



## Effect of distance from the coast on phytoplanktonic populations in Lebanese coastal waters during 2008-2009

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### Summary

*The aim of this research is to study the effect of distance from the coast on the environmental conditions and phytoplankton populations in the coastal area of North Lebanon. Water samples were collected monthly at an offshore station (N 34° 14,856; E 35° 36,067; Z=500 m; distance from the coast= 6.5km) and inshore one (N 34° 15,600; E 35° 39,364; Z=8 m; distance from the coast=150m) for a period of 2 years from January 2008 to December 2009. Annual cycles, descriptive statistics and t-test to compare the mean values of all studied parameters (physico-chemical parameters and phytoplankton populations) were recorded.*

*Results showed that the differences of mean values between the two stations were significant in nitrates (0.84 vs 0.3  $\mu\text{M L}^{-1}$ ), total nitrites + nitrates (0.91 vs 0.37  $\mu\text{M L}^{-1}$ ) and orthophosphates (0.62 vs 0.2  $\mu\text{M L}^{-1}$ ) while the differences were not significant ( $p>0.5$ ) for temperature (23.18 vs 23.23°C), ( $p<0.5$ ), salinity (39.07 vs 39.37psu), Chlorophyll a (0.08 vs 0.05  $\text{mg/m}^3$ ), total phytoplankton (226523 vs 242558 cells  $\text{L}^{-1}$ ), diatoms (80421 vs 77700 cells  $\text{L}^{-1}$ ) and dinoflagellates (17396 vs 11660 cells  $\text{L}^{-1}$ ). The comparison of the dominant species of microplankton at the two stations, with some exception, showed that during spring and summer periods these species were the same but their percentage to the total of microplankton are different. Diatoms which are more exigent for nutrients availability were for a longer time present in inshore station while during summer time, they were replaced earlier by dinoflagellates in offshore station. The effect of the Sea State, the meteorological conditions during the trip and the morphological characteristics of the coast on the distribution or accumulation of continental inputs were discussed.*

**Keywords:** Eastern Mediterranean, Lebanese coastal waters, inshore-offshore stations, environmental conditions, phytoplankton populations.

## 1. Introduction

Lebanese waters are a part of the Eastern Mediterranean, which is an extreme oligotrophic environment [13]. The Mediterranean Sea is a semi-enclosed basin with an eastward decrease in productivity [16]. However, the concentrations of nitrates and phosphates are increasing [6] and the cultural eutrophication due to the rising demographic impact is becoming an important ecological issue for the Mediterranean coastal zones [18].

In such oligotrophic environment, continental inputs from river, sewage and rainfall can favor the development of the primary production; but river inputs are limited to the rain season; during strong thermal stratification the production is limited to the recycling nutrients [8].

Coastal morphology and meteorological conditions play a role in the concentration or dispersion of these inputs and therefore, their prolific effect can be limited to the coastal area or can be extended far too offshore stations. These effects can be detected by the measurement of the environmental parameters and the primary production represented by algal biomass (chlorophyll-*a* and phytoplankton populations).

In the studied area at Batroun coastal waters, two major sources of continental inputs: the Chemical Plant of Selaata (heavy product of phosphoric acid and raw chemical effluents) and Al- Jaouz River (fresh water) are present. The impact of these two continental sources creates continuous variations in the hydrobiological characteristics of Batroun marine area [9]. The networking strategy that was adopted in water analysis and that was based on periodic sampling at fixed stations has provided results about the existence of zones of influence that are able to superimpose according to weather conditions but nevertheless it has also traced limits from north to south while following the coastal aspects [10].

In Lebanese coast, during calm periods, the surface current circulates from the south towards the north. The wind stress and direction can modify the circulation pattern. During persistent strong south west wind regime surface water from continental input especially from rivers can reach the offshore area.

As part of a large study of phytoplankton in the Lebanese coastal waters [4], the present work focuses for the first time on the effect of distance from the coast on environmental and biological parameters; this effect is realized by comparing the composition, the seasonal cycle, the dynamics of phytoplankton and the succession of populations at inshore and offshore stations during two years cycle between 2008 and 2009.

## 2. Material and methods

### Study site and sampling

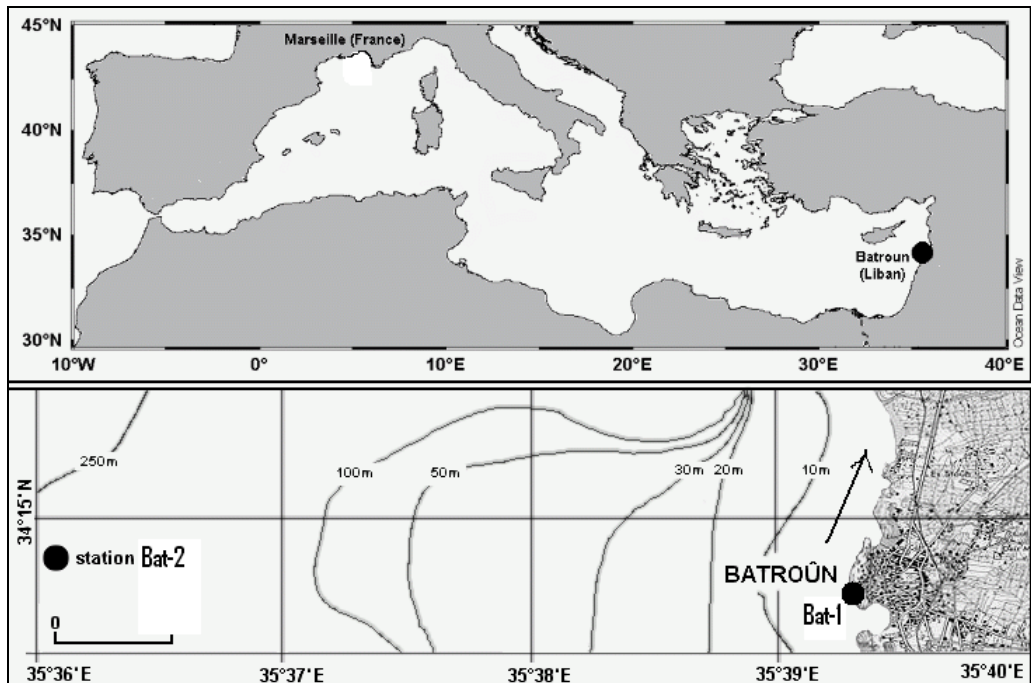
Sampling was performed monthly for a period of 2 years from January 2008 till December 2009 using 10L sampler at surface level at two stations : Bat-1 an inshore station (N 34° 15,600; E 35° 39,364; Z=8 m; distance from the coast=150m) affected by the continental input in the area especially in winter time and during flow of river and an offshore one (N 34° 14,856; E 35° 36,067; Z=500 m; distance from the coast= 5.5km) is not protected from the discharges of the chemical plant of Selaata and the plume Al-Jaouz river during the period of rough sea and strong wind conditions(Fig.1). These stations are part of the long term research programme carried out in this area by the National center for Marine sciences since 1999.

