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Preliminary Assessment of Macrophytic Community in Qaraoun Reservoir, Lebanon

[2,3]Abou-Hamdan, H., [2,3]Ismaïl, H., [4]Amacha, N., [5]Chalak, L., [4]Jomaa, R., [1]Kamar, M., [3]Kobaissi, A., [1]*Baydoun, S

[1]Research Center for Environment and Development, Beirut Arab University, Bekaa, Lebanon
[2]National Center for Marine Sciences, National Council for Scientific Research, Beirut, Lebanon
[3]Biology Department, Faculty of Sciences I, Lebanese University, Beirut, Lebanon
[4]Litani River Authority, Ministry of Energy and Water, Beirut, Lebanon
[5]Faculty of Agronomy, Lebanese University, Beirut, Lebanon

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Abstract: ***Although aquatic macrophytes have a substantial role in the structuring and productivity of fresh aquatic ecosystems, little attention has, so far, been paid to this important biological group in Qaraoun reservoir in Bekaa Valley – Lebanon. In this study, the occurrence and taxonomic composition of macrophytes were assessed in the littoral zone of reservoir at Qaraoun and Aitanit towns. Our preliminary results revealed the first inventory of the macrophytic community of the reservoir. This community included 18 taxa including green algae and both submersed and emergent aquatic plants. The values of assessed water quality variables (pH, TDS, EC, DO, BOD, NO3-, SD and chlorophyll-a) indicated the eutrophic conditions of the surrounding aquatic habitat and high tolerance abilities of the settling macrophyte species. The protection and appropriate management of the reservoir's macrophytes may be considered among the integrated management tools of the reservoir and restoration of its natural biota.***

Keywords: Aquatic, Macrophytes, Reservoir, Water Quality, Physical and Chemical Properties

1. Introduction

Macrophytes play a major role in the structuring of fresh aquatic ecosystems. They play a significant role in primary production, nutrient recycling, and providing food and shelter for other aquatic assemblages (Wetzel, 2001; Thomaz and Ribeiro da Cunha, 2010). Macrophytes affect nutrient recycling by retention of nutrients and minerals from water column and sediments using their submersed leaves and anchored roots (Clarke, 2000; Schulz *et al*, 2003; Spencer and Ksander, 2003). They release important nutrients which can be rapidly utilized by free-living or attached microalgea and bacteria (Stets and Cotner, 2008). Macrophytes provide also important *Source* of organic maters for many different aquatic herbivores and detritivorous (Hamilton *et al*, 1991; Papas, 2007). Due to their abilities to respond to environmental conditions and selective absorption of certain ions and heavy metals, macrophtyes have long been indicated in several studies as measurable indicators for the ecological status of surface water bodies (Onaindia *et al*, 2005; Penning *et al*, 2008; Brittenham, 2009; Kolada, 2010; Ciecierska *et al*, 2010). Oligotrophication is indicated to influence macrophytic community composition and distribution. Submersed macrophytes, in particular, are often used for the monitoring of heavy metals and other pollutants in water and bottom sediment (Sawidis *et al*, 1995). In Qattieneh Lake (Syria) submersed macrophytes were reported to reflect the concentration gradients of nutrients and heavy metals in water and sediments (Hassan *et al*, 2010). Whereas, emergent helophytes, occupying the inshore part of phytolittoral zones of surface waters, were indicated for their high sensitivity to water level fluctuations, hydromorphological pressures and other physical alternations of shoreline (Hellsten, 1997; 2000). Major efforts are recently focused on the role of macrophytes as efficient biofilters for self-purification of eutrophic water bodies (Dhote and Dixit, 2007; Peng *et al*, 2008).

Qaraoun reservoir is manmade reservoir that was constructed in 1962 over 12.3 km2 area with a storage capacity of 224 Mm3. The reservoir was designed to harvest water from Litani River, most important water re*Source* in Lebanon. Since its establishment, the reservoir has been providing hydropower generation, water for irrigation and domestic use and a facility for community recreational activities. During the last decade, serious concerns regarding the deteriorating water quality of Litani River and Qaraoun reservoir have greatly grown across the country. The increasing degradation of water quality is attributed to the increased urbanization pressure, inappropriate agricultural practices and a wide range of industrial activities along water channeling, increased demand and absence of effective management policies (Assaf and Saadeh, 2008; MoE and UNDP, 2011; Saadeh *et al*, 2012). Several studies have reported high mortality of ichtyofauna in both Litani River and Qaraoun reservoir during the drought season and abandon of favorable spawning areas (El Zein, 2003; El Zein and Hanna, 2010). Also changes in the diatoms communities and appearance of unusual Micorcystis aeruginosa leading to cyanotoxin production were observed (Slim *et al*, 2012; Ismail, 2008; Ismail *et al*, 2009). Such alarming findings make it necessary to further investigate other important biological assemblages such as macrophytes. Actually, attempts to study macrophytes have been modest till the mid of the last decade (Tohme and Tohme, 1985). Since then, considerable efforts have been deployed by Abou-Hamdan and collaborators on macrophyte assessment in the water bodies of the country (Abou-Hamdan *et al*, 2007; 2010; Ismail, 2008; Ismail *et al*, 2007; 2009): 27 taxa of, hydrophytes, helophytes and terrestrial species were found to occupy Upper Litani River, the successive species and the rates of cover of macrophyte population was concluded to be affected by the heavy anthropogenic disturbances in the Litani Upper Basin. Nevertheless, macrophytes inhabiting the Qaraoun Lake which is severely impacted by direct anthropogenic pressure or through the river influences haven't, to date, been investigated. The main aim of the present study was to assess the taxonomic composition and distribution of macrophytes in the littoral zone of Qaraoun reservoir.

