Sangchris Lake Aquatic Vegetation Restoration Project

2017 WATER QUALITY MONITORING REPORT

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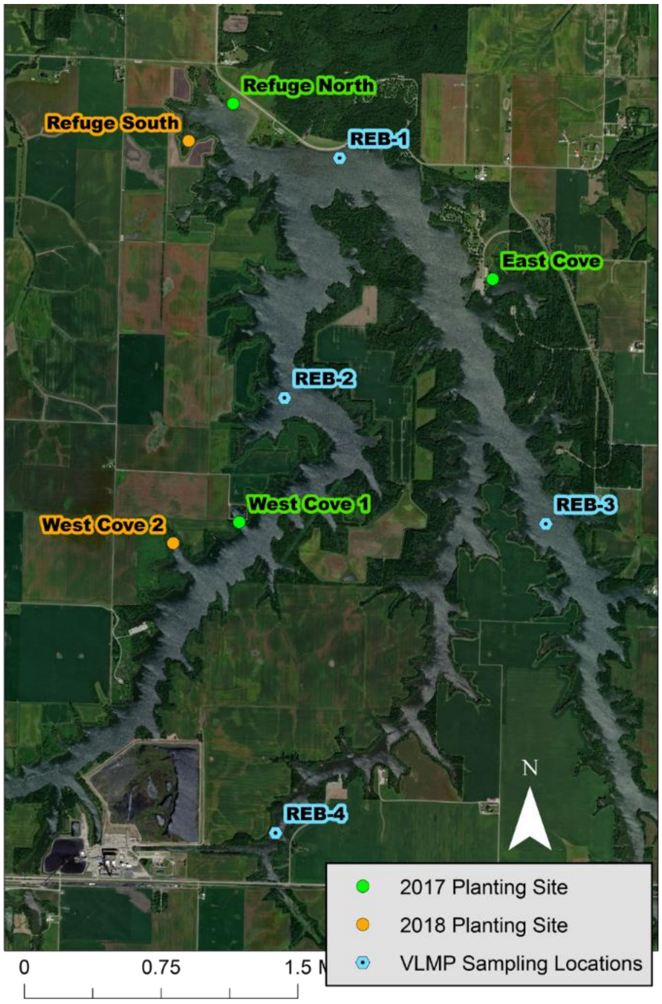
1. Introduction

In 2017, the Illinois Department of Natural Resources' Contaminant Assessment Section (IDNR CAS) began implementing an aquatic vegetation restoration project at Sangchris Lake in Christian County, IL. The goal of this project is to restore, diversify, and increase the abundance of aquatic plants within the lake. These plants will provide habitat for a wide range of aquatic organisms and improve water quality by aiding in biogeochemical processes, reducing erosion, and sequestering excess nutrients in the water column and sediments. This project is funded through a settlement related to a release of a hazardous substance into the lake in 2014. For more information on the settlement and restoration project, please visit https://www.dnr.illinois.gov/programs/NRDA/Pages/Sangchris-Lake---.aspx.

In ecological restoration projects it is important to establish baseline environmental conditions for the restoration area. This gives restoration managers a point of reference for the physical, chemical or biological conditions of the ecosystem being restored. Changes in these conditions over time can provide insight into the success or failures of the project. Restoration methods can be altered accordingly to achieve the stated goals of the project, a process called adaptive management

Figure 1. Sangchris Lake Monitoring Locations



Baseline conditions for Sangchris Lake were established through regular water quality monitoring and the collection and analysis of water samples. Monitoring was carried out through a joint effort between IDNR CAS staff and the Illinois Environmental Protection Agency's Volunteer Lake Monitoring Program (VLMP). The VLMP is a statewide lake monitoring program that provides training and equipment for local volunteers who conduct monitoring and collect water samples. This program provides opportunities for community engagement while also greatly expanding scope of the IEPA's monitoring and assessment capability. More information and a database of all data collected through the VLMP can be found on the IEPA's web site at www2.illinois.gov/epa/topics/water-quality/monitoring/vlmp/Pages/default.aspx.

