EVALUATION OF THE ECOLOGICAL CONDITION OF LAKE ULUABAT

Eddy Lammens
Marcel van den Berg

RIZA
Werkdocument 2001.197X

CONTENTS

SUMMARY *2*
KEY-PROCESSES *4*
External factors 4
Internal processes 4
Effects on birds 5
EVALUATION OF DATA *6*
Physical environment 6
Pollution 8
Submerged vegetation 11
Fish 11
Fishery 13
Birds 14
Zooplankton 14
SUGGESTIONS FOR FURTHER RESEARCH *15*
Fish 15
Birds 15
Zooplankton 15
Algae 15
Vegetation 15
RECOMMENDATIONS *17*
Water level 17
Pollution 17
Suspended matter 17
Fish stockings .... **Fout! Bladwijzer niet gedefinieerd.**
Fishery 17
LITERATURE *19*

SUMMARY

This report evaluates the ecological status of the lake using the results of the 1999-2000 monitoring and interviewing all the local experts regarding hydrology, fysico-chemical characteristics, fishery, birds and algae. Lake Uluabat is a lake with a natural water regime, but a high load of nutrients and a high fishing pressure. Water regime, nutrient load, fish exploitation and suspended matter are key-factors in ecological functioning of this shallow lake.

The water balance is dominated by the river inflow and outflow (River Kemalpasa). The water level follows the input of river Mustafa Kemalpasa with the highest levels in early spring (March-April) and the lowest levels in end of the summer (September). Both inflow and resuspension will be one of the main causes of turbidity. The residence time varies spatially over the lake, low in the western part, high in the eastern part. The nitrogen and phosphorus pool in the lake originates for 80 % respectively 70 % from the main inflow the river M. Kemalpaşa. The concentration of PO_4-P at the inflow of the river declined over the past 10 years from very high (0.15 mg l-1) to c. 0.02 in the end of the 1990's. The declining load is reflected in lower in-lake concentrations. In recent years the inlet water showed higher concentrations again. In the past, chlorophyll-a concentrations in the lake were probably affected by presence of aquatic vegetation and influence of the river. In spring 1999 outside the vegetation (based on mapping 1997) higher concentrations PO_4-P were found than inside the vegetation, where a clear water phase is observed. In summer 1999, the chlorophyll-a concentration was around 80 μgl^{-1} in the vegetation, but in spring and winter less that 30 $\mu g\ l^{-1}$. Outside the vegetation chlorophyll-a concentration was higher than inside the vegetation in spring and winter, with maximum values of 150 μgl^{-1}.

The emergent vegetation around the lake is zonated along a height gradient and the development is primarily caused by water level fluctuations. Based on the present zonation and literature data, a reduction in water level amplitude from 2 to 1 m may result in a reduction of about 50 % of the present area of reed vegetation. This has major negative consequences for the number and diversity of species directly and indirectly related to the reed beds.

From 1997 a map is available showing that plants cover c. 50 % of the lake, dominated by *Potamogeton*, *Najas*, *Valisneria*, *Ceratophyllum*, *Myriophyllum* and *Chara* spp. In 2001 it was observed that the submerged vegetation had almost completely declined. The fish community was dominated by pike, rudd, roach, white bream and *Alosa maeotica* in 1999. All fishes are relatively small. It is not clear why the population of crucian carp has developed so rapidly since that time. The main fishery is on cray fish, carp, pike and small fishes such as rudd, roach and crucian carp. Catches of cray fish varied from 2-40 tonnes, that is 1-5% of the original catch. Pike catches varied from 50-200 tonnes, carp 2-40 tonnes. Only the catches of small fish have increased in comparison to the period of intensive cray fish fishery. A very large part of fish community is available for the pigmy cormorants birds and most others fish-eating birds. However, the high turbity may cause some difficulties.

Suggestions are made for monitoring nutrients, algae, zooplankton and fish.

It is recommended that the natural water level fluctuation should be maintained as much as possible. The nutrient load has to go down from the current 1-4 g P $m^{-2}\,y^{-1}$ *to less than 1 g P* $m^{-2}\,y^{-1}$. *The fishery with the 18 mm gill-nets should be replaced with 60 mm nets and the number of nets should be reduced from ca. 10.000 to 500 60 m nets. The fishery with the fykes should be stopped*.

INTRODUCTION

On 15 April 1998 the Republic of Turkey designated the Ramsar status to lake Uluabat, a large lake just south of the Sea of Marmara.

It was decided (letter of the Ministry of Environment, ref.B.19.0.CKG.0.10.00/02) to prepare a Management Plan for lake Uluabat under the overall coordination of the Ministry of Environment with the participation of the General Directorate of State Hydraulic Works and the Society for the Protection of Nature (DHKD) as the main stakeholders. Other institutions, such as the Ministry of Agriculture and Rural Affairs, will also contribute to relevant parts of the study.

The Netherlands Ministry of Agriculture, Fishery and Nature Management provided expertise on wetland hydrology and ecology, as well as training on wetland management for two persons through participation to the International Course on Wetland Management in Lelystad, The Netherlands in 1999. This resulted in 1998 in a proposal for a hydrological and ecological study by Schot, Buijse & Wassen (1999). Following the recommendations of this report monitoring was done for one year and at the university of Utrecht a hydrological model of the catchment basin Uluabat/M. Kemalpass is developed in 2001 in order to determine the impact of dams on the hydrology of the lake (Vonk, 2001)

This report will evaluate the ecological status of the lake using the results of this monitoring and interviewing all the local experts regarding hydrology, physical-chemical characteristics, fishery, birds and algae. The evaluation will result in recommendations for extra monitoring next year and it will give recommendations leading to a durable ecosystem.

