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The effects of bird exclusion on the chemical and biological characteristics of a soda lake

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Abstract: The effects of water birds on water quality in a shallow Turkish soda lake, Lake Aktaş, were investigated by comparing protected areas and those exposed to birds, in order to understand interactions between the birds and the ecosystem in this study. The experiment was carried out over five months between June and October 2009, in four widely distributed bird-proof enclosures in treatment areas and four open-top enclosures (control areas), a total of eight plots, (with a fish density of about 1000 $kg.ha^{-1}$, similar to the lake) in the lake. Physico-chemical analyses, phytoplankton, zooplankton, Secchi depth measurements, were determined each month in both treatment and control areas. The significant differences were found only for chlorophyll *a* ($P<0.001$) and Secchi depth ($P<0.05$) throughout the experiment between the open and bird-proof enclosures. Although some effects of water birds were clear in the present study such as decrease in turbidity and chlorophyll *a*, it is difficult to determine the effect of waterfowl on water chemistry using enclosure experiments, since they are designed to test the effect of ornithogenic inputs on the water column, not the effects of other factors (e.g. natural chemistry).

Key Words: waterfowl, water quality, aquatic ecosystem, ornithogenic input, nutrients

Introduction

Waterfowl such as geese, swans, wild ducks, and others are natural components of shallow lake ecosystems that can have important effects on both the biology and chemistry of these ecosystems. The majority of research on the observable effects of birds on aquatic systems (Manny *et al.*, 1975, 1994; Scherer *et al.*, 1995; Kear, 1963; Olson, 2005; Post *et al.*, 1998; Kitchell *et al.*, 1999) has been performed in large lakes and bays, and these studies have indicated that goose faeces impact water quality. Although the effects of waterfowl on water quality have been much studied (Gould and Fletcher, 1978; Bedard and Gauthier, 1986; Portnoy, 1990; Bales *et al.*, 1993; Dobrowolski *et al.*, 1993; Baxter and Fairweather, 1994; Manny *et al.*, 1994; Marion *et al.*, 1994; Smith and Johnson, 1995; Gwiazda, 1996; Kitchell, *et*

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al. 1999; Hahn *et al*., 2007; Nakamura *et al*. 2010) interactions between the ecosystem and birds are poorly understood. Declines in aquatic plants are associated with bird diversity as most aquatic birds are herbivorous (Harper, 1992; Bales *et al*., 1993; van Donk and Otte, 1996; Strand, 1999; Marklund *et al*., 2002). On the other hand, increases in the number of birds as a result of artificial feeding may also affect the aquatic system in a bad way, such as severe eutrophication (Moss and Leah, 1982; Chaichana *et al*., 2010, 2011) (called guanotrophication by Leentvaar, 1967).

This study tested the possible causes of absence of birds influence on chemical and biological charecters of the soda lake. For this, the effects of water birds on the water quality in Lake Aktaş were investigated by comparing protected areas from birds with areas exposed to birds to elucidate the interactions between the birds and the ecosystem.

Materials and methods

Study site

Lake Aktaş is a shallow, turbid, high-elevation soda lake on the Turkish-Georgian border in eastern Anatolia (41°12' 15″ N, 43°12' 23″ E) in area of 23.86 km^2 or 2386 hectares,. 1798 m above sea level, and in average depth 1.5 m, maximum depth 3.5 m the lake's primary water sources are rainfall and seasonal streams. The Ağagil seasonal stream, which is situated northwest of the lake and flows exclusively when lake levels are high in the spring, channels the outflow to the Kura River. Three villages are located near the lake, but human activity in and around the lake is limited. In 1995, Lake Aktaş was established as one of three Turkish breeding sites for the White Pelican (*Pelicanus onocrotalus*) and as one of seven breeding sites for the Dalmatian Pelican (*Pelicanus crispus*) (Magnin and Yarar, 1997). Interest in conserving this site is further enhanced by the large numbers of Velvet Scoter (*Melanitta fusca*) and Ruddy Shelduck (*Tadorna ferruginia*) that reside here (Yarar and Magnin, 1997). A research group from Stanford University identified 2500 individual birds, comprising 50 species, on the lake (Şekercioğlu, Personal communication). Migratory birds generally depart from the lake in September-October and return in March-April. Geese are bred in three villages around the lake, and the total number of geese reared for commercial purposes can be greater than 1000. Therefore during the study period approximately 3500 individual birds have been recorded around the lake. Based on previous records from The State Hydraulic Works Department of Turkey, no native fish species are present in the lake, but *Cyprinus carpio* was identified in the lake during a previous study (Özbay and Kılınç, 2008).