2. Material and Methods

2.1 Study Sites

The littoral zone of the reservoir at the small towns of Qaraoun and Aitanit in west Bekaa plain in Lebanon (Fig 1) were the selected sites for the study. The selection of the sites was based on community knowledge and bathymetric survey of Litani River Basin Mangement Support Program (2013). The bathymetric survey clearly indicated the formation of sediments of various thicknesses within the vicinity of the dam (Fig 1). This selection was further supported by underwater screening process by a Remote Operating Vehicle (ROV Model 1000, OUTLAND Technology, USA) which allowed clear visualization of a macrophytic community at the littoral zone of Qaraoun site.

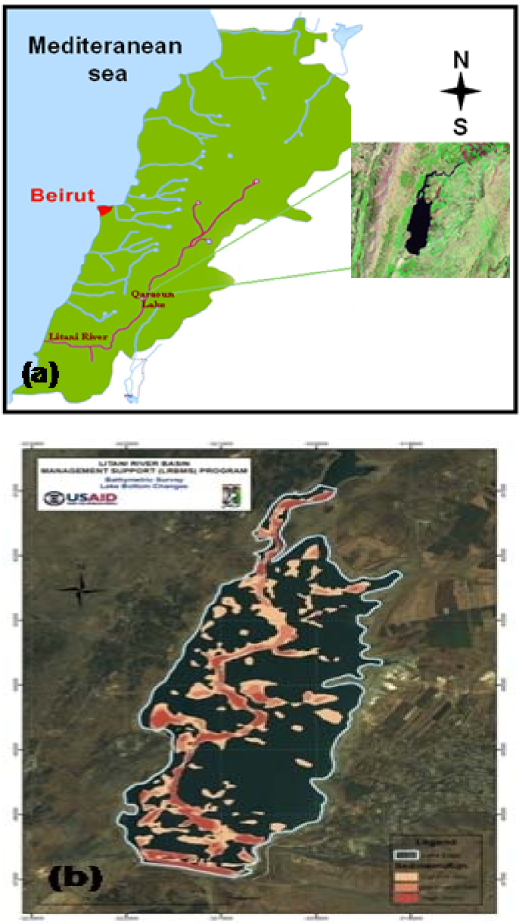

Figure 1: a) Map of Lebanon with Litani River and Qaroun Reservoir (*Source*:wikipedia), b) Map of Sedimentation of Qaroun Reservoir (*Source*:Bathymetric Survey, Litani River Basin Management Support Program, USAID, Lebanon, 2013).

2.2 Sampling and Field Analyses

Several sampling campaigns of macrophytes and their water habitat were conducted during the duration between March and October of 2013. It is worthy to note that previous screening surveys of both study sites were performed in December 2012 and February 2013; but no occurrence of macrophytes was observed.

2.3 Water Quality Variables and Substratum Granulometric Analyses

500 ml of water at one m depth of macrophytes habitat were collected. Secchi Disk readings, dissolved oxygen and temperature (Gondo Ezodo PDO-408, Taiwan) and turbidity (LT Lutron TU-2016, Taiwan) were on site determined. pH (370 pH Meter, JENWAY, E.U), electrical conductivity, total dissolved solids and salinity (TRACER Pocket tester, LaMotte/ code 1749, USA), biological oxygen demand (B.O.D System 6 – FTC 90 – Refrigerated incubator, VELP-Scientifica, Spain) and chemical oxygen demand (ECO6 Thermoreactor, VELP, Spain) were also measured. Phosphate, nitrate, nitrite, sulfates and ammonia were all determined by colorimetery (La Motte, Model SMART2, USA). Chlorophyll-a (Chl-a) as a common measure of phytoplankton biomass in water bodies was extracted by dimethyl sulfoxide and acetone and measured by a spectrophotometric method (Jeffrey and Humphrey, 1975; Burnison, 1980). With the exception to BOD and Chl-a, all measurement were performed in triplicates. With the purpose to compare the aquatic habitat conditions of macrophtyes in studied sites t-test analysis by PAWAS Statistics 18 was used. In order to synthetize the information a multivariate analysis (PCA) was applied to the physico-chemical data respectively (ADE 4 program by Thioulouse *et al*, 1997). Granulometric analysis of the substratum of anchored macrophytes was performed by sieve analysis to determine the distribution of particle sizes (American Society for Testing and Materials, 1972).This analysis was conducted twice during the course of study; May and July – 2013. Triplicates of samples of 500 grams of sediments of relevant studied depth belts were dried and mixed for analysis. The percentage of different particles was calculated.