Monitoring was conducted at four locations in Sangchris Lake every two weeks from June through October. The four monitoring sites were labeled REB-1 through REB-4 (Figure 1). Monitoring activities included collecting Secchi disk transparency, temperature, and dissolved oxygen (DO) readings every two weeks. Water samples were collected once each month and were analyzed for a variety of factors including physical and chemical properties, nutrients, chlorophyll, pesticides, and metals (see Table 1 for a complete list of analytes). Water samples were analyzed at the IEPA lab in Springfield. Detailed monitoring and sample collection methods can be found in the VLMP training manual, available online at https://www2.illinois.gov/epa/Documents/epa.state.il.us/water/conservation/vlmp/training-manual-012010.pdf.

Table 1. Water Sample Analytes

Nutrients	Metals	PESTICIDES	
Inorganic nitrogen	Aluminum	2,4-D	Hexachlorobenzene
Kjeldahl nitrogen	Arsenic	Acetochlor	Lindane
Ammonia-nitrogen	Barium	Acifluorfen	Malathion
Phosphorus	Beryllium	Alachlor	Methoxychlor
Chlorophyll	Boron	Aldrin	Methyl parathion
Chlorophyll a, corrected for pheophytin	Cadmium	alpha-Hexachlorocyclohexane	Metolachlor
	Calcium	Atrazine	Metribuzin
Chlorophyll a, uncorrected for pheophytin	Chromium	Butylate	p,p'-DDD
	Cobalt	Captan	p,p'-DDE
Chlorophyll b	Copper	Chlorpyrifos	p,p'-DDT
Chlorophyll c	Iron	cis-Chlordane	Parathion
Pheophytin a	Lead	Cyanazine	Pendimethalin
Bulk	Magnesium	Dalapon	Pentachlorophenol
Hardness, Ca, Mg	Manganese	Diazinon	Phorate
Alkalinity, total	Nickel	Dicamba	Picloram
Residues	Potassium	Dieldrin	S-Ethyl dipropylthiocarbamate
Total suspended solids	Selenium	Dinoseb	Silvex
Volatile suspended solids	Silver	Endrin	Simazine
Inorganics	Sodium	Fonofos	Terbufos
Chloride	Strontium	Glyphosate	Toxaphene
Sulfate	Vanadium	Heptachlor	trans-Chlordane
PCBs	Zinc	Heptachlor epoxide	Trifluralin

1.2 Trophic State

A common method for evaluating and classifying a lake is to determine its trophic state. Trophic state refers to the amount of energy or food available, which limits lake productivity in the form of algae, plants, and higher life forms. Lakes with low energy availability and productivity, classified as oligotrophic, are often found high in a watershed and outside of agricultural areas. These lakes often have very clear water due to limited algal growth. Lakes with high energy availability and productivity, often lower in the watershed and in areas with some agricultural land use, are classified as eutrophic. These lakes have excess nutrients and are characterized by murky, green or brown water due to large amounts of algae. Oxygen may be very low in the hypolimnion in eutrophic lakes and nuisance levels of rooted aquatic plants may be present. Lakes that fall in between these two categories are referred to as mesotrophic. Lakes with extreme amounts of nutrient inputs and productivity are classified as hypereutrophic.

In many lakes, a transition occurs over long periods of time from oligotrophic to eutrophic as sediment and nutrients build up and are trapped in the lake basin. This transition is sometimes accelerated by human activity through a process called cultural eutrophication. Wastewater from sewage treatment plants, phosphates from detergents, and runoff from agricultural land can dramatically increase nutrient availability in lakes and streams. This results in a hypereutrophic state marked by large algal blooms that reduce water clarity, the formation of surface scum, foul odors, and oxygen depletion. Once nutrients are depleted, algae quickly die and begin to decompose. Decomposition rapidly reduces dissolved oxygen and can cause fish kills. Monitoring and managing nutrient inputs is therefore integral to maintaining healthy lakes for fisheries and recreation.