KEY-PROCESSES

Lake Uluabat is a lake with a natural water regime, but a high load of nutrients and a high fishing pressure. Water regime, nutrient load, fish exploitation and suspended matter are key-factors in ecological functioning of this shallow lake. Because these factors are affected by human impact it is important to realise what the consequences of changes in these factors are.

External factors

1. Water level fluctuation: the fluctuation is crucial for the development of emergent macrophytes and the high spring levels provide excellent conditions for spawning places for many fish species particularly pike and carp.
2. Nutrients: a high nutrient load will increase the instability of the ecosystem: the concentration of nutrients is very high and is an immanent threat for the water quality. The instability of the system increases as a consequence.
3. Fishery: overexploitation of the fish stocks changes the fish community into a community composed of mainly small fish. The fish yield will be much lower than its potential optimal yield and be composed of small fish. It will have a negative effect on the water quality , but the availability of prey fish for fish eating birds will be good.
4. Suspended matter: The river contains high concentrations of suspended matter mainly originating from mining activities and erosion. This causes a high water turbidity in the lake and due to sedimentation the lake gets filled up.

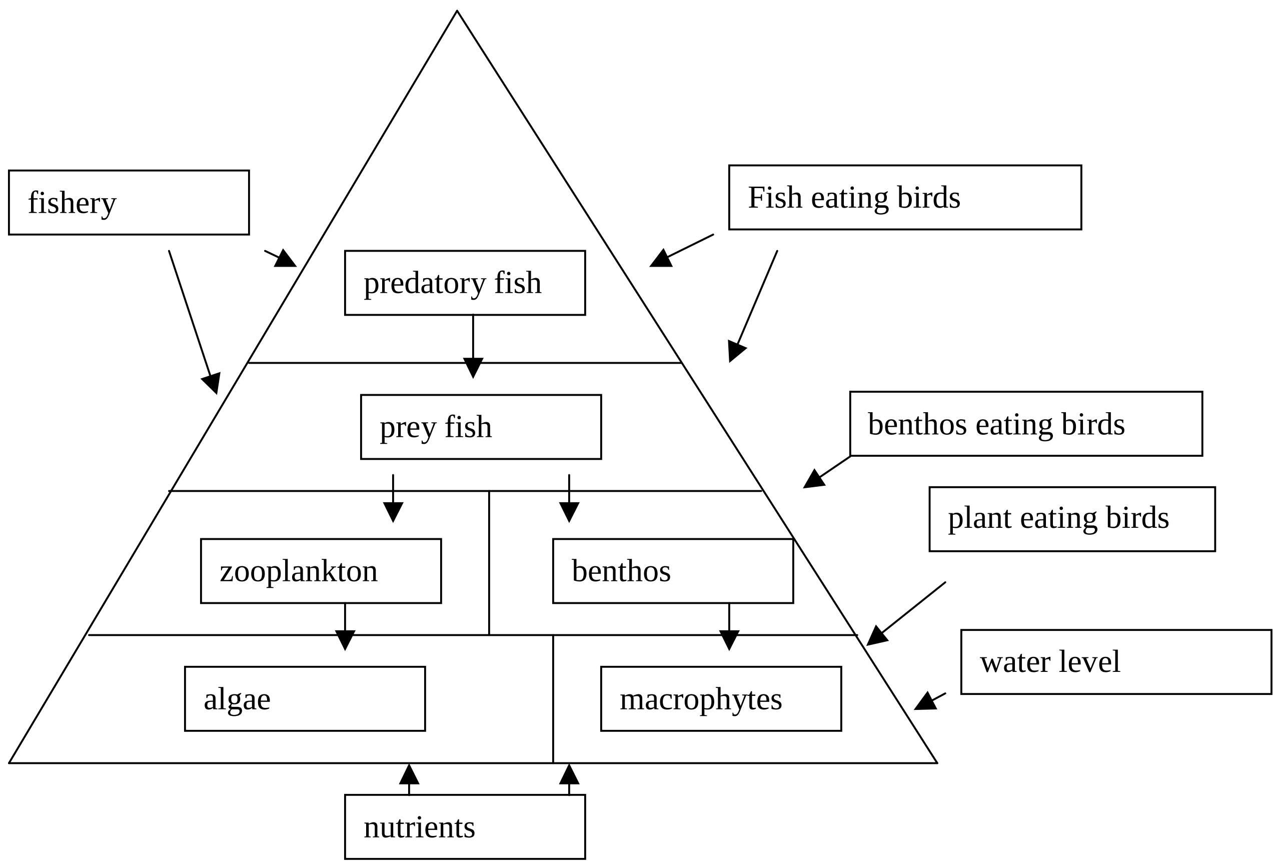
Internal processes

The external factors influence internal processes which are related with the population dynamics of macrophytes, fishes, zooplankton, algae and benthos.