2.4 Macrophytes Community Structure

Due to the dominating rocky structure of the littoral zone of reservoir, the study sites were progressively surveyed in depth belts that were parallel to the shoreline. These depth belts were of around 100 m length and 1m depth (Fig 2). These belts extended from the shoreline towards the maximum depth of plant growth between the water levels of 856.90 mASL in May and 843.51 mASL in October (Fig 2). Macrophytes in the accessible belts were clearly observed and easily sampled. Specimens were carefully transported in ice containers, washed and stored at 4oC or preserved post drying and pressing. Algae were collected by disposable jars and preserved in 70% of alcohol. Based on morphological and microscope observations, macrophytes were identified according to the Flora Europea (Tutin et al., 1964-1980), Flora of Lebanon (Tohme and Tohme, 2007) and Rodriguez and Vergon (1996).

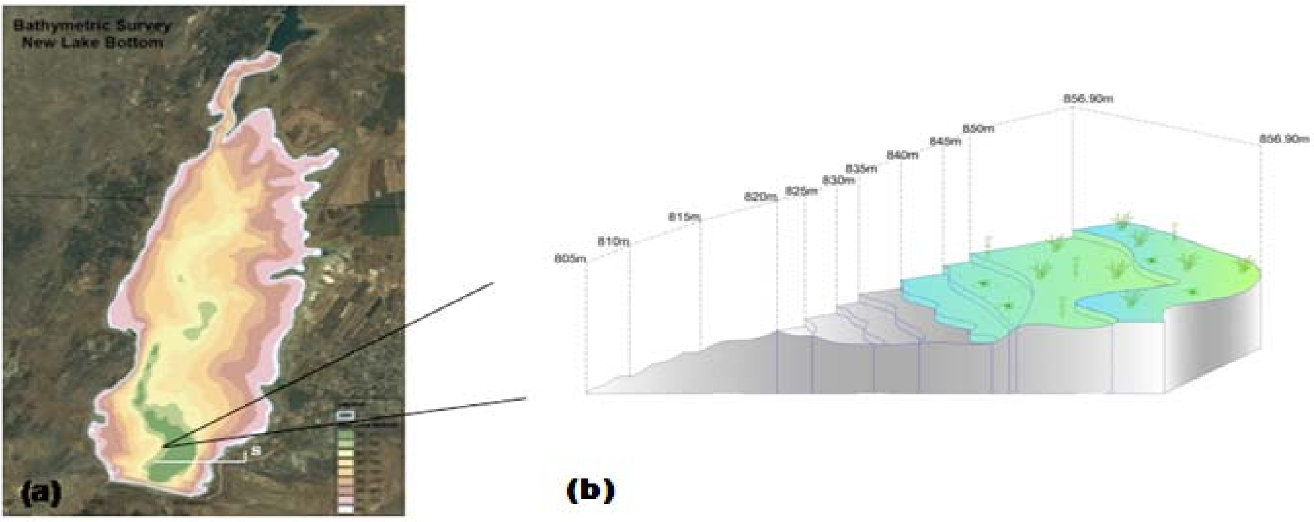

Figure 2: a) Bathymetry of Qaroun Reservoir (*Source*: Bathymetric Survey, Litani River Basin Management Support Program, USAID, Lebanon, 2013), b) Scheme of depth belts studied of Qaroun Reservoir at the littoral zones of Qaroun and Aitanit towns.

3. Results

3.1 Water Quality Variables and Substratum Granulometry

The mean values of water quality variables assessed in studied sites of Qaroun reservoir (Qaraoun and Aitanit) are presented in Table 1. In this table, it can be seen that the pH mean values were moderately alkaline (8.35 ± 0.16 in Qaraoun and 8.46± 0.13 in Aitanit). Both TDS values (240.74± 58.46 mg/l in Qaraoun and 235.36± 64.95mg/lin Aitanit) and conductivity values (0.34 ± 0.08dS/m in Qaraoun and 0.33 ± 0.09dS/min Aitanit) were within acceptable limits for human use and irrigation. While DO values were below the suitable level for aquatic life (5mg/l) (EPA, 1986). BOD values were around 2 mg/l, the typical level of unpolluted water. With regards to nutrients, it is apparent that undesirable levels of nitrogenous species, NH3 particularly, and phosphates were recorded reaching the mean values 0.31 ± 0.24 mg/l and 0.88 ± 0.45 mg/l, in Qaroun and 0.22 ± 0.20 mg/l and 0.58 ± 0.10 mg/l in Aitanit, respectively. Concerted with Secchi disk readings (1-2 m), the high Chl-a values (83.45 ± 55.22 µg/l in Qaraoun and 109.93± 83.07 µg/l in Aitanit) clearly indicated the eutrophic conditions of surrounding water habitat. Figure 3 reflects the evolution of some of the water quality variables during the course of study. Decreasing trends in the levels of DO, TDS, SD and EC between March and October, 2013 were noted. The fluctuating patterns of BOD, nitrates and Chl-a exhibited their highest during the period between May and August- 2013 and the relation between these three parameters specially nitrates and Chl-a .

