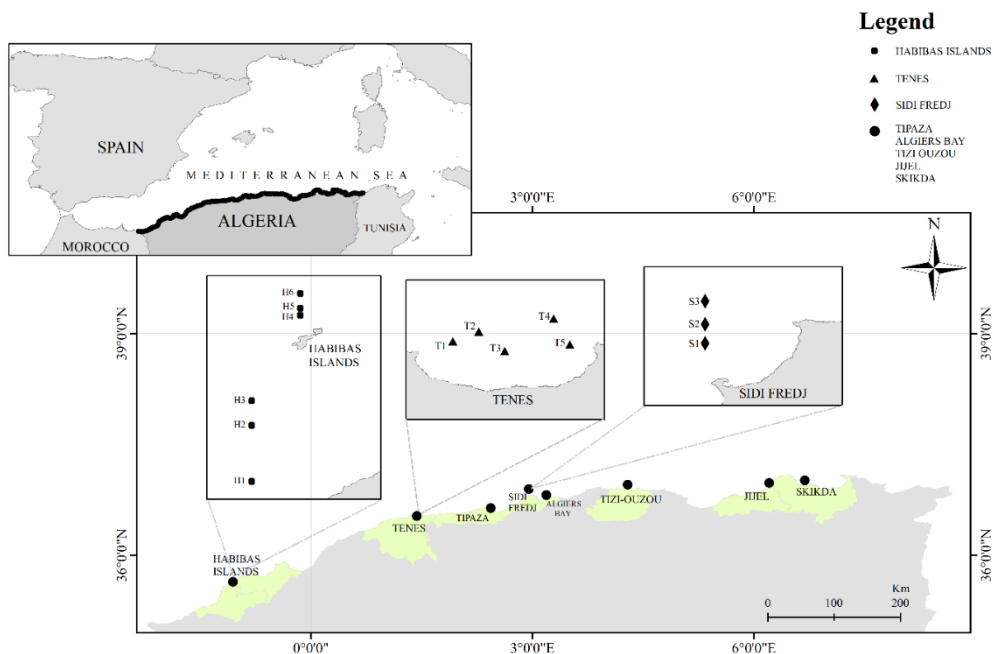


Figure 1.— Gelatinous zooplankton sampling locations off Algeria.

Populations were sampled by vertical hauls at the epipelagic layer (0-100 m) with a Working Party II (WP2) net with 200 μ m mesh (Unesco, 1968). Samples were fixed immediately in 4 % formalin solution (Unesco, 1968). Species were identified using a stereomicroscope (Zeiss Stemi SV 6/ Germany) and appropriate taxonomic literature (e.g., Tregouboff & Rose, 1957; Fenaux, 1966; Rampal, 1975; Bone, 1998; Boltovskoy, 1999).

Hydrological parameters such as temperature ($^{\circ}$ C) and salinity (psu) were measured from surface (0-20 m) and bottom (30-50 m) water layer samples using a multiparameter (HI 9828-12202/ Romania) with a 50 m long cable-logging probe. Calculations of the frequency of occurrence were also performed, with species classified according to their frequency in various classes of occurrence (frequent ($Fr > 50\%$), common ($50\% \leq Fr \leq 25\%$), and rare ($Fr < 25\%$)); with $Fr = (Pi/P) \times$

100, where Fr represents the species occurrence frequency; P_i represents the total number of samples containing the species; and P represents the total number of samples.

TABLE I
Gelatinous zooplankton sampling coordinates

Region	Station	Coordinates	
		Longitude	Latitude (N)
Habibas Islands	H1		35°37'42"
	H2	1°10'W	35°40'00"
	H3		35°41'00"
	H4		35°44'30"
	H5	1°8'W	35°44'48"
	H6		35°45'24"
Sidi-Fredj	S1		36°47'24"
	S2	2°50'E	36°48'12"
	S3		36°49'10"
Tenes	T1	1°28'44.4"E	36°32'34.8"
	T2	1°29'13.2"E	36°32'45.6"
	T3	1°29'42"E	36°32'24"
	T4	1°30' 36"E	36°33'0"
	T5	1°30'54"E	36°32'31.2"
Tipaza	1	2°39'8"E	36°39'9"
Algiers Bay	2	3°19'3"E	36°50'5"
Tizi-Ouzou	3	4°24'9"E	36°56'9"
Jijel	4	6°13'5"E	37°1'26"
Skikda	5	6°34' 4"E	37°3'6"

The Shannon-Wiener diversity index was calculated using R with a vegan package for each sampling region (Oksanen *et al.*, 2017). The difference in diversity index between regions was assessed using the non-parametric Kruskal-Wallis test. Pairwise comparisons between regions were assessed using post hoc Tukey and Kramer tests (Pohlert, 2014).

Non-metric multidimensional analysis (NMDS) was used to identify different groups. Environmental factors and Shannon's diversity index (H') were fitted as vectors onto station scores ordination (Oksanen *et al.*, 2017). In addition, the abundance of all gelatinous species between groups was compared using analysis of similarity (ANOSIM) — a non-parametric multivariate analysis of variance test for differences between groups based on the Bray-Curtis distance (Clarke, 1993). The main species responsible for creation of similarity patterns between groups assessed by ANOSIM were identified using similarity percentage analysis (SIMPER) (Clarke, 1993).

SOFTWARE

All analyses and graphics were carried out using statistical software R (R, 2016), with vegan (Oksanen *et al.*, 2017) and BiodiversityR (Kindt & Coe, 2005) used to calculate statistics.