Experimental design

The experiment was carried out over five months between June and October 2009, in four widely distributed bird-proof enclosures in treatment areas and four open-top enclosures in control areas (with a fish density of about 1000 kg.ha^{-1}, similar to the lake), a total of eight plots, in the lake. The enclosures were polyethylene (0.25 mm wall thick) structures that were supported at the bottom and the top by cylindrical plastic tubes. Thus, the top of each enclosure was open to the atmosphere and the bottom was buried in the sediment. The top of each bird-proof enclosure was covered by wire netting with a mesh size of 25 mm to prevent birds from flying in. The enclosures were placed in water at a depth of 0.7 to 0.9 m with 5m distance from each other. Both treatment and control plots covered 6.25 m^2 with dimensions of 2.5 m x 2.5 m.

Sampling

The first samples for physico-chemical analyses were taken immediately after the enclosures were set up, and then samples were taken monthly during the experiment. Therefore 8 samples, 4 for treatment and 4 for control plots, were collected. Phytoplankton, zooplankton, Secchi depth measurements were determined each month. At each sampling station, temperature, dissolved oxygen (DO), conductivity and pH were measured in situ with a WTW Oxi 197i oxygen meter, a WTW cond 315i/set, and a WTW pH meter 315i/set respectively. Transparency was measured with a Secchi disc. Composite water samples for chemical analyses and plankton were collected from a depth of 0-0.5m, using a hose pipe 3 cm in diameter and stored in acid–washed 1 L Pyrex bottles.

Total phosphorus (TP), Solubl Reactive Phosphorus (SRP), Ammonium-nitrogen and nitrate-nitrogen were determined according to APHA (1999). Chlorophyll *a* was extracted in acetone, and its concentration was calculated by measuring the absorbance at a wavelength at 663 nm (Talling and Driver, 1961). All water analysis was done within 24 hours of collection.

Phytoplankton samples were preserved in Lugol's solution immediately after sampling and subsamples were examined and enumerated with an inverted microscope at a magnification of 400x according to the method described by Lund *et al*. (1958). Zooplankton was sampled with vertical hauls (55 µm mesh net) approximately 0.5 m below the surface. Samples were preserved in 4% buffered formaldehyde solution, and at least 100 of each of the most common species were counted from each subsample (Bottrell *et al*., 1976) under the stereo microscope. All statistical analyses (two-way ANOVA) were performed using Minitab 11 (Minitab, 1996).

Results and Discussion

According to the mean monthly values of physico-chemical and biological variables throughout the experiment no significant differences were found between open and bird-proof enclosures for phytoplankton, zooplankton, NH_4-N, NO_3-N, SRP, TP, temperature, pH, conductivity, or DO during the experiment (Table 1).

On the other hand significant differences were found only for chlorophyll *a* ($P<0.001$) and Secchi depth ($P<0.05$) throughout the experiment between the open and bird-proof enclosures.

As a soda lake, Lake Aktaş is highly alkaline with a pH value between 9.1-9.6. The recorded pH values changed not significantly during the study between the open and the bird-proof enclosures (Table 1). This result indicated that waterfowl had no effect on pH. In alkaline environments, large amounts of carbonate minerals can generate pH values > 11.5 (Jones *et al*., 1998). Therefore, in Lake Aktaş, abiotic factors such as carbonate could play primary role on pH rather than biotic factors (e.g. birds).

