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Unique locality with charophytes in the Mount Arbel National Park, Israel

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ABSTRACT

First study of new locality the Mount Arbel National Park and Nature Reserve with charophyte algae in the Lower Galilee region of Israel has been implemented for revealing of algal diversity and ecological assessment of the water object environment by bio-indication methods. Altogether twenty nine species of algae including one of them macro-algae *Chara vulgaris* L. were revealed in the Arbel stream. *Chara* was found in massive growth in the middle part of studied stream. Bio-indication and chemical variables characterize the charophyte site environment as mesotrophic to eutrophic with prevailing of benthic type of organisms of autotrophic type of nutrition, which are mostly attached of substrate and preferred slow streaming water with temperate temperature, low salinity, low alkalinity, and low to middle organic pollution, Class II-III of water quality. Seasonality of algal community and water quality showed of organic and other contaminants pollution during winter rainy period as a result of grazing impact. Charophyte community is sharp limited in its development as a result of periodical desiccation of the stream. We found unique property of *Chara vulgaris* to renewing after two years desiccation. We can recommend the Arbel Biblical stream for monitoring of natural aquatic object in the Lower Galilee, and *Chara vulgaris* as climatic indicator of surviving under future climate change.

Introduction

Diversity of algae in Israel has been studied sporadically during the last century, but from 2000 we continue regular work in the rivers and other water bodies [1]. As a result we studied known localities as well as find new localities not only for algal diversity update but especially for charophyte macro-algae revealing. In present time we revealed 14 charophyte species (16 with ifraspecific variety) that known for Israel [2] from references and our studies.

The charophytes prefer alkaline water environment which forms on the carbonates that are very distributed in studied region. This environment gives us more chance to find new, unstudied aquatic objects in which can be identified charophyte algae. The most important localities can be found in the mountain areas because altitude play the major role in historical species diversity forming process [3] especially it can be interesting in the Upper Jordan River basin, which placed in two different slopes of the Jordan Rift Valley [4,5].

We assume that the diversity of this group of algae in Israel is still far from complete. Thus, the aim of our work was to find new habitats of charophytes and study their community and the environment.

Material and Methods

Sampling and laboratory studies

Material for this study comes from eleven living and ten fixed algological samples, eighteen samples of charophytes and eight samples of water that were collected during four field trips in February 2002, August 2004, April 2008, and April 2013 in nine stations of the Arbel stream.

Algological samples were collected by scratching and scooping, placed in 15 ml plastic tubes, and partly fixed with 3% neutral formaldehyde solution, as well as partly not fixed and transported to the laboratory in the ice box.

Charophytes were treated with 2-3% HCl to remove calcium carbonate. After washing several times with distilled water the material was studied with Nikon stereomicroscope with distilled water the material was air-dried on cover glasses and mounted in Naphrax®. The structure elements were observed with Nikon with digital camera, DinoLight camera, and light microscopes (LM) in the Institute of Evolution, University of Haifa and the Central Siberian Botanical Garden with help of international handbooks [6,7]. Charophyte and microscopic algae abundance were assessed as abundance scores according 6-score scale [8].

Algae and cyanobacteria were studied with the SWIFT and OLYMPUS dissecting microscopes under magnifications 740x–1850x from three repetitions of each sample and were photographed with a DC (Inspector 1). The diatoms were prepared by the peroxide technique [9] modified for glass slides [10] and were placed in the Naphrax® resin from two repetitions of each sample.

Temperature was measured with a thermometer. Acidity (pH), conductivity (EC), and TDS were measured with HANNA HI 9813-0. This meter has a full-spectrum pH measurement range. The Electrical conductivity range goes to 4.00 mS cm-1. The TDS ranged from 0 to 1999 mg l-1. Measurements were made by adding the probe into the water till the reading was stabilized. The concentration of N-NO3 was measured with HANNA HI 93728.

Index saprobity s was calculated according to [11]. Index of aquatic ecosystem sustainable was calculated according to [1,8] as (1):

WESI = Rank S / Rank N-NO3. (1)

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Where: Rank S – rank of water quality on the Sládeček's indices of saprobity; Rank N-NO3 – rank of water quality on the nitric-nitrogen concentration.