### Analytical determinations

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The temperature was immediately recorded. The salinity was measured using an induction salinometer and presented on a practical salinity scale. Fresh samples of nutrients were brought to the laboratory in ice box in darkness where the samples were stored at  $-20^{\circ}\text{C}$ . Orthophosphates (P-PO<sub>4</sub>) were analyzed according to Murphy & Riley [15], Nitrites (N-NO<sub>2</sub>) according to Bendschneider and Robinson [7] and Nitrates (N-NO<sub>3</sub>) according to Strickland and Parsons [17] with a small modification consisting of utilizing ammonium chloride as activator [11]. Samples for total Chlorophyll-*a* (Chl-*a*) measurement were filtered through a Whatmann GF/F filter at low pressure. Pigments were then extracted in 90% acetone for 24h. The concentration was determined by a spectrophotometer according to the monochromatic method of Lorenzen [14]. The volume of sea water filtered was about 4 liters. The biomass is expressed in quantity of Chl-*a* over volume of sea water ( $\text{mg}/\text{m}^3$ ).

For phytoplankton cells count, samples were preserved with lugol's solution at a final concentration of 0.5 % for species determination and populations were counted using Utermöhl's sedimentation method [19]. After 100ml of a homogenous sample had settled for 48h in a 25mm diameter sedimentation chamber, the base of the chamber was examined with a Wild M 40 phase-contrast inverted microscope. Counts were performed with 200 magnifications for cells of  $20\mu\text{m}$  or more (microplankton) and 400 magnifications for smaller cells (nanoplankton).



**Fig.1:** Sampling sites in the northern Lebanese coastal waters.

### Statistical analysis of Data

Descriptive statistics (mean, standard deviation, minimum and maximum values) of the measured parameters at each station were realized. T-test was used to compare the variation of each parameter at the 2 studied stations. In case of failed normality, Mann-Whitney Rank Sum Test was used. Data were performed with Jandel Sigma Stat 2 software.

Data of 5 environmental parameters (T °C, S, N-NO<sub>2</sub>, N-NO<sub>3</sub>, P-PO<sub>4</sub>) and 5 biological parameters (Chl-*a*, total phytoplankton populations, total microplankton (micro), total nanoplankton (nano),

diatoms and dinoflagellates (dino)) measured in 24 samples for each station were organized in 2 matrices of correlation using SPSS software for statistics.

### 3. Results

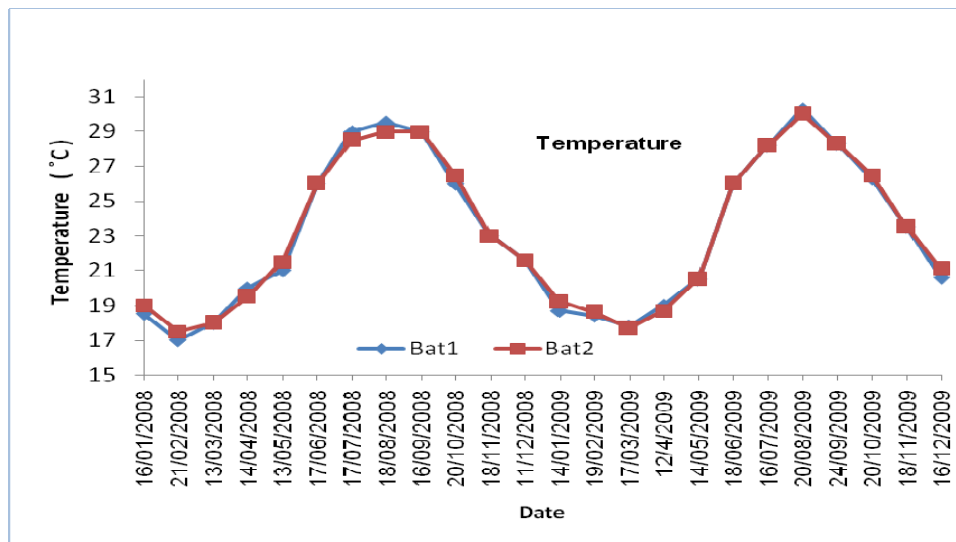
Descriptive statistics (mean, standard deviation, minimum, maximum) for each environmental parameter are presented in table 1.