RESULTS

ENVIRONMENTAL CONDITIONS

Average sea surface temperature (0-20 m) off the Habibas Islands was $18.2 \pm 1.25^\circ\text{C}$ in spring and $23.79 \pm 0.91^\circ\text{C}$ in summer (Tab. II). The bottom layer (30-50 m) had an average temperature of $15.76 \pm 0.38^\circ\text{C}$ and $19.31 \pm 1.58^\circ\text{C}$ in spring and summer, respectively. In this region, the average value of surface salinity was around 35 in spring and summer; while the bottom layer averaged 34.94 ± 0.15 and 34.89 ± 0.11 in spring and in summer, respectively.

Off Sidi Fredj, average sea surface temperature varied between $15.7 \pm 0.09^\circ\text{C}$ in winter and $21.12 \pm 1.64^\circ\text{C}$ in summer (Tab. II), while bottom temperatures averaged $15.6 \pm 0.26^\circ\text{C}$ in winter to $18.27 \pm 0.46^\circ\text{C}$ in summer. Sea surface salinity ranged from 35.5 ± 0.09 in winter to 36.25 ± 0.23 in autumn; while the bottom layer averaged 35.73 ± 0.12 and 36.97 ± 0.18 in summer and in spring, respectively.

Average sea surface temperatures in Tipaza, Algiers Bay, Tizi-Ouzou, Jijel, and Skikda were more than 20°C during autumn; the bottom layer average temperature varied between $18 \pm 1.27^\circ\text{C}$ off Skikda and $21.1 \pm 1.7^\circ\text{C}$ off Tipaza (Tab. II). In all these regions, the average value of surface and bottom salinity was around 35 in autumn.

Off Tenes, average sea surface temperature showed high values in summer at $25.07 \pm 0.46^\circ\text{C}$, and $24.34 \pm 0.4^\circ\text{C}$ in the bottom layer; average surface and bottom salinity was around 35.

TABLE II

Hydrological data average values (\pm standard error) by location and year

		Habibas Islands		Sidi Fredj				Tipaza	Algiers Bay	Tizi-Ouzou	Jijel	Skikda	Tenes
		2012		2012	2013		2014				2015		
		Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Autumn	Autumn	Autumn	Autumn	Summer
Temperature ($^\circ\text{C}$)	0–20 m	18.2 ± 1.25	23.79 ± 0.91	18.02 ± 0.08	15.7 ± 0.09	16.1 ± 0.24	21.12 ± 1.64	24.15 ± 0.49	24.2 ± 0.28	23.85 ± 0.64	23.75 ± 0.78	24.15 ± 0.21	25.07 ± 0.46
	30–50 m	15.76 ± 0.38	19.31 ± 1.58	17.37 ± 0.59	15.6 ± 0.26	15.65 ± 0.1	18.27 ± 0.46	21.1 ± 1.7	19.65 ± 1.06	20.8 ± 0.28	18.15 ± 0.78	18 ± 1.27	24.34 ± 0.4
Salinity (psu)	0–20 m	35.01 ± 0.21	35.11 ± 0.12	36.25 ± 0.23	35.5 ± 0.09	35.88 ± 0.2	35.73 ± 0.14	35.15 ± 0.07	35.2 ± 0	35.05 ± 0.21	35.1 ± 0.14	35.15 ± 0.07	35.69 ± 0.03
	30–50 m	34.94 ± 0.15	34.89 ± 0.11	36.82 ± 0.45	35.95 ± 0.05	36.97 ± 0.18	35.73 ± 0.12	35.05 ± 0.07	34.9 ± 0	34.95 ± 0.07	34.85 ± 0	34.75 ± 0.07	35.75 ± 0.01

SPECIES COMPOSITION

Altogether, 56 species of gelatinous zooplankton were recorded during the study period. Of these, 18 species were siphonophores, with the maximum number recorded off Sidi Fredj (from winter to summer), Algiers Bay, Tizi-Ouzou, and Skikda, while minimum numbers occurred off Jijel. A total 12 appendicularian species were recorded, with maximum and minimum numbers of species found off Habibas Islands and Sidi Fredj, and Tenes, Tipaza, and Tizi-Ouzou stations, respectively. Of the six species in families Salpidae and Doliolidae, maximum and minimum numbers occurred off Habibas Islands (in spring) and Sidi Fredj (in winter and spring), and Tenes, respectively; none was found off Jijel. Of six chaetognath species, the maximum number was recorded from Sidi Fredj (in winter). A total of 14 molluscan species were recorded, with the greatest number of species found off Tipaza and Tizi-Ouzou, while the least number of species occurred off the Habibas Islands, Tenes, and Sidi Fredj (in summer). Details of species composition are presented in Appendix.

DIVERSITY OF GELATINOUS ZOOPLANKTON

The different diversity indices are shown in Fig. 2. Species diversity ranged from 2.30 to 3.73 off the Habibas Islands. Maximum species diversity was recorded in spring and minimum diversity in summer. The diversity index ranged from 1.38 to 2.80 off Tenes in summer. Species diversity ranged from 2.43 to 3.20 off Sidi Fredj. The maximum species diversity was recorded in spring and the minimum diversity in autumn. The diversity index in autumn was 2.61, 2.58, 2.43, 1.59, and 2.92 off Tipaza, Algiers Bay, Tizi-Ouzou, Jijel, and Skikda, respectively. The Shannon-

Wiener diversity index was subjected to the non-parametric Kruskal-Wallis test, with significant statistical difference between regions ($p < 0.01$). Post-hoc pairwise comparisons showed a difference between the Habibas Islands–Tenes ($p < 0.05$) and Sidi Fredj–Tenes ($p < 0.01$).