If WESI is equal to or larger than 1, the photosynthetic level is positively correlated with the level of nitrate concentration. If the WESI is less than 1, the photosynthesis is suppressed presumably according to toxic disturbance [1,8].

Description of study site

New locality of charophytes was found in the Arbel stream which placed in the Wadi Hamam, in the Mount Arbel National Park and Nature Reserve, Lower Galilee (Figure 1,2) on altitude about 101 m below sea level with coordinates 32°49'17N, 35°29'13E on the western slope of the rift valley near the Lake Kinneret [12]. The Mount Arbel is about 162 m in the top, therefore studied stream have high flow rate. Its length not excided 1.5 km and watered in the heavy winter rains period only. Studied site is placed in the middle part of stream and included the stream canal and some part of stream with low streaming water (about 0.01-0.2 $m\ c^{-1}$) with width of about 2-7 m (Figure 3). In Arbel, the climate is warm and temperate. In winter there is much more rainfall in Arbel than in summer. Air temperature varied between 13.3 °C and 29.6 °C with average annual temperature about 21.7 °C. The average annual rainfall is 459 mm [13]. Climatic conditions of Mount Arbel, have low humidity, the mountain slopes are bare, covered by grass vegetation, but in the center of the valley along the creek bed are grow trees of *Ceratonia siliqua* which slightly shadowed of stream canal. Very famous caves which dug into the slopes of Mount Arbel were the hideouts for the Jews who fought against the Greeks and Romans are documented as period of the Second temple [14].

Results and Discussion

Chemical composition of the pool water

Chemical variables were measured in nine stations during rainy seasons (Table 1). Can be seen that environment variables are fluctuated in small range and reflected fresh, low alkaline, low to temperate temperature, and low polluted waters [1,8]. Index of saprobity S fluctuated in small range and reflects low level of organic pollution, Class II-III of water quality.

Figure 1. Study site in the Lower Galilee, Mount Arbel, Israel, http://en.wikipedia.org/wiki/Mount_Arbel

Figure 2. Mount Arbel stream

Diversity and ecology of algae

We revealed 29 species of algae (Table 2) diversity of which is rather constant during the sampling dates. Studied part of stream is only one locality that represented of charophyte algae. The stream bottom was covered by macrophyte alga *Chara vulgaris* (Figure 4), which was found in 2004 and 2013, but was more abundant in 2013. Structural elements and thallus habitat show (Figures 5,6), that our samples are in the typical diagnosis ranks. Species is also widely distributed in the Mediterranean countries and some climatic similar dry regions [15]. Previously we revealed that in Israeli populations of charophytes species is simply separated from the other members of the genus *Chara* by AFLP analysis [16]. *Chara vulgaris* community was dominated by diatoms (Table 2) that attach of macro-alga as well as stones in the stream bottom. As a result of periodically desiccation, the charophyte plants are died, but renewed after one-two years dry period. We assume that surviving of *Chara vulgaris* in this dry land site can be possible with oospores storage in the stream sediments. It is very important that studied population of *Chara* demonstrated high tolerance to desertification as bearing on ecological consequences of climate change [17] in region under desertification coming [18].

Bio-indication of the studied pool environment

We use bio-indication methods in purpose to characterize of the stream water quality and ecosystem sustainable. As can be seen in Table 2, the water quality defined by bio-indication is the same that show by water chemistry (Table 1). In addition we can characterize studied part of stream as mesotrophic to eutrophic with prevailing of benthic type of organisms with autotrophic type of nutrition, which are mostly attached of substrate and preferred slow streaming water with temperate temperature, low salinity, low alkalinity, and low to middle organic pollution.

We use Table 2 with Index saprobity S value that we calculated on the base of species abundance scores and species-specific index s after Sládeček [19] model, and nitrate concentration (Table 1) data for ecosystem state index WESI calculation. Despite the Index Saprobity S value show low organic matter concentration, the index WESI is fluctuated from 0.50 to 0.7, which can characterize studied site as impacted. Few species of euglenoids as well as cyanobacteria filaments (Table 2) can confirm that charophyte site is impacted by organic and other contaminants. Visually during each our trip we can recognize that the forested part of the valley is used for grazing. We can assume that it is only one cause of the water quality impact because all other part of the Mount Arbel National Park and Nature Reserve is well organize and protected.