1.3 Trophic State Index

The trophic state index (TSI), developed by Carlson in 1977, is a standard approach for determining the trophic state of freshwater lakes. This method classifies lakes as oligotrophic (low productivity), mesotrophic (moderate productivity), eutrophic (high productivity), or hypereutrophic (extremely productive). Secchi depth, concentration of chlorophyll a (phytoplankton), and/or total phosphorus can each be used to mathematically derive a TSI value (Tables 2 & 3). Kratzer and Brezonik (1981) developed an additional algorithm to determine the TSI based on total nitrogen. Values derived from the various measurements may be similar, although difference in TSI values can be used to further characterize conditions within a lake (Table 4).

Table 2. Trophic State Index Equations.

Carlson's TSI Equations	Where
TSI(SD) = 60 - (14.4)(LN(SD))	SD = Secchi depth transparency (m)
TSI(TP) = 4.15 + (14.42)(LN(TP))	TP = total phosphorus concentration (mg/L)
TSI(Chl) = 30.6 + (9.81)(LN(CHL))	Chl = chlorophyll-a concentration (ug/L)
TSI(TN) = 54.45 + (14.43)(LN(TN))	TN = total nitrogen concentration (mg/L)

Table 3. Trophic State and Corresponding TSI Values and Measurements.

Trophic State	TSI	Secchi Depth (inches)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll-a (µg/L)
Oligotrophic	<40	>145	<0.367	<0.012	<2.5
Mesotrophic	40-50	79-145	0.367-0.735	0.012-0.025	2.5-7.5
Eutrophic	50-70	18-79	0.735-2.938	0.025-0.100	7.5-55
Hypereutrophic	>70	<18	>2.938	>0.100	>55

Table 4. TSI Value Comparisons

Relationship Between TSI Variables	Conditions
TSI(CHL) = TSI(TP) = TSI(SD)	Algae dominate light attenuation; TN/TP ~ 33
TSI(CHL) > TSI(SD)	Large particulates, such as Aphanizomenon flakes, dominate
TSI(TP) = TSI(SD) > TSI(CHL)	Non-algal particulates or color dominate light attenuation
TSI(SD) = TSI(CHL) > TSI(TP)	Phosphorus limits algal biomass (TN/TP >33)
TSI(TP) >TSI(CHL) = TSI(SD)	Algae dominate light attenuation but some factor such as nitrogen limitation; zooplankton grazing or toxics limit algal biomass.

2. Monitoring and TSI Results

2.1 Secchi Depth/TSI(SD)

Secchi Depth is obtained by lowering a black and white metal "Secchi" disk into the water until it is no longer visible. The depth at which it is no longer visible is reffered to as the Secchi Depth. This measurement is related to the water's transparency and is reduced by algal growth, suspended sediments, and color. A deeper Secchi depth indicates more transparent water, and a shallow Secchi depth indicates less transparent water.

The average Secchi depth of all sites in 2017 was 26 inches, with a median of 25 inches. The deepest measurement was 39 inches at REB-1 on June 6th, and the shallowest measurement was at REB-4 on Augist 1st (TABLE 5). In general, Secchi depth was greatest in late spring, decreased sharply in July and early August, and steadily increased through October (Figure 2). Secchi depths were much shllower at REB-4 near the outflow channel from the power plant. These decreased depths are possibly due to higher quantitites of suspended sediments created by the outflow current. The TSI(SD) value caclulated from the median Secchi depths at all sites is 67, indicating a eutrophic state.