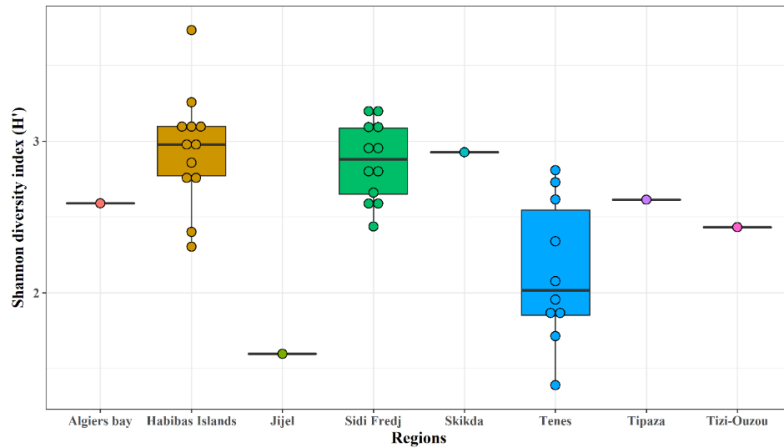


Figure 2.— Shannon-Wiener diversity index for gelatinous zooplankton communities off Algeria.

TOTAL SUMMER ABUNDANCE OFF THE HABIBAS ISLANDS, SIDI FREDJ, AND TENES

Significant differences in total summer gelatinous zooplankton densities were apparent between the Habibas Islands, Sidi Fredj, and Tenes ($p < 0.001$) (Fig. 3). High densities were recorded off Sidi Fredj (to 10×10^3 ind. m^{-3}), while the lowest values occurred off Tenes (below 3×10^2 ind. m^{-3}). Important values were also registered off the Habibas Islands, at 5.68×10^2 ind. m^{-3} . Post hoc Tukey and Kramer tests revealed significant differences between the Habibas Islands and Tenes ($p < 0.001$). Significant differences also existed between Sidi Fredj and Tenes ($p < 0.001$).

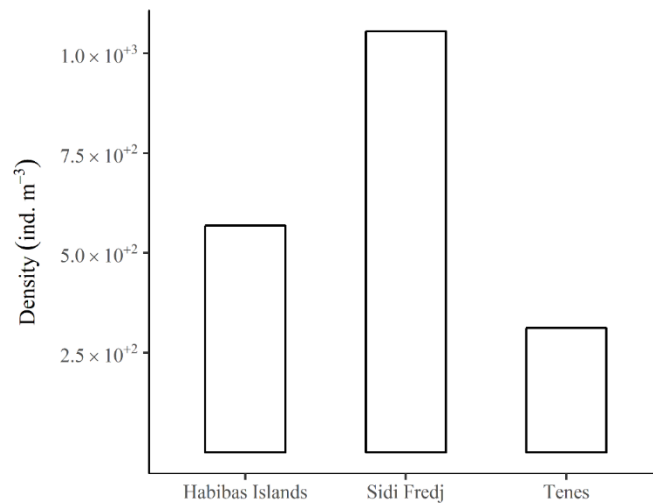


Figure 3.— Total abundance of gelatinous zooplankton in summer.

ABUNDANCE AND DISTRIBUTION OF THE MAIN SPECIES

Spatial distribution

Samples in Tipaza, Algiers Bay, Tizi-Ouzou, Jijel, and Skikda were all collected during autumn. Of 14 siphonophore species (cf. Appendix), *Abylopsis tetragona* was most frequent and abundant, with maximum density in Tizi-Ouzou at 29.44 ind. m⁻³ (Fig. 4), and minimum density in Jijel, at 0.95 ind. m⁻³.