The student t-test analysis revealed no significant differences (p> 0.05) between both sites studied reflecting homogeneity of the environmental conditions of studied sites. However, if the PCA analysis confirms that there is no variation in space for environmental conditions, this multivariate analysis show a variation according to time and describe a seasonal gradient with a winter/spring period characterized by a high nutrient level and a summer/autumn period characterized high temperature and high value of BOD and COD (Fig 4). Granulmetry analysis of substratum showed that gravel constituted 67.05% in Qaraoun and 63.72% in Aitanit. Sand and fines were 19.31% and 13.63% in Qaraoun and 16.98% and 19.27% in Aitanit, respectively. The substratum was meanly fine in both sites with no spatio-temporal variation.

Table 1: Mean Values, standard deviations (± SD; n= 5 samples), minimum and maximum of 16 variables analyzed at the two studied stations of Qaraoun reservoir and *p* values of t test (all > 0.05).

Water Quality Variable	Qaraoun			Aitanit			p Values for T Test
	Mean± SD	Min	Max	Mean±SD	Min	Max	
pH	8.35 ±0.16	7.9	8.7	8.46 ± 0.13	8.28	8.7	0.134
T °C	24.67 ±5.92	17.8	32.2	25.65 ±6.37	18.67	33.5	0.686
TDS mg/l	240.74 ± 58.46	189	337.3	235.36 ± 64.95	179	337.3	0.661
EC dS/m	0.34 ± 0.08	0.26	0.48	0.33 ± 0.09	0.26	0.48	0.628
SD m	1.43 ± 1.80	0.25	4.64	1.41 ±1.90	0.25	5.12	0.865
Turb. NTU	13.97 ± 12.00	0.22	34.88	49.72 ± 77.10	1.44	211	0.042
Salinity mg/l	170.20 ± 42.19	136	240	167.98 ± 46.88	130	240.7	0.72
NO2- mg/l	0.38 ± 0.22	0.03	0.58	0.40 ±0.14	0.13	0.56	0.406
NO3- mg/l	11.38 ± 5.67	4	22	12.26 ± 5.59	5	20	0.992
NH3mg/	0.31 ± 0.24	0.02	0.49	0.22 ± 0.20	Below detection	0.54	0.278
PO4-3mg/l	0.88 ± 0.45	0.7	1.6	0.58 ± 0.10	0.5	1	0.198
SO4-2mg/l	26.62 ± 7.11	18	38	26.46 ±5.90	19	35.67	0.725
DO mg/l	3.71 ± 2.06	1.66	6.99	3.43 ± 1.90	1.72	6.29	0.88
COD mg/l	89.57 ± 86.69	10.48	194.8	233.47 ± 261.08	7.6	747.1	0.076
BOD mg/l	3.91 ± 2.63	0.33	6.5	2.05 ± 1.42	2.3	5.43	0.101
Chl-a µg/l	83.45 ± 55.22	6.18	131.4	109.93 ± 83.07	8.23	207.9	0.49