Table 2. Algal diversity with abundance scores and species ecological preferences (according to [8,20]) in the Arbel stream charophyte site in 2002-2013.

Taxa	Scor	Sub	T	Reo	pH	pH range	Hal	D	Sap	S	Aut-Het	Tro
Charophyta												
Chara vulgaris L.	4-6	B	-	st-str	-	-	-	-	o	1.10	-	-
Ochrophyta												
Amphora pediculus (Kützing) Grunow ex A.Schmidt	1-2	B	temp	st	alf	8.0	i	sx	o-a	1.70	ate	e
Caloneis silicula (Ehrenberg) Cleve	1	B	-	st	alf	6.3-9.0	i	sp	x	1.30	ats	me
Cocconeis placentula Ehrenberg	1-2	P-B	temp	st-str	alf	5.5-9.0	i	es	o-b	1.30	ate	e
Fallacia pygmaea (Kützing) A.J.Stickle & D.G.Mann	1	B	-	st-str	alb	7.55-8.45	hl	es	b-o	2.70	hne	e
Frustulia rhomboides (Ehrenberg) De Toni	1	B	-	st	acf	5.5-7.2	hb	es	x-b	0.30	ats	ot
Gomphonema angustatum var. *sarcophagus* (Gregory) Grunow	1	B	-	-	alf	-	i	-	b-a	1.30	-	m
Gomphonema parvulum (Kützing) Kützing	2-5	B	temp	str	ind	7.1-7.8	i	es	x	2.30	hne	e
Gyrosigma acuminatum (Kützing) Rabenhorst	1-3	B	cool	st-str	alf	-	i	-	o-x	1.90	ate	e
Melosira varians C.Agardh	1-3	P-B	temp	st-str	alf	5.0-9.0	i	es	a-b	2.10	hne	e
Navicula exigua Gregory	1-3	B	-	str	alf	-	i	es	x-o	1.40	ats	e
Navicula recens (Lange-Bertalot) Lange-Bertalot	2-4	P-B	-	-	alf	-	i	es	o-b	2.50	-	e
Navicula rhynchocephala Kützing	1-2	B	-	-	alf	6.5-9.0	i	-	b	1.30	ate	o-e
Neidium dubium (Ehenberg) Cleve	1	B	-	str	alf	-	i	-	x	1.70	ats	me
Nitzschia amphibia Grunow	1-2	P-B,S	temp	st-str	alf	4.0-9.0	i	sp	o	2.10	hne	e
Nitzschia palea (Kützing) W.Smith	1-3	P-B	temp		ind	7.0-9.0	i	sp	o-x	2.80	hce	he
Pinnularia viridis (Nitzsch) Ehrenberg	1	P-B	temp	st-str	ind	7.10	i	es	o-x	0.30	ate	o-e
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	2-4	P-B	-	st-str	alf	6.7	i	es	x-o	1.90	ate	e
Surirella angusta Kützing	1	P-B	-	st-str	alf	-	i	es	o	1.70	ate	e
Surirella brebissonii Krammer & Lange-Bertalot	1	B	-	st-str	alf	-	i	-	x	1.70	-	-
Surirella linearis W.Smith	1-2	P-B	-		ind	5.0-9.0	i	es	o-b	0.50	-	o-m
Surirella ovalis Brébisson	1-3	B	-	st-str	ind	-	i	es	o-a	1.70	-	-
Ulnaria ulna (Nitzsch) P.Compère	1-2	P-B	temp	st-str	ind	5.0-9.2	i	es	b-o	2.10	ate	o-e
Chlorophyta												
Bulbochaete sp.	1	-	-	-	-	-	-	-	-	1.20	-	-
Chlamydomonas sp.	1	P	-	-	-	-	-	-	b-p	2.80	-	-
Euglenozoa												
Euglena limnophila Lemmermann	1	P-B	eterm	st-str	-	-	-	-	o-b	1.50	-	-
Lepocinclis globulus Perty	1	P	eterm	st	ind	-	i	-	a-b	2.40	-	-
Cyanobacteria												
Oscillatoria sp.	1	-	-	-	-	-	-	-	-	-	-	-
Phormidium sp.	1	-	-	-	-	-	-	-	-	-	-	-