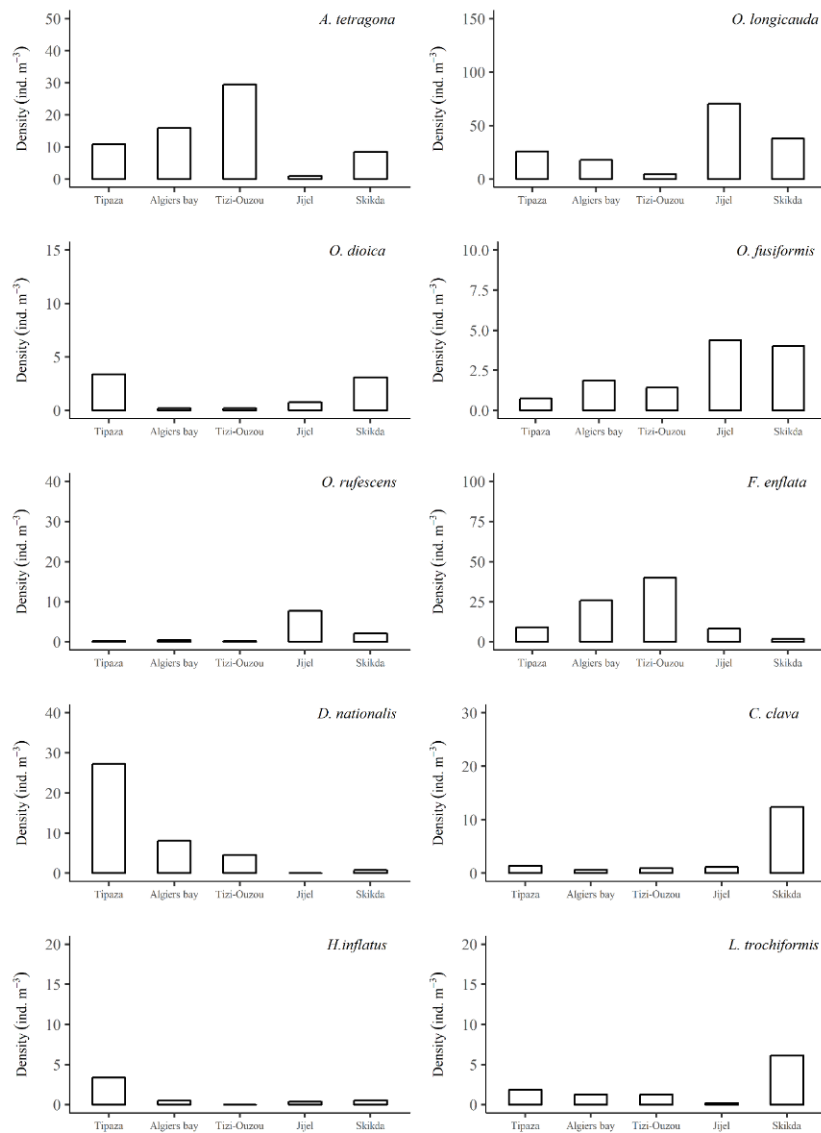


Figure 4.— Spatial distribution of major gelatinous zooplankton species.

Seven appendicularian species were recorded: *Oikopleura dioica*, *O. fusiformis*, *O. rufescens*, *O. longicauda*, *Fritillaria borealis*, *F. megachile* and *F. urticans* (cf. Appendix). Of these, *O. longicauda* dominated numerically, with a maximum number of 70.46 ind. m⁻³ recorded off Jijel (Fig. 4); *O. dioica*, *O. fusiformis*, and *O. rufescens* occurred frequently; abundances of *O. dioica* varied between 0.2 ind. m⁻³ off Tizi-Ouzou and 3.39 ind. m⁻³ off Tipaza; the maximum density of *O. fusiformis* (4.39 ind. m⁻³) occurred off Jijel, and the minimum (0.74 ind. m⁻³) off Tipaza; the maximum density of *O. rufescens* (7.74 ind. m⁻³) occurred off Jijel (Fig. 4).

We found five chaetognath species (*Sagitta bipunctata*, *Mesosagitta minima*, *Parasagitta friderici*, *Pterosagitta draco* and *F. enflata*) (cf. Appendix), of which the most dominant and frequent was *F. enflata*, with the highest densities recorded off Algiers Bay and Tizi-Ouzou, at 25.81 ind. m⁻³ and 40.02 ind. m⁻³, respectively (Fig. 4).

D. nationalis was the most abundant thaliacean, with maximum densities (27.28 ind. m⁻³) recorded off Tipaza (Fig. 4).

Thirteen planktonic mollusc species were found (cf. Appendix), of which only *Heliconoides inflatus* and *Limacina trochiformis* proved frequent and abundant. The maximum number of *H. inflatus* (3.39 ind. m⁻³) was recorded off Tipaza, but it was absent from off Tizi-Ouzou, while the maximum number of *L. trochiformis* (6.13 ind. m⁻³) occurred off Skikda; one further species, *Creseis clava* (12.39 ind. m⁻³) also dominated off Skikda (Fig. 4).

Seasonal distribution in Sidi Fredj

Nine siphonophore species were found, of which *A. tetragona* and *Muggiaea atlantica* were frequent and dominant. The highest densities of *M. atlantica* occurred during spring (63.51 ± 16.48 ind. m⁻³) and winter (44.18 ± 29.46 ind. m⁻³) (Fig. 4), while high densities (15.09 ± 8.45 ind. m⁻³) of *A. tetragona* occurred during winter (Fig. 5).

Tunicata comprised two groups: thaliaceans, including both Doliolidae and Salpidae, and Appendicularia, encompassing fritillarians and oikopleurids. Of the nine appendicularian taxa off Algeria (cf. Appendix), *O. longicauda* and *O. fusiformis* were the most dominant and frequent species. *O. longicauda* reached densities of 30.37 ± 16.48 ind. m⁻³ in spring, and *O. fusiformis* reached maximum densities (10.45 ± 14.21 ind. m⁻³) in summer. The maximum values of *Fritillaria pellucida* peaked in spring (98.61 ± 25 ind. m⁻³) (Fig. 5). Thaliaceans were represented by Salpidae and Doliolidae, with *Doliolum nationalis* the most abundant and frequent species off Sidi Fredj in spring and summer (175.44 ± 26.81 ind. m⁻³ and 117.36 ± 54.04 ind. m⁻³, respectively) (Fig. 5).

Of the four chaetognath species (*F. enflata*, *M. minima*, *P. friderici*, and *P. draco*) (cf. Appendix), the most frequent and dominant species was *F. enflata*, with maximum numbers in summer 102.56 ± 27.59 ind. m⁻³ and spring 76.13 ± 56.51 ind. m⁻³.

L. trochiformis and *H. inflatus* were the most dominant and frequent molluscan species, *L. trochiformis* reached maximum densities (26.23 ± 8.98 ind. m⁻³) in spring, and *H. inflatus* reached maximum densities in spring and summer (6.50 ± 4.64 ind. m⁻³ and 5.71 ± 3.75 ind. m⁻³, respectively) (Fig. 5).

STATISTICAL ANALYSIS

NMDS based on Bray-Curtis distances clearly revealed four main groups of stations, namely Groups: (A) comprising samples collected in autumn (1, 14, 15, 16, 17, 27, 38, and 39); (B) comprising assorted stations collected in summer (8, 9, 10, 11, 12, 13, 24, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36, and 37); (C) comprising stations collected in spring (2, 3, 4, 5, 6, 7, 21, 22, and

23); and (D), comprising the winter-collected stations (18, 19, and 20) (Fig. 6). ANOSIM demonstrated significant differences between groups A, B, C, and D ($R = 0.37$; $p < 0.001$).

