Natural and anthropogenic effects of nutrient, salinity, and organic contaminant levels on the agriculturally influenced aquatic ecosystem in Khorezm, Uzbekistan

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Abstract:
Decades of unsustainable land and water resource management related to agriculture, a cotton monoculture, have led to severe environmental and human health problems in the former Soviet state of Uzbekistan. This is exemplified in the Khorezm province in northwest Uzbekistan, a highly productive agricultural area under intense water use stress. A water resource in this province that remains largely unstudied is a series of small lakes that has formed recently from agricultural runoff water. These lakes potentially could provide a suitable source of irrigation water for small scale cropping, as well as income from fish production. Water quality (e.g., salinity, nutrient and organic contaminants) and aquatic food web samples were collected in 11 of these lakes and the nearby Amu Darya River between May and November 2006 to assess water quality and possible limits to aquatic production. Salinity in the monitored lakes differed both between lakes and on a seasonal basis, with monthly salinity measurements varying between 1 to over 10 g/L. A preliminary trend towards increasing salinity with time was observed in most lakes during this short period. Sampling of organic contaminants in June 2006 yielded low concentrations of hydrophobic contaminants such as polycyclic aromatic hydrocarbons and organochlorine compounds. Further tests are necessary to determine if other organic chemicals associated with agricultural practices are present. Although concentrations of hydrophobic organic contaminants appear to be low, aquatic species diversity and relative density were very low in many of the lakes. Stable isotope analysis is planned for aquatic samples to determine food web structure and detect if anthropogenic inputs such as fertilizer or wastewater may be linked to the aquatic food webs of the lakes. Water quality and food web sample data will also be used to parameterize water quality models for some lakes that are representative of the general system to relate anthropogenic impacts to biotic productivity and food web structure.

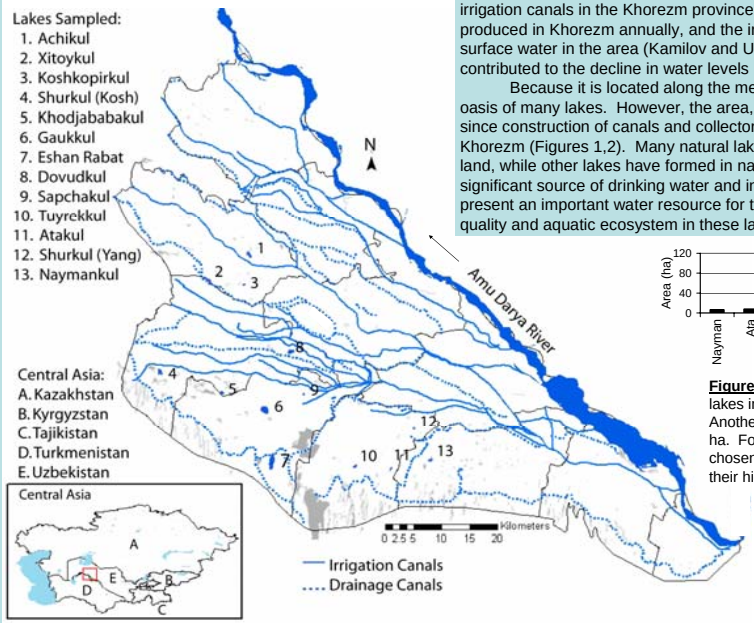

Figure 1: Location of lakes sampled in the Khorezm oblast

Background:
Beginning around 1960, vast tracts of arid land in the Khorezm region came under cultivation to supply the Russian textile mills with cotton. Currently, water from the Amu Darya River is drawn through 900 km of irrigation canals in the Khorezm province (Kamilov and Urchinov 1995). Almost a million tons of cotton is produced in Khorezm annually, and the irrigation canal systems and agricultural runoff have highly impacted surface water in the area (Kamilov and Urchinov 1995). Additionally, increased irrigation in this region has contributed to the decline in water levels in the nearby Aral Sea.

Because it is located along the meandering Amu Darya River, Khorezm has historically been a lush oasis of many lakes. However, the area, location, and water quality of these lakes has changed significantly since construction of canals and collectors. Current satellite images show that over 450 lakes remain in Khorezm (Figures 1,2). Many natural lakes have decreased in size as they were drained for agricultural land, while other lakes have formed in natural depressions from agricultural runoff. Although currently not a significant source of drinking water and income generation via fish breeding and catch, these lakes may present an important water resource for the surrounding communities. Little is known about the water quality and aquatic ecosystem in these lakes.

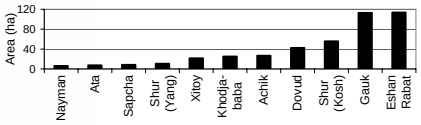

Figure 2: Area Approximately 55 percent of all the lakes in Khorezm oblast have an area of 1-5 ha. Another 27 percent of the lakes have an area of 5-20 ha. For this study, lakes of a variety of sizes were chosen, with an emphasis put on smaller lakes, due to their higher abundance.