1. Submerged macrophytes: submerged macrophytes have a key role in stabilizing the ecosystem, and provide habitat and food for organisms including birds and fishes. A high nutrient load is associated with a decline of submerged macrophytes because algae will profit more from the increasing nutrient concentrations and will shade macrophytes.
2. Emergent macrophytes: The development of emergent macrophytes is strongly dependent on water level fluctuation. Emergent macrophytes will decline when the water level is stabilized. For pike and carp emergent vegetation inundated in spring is a important spawning area.. Additionally, emergent macrophytes provide a key habitat and breeding places for many bird species.
3. Fishes: fish density and fish composition is affected in a direct and indirect way by fishery. If the fishery removes relatively more pike than prey-fish of pike, the survival of prey fishes will increase and may be favourable for fish eating birds.
4. Zooplankton: particularly large zooplankters will be negatively affected by a high abundance of prey fish and the chance for algal blooms will increase.
5. Algae: algal blooms will increase when macrophytes disappear and turbidity will increase
6. Benthos: the benthos will change towards chironomids and oligochaetes and will have negative effects on benthivorous birds

Effects on birds

1. Fish eating birds usually profit from the fishery, but can be caught in the nets. It is unsecure what their fate will be when the turbidity will increase. The foraging efficiency may become too low.
2. Benthos-eating birds. Feeding conditions will decline when macrophytes decline.
3. Plants-eating birds will disappear as soon as the macrophytes collapse and algae take over



EVALUATION OF DATA

Physical environment

Water balance

The water balance is dominated by the river inflow and outflow (River Kemalpasa). Less than 20 % of the total water in and outflow is determined by precipitation, irrigation and evaporation (p 44 of Altyanayar, 1998). The physical and chemical composition of the lake water is therefore primary related to river water quality. Over the past 10 years total inflow ranged between 20 and 100 $m^3s^{-1}y^{-1}$.

Table 1 Waterbalance of Uluabat based on a monthly time interval (hm^3; Altynayar, 1998)

Inflow		
River	Max	250
	Min	25
Precipitation	Max	10
	Min	3
Outflow		
River	Max	300
	Min	25
Evaporation	Max	30
	Min	4
Irrigation	Max	3
	Min	0

Water Level fluctuation and lake profile

The water level follows the input of river Mustafa Kemalpasa with the highest levels in early spring (March) and the lowest levels in end of the summer (September). The fluctuation typically varies between 1.5 and 3.5 m. From 1989 onwards the minimum water level highered with c. 1 m due to man-made construction at the outlet (Schot et al., 1999). The level profile of Uluabat is characterised by a more or less homogeneous distribution. Only the zone between 1 and 2 m occurs clearly more frequently than the other zones (total 40 %). The effect of water level changes are relatively large in this zone. The level profile is changing due to the suspended solid load through M. Kemalpaşa brook (Anonymous, 1989), with increasing shallower areas around the inflow of the river. The amount of suspended matter in inflow decreases over the past decades (c. 1200 ppm in the end of the sixties to c. 300 ppm in end of the eighties; conversion factor around 1.3 times ppm to get mg l^{-1}, provided by dhkd). The inlet water concentration was around 200 mg l-1 in 2000. The decrease in the suspended matter load is probably related to the lower activity of mining activities. In the present situation the suspended matter concentration is related with erosion and sand mining, and is in comparison to other rivers (Rhine, varying between 50 to

100) about 3 times as high.

Sedimentation rate
Because of the input of suspended matter a net sedimentation rate in the lake is expected. A rough estimation of the net sedimentation based on inlet quantity and concentration suspended solids in the inlet water showed that averaged sedimentation rate varies between 1 (1970) and 0.2 cm per year (2000). The sedimentation pattern, however, will not be evenly distributed over the lake. Around the entrance of the river in the lake, sedimentation will be much higher than at sites at some distance. Because of resuspension the *gross* sedimentation rate will be orders of magnitude higher, but this compromises effects on a local scale only. Both inflow and resuspension will be one of the main causes of turbidity.

Residence time
The residence time varies spatially over the lake. In the western part of the lake the water is transported in 2 to 5 weeks to the outlet. In the eastern part the residence time is probably much higher and may be last up to 6 months.