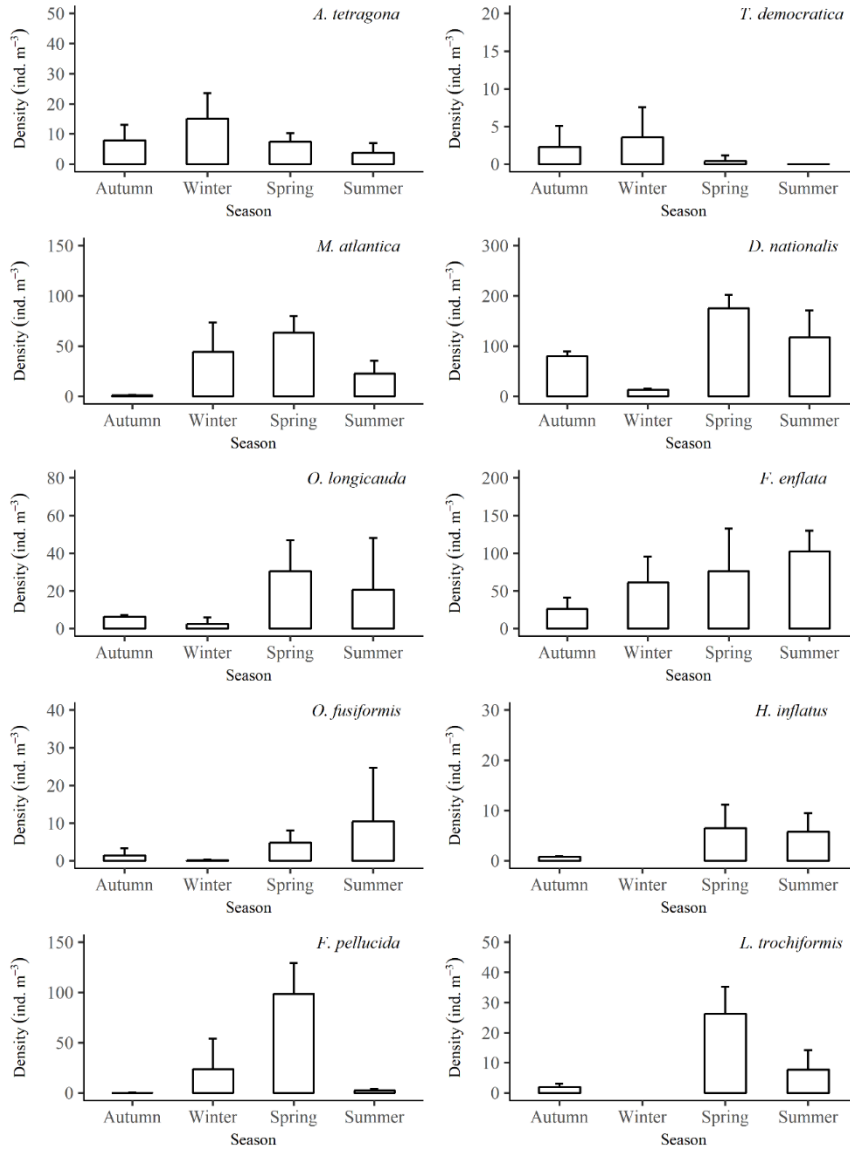


Figure 5.— Seasonal distribution of major gelatinous zooplankton species in the Sidi Fredj region.

ANOSIM of 39 samples revealed significant differences between seasons ($P < 0.001$). In terms of contribution to total community similarity (SIMPER), the dominant species in various seasons were *O. longicauda*, *O. fusiformis*, *F. pellucida*, *A. tetragona*, *M. atlantica*, *D. nationalis*, and *T. democratica* (Fig. 7). *O. longicauda* was the most dominant species in autumn followed by *F. enflata*, with 28.31% and 26.18% of total abundance, respectively. *F. enflata* (30.52%) led in winter, followed by *M. atlantica* (22.09%). The thaliacean species (*Thalia democratica*, *D. nationalis*, *O. longicauda*, *F. pellucida*, and *O. fusiformis*) were the most dominant in spring—a

group contributing to more than 50% to total abundance. Populations of *D. nationalis* and *F. enflata* dominated the summer season, at 28.51% and 27.02%, respectively.

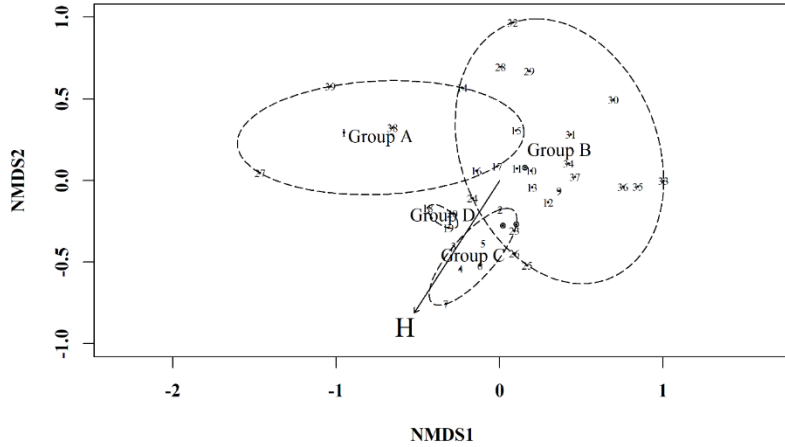


Figure 6.— Multidimensional scaling ordination for samples in relation to Shannon-Wiener diversity index (H').

