PROJECT TITLE:

Strengthening the scientific foundation of water quality programs

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ACTION 3: RIVER BASIN FUNCTIONS AND VALUES ANALYSIS AND WATER QUALITY CRITERIA DETERMINATION

DELIVERABLE 3: LIST OF ECOLOGY- DRIVEN WATER QUALITY INDICATORS AND CRITERIA VALUES

Final Report

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Contents

1. INTRODUCTION

The estimation of reference conditions is crucial in any ecological assessment program (Moss et al., 1996). These provide the baseline which is used to determine human-induced lake changes . This made it possible to draw conclusions of the degree of the human impact on a lake's current status or potential for future changes. The most recent comprehensive European water legislation, the Water Framework Directive (WFD), prescribes the assessment of ecological status of surface waters as determined by the lower of the values for the biological and physico-chemical monitoring results for the relevant quality elements. This is done by using an Ecological Quality Ratio (EQR), which describes the ratio between reference and observed values of the relevant biological quality elements as a number between zero and one (European Commission, 2000).

Most if not all inland standing water bodies have been impacted in some degree by human activities, either regionally or by means of long-range transboundary air pollution, and reference conditions could realistically represent the least impacted conditions or what is considered to be the best known attainable conditions. This situation is much worse in the case of salt lakes especially in Cyprus where the researches for the temporary standing water bodies are very limited. The limited number of studies on the ecosystems of temporary salt lakes is restricted in Cyprus but is a global phenomenon (Williams, 2002). Thus, there is a significant lack of scientific information about the reference condition of temporary salt lake ecosystems.

The principles behind the establishment of physico-chemical quality boundaries for Larnaca salt lake were based on the "reference best case situation" which allows authorities to set the standards/objectives at appropriate levels. This definition is however not in line with the wording of the WFD and WFD guidance documents but is essential in cases like temporary ecosystems where there is no other scientific way of setting reference values.

Best available is not the same as reference conditions. Reference conditions are not a target but are the point from which to measure change, estimate the ecosystem's degradation and get guidelines of how to improve the ecological status of the ecosystem (Wallin *et al.,* 2002).

The main concept for defining the boundaries for managing Larnaca's Salt Lake ecosystem was based on the appearance and abundance of aquatic macrophyte species, which are identified as indicators of good ecological status, in combination with the results from Deliverable 2.

The main criteria for setting the boundaries are:

- **Presence** and **abundance** of **indicator** aquatic macrophyte species According to WFD, different lake sites can be sorted by their deviation is species composition and abundance from reference sites (Schaumburg *et al.*, 2004).
- **Good chemical quality status**. Although many nutrients are involved in plant growth, carbon, nitrogen and phosphorus are the key factors for aquatic plant life, and their availability therefore governs primary production in aquatic ecosystems (Bornette & Puijalon, 2010). Nitrate may be used as a nitrogen source by aquatic macrophytes but high concentrations may lead to the dominance of more competitive species and low species richness (James et al., 2005). Nutrients concentration is the crucial factor that can control the ecosystems ecological status. Extreme values of nutrients especially nitrogen nitrate may lead to eutrophication (Irfanullah & Moss, 2004). Eutrophication was first recognized as a problem in freshwater ecosystems (Cardoso *et al.*, 2001). In coastal waters is a more recently recognised phenomenon, the scientific understanding of which is still in progress (Cloern, 2001).

- **The hydrological processes** constitute a main controlling factor for the formation, functionality, size and persistence of the salt lake complex Changes to the ecosystem status can be the result of water's move within or through the wetland (Carter, 1999).
- **Aquatic macrophytes tolerance in fluctuations of Water Environmental Parameters.** The most significant factors affecting macrophyte distribution are *pH*, total *dissolved* solids and total *alkalinity* (Rout & Shaw, 2001, Pip, 1984)
- **Control** and **identification** of the best quality sampling site. Sites appearing nearly undisturbed in physico-chemical parameters (e.g. pH, salinity, saprobic and trophic status) and hydromorphological and biological conditions can be chosen. In the REFCOND- Guidance of the EU is defined that high ecological status is equal to reference conditions (Wallin *et al*., 2002).
- **Definition of the water quality standards** according with legislation and the fluctuation of physicochemical parameters of the reference site.

2. RESULTS

According to the results and the field observations, the southwestern section (station 3) of the salt lake has been assessed as of Good quality, suitable for being considered as a reference location. It is therefore considered that the physicochemical characteristics of this area are appropriate criteria for ensuring the long term preservation of the good ecological status of the salt lakes. These values will furthermore be used as the basis for determining criteria values for the entire salt lake. Suitable analysis and interpretation of these measurements has therefore been undertaken.

Specifically the main criteria for defining Station 3 as the best representative location were:

- **Low abundance or lack of filamentous algae** during sampling periods. The filamentous algae appear to have an opportunistic strategy. The most tolerant marine algae, such as *Ulva* and *Enteromorpha*, appear to be opportunistic species (Orfanidis *et al*., 2001; Coelho *et al*., 2000; Lobban & Harrison, 1994).
- **Presence and abundance of *Riella helicophylla***, a liverwort with low tolerance and high standards of environment quality (Hugonnot & Hebrard, 2004)
- **Abundance of angiosperms** dominating the site, and creating microhabitats supporting the ecosystems functionality (Loreau *et al*., 2001, Fridley, 2001)
- Functionality supporting **biodiversity**. Numerous avifaunal species were recorded feeding and breeding during the sampling periods 2010-2011, (Hooper *et al*., 2005).
- The **good quality scores of Ecological Evaluation Index (EEI)** (Orfanidis *et al*., 2003) index were encouraging and helpful in defining the status of which the ecosystem should be monitored.