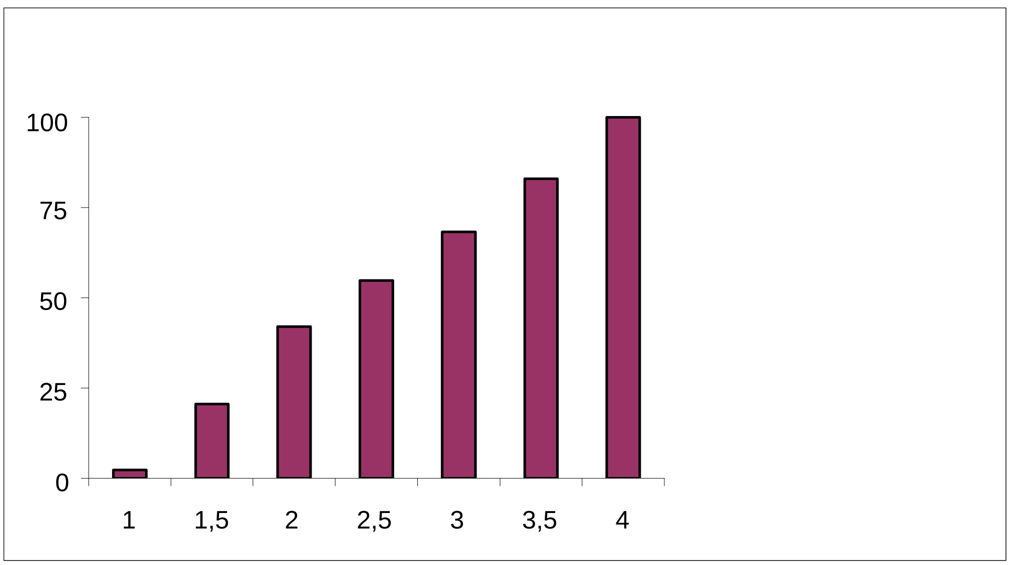


Fig. 1 Cumulative frequency distribution of water depth classes of Lake Uluabat based on a 1 km^2 grid (total 220 points) based on a map provided by dhkd. At around 4.5 m a dike is present.

Turbidity
Light attenuation is caused by suspended matter, chlorophyll-a, humic acids and the water itself. Suspended matter and chlorophyll-a will be the most important factors affecting the turbidity. The concentration of humic acids in Uluabat is expected to be low and more or less constant. Measurements in the eighties showed that the concentration of suspended matter varies in the lake on a temporal and spatial scale between 5 and 150 mg l^{-1}, with a average value of c. 50 mg l^{-1}. The highest concentrations are found at the inlet of the river. Suspended matter largely contributes to light attenuation. Concentrations of chlorophyll-a at the pumping station are low (< 10 µg l^{-1}) with some out layers to 40 during winter (1999-2000). In the lake, concentrations are

probably affected by presence of aquatic vegetation and influence of the river. In spring, at two spots outside the vegetation (considering the map of 1997) higher concentrations were found than two spots with some vegetation, where a clear water phase is observed. In summer (August 1999), chlorophyll-a concentration was around 80 µgl^{-1} at sites with some vegetation, but in spring and winter less that 30 µg l^{-1}. Outside the vegetation chlorophyll-a concentration was higher than inside the vegetation in spring and winter, with maximum values of 150 µg l^{-1}. Transparency in 1998-1999 was fluctuating between 40 and 160 cm Secchi depth, with the higher values in spring and lower values in end of the summer. Based on literature data the transparency in spring (160 cm) allows submerged macrophytes to colonise a maximum depth of 2 to 3 m, indicating that the light climate only at the most deepest sites can limit the development of submerged macrophytes. In July 2001, Secchi depth of almost the whole lake was between 10 to 20 cm. If this situation is representative for the whole year light is strongly limiting the growth and development of submerged macrophytes. Because vegetation was absent in 2001 and sediments are very vulnerable to wind induced resuspension, the water is expected to remain turbid.

Pollution

Nutrients

The nitrogen and phosphorus pool in the lake originates for 80 % respectively 70 % from the main inflow River M. Kemalpaşa. The inflow of PO_4-P declined over the past 10 years from very high (0.15 mg l^{-1}) to c. 0.02 in the end of the nineties possibly due to a periodically closing of slaughter houses along the river. The declining load is reflected in lower in-lake concentrations. In recent years the inlet water showed higher concentrations again (between 0.5 and 1.5 mg l^{-1} PO_4-P in 1999 to 2000). Indicatively, the averaged yearly nutrient load of Uluabat ranges between 1 and 8 g P m^{-2} y^{-1} (Table 2).

Measurements in 1999-2000 showed large spatial and temporal differences. At two sites the concentrations of PO_4-P concentration were low in spring (c. 0.005 mg l^{-1}) probably limiting for growth of algae. The total P concentrations are not measured, but can provide valuable information about the total amount of P in the water. Over the season concentrations of P are lowest in spring, but concentrations of nitrate were highest in this period. Nitrate concentrations were generally higher than 0.5 mg l^{-1} and unlikely to limit phytoplankton growth.

Table 2. Rough estimation of the nutrient load (N and P) of Uluabat over the past decade based on the average concentration of the dissolved nutrients in the inlet water (PO_4-P, NO_x and NH_x, see Altyanayar, 1998) and the yearly average water input. Note that the values are indicative, because total P and total N are not known and calculations are based on year averages.

Year	Concentration sum of dissolved P of river water mg l^{-1}	Concentration sum of dissolved N of river water mg l^{-1}	Inflow m^3 s^{-1}	P load g P m^{-2} y^{-1}	N load g N m^{-2} y^{-1}
83	0,08	0,848	38	1,0	10,2
84	0,225	0,91	118	8,4	33,9
85	0,1	1,1	32	1,0	11,1

86	0,115	0,835	76	2,8	20,0
87	0,146	0,641	66	3,0	13,3
88	0,128	1,068	38	1,5	12,8
89	0,302	0,971	17	1,6	5,2
90	0,256	0,968	36	2,9	11,0
91	0,308	1,333	38	3,7	16,0
92	0,358	0,986	27	3,0	8,4
93	0,133	1,018	35	1,5	11,2
94	0,02	1,169	21	0,1	7,7

Other sources of pollution

Pollution originating from leather and food (slaughter houses, fruits) industry have probably a negative impact on the water quality. The total amount of waste water and origin is roughly known (totally about 1 x 10^6 m^3 y^{-1}), but data on concentrations and exact composition of the pollution are not available. In general pollution consist of minerals (different chlorides: NaCl, $CaCl_2$ and carbonates) and a number of organic substances such as antioxidants. In addition, mining activities cause discharge to the lake of heavy metals (Arsenic, Boron). It is likely that these discharges can have a serious impact on the lake, but detailed data are necessary for interpretation.