The waterfowl not significantly affected the DO concentration in the lake non in the examined months. DO concentrations remained well saturated (minimum 78%) throughout the experiment in both the open and the bird-proof enclosures. These high dissolved oxygen levels could be attributed to the atmospheric diffusion into the lake occurring at all times due to its large surface area and shallow depth. During the study period, no significant differences were also observed regarding the temperature, pH, conductivity, TP, SRP, NH_4-N and NO_3-N levels. However, the Secchi depth was greater in the bird-proof enclosures than in the open ($p< 0.001$), revealing a negative correlation between the Secchi depth and DO levels. It is also known that there is a positive relation between DO and pH which may be the reason why, in most of the experimental period, both the pH and DO were higher in open than the bird- proof enclosures. As a result of the levels of precipitation and wind-driven wave action, water column mixing and atmospheric diffusion might be more of a factor for open than for the bird-proof enclosures because of the absence of top refuge (net) on the top of the open encloures. Therefore, turbidity and DO were increased in open, whereas turbidity and DO were decreased in the bird-proof enclosures.

There were no differences for NO_3-N and NH_4-N between the treatments in this experiment. Generally, both nutrient levels were a little higher in open than the bird-proof enclosures. The presence of common carp as an alien species has a potentially important influence on the structure of nutrient release from sediment in the lake, since digging on the bottom of the lake in the search for food items results in more nutrient release from the sediment. However, both treatment areas had common carp in this study, and therefore the effects of common carp on nutrient release from the sediment have been similar in open and in the bird-proof enclosures. However, wave actions also play a more important role in nutrient release from the sediment in open

Tab. 1: Effects of presence or absence of waterfowl on water chemistry, zooplankton, phytoplankton, chlorophyll *a* in Lake Aktaş during the study period. Means (±SD), O= open sites for birds, E= birds exclusion sites. The significance of the two-way ANOVA results for the interaction mount (M) x sites (S) are indicated as NS= p>0.05, *= p<0.05 and ***= p<0.001.

Parameters	June		July		August		September		October		ANOVA
	O	E	O	E	O	E	O	E	O	E	MxS
Tem. (˚C)	14.25 (±0.50)	13.50 (±0.57)	16.75 (±0.50)	18.50 (±0.57)	25.25 (±0.95)	26.25 (±0.95)	20.75 (±1.71)	21.25 (±0.95)	15.75 (±0.50)	16.75 (±0.50)	NS
pH	9.2 (±0.08)	9.2 (±0.08)	9.5 (±0.05)	9.3 (±0.12)	9.6 (±0.05)	9.6 (±0.08)	9.5 (±0.05)	9.3 (±0.22)	9.4 (±0.05)	9.1 (±0.15)	NS
Secchi depth (cm)	19 (±1.15)	19.7 (±1.26)	19.50 (±1)	21.50 (±1)	19.7 (±1.26)	25 (±1.63)	20.7 (±1.71)	27.2 (±2.06)	15.5 (±0.57)	19.5 (±1)	*
$N\text{-}NO_3$ (µgl^{-1})	157.7 (±2.63)	159 (±4.32)	166.3 (±28.7)	161.7 (±30.9)	181.5 (±39.8)	173.7 (±32.9)	162 (±29.9)	160 (±34.3)	145.8 (±42.4)	140 (±36.7)	NS
$N\text{-}NH_4$ (µgl^{-1})	14.2 (±2.09)	13.42 (±2.43)	48.17 (±4.65)	44.85 (±4.59)	46.53 (±7.53)	44.23 (±7.4)	45.43 (±8.39)	42.53 (±6.34)	75.3 (±8.34)	73.97 (±8.62)	NS
TP (µgl^{-1})	50.98 (±2.91)	51 (±4.29)	65.85 (±1.35)	64.42 (±2.28)	65.5 (±2.88)	62.65 (±0.99)	64.85 (±1.32)	62.35 (±1.72)	62.62 (±0.61)	60.42 (±1.06)	NS
SRP (µgl^{-1})	23.47 (±1.13)	23.75 (±5.38)	24.08 (±1.99)	20.95 (±1.14)	29.92 (±1.11)	26.5 (±1.65)	27.1 (±5.52)	25.17 (±0.96)	19.45 (±1.01)	18 (±0.97)	NS
T.P (orgml^{-1})	7177551 (±1751257)	7116023 (±1767941)	9859448 (±2172770)	9604450 (±1582063)	7178305 (±1091814)	6228951 (±343261)	5428796 (±1537159)	4600585 (±888864)	1175663 (±4490529)	8309651 (±1490752)	NS
T.Z (orgl^{-1})	143.1 (±46.5)	141.2 (±49.2)	706 (±172)	648 (±170)	83.7 (±89.7)	50.76 (±9.86)	537 (±299)	352.7 (±62.1)	497 (±159)	286.9 (±58.2)	NS
Chlorophyll *a* (mgl^{-1})	0.078 (±0.04)	0.071 (±0.02)	0.124 (±0.02)	0.105 (±0.01)	0.138 (±0.04)	0.109 (±0.01)	0.461 (±0.22)	0.09 (±0.007)	0.028 (±0.02)	0.012 (±0.005)	***