**Table 1:** Descriptive Statistics (Mean, Standard Deviation, Minimum and Maximum Values) of the environmental parameters measured at the 2 stations studied between January 2009 and December 2010 in the Lebanese marine waters

Stations	T (°C)	Salinity (psu)	N-NO2 (µM/L)	N-NO3 (µM/L)	P-PO4 (µM/L)	N/P ratio
<b>Bat-1</b>						
Mean ±SD	23.175±4.43	39.07± 0.70	0.08 ±0.04	0.84 ±0.58	0.62 ± 1.25	6.31 ± 5.23
Min-Max	17 - 30.3	36.34-39.60	0.01-0.19	0.25-2.35	0.060-5.3	0.08-18.8
<b>Bat-2</b>						
Mean ±SD	23.225±4.3	39.37±0.18	0.07 ±0.05	0.30 ±0.13	0.2 ±0.58	6.045 ±9.41
Min-Max	17.5 - 30	38.94-39.66	0.01-0.23	0.14-0.75	0.01-2.92	0.06-48.1

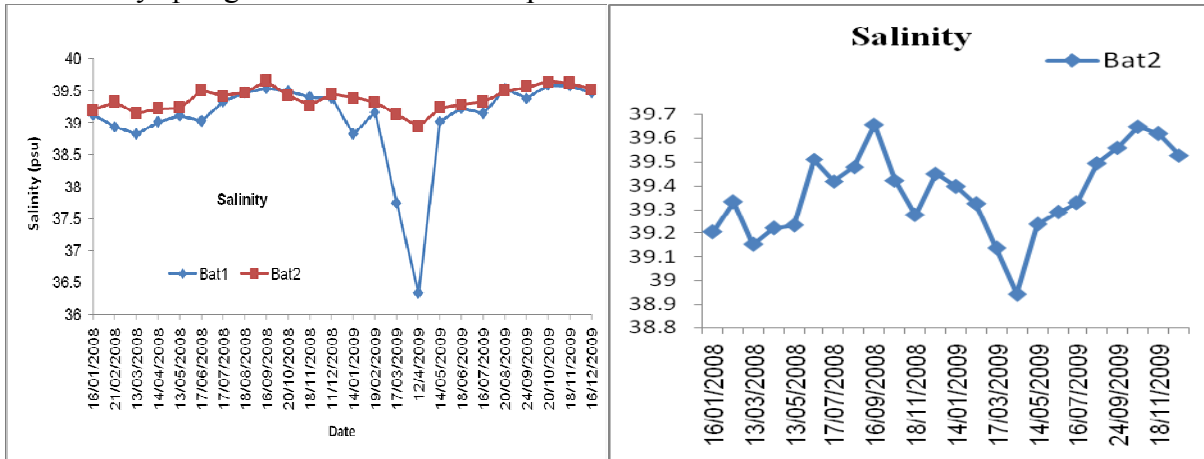
#### Hydrological parameters

The annual Sea surface temperature showed a regular seasonal fluctuation (Fig. 2), ranging from 17°C in February-March to 30.3 in August (mean =23.175 ± 4.43°C) at Bat-1 and from 17.5 to 30 °C (mean = 23.225 ± 4.30°C) at Bat-2; there is not a statistically significant difference between stations (p>0.05).



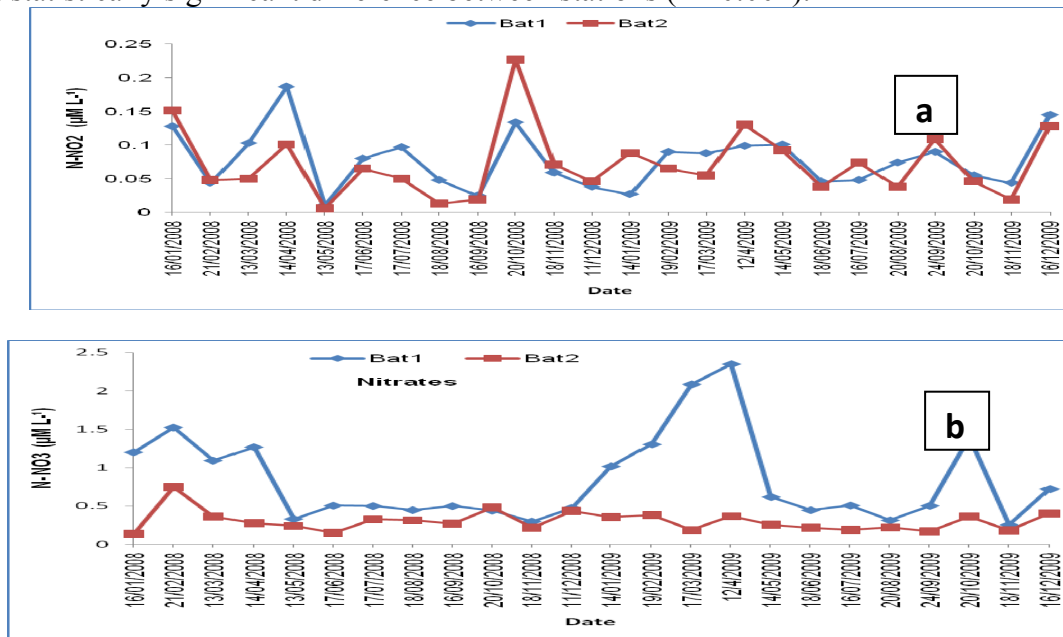
**Fig. 2:** Monthly distribution of temperature at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

The sea surface salinity was more variable. The highest variability and the lowest value were recorded in the inshore station Bat-1 (Fig.3). Values varied from 36.34 psu (April 09) to 39.6 (October 09) (mean= 39.07 + 0.7psu) in the inshore station and from 38.94 to 39.66 psu (mean= 39.37 ± 0.18 psu) in the offshore station. Taken separately, Surface Salinity at B2 shows a regular cycle with minimum in winter and early spring and a maximum in September or October.