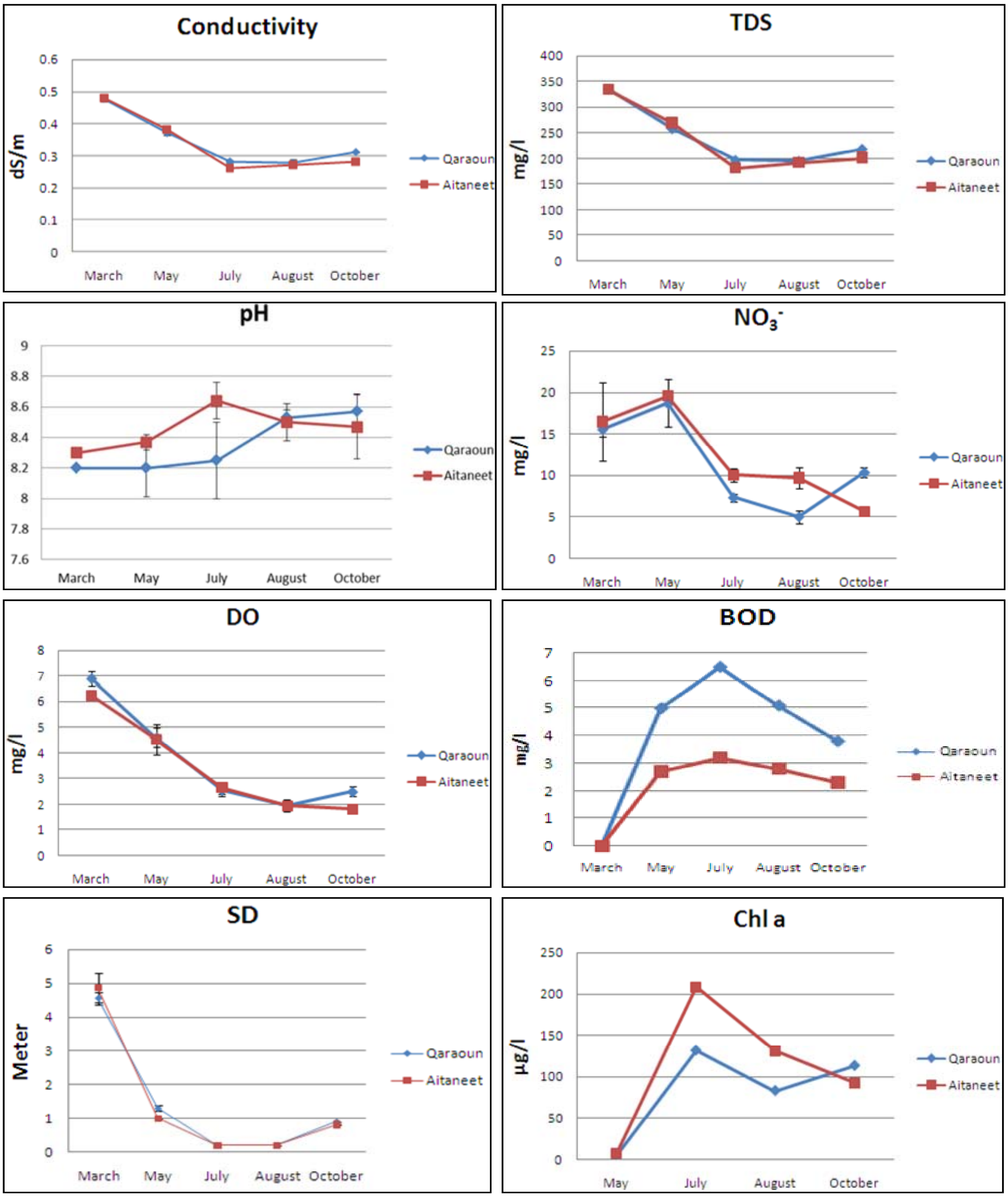

Figure 3: Variations of 8 abiotic variables (Cond, TDS, pH, NO3, DO, BOD, SD, Chla) in Qaraoun and Aitanit stations of Qaroun reservoir at each sampling month during 2013.

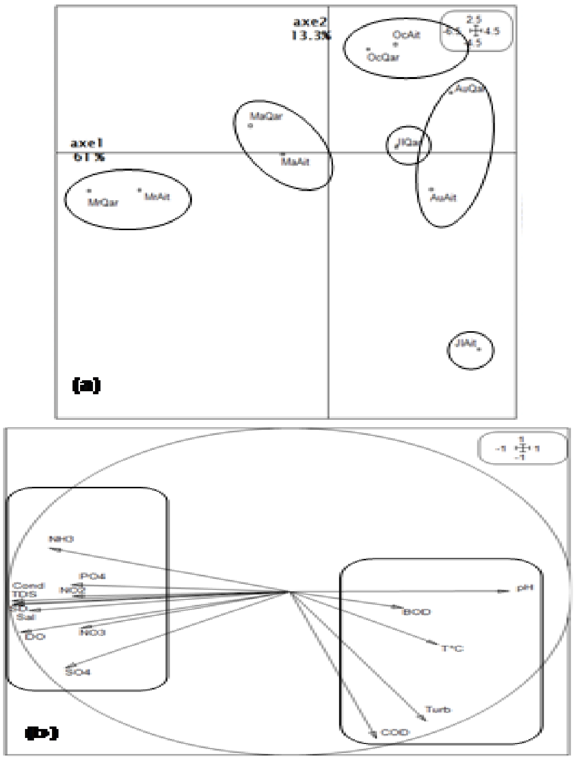

Figure 4: PCA applied on the 15 abiotic variables (average for the quantitative statement) in Aitanit (Ait) and Qaraoun (Qar). Projections of the stations points (a) and abiotic variable points (b)

3.2 Macrophytic Community Structure

A community of 18 different taxa of macrophytes including algae and both submersed (hydrophyte) and emergent plants (helophyte) inhabiting the littoral zone of studied sites was observed (Table 2).

Table 2: List of the macrophytes growing at the two sites studied in Qaraoun reservoir.

