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Vascular plants as indicators of pollution in Lake Skadar

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Abstract

The project was carried out during ten months, including a field study of potential vascular plant bioindicators in Lake Skadar, Montenegro, the analysis of findings, and production of a report. Eleven locations, assumed to differ in anthropogenic disturbance type and level of pollution were investigated. The aim was to investigate through the analysis of correlation patterns which species among the macrophyte vascular aquatic vegetation that could be used as a reliable indicator of water pollution.

The study was done by transect inventory. Data on the distribution and abundance of vascular plants were gathered, using methods that include semi-quantitative estimation and composition zonings of the aquatic flora, maps, aero photos, chemical analyis, and literature reviews.

Lake Skadar suffers great stress and pressure from human activities. Lack of data, research and monitoring system make the management, control and preservation this National Park and Ramsar site a very hard aim to achieve. Given the advantages of macrophyte species as bioindicators, and the urgent need to establish ecological assessment parameters in the research area, this proposed project intended to contribute important data and recommendations.

Valisneria spiralis and *Ceratophyllum demersum* showed some patterns related to the pollution load, but not strong enough to claim them to be bioindicator species. Chloride ions and detergent parameters showed differentiation in values comparing polluted against unpolluted sites (although chemical data obtained are not the totally corresponding ones). Other results didn't meet the expectations, due to very poor data resources currently existing, resulting in very low trust in pollution load estimation. Advanced data in hydrology, physical and chemical conditions, are necessary for further studies, due to the complex picture of existing background information and the field situation.

Keywords: vascular plants, indicator, pollution, macrophyte, maping, inventory, lake, Montenegro

Contents

Introduction

Aquatic vascular macrophytes, large water plants, visible to the naked eye, are widely utilized as reliable indicators of human disturbances in aquatic environments. There are several features which make them suitable for an aquatic bioindicator approach. In large lakes, lake-wide investigations of submersed macrophytes are time-consuming and expensive (Lehmann & Schmieder 2004); thus selected vascular plant indicators (among which there are much less submerse vegetation), easily inventoried and monitored, are used as a time- and cost-saving tool. Vascular plants show a clear response to water quality changes. They react slowly and progressively to changes in nutrient conditions, in contrast to bacteria and microalgae, i.e. over several years. As primary producers many of them are indicators of eutrophication, others are sensitive to acidification or salinisation. The developed classification system provides simple yet reliable multi metric assessment of ecological quality according to the WFD (Water Framework Directive), superseding trophic status as an indicator of water quality, (Hofmann et al. 2004). Macrophytes therefore function as integrators of environmental conditions to which they are subjected and thus can be used as long-term indicators with high spatial resolution (Melzer 1999). They show patterns of nutrition or pollutant loads, caused by natural or artificial inflows as well as by diffuse, non-point sources (Melzer 1999). All these attributes make vascular macrophyte indicators superior as comprehensive tools of water quality assessment and monitoring compared to chemical analysis alone. Consequently aquatic vascular macrophytes can be used in monitoring, management and assessment activities when increasing human activities, urbanization, agricultural and industrial activities put pressure on aquatic ecosystem. Development of criteria and standards by which to evaluate the presence/absence or extent of degradation not only would serve in prevention and mitigation but would greatly assist inventory and restoration activities (Armitage et al. 2002).

Lake Skadar (Shkodra in Albanian) is the largest lake on the Balkan Peninsula, located on the border between Montenegro and Albania at 40º 10' North altitude, 19 º 15' East longitudes. It is a transboundary wetland Ramsar site (No. 784 in 1995), and the Montenegro part is a National Park since 1983. The surface area fluctuates seasonally between 370 and 600 km2. Being a shallow lake it lacks stratification; the mean depth of the lake is 5m with maximum depth of 8.3m. The direct drainage basin is 5490 km2, of which 4460 km2 are in Montenegro and 1030 km2 are in Albania. The largest inflow is the Moraca river (Montenegro), providing more than 62% of the lake water, while Bojana river (Albania and Montenegro) flows out from the south end and drains into the Adriatic Sea. Lake Skadar is subtropical and lies in the sub-Mediterranean climate zone, which means that it has an extremely high evaporation rate. To the southwest of the lake high mountains rise, with mostly rocky shorelines, while to the northeast a wide swamp provides an extensive semi-littoral zone with dense macrophyte cover. The frequent winds and the shallow depths do not permit the formation of permanent thermal stratification. The lake is regarded as mesotrophic with a tendency to become eutrophic in summer months.

Lake Skadar requires careful regulation, management and the formulation of action plans for sustainable development, not just to satisfy the National Park and Ramsar Site authorities, but to ensure the long-term subsistence of the local population. The situation concerning municipal sewage and industrial waste water is comparable to that in many other developing countries. Urban centers are at the same time the main industrial centers, where there is hardly any treatment of wastewaters. Industrial growth during a period of almost five decades was not accompanied by adequate technical pollution prevention measures. Wastewater from major Montenegrin towns (Podgorica, Niksic and Cetinje) ends up in Lake Skadar with minimum or no treatment at all.

Furthermore, wars in past decades and the present political transition increase the risk of ecosystem stability disturbance. The current situation, with human activities including illegal fishing and tourism, as well as poaching, boating, illegal constructions, agriculture, urban effluents, and the lack of treatment of waste waters polluted by PCBs and heavy metals (red mud disposed by the KAP aluminum plant), endanger the stability of the Lake Skadar ecosystem. The spectacular drop in wintering water bird numbers in 2005, as well as in the numbers of breeding water-birds, reported by ornithological monitoring programs, (Nela Vesovic, Ondrej Vizi pers. comm.), illustrates the problem.

It is also important to emphasize that regardless of the regulations on the measurement of the pollution load; the pollutant has not been precisely determined and treated, leaving space for different interpretations of the problem. Fortunately there is little evidence of man's effect on the lake through pollution (Beeton & Petkovic 1981). Long-term monitoring is required as a better estimation of state and the conditions of Lake Skadar, (Hollert & Rakocevic-Nedovic 2005).

The establishment of a detailed monitoring programme for Lake Skadar is urgently needed. Such a program should employ key indicator species: in addition to birds, e.g. waterbird food organisms, water plants and specific vertebrates, to explain changes that caused the decrease in bird numbers and other changes in the ecosystem, and to enable predictions about the future. This is recognized by the National Park authorities, the Government of Montenegro and the Ramsar Secretariat. Careful zoning of the National Park area should be implemented, as well, in order to regulate different levels of human uses in the respective. The fact, that lake belongs to two states, both developing countries, gives a multifaceted picture, and adds challenge to the future exploration of the lake.

The floating macrophyte vegetation in Lake Skadar mainly consists of *Nuphar lutea*, *Nymphaea alba*, *Trapa natans*, *Nymphoides peltata*, and *Potamogeton natans*. Under the surface many submerged species exist, such as *Najas marina*, *N. minor*, *Potamogeton perfoliatus*, *P. crispus*, *P. lucens*, *P. gramineus, and Utricularia vulgaris*. The third ecological group is composed of immersed aquatic plants such as *Phragmites australis*, and *Schoenoplectus lacustris*.

The diversity and the abundance of chosen bioindicators may reveal gradients in nutrient levels, mineral loading, and in the pollution load. Using such and other macrophyte attributes and preferences, the causes and consequences of environmental disturbances may be elucidated, solutions suggested and long-term monitoring for better estimation of lake state set up. Macrophyte vegetation, in particular vascular plants, which grows very abundantly in Skadar Lake, may help in the zoning of the lake, as well, through pointing at the biodiversity hot spots for vascular plants.

The process of assessing ecological condition in aquatic systems involves both the interpretation of sometimes complex data, usually in the form of a metric or index, and the scoring of results against some expectation of what the index or metric score should be, (Stoddard 2005). This study tries to find relationships between the pollution load and vascular plant parameters, showing the influence of pollution on plant community composition. Such differences in plant parameters between polluted and unpolluted areas, may point to practical bioindicator plants. In addition, basic inventory results and mapping of the plant belts can be seen as a baseline for further investigations and more in-depth studies.

Material and methods

Selected sites

A preparatory study of potential field sites included collecting of data about pollution, hydromophological lake typology and the expected reference conditions, provided by different institutions dealing with water quality in Lake Skadar. A preliminary field survey was done in July to inspect suitable sampling sites, previously tentatively chosen based on recognized zones of environmental disturbance in the lake according to literature data and information from institutions and researchers. For this study, two contrasting types of sites were selected. Five locations were placed in direct vicinity of point pollution sources, and six locations were chosen as reference sites, assumed to be less polluted (Tab. 1). A transect inventory was done in the 11 locations between July 27 and September 5, 2006.

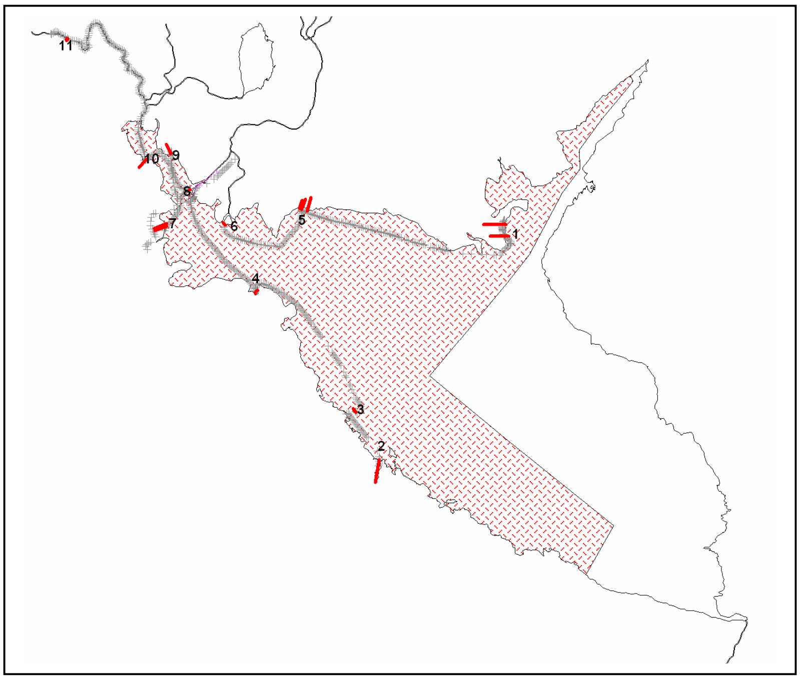
Table 1. Locations selected for transect inventories of macrophytes.