Emergent vegetation

The vegetation around the lake is zonated along a height gradient and is primarily caused by water level fluctuations. From low to height roughly 3 important zones can be recognised:

1 open water (latitude 1 –2.5 m; c. 55 % of area)
2 reed zone (latitude 2.5- 3.25 m; c. 21 % of area)
3 frequently inundated land zone (latitude 3.25-4 m; c. 24 % of area)

The reed zone consists mainly of *Phragmites australis*, but scattered clumps of willows (*Salix* spp.) and *Typha* spp. are found frequently. The frequently inundated land zone consists of various vegetation types: marches of *Eleocharis*, *Scirpus*, *Tamerix* spp., but also cultivated land. From c. 1966 to 1998 the shoreline showed an increase of the reed zone, but dominantly related at the site where the river flows in the lake.

The potential role of changes in water level fluctuations for the reed zone can be estimated using the present zonation in Uluabat and experimental and empirical data presented for other ecosystems (Coops, 1996; Lenssen, 1998). Two important aspects can be recognized concerning the role of water level (see also figure 2):

1. A lower highest water level (spring) results in a lower the highest latitude of the reed bed. Under drier conditions the competition between reed and other plants is lost by reed and will rapidly lead to domination of highly competitive terrestrial species. This phenomenon occurs at many places in the Netherlands. Additionally, plants just out the water are vulnerable to bird or cattle graze, but as far as we know this is not very important in Uluabat.

2. A higher lowest seasonal water level (autumn) results in a higher lowest latitude of the reed bed. The maximum water depth of colonisation decreases in the same extent as the decrease in minimum water level. The die-back of the reed zones in the water may have two additional aspects: 1. deteriorating physical conditions due to wave action. Due to the reduction of water level change wave action occurs more often at the same latitude of the shoreline. Increased wave action reduces the biomass of emergent species due to mechanical damage. 2. Low water levels are needed for colonisation of emergent macrophytes species, because some species (i.e. *Phragmites australis*) germinate hardly under submerged conditions.

The seasonal course of the water level fluctuation is very critical, but is very complex and not considered here. Generally, the present seasonal course (in spring high and autumn low water levels) in Uluabat is close to ideal now.

This leads to the conclusion that a reduction in the water level amplitude on emergent vegetation will depend on the morphology of the lake. The latitude distribution of the reed zone is more or less homogeneous (figure 1). This implies that effects of changes in water level will be proportional to the decrease of amplitude of the water level. Indicatively, a reduction in water level amplitude from 2 to 1 m may result in a reduction of about 50 % of the present area of reed vegetation. This has major negative consequences for the number and diversity of species directly and indirectly related to the reed beds.