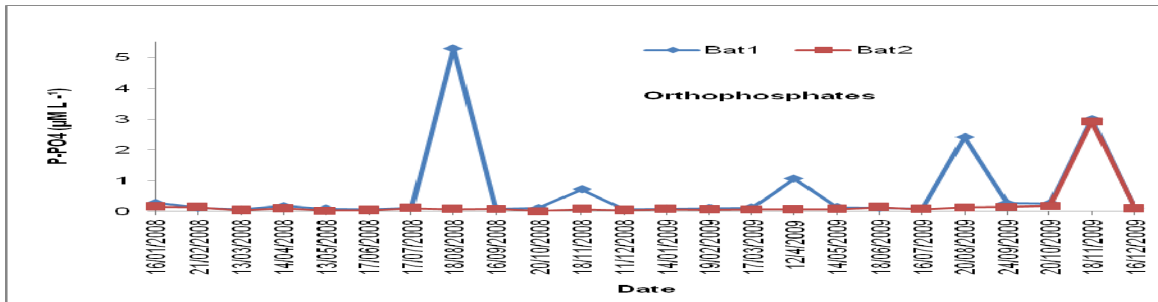
**Fig. 3:** Monthly distribution of salinity at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

The values of nitrites ranged from 0.01 to 0.19  $\mu\text{M L}^{-1}$  (mean= 0.08 + 0.04  $\mu\text{M L}^{-1}$ ) in the inshore station and from undetectable value to 0.23 (mean= 0.07 ± 0.05  $\mu\text{M L}^{-1}$ ) in the offshore station (Fig. 4a) while the nitrates ranged from 0.25 to 2.35  $\mu\text{M L}^{-1}$  (mean= 0.84 ± 0.58  $\mu\text{M L}^{-1}$ ) in the inshore station and from 0.14 to 0.75  $\mu\text{M L}^{-1}$  (mean= 0.30 ± 0.13  $\mu\text{M L}^{-1}$ ) in the offshore station (Fig. 4b); there is a statistically significant difference between stations ( $P < 0.001$ ).



**Fig. 4:** Monthly distribution of nitrites (a) and nitrates (b) at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

The concentrations of orthophosphates ranged between 0.06 to 5.030  $\mu\text{M L}^{-1}$  (mean =  $0.62 \pm 1.25 \mu\text{M L}^{-1}$ ) in the inshore station and from 0.01 to 2.92 (mean =  $0.20 \pm 0.58 \mu\text{M L}^{-1}$ ) in the offshore station (Fig. 5). There is a statistically significant difference ( $P < 0.01$ ) between stations.



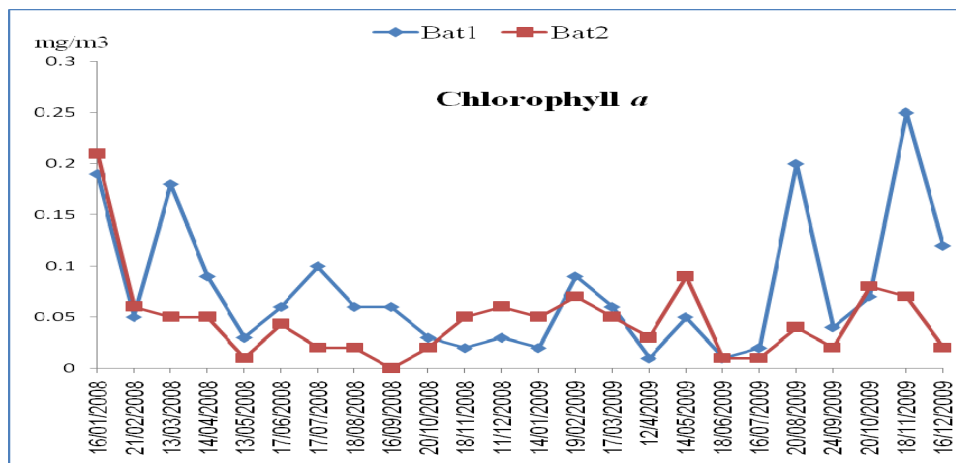
**Fig. 5:** Monthly distribution of orthophosphates (P-O-PO<sub>4</sub>) at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

The ratio N/P ranged between 0.08 and 18.8 (mean =  $6.31 \pm 5.23$ ) in the inshore station and between 0.06 to 48 (mean =  $6.045 \pm 9.41$ ) in the offshore station. There is no statistically significant difference between stations.

### Phytoplanktonic Populations

Descriptive statistics for all biological parameters are presented in table 2.

Figure 6 shows monthly Chlorophyll-*a* variations. The concentrations varied between 0.01 and 0.25  $\text{mg/m}^3$  (mean =  $0.08 \pm 0.07 \text{ mg/m}^3$ ) at Bat-1 and undetectable-0.21 (mean =  $0.05 \pm 0.42 \text{ mg/m}^3$ ). No significant difference is noted between stations but clear peaks were observed at Bat-1 (January, April, July 2008 and February, August, November 2009) while peaks at Bat -2 were more mitigated except January 2008.



**Fig. 6:** Monthly distribution of Chlorophyll-*a* (Chl-*a*) at the two sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

The variations of the total phytoplankton abundance and the main groups considered (nanoplankton, microplankton, dinoflagellates, and diatoms) at the surface level at the two stations are shown in Figure 7, 8 and 9.