1	Humsko blato
2	Maci/Mrci luka
3	Beska
4	Radus
5	Plavnica □
6	Left mouth of Moraca river
7	Virpazar
8	Right mouth of Moraca river
9	Kamenik □
10	Modra oka □
11	Crnojevica river

□ - polluted
□ - unpolluted

Sites 6 and 8 (left and right mouth of Moraca river) are considered as the major source of pollution into the lake, receiving industrial waters from an aluminum factory (the biggest pollutant of the Skadar lake water), and other industrial and urban waste water from the towns of Podgorica, Niksic and other smaller rivers in confluence of Moraca (Fig. 1). The physical (abiotic) attributes of these two locations are quite different, which argues for the inclusion of both. Site 5 (Plavnica) is on the mouth of Plavnica river, which flows trough the agricultural area of Zeta valley. Site 11 (Crnojevica river) is located in the confluence of Crnojevica river, bringing wastewater from Cetinje city, and pollutants from a fish factory nearby. Site 7 (Virpazar) is polluted by municipal sewage and waste. Site 9 (Kamenik) was chosen in the same bay as site 8, taken as a reference site, based on results of previous investigations done. Site 10 (Modra oka) is near to the Kamenik but in a separate bay and with "okos" - clear water sources. Due to the fact that it is a very narrow bay, the wind influence is quite negligible, which may affect vegetation abundance. Site 1 (Humsko blato) could serve as a reference for the Plavnica, due to unpolluted water and similar abiotic conditions. Sites 4, 3 and 2 are taken as unpolluted sites. The east-south side of the lake, where these three sites are located, is quite clean but unfortunately they also differ in abiotic factors. This makes them less suitable as reference sites, but no better alternatives are available.

Fig. 1. Selected locations in Lake Skadar. Transect layout indicated, not to scale. Boundary of the water mirror not whole water shade is presented.



During the preliminary work a compilation of high resolution maps and satellite images of the lake were used for mapping of vegetation belts. The best map available was topographical (1:25 000). To complement this, a pedology map (1:50 000), and hydrological, bathymetric and morphometric charts (1:50 000) of Lake Skadar, and satellite images (IRS, 5m resolution) were used. No appropriate map of vegetation zones was available. In order to get a better picture and an analyzing tool for species distribution estimation, it was necessary to produce such a map.

The lake and its vegetation were documented with as many photographs as possible, taken from the boat and surrounding places. Aero photos were taken in September, with resolution 0.1 – 0.5 m, enabling an overview of the surveyed sites and additional estimation of vegetation belts. The photos were processed and placed on the 1:25 000 topographical map in the GIS tool programme MapInfo Professional (version pro 8.0, Release Build 18, 1895-2005 MapInfo Corporation). Locations, transects and sections within the transects surveyed in field work were also marked on the map, and a data base made for each of them. The data base contain description of the site information (location, transect and zone info.), as well as plant community and physical parameters information. This was done in order to get a good template for saving, adding and comparing data that exist and could be worked on in future.

Vegetation sampling methods

A transect method was applied, with two parallel transects for each site, perpendicular to the shoreline. Each transect was 2m wide (CEN/TC 230 2004). In some locations this was modified due to the circumstances met in the field. In some locations just one transect was laid, e.g. in narrow bays, and in some three transects were done, due to circumstance that in some places transect were finished perpendicular to shoreline without reaching the end of the bay (some bays, except that they are very narrow, are with a lots of curves), or that species saturation was not reached. The number of transects should be increased until the species number does not increase with each addition (CEN/TC 230 2004). The length of transects were not constant, but depended on the width of the zone of vascular plant growth along the shoreline. The transects were started at the point where floating vascular plants first appears when moving from the lake center towards to shore, and ended at the shore. Each transect was divided into sections, based on the recognizable plant communities. The number and length of zones (sections) inside each transect were thus different. The pans were assessed on accordance to description given in the unpublished data by Balzenchich et al. (in press).

Each transect was inventoried by visual estimation from a boat. The abundance of vascular macrophytes was measured using a semiquantitative descriptive scale, through visual estimation of composition and abundance of species. Within each transect section each plant species was assigned an MI index value (Mengenindex) on a five level scale developed by Balzenchich et al. (in press). A rare plant that occupied 10% of the section received the index value 1, an occasional species that occupied 10–25% was given the index value 2, a frequent plant with 25–50% coverage corresponded to index value 3, an abundant plant with 50-75% coverage was given the value 4, and a dominant plant species that occupied 75-100% was given the index value 5. Plant samples were taken as voucher specimens. Plant preservation was done as herbarium material or wet collection. A GPS was used to record the exact location of sampling sites. Preserved material was deposited in the herbarium of the biology department, Faculty of Science, in Podgorica, and the identification was confirmed by an expert in the systematic of higher plants, Danijela Stesevic. Photos were taken in each point of survey.

Physical and chemical parameters

Physical measurements were taken at each location just in front of floating vegetation survey starting point, and they were complemented by chemical data obtained on request from the Hydro-meteorological institution at Podgorica. This was done for the reason of getting site situation as better and realistic as possible for analyzing water quality and interpretation of results. Analyses of the following variables were done during the survey and in the laboratory by Prof. Slavoljub Mijovic (Department of physics, Faculty of Science, Podgorica):

temperature, pH, color, absorbency, conductivity, oxygen concentration (absolute and in percentage), and REDOX potential. Beside these parameters, the kind of substrate (sediment), Secchi depth and depth were registered at each site. Sediment types were characterized according to classes given in Tab. 3. The chemical measurements employed were: dry remain exp., suspended material., solute O_2, saturation O_2, BPK_5 (biochemical oxygen demand), alkalinity, HCO_3^- , Hardness, HPK from $KMnO_4$ (Chemical consumption of oxygen in 1 liter from KMnO4), Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+}, NH_4^+, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_3^-, NO_2^-, Phenols, Detergents, Total number of living microbes and Total number of fecal microbes. The locations where chemical measurements were taken do not correspond directly to the field locations of this study (table 15.), but correspond to sites 1, 3, 5, 6, 7, 8 and 9.

Table 3. Substrate classes.

Class	Substrate material
1	naked rock
2	cobble
3	sand
4	mud
5	artificial material (concrete, asphalt...)
6	detritus or other organic material

Plant community parameters

The abundance index MI can be used to express a biomass-related measurement, PM (Pflanzenmenge). PM can be obtained as a function($f_{(x)}=x^3$) of the MI index (Blazenchich et al. in press), meaning that PM is equal to the cubic plant index number(MI^3).

The relative plant quantity (RPM, Relative Pflanzenmenge) taken from Blazenchich et al. (in press), expresses relative quantity of a certain species in the surveyed ecosystem, as a function of the biomass (PM_i) of the species per section i, the biomass of all other species (PM_{ji}), and the length (L_i) of the section i (Eq. 1). The RPM simply expresses the proportion of biomass for each species in the transect, in a dimensionless index.

$$RPM\left[\%\right]=\frac{\sum_{i=1}^{n}(PM_i \bullet L_i)\bullet 100}{\sum_{j=1}^{k}\left(\sum_{i=1}^{n}(PM_{ji} \bullet L_i)\right)} \qquad (1)$$

The mean value quantity index of a certain plant species (MMT, Mittlerer Mengenindex) (Blazenchich et al. in press), expresses the cubic root of the average biomass per unit length of the transect, as a function of the biomass (PM_i) of the species per section i, the length (L_i)

of the section i, and the total transect length (L) (Eq. 2). The related measurement MMT is simply the average biomass per unit length. A variant based only on sections in which the species occur can be calculated as MMO (Eq. 3).

$$MMT = \sqrt[3]{\frac{\sum_{i=1}^{n} PM_i \bullet L_i}{L}} \qquad (2)$$

$$MMO = \sqrt[3]{\frac{\sum_{i=x}^{n} PM_i \bullet L_i}{\sum_{i=x}^{n} L_i}} \qquad (3)$$

The diffusive coefficient (d) (Blazenchich et al. in press) was then gained through Eq. 4. The diffusive coefficient indicates the degree of presence of a certain plant species in an ecosystem. If the value of the coefficient is 1 (maximal), that indicates the presence of the species in all surveyed transect sections.

$$d = MMT^3/MMO^3 \qquad (4)$$

Shannon-Wiener alpha diversity indices were calculated for each location, using the Species diversity and richness software package by Peter Henderson and Richard Seaby (version 2.2) inputting a PMi*Li parameter for each species at each location. The Shannon-Wiener index (Eq. 5) reflects the number of species and the relative abundances of species, giving a higher index value when relative abundances are more equal.

$$H = \sum_{i=1}^{Sabs} p_i \log_e p \qquad (5)$$

Statistical analysis

A matrix of pairwise correlations between the following location specific parameters, species number, H (Shannon-Wiener index), d, MMT, sum of MMT over all species, and all physical and chemical variables, was calculated in order to explore general interdependencies between parameters. Pearson product-moment correlations were run in SPSS, applying a 0.01 level of significance (2-tailed), as a large number of tests was made.

Next attention was to search for patterns comparing sites assumed to be polluted against unpolluted ones, regarding physical and chemical properties, as well as plant community parameters.

One-way ANOVAs were used to search for any patterns to support the assumption that the two groups of locations are different in terms of pollution load. The two groups were also compared regarding their plant community structures.

Trying to find another way of arranging locations, based on patterns among them, rather than on assumptions of degree of pollution, cluster analyses were employed. The Principal Components Analysis used here makes new groupings by reducing the number of variables by means of taking out the effect of covariation between them. This was first run on physical properties, then on physical and chemical parameters together, and thirdly on the MMT values for each species, and fourthly on this together with other plant community parameters (species number, H and the sum of MMT values for each species).

The groups of locations recognized in the PCA test were compared using one-way ANOVA tests, seeking for parameters that could show clear patterns in this new grouping.

Next analysis applied was multiple stepwise regressions, which makes a regression between one dependent variable (e.g. species number, H, d or MMT) and a set of independent variables.