Figure 2. Secchi Depth (in)

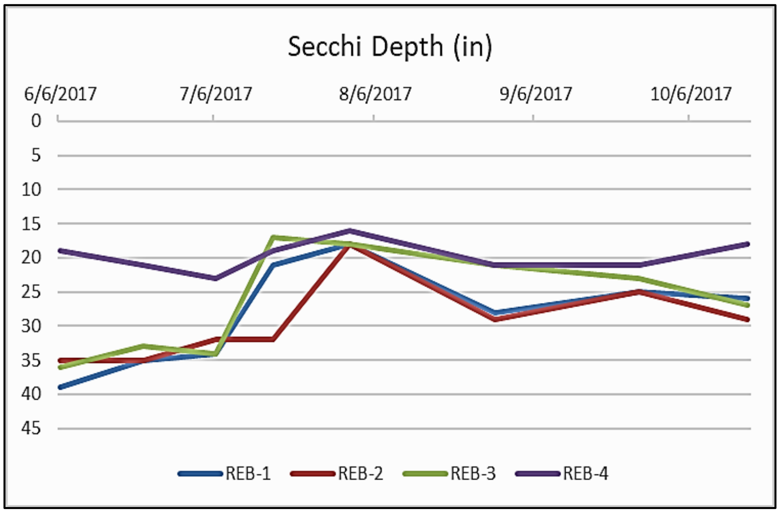


Table 5. Secchi Depth (in.)

	6/6/2017	6/22/2017	7/6/2017	7/17/2017	8/1/2017	8/29/2017	9/26/2017	10/17/2017
REB-1	39	35	34	21	18	28	25	26
REB-2	35	35	32	32	18	29	25	29
REB-3	36	33	34	17	18	21	23	27
REB-4	19		23	19	16	21	21	18

2.2 Chlorophyll a

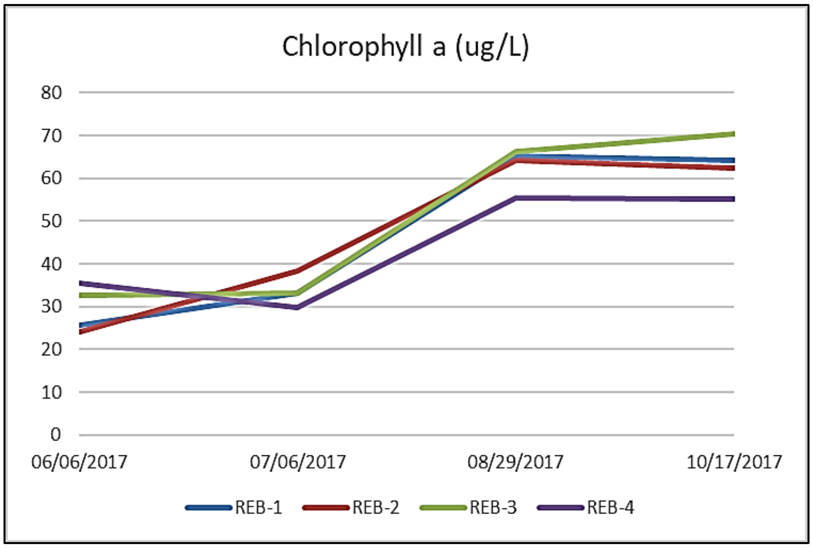
Chlorophyll a, a pigment used in photosynthesis in plants and algae, is proportional to the quantity of planktonic algae in the water column. Its concentration can therefore be used to estimate the density of algae.

The average chlorophyll a concentration for all sites was 67.8 µg/L, with a median concentration of 68.2 µg/L. The highest concentration was 70.3 µg/L at REB-3 on October 17th, and the lowest concentration was 24 µg/L at REB-2 on June 6th (Table 6). Chlorophyll a concentration was lowest in late spring, rose quickly through July and August, and remained steady through the end of the sampling season in October (Figure 3). Concentrations tracked closely between sampling locations throughout the season, with no single location consistently having the highest or lowest chlorophyll a concentration. The Trophic State Index value (TSI(Chl)) calculated from the median chlorophyll a concentration at all sites was 68, indicating a eutrophic state bordering on hypereutrophic. Notably, TSI(Chl) values were in the hypereutrophic range in all samples at all locations from August through October.