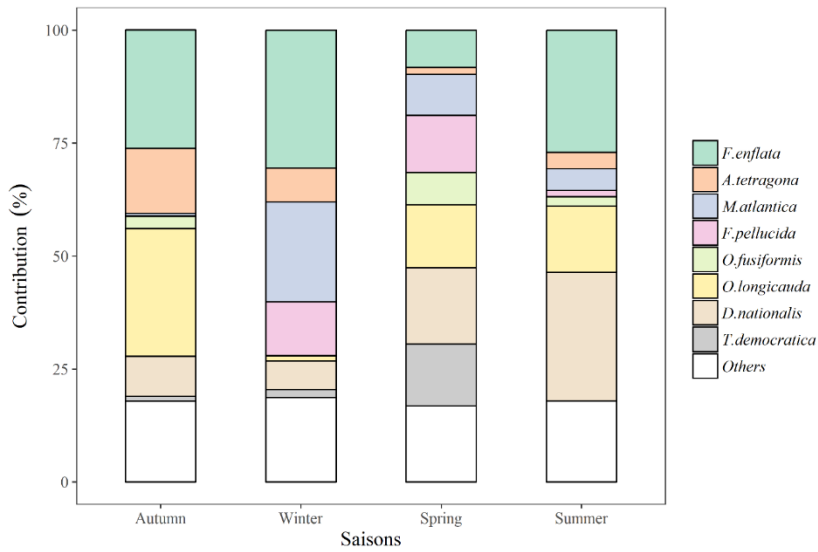


Figure 7.— Contribution of species to the average similarity of gelatinous zooplankton communities along the Algerian coast, illustrated by SIMPER.

DISCUSSION

There are few records of the entire gelatinous zooplankton assemblages off the Algerian coast. We recorded six taxonomic groups from this region: Siphonophorae, Appendicularia, Doliolidae, Salpidae, Chaetogantha, and Mollusca.

Siphonophorae are among the most abundant carnivores in the marine system (Mapstone, 2009; Licandro, 2012). We report the abundance of *M. atlantica* to be higher in spring, consistent with an established general pattern of siphonophoran seasonal distribution in the sea (Purcell, 1981; Graham, 2001; Lo, 2014). The presence of important densities of this species in winter may be a consequence of passage of the Modified Atlantic Water (MAW). Further, recent data in the Bay of Bizerte – influenced to a greater extent by offshore Atlantic circulation - shows relatively high abundances of *M. atlantica* in winter (Touzri *et al.*, 2012). The occurrence of this species in the Adriatic Sea has also been associated with the colder and less saline MAW, especially in winter during periods of stronger inflow of Mediterranean water to the south Adriatic (Batistic, 2004, 2014).

Among the most frequent siphonophore taxa, *A. tetragona* is considered cosmopolitan in distribution, and to inhabit shallow epipelagic layers (López-López, 2013; Mapstone, 2014). We recorded this species in all regions, with significant densities in winter. Bernard (1955), who studied the seasonal distribution of zooplankton in Algiers Bay, found what he called 'cold water species' like *A. tetragona* in the southerly branch of MAW.

Among appendicularians, populations of *Oikopleura longicauda*, *O. fusiformis*, and *O. rufescens* can contribute significantly to zooplankton communities as grazers on primary production, because of their efficiency at collecting food particles, and their cosmopolitan warm and temperate water distribution (Purcell *et al.*, 2004; Sato *et al.*, 2005). We report *Oikopleura* to be widely distributed off the Algerian coast. Of reported species, *O. longicauda* was numerically abundant with maximum abundance in spring and summer, as reported by Fenaux *et al.* (1998), while *O. fusiformis* was found at high density in summer, as reported by Tomita *et al.* (2003) for Toyama Bay, in the southern Japan Sea. *O. longicauda* and *O. fusiformis* are typically regarded to be warm-water species and tend to be among the most abundant appendicularians wherever they occur (Fenaux *et al.*, 1998). Significant densities of *Fritillaria pellucida* were observed in spring and winter; high spring densities of this species have been previously reported from the Mediterranean Sea (Fenaux, 1966), and it has been reported as more abundant in winter in the Balearic Sea (Puelles, 2003); this species seems to have the capacity to develop large populations very quickly under favorable conditions (Siokou-Frangou, 1998).

Doliolidae have a cosmopolitan distribution, preferring warm, continental shelf waters (Deibel, 1998, 2009). Doliolidae begin to be numerous from May to June, with high abundances in summer and autumn (Braconnot & Dallot, 1995). Gibson & Paffenhöfer (2002) proposed that the blooming of Doliolidae was related to high rates of sexual or asexual reproduction. In the present study, two peaks of *D. nationalis* were recorded: in spring, related to phytoplankton blooms (Deibel, 1998), and in summer, when the environment was most oligotrophic (Menard *et al.*, 1997); this species was also most dominant in early summer in the neritic area of the Balearic Sea (Puelles, 2003). A second taxon, *F. enflata*, is cosmopolitan in temperate and warm waters, where it occurs mainly in the upper 200 m (Pierrot-Bults & Nair, 1991); it was the dominant chaetognath species by number in the Alboran Sea (Dallot *et al.*, 1988), and was the most dominant chaetognath in our study off Algeria.