**Table 2:** Descriptive Statistics (Mean, Standard Deviation, Minimum and Maximum Values) of the biological parameters at the 2 stations studied between January 2009 and December 2010 in the Lebanese coastal Area.

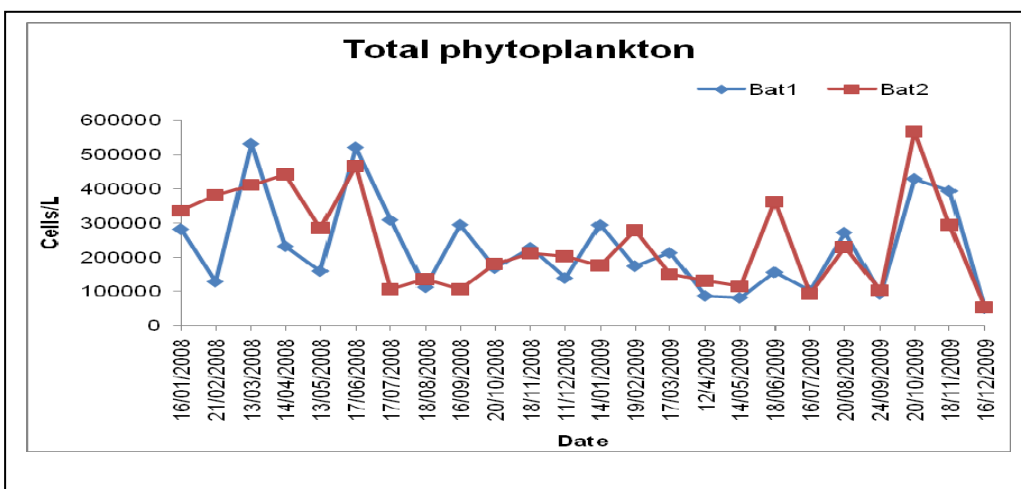
Stations	Chl-a (mg/m <sup>3</sup> )	Total phytoplankton (Cells L <sup>-1</sup> )	Nanoplankton (Cells L <sup>-1</sup> )	Microplankton (Cells L <sup>-1</sup> )	Diatoms (Cells L <sup>-1</sup> )	Dinoflagellates (Cells L <sup>-1</sup> )
<b>Bat-1</b>						
Mean ±SD	0.08 ± 0.07	226524±135115	128450± 69385	98065 ±93550	80421 ± 87830	17395±14645
Min-Max	(0.01-0.25)	49879-530360	34835-313510	5544-320560	2640-294030	2905-49500
<b>Bat-2</b>						
Mean ±SD	0.05 ±0.042	242558±138975	155340±93150	89470 ±106855	77700±104570	11660±5740
Min-Max	(0.00-0.21)	53211-566630	45920-367350	7290-438370	1090- 428275	4488-24948

\*The Total phytoplankton abundance varied between 49879 and 530360 cells L<sup>-1</sup> (mean= 226524 ± 135115 cells L<sup>-1</sup> at Bat-1 and varied between 53211 and 566630 cells L<sup>-1</sup> (average = 242558 ±138975) at Bat 2.

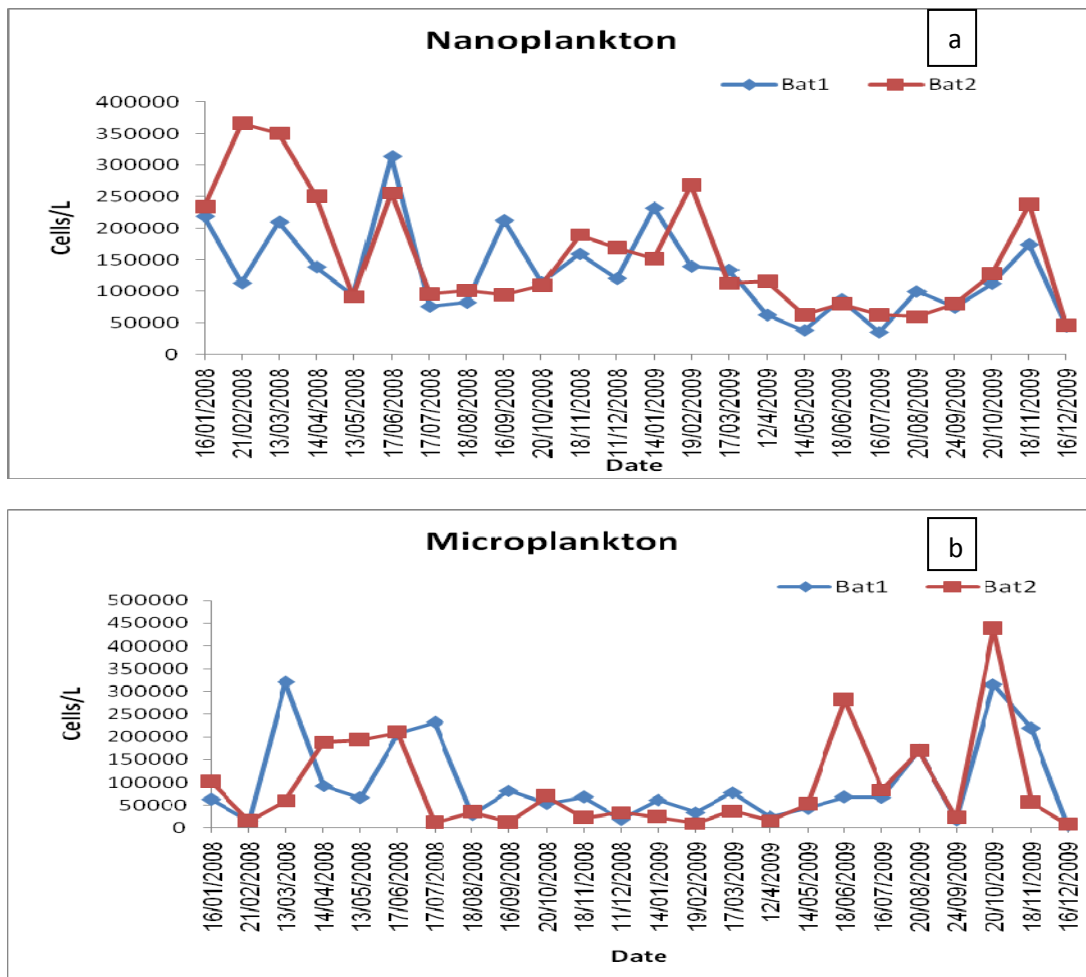
In both stations, the total phytoplankton abundance showed an increase during spring 2008 and fall 2009 when diatoms were the taxa responsible for abundance fluctuations and remained low from July 08 to May 09 with an increase in June and in fall (October–November). In 2009, the spring maximum was not observed as usual in microplankton populations; only nanoplankton populations noted a slight increase in January and February successively at Bat-1 and Bat-2.