2.1 Tolerance of aquatic Plants in Environmental Parameters

According to the literature and the site observations, the environmental factors that seem to influence species occurrence and abundance in the Larnaca Salt Lake complex are *salinity* and the *length of the wet period*. In brackish temporary lakes, because of their intermittent position between land and sea, the salt content, and therefore their freshwater content, fluctuates widely. These factors formulate a harsh environment, which considerably influences the establishment of aquatic plant assemblages and results in low aquatic biodiversity. Only a small number of species manage to develop survival strategies adaptive to such hypersaline temporary environments. These species have specific adaptations to high salinity and water level fluctuations. Some species for example reduced their life-cycle (from germination to fruit production) duration in order to complete its life-cycle within a period of 3 months, and this enables them to occur in habitats drying up early in summer. Some other species produce spores that exhibit dormancy and are capable of retaining their germinative capacity for at least three months, while they can survive desiccation for many years.

As a result, it is important to protect the small number of species which develop survival strategies in temporal brackish environment by protecting and providing the minimum length of the wet period.

Considering nutrient concentrations, Total Phosphorus (TP) and nitrate nitrogen (NO_3-N), seem to be the most important water chemical parameters that affect plant abundance by influencing the appearance of filamentous algae. Many species of algae in temporary environments appear to be opportunists. In many types of temporary waters, the formation of algal mats, especially those formed from the drying and felted remains of filamentous species, can be crucial to the survival of other organisms that may take refuge under them during drought. However, opportunistic species, favoured by high nutrient concentrations like *Ulva intestinalis* and *Chaetomorpha linum* can take a competitive advantage and really dominate the Salt Lake. The phenomenon was observed at the area, for a period of 6 months (Winter 2009-Spring 2010).

Therefore it is necessary to set a minimum level of Total Phosphorus (TP) and nitrate nitrogen (NO_3-N) concentrations in order to preserve the co-existence of angiosperms and algae species. It is well known that the most important chemical parameters that could lead to eutrophication are nitrate nitrogen and phosphorus nutrients. Thus we suggest to further research the range of concentrations of the above nutrients in the concept of habitat conservation and management.

Biodiversity decreases generally as salinity increases. However, the relationship may not be linear and direct. Decrease in biodiversity may follow drastic changes in abundance of species in accordance with salinity preference or tolerance. Generally biota typical of low salinities has narrow salinity tolerance. There is some biota with a wide range of tolerance especially at intervals of 50-100g/l and 100-200g/l. Beyond a specific point of salinity, other factors may determine species richness. It is important to determine the salinity tolerance of biota to assess the impact of mining (John 2001).

Table 1: Range of values of the most important environmental and physicochemical variables of each aquatic plant species.

	Depth (m)	***Length of wet period (months)**	***Salinity (‰)**	**pH**	***TP** (mg/l)	**PO$_4$-P** (mg/l)	***NO$_3$-N** (mg/l)	**NH$_4$-N** (mg/l)	**T (°C)**
Dunaniella salina	<1[w]		20 - 350[w]						
Artemia salina	<1[w]		20 - 350[w]						
Branchinella spinosa	<1[w]		20 - 350[w]						
Riella helicophylla	0-1[a]	3	2-190[a]	7-8.5[a]					
Lamprothamnium papulosum	<2		6-3[a]		<103				
Chara canescens	shallow		1.77-22[r]	Appeared in large eutrophic lake with well-developed vegetation of halophytes [r]					
Chaetomorpha linum			7.7-30.2 [b]		Opportunistic species, favored by high nutrient concentrations. [u,v]				
Ulva intestinalis									
Ulva olivascens									
Ruppia maritima var *brevirostris*	<2 [f]	3	1-42[J]	6.0-10.4[i&j]		0.06-4.94[n&p]	0.0-7.1[k&l]	0.01-2.6 [m&n]	15-25 [&g]
Althenia filiformis	<0.5[c]		<34[c]						10-30 [D]

a:Hugonnot & Hebrard (2004) , b: Phillips, (1960), c: Onnis, A., (1974), d: Cook, and Guo, (1990), e: Bourn, (1935), f: Phillips, (1960), g: Setchel, (1924), h: Verhoeven, (1980), i: Joanen and Glasgow, (1965), j: Verhoeven, (1979), k: U.S. Geological Survey, (1976-1979), l: Schwartz and Gallup, (1978), m: Neel, Peterson and Smith, (1973), n: Orth and Moore, (1982), o: Roy and Neely, (1962), p: Van Vierssen, (1982b), q: Winter and Kirst, (1991), r: Langangen, (2004), s: Menendez, (2005), t: Vidal and Morgui, (2000), u: José et all, (2009), v: Aquatic Botany Volume (82) (2005), w: NATURA 2000 Network, x: Orfanidis et al. (2001,2003)

2.2. SUGGESTED QUALITY CRITERIA

The water quality standards for the sustainable management of Larnaca Salt Lakes ecosystem are defined on the tables below (Table 2, 4 &5). The upper and lower limits of each parameter are defining the ecological conditions, for the conservation of ecosystems functionality.