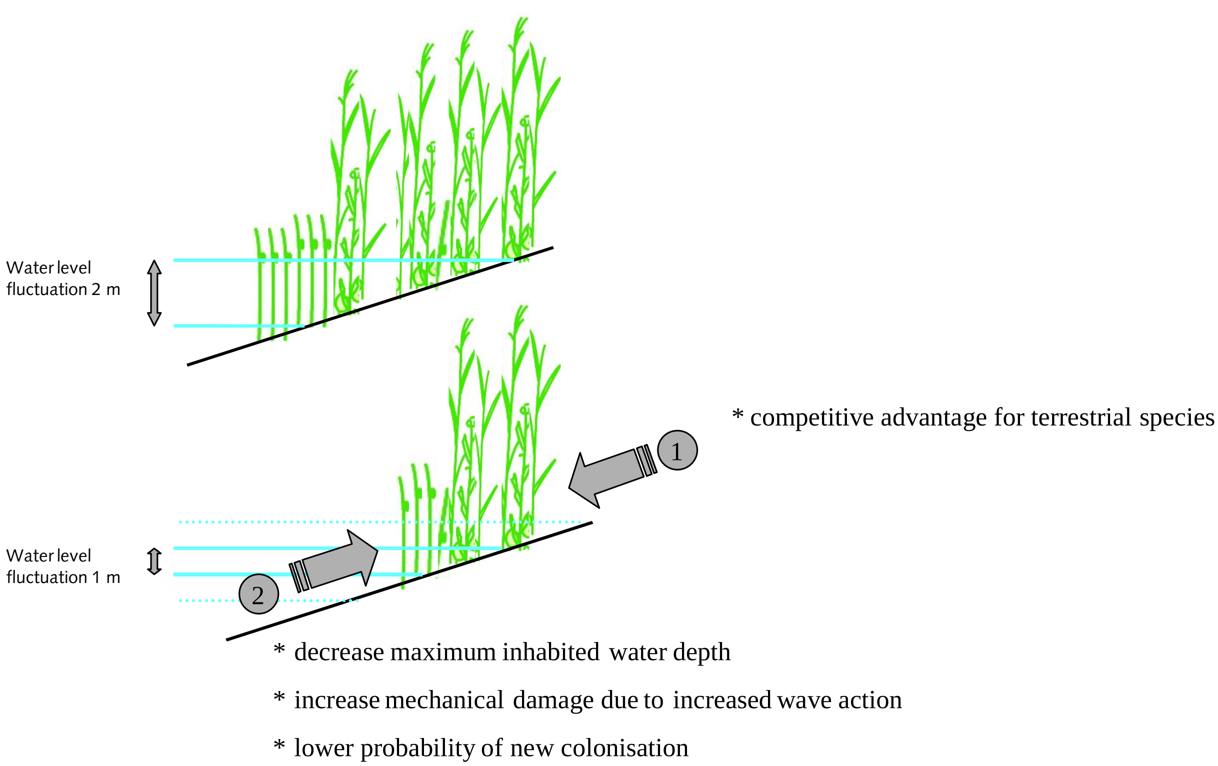


Fig. 2. Schematic overview of the relationship between water level fluctuation and emergent vegetation. The numbers in the figures refer to the causes for the die- back of the emergent vegetation and are further explained above.

Submerged vegetation

In three different studies (1954, 1987 and 1997) the aquatic vegetation was studied. Only from 1997 a map is available showing that plants cover c. 50 % of the lake, dominated by *Potamogeton* spp., *Najas* spp., *Valisneria*, *Ceratophyllum*, *Myriophyllum spicatum* and *Chara* spp. Altynayar (1998) referred to a study of Newman (1958) that the coverage in 1954 was estimated at 7.4 % of the lake. There is no information about the density of the stands. During our visit at the lake (early July 2001) only fragmentary stands of submerged macrophytes were found. Only the first 50 m along the shoreline vegetation occurs frequently, as well as in a very small part of the isolated NE part of the lake where also crystal clear water was observed. In the open water only *P. perfoliatus* was present in dense, but very small stands (<100 m^2 and very scattered over the lake, total cover far less than 1 %). Especially, in the northern part scattered vegetation of *Scirpus spp.* and *Potamogeton crispus* was found also covering less than 1 % of the lake area. Taxa as *Chara, Valisneria, Najas* spp. were not found in the open water at sites where they occurred frequently in 1997. Moreover, the number of herbivorous birds spending the winter (Coot) showed a strong decline the last years. This information together with anecdotic information provided by fishermen the submerged macrophyte cover and density declined dramatically since 1999. The present cover of submerged macrophytes is less than 1 % and the water is turbid.

Fish

1. Fish composition. The fish community is dominated by pike, rudd, roach, white bream and *Alosa maeotica*. (table 2*).* Particularly pike and rudd are merely associated with macrophytes. Pike needs high water levels in March-April for spawning in the flooded reed beds. At the moment the spawning conditions for pike and carp are still good, but the fishery pressure is extremely high (see next section

Table 2.Total number and total weight of fish caught in two sampling stations, once every two months with 18-20-22-26-30-36-55-70 mm mesh size and 40-50-60 mm mesh size monofilament gill nets.

Fish species	N	W	%W
S. erythrophthalmus (rudd)	6671	461.258	29.113
R. rutilus (roach)	9499	433.322	27.349
B. björkna (white bream)	8037	257.174	16.232
A. maeotica	3786	185.070	11.681
V. vimba (Blue bream)	1460	80.070	5.054

A. alburnus (Bleak)	1080	56.130	3.543
E. lucius (Pike)	70	49.871	3.148
C. chalcoides	734	46.084	2.909
C. carassius (Crucian carp)	81	8.637	0.545
C. carpio (Carp)	8	5.511	0.348
S. glanis (Catfish)	1	0.434	0.027
M. cephalus	1	0.410	0.026
B. plebejus	1	0.329	0.021
T. tinca (Tench)	2	0.061	0.004
Total	31433	1584.391	100

Special about the carp is that it has been stocked since 1983 (table 3). The stocking density is 4-100 per ha. There is no indication that this stocking has contributed to the yield of carp (see table 5).

Table 3. Number of juvenile carps stocked

Year	Number of juveniles
1983	1000.000
1984	400.000
1993	45.000
1995	200.000
1996	50.000
2000	50.000
2001	100.000

The fish community was monitored in 1999-2000. At that time crucian carp was not dominant yet (table 2). It is not clear why the population of crucian carp has developed so rapidly. It may be related to the overexploitation of the pike population and the consequent low predation pressure of pike on crucian carp. It is not uncommon to have crucian carp in vegetation-rich lakes, but is uncommon when they are as dominant as in Uluabat. The disappearance of the aquatic macrophytes in the open water and the high turbidity may be a direct consequence of the physical disturbance by crucian carp, as it is a benthic feeder.

2. Growth. Considering the long growing season and the high temperatures the growth seems to be extremely low for all fish species, at least after the first year. In the first year the growth is fast , but afterwards it is very slow. It is unclear why the growth rate is so slow, especially for pike considering the high abundance of prey fishes. For the other fish species it may be related to the high density of fish and consequent food competition.