Macrophyte Species	*Qaraoun*	*Aitanit*
Green Algea		
Cladophora sp.	+	+
Mougeotia sp.	+	+
Rhizoclonium sp.	+	+
Spirogira sp.	+	+
Ulothrix sp.	+	+
Zygnema sp.	+	+
Submersed Plants:		
Ceratophyllum demersum L.	+	-
Myriophyllum spicatum L.	+	+
Potamogetone sp.	+	+
Potamogeton crispus L.	+	+
Potamogeton trichoides Cham.	-	+
Ranunculus aquatilis L.	+	+
Zannichellia palustris L.	-	+
Emergent Plants:		
Phalaris arundinacea L.	+	+
Phragmites australis (Cav.) Trin. Ex Steud	+	+
Sparganium sp.	+	+
Sparganium emersum Rehmann	+	+
Sparganium erectum subsp.*neglectum* (Beeby) K.Richt	+	+

The taxonomic composition was nearly the same at both sites. The emergent species; Phalaris arundinacea, Phragmites australis, Sparganium emersum and Sparganium sp. Sparganium neglectum appeared as scattered small patches each occupying an area of less 1% of the area screened depth belts. Similar distribution pattern was also noted with Ceratophyllum demersum, Myriophyllum spicatum, Potamogeton sp. Potamogeton crispus, Potamogeton trichoïdes, Ranunculus aquatilis and Zannichllia palustris. On the contrary, the green algal species appeared as a dense cover close to the edges of the shoreline particularly between July and August, 2013. During this duration, most macrophytes formed a substratum for a crowded community of periphyton.

The distribution of species over the different depth belts expressed some variations (Table 3). Apparently, emergent species occupied the inshore part of the littoral zone while the submersed species extended to a maximum depth of 843.51 mASL. In general terms, it can be noted that duration between May and July represented the suitable growth period of macrophytes in the reservoir ecosystem.

Table 3: Distribution of macrophytic species along depth belts studied in Qaraoun reservoir.

Average Water Level / Depth Belts (mASL)	*Month/2013*	*Algae*	*Submersed Plants*	*Emergent Plants*
856.52 mASL	May	Cladophora sp. Spirogira sp. Ulothrix sp.	Potamogetone sp. Potamogetone Potamogeton crispus Ranunculus aquatilis	Phalaris arundinacea Phragmite australis Sparganium neglectum Sparganiu memersum Sparganium sp.
854.77 mASL	June	Cladophora sp. Mougeotia sp. Rhizoclonium sp. Spirogira sp. Ulothrix sp. Zygnema sp.	Potamogeton crispus Ranunculusaquatilis	Phalaris arundinacea Phragmite australis Sparganium neglectum Sparganium emersum
852.31 mASL	July	Cladophora sp. Mougeotia sp. Rhizoclonium sp. Spirogira sp. Ulothrix sp. Zygnema sp.	Potamogeton crispus Ranunculusa quatilis Zannichlli apalustris Ceratophyllumdemersu	Phalaris arundinacea Phragmite australis Sparganiumneglectum Sparganiumemersum
849.36 mASL	August	Cladophora sp. Rhizoclonium sp. Spirogira sp. Zygnema sp.	Ranunculus aquatilis Potamogeton crispus	Phragmites australis Sparganium neglectum Phalaris arundinacea
mASL 843.51♀	October	Cladophora sp. Rhizoclonium sp. Spirogira sp.	Potamogeton crispus Ranunculu saquatilis	Phragmite australis Sparganium neglectum Phalaris arundinacea

4. Discussion

With regards to abiotic parameters, it is apparent that the mean values of nutrients such as inorganic nitrogen species and phosphates exceed the international recommended levels for the protection of aquatic life (EPA 1986, 1988; USGS 1996-1998; Canadian Council of Ministries, 2003; 2010). This indicates high agricultural runoff and nutrient delivery resulting in the eutrophication of the reservoir ecosystem. The values obtained in this study are closely in alignment with those of recent reports (BAMAS, 2005; LRBMS, 2011). Nevertheless, the levels of nitrates only as the main components of fertilizers (2.57mg NO3-N/l in Qaraoun and 2.77 mg NO3-N/l in Aitanit), continue to remain below the USEPA criteria for drinking water as 10 mg NO3-N/l (USGS 1996-1998) and that of the Canadian Council of Ministers of the Environment (2003) for the protection of freshwater and marine life (2.9-3.6 mg NO3-N/l). This indicates highly active reduction processes particularly under the observed reduced DO levels. Under such conditions, the noted levels of NH3, ranging 0.22 and 0.31 mg/l, may become harmful according to the guidelines of the Canadian Council of Ministries (2010) to protect fresh aquatic life ranging between 0.125and 0.354 mg/l at 25oC and pH of 8.0 – 8.5. The decreasing temporal variations of nitrates and TDS may be a result of the efficient utilization of both macrophytes and phytoplankton and possible role of the reservoir as a sink for nutrients and other elements, a result of the warm monomictic behavior and summer stratification (Saad *et al,* 2009). Numerous studies have shown that the addition of nitrogen and phosphorus nutrients to water systems result in large proliferation of algae which have detrimental effects on aquatic ecosystems (Fried *et al,* 2003). In freshwater environments, phosphorus has often been identified as the fore most limiting nutrient for algal growth (Smith, 2003; Camargo *et al,* 2005). To maintain a healthy water system and minimize algal growth, the phosphate levels are recommended not to exceed 0.1 mg/l (USGS 1996-1998).