Table 2: Mean and median values of water physicochemical parameters, for all sampling visits at Station 3.

	Mean±Std.Error	Median	Std. Deviation	Minimum	Maximum
Temperature (^{0}C)	24,22±3,206	25,21	7,85	12,8	36,4
Conductivity (mS/cm)	**37,51±6,933**	**39,94**	**16,98**	**15,59**	**62,08**
DO (mg/l)	8,15±3,482	4,21	8,53	3,55	25,24
%O_2	94,43±32,160	61,00	78,78	44	251,8
Salinity ($^0/_{00}$)	**31,14±8,843**	**27,51**	**21,66**	**9,15**	**67,7**
pH	9,02±0,296	9,12	0,72	7,69	9,82
NO_3-N (mg/l)	1,80±0,802	0,86	1,96	0,24	4,4
NO_2-N (mg/l)	0,01±0,003	0,01	0,01	0	0,02
NH_4-N (mg/l)	2,85±0,830	2,55	2,03	1,09	6,6
DIN (mg/l)	4,66±1,123	4,78	2,75	1,33	7,61
SRP (mg/l)	**0,26±0,066**	**0,22**	**0,16**	**0,1**	**0,5**
TP (mg/l)	0,46±0,202	0,30	0,49	0,04	1,25

The fluctuations of Conductivity, Salinity and SRP appear to have significant differences between all sampling visits, which signify the trend of seasonal changes in water chemical status (Table 2). These fluctuations of environmental parameters seem to be the limiting growth factor which determine the seasonal functionality of the ecosystem.

Table 3: Normality test and ANOVA test between dry and wet period. Bold =significantly different

	Normality test	ANOVA Test	
	Kolmogorov-Smirnov	F	Sig.
Temperature (^{0}C)	0,20	4,920	0,091
Conductivity (mS/cm)	**0,20**	**11,276**	**0,028**
DO (mg/l)	0,05	0,445	0,541
%O_2	0,10	0,176	0,696
Salinity ($^0/_{00}$)	**0,20**	**8,872**	**0,041**
pH	0,14	1,401	0,302
NO_3-N (mg/l)	0,11	2,745	0,173
NO_2-N (mg/l)	0,12	1,000	0,374
NH_4-N (mg/l)	0,20	0,563	0,495
DIN (mg/l)	0,20	0,157	0,712
SRP (mg/l)	**0,20**	**10,265**	**0,033**
TP (mg/l)	0,20	2,022	0,228

The results showed that there is no statistically significant difference between Wet and Dry period of the physicochemical variables in sampling station 3. However, it is well known that ecosystems functionality, productivity and primary producers growth rate is strongly influenced by water salinity and the water level fluctuations (De Casabianca et al., 1997; Bonis & Lepart 1994, Grillas 1990, Haller et al., 1974, etc).

According to the Wetland Management Profile of Australian Government about arid and semi-arid lakes, a variation in size, depth, salinity and turbidity is observed while they cycle through periods of wet and dry. The ecology of their plant and animal species is tied to this cycle. (Wetland Management Profile: Arid and Semi-Arid Lakes).

The limited available data (only 8 monthly samplings) might affect the reliability of ANOVA results. The time limitation for intergrading this study, might not reflect the real changes on the ecosystems status and functionality during Wet (Table 4) and Dry period (Table 5). In addition, short duration of Wet period has limited even more the field work which it was confined to 4 months annually (December-March). Furthermore the early beginning of Dry period (April-June), characterized with high temperature and evaporation (http://www.moa.gov.cy), has dramatic effects on water depth and salinity. According to literature and our own observations during the application of Action 3, the implementation of a management model separated in two different periods (Wet-Dry), seems to be the ideal for effective management and conservation of the Wetland.

Furthermore, organizing a sampling schedule that considers environmental factors (avoid sampling after rainfall incidents during Wet period or at the end of Dry period because of organic material degradation) would lead to a more comprehensive collection of reliable data.

Table 4: Mean and median values of water physicochemical parameters of wet period sampling visits at Station 3.

	Mean±Std.Error	Median	Std. Deviation	Minimum	Maximum
Temperature (^{0}C)	18,897±3,359	19,5	5,819	12,80	24,39
Conductivity (mS/cm)	24,19±5,591	22,3	9,684	15,59	34,68
DO (mg/l)	11,14±7,053	4,43	12,22	3,75	25,24
%O_2	118,4±66,848	59,4	115,78	44,00	251,8
Salinity ($^0/_{00}$)	14,72±3,73	13,2	6,47	9,15	21,81
pH	9,353±0,242	9,23	0,419	9,01	9,82
NO_3-N (mg/l)	0,66±0,265	0,56	0,458	0,26	1,16
NO_2-N (mg/l)	0,01±0,006	0,01	0,01	0	0,02
NH_4-N (mg/l)	3,5±1,626	2,8	2,816	1,10	6,6
DIN (mg/l)	4,17±1,522	3,06	2,637	2,27	7,18
SRP (mg/l)	0,133±0,028	0,11	0,049	0,10	0,19
TP (mg/l)	0,193±0,153	0,04	0,266	0,04	0,5

Table 5: Mean and median values of water physicochemical parameters of dry period sampling visits at Station 3.