Methods:
Water quality information has been collected monthly from up to 13 lakes since June 2006. Measurements include mid-lake grab samples and in-situ profiles of temperature, salinity, dissolved oxygen, conductivity and pH. Grab samples are analyzed in the laboratory for nitrate, nitrite, ammonium, total phosphorous, orthophosphate, and total dissolved solids.
Semipermeable membrane devices (SPMDs) were deployed for four weeks during June-July and October-November 2006. SPMDs mimic the rate of fish tissue uptake of organic contaminants such as pesticides.
Food web samples were collected during June and October 2006. Samples of fish, macroinvertebrates, and zooplankton were collected, identified, dried at 60°C for 24 hours, and processed for stable isotope analysis.

Above left: Uzbek students Diana Shermetova and Marhabo Bekchanova processing fish samples at Dovud Lake while local residents look on.
Above right: Students using a boat to deploy an SPMD in Tuyrek Lake, October 2006.
Left: Marhabo Bekchanova and Margaret Shanafield collecting vertical profiles of physical water quality from Gaukkul using a handheld YSI instrument in November 2006.
Right: Uzbek student Diana Shermetova removing an SPMD from Koshkopir Lake, July 2006.

Results: Physical and chemical water quality data has been analyzed through December. Monthly water quality surveys showed average lake salinity was 1-4 g/L for most lakes (Figure 3), and no vertical gradient was observed. In most, but not all, lakes, salinity increased from summer into fall, likely due to the sharp decline in input from irrigation drainage canals once harvesting of cotton and rice began in late summer (Figure 4). Chemical analysis of water samples for dissolved inorganic nitrogen and orthophosphate through December 2006 suggests that the lakes are relatively rich in nitrogen during the summer months, with molar N:P ratios ranging from 189 to 3699. In October, this trend is reversed, and by November N:P ratios are only 0.1 to 43 (Figure 5). Organic contaminant levels in the water columns of all lakes in the summer were low (Figure 6) and future analysis of SPMDs deployed in late fall will determine whether contaminants may be more concentrated during low water levels in fall and winter. Zooplankton abundance increased with lake area for samples collected from the open water of lakes in June and October 2006. No zooplankton were present in the open waters of the smaller lakes (Figure 7).

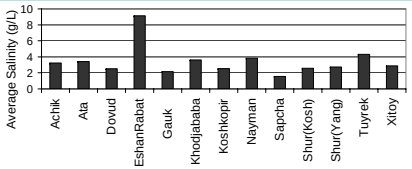

Figure 3: Average salinity in 13 lakes for the period of measurement (June-December for most lakes; summer only for Achik and Shur (Kosh) and fall only for Nayman).

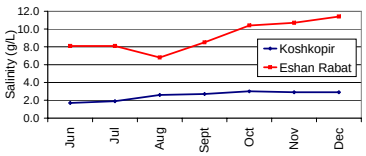

Figure 4: Salinity over time for two lakes. Salinity in most of the lakes is in the approximate range of Koshkopir Lake, while Eshan Rabat has much higher salinity.

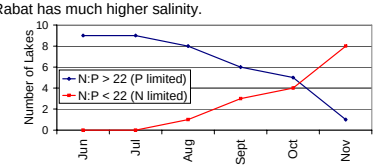

Figure 5: Nutrient availability in nine lakes over time.

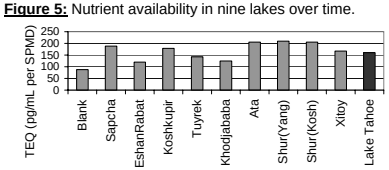

Figure 6: Results of the summer SPMD sampling and average concentration measured in Lake Tahoe (2002-2003; Rosen et al. 2006) shown for comparison.

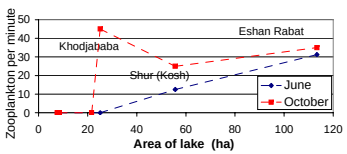

Figure 7: Zooplankton abundance during June and October 2006 samplings. Samples were collected for a ten-minute period.

Future work:
This project will continue through summer 2009. Research will focus on a subset of the lakes sampled in 2006. Questions to be addressed during this time include:
•Does the concentration of organic contaminants in lake water increase as lake volume decreases seasonally?
•Is there strong variation between lakes or is there a strong seasonal pattern to explain observed water quality fluctuations at all lakes?
•Is phosphorous mobilized from the soil during the harvest in early fall?
•How does production in the lakes relate to water quality?

Left: Relaxing on a bed of cotton. Almost a million tons of cotton are produced in the Khorezm oblast each year. Farmers are required to plant a state-mandated percentage of their fields with cotton each year. In order to harvest all the cotton, students, including university students, leave the classroom for several weeks each fall. Piles of cotton such as this one can be seen along the sides of the road, drying in the sun before being weighed and graded at a nearby cotton gin.

Left: Sapcha Lake, June 2006. Two drainage canals feed this small lake with water from surrounding fields.

References:
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Rosen, M., Rowe, T., Goodbred, S., Shipley, D., Arufe, J. 2006. Importance of Land Use, Streamflow, and Water Quality on Stream Toxicity in the Lake Tahoe and Truckee River Watersheds. American Fisheries Society Symposium 48:129–149.

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