With regards to biotic parameters, the ability of Qaraoun reservoir to host aquatic macrophytes is, for the first time, reported in the present study. A first inventory list encompassing 18 taxa of green algae and both submersed and emergent plants is drawn. The buildup of sediments in some parts of the littoral zone of reservoir appears to offer the opportunity for a diverse macrophytic community to grow (Table 2). The thriving settlement ability of these taxa appears to be highest between May and July 2013 with the species i.e. Caldophora sp., Phalaris arundinacea, Phragmites australis, Potamogeton crispus, Ranunculus aquatilis and Sparganium neglectum being most successful. This may indicate the relatively higher abilities of these taxa to colonize the reservoir ecosystem and tolerate its environmental conditions. Such abilities, however, appears be constrained by water level fluctuation. The 12 m drop in water level between May 2013 and October 2013 resulted in riparian corridors of several hundred squared meter area at which all the inhibiting macrophytes and accompanied organisms were exposed to high summer temperatures, the risk of destructive dehydration and, consequently, a decrease in density and biodiversity richness. Actually, the impact of water level variations on macrophytes has been worldwide shown in several lakes and reservoirs (Harvey *et al,* 1987; Koc, 2008). Significant morphological responses, inhibition of flowering and seed production have been illustrated in Myriophyllum spicatum and Hydrilla verticillata with high amplitude of water level fluctuation (Zhang *et al,* 2012). With this influence, the certainty about any possible temporal variations in the structure and distribution of macrophtyes across the different depth belts can be not obtained.

With regards to ecological characteristics of macrophytes, light unavailability as indicated by SD readings and turbidity (averaging 1.43 ± 1.80 m and 13.97 ± 12.00 NTU for Qaraoun and 1.41 ±1.90 m and 49.72 ± 77.10 NTU for Aitanit, respectively) seems to be among the important factors influencing the settlement abilities of macrophytes in the reservoir. Decreases in light penetration caused by high water turbidity have been shown in several reports to reduce the density and growth depth limits of macrophyte and to induce changes in their community structure (Middleboe and Markager, 1997; Kolada, 2010). Moreover, the high SD values in March, 2013 and occurrence of submerged macrophytes clearly indicate adequate light availability at certain periods of the year.

In addition, the importance of sediments in the ecology of submersed rooted macrophytes species have been reported in many studies (Spencer and Ksander, 2003). This is due to its dual role as a *Source* of nutrients and a means of anchorage within water bodies (Ismaïl et al., 2009; Abou-Hamdan et al., 2005; Abou-Hamdan, 2004; Wijck et al., 1992). That's why the texture and chemical conditions of macrophyte substratum may have important influences on their growth and distribution (Spencer and Ksander, 2003). Consequently, fine grained silts and clays provide high binding capacity of elements and exchange ability with water and macrophtyes. In this study, gravel as the major component of substratum is expected to result in a reduced nutrient availability and physical support which may affect the settlement ability of macrophytes in the reservoir ecosystem (Stone and English, 1993, Maher *et al,* 1999).

In view of the eutrophic status of the reservoir as revealed by Chl-a values and SD readings, all the taxa observed in reservoir, mainly Cladophora sp., Rhizoclonium sp., Spirogyra sp., Phalaris arundinacea, Phragmites australis, Sparganium emersum and Sparganium neglectum may feature certain tolerance abilities to such ecological conditions which express a critical mineralization status of the lake. These taxa have been associated with high nutrients and mineralization levels of rivers and lake in France, Great Britain, Germany, Spain, Turkey and Syria (Grasmuk *et al,* 1995, Dawson *et al,* 1999; Clarke and Wharton, 2001, Shneiderand Melzer 2004; Onaindia *et al,* 2005; Hassan *et al,* 2010). Of particular interest is the appearance of only 5 taxa (Cladophora sp., Myriophyllum spicatum, Potamogeton crispus, Phalaris arundineacea and Phargmites australis) of the 14 taxa previously reported in Upper Litani River (Ismail *et al,* 2009). This indicates a discontinuity in the distribution of macrophytes between the Upper Litani River and Qaraoun reservoir. This discontinuity may be, partially, attributed to the disruption caused by Qaraoun dam to the natural environmental processes of the river. These observations may allow us to better understand the River Continuum Concept (Vannote *et al,* 1980; IUCN and UNEP, 2001).