	Mean±Std.Error	Median	Std. Deviation	Minimum	Maximum
Temperature (^{0}C)	29,54±3,43	26,2	5,94	26,03	36,4
Conductivity (mS/cm)	50,83±5,63	45,2	9,75	45,2	62,08
DO (mg/l)	5,15±1,39	3,99	2,41	3,55	7,92
%O_2	70,47±11,33	62,6	19,62	56	92,8
Salinity ($^0/_{00}$)	47,55±10,37	41,76	17,96	33,2	67,7
pH	8,68±0,51	8,93	0,89	7,69	9,42
NO_3-N (mg/l)	2,95±1,35	4,2	2,35	0,24	4,4
NO_2-N (mg/l)	0,00±0,00	0	0,01	0	0,01
NH_4-N (mg/l)	2,20±0,61	2,3	1,06	1,09	3,2
DIN (mg/l)	5,147±1,935	6,50	3,35	1,33	7,61
SRP (mg/l)	0,38±0,07	0,4	0,13	0,25	0,5
TP (mg/l)	0,72±0,33	0,8	0,58	0,1	1,25

3. General Conclusions

According to the results of the 2 years monitoring of abiotic and biotic parameters, the ecosystem is in a delicate balance with the environmental factors (Temperature, Rainfall, and Salinity).

Due to the ecosystem type -semi-arid temporary salt lake- any change that could affect the ecosystems main characteristics (drainage water diversion, nutrients increase, low annual rainfall etc.) could lead the functionality of the ecosystems to imbalance and collapse.

The chemical evaluation of Salt Lake water body, due to the lack of trophic indices specified on semi-arid temporary salt lakes, was performed using trophic indices developed for freshwater lakes (OECD, 1982) and coastal waterbodies (Vollenweider *et al*. 1998). The implementation of both trophic indices resulted low ecological quality because of high nutrients concentrations. The relatively low chemical condition of the salt lake complex might possibly cause from the application of inappropriate indices. The implementation of a biological indicator (Orfanidis, 2003), resulted higher quality score about the ecological status. Due to their key role on ecosystem functionality, aquatic plants are essential for getting good ecological status of aquatic ecosystems and it is therefore necessary to preserve such communities in wetlands.

For the purposes of the current project (Life-Water), the methodology chosen for setting boundaries for all environmental parameters and the evaluation of the ecological status, was that of the *best representative location* (Wallin, 2002). The "Best representative" approach is not the same as the "reference condition". Reference conditions is not the target but it is the point from which to measure change, estimate the ecosystem's degradation and get guidelines of how to improve the ecological status of the ecosystem. Most if not all inland standing water bodies have been impacted to some degree by human activities, either regionally or by means of long-range transboundary air pollution, and reference conditions could realistically represent the least impacted conditions or what is considered to be the best known attainable conditions (Wallin *et al*., 2002).

According to the results and the field observations, the southwestern section (Station 3) of the salt lake has been assessed as of *good* quality, and therefore suitable for being considered as a best representative site.

Lapidary, the main reasons of defining Station 3 as the *best representative* site are:

- **Low abundance or lack of filamentous algae** during sampling periods. (Orfanidis *et al*., 2001; Coelho *et al*., 2000; Lobban & Harrison, 1994).
- **Presence and abundance of *Riella helicophylla***, (Hugonnot & Hebrard, 2004)
- **Abundance of angiosperms** dominating the site, and creating microhabitats supporting the ecosystems functionality (Loreau *et al*., 2001, Fridley, 2001)
- **Functionality supporting biodiversity**. High number of aquatic macrophytes as well as helophytic and halophytic vegetation
- The **good quality scores of Ecological Evaluation Index** (EEI, 2003)

It is therefore considered that the physicochemical characteristics of this area are appropriate criteria for ensuring the long-term preservation of a *good* ecological status of the salt lakes. These values will therefore be used as the basis for determining criteria values for the entire salt lake. On the other hand, the most impacted part of the lagoon is located at the northwestern part (Station 5). This assumption is improved by the plant community observed (lack of angiosperms) in the area and is expected to be confirmed by water quality Index (Orfanidis, 2003).

Therefore, the proposed limits for the physicochemical parameters (Table 4 & 5) that we suggest as boundaries for the Basins 4 software are based on the seasonal fluctuations of the parameters, recorded at Station 3. Concluding, the proposed limits (Table 4 & 5) are safety limits for the conservation of the current ecological status at the ecosystem for each period (Wet-Dry). However in order to assess the habitat quality of salt lake ecosystems, the development of a biological index adjacent to temporary semi-arid a salt lake is necessary. The development of such index, requires basic research for the correlations between biotic parameters, physicochemical water parameters, environmental parameters and the anthropogenic impacts.

4. BIBLIOGRAPHY

Bonis, A., & Lepart, J., (1994). Vertical structure of seed banks and the impact of depth of burial on recruitment in two temporary marshes. Kluwer Academic Publishers. Printed in Belgium. 127 Vegetatio 112: 127-139, 1994.