Table 6. Chlorophyll a concentration (µg/L).

	06/06/2017	07/06/2017	08/29/2017	10/17/2017
REB-1	**25.6**	**33.1**	**65.1**	**64.1**
REB-2	**24**	**38.4**	**64.1**	**62.3**
REB-3	**32.6**	**33.1**	**66.2**	**70.3**
REB-4	**35.6**	**29.9**	**55.5**	**55.2**

Figure 3. Chlorophyll a concentration (µg/L).



2.3 Total Phosphorus

Average total phosphorus (TP) concentration for all sites was 60.3 µg/L, with a median concentration of 61 µg/L. The highest concentration was 86 µg/L at REB-3 on August 29th, and the lowest concentration was 35 µg/L at REB-4 on June 6th (Table 7). Phosphorus concentrations tracked closely with chlorophyll a concentrations, peaking in early August and remaining high through October (Figure 4). The median total phosphorus TSI(TP) value of 63 indicates a eutrophic state.

Figure 4. Total Phosphorus Concentration (µg/L).

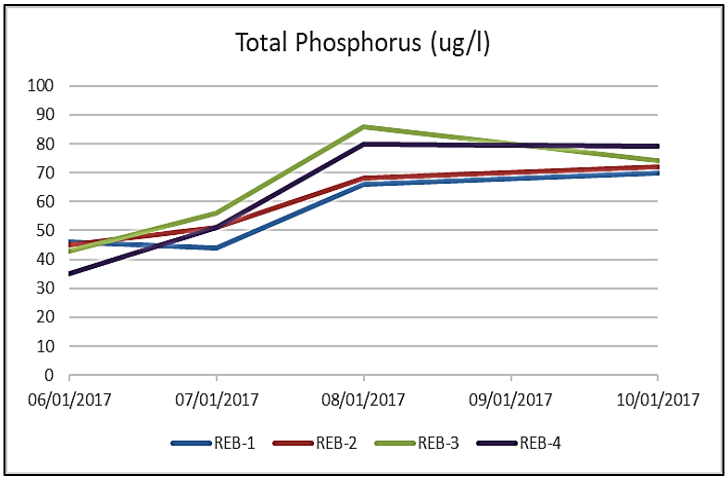


Table 7. Total Phosphorus Concentration

	06/06/2017	07/06/2017	08/29/2017	10/17/2017
REB-1	46	44	66	70
REB-2	45	51	68	72
REB-3	43	56	86	74
REB-4	35	51	80	79

2.4 Total Nitrogen

The average total nitrogen (TN) concentration for all sites was 2.7 mg/L, with a median concentration of 2.15 mg/L. The highest concentration was 6.28 mg/L, recorded at REB-4 on June 6th. The lowest concentration of total nitrogen was 0.73 mg/L, recorded at REB-3 on October 17th (Table 8). Nitrogen levels were highest in the spring and dropped steadily through August (Figure 5). High nitrogen levels in the spring may be related to agricultural runoff from the surrounding farmland. The median total nitrogen concentration from all sites throughout the sampling season corresponds to a eutrophic TSI(TN) value of 65. TN concentration changes noticably throughout the sampling season, with June and July samples indicating a hypereutrophic state.

Figure 5. Total Nitrogen Concentration (mg/L)

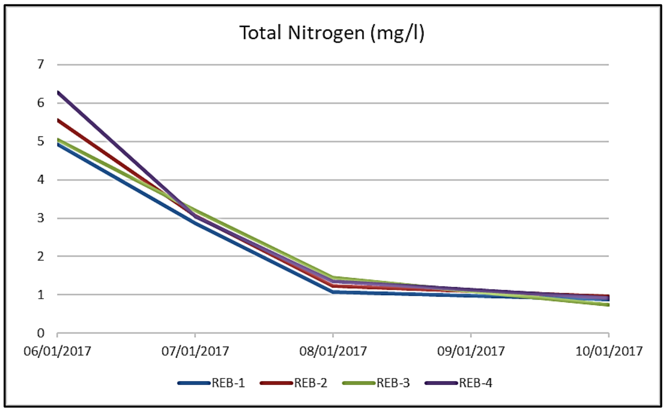


Table 8. Total Nitrogen Concentration (mg/L)