Pteropod abundance can vary suddenly and considerably: they can occasionally occur in large numbers, then disappear completely from the plankton (Rampal, 1975). *L. trochiformis* and *H. inflatus* were recorded in all study areas, while *C. clava* was absent from off Sidi Fredj. *L. trochiformis* and *H. inflatus* were the most abundant species, with maximums during spring and summer. A similar situation was observed in the Boka Kotorska Bay Sea in the southern Adriatic, where *L. trochiformis* and *H. inflatus* prevailed from February to September (Pestori, 2016). *H. inflatus* was the most abundant pteropod, with maximum numbers in spring and summer in the same region (Vukanic, 2007). *L. trochiformis* and *H. inflatus* had high abundances in spring and

summer, accompanied by a higher abundance of phytoplankton, particularly nanophytoplankton (Pestoric, 2013). A similar situation was observed in the open sea of the southern Adriatic, in the area of the Jabuka Pit (Batistic, 2004).

Densities sampled off Tenes were very low compared to abundances off the Habibas Islands and Sidi Fredj. Bernard (1952) described the region off Tenes as special, and unique in North Africa, being characterized by the rise to the surface of deep oligotrophic Mediterranean waters, leading to reduced planktonic abundance.

Non-metric multidimensional analysis (NMDS) and analysis of similarity (ANOSIM) clearly revealed four groups: an autumn group comprising the most abundant and frequent of gelatinous species (*F. inflata* and *O. longicauda*); a less diverse summer group, dominated by *D. nationalis* and *F. inflata*; a winter group characterized by carnivorous species; and a diverse spring group, essentially comprising species of Thaliacea. Saiz *et al.* (2014) reported the Chaetogantha to be typically very scarce during winter, with maximum densities occurring during August and September. This is particularly true of *F. inflata*, the most abundant species in the western Mediterranean Sea (Vives, 1966; Dallot *et al.*, 1988; Andréu, 1990). Oikopleuridae seem to be more abundant in summer (Fenaux, 1968) and Doliolidae more abundant during the second half of the year (Braconnot, 1971; Ménard *et al.*, 1997). Thaliaceans are more common in spring and are associated with a peak in primary production in the Mediterranean Sea (Vives, 1966; Ménard *et al.*, 1994).

The diversity of gelatinous zooplankton described by the Shannon-Wiener index was higher at all stations sampled during spring (Habibas Islands and Sidi Fredj). This is the period in which gelatinous zooplankton reproduce intensively (Batistic *et al.*, 2007; Touzri *et al.*, 2012). The low diversity recorded off Tenes (summer) and Jijel (autumn) probably reflects the end of the productive seasons.

Species found in the present study have been recorded previously in the western Mediterranean Sea (Mills *et al.*, 1996; Licandro & Ibanez, 2000; Fernandez de Puelles *et al.*, 2003; Daly Yahia *et al.*, 2004; Molinero, 2005, 2008; Batistic *et al.*, 2007). The species richness off the Algerian coast was low in comparison with species composition recorded in the Adriatic Sea (66 species, Batistic *et al.*, 2007) and high in comparison with species recorded in the Bay of Bizerte (48 species, Touzri *et al.*, 2012).

CONCLUSION

The epipelagic ecosystem along the Algerian coast contains a variety of wildlife from various zoological groups. Six groups of gelatinous zooplankton were observed during the present study: Siphonophorae, Salpidae, Doliolidae, Mollusca, Appendicularia, and Chaetogantha. Results indicate that the composition of different species in each group vary between seasons. The diversity of gelatinous zooplankton species was higher in spring, and their occurrence greater in spring and summer.

The study area off the Algerian coast of the southwestern Mediterranean Sea is of great interest from the biogeographical point of view. Unfortunately, it has been poorly studied and there is little information on the gelatinous plankton. Further researches are needed to understand the role of gelatinous zooplankton in the local ecosystem, provide a better understanding of trophic dynamics in this area, and investigate the impact of gelatinous zooplankton on fisheries and tourism.

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APPENDIX

Gelatinous zooplankton per location and season

Autumn, Au; Winter, Wi; Spring, Sp; Summer, Su; ***Frequent (Fr > 75%), **common (75% ≤ Fr ≤ 25%), *rare (Fr < 25%); Present (+); Absent (-).