Results

Basic physical data

Physical variables were measured in order to provide a description of habitat attributes of all locations. Most of the locations have mud as a substrate material (Table 3 (in appendix), mark 4), although the shoreline of such locations may vary, from rocky biotopes for the southern locations (3 and 4) to a flooding swamp in northern area. Sand appears at the 6 and 8 sites, mainly river banks. The very narrow and shallow bay at the site 2 have cobble with sporadic mud as a substrate. This variable generally describes the difference between mouths of river Moraca (6 and 8), site no. 2 and all the remaining locations. Locations 2, 6, and 8 have a maximum depth below 1m, identifying these three sites as extremely shallow ones. The depth of 1, 3, 4 and 9 locations is more than 2 m. The Secchi depth could not be measured at the sites 1, 6 and 10, as the bottom was reached with the disc still visible, taking into account the value attained for the depth in analyses. Site 9 has a low value for this parameter, although it is taken as an unpolluted site giving the assumption that it can be influenced by the river Moraca, loc. 8 or Crnojevica River, loc 11 and thus, not quite transparent as supposed. Very low temperature was measured in the points of the river mouths Moraca (loc. 6 and 8) and Crnojevica River (loc. 11) due to the cold water inflow from these rivers. This in turn affected water chemistry, in particular the oxygen concentrations which are highly dependent on the temperature. pH values in locations 1,3, 4, 6 and 8 are higher than 8, and lower in the other locations. Looking at the REDOX potential sites 2, 5 and 9 had high negative value, and the conductivity parameter for sites 5, 6, 7, 8, 9, 10 and 11 was higher than 248 µS/cm whereas the rest of the localities had values lower than 220 µS/cm. The absorbency is biggest at the site no. 5 and pretty low in sites 3, 8, 10 and 11. and color parameters follows this scheme.

Without going into detailed analyses and meaning of each parameters, all the physical variables show that there is variation in the physical attributes for the different locations, sometimes opposed to the ones expected, and this mainly was due to other circumstances met in field, that were not obvious and easy to predict.

Basic chemical data

The chemical data presented in table 5 (in appendix) and used in this study were not measured at the actual locations of this study, but applied as approximations for the chemical conditions at locations. The correspondence between locations used in this study and the sites where chemical data were measured is presented in table 6. Location 1 corresponds to samples taken at in the Podhum area. Location 3 (Beska) is the island situated between Moracnik and Starcevo islands, and the chemical data applied for this location is the average of the values measured at the two neighboring islands. Site 5 corresponds to the Plavnica area. Vranjina is a place situated in between locations 6 and 8 on the mouth of the Moraca River, and identical data was used for both locations. Site 7 corresponds to Virpazar, and the Kamenik area corresponds to location no. 9. For other localities no similar site with chemical data measured existed.

Table 6. Location in correspondence with chemical data areas.

1	Podhum
3	average of Moracnik and Starcevo
5	Plavnica
6	Vranjina
7	Virpazar
8	Vranjina
9	Kamenik

Vegetation data and mapping

Macrophyte vegetation is well developed on the northern, wetland shore of the lake. It covers a much smaller area on the southern, rocky part of the shoreline, where macrophytes mostly occur in bays sheltered from the wind, although still similar to the southern in respect to the plant community composition..

The aquatic macrophyte vegetation is expanding from year to year, especially in places where the pollution load has influenced water quality. This is clearly visible when comparing satellite images, existing maps and ones that were made during this study.

Due to very large area of the lake and small location points where pictures were passed off, as well as necessity of map info program, the analyzed location points treated on this way are not going to be all presented but stored as a back up data. Assessing this map is possible by contacting writer of this work or UNDP GIS office in Podgorica. Example of what is done is extracted as map 1, showing location number 3 – Beska with surveyed transects and sections marked.

Basic vegetation data

During the field survey each transect was divided into sections and a corresponding abundance index, i.e. the MI value, was assigned to each species found inside the section. The results of this semiquantitative estimation are presented in table 7 with all the species found during this survey at each location. To understand the table it is important to know that one species could be found several times in one location but in different sections of the transect examined. The MI value entered here estimates the abundance of each species in the measured section. It should also be noted that not all the transects and sections are of equal length.

It is obvious that *Nuphar luteum, Nymphea alba, Trapa natans* and *Scirpus lacustris* are present in most of locations, and could be taken as neutral plants, and thus not affected by pollution, in this case study, but not wider, and more as an assumption that should be tested further on. *Ceratophyllum demersum* is present just in polluted sites, but just in two of them, which does not give a clear pattern. Several species are present in just one site, making location no. 2 the richest in biodiversity.

Calculated vegetation data

The abundance of vascular flora species registered in the region of Skadar Lake, is expressed by four calculated parameters presented in table 9 and charts (1, 2 and 3) that correspond to it. These results show the relative plant quantity (RMP), the mean value quantity indices (MMT and MMO) and the diffusive coefficient for each species separately. The overall pattern, summarizing over all locations, is that *Nymphaea alba, Trapa natans* and *Ceratophyllum demersum* have the highest value for the relative plant quantity (chart 1); and when it comes to the diffusive coefficient *Nuphar luteum* can be added to this group of common species (chart 3). The diffusive coefficient shows the level of presence of each species in the aquatic ecosystem, being very high for the values that approach to 1. In this study *Trapa natans* was found to have the highest presence in the surveyed ecosystem, accompanied bywith *Nymphaea alba, Nuphar luteum and Ceratophyllum demersum*. MMO and MMT add one more estimation to the results, differing quite much in values for some species, ex. Carex elata value (chart 2). From the chart it is obvious that a very small value is given to the species found in very low abundance and in a just 1 or a few transects. Other species follows the equation, if high abundance with high length value it gives high value of MMT (*Nymphea alba, Trapa natans* and *Cratophyllum demersum*).

The Shannon-Wiener index (table 10) shows that alpha diversity is highest in site no. 2 and lowest, or better to say there is no diversity in location no. 6, due to the presence of just one species. Site no. 5 comes right after no. 6, by the H index, followed by site no. 7 and 10. What is obvious from the charts 4 and 5 and the Table 9 (Length (m) row) and 10 is that length of the transects at each location does not affect the Shannon-Wiener diversity index or number of species. Some short transects actually show a higher diversity than longer ones.

For example site no. 2 has the highest H value, but length of it is among lowest. Site no. 8 has the second highest length and among the lowest Shannon-Wiener diversity index.

Table 11 (in appendix) presents a more detailed picture of the same parameters, with data for each location separately. This table is mainly used for further statistical analyses of relationships between parameters.

Table 9. RPM, MMT, MMO, d for all locations combined.

Species	RPM (%)	MMO	MMT	d
Scirpus lacustris	7	3.19	2,02	0,25
Phragmites australis	3,12	3,91	1,57	0,06
Nymphea alba	21,68	3,85	2,99	0,47
Nuphar luteum	7,2	2,59	2,08	0,52
Nuphar pumilum	0,33	3,10	0,74	0,01
Scirpus maritimus	0,97	4,26	1,06	0,02
Trapa natans	29,26	3,93	3,3	0,6
Nymphoides peltata	0,09	4	0,48	0
Ludwigia palustris	0,01	2	0,24	0
Valisneria spiralis	0,41	3,24	0,79	0,01
Najas marina	0,63	3,76	0,92	0,01
Najas minor	0,02	2,13	0,29	0
Potamogeton gramineus	0	1	0,12	0
Potamogeton lucens	0	1	0,12	0
Utricularia vulgaris	0	1	0,1	0
Ceratophyllum demersum	29,42	4,8	3,21	0,3
Carex elata	0	5	0,38	0

Chart 1. RPM values for all locations combined.

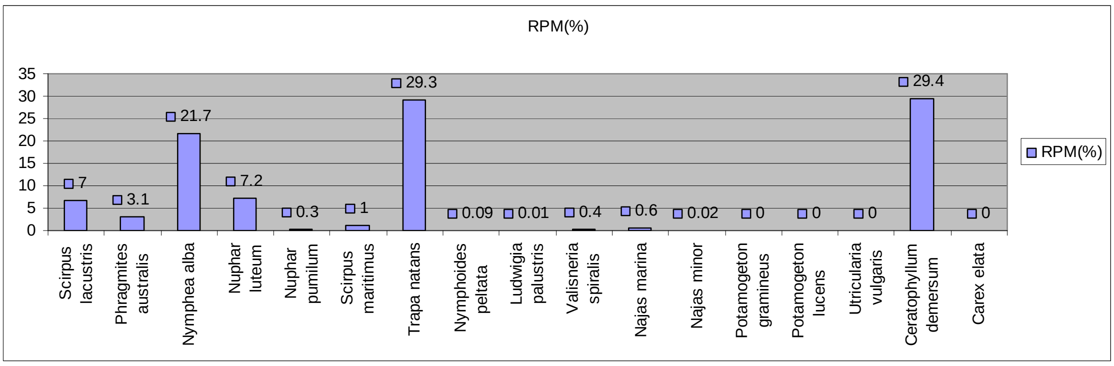


Chart 2. MMO and MMT for all locations combined.

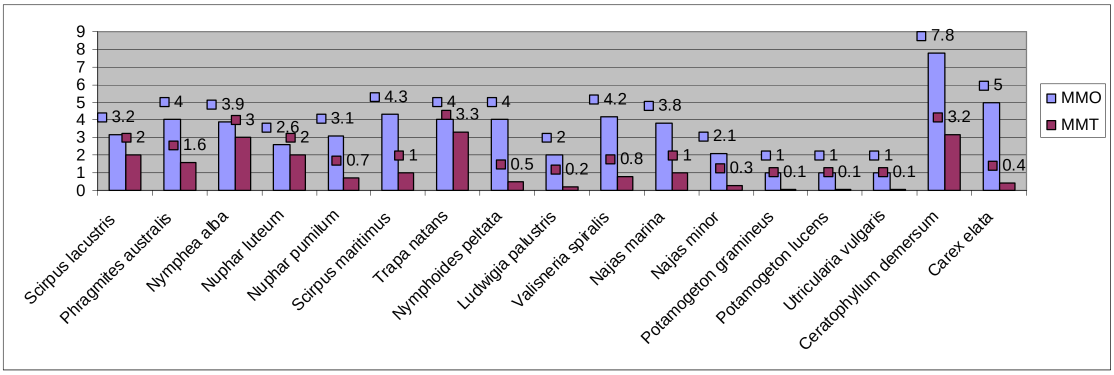


Chart 3. d for all locations combined.