	06/06/2017	07/06/2017	08/29/2017	10/17/2017
REB-1	4.93	2.86	1.07	0.88
REB-2	5.56	3.06	1.24	0.95
REB-3	5.04	3.20	1.44	0.73
REB-4	6.28	3.04	1.35	0.93

2.5 Total Nitrogen:Total Phosphorus Ratio

An important consideration for determining a lakes' overall trophic state is the ratio of total nitrogen to total phosphorus (TN:TP). The nutrient that is less available to algae limits overall growth and abundance and is therefore referred to as the limiting nutrient. Where the TN:TP ratio is less than 10:1, nitrogen is the limiting nutrient; ratios of 10:1 to 20:1 indicate that the nutrients are balanced, or equally available; a ratio greater than 20:1 indicates that phosphorus is the limiting nutrient (Ratliff, 2017). As discussed above, total nitrogen concentrations are very high in June and July. TN:TP ratios during those months ranged from 179:1 at REB-4 on June 6th to 57:1 at REB-3 on July 7th. From August through October, TN concentrations were much lower with TN:TP ratios in the the 10:1 to 20:1 range. These ratios show that phosphorus is by far the limiting nutrient early in the growing season, but they reach a balance beginning in August. The median (35:1) and average (55:1) ratios indicate a phosphorus limited system during the study period.

2.6 Whole Lake TSI

Once the TN:TP ratio has been determined, a final calculation is performed to ascribe an overall Carlson Trophic State Index (CTSI) score to the the lake (Table 3). As discussed above, Sangchris Lake is phosporus limited. Therefore the CTSI is the average of TSI(Chl) and TSI(TP). The median TSI(Chl) was found to be 68, and the median TSI(TP) was 63; therefore, the overall CTSI for Sangchris lake is 65. This value falls within the range of eutrophic (50-70).

Table 9. Whole Lake TSI Calculations.

Limiting Nutrient	TN:NP Ratio	Formula
Nitrogen - Limited Lakes	(TN/TP < 10)	TSI = [TSI (Chl) + TSI (TN)]/2
Nutrient - Balanced Lakes	(10 ≤ TN/TP ≤ 30)	TSI = [TSI (Chl)+ [TSI (TN) + TSI (TP)] /2}/2
Phosphorous - Limited Lakes	(TN/TP > 30)	TSI = [TSI (Chl) + TSI (TP)]/2

2.7 Aquatic Life Use

Aquatic Life Use (ALU) is a tool used by the IEPA to evaluate a lake's potential for supporting aquatic life (Ratliff, 2017). This tool assigns points based on the TSI score, macrophyte (aquatic plant) cover recorded by the VLMP volunteer, and the median concentration of non-volatile suspended solids (NVSS) in surface water samples (Table 10). These points are added together to assign a narrative score of fully supporting (good), not fully supporting (fair), or not fully supporting (poor) (Table 11).

Table 10. Aquatic Life Use Criteria.

Evaluation Factor	Weighting Criteria for ALU	Points
Trophic State Index	< 60	40
	60 - 84	50
	85 - 89	60
	> 89	70
Macrophyte Coverage	<5%	15
	5% - 25%	0
	26% - 50%	5
	51% - 70%	10
	> 70%	15
NVSS Concentration	< 12	0
	12 - 14	5
	15 - 19	10
	> 19	15

As discussed above, the whole lake TSI was determined to be 65 (50 ALU points). The macrophyte coverage observed throughout the monitoring season was found to be less than 5% (15 ALU points). The median concentration of NVSS, calculated by subtracting volatile suspended solids from total suspended solids, was 4.5 mg/L (0 ALU points). This translates to a total ALU score of 65, or fully supporting (good).

