Standing Waters Assessment: IOWATER Program Results (2000-2008)

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INTRODUCTION

Iowa's volunteer water quality monitoring program, IOWATER, began as an idea in 1998 and has since grown into a network of volunteers across the state dedicated to monitoring Iowa's water. From 2000 through 2008 there were 2,913 Level 1 Certified IOWATER volunteers trained throughout the state and 4,024 monitoring sites registered. The IOWATER program provides training, equipment, and technical support to volunteers, while the volunteers decide where, when, and what they will monitor.

The Level 1 training consists of four different assessment types: chemical/physical, habitat, biological, and standing waters (IDNR 2006). The chemical/physical and habitat assessments are specific to streams. From this point forward this report will focus on the standing waters assessments. The standing waters assessment combines the chemical/physical assessment and habitat assessment in a format specific to lakes, ponds, and wetlands.

The physical assessment for standing waters includes information on weather, air temperature, precipitation, wind direction and speed, site location, Secchi depth or water transparency, water temperature, water level, and water odor.

The chemical assessment for standing waters includes the same parameters as the stream chemical assessment; however the method of collecting the sample differs. The standing waters assessment uses a point sampling technique where volunteers collect a sample from elbow depth. The chemical assessment for standing waters includes: pH, nitrite nitrogen, nitrate nitrogen, dissolved oxygen, phosphate, and chloride.

The biological assessment for standing waters includes the analysis of benthic macroinvertebrates, using the biological assessment form used for stream sampling, as well as analysis of water color and the presence of algal blooms.

The habitat assessment for standing waters is less complex than that for streams and only consists of two observations: a description of the lake banks and a description of the adjacent land use.

The Level 2 assessments may also be used on standing waters. There are two Level 2 assessments: bacteria and benthic macroinvertebrate indexing. This report will include results from bacteria monitoring at standing waters sites.

MATERIALS AND METHODS

All volunteers are given a complete set of the equipment necessary to do the standing waters assessments when they complete an IOWATER workshop. This includes a thermometer, Secchi disk, Hach® pH test strips, Hach® nitrate-N/nitrite-N test strips, a Chemetrics® dissolved oxygen test kit, a Chemetrics® phosphate test kit, Hach® chloride titrators, a waste container, and a net, container, and magnifying cube for benthic macroinvertebrate collection.

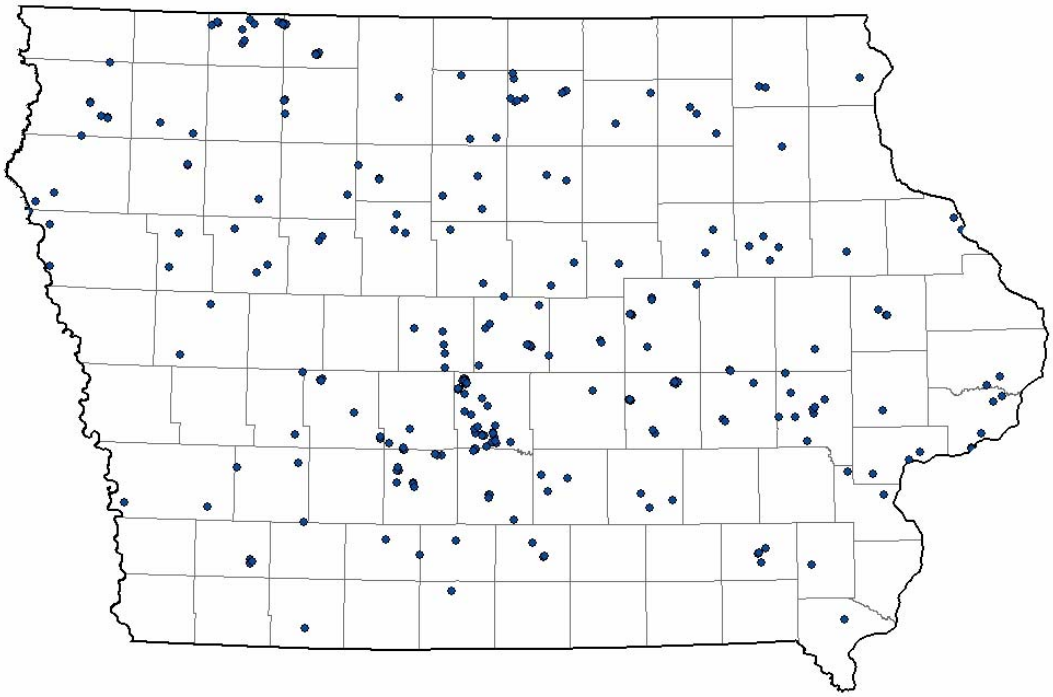
Volunteers register a specific site on a lake or wetland by providing the Universal Transverse Mercator (UTM) coordinates for the site. Volunteers are encouraged to choose a site location that is representative of the water body. Many times in lakes, this location is at the deep part of the lake. If volunteers do not have access to a boat, they may also sample from the shoreline or a dock. Whether the lake is sampled from shore or open water is indicated on the field datasheet.