3. Size composition: fishes are relatively small. Considering the high fishing pressure with small-meshed nets is it quite common

Fishery

1. Present situation

- Size composition catch: the size composition is not known in detail. In general it confirms the small mesh size used as sizes of landed fish are small.
- Seasonal variation: only during the shortest month of the year, Februari, fishing is not allowed, during the other months ca. 11.000 gill nets (60 m per net, 660 km when attached to each other) are used and 36.000 fykes. This exploitation is extremely high.
- The mesh size of the gill nets is 18 mm, which means that all fish larger than 9 cm are vulnerable for the nets.
- Total catch: 25-50 kg ha^{-1} $year^{-1}$ is caught of which ca. 10 kg is valuable fish (pike and carp). The rest is small (ca. 10 cm) , mainly rudd, roach and white bream. Last year (2001) crucian carp has become a large part of the catch.
- Birds are caught as by-catches. Experimental fishing learnt that pigmy-cormorants are regularly caught. Considering the large number of gill-nets it is probable that 250-1000 cormorants are killed by these gill-nets per year

1973-1986: the main fishery is focused on cray fish (*Astacus leptodactylus)* Catches varied from 250-860 tonnes per year (table 4). Apart from the intensive cray fish-fishery, there was an extensive fishery on pike and carp.

Table 4. Catch in tonnes of cray fish

Year	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	84
Catch	390	370	860	420	820	690	680	550	765	275	250	263

2. 1987-2000: the main fishery is on cray fish, carp ,pike and small fishes such as rudd, roach and crucian carp. Catches of cray fish varied from 2-40 tonnes, that is 1-5% of the original catch. Pike catches varied from 50-200 tonnes, carp 2-40 tonnes. Only the catches of small fish have increased in comparison to the period of intensive cray fish fishery.

Table 5. Catch of cray fish, pike, carp and other fish in kg

Years	Crayfish	Cyprinus carpio	Esox lucius	others
1985-86	311.496	74.000	156.000	46.000
1986-87	8.000	95.000	210.000	90.000
1987-88	-	30.000	75.000	30.000
1988-90	-	64.100	93.500	40.000
1990	11.053	22.400	76.300	22.300
1991	11.200	20.300	68.900	24.000
1992	23.111	6.595	66.300	28.000
1993	4.681	2.210	44.600	24.070
1994	38.735	17.110	178.666	373.647
1995	25.422	3.682	84.253	183.240
1996	3.000	26.218	95.202	73.056
1997	7.452	36.787	175.946	487.941

1999	39.708	28.122	78.976	258.799
2000	2.013	24880	52.536	100.810

The first years after 1984 the yield was similar or somewhat higher than in the period after 1990 when the fishery intensity was very high.

Birds

1. Prey selection: about the diet of pigmee cormorant is known that they feed on prey < 15 cm. This implicates that a very large part of fish community is available for these birds. Also for most of the other piscivorous fish size is not limiting. However, the high turbity may cause some difficulties. Cormorants and pelicans solve this problem by social foraging (observed in the lake): a large group of birds chases and exhausts the fish which makes them an easy prey. For solitary birds turbidity may be a serious problem. It still not clear if the number of other piscivorous birds has decreased yet.
2. Consumption per day: on a yearly basis the amount of fish eaten by piscivorous birds will be ca 2.5-5 kg ha^{-1} $year^{-1}$. This is little in comparison the amount caught by the fishery (ca. 10%)
3. Number of visits during the season: there will a new counting in the period September 2001-May 2002.

Zooplankton

1. Species and size composition: the size composition of the zooplankton is an index for the predation pressure of planktivorous fish. Nothing is known about the zooplankton community. A study will start this year (2001).

SUGGESTIONS FOR FURTHER RESEARCH

Fysico-chemical

It is recommended:

- to measure total phosphorus (tP), total nitrogen (Kjedahl), inorganic matter content of suspended matter (ash weight after drying,)
- to calculate the fraction of NH4-N in water from the NH3-N fraction
- to measure light attenuation. At the moment the turbidity is measured using NTU meter, but this reflects more the light scattering that light absorption
- to make a simple calculation of the nutrient load over a year and compare with other lakes using basis data of water inlet, outflow and concentration of inlet water.
- to analyse the cause for the decrease of suspended matter
- to montor year round (monthly interval) and at different characteristic sites in the lake.
- To monitor both water-inflow and outflow in order to make a good water balance.

Fish

- If the vegetation does not come back it is likely that the fish community will shift towards a community more adapted to turbid open water. Therefore it would be sensible to repeat the fish research programme of 1999-2000 in 2002 to evaluate if there are any changes in the fish community
- Use another method for age determination, for example fin-rays

Birds

- counting visits of birds (will be done in the period September-May)

Zooplankton

- Species and size composition
- Distribution

Algae

- if the vegetation does not come back it is likely that the algae community will shift towards a community more adapted to turbid open water. Therefore it would be sensible to repeat or continue the phytoplankton research in 2002 to evaluate if there are any changes

Vegetation

- Determination of density, and area per species, combining with level profiles of the lake. The depth distribution is a very good indicator for how critical the light conditions in the lake. Vegetation
- Short description of possible monitoring technique: The best technique is mapping the vegetation using permanent quadrates located by steel or wooden corners. Easier is the use of DGPS, but sufficient spatial resolution is a precondition (< 2 m). The quadrates (about 10 x 10 m) can be located along transects covering the whole lake and latitude (for example each dm change a new quadrate, starting at 4.5 m and ending at 1.5 m). At least

three transsects are needed at different parts of the lake to have an idea of the total vegetation cover. Vegetation cover is mapped by estimating the bottom covering area per species using the naked eye.