Dinoflagellates abundance was more variable and the peaks were noted at Bat-1 (March–April, June 2008 and January, August, October 2009) while peaks were mitigated at Bat-2.

The comparison of the observed abundance between the 2 stations did not show significant differences between these groups in the different components of phytoplankton.



**Fig. 7:** Monthly distribution of total phytoplankton at the two sampling stations in the Lebanese coastal waters between January 2008 and December 2009.



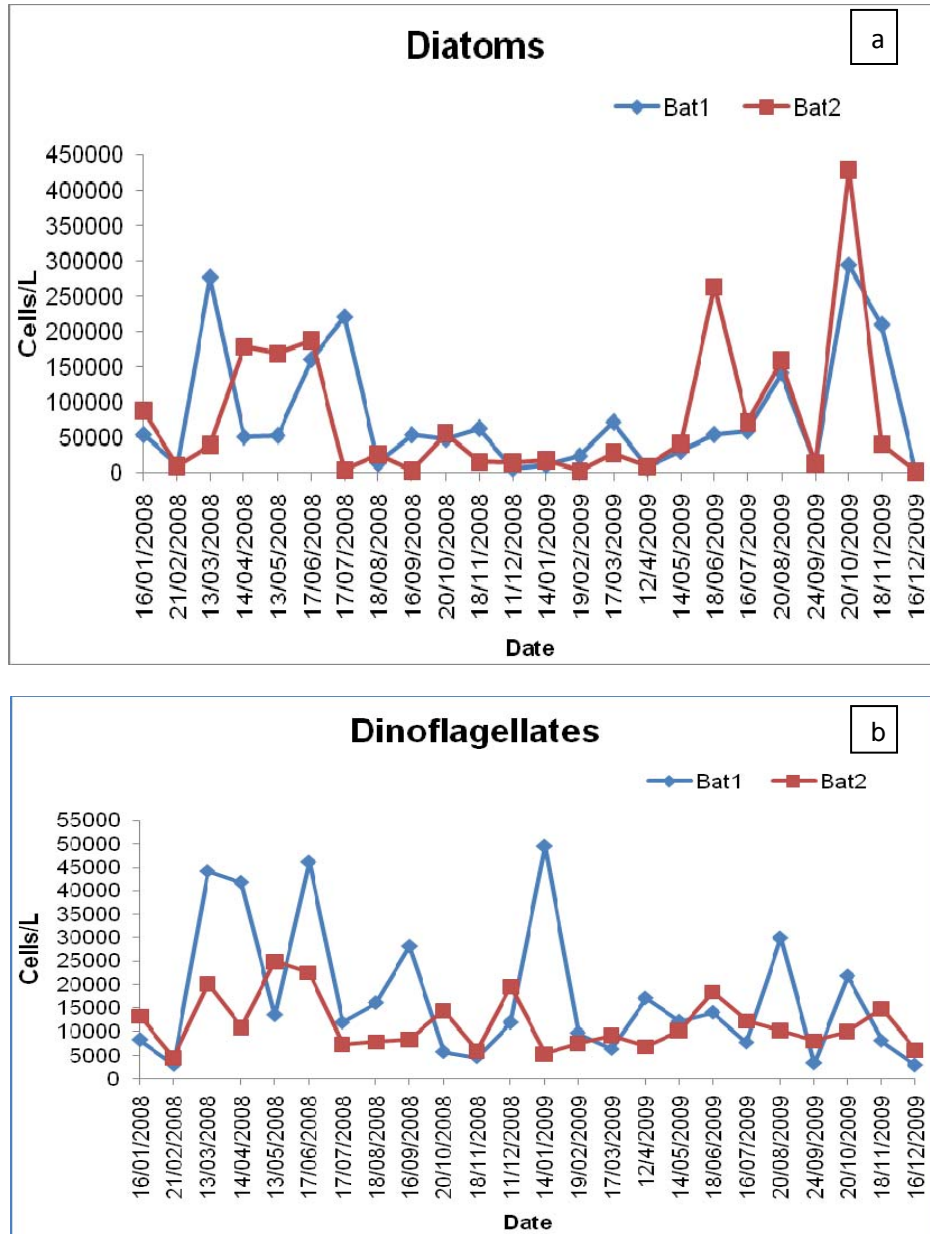
**Fig. 8:** Monthly distribution of nanoplankton (a) and microplankton (b) at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