The use of macrophytes in the biological assessment of water bodies has been receiving considerable interests. In this application various macrophytic metrics have been utilized to identify and assess trophic and high mineralization levels in rivers and lake (AFNOR, 2003; Abou-Hamdan, 2004; Onaindia *et al,* 2005; Abou-Hamdan *et al,* 2005; Kolada, 2010, Hassan *et al,* 2010). However, several research studies have shown that local environmental conditions may be a less important fact than species colonization processes in the distribution of macrophytes (Demar and Harper, 2005). As for reservoirs, this approach may be restricted by the hydrological conditions and water fluctuation levels. Chl-a is recommended as a suitable indicator (Boyer *et al,* 2009; NDEP- Nevada, 2008). Further investigations are required to test the suitability of different potential bioindicators for the assessment of ecological status of reservoir.

5. Conclusion

A first list of macrophytes of reservoir Qaraoun has been drawn out. The observed macrophytic community is characterized by a low covering rate and a total absence of bryophytes and pteridophytes. Both studied abiotic and biotic factors indicated a high anthropogenic disturbance (agricultural, urban and industrial) of the reservoir expressed by the strong mineralization of water. This mineralization seemed to benefit the macrophytes of the reservoir during their vegetative growth and to reduce the loads of nutrients especially between May and October. The fluctuation of the level of water presented a great risk of destructive dehydration and consequent disappearance of associated species and a drop in the diversity of macrophytes. In terms of habitat diversity no spatial variations in substratum granulometry and physic-chemical parameters were apparent at both study sites of reservoir resulting in the homogeneity of the taxonomic composition of macrophytic communities. This may suggest a possible homogeneity of the whole lake. Moreover, the observed seasonal gradient in the physico-chemical parameters may be directly related to the proliferation of macrophytes, phytoplankton and increase of the biodegradation activities of organic matters by aerobic microorganisms of the reservoir.
A more thorough study of the taxonomic composition the macrophytic communities of other parts of the reservoir over a longer duration is necessary to develop a more comprehensive understanding of their role in the functioning of the reservoir ecosystem. In addition, the development of protection and restoration approaches of these communities is considered necessary for the management and the restoration of the reservoir ecosystem.

6. Acknowledgement

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Author Profile

Safaa BAYDOUN (Corresponding Author): Holds a Ph. D in Photobiology, United Medical and Dental School of Guy's and St Thomas's Hospitals, London University, 1990. Currently is the Director of Research Center for Environment and Development at Beirut Arab University, Lebanon. Has been the Dean of Arts and Sciences- Lebanese International University- Lebanon, and research fellow at the Atomic Energy Commission, Damascus, Syria. Current research interests are focused on assessment of ecological status of water bodies and flora biodiversity.

Hussein ABOU-HAMDAN, Université Libanaise, Faculté des sciences (1), Hadath, Beyrouth – Liban, Centre National des Sciences Marines, Batroun. B.P. 534, Batroun, Liban. Professeur adjoint à l'Université Libanaise Faculté des Sciences, Chercheur associé au CNRSL (Centre National des Sciences Marines – CNSM)

Hanadi ISMAIL, Université Libanaise, Faculté des Sciences I, Campus Universitaire Hadath, Beyrouth, Liban. CNRS, Centre National des Sciences Marines, Batroun – Liban. Professeur adjoint à l'Université Libanaise Faculté des Sciences. Chercheur associé au CNRSL (Centre National des Sciences Marines – CNSM)

Lamis Chalak holds a Ph.D in Plant Physiology from University of Montpellier II – INRA (Corse and Angers), France, 1995. Currently is the Chair of Plant Production Department at the Faculty of Agronomy/ Lebanese University, Lebanon. Has been the Head of the Department of Plant Biotechnology at Agricultural Research Institute (LARI), Ministry of Agriculture, Lebanon. Current research interests are focused on plant genetic resources and flora biodiversity. Is currently the coordinator and a consultant at a number of FAO projects.

Nabil Amacha holds a Ph.D in Industrial Environment, University of Oil and Gas, Moscow, Russia, 2003. Currently is Head of Environment Unit, Litani River Authority, Ministry of Energy and Water, Lebanon and adjunct professor at Faculty of Sciences, Lebanese University, Lebanon. Research interests are focused on the Ecological Status of Litani River and Qaraoun Reservoir.

Mahmoud Kamar holds a Bachelor Degree in Biochemistry, Beirut Arab University, Lebanon, 2003. Currently is a research assistant at the Research Center for Environment and Development, Beirut Arab University, Lebanon. Previously served as a medical representative at Pharmamedic Pharmaceutical Company, Lebanon and Hikma, Pharmaceutical Company, Jordan.

Ryda Jomaa holds a Masters in Agricultural Sciences, Lebanese University, Lebanon. Currently serves as Natural Resources Engineer at the Environment and Water Monitoring Department, Litani River Authority, and the Litani River Basin Management Support System, USAID, Lebanon.