Table 11. Aquatic Life Use Designation.

Aquatic Life Use	Guidelines
Fully Supporting Good	**Total ALU points are less than 75**
Not Fully Supporting Fair	**Total ALU points are greater than or equal to 75, but less than 95**
Not Fully Supporting Poor	**Total ALU Points are equal to 95 or greater**

3. Pesticides

Water samples were collected once per month at sites REB-2 and REB-4. These were analyzed for a wide range of pesticides (Table 11) and metals. Pesticides detected in 2017 included acetochlor, atrazine, dieldrin, heptachlor epoxide, metolachlor, metribuzin, p,p'-DDE, and pendimethalin. Of these, dieldrin, malathion, and p,p'-DDE (DDE) were detected at concentrations exceeding state or federal standards for aquatic life (Table 12).

Table 11. Pesticides detected in water samples.

Substance	No. of Detects (n=8)	Sample Concentration		Aquatic Life Criteria[a]		USEPA ESL[b]	Unit
		MIN	MAX	Acute	Chronic		
Acetochlor	8	0.012	0.71	150	12	--	µg/L
Atrazine	8	0.4	3.5	82	9	--	µg/L
Dieldren	1	ND	0.0029	0.24	0.056	0.000071	µg/L
Heptachlor epoxide	2	ND	0.0033	0.52	0.0038	0.0038	µg/L
Malathion	2	ND	0.092	0.4	0.04	--	µg/L
Metolachlor	8	0.42	3.6	380	30.4	--	µg/L
Metribuzin	6	ND	0.44	8400	--	--	µg/L
p,p'-DDE	2	ND	0.0028 (J)	--	--	4.51E-9[c]	µg/L
Pendimethalin	4	ND	0.038 (J)	350	30	--	µg/L

a IEPA Derived Water Quality Criteria List (Revised 04/2013).
b USEPA, Region 5, RCRA, Ecological Screening Level for Surface Water (8/22/2003).
c Water ESL based on exposure to a belted kingfisher (Ceryle alcyon).
ND = Not detected

3.1 Dieldrin

Dieldrin was detected in one surface water sample taken at REB-4 on 6/6/2017 at a concentration of 0.0029 µg/L. This does not exceed the IEPA's derived surface water criteria, but does exceed the USEPA's Region V Ecological Screening Level for surface water of .000071 µg/L (USEPA, 2003). Dieldrin was a widely used insecticide from the 1950s until 1970. It was banned in the US in 1970 but was again approved for use against termites from 1972 to 1987. Despite being banned for several decades, this persistent organic pollutant can still be found in water and soil in areas where it was used by farmers and exterminators. It is generally not found in high concentrations in water due to low solubility but can be found in higher concentrations in soils and sediments. It is highly fat soluble can therefore be found in high concentrations in the fatty tissues of animals exposed to contaminated water and soil. These concentrations become greater through biomagnification, where animals higher in the food chain consume and accumulate ever larger concentrations within organs and fatty tissue. Dieldrin effects the central nervous system, kidneys, and liver, and reduces the ability to fight off infections (ATDSR, 2002).

3.2 Malathion

Malathion was detected in surface water samples collected from REB-2 and REB-4 on 8/29/2017 at concentrations of 0.033 µg/L and 0.092 µg/L, respectively. The IEPA derived water quality aquatic life criteria standard is 0.4 µg/L for acute exposure and 0.04 µg/L for chronic exposure. One sample exceeded this standard for chronich exposure. Malathion is an organophosphate insecticide and is one of the most widely used insecticides in North America (Atwood and Paisley-Jones, 2017). It effects the central nervous system by distrupting the function of neurotransmitters (ATDSR, 2003). Malathion is degraded chemically and microbially at a rate dependent upon temperature and pH. Under alkaline conditions ($pH > 7$) malathion has a half-life of 1-10 days. This rate is increased at higher temperatures and with increased alkalinity (ATDSR, 2003). Since malathion is not persistent and was only found in samples on one date, the risks related to chronic exposure may not be evident at this time.