Note: Ecological types (Hab): B, benthic; P–B, planktonic-benthic, S, soil. Temperature (T): cool, cool water inhabitant; temp, temperate waters inhabitant. Streaming and Oxygenation (Reo): str, streaming waters inhabitant; st-str, low streaming waters inhabitant; st, standing waters inhabitant. Acidity (pH): ind, indifferent; alf, alkaliphil; acf, acidophil. pH rank: pH range in which species was found. Halobity (Sal): i, oligohalobious-indifferent; hl, oligohalobious-halophilous; hb, oligohalobious-halophobous. Saprobity (D): es, eurysaprob; sx, saproxen; sp, saprophil. Saprobity (Sap): o, oligosaprob; o-a, oligo-alpha-mesosaprob; x-o, xeno-oligosaprob; x-b, xeno-betamesosaprob; o-x, oligo-xenosaprob; b, betamesosaprob; b-o, beta-oligosaprob; o-b, oligo-beta-mesosaprob; b-p, beta-meso-polysaprob a-b, alpha-beta-mesosaprob; x, xenosaprob. S: species-specific Index saprobity according Sládeček. Nitrogen uptake metabolism (Aut-Het) [20]: ats, nitrogen-autotrophic taxa, tolerating very small concentrations of organically bound nitrogen; ate, nitrogen-autotrophic taxa, tolerating elevated concentrations of organically bound nitrogen; hne, facultatively nitrogen-heterotrophic taxa, needing periodically elevated concentrations of organically bound nitrogen. Trophic state (Tro) [20]: me, meso-eutraphentic; e, eutraphentic; o-e, oligo- to eutraphentic (hypereutraphentic); m, mesotraphentic; ot, oligotraphentic; o-m, oligo-mesotraphentic he, hypereutraphentic.

Unfortunately impacted part is the stream canal collected all nutrients and toxicants from the catchment area during winter rainy season. This situation is similar to that of the Upper Jordan River previously examined by us [5] where the pollution coming from the catchment area pollute the water more in winter than in summer.

Table 1. Chemical and biological variables in the Arbel stream in 2002-2013

Variables	Min	Max
Conductivity, mS cm^{-1}	0.63	0.81
$N\text{-}NO_3$, mg l^{-1}	1.8	1.9
pH	6.8	8.3
Total Dissolved Solids (TDS), mg l^{-1}	454	614
Temperature	19	31
Index saprobity S	1.28	1.56
WESI	0.5	0.7
No. of Species	24	29

Figure 3. Charophyte habitat in the Mount Arbel stream

Figure 4. Massive growth of *Chara vulgaris* in the Arbel stream

Figure 5. *Chara vulgaris*, view of thallus

Figure 6. *Chara vulgaris*: 1 – axis with stipulodes, base of whorl, and axial cortex, 2 – axis with branchlets

Conclusion

The new unique locality of charophytes in the Biblical place in the Arbel stream in protected area of the Mount Arbel National Park and Nature Reserve in the Lower Galilee can be characterize as natural, fresh, low alkaline with low- to middle organic polluted waters that inhabit by twenty nine algal species from which the charophyte *Chara vulgaris* (Characeae) and diatoms were rather dominated. The charophyte species *Chara vulgaris* which distributed over the Mediterranean and southern deserted phytogeographic regions can survive after one-two years of desiccation. This unique property of *Chara vulgaris* can help charophyte species to survive in the Eastern Mediterranean region that is under desertification process impact as a result of regional climate change. Therefore, the Arbel stream as unique charophyte habitat can be monitored, and the Mount Arbel National Park and Nature Reserve algal communities can be studied more detail for characteristic of diversity of National Reserve that we here presented in the first time

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