Bornette, G., Puijalon S., (2010). Response of aquatic plants to abiotic factors: Aquatic Sciences. 2010 73(1).

Bourn, W.S (1935). Sea-water tolerance of Ruppia maritima L. Contrib. Boyce Thompson Institute.

Cardoso, A.C., Duchemin, J., Magoarou, G., Premazzi, G., (2001). Criteria for the identification of freshwaters subject to eutrophication. Their use for the implementation of the 'Nitrates' and'Urban Waste Water Treatment Directive'. Office for official publications of the European Communities, Luxembourg, p. 87.

Carter Virginia (1999). Wetland Hydrology, Water Quality, and Associated Functions, Technical Aspects of Wetlands. National Water Summary on Wetland Resources. United States Geological Survey, Water Supply Paper 2425.

Cloern, J.E., (2001). Our evolving conceptual model of the coastal eutrophication problem. Marine Ecology Progress Series 201, 223–253.

Coelho, S. M., Rijstenbil, J. W. & Brown, M. T., (2000). Impacts of anthropogenic stress on the early development stages of seaweeds. Journal of Aquatic Ecosystem Stress and Recovery, 7: 317- 333.

Cook, C.D.K. and Guo Y.H, (1990). A contribution to the natural history of Althenia filiforrnis Petit (Zannichelliaceae). Aquatic Botany, (38):261-281.

De Casabianca, M. L., Laugier, T., & Marinho-Soriano, E. (1997). Seasonal changes of nutrients in water and sediment in a Mediterranean lagoon with shellfish farming activity (Thau Lagoon, France). – ICES Journal of Marine Science, 54: 905–916.

Fridley, J.D., (2001). The influence of species diversity on ecosystem productivity: how, where, and why? Oikos, 93, 514–526.

Grillas, Patrick (1990). Distribution of submerged macrophytes in the Camargue in relation to environmental factors. Journal of Vegetation Science 1: 393-402, 1990.

Hammer, U.T (1986) Saline lake ecosystems of the World. Dr. W. Junk, Dordrecht, The Netherlands.

Hooper, D.U., F.S. Chapin III, J.J. Ewel, A. Hector, P. Inchausti, (2005). Effects of biodiversity on ecosystem functioning: a consensus of current knowledge and needs for future research. Ecological Monographs, 75, 3–35.

Hugonnot V. & Hebrard J.P, (2004). Riella helicophylla Information, note in Mediterranean Temporary Pools. Volume 2, Species information sheets Edited by Grillas, P., Gauthier, P., Yavercovski, N. & Perennou, C. 2004, pp. 130.

Irfanullah H. M., Moss B., (2004). Factors influencing the return of submerged plants to a clear-water, shallow temperate lake. Aquatic Botany Volume 80, Issue 3, November 2004, Pages 177-191.

IUCN (1993). The Wetlands of Central and Eastern Europe. IUCN, Gland, Switzerland, and Cambridge, UK.

James C, Fisher J, Russell V, Collings S, Moss B (2005) Nitrate availability and hydrophyte species richness in shallow lakes. Freshw Biol 50:1049–1063

Joanen T. and L.L Glasgow, (1965). Factors influencing the establishment of wigeongrass stand in Louisiana. Proc. Southeast Association. Game Fish Community. (19) pp.78–92.

José A. Zertuche-González, Víctor F. Camacho-Ibar, Isaí Pacheco-Ruíz, Alejandro Cabello-Pasini, Luis A. Galindo-Bect, José M. Guzmán-

Calderón, Víctor Macias-Carranza and Julio Espinoza-Avalos (2009). The role of Ulva spp. as a temporary nutrient sink in a coastal lagoon with oyster cultivation and upwelling influence. Journal of Applied Phycology Volume 21, Number 6, 729-736.

Langangen A, (2004). Charophytes from four Cyclades Islands (Mykonos, Naxos, Paros and Antiparos) in Greece p. 31-38. Journal of Biological Research 1: 31– 38.

Lobban, C. & Harrison, P. J., (1994). Seaweed ecology and physiology. Cambridge University Press. 366 p.

Loreau, M., S. Naeem, P. Inchausti, J. Bengtsson, J.P. Grime, (2001). Ecology—Biodiversity and ecosystem functioning: Current knowledge and future challenges. Science, 294, 804–808.

Menendez M, (2005). Aquatic Botany 82: 181–192.

Mitsch, W.J. and J.G. Gosselink, (1986). Wetlands. Van Nostrand Reinhold, New York. 539 pp.

Mitsch, W.J. and J.G. Gosselink, (2000). Wetlands, 3rd Ed. John Wiley & Sons, New York. 920 pp.

Mitsch, W.J. and Wilson, R.F. (1996). Improving success of wetland creation and restoration with know-how, time and self-design. Ecological Applications 6:77-83.

NATURA 2000 Network. Cite Name:Alykes Larnakas Cite Code: CY6000002

Neel J.K., S.A. Peterson and WL Smith, (1973). Weed harvest and lake nutrient dynamics. USEPA Ecol. Res. Ser. No. 660/3-73-001.