3.3 DDE

DDE is a metabolite of the once widely used insecticide DDT. Although DDT was banned in the US in 1972, it can still be found in areas where it was used for agriculture and pest control. Like dieldrin, DDE is fat soluble and accumulates in fatty tissue and the liver. Exposure in aquatic ecosystems occurs through contact with or consumption of polluted water or sediment. DDE then travels through the food chain in ever increasing concentrations, a process known as biomagnification. This puts higher level predators at a greater risk of harmful effects as DDE builds up in their bodies (ATSDR, 2002b).

Symptoms of DDE poisoning include neurological, developmental, and reproductive impairment. The thinning of avian egg shells due to DDE exposure is a well known consequence of DDE pollution, which contributed to the population decline of predatory birds such as the bald eagle in the middle of the 20th century (ATSDR, 2002b).

Samples containing DDE were collected at REB-2 and REB-4 on 8/29/2017. Concentrations were estimated to be 0.0017 µg/L at REB-2 and 0.0028 µg/L at REB-4. These concentrations are many times higher than the USEPA Region 5 Ecological Screening Level (ESL) for surface water of $4.51e^{-9}$ µg/L (USEPA, 2003). The ESL concentration is based on exposure risks to the belted kingfisher, a predatory bird, and therefore reflects the risks to higher trophic level organisms from low concentrations in surface water.

4. Metals

Water samples were also analyzed for a variety of metals (Table 1). Metals occur naturally in lake sediments and bedrock and the presence of many of these metals would be expected at some concentration in surface water. Some metals such as lead, mercury, and arsenic can be harmful even in small amounts. Others such as iron, manganese and zinc are nutritionally important for living organisms, but can be harmful in excess.

In 2017, iron was the only metal that exceeded established benchmarks for surface water. On October 17th at REB-4, total iron concentration was 2860 µg/L. This is nearly three times the aquatic life criteria for chronic exposure of 1000 µg/L established by the USEPA (USEPA,1986). High iron concentrations can impact aquatic organisms and ecosystems in a variety of ways. Iron can disrupt cell membranes, damage the DNA of plants and animals, limit respiration in fish by accumulating on gills, alter the structure and composition of benthic habitats, and alter the abundance and diversity of aquatic organisms (Linton et al., 2007).

Acid mine drainage, a legacy byproduct of coal and mineral mining, is often a source of metal pollution in surface water (Cadmus et al., 2018; RoyChowdhury et al., 2015). This acidic, metal-laden effluent mobilizes metals in the soil which then leach into surface water. The abandoned coal mines and acid mine drainage ponds near Sangchris Lake are therefore a potential source of metal pollution, although no direct impacts have been documented.

5. Conclusion

Based on this water quality monitoring study, Sangchris Lake is an overall healthy lake. It is in a eutrophic state, which is to be expected in an area dominated by large-scale intensive agriculture. To prevent the lake from transitioning to a hypereutrophic state unable to fully support aquatic life, nutrient inputs should be reduced wherever possible. Limiting nutrient inputs would reduce algal growth and improve water quality. Measures to decrease agricultural runoff may also decrease the prevalence of pesticides and their effects on aquatic life. The aquatic vegetation restoration project may also aid in improving water quality by sequestering excess nutrients and reducing resuspension of nutrient rich sediments.

While the pesticides detected in this study were often at or lower than regulatory standards, there is some evidence that cocktails of pesticides may pose a risk to aquatic communities even at low concentrations (Relyea, 2009). Metal pollution may also pose a risk at this site due to the presence of abandoned coal mining operations adjacent to the lake. Because treated acid mine drainage water enters the lake directly, continued monitoring will be important to ensure that concentrations of metals are below regulatory standards for aquatic life.

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