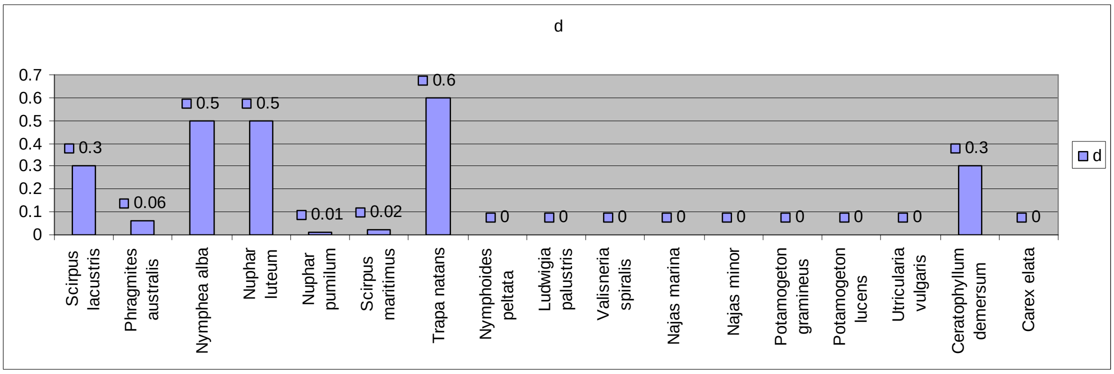


Table 10. Shannon Wiener - alpha diversity.

Location	H	Variance in H	Species number
1	0,9	1,3E-5	4
2	1,35	6,86E-5	12
3	1,12	1,32E-5	4
4	0,22	2,59E-5	3
5	1,29	1,03E-5	8
6	0	0	1
7	1,2	7,73E-6	6
8	0,73	1,83E-6	3
9	0,95	8,3E-6	6
10	1,2	1,48E-5	4
11	1,01	4,35E-5	5

Chart 4. Shannon Wiener index.

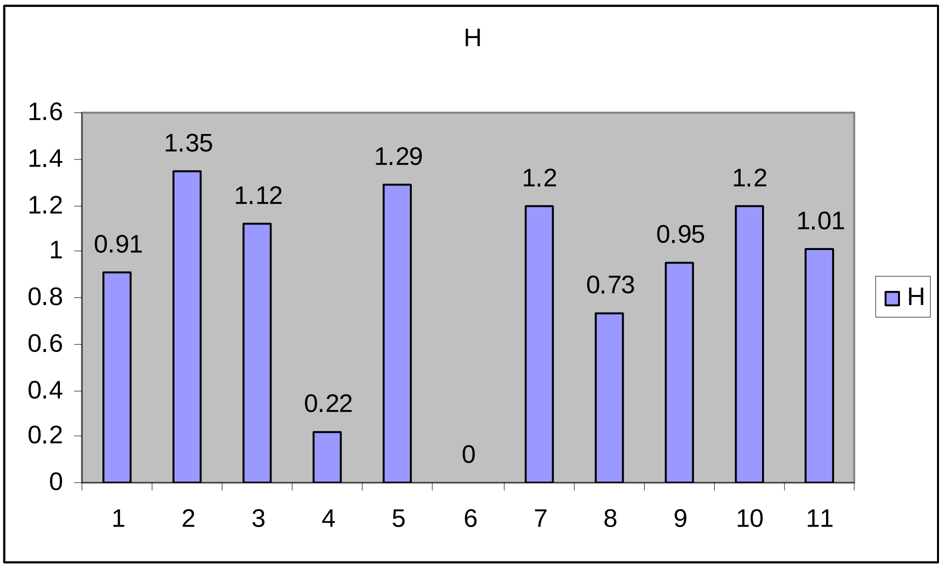
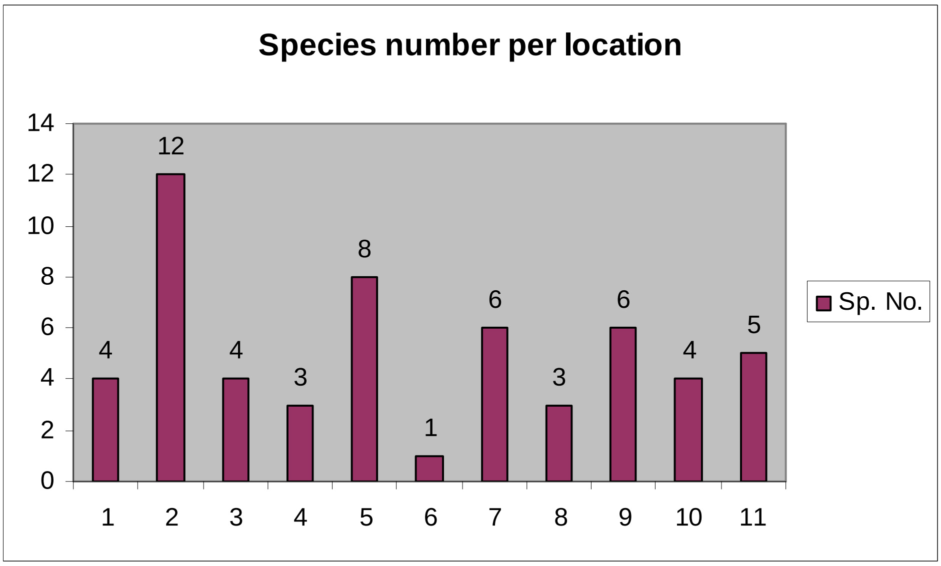


Chart 5. Species number per location.



Pearson correlations

Correlation tests identified many positive and negative relationships between entered parameters, but analyzing them it comes out that they are not applicable in some cases. For ex. by this test it is recognized positive correlation between Species number and MMT of *Valisneria spiralis*, *Utricularia vulgaris*…, and the same for d of *Utricularia vulgaris*, and it is obvious from the Table 9. that such correlation cant be drawn from this Species parameters presented just in one site. In addition, correlation that should be met, between oxygen and temperature parameters are not convened in this test. Examples of correlations that could be considered as not trivial ones are between sum of MMT and H and species number parameters with very high significant value (lower than 0.0022). However, Pearson

Correlation was put aside, and not considered in further analysis of results as a relevant one, because there is a question how big trust it can be given to this estimation.

Comparison of polluted versus non-polluted locations

The averages of physical parameters at polluted locations, compared to the averages for unpolluted locations, shows very little differences (table 12, in appendix). There is a tendency for lower temperatures at polluted sites, caused by the inflow of cold water in polluted sites from the rivers. No parameters show a significant pattern using a one-way ANOVA. Similarly, an analysis of the chemical data (table 5 in appendix) shows few differences between the groups. There is a tendency for fecal microbe concentrations to be higher in polluted areas. Tested by one-way ANOVA the chemical parameters showed a significant difference between polluted and unpolluted sites only for chloride ions ($F=14.13$, d.f.=1, $p=0.013$) and detergents ($F=10.89$, d.f.=1, $p=0.021$). Among the vegetation parameters (table 11) only the MMT value for *Ceratophyllum demersum* showed a significant difference ($F=6.35$, d.f.=1, $p=0.033$).

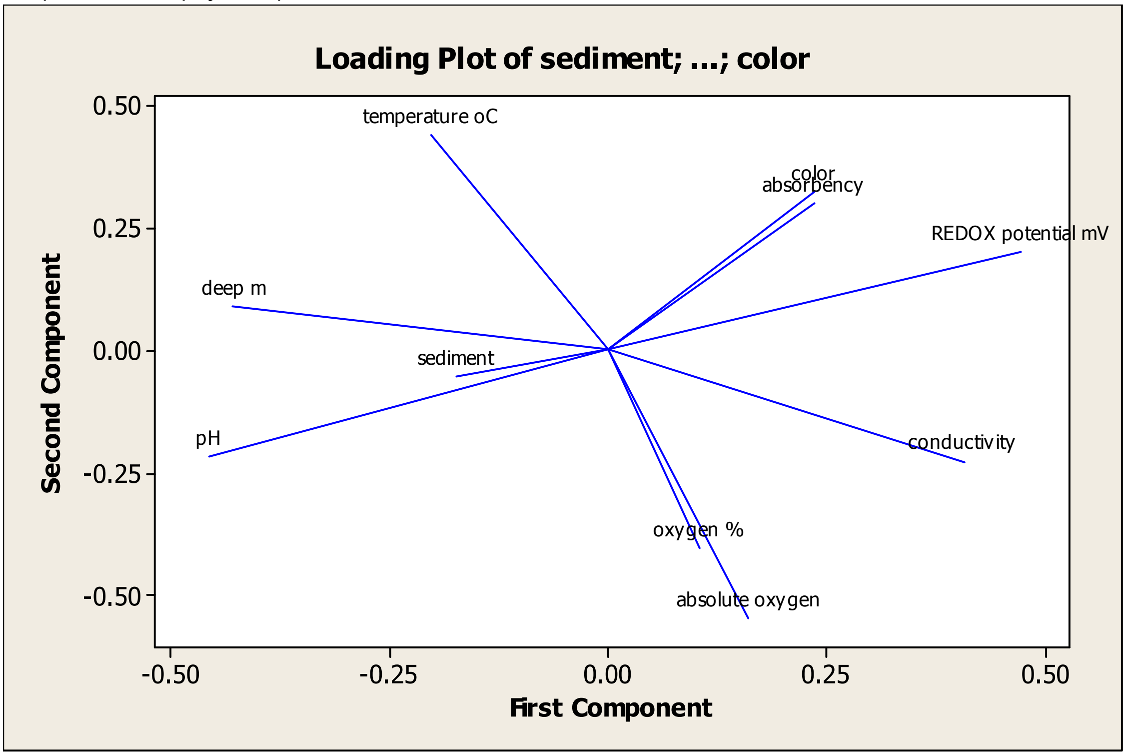
Regarding the presence/absence of each plant species it is obvious from table 7 that it is not possible to find clear patterns among the two groups of locations. One can note that *Ceratophyllum demersum* is just present in unpolluted sites, but as it is found just in two of them, and with a very low abundance, this cannot be taken as significant enough to claim patterns. Nor does species number bring any solution to the problem as it shows no difference between sites which are taken as polluted and unpolluted in this study.