Nixon, S.W., Buckley, B., Granger, S., Bintz, J., (2001). Responses of very shallow marine ecosystems to nutrient enrichment. Journal of Human and Ecological Risk Assessment 7, 1457–1481

Onnis, A., (1967). Contributo alla conoscenza dell'areale e della ecologia della Althenia filiformis. Petit in Sardegna. Atti Soc. Toscana Sci. Nat. Nem. P. V. Pisa Ser. B, 74: 1-20.

Onnis, A., (1974). Althenia filiformis Petit: Contributo alla conoscenza della ecologia della germinazione. G. Bot. Ital., 108:105-111.

Orfanidis, S., Stamatis, N., Tsiagga, E. & Schramm, W., (2001). Variability of the characteristics of seaweed communities in a eutrophic lagoon (Vassova, N. Greece). Proc. 7th Int. Phycological. Cong. Phycologia 40 (4), supplement, 117 p.

Orfanidis, S., Panayiotides, P., Stamatis ,N. (2003). An insight to the ecological evaluation index (EEI). Ecological Indicators 3 (1): 27-33.

Orth and Moore, (1982). Anthesis and seed production in Zostera marina L. (eelgrass) from the Chesepeak Bay. Contribution No.1068 from the Virginia Institute of Marine Science, College of William and Mary. Aquatic Botany Volume 15, Issue 2, February 1983, Pages 133-144.

Panayotidis, P., Siakavara, A., Orfanidis, S. & Haritonidis, S., (2001). Identification and description of habitat types at sites of interest for conservation. Study 5: Marine habitats. Final Technical Report, Athens October 2001.

Phillips, (1960). Observations on the ecology and distribution of the Florida sea grasses, Florida State Board of Conservation, Marine Laboratory, St. Petersburg, Florida.

Pip Eva (1984). Ecogeographical tolerance range variation in aquatic macrophytes, Hydrobiologia, Springer, Netherlands 0018-8158, Biomedical and Life Sciences, Volume: 108 Issue: 1 pp: 37-48

Ramsar Convention Secreteriat (2007). Wise use of wetlands: A Conceptual Framework for the wise use of wetlands. Ramsar handbooks for the wise use of wetlands, 3rd. edition, vol. 1. Ramsar Convection Secreteriat. Gland, Switzerland.

Rout, N.P., Shaw, B.P., (2001). Salt Tolerance in Aquatic Macrophytes: Ionic Relation and Interaction.Biologia Plantarum, 2001-03-01, Vol. 44, pp95-99, Springer Netherlands.

Roy A., and W.W. Neely, (1962). Biological controls for water- weeds. Transactions, North American Wildlife Conference, vol. (27), p. 107-113.

Schaumburg J., Schranz C., Hofmann G., Stelzer D., Schneider S., Schmedtje U., (2004). Macrophytes and phytobenthos as indicators of ecological status in German lakes. A contribution to the implementation of the Water Framework Directive Limnologica 34, 302–314. http://www.elsevier.de/limno

Schwartz F. W. and D. N. Gallup, (1978). Some factors controlling the major ion chemistry of small lakes: Examples from the prairie parkland of Canada. Hydrobiologia Volume (58), Number 1, 65-81.

Selig ER, Harvell CD, Bruno JF, Willis BL, Page CA, et al. (2006) Analyzing the relationship between ocean temperature anomalies and coral disease outbreaks at broad spatial scales. In: Phinney J, Hoegh-Guldberg O, Kleypas J, Skirving W, Strong A, editors. Coral reefs and climate change: science and management. Washington, DC: American Geophysical Union. pp. 111–128.

Setchel W. A., (1924). Ruppia and its Environmental Factors. Department of Botany, University of California. 1924 June; 10(6): 286–288.

Mendez M. (2005). Effect of nutrient pulses on photosynthesis of Chaetomorpha linum from a shallow Mediterranean coastal lagoon. Aquatic Botany Volume (82) (2005) p.181–192.

U.S. Geological Survey, (1976-1979) unpublished data. Eastern Stump Lake, Nelson County, North Dakota, May-October 1976-1979.

U.S. Water Resources Council, (1978). The Nation's water resources 1975–2000, Second National Water Assessment: Washington, DC, U.S. Government Printing Office.

Van Vierssen V, (1982). The ecology of communities dominated by Zannichellia taxa in Western Europe. I. Characterization and autecology of the Zannichellia taxa. Aquatic Botany Volume 12, 1982, Pages 103-155.

Verhoeven J.T.A., (1979). The ecology of Ruppia-dominated communities in western Europe. I. Distribution of Ruppia representatives in relation to their autecology. Aquatic Botany Volume (6), 1979, Pages 197-267.

Verhoeven, (1980). The ecology of Ruppia-dominated communities in western Europe. III. Aspects of production, consumption and decomposition. Aquatic Botany Volume 8, 1980, Pages 209-253.

Vidal, M., Morgui, J.A., (2000). Close and delayed benthic–pelagic coupling in coastal ecosystems: the role of physical constraints. Hydrobiology (429), 105–113.