RECOMMENDATIONS

Water level

The natural water level fluctuation should be maintained as much as possible. Dramatic consequences for the emergent macrophytes (especially the reed beds, but also the frequently inundate meadows) are expected when declining the amplitude of the water level fluctuation. The present ecological value is strongly related to these habitats. The reed beds as well as the frequent inundated land zones are the main spawning habitats of many fish species, in particular pike and carp, and form the most important areas for breeding and foraging birds. When the electric power plant becomes operational the discharge of water should follow the natural regime and should not lead to a regular decrease in the amplitude of the water level fluctuation. The hydrological model developed by Vonk (2001) can be used to calculate the impact of dams on the lake.

Pollution

Nutrients
The nutrient load has to go down from the current c. 3 g P $m^{-2}y^{-1}$ (but probably higher) to less than 1 g P $m^{-2}y^{-1}$. The shift from a vegetation dominated system towards an algae dominated system is accelerated by high nutrient loads. Going back to the old situation can only be reached by a serious decrease in the nutrient load. As long as algae (and suspended matter) will dominate the system the conditions for fish and fish eating birds will change dramatically and therefore the switch to macrophytes is essential. Detailed knowledge about the origin of the nutrient load and the origin of its fluctuation are the first steps needed before making a plan to reduce the load.

Other
It is likely that the discharges originating from food industry and mining have a serious impact on the lake, but detailed data are necessary for interpretation of the consequences.

Suspended matter

Turbidity and filling up the lake
Because of the disappearance of the vegetation, wind and fish have more grip on the sediments and resuspension easily occurs, causing extra turbidity next to the algae. This problem seems to be more important than the amount of sediment coming into to the lake. The amount is steadily decreasing. Assuming an evenly distributed sedimentation and no outflow from the lake, it takes 500 years before the lake is 1 m shallower. So the first priority is to stabilize the sediments by the return of the macrophytes which is related to measures taken regarding nutrients (see above) and fishery (see below).

Fishery

In the current situation the fishery intensity is extremely high. The combination of a large number of nets and a small mesh size makes it very difficult for most fishes to attain a large size. Most fish are caught when they are small by gill-nets. The ones escaping these nets will be caught in the fykes. Especially pike and carp, the most valuable fishes become vulnerable. At the moment the fishery is very inefficient. Although the intensity is higher than in the 1980's the catches of pike and carp are lower. Only the catches of the low-valued small fishes are higher.

Apart from that, many birds (mainly pigmy-cormorant) die because of the gill-net fishing. *The change in the fishery should serve the purpose of stopping the overexploitation, increase the catches of commercial interesting carp and pike, accellerate the recovery of the ecosystem and protect the birds*. We recommend to change the fishery in the following way:

1. **stop the fishery with the 18 mm gill-nets completely. The profits are very low and they negatively affect the catches of pike and carp by causing a high mortality in the young fish.**
2. **Stop the fishery with the fykes. It is best to aim at carp and pike when they 5-6 years old, that is > 50 cm. Is is better to use a few large meshed gill-nets of 60 mm nets and the number of nets should be reduced from ca. 10.000 60 m nets to ca. 500 60 m nets**.
3. **An alternative would be to establish a gradual shift from overexploitation to extensive durable exploitation. In this case the nets will be replaced first by 40 mm nets and after two years by 60 mm nets. The advantage is that catch will increase earlier, but the disadvantage is that new investments have to be made for a period of only a few years. In this scenario the fish community will restore more slowly, so it is questionable whether the gradual shift is sensible**.

When the pike population will have the opportunity to restore again the proportion piscivorous fish to other fish will become larger. As a consequence small fish will be replaced by large fish. Crucian carp will be no longer dominant and changes for an accelerated recovery will increase.

LITERATURE

Coops, H. 1996. Helophyte zonation. PhD thesis, Nijmegen, ISBN9036945089.

Altynayar, G. 1998. Review of the studies on Lake Uluabat.

Lenssen, 1998. Species richness in reed marshes, PhD thesis, Nijmegen, ISBN9090122370.

Lammens, E.H.R.R. 2001. Consequenses of biomanipulation for fish and fisheries. FAO Fisheries Circular. No. 952. Rome, FAO. 23p.

Meijer, M-L. (2000). Biomanipulation in the Netherlands 15 years of experience. Ph.D.Thesis. Wageningen University. 208 pp

Moss, B., Madgwick, J. & Phillips, G. 1996. A guide to the restoration of nutrient-enriched shallow lakes. University of Liverpool/Broads Authority/Environment Agency.

Ministry of Environment letter d.d. 9 June 1998 with ref. b.19.0.ckg..0.10.0/02 to Royal Dutch Embassy concerning a sustainable management plan for Uluabat Lake.

Rahe, R. & Worthmann, H. 1986. Project to develop aquatic products of inland waters of Marmara region, Turkey. Final Report PN 78.20032.7

Schot, P.P., Buijse, A.D. and Wassen, M.J. 1999. Hydrology and ecology of lake Uluabat, Recommendations for research, Report of a short term mission, 25-30 October 1998

Scheffer, M. 1998. Ecology of Shallow Lakes. Chapman & Hall. London. 357 pp.

Van den Berg, M.S. (1999). Charophyte colonization in shallow lakes. Processes, ecological effects and implications for lake management. Ph. D. Thesis. Vrije Universiteit, Amsterdam.

Vonk, G. 2001. Development of impact assessment tools for dams and reservoirs in PCRaster. Application to Lake Uluabat, Turkey. Student Report University of Utrecht.