The Shannon-Wiener alpha diversity index shown in Table 10 furthermore gives no contribution to any pattern recognition among the two categories of locations. The 11 samples varied in the number of species and in the relative abundances of species without any relationship to the polluted versus unpolluted division. This is confirmed with one-way ANOVA test which showed no significant difference between polluted/unpolluted sites in this parameter.

PCA analyses

The physical parameters applied to a Principal Component Analysis indicated a new grouping of locations, as shown in graph 2. Based on the two first axes of the PCA localities 1, 3 and 4 can be grouped as similar according to the variables measured in the field during the survey, localities 2, 5 and 9 form another group, and consequently a third group of the five remaining localities is formed. The loading plot (graph 1) shows that temperature has high loading on PCA axis 2, whereas conductivity and REDOX potential are important for PCA axis 1. The first group of locations (1, 3 and 4) has high pH-values, deep water, and low REDOX and conductivity values. The second group (2, 5 and 9) instead has high values in the REDOX potential, absorbency and water color parameters, and low in pH, while the third group has high values in the conductivity and absolute oxygen parameters, and a low value in temperature. Noted from graph 1, the loading values (all<0.5) indicate no significant correlation between the PCs and variables, thus there is no base to put much trust in this analysis.

Graph 1. Plot of physical parameters.



Graph 2. Plot of physical parameters localities grouping.

Other PCAs, using chemical parameters (graphs 3 and 4), the MMT for each species (graphs 5 and 6), and MMT for each species together with other plant community parameters (species number and H) respectively (graphs 7 and 8), did not results in a clear division of localities into groups and were not utilized for further groupings. Two last PCA plots emphasize that site number 2 differ from the others on accordance of MMT for each species and MMT for each species together with other plant community parameters.

Comparison among the new groups

The three new groups of localities, based on the PCA results, were compared using one-way ANOVAs, in the same way as done for the polluted/unpolluted division, for all physical, chemical and plant community parameters. This analysis showed significant differences between the groups only for the species number (F=6.18, d.f.=2, p=0.024), and the MMT for *Valisneria spiralis* (F=5.60, d.f.=2, p=0.03).

Stepwise regressions

A stepwise regression analysis gives information on which among the independent variables contributed most to the variation in the dependent variable. It was run for species number, H, MMT and d of each species as dependent variables, versus physical parameters. A number of significant results turned up (table 13), with species number being negatively related to the value of pH and the conductivity, in a model with a high level of variation explained: 84.90%.

The Shannon-Wiener alpha diversity was positively correlated with the pH and the REDOX potential, and negatively related to the Secchi disc value.

MMT of *Scirpus maritimus, Nymphoides peltata, Ludwigia palustris, Najas minor, Potamogeton gramineus, Potamogeton lucens* and *Utricularia vulgaris* appears to be negatively correlated with depth and absolute oxygen with the same level of R-Sq (50.86%) and d of *Nuphar pumilum, Scirpus maritimus, Nymphoides peltata, Ludwigia palustris, Najas minor, Potamogeton gramineus, Potamogeton lucens* and *Utricularia vulgaris* have the same correlation with the same paramethers and same level of variation explained.

Table 13. Stepwise regression.

Response	Positive correlation	Negative correlation	R-Sq %	P for pos.	P for neg.
Species number		pH	84,9		0
		conductivity			0,001
H	pH	Secchi disc	87,37	0,003	0,022
	REDOX potential			0,006	
MMT Nuphar pumilum		depth	50,86		0,024
		absolute oxygen			0,018
MMT Scirpus maritimus		depth	50,86		0,024
		absolute oxygen			0,018
MMT Nymphoides peltata		depth	50,86		0,024
		absolute oxygen			0,018
MMT Ludwigia palustris		depth	50,86		0,024
		absolute oxygen			0,018
MMT Najas minor		depth	50,86		0,024
		absolute oxygen			0,018
MMT Potamogeton gramineus		depth	50,86		0,024
		absolute oxygen			0,018

MMT Potamogeton lucens		depth	50,86		0,024
		absolute oxygen			0,018
MMT Utricularia vulgaris		depth	50,86		0,024
		absolute oxygen			0,018
MMT Ceratophyllum demersum	Conductivity		74,51	0,001	
	Secchi disc			0,021	
d Nuphar pumilum		depth	50,86		0,024
		absolute oxygen			0,018
d Scirpus maritimus		depth	50,86		0,024
		absolute oxygen			0,018
d Nymphoides peltata		depth	50,86		0,024
		absolute oxygen			0,018
d Ludwigia palustris		depth	50,86		0,024
		absolute oxygen			0,018
d Najas minor		depth	50,86		0,024
		absolute oxygen			0,018
d Potamogeton gramineus		depth	50,86		0,024
		absolute oxygen			0,018
d Potamogeton lucens		depth	50,86		0,024
		absolute oxygen			0,018
d Utricularia vulgaris		depth	50,86		0,024
		absolute oxygen			0,018

d Ceratophyllum demersus	Secchi disc	76,09	0,004
	conductivity		0

Discussion

Considering the time and resources available, the main purpose of this study was to nominate and test vascular plants, being the main and largest macrophyte group, as possible bioindicators of pollution and ecological status of Lake Skadar,

The diversity and abundance of plants is affected by eutrophication, acidification and other changes in the environment. Both individual species and entire types of plant community can serve as indicators of the state of ecosystem (Wiederholm 2000). In general, aquatic vascular macrophytes are long-lived sessile organisms regarded as sensitive to important anthropogenic pressures over long time periods. Vascular plants thus can be used as tools for the estimation of water pollution due to their response to disturbance and human pressure. The specificity of their reaction, the chronological perspective that can be given, their abundance and wide distribution in lakes and the easy application and detection were the reasons of choosing them as an object of this study.

In this study most trust was put in data obtained during the field work. All results show quite weak relationship between measured parameters of species community and physical ones within no clear patterns among them. Even when physical parameters were applied for a new grouping of localities, no clear pattern was obtained.

Ceratophyllum demersum and *Valisneria spiralis* are the only species that gave some patterns in the analyses, which suggests that they could possibly be used as indicators, but that needs further evaluation. Other species showed no relevant parameters that could be utilized for indicator approach. *Ceratophyllum demersum* is present in unpolluted sites but just two of them, claiming week patterns.

Site no. 2 appeared as the one with very high diversity but with no correlation with other reference locations. The reason for this can be difference in substrate, and some other physical attributes present in that site (low depth, high value for Secchi depth, narrow bay, low influence of wind and no human impact) that all together give the good base for high biodiversity in this spot.

Comparing location assumed to be polluted against unpolluted sites, very few physical or chemical parameters actually show any clear pattern, the only exception being in Chloride ions and detergents. Small amounts of chloride come from soaps, detergents, and other cleaning products. Some also comes from industrial and commercial processes. High concentrations of chloride are harmful to aquatic plants and animals, and thus influence in great amount abundance and diversity of vascular communities. As these results are established based on chemical analysis that covers just 7 sites the confidence put in the lack of patterns may be low. There were no chemical measurements done in this study, owing to budget limitations, but as they are necessary to complete the picture, an existing dataset was obtained from the Hydrometeorological institution, and considered in the study. The problem with this set of data, apart from the relevance in time, which may be less of a problem due to the slow reaction of macrophytes, and number of location, was the fact that the sampling places were not exactly in the same locations were my survey was done. Consequently the dataset does not permit too much trust to be put in the results obtained. However, there are also very few patterns among the vegetation parameters that could separate the two groups of locations.

Following PCA results another grouping of locations was set up, based on physical parameters. In this case a pattern in total number of species was seen, and in the MMT value for *Valisneria spiralis*. Due to the fact that *Valisneria spiralis* is noted in just one site it is clear that this pattern cannot be taken too literally. The pattern seen in number of species does however indicate that similarities within groups exist, with differences between each one of them, and as physical parameters are the one that are causing this pattern, correlations can be drawn.

It would be desirable to use bioindicators to provide necessary data on ecological status and levels of threat in Skadar Lake, and to find an easily applicable method for monitoring of pollution through indicator species. However, in this study aquatic plants could not provide clear information on the status of the lake regarding pollutants.

The freshwater aquatic environment, including lakes, can be subdivided and classified into a number of types, based on different approaches. Even within one type of lake there may be considerable variation in ecological functions and hence between suitable indicator species. Consequently the bioindicator approach turns out to be complicated. Likewise, Lake Skadar has unique features, which makes it hard to place it in any given lake type or categorization system that already exists. In addition, the lack of background information, such as maps, detailed studies about pollutants and their effects on the lake, hydrology data, living organisms, adds complexity to this picture. For many years, investigations of this lake and its vicinity proceeded partially, temporarily and independently (Karaman 1981). Specifically, there was not much done previously on the relationship of macrophytes to the pollution of Lake Skadar. Being situated in developing countries there is also the problem with access to information that exists, not just the lack of data itself.

It is important to emphasize that regardless of all literature and field studies the total pollution load has not been precisely determined. What is known is that the urban and industrial growth during the period of almost five decades was not accompanied by adequate technical pollution prevention measures. On the other hand analyses for various possible pollutants show that in general the quality of Lake Skadar is satisfactory, and that Lake has a great ability to clear itself by huge turnover effects (all lake water changes 3-4 times per year). Generally speaking, the lake receives pollutants, but in what amount and significance, from what sources and with what effect is a big challenge yet and deep study invitation.

One more difficulty, apart from the lack of background data, involved finding non-polluted reference sites which otherwise was comparable to the ones assumed to be polluted. In Lake

Skadar almost all pollutants come from the northern part, whereas most sites assumed to be unpolluted are on the southern part of the lake, which is different in many respects. This makes the statistic analysis less reliable, and conclusion much harder to draw.