Vollenweider, R.A., and Kerekes, J. (1982). Eutrophication of waters. Monitoring, assessment and control. OECD Cooperative programme on monitoring of inland waters (Eutrophication control), Environment Directorate, OECD, Paris. 154 p

Vollenweider R. A., Giovanardi F., Montanari G., Rinaldi A., (1998). Characterization of the trophic conditions of marine coastal waters with special reference to the NW Adriatic Sea: proposal for a trophic scale, turbidity and generalized water quality index. Environmetrics 1998;9:329-357.

Wallin, M., Wiederholm, T. & Johnson, R.K. (2002): Guidance on establishing reference conditions and ecological status class boundaries for inland surface waters. Produced by CIS Working Group 2.3 – REFCOND. 5th and final draft, Stand 20.12.2002, 89 pp.

Wetland Management Profile: Arid and Semi-Arid Lakes. Australian Government, Queensland Government.

William T. Haller, D. L. Sutton and W. C. Barlowe (1974). Effects of salinity on growth of several aquatic macrophytes. University of Florida and U.S.

Department of Agriculture, Agricultural Research Center, Fort Lauderdale, Florida 33314, Ecology (1974) 55, pp. 891-894

Williams, S.L. and M.H. Ruckelshaus. (1993). Eelgrass and epiphytes: the relative effects of nitrogen availability and mesoherbivory. Ecology 74:904-918.

Williams, S.L. and R.C. Carpenter. (1997). Grazing effects on nitrogen fixation in coral reef algal turfs. Marine Biology 130:223-231.

Williams W.D., (2002). Environmental threats to salt lakes and the likely status of inland saline ecosystems in 2025. Environmental Conservation 29 (2): 154–167.

Winter U. and Kirst G. O., (1991). Botanica acta, vol. (104), No. 1, pages 37-46.

Zalidis, G.C., Tavakoglou, V. and Gerakis, A. (1999b). Wetland restoration in the Mediterranean Basin. Pages 55-68 in W. Streever, editor. An international perspective on wetland rehabilitation. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Links:

http://www.moa.gov.cy

APPENDIX I: Raw data for all physicochemical parameters of all sampling periods.

YEAR	DATE	SAMPLE	T	Cond	D.O	%O2	Sal	pH	NO3	NO2	NH4	SRP	TP	Depth(m)
2010	1/4/2010	1	17,6	30,1	4,75	54	18,7	9,29	3,57	0,02	2,4	0,5	0,6	0,05
2010	1/4/2010	2	18,5	30,8	4,25	50	19,1	9,4	3,06	0,01	2,2	0,2	0,8	0,4
2010	1/4/2010	3	19,5	22,3	3,75	44	13,2	9,01	1,16	0,01	1,1	0,1	0,5	0,08
2010	1/4/2010	4	19,4	31,3	4,7	55,5	19,1	9,35	5,57	0,03	1,4	0,5	0,6	0,1
2010	1/4/2010	5	22,7	29,2	3,4	42	17,7	8,32	8,8	0,02	2	0,11	1,19	0,05
2010	1/4/2010	6	23,6	29,2	2,7	34,5	17,7	8,66	8,4	0,01	2,4	0,03	0,77	0,05
2010	1/4/2010	7	22	33,4	2,6	32,5	20,6	8,7	3,6	0,06	1,8	0,05	0,45	0,1
2010	1/4/2010	8	24,5	26,4	2,65	35	16	9,75	9,4	0	1,7	0,09	0,71	0,05
2010	25/4/2010	1	23,5	64,6	6,6	72,5	49,8	8,95	7,8	0,04	4,4	0,5	0,4	0,05
2010	25/4/2010	2	23	64,1	6,8	72,8	49,2	8,9	4,4	0	4,45	0,4	0,1	0,4
2010	25/4/2010	3	26,2	45,2	7,92	92,8	33,2	8,93	4,2	0	2,3	0,4	0,1	0,2
2010	25/4/2010	3	26,2	45,2	7,92	92,8	33,2	8,93	4,2	0	2,3	0,4	0,1	0,25
2010	25/4/2010	4	23,1	64,1	5,24	61,2	48,9	8,89	7,2	0	3,4	0,2	0,4	0,1
2010	25/4/2010	4	23,1	64,1	5,24	61,2	48,9	8,89	7,2	0	3,4	0,2	0,4	0,15
2010	25/4/2010	5	26,8	19,3	8,32	91,5	12,7	8,47	4,6	0,01	1,1	2,2	1,2	0,15
2010	25/4/2010	6	24,8	67,4	5,36	63,8	52,3	8,87	2,2	0,01	5	0,1	0,1	0,3
2010	25/4/2010	7	28,7	68,1	4,78	61,4	53,3	8,82	8,2	0,01	10	0	0,1	0,1
2010	25/4/2010	8	28,8	53,2	6,65	84,6	40	8,9	8	0,01	4,65	1,2	3,5	0,1
2010	25/4/2010	8	28,8	53,2	6,65	84,6	40	8,9	8	0,01	4,65	1,2	3,5	0,1
2010	29/5/2010	1	36,3	69,55	2,6	41,5	47,61	8,47	6,8	0,02	3,9	9	2	0,06
2010	29/5/2010	2	36	69,79	2,8	41,9	47,82	8,43	9,2	0,01	3,7	1,7	1,1	0,3
2010	29/5/2010	3	36,4	45,2	3,55	56	67,7	7,69	4,4	0,01	3,2	0,5	3,8	0,05
2010	29/5/2010	4	33,1	69,59	2,55	39	47,64	8,35	5,2	0,03	3,8	3,8	2,4	0,15
2010	29/5/2010	5	31,5	99,57	3,5	52	70	8,36	4,4	0,01	7,6	1,6	0,7	0,05