### Dominance and succession of populations

The dominant phytoplankton species in both stations are summarized in table 3. In January 2008 at Bat-1, the dominant species were *Chaetoceros sp* and *Asterionella japonica* followed by *Thalassiothrix frauenfeldii* and *Cylindrotheca closterium* in February. In March, *Chaetoceros curvisetus* and *A. japonica* dominated; *Ch. curvisetus* continues to dominate in April. May was dominated by *Skeletonema costatum* followed by *Pseudonitzschia pseudodelicatissima* and *Leptocylindrus danicus* in June. This latter dominates from July to October with lower density; *Rhysosolenia fragilissima* was dominant also in July and October and November; it was replaced by *Pseudonitzschia pungens* in November and *Chaetoceros affinis* in December. Bat-2 presents the same succession except for February and October; the differences are in the percentage and the order of dominant species. In 2009, the dominant species were slightly the same but with differences in the date. In spring period the dominant species were comparable in both stations with differences in the percentage

**Table 3:** Monthly abundant species, their density and their percentage to the total microplankton into two stations in Lebanese coastal waters between January 2008 and December 2009.

Date	BAT-1	Density	%	BAT-2	Density	%
16/01/2008	<i>Chaetoceros</i> sp <b>A. japonica</b>	19602 18612	31 30	<b>Asterionella japonica</b> <i>Chaetoceros</i> sp	40392 11682	40 11
21/02/2008	<i>Thalassiothrix frauenfeldii</i> <i>Cylindrotheca closterium</i>	2376 1452	16 10	<i>Skeletonema costatum.</i> <i>Asterionella japonica</i>	3300 2904	23 20
13/03/2008	<b>Chaetoceros curvisetus</b> <i>A. japonica</i>	118998 86724	37 27	<b>Ch. curvisetus</b>	17028	29
14/04/2008	<b>Ch. Curvisetus</b>	38016	41	<b>Ch. curvisetus</b>	167112	88
13/05/2008	<b>S. costatum</b>	33066	50	<b>S. costatum</b>	92268	48
17/06/2008	<b>Pseudonitzschia pseudodelicatissima</b> 70686 <i>L. danicus</i>	34 60984	29.5	<b>Leptocylindrus danicus</b> <i>P.p delicatissima</i>	96030 40194	46 19
17/07/2008	<b>L. danicus</b> <i>Rhizosolenia fragilissima</i>	119394 81774	51 35	<b>L. danicus</b>	2112	19
18/08/2008	<b>L. danicus</b>	6930	23	<b>L. danicus</b>	12078	35
16/09/2008	<i>L. danicus</i>	23166	28	<i>Scropsiella trochoidea</i>	924	8
20/10/2008	<b>L. danicus</b> <b>Rh. fragilissima</b>	28116 6732	52 12.5	<b>L. danicus</b> <i>L. minimus</i> <b>Rh. fragilissima</b>	12870 12078 9504	18 17 13
18/11/2008	<b>Pseudonitzschia pungens</b> <i>Rh. fragilissima</i>	41580 8118	61 12	<i>Bacteriastrum delicatulum</i> <i>Rh. fragilissima</i> <i>Pseudo. fraudulenta+ pungens</i>	4356 3036 2904	20 14 13
11/12/2008	<b>Chaetoceros affinis</b>	3036	16.6	<b>Chaet. affinis</b> <i>Chaetoceros socialis</i>	6864 3300	20 10
14/01/2009	<b>Cylindrotheca closterium</b>	5148	8	<b>Cy. closterium</b> <i>L. minimus</i>	6864 4752	29 20
19/02/2009	<i>A. japonica</i> <b>Cy. closterium</b>	12144 3168	36 9	<i>Pseuon. pungens</i> <b>Cy. closterium</b>	1056 792	10.5 8
17/03/2009	<b>Ch. affinis</b>	15840	20	<b>Ch. affinis</b>	3464	36
12/4/2009	<b>Cha. affinis</b>	924	4	<b>S. costatum</b>	2640	1
14/05/2009	<b>L. danicus</b> <b>Chaet. affinis</b>	13860 7326	32 17	<b>Ch. affinis</b> <b>L. danicus</b>	16830 7722	32.5 15
18/06/2009	<b>L. danicus</b> <b>P. p.delicatissima</b> <i>Cy. closterium</i>	37488 6336 6072	55 9 9	<b>L. danicus.</b> <b>P. p.delicatissima</b>	201168 23760	71.5 8.5
16/07/2009	<b>L. danicus</b>	50292	75	<b>L. danicus</b>	59994	72
20/08/2009	<b>Rh. Fragilissima</b> <i>L. danicus</i>	57024 10494	33 6	<b>Rh. fragilissima</b> <i>L. minimus</i>	59004 15444	35 9
24/09/2009	<i>Cy. closterium</i> <b>Ch. curvisetus</b>	2178 1386	12 8	<b>Ch. curvisetus</b> <i>Ch. compressus</i>	1980 1584	9 7
20/10/2009	<b>Rh. fragilissima</b> <b>L. danicus</b>	243540 27720	77 9	<b>Rh. fragilissima</b> <b>L. danicus</b>	391644 11880	89 3
18/11/2009	<i>Chaetoceros</i> spp	182160	83	<i>Ch. compressus</i>	13662	24.5
16/12/2009						



**Fig. 9:** Monthly distribution of diatoms (a) and dinoflagellates (b) at the sampling stations in the Lebanese coastal waters between January 2008 and December 2009.