Beside the pollution, various environmental factors influence physical and chemical parameters measured in this study and consecutive plant parameters, with no stronghold in present scientific data. Macrophyte grows very abundant in the lake, especially in the northern part and once dense beds are established in summer they have a major influence on the chemistry of lake water, differing from the one present in the winter time (Beeton 1981). Information on "Micro" –hydraulics (local hydraulic) relevant to the occurrence, prevalence and extinction of aquatic plants is still missing, at least seen from biologist's view (Janauer 1997). Dynamic water flow, which is very prevalent in Lake Skadar due to substrate permeability and inflow of fresh cold water from mountain rivers, streams and underground waters could explain the lack of differences in physical parameters between polluted and unpolluted sites. As the dynamics of the water flows within the lake are unknown in details, there is the possibility that the pollutants could be spread in all parts of the lake. Conversely, freshwater sources may appear in the polluted areas as well, contributing to a much better water quality than expected from the anthropogenic activities in the area.

In Lake Skadar oxidized surficial sediments do not remain intact due to wind induced mixing. Lake Skadar is affected by frequent and numerous winds all year. Winds also cause considerable turbidity of the lake water, transparency 1-3 meters due to waves shifting the surface layer particles of the mud (Petkovic 1981), which induce changes over physical parameters not just in one point but among locations, as well.

Taking it all into account more estimation can be confirmed: the physical factors are very much influenced by movements of the water; inflows of rivers and clear water from streams, underground waters of "okos" shift the water quality; flooding of the lake increase possibilities for nutrition and other materials exchange; consequently the pollution is spared in whole lake, leaving no reference sites available. This is, maybe, one additional reason why the polluted/unpolluted division cannot be verified in more patterns than in chloride ions and detergents in the tests run. Furthermore, the lack of data for underground water currents, the influence of strong winds, and turbidity, make such an analysis much more difficult. This makes hard finding fast, reliable, long range, short time and cost efficient estimation methods based on aquatic bioindicators, at present. One additional difficulty regarding the realization of the monitoring program is that Lake Skadar belongs to two different states, Montenegro and Albania; consequently, any major decisions require the agreement of both countries (Beeton & Karaman 1981). The plant community parameters and vascular plants itself are thus influenced by numerous factors, water dynamic, physical and chemical variables which are likely to fluctuate unpredictably in time, making the whole lake susceptible to variations in water quality.

Based on these findings it can be suggested that detailed investigations on physical and chemical parameters should be set up, and based on them grouping and analyses made, and more reliable patterns are likely to be met with. Future studies should be based on physical and chemical values (done as detailed as possible) investigated during the survey. This is because currently background information is hard to trust and rely on, due to many technical (lack of equipment) insufficiencies and interpretative conflicts.

Presenting the description of the current state, gaps and prospects of Skadar lake limnology data, vascular plant identification and pollution estimation allows us to arrive at some general conclusions and recommendations. Ecology of most species in the lake is poorly known. Current models of cold temperate limnosystems have very restricted geographical application and Mediterranean limnosystems do not meld with them (Angeler et al. 2005). Present models for bioindicators need to be adapted to the Mediterranean limnosystems with very restricted geographical application, too. More research is urgently needed. Moreover, physical conditions of aquatic plant habitats in general still need to be done, and much more.

More people and more funding must be devoted to researching of such an important limn system, the largest in Balkan. These goals can be achieved partly involving more investigations, better data treatment, more comprehensive studies, institutional cooperation, and publicity and sharing of data and longer-term study perspective plans. This study is more like to be starting point for one such profound investigation due to its time and cost limitations. Further on this project could contribute to data about biodiversity, considering vascular aquatic plants.

Conclusions

The lake is polluted in spite of numerous regulations on protecting the national park Skadar Lake. Lack of water-related research and monitoring in some way legalizes the pollution of Lake Skadar. Deeper studies on physical, chemical and hydrological parameters need to be done to establish baseline data. This would enable more profound and comprehensive assessments, monitoring and predictions using aquatic plants as indicators, due to their conditional reaction on pollution, easy application and detection.

Ceratophyllum demersum and *Valisneria spiralis* are species that show some weak patterns in this study and certainly should be further and more carefully investigated.

Based on the above, it can be concluded that Lake Skadar's aquatic vascular macrophytes should be a basic estimation element of this unique Balkan ecosystem, but results obtained in this study for achieving that aim gives some obstacles and put this statement into question, at present.

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SPSS ref ? – I do not know. I do not have that program any more!?

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Appendix 1. Variables

Loc. Tab.1	Sed. Tab.3	depth m	Secchi depth m	Temp. °C	pH	REDOX potential mV	conduction µS/cm	oxygen %	absolute oxygen mg/l	absorbency 420 nm	color mgPt/l
1	4	2,4	/	25,2	8,57	-81	215	126,9	10,54	0,061	30,5
2	2	0,5	2,25	26,6	7,7	-38	220	104,9	8,2	0,069	34,5
3	4	3,4	3,4	28,1	8,52	-80	210	118,9	9,68	0,044	22
4	4	2,8	2,00	25,5	8,66	-83	219	121,00	9,83	0,085	42,5
5	4	1,2	1,4	25,3	7,73	-39	249	120,9	9,51	0,11	55
6	3	0-0,5	/	15,9	8,28	-64	250	158,00	15,19	0,087	43,5
7	4	1,5	1,2	28,5	7,96	-52	254	140,00	12,1	0,07	35
8	3	0,8	1,8	15,1	8,2	-61	248	114,6	11,35	0,044	22
9	4	2,2	1,00	25,7	7,63	-34	266	120,11	9,86	0,094	47
10	4	1,6	/	23,6	7,99	-52	260	141,7	11,96	0,045	22,5
11	4	1,8	2,4	13,5	7,9	-46	281	122,2	12,38	0,05	25

Appendix 2. Chemical parameters adjusted to the study locations.

Location			1	3	5	6	7	8	9	Unpolluted	Polluted
dry remain	exp.	mg/l	144,25	128,5	137,5	162	145	162	147,5	140,0833	151,625
dry remain	figuring	mg/l	138,75	130,375	137	167	150	167	156,25	141,7933	155,25
Solute.	O2	mg/l	8,65	8,9625	8,945	8,65	8,925	8,65	8,825	8,813333	8,795
saturation	O2	%	108	110,5	110,25	99,5	106,5	99,5	105	107,8333	103,9375
BPK5		mg/l	0,625	0,9875	0,725	0,95	1,325	0,95	1	0,873333	0,99
HPK	from KMnO4	mg/l	1,925	2,375	2,175	1,625	2,125	1,625	2,325	2,213333	1,8925
Alk.		mg/l	117,75	112,5	121,5	145,25	135,75	145,25	141,5	123,9167	136,9375
HCO3-		mg/l	145	138,5	149,5	178,5	164	178,5	170,25	151,25	167,625

Hardness.		dH0	7,225	6,95	7,225	8,725	8,1	8,725	8,5	7,56	8,1975
Ca2+		mg/l	44,325	39,025	41,125	56,225	49,975	56,225	49,675	44,34667	50,8925
Mg2+		mg/l	4,425	4,275	6,475	3,85	4,775	3,85	6,8	5,17	4,74
Na+		mg/l	2,625	2,75	3,85	2,475	2,65	2,475	2,525	2,636667	2,865
K+		mg/l	0,775	1,0625	0,725	0,75	1,175	0,75	0,45	0,763333	0,8525
Fe2+		mg/l	0,015	0,01	0,015	0,02	0,015	0,02	0,025	0,02	0,02
NH4+		mg/l	0,34	0,315	0,2825	0,285	0,3725	0,285	0,4175	0,36	0,3075
Cl-		mg/l	5,35	5,225	4,725	4,725	4,25	4,725	5,05	5,21	4,61
SO42-		mg/l	6,625	3,5375	3,6	7	3,75	7	5,15	5,106667	5,3375
PO43-		mg/l	0,01	0,04	0,0825	0,03	0,1275	0,03	0,1775	0,076667	0,0675
NO3-		mg/l	0,8825	0,5275	0,462	1,45	0,7875	1,45	0,60725	0,673333	1,0375
NO2-		mg/l	0,00125	0,0015	0,00125	0,00575	0,001	0,00575	0,001	0	0,005
Phenols		mg/l	0,00025	0,000875	0,00175	0,00175	0,00075	0,00175	0,002	0	0
Deter.		mg/l	0,0205	0,0235	0,0365	0,0325	0,048	0,0325	0,014	0,016667	0,0375
total no.	liv.microbe	in 1ml of water	81,33333	42	50,25	72,25	44,5	72,25	60,5	61,27667	59,8125
total no.	fek.microbe	in 100ml of water	0	32,625	13,25	143,25	39	143,25	6	12,87667	84,6875

Appendix 3.. Abundance indices (MI) of aquatic vascular plant species at each location, with a separate value for each section of the transects.

Species/location	1	2	3	4	5	6	7	8	9	10	11
Carex elata								5,5	5,5	5	
Ceratophyllum demersum					3		5				
Ludwigia palustris		2									
Najas marina		1,2			4						
Najas minor		1									
Nuphar luteum	1,1	1,5	3	5	3,3,3,2		2,3,3,3	1	1	5,4	5,5,5,2,3
Nuphar pumilum		3,3,1,4									
Nymphea alba	4,4		4		5,5,3,3,3		3,4,4,5		5,5	5	4
Nymphoides peltata		4									
Phragmites australis	3,3			5	5,1,5	5	5,5				
Potamogeton gramineus		1									
Potamogeton lucens		1									
Scirpus lacustris	3,5,5		5		5,1,5,5,3,5		1,4,5		1	2	4
Scirpus maritimus		1,5,1,4									
Trapa natans		1	4	5,5	2		1,1,1,5	5,5	5	5	5,5
Urticularia vulgaris		1									
Valisneria spiralis		3,3			1						
Species no.	4	12	4	3	8	1	6	3	5	5	4
No. of transect	2	3	1	2	3	1	2	2	2	1	2
Length (m)	730	148	253,5	189	1077	15	1466	1360	232,5	175	151

Appendix 4. RPM, MMT, MMO, d per location.