2010	29/5/2010	6	31,4	82,83	2,4	37	58,25	8,18	3,6	0,02	3,2	0,78	0,32	0,2
2010	29/5/2010	7	29,4	79,14	2,65	36,5	55,26	8,52	12,8	0,01	4,1	0,81	0,99	0,05
2010	29/5/2010	8	34,5	132,1	3,7	56	70	7,74	9,6	0,01	8,8	1,15	0,75	0,05
2010	4/7/2010	1							22	0	8,9	0,33	0,97	0,02
2010	4/7/2010	2							12,8	0,06	11,7	0,68	0,52	0,05
2010	4/7/2010	4							5,6	0,01	9,7	0,66	0,44	0,03
2010	4/7/2010	5							15,2	0,01	7,4	0,37	0,93	0,02
2010	4/7/2010	6							19,2	0	12,7	0,47	1,43	0,03
2010	4/7/2010	7							7,2	0	12,3	0,36	0,24	0,02
2011	16/1/2011	1	12,86	23,4	21,7	223,6	14,21	9,37	0,62	0,18	4,5	0,19	1,51	0,05
2011	16/1/2011	2	12,23	43,09	20,82	230,5	27,75	9,53	1,78	0,1	7,1	0,24	0,86	0,4
2011	16/1/2011	3	12,8	15,59	25,24	251,8	9,15	9,23	0,56	0,02	6,6	0,11	0,04	0,3
2011	16/1/2011	4	13,12	45,38	23,13	263,6	29,41	9,51	0,7	0,11	5,8	0,12	0,98	0,2
2011	16/1/2011	5	19,83	14,84	24,49	281,9	8,66	8,53	0,48	0,04	6,5	0,25	0,31	0,07
2011	16/1/2011	6	11,1	62,63	12,08	142,7	42,04	9,18	1,26	0,1	7,6	0,25	0,35	0,07
2011	16/1/2011	7	10,11	52,86	17,26	190,7	34,7	9,11	1,7	0,1	2,8	0,35	0,1	0,08
2011	16/1/2011	8	13,84	17,92	25,34	261,1	10,64	9,78	0,28	0	3,7	0,17	0,73	0,2
2011	13/3/2011	1	20,91	78,98	5	76,5	55,16	8,76	0,24	0,01	2,8	0,33	0,02	0,1
2011	13/3/2011	2	17,83	79,3	5,45	79,1	55,39	8,6	0,24	0,01	6,7	0,23	0,01	0,4
2011	13/3/2011	3	24,39	34,68	4,43	59,4	21,81	9,82	0,26	0	2,8	0,19	0,04	0,35
2011	13/3/2011	3	24,39	34,68	4,43	59,4	21,81	9,82	0,26	0	2,8	0,19	0,04	0,1
2011	13/3/2011	3	24,39	34,68	4,43	59,4	21,81	9,82	0,26	0	2,8	0,19	0,04	0,08
2011	13/3/2011	4	14,58	78,48	7,42	100,6	54,61	8,4	0,42	0,03	7,3	0,18	0,02	0,35
2011	13/3/2011	5	21,98	74,88	5	76,3	51,86	8,58	0,98	0,01	2,8	0,23	0,03	0,1
2011	13/3/2011	6	16,98	79,57	5,75	82,1	55,59	8,6	0,52	0,01	6,7	0,3	0,15	0,07
2011	13/3/2011	7	23	79,08	3,31	52,4	55,21	8,53	0,42	0,01	3,6	0,19	0,15	0,05

2011	13/3/2011	8	14,29	31,71	9,11	99,2	19,82	10,36	0,28	0	2,4	0,12	0,06	0,2
2011	10/4/2011	1	24,43	86,74	3,16	54,1	61,45	9,15	0,18	0,01	5	0,26	3,44	0,05
2011	10/4/2011	2	20,37	88,26	4,32	69,5	62,76	9,71	0,42	0,02	0,97	0,27	2,23	0,35
2011	10/4/2011	3	26,03	62,08	3,99	62,6	41,76	9,42	0,24	0	1,09	0,25	1,25	0,35
2011	10/4/2011	3	26,03	62,08	3,99	62,6	41,76	9,42	0,24	0	1,09	0,25	1,25	0,05
2011	10/4/2011	4	21,47	84,22	3,63	58,4	59,42	8,86	0,16	0	4,9	0,2	3,6	0,15
2011	10/4/2011	5	19,46	3,668	6,03	66,7	1,94	8,49	0,88	0,01	7	1,1	1,3	0,08
2011	10/4/2011	6	20,02	78,75	3,92	60	54,94	8,73	0,12	0	3,2	0,06	0,54	0,05
2011	10/4/2011	7	20,47	88,88	3,46	56	36,28	8,96	0,28	0	5,1	0,34	0,76	0,05
2011	10/4/2011	8	22,87	44,6	4,52	62,5	28,86	9,67	0,68	0,03	0,31	0,24	0,26	0,08