T.P = Total Phyto-plankton

T.Z = Total Zooplankton

compared to the bird-proof enclosures because of the reasons explained above (see the discussion on DO). This probably explains why both NO_3-N and NH_4-N were found to be slightly elevated in open enclosures.

There were no significant differences between the treatments for SRP and TP in any of the analyses. The bird population increases rapidly in July and August as this is the end of the breeding season for both migratory birds and commercial geese. The increasing bird population has also increased the amount of bird droppings in the lake. Unckless and Makarewicz (2007) have suggested that the bulk of the nutrients contained in the faeces would simply sink to the sediment where they would eventually become part of the benthic detritus food web or be cycled back into the water column during a mixing event. Therefore, the impact of these nutrients will not be evident until long after they have been added. However, due to the morphological and biological characteristics (shallow depth, wind and carp effect) of the lake, phosphate rapidly cycles in the lake and does not remain in the sediment for a long time. Furthermore, Pettigrew *et al*. (1998) concluded that phosphorus and nitrogen do not remain in the water column after nutrient addition. Nutrients are assimilated by plankton, adsorbed into the sediment or denitrified (nitrogen only). It is likely that the nutrient concentration in the sediments would be similar both in bird-proof enclosures and in open and, therefore, would be difficult to differentiate, since the bottom of the lake is largely composed of decaying materials (e.g. macrophytes and phytoplankton).

Although total phytoplankton levels tended to slightly increase in open compared to the bird-proof enclosures, differences between the treatments were not significant during the experiment. On the other hand, differences between the treatments were not found to be significant also for total zooplankton during the experiment. However, the treatments significantly differed ($p<0.001$) in terms of chlorophll *a*. According to Unckless and Makarewicz (2007), if the fate of most of the faecal nutrients is to end up in the sediment, the impact of those nutrients on water quality may not be manifested until a mixing event occurs. However, this is not the case for Lake Aktaş, since the shallow depth, wind and carp effects allow good mixing to take place in the lake water almost all year round. Nutrients may have also passed quickly through the food web and ended up in zooplankton communities, but there is no evidence for this in either the water chemistry data or the phytoplankton community data, at least in this study.

As a conclusion, this study quantified the effects of waterfowl exclusion on the biology and chemistry of Lake Aktaş, a shallow-water soda lake. The results of this study suggest that waterfowl might have the potential to affect both the biology and chemistry of water bodies, albeit to different extents, and interactions with specific characteristics of the lake may increase or decrease the impact of birds. Further studies should be conducted to assess the effects of waterfowl on aquatic systems on a longer-term scale.

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