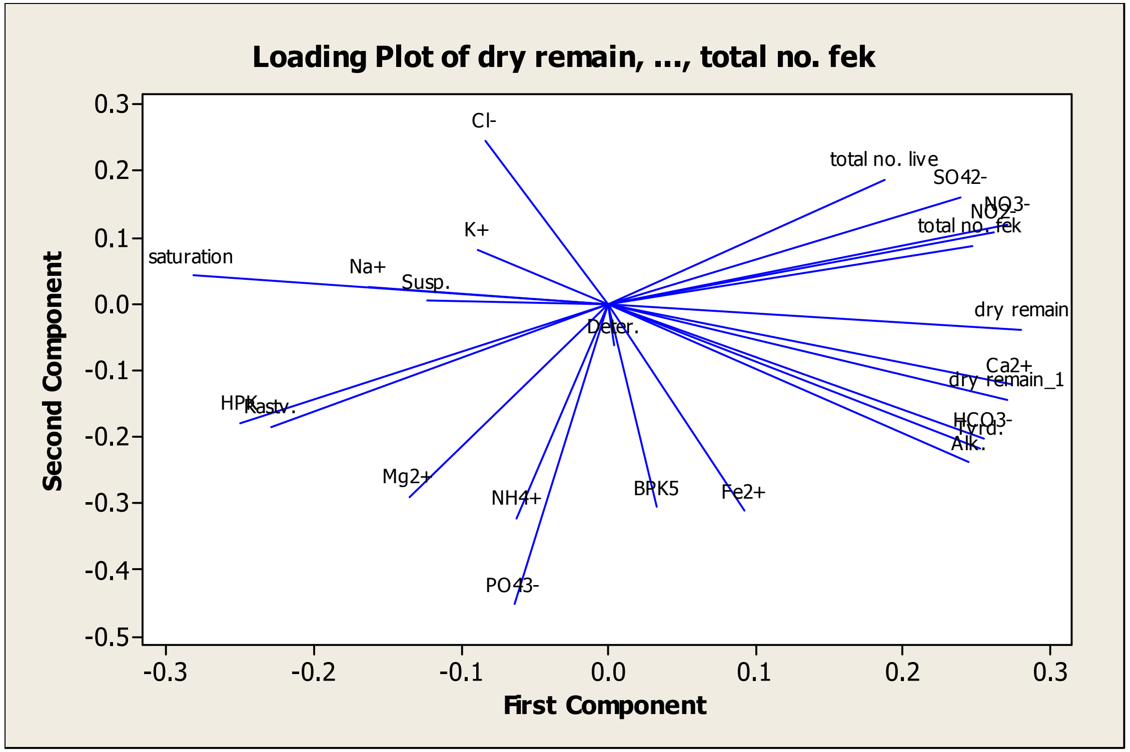
Species	RPM (%)	d	MMO	MMT	Location
Scirpus lacustris	64,6	0,465753	4,068667	3,153825	1
Phragmites australis	15,2	0,273973	3	1,948455	1
Nymphea alba	19,9	0,150685	4	2,128547	1
Nuphar luteum	0,3	0,150685	1	0,532137	1
Nuphar luteum	3,03	0,166667	2,58002	1,41984	2
Nuphar pumilum	15,7	0,57971	3,102911	2,587257	2
Scirpus maritimus	53,3	0,652174	4,256366	3,691137	2
Trapa natans	0,2	0,217391	1	0,601285	2
Nymphoides peltata	4,9	0,072464	4	1,667632	2
Ludwigia palustris	0,6	0,072464	2	0,833816	2
Valisneria spiralis	4,2	0,108696	5,738794	2,738785	2
Najas marina	0,4	0,108696	1,493802	0,712903	2
Najas minor	4,8	0,108696	2,130226	1,01663	2
Potamogeton gramineus	0,08	0,072464	1	0,416908	2
Potamogeton lucens	0,08	0,072464	1	0,416908	2
Urticularia vulgaris	0,04	0,006849	1	0,189911	2
Trapa natans	31,2	0,394477	4	2,933598	3
Nuphar luteum	19,8	0,591716	3	2,518599	3
Nymphea alba	46,9	0,591716	4	3,358132	3
Scirpus lacustris	2,1	0,013807	5	1,199499	3
Trapa natans	95,2	0,952381	5	4,919341	4
Nuphar luteum	1,85	0,018519	5	1,322834	4
Phragmites australis	2,9	0,029101	5	1,537931	4
Nuphar luteum	13	0,492108	2,532653	1,999536	5
Trapa natans	0,8	0,064995	2	0,804126	5
Ceratophyllum demersum	2,8	0,064995	3	1,206189	5
Najas marina	6,75	0,064995	4	1,608252	5
Valisneria spiralis	0,1	0,064995	1	0,402063	5
Nymphea alba	42,2	0,752089	3,777746	3,435494	5

Scirpus lacustris	33,5	0,475395	3,513131	2,741863	5
Phragmites australis	2,9	0,051068	3,265392	1,211484	5
Phragmites australis	100	1	5	5	6
Trapa natans	0,6	0,488435	1,191328	0,938211	7
Ceratophyllum demersum	44	0,478912	5	3,911906	7
Scirpus lacustris	0,7	0,348299	1,395024	0,98152	7
Nuphar luteum	18,3	0,92517	2,396137	2,334813	7
Nymphea alba	30,5	0,921088	3,558255	3,462083	7
Phragmites australis	6,2	0,068027	5	2,0411	7
Ceratophyllum demersum	37	0,588235	5	4,189418	8
Trapa natans	62,8	1	5	5	8
Nuphar luteum	0,2	0,411765	1	0,74396	8
Nymphea alba	52,2	0,860215	5	4,755239	9
Ceratophyllum demersum	39,2	0,645161	5	4,320421	9
Trapa natans	7,8	0,129032	5	2,526598	9
Nuphar luteum	0,1	0,215054	1	0,599123	9
Scirpus lacustris	0,005	0,010753	1	0,220719	9
Carex elata	1,1	0,010753	5	1,103593	9
Trapa natans	18,85	0,142857	5	2,61379	10
Nymphea alba	37,7	0,285714	5	3,293169	10
Scirpus lacustris	4,83	0,571429	2	1,659653	10
Nuphar luteum	38,6	0,571429	4	3,319306	10
Nuphar luteum	67,3	0,907285	4,557755	4,412305	11
Ceratophyllum demersum	9,7	0,099338	5	2,31566	11
Trapa natans	9,1	0,092715	5	2,263013	11
Scirpus lacustris	0,7	0,013245	4	0,946406	11
Nymphea alba	13,3	1	4	4	11

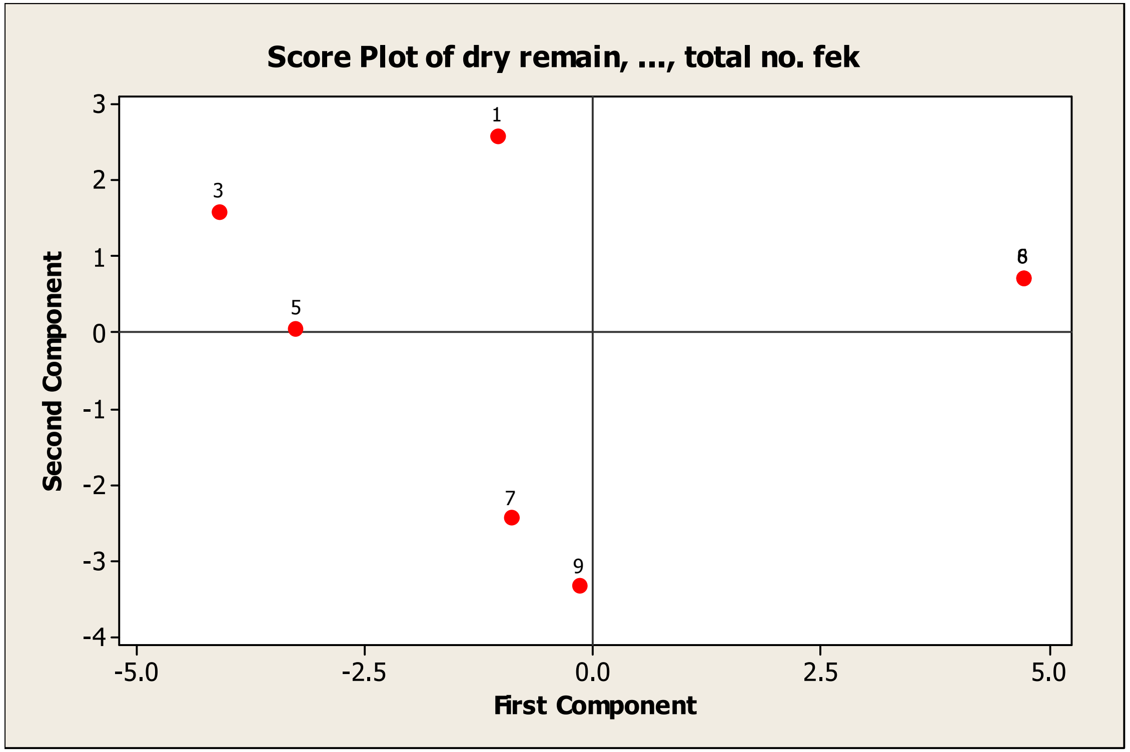
Appendix 5. Polluted versus unpolluted on physical parameters.

