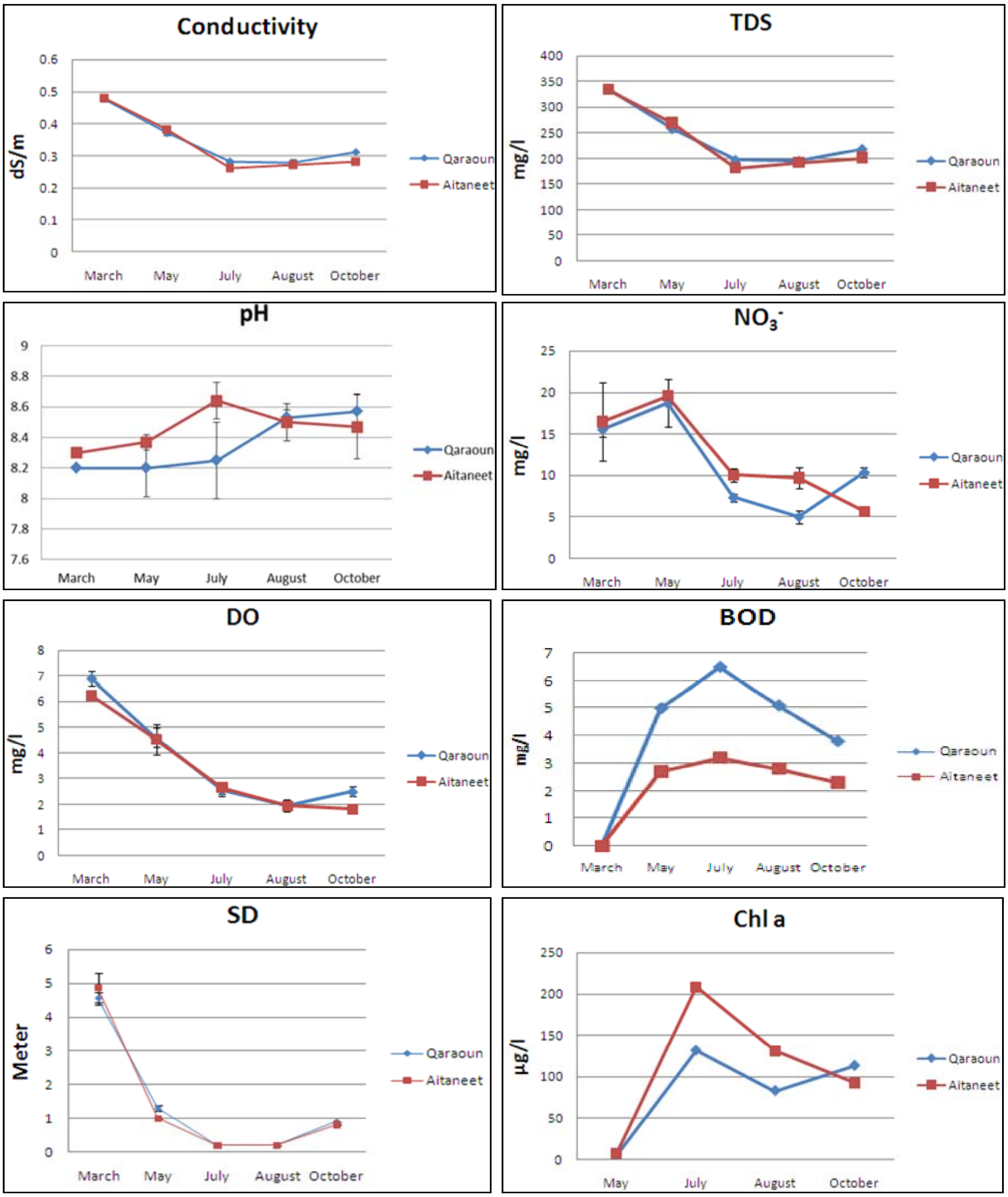

Figure 3: Variations of 8 abiotic variables (Cond, TDS, pH, NO3, DO, BOD, SD, Chla) in Qaraoun and Aitanit stations of Qaroun reservoir at each sampling month during 2013.

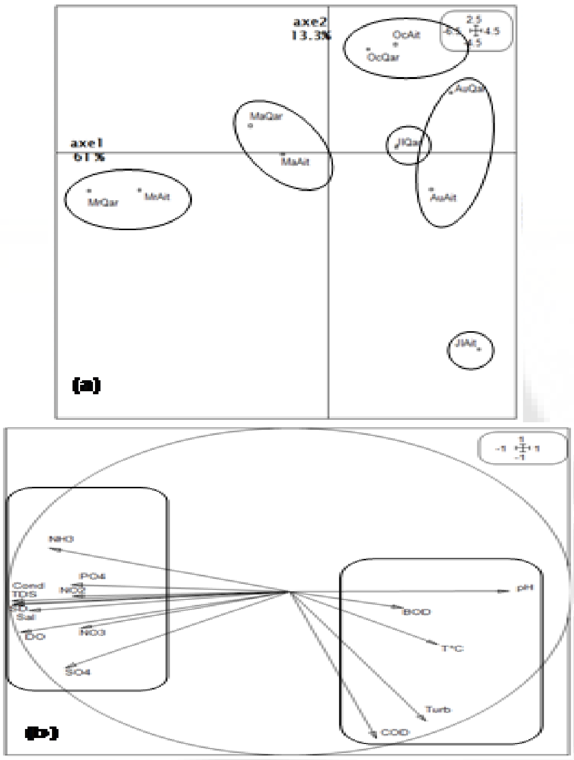

Figure 4: PCA applied on the 15 abiotic variables (average for the quantitative statement) in Aitanit (Ait) and Qaraoun (Qar). Projections of the stations points (a) and abiotic variable points (b)

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.

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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.