**Correlation coefficient matrix**

The comparison between matrix of correlation in both stations (table 3) showed that temperature was positively correlated with salinity at both stations at different level; negatively with orthophosphates and nitrates at Bat-1 only and negatively with chlorophyll-*a* at Bat-2 only. Salinity was negatively correlated with nitrates and dinoflagellates at Bat-1 only. Orthophosphates concentration was negatively correlated to dinoflagellates at Bat-1 only. Chlorophyll-*a* noted a positive correlation with microplankton and diatoms at Bat-1 while it was correlated with nanoplankton populations at Bat-2. Nanoplankton was positively correlated with microplankton and dinoflagellates at Bat-1 only while

microplankton populations abundance was correlated to diatoms and dinoflagellates at both stations and diatoms to dinoflagellates only at Bat-2.

**Table3.** Correlation coefficient matrix (Bravais-Pearson) between parameters at two stations in Lebanese marine waters.

Bat-1	T (°C)	Salinity	P-PO4	N-NO2	N-NO3	Chl-a	Nano	Micro	Diatoms	Dino
T (°C)	1	<b>.49**</b>	<b>.37*</b>	-.232	<b>-.63***</b>	-.034	-.18	.22	.23	-.01
Salinity		1	.115	-.147	<b>-.79***</b>	.26	.07	.18	.20	<b>-.07***</b>
PO4			1	-.187	-.22	.33	-.12	.03	.04	<b>-.04*</b>
NO2				1	.29	.26	-.09	-.02	-.02	.02
NO3					1	-.094	.01	-.06	-.07	.05
Chl a						1	.26	<b>.51**</b>	.52	.11
Nano							1	<b>.36*</b>	.28	<b>.61***</b>
Micro								1	<b>.99***</b>	<b>.46*</b>
Diatoms									1	.33
Dino										1

Bat-2	T (°C)	Salinity	P-PO4	N-NO2	N-NO3	Chl-a	Nano	Micro	Diatoms	Dino
T°C	1	<b>.66***</b>	.03	-.18	-.31	<b>-.45*</b>	-.55	.24	.24	.03
Salinity		1	.32	-.24	-.01	-.19	-.19	.16	.17	-.06
PO4			1	-.23	-.19	.14	.18	-.04	-.05	.09
NO2				1	.13	.24	-.07	-.18	-.17	-.19
NO3					1	-.11	.34	-.22	-.21	-.29
Chl a						1	<b>.42*</b>	.08	.08	-.01
Nano							1	-.07	-.08	.13
Micro								1	<b>.99***</b>	<b>.43*</b>
Diatoms									1	<b>.39*</b>
Dino										1

\*K=n-2=22 Level of significance: \*P<0.05 \*\*P<0.01 \*\*\*P<0.001

#### 4. Discussion

Seasonal variation of water temperature is an annual regular phenomenon in the Lebanese coastal waters with minor spatial irregular variations and differences from one site to another. Our results confirm those found in the Lebanese coast [4]. The quick melting of snow due to the warm weather caused by Chlouk (warm winds coming from the desert) in April 2009 caused a strong reduction in the salinity at Bat-1 noted by a high standard deviation and a high value of nitrates. The contribution of fresh water due to rainfall in winter, the rough sea state, the wind forces and direction induce the mixing of water masses and the spreading of fresh waters towards offshore station; these phenomena, facilitated by the straight morphology of the coastal area, contribute to a progressive decrease in salinity values and increase in nitrate concentrations at Bat-2 compared to a rapid decrease in salinity values at Bat-1. As consequence, the values of N/P ratio were far from the normal value which is 16 in Ocean waters and in Mediterranean Sea which is around 20 [12]. This is due to the direct effect of continental input and the unpredictable meteorological conditions which became extreme these last years. In Lebanon, there are no closed bays and water is being continuously mixed thus helping continental input to spread easily; water mixing helps the dispersion of nutrients.

The significant differences between stations in nutrients were not materialized by significant differences in algal biomass. In this study the values of chlorophyll-*a* were lower than the normal mean values found at littoral area which varied between 0.01- 0.3 mg/m<sup>3</sup> (mean 0.11 ± 0.08) [5]. Also, it is important to mention that the peaks noted at Bat -1 correspond to the calm sea state; in the presence of available nutrients, the calm sea contributes to the development of phytoplankton population while in rough sea, even in the presence of nutrients, the low stability and high turbidity of waters did not help harmonious development of phytoplankton populations [3]. The seasonal cycle was slightly comparable as shown in other studies in Lebanese coastal waters [1; 2] with a clear spring bloom in 2008 but mitigated in 2009.

It was interesting to mark that in the inshore station, many significant correlations between environmental and biological parameters were noted while it was absent in the offshore one. Also, it is important to mention that chlorophyll-*a* is more related to nanoplankton populations at Bat-2 while it is more related to microplankton at Bat-1.

## 5. Conclusion

We can conclude that:

i) The significant differences between stations in nitrates and orthophosphates, do not necessary conduct to a significant positive effect on algal biomass represented in this study by chlorophyll-*a* and phytoplankton populations and to a significant differences between stations.

ii) The strong effects on environmental parameters can be detected at offshore stations during special meteorological conditions such as rough sea and wind directions.

iii) The high turbidity can affect negatively the normal development of phytoplankton especially despite of high low of nutrients.

vi) The correlations coefficients are subjected to the variations according to the locality of station in relation to the distance from the coast and continental inputs.

v) As direct application to this work, it is possible in straight coast and at large spatial scale to reduce the number of explored stations if we aim to have a global overview of an area.

*N.B. Part of this study is in the framework of SESAME project.*

## 6. References

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