Locality division	depth m	Secchi depth m	Temp. ºC	pH	REDOX potential mV	conductivity µS/cm	oxygen %	absolute oxygen mg/l	absorbency 420 nm	color mgPt/l
Unpolluted	2,15	1,4	25,8	8,18	-61,3	231,7	122,25	10,01	0,07	33,17
Poluted	1,16	1,36	19,66	8,014	-52,4	256,4	131,14	12,106	0,072	36,1

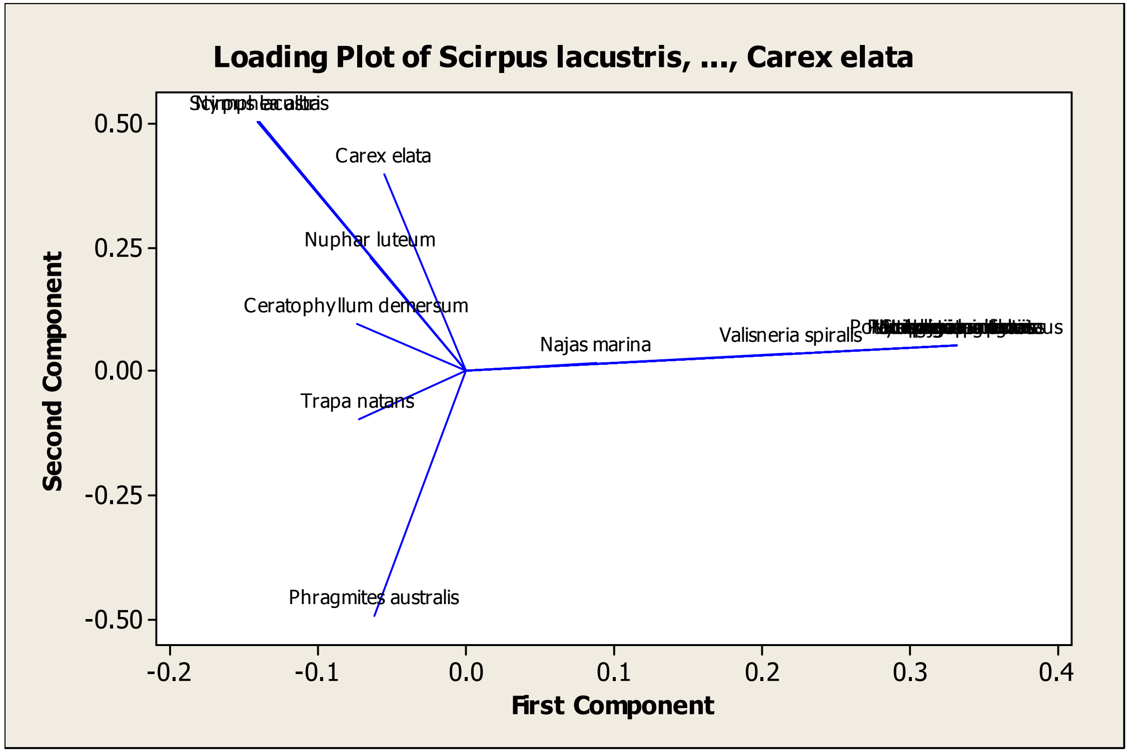
Appendix 6. Plot of chemical parameters.



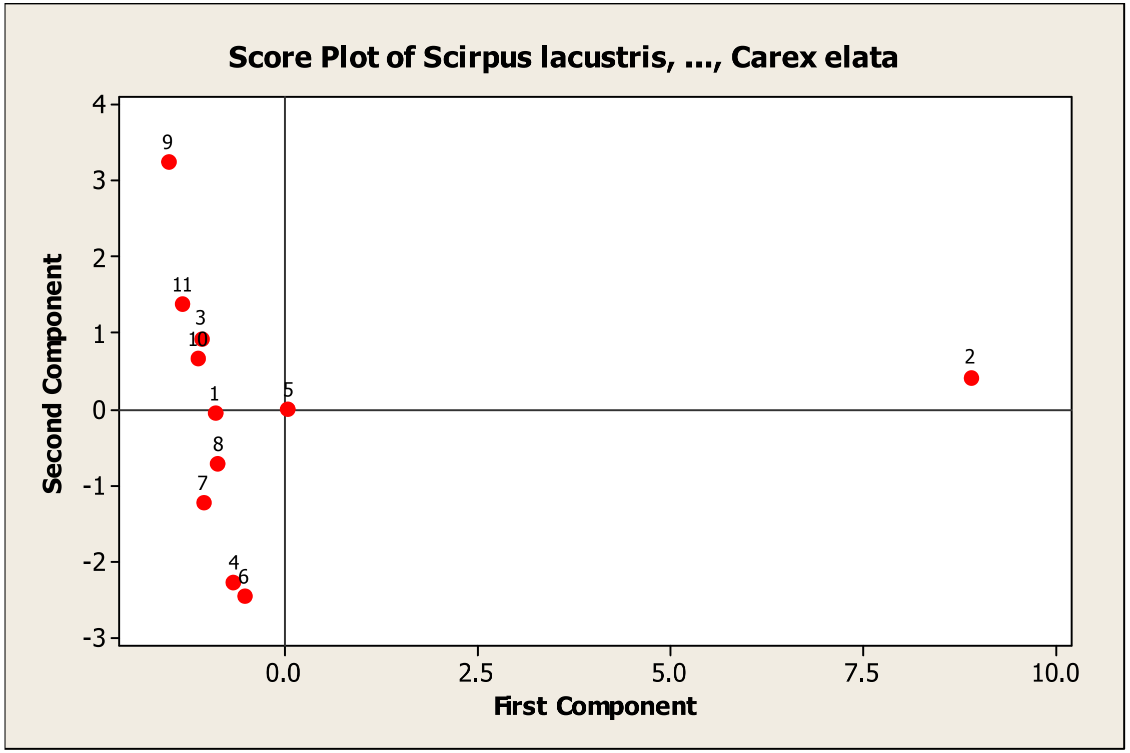
Appendix 7. Plot of chemical parameters localities grouping.



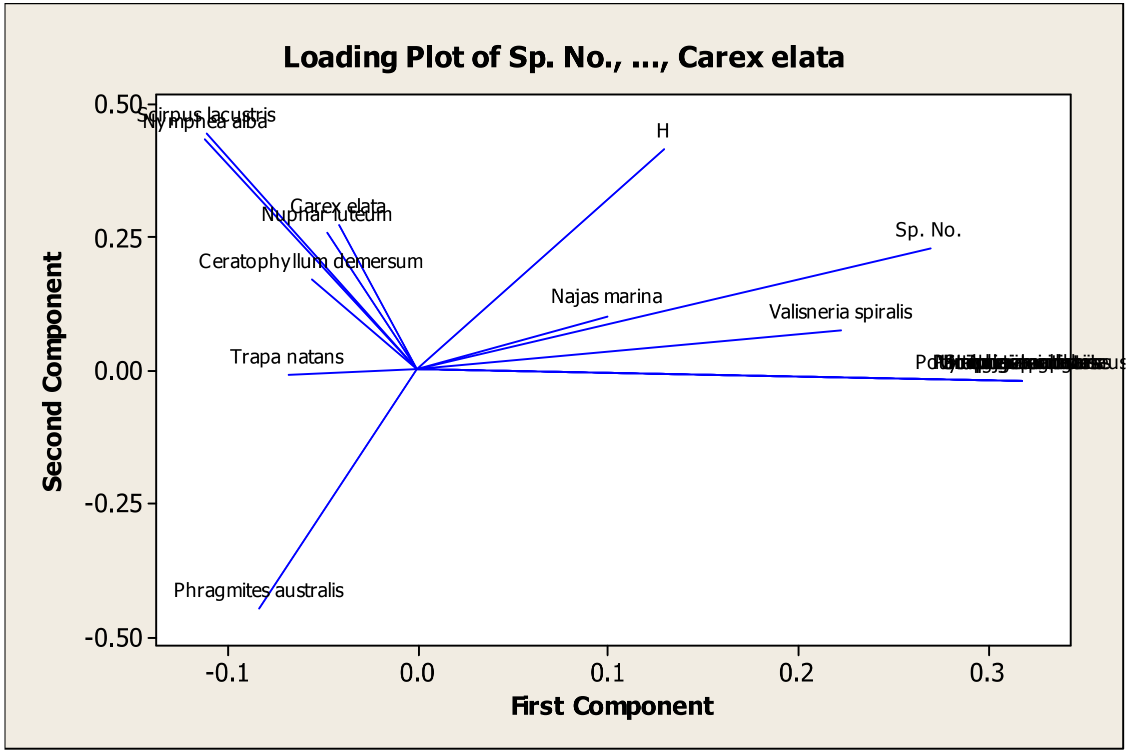
Appendix.8. Plot of MMT for each species parameters.



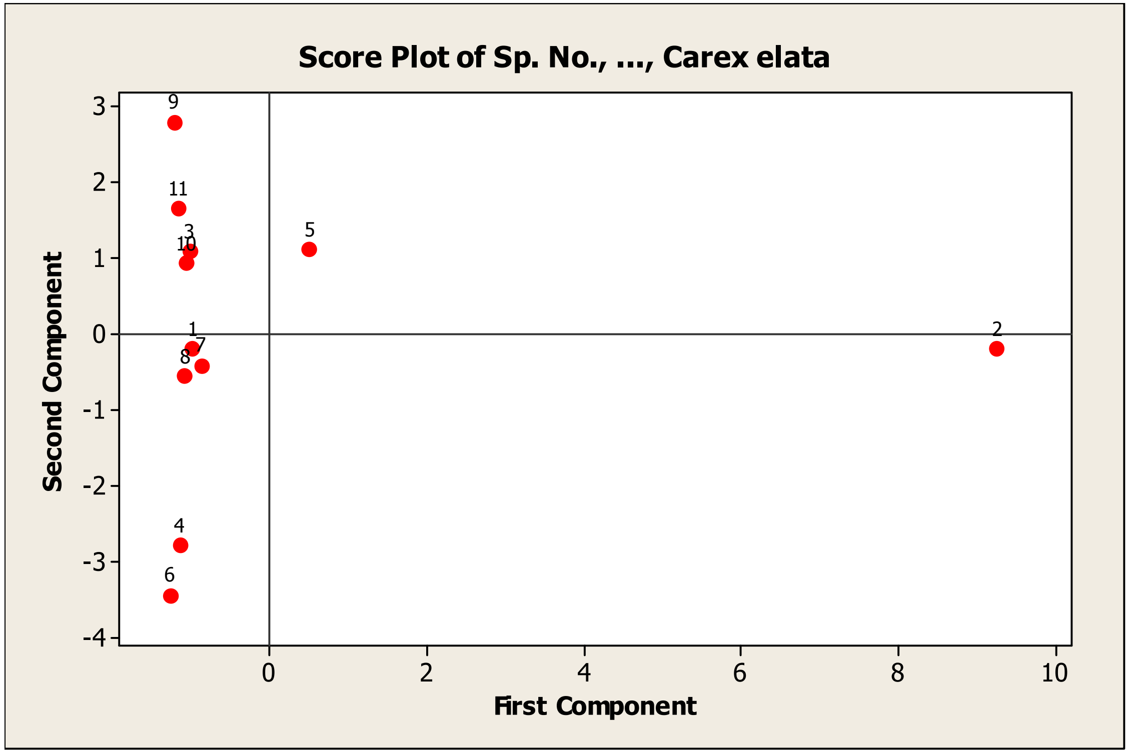
Appendix 9. Plot of MMT for each species parameters localities grouping.



Appendix 10. Plot of MMT for each species together with other plant community parameters.



Appendix 11. Plot of MMT for each species together with other plant community parameters localities grouping.



Appendix 12. Location 3 – Beska.