The frequency of assessments is determined by the individual volunteers; however, IOWATER provides recommended frequencies for each assessment. Volunteers are encouraged to conduct chemical and physical assessments at least once per month from ice-out to freeze-over, biological assessments no more than 3 times per year (spring, summer, fall), and habitat assessments once per year or after major land use changes.

PROGRAM GROWTH

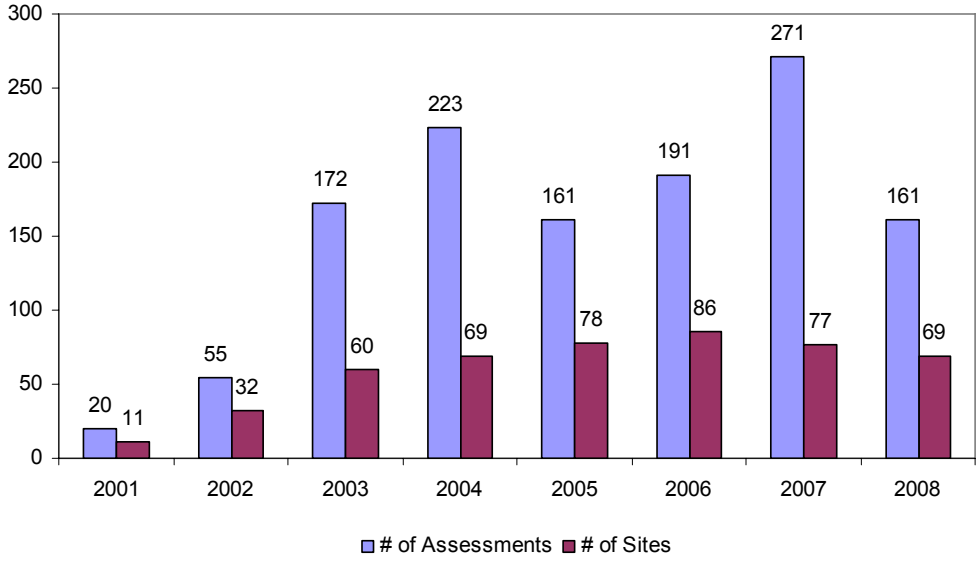
While the IOWATER program began in 1998, the first standing waters assessment wasn't completed until 2001 when the standing waters module was introduced. In 2001, 20 standing waters assessments were completed at 11 sites. From 2001 until 2003 the standing waters assessments were not included in the Level 1 Workshop, but were instead taught through a separate module. In 2003, the standing waters methods were incorporated into the Level 1 Workshop and were therefore taught to all new volunteers in the IOWATER program. From 2001 through 2008, 1,254 standing waters assessments were completed at 222 different sites.

Figure 1. IOWATER Standing Waters Assessment Sites 2001 through 2008



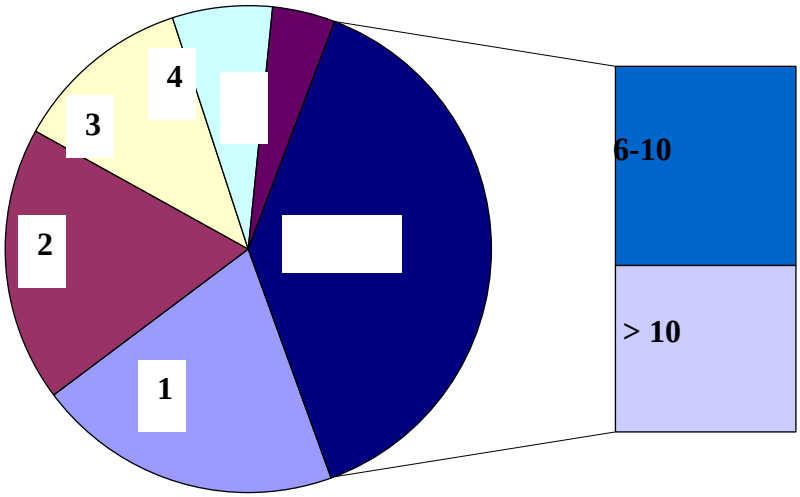
The number of assessments and sites per year is summarized in Figure 2. The maximum number of sites monitored was in 2006, while the maximum number of individual assessments completed was in 2007. Overall, the number of sites being monitored and the number of individual assessments being completed each year has not shown an increasing trend since 2004.

Figure 2. IOWATER Standing Waters Assessments



The number of assessments collected at each site varies. Over half of the sites monitored (57%) had less than 5 standing waters assessments completed (Figure 3). There were also a large number of sites that only had one (20%) or two (18%) assessments for them. There were only 39 sites that had more than 10 assessments completed (18%).

Figure 3. Number of assessments completed per site.



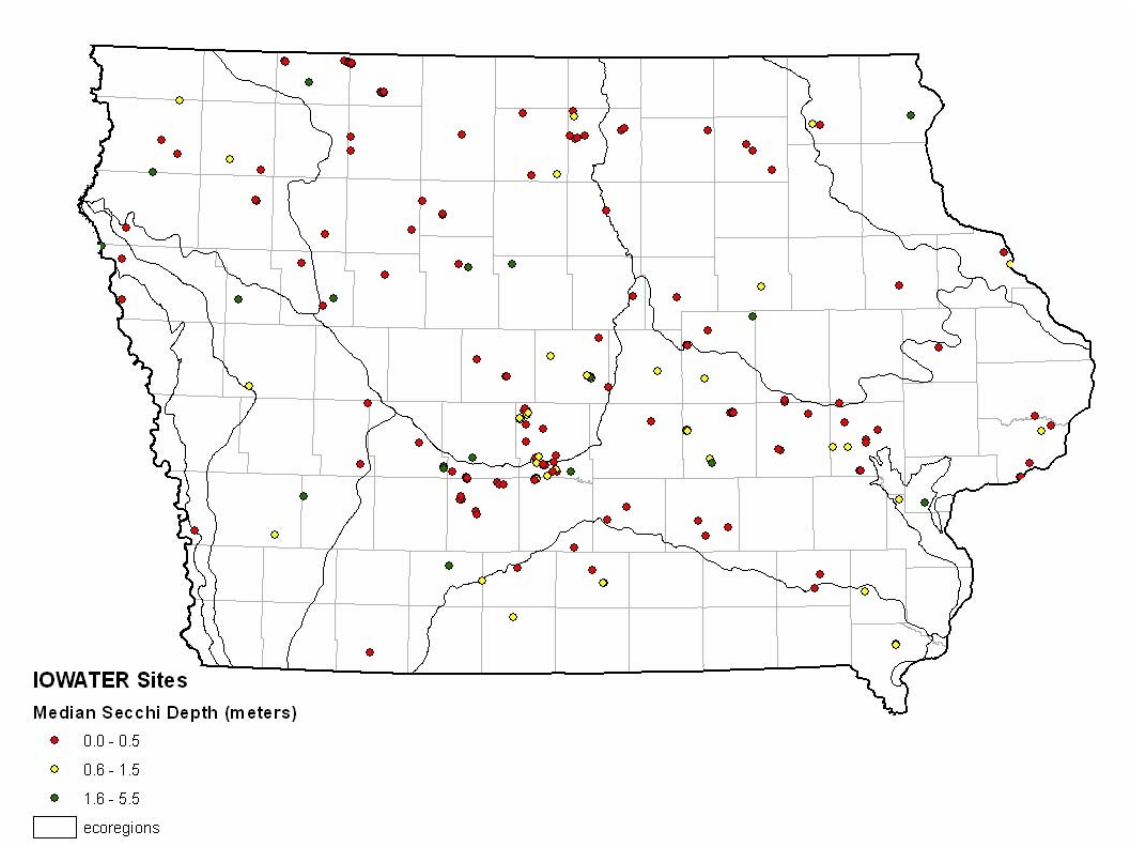
RESULTS

Water Clarity

Secchi depth is a measure of the clarity of a lake. Clarity is affected by algae, soil particles, and other materials suspended in the water. Secchi depths vary seasonally with the deepest Secchi depths generally occurring in the early spring before algae become abundant. Secchi depths then decrease through the summer when algae production is greatest. Of the 1,254 standing waters assessments submitted to the IOWATER database, only 380 contained a Secchi depth value from 2001 through 2008. The measured Secchi depths ranged from 0.1 meters (m) to 6.8 m with an average of 1.1 m. The average Secchi depth from the IOWATER monitored sites is similar to the average Secchi depth from the ambient lake monitoring program (1.2 m). The ambient lake monitoring program has monitored 131 publicly owned lakes throughout the state from 2000 through 2008. The ambient program monitors for a variety of chemical and physical parameters at the deep spot of each lake.

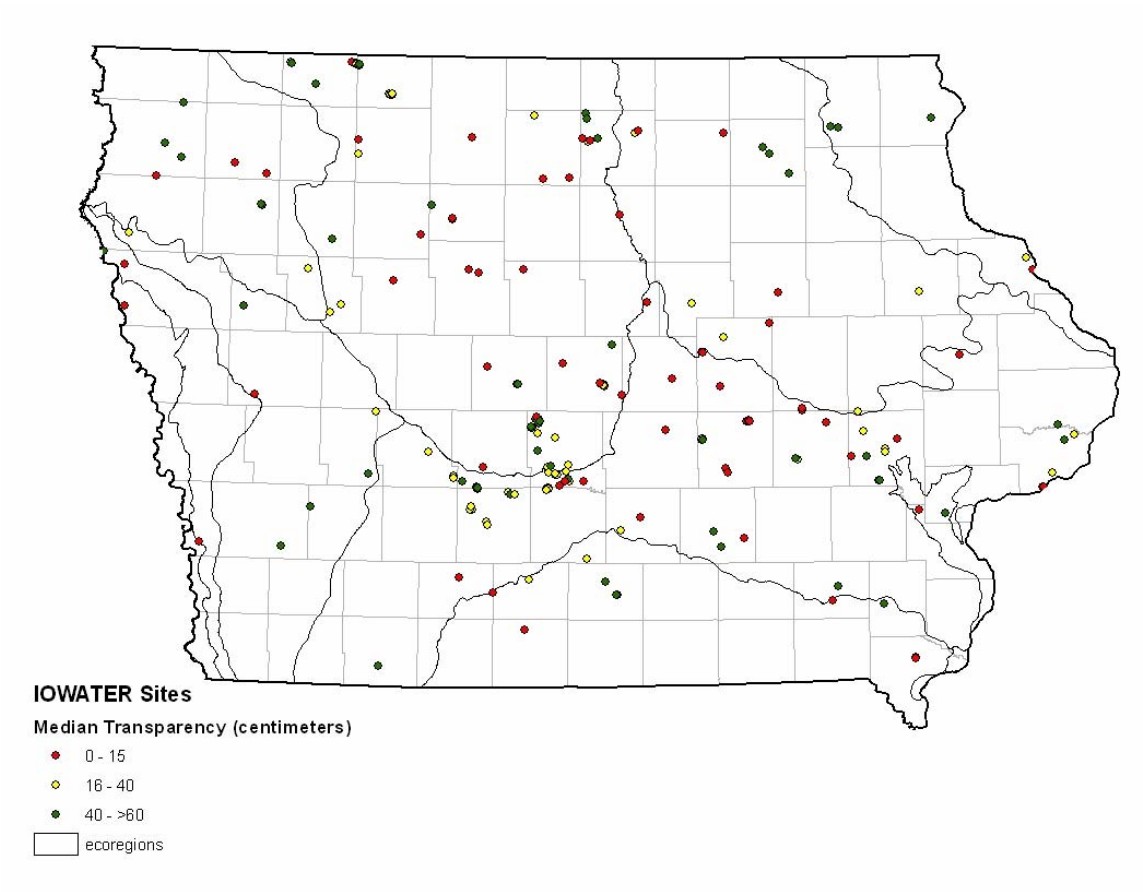
NOTE: Ecoregions are areas in which there is relative homogeneity in ecological systems and relationships between organisms and their environment. Ecoregions are included in the following maps to show major landform areas across the state. See below for a more detailed explanation of ecoregions and data analysis by ecoregion.

Figure 4. Median Secchi Depth at IOWATER Standing Waters Sites (2001-2008).



An alternative option to measure water clarity is to use a transparency tube. The transparency tube is commonly used to measure water clarity in streams where shallow depths preclude the use of a Secchi disk, while the Secchi disk is the preferred method for lakes and ponds. Transparency measurements obtained using the transparency tube are limited to 60 centimeters (cm), which can limit the amount of useful information collected. There were 730 transparency tube measurements taken by IOWATER volunteers on standing waters from 2001 through 2008. Transparency measurements using a transparency tube ranged from 2 cm to >60 cm with an average transparency of 36 cm.

Figure 5. Median Water Transparency at IOWATER Standing Waters Sites (2001-2008).



Dissolved Oxygen

Dissolved oxygen is the amount of oxygen in the water. Dissolved oxygen is important because fish and other aquatic organisms need oxygen to live. Oxygen enters the lake by diffusion with the atmosphere and photosynthesis of algae and aquatic macrophytes. Oxygen is removed from the water by the processes of decomposition and respiration. Dissolved oxygen varies throughout the day, seasonally, and at various depths of a lake. Dissolved oxygen increases during the day when sunlight is present and photosynthesis is occurring and decreases at night when photosynthesis is not occurring. Water temperature also affects the amount of dissolved oxygen the water is able to hold. Cold water is able to hold more dissolved oxygen than warm water; however, warm water temperatures also increase photosynthesis which can cause increased dissolved oxygen concentrations. Finally, dissolved oxygen can be different at various depths of the lake. This is especially true in lakes that experience thermal stratification.

There were 1,136 dissolved oxygen values reported from the 1,254 standing waters assessments. Dissolved oxygen concentrations at IOWATER standing