Taxon	Habibas Islands		Tenes	Tipaza	Sidi Fredj				Algiers bay	Jijel	Tizi-Ouzou	Skikda
	Sp	Su	Au	Au	Au	Wi	Sp	Su	Au	Au	Au	Au
Siphonophorae												
<i>Abylopsis tetragona</i> (Otto, 1823)***	+	+	+	+	+	+	+	+	+	+	+	+
<i>Agalma elegans</i> (Sars, 1846)*	-	-	-	-	-	-	+	+	-	-	-	-
<i>Agalma okenii</i> Eschscholtz, 1825*	-	-	+	-	-	-	-	-	-	-	-	-
<i>Bassia bassensis</i> (Quoy & Gaimard, 1833)*	-	-	+	+	-	-	-	-	-	-	+	-
<i>Chelophyes appendiculata</i> (Eschscholtz, 1829)*	-	-	+	+	-	+	-	+	+	-	+	+
<i>Erenna richardi</i> Bedot, 1904*	-	-	-	-	-	-	-	-	-	-	-	+
<i>Forskalia edwardsii</i> Kölliker, 1853*	-	-	-	-	-	-	-	-	-	-	-	+
<i>Hippopus hippopus</i> (Linnaeus, 1758)*	-	-	-	-	-	-	-	-	+	-	+	+
<i>Lensia conoidea</i> (Keferstein & Ehlers, 1860)*	-	-	-	-	-	-	-	-	-	-	-	+
<i>Lensia subtilis</i> (Chun, 1886)**	+	-	+	+	+	+	+	+	+	-	-	-
<i>Lensia subtiloides</i> (Lens & van Riemsdijk, 1908)**	+	-	+	-	-	+	+	+	-	-	-	-
<i>Muggiaea atlantica</i> Cunningham, 1892***	+	+	+	-	+	+	+	+	+	-	+	+
<i>Muggiaea kochi</i> (Will, 1844)**	+	-	+	-	+	+	+	-	+	-	+	-
<i>Nanomia bijuga</i> (Delle Chiaje, 1844)*	-	-	-	-	-	+	-	-	+	-	+	-
<i>Pyrostephos vanhoeffeni</i> Moser, 1925*	-	-	-	-	-	-	-	-	-	-	-	+
<i>Sphaeronectes irregularis</i> (Claus, 1873)**	+	-	-	-	+	+	+	+	-	-	-	-
<i>Sulculeolaria monoica</i> (Chun, 1888)*	-	-	-	-	-	-	-	-	+	-	-	-
<i>Vogtia glabra</i> Bigelow, 1918*	-	-	-	-	-	-	-	-	+	-	-	+
Appendicularia												
<i>Fritillaria borealis intermedia</i> Lohmann, 1905*	-	-	-	-	-	-	-	-	-	-	-	+
<i>Fritillaria formica tuberculata</i> Lohmann in Lohmann & Buckmann, 1926**	+	+	-	-	+	+	-	-	-	-	-	-
<i>Fritillaria fraudax</i> Lohmann, 1896*	-	-	-	-	+	-	-	-	-	-	-	-
<i>Fritillaria megachile</i> Fol, 1872*	-	-	+	-	-	-	-	-	-	+	-	-
<i>Fritillaria pellucida</i> (Busch, 1851)**	+	+	-	-	+	+	+	+	-	-	-	-
<i>Fritillaria urticans</i> Fol, 1872*	-	-	-	-	-	-	-	-	+	-	-	-
<i>Kowalevskia oceanica</i> Lohmann, 1899*	-	-	-	-	-	-	-	+	-	-	-	-
<i>Oikopleura dioica</i> Fol, 1872***	+	+	+	+	+	+	+	+	+	+	+	+
<i>Oikopleura fusiformis</i> Fol, 1872**	+	+	-	+	+	+	+	+	+	+	+	+
<i>Oikopleura intermedia</i> Lohmann, 1896*	-	-	-	-	-	-	+	+	-	-	-	-

	<i>Oikopleura longicauda</i> (Vogt, 1854)***	+	+	+	+	+	+	+	+	+	+	+
	<i>Oikopleura rufescens</i> Fol, 1872**	+	+	+	+	+	+	+	+	+	+	+
Chaethognatha												
	<i>Flaccisagitta enflata</i> (Grassi, 1881)***	+	+	+	+	+	+	+	+	+	+	+
	<i>Mesosagitta minima</i> (Grassi, 1881)*	-	-	-	+	-	+	-	-	+	+	-
	<i>Parasagitta friderici</i> (Grassi, 1881)***	+	+	+	+	+	+	+	+	+	+	+
	<i>Prerosagitta draco</i> (Krohn, 1853)*	-	-	-	-	-	+	-	-	-	-	-
	<i>Sagitta bipunctata</i> Quoy & Gaimard, 1827*	-	-	-	-	-	-	-	-	-	-	+
	<i>Sagitta lyra</i> Krohn, 1853*	-	-	-	-	-	+	-	-	-	-	-
Thaliacea												
	<i>Cyclosalpa affinis</i> (Chamisso, 1819)*	+	-	-	-	-	-	-	-	-	-	-
	<i>Doliolina krohni</i> Herdman, 1888**	+	-	+	+	+	+	+	+	-	+	+
	<i>Doliolum nationalis</i> Borgert, 1893***	+	+	+	+	+	+	+	+	-	+	+
	<i>Salpa fusiformis</i> Cuvier, 1804*	+	-	-	-	-	+	+	-	-	-	-
	<i>Salpa maxima</i> Forskål, 1775*	-	-	-	-	-	-	-	-	-	+	-
	<i>Thalia democratica</i> (Forskål, 1775)**	+	-	-	-	+	+	+	-	-	-	-
Mollusca												
	<i>Atlanta peronii</i> Lesueur, 1817*	-	-	-	+	-	-	-	-	+	+	+
	<i>Cavolinia inflexa</i> (Lesueur, 1813)*	+	-	-	-	-	-	-	-	-	-	-
	<i>Clio polita</i> Pelseneer, 1888*	+	-	-	+	-	-	-	-	-	-	-
	<i>Creseis clava</i> (Rang, 1828)*	-	-	-	+	-	-	-	-	+	+	+
	<i>Creseis virgula</i> (Rang, 1828)**	+	-	+	+	-	+	+	-	+	-	+
	<i>Heliconoides inflatus</i> (d'Orbigny, 1834)**	+	+	-	+	+	+	+	+	+	+	+
	<i>Hyalocylis striata</i> (Rang, 1828)*	+	-	-	-	-	-	-	-	-	-	+
	<i>Limacina bulimoides</i> (d'Orbigny, 1834)*	-	-	-	-	+	-	-	-	-	+	-
	<i>Limacina helicina</i> (Phipps, 1774)*	-	-	-	+	-	-	-	-	+	-	-
	<i>Limacina lesueurii</i> (d'Orbigny, 1835)*	-	-	-	-	-	-	-	-	+	-	-
	<i>Limacina trochiformis</i> (d'Orbigny, 1834)***	+	+	+	+	+	+	+	+	+	+	+
	<i>Peracle elata</i> (Seguenza, 1875)*	-	-	-	+	-	-	-	-	-	+	-
	<i>Styliola subula</i> (Quoy & Gaimard, 1827)*	-	-	-	-	-	-	-	-	-	-	+
	<i>Thielea helicoides</i> (Jeffreys, 1877)*	-	-	-	+	-	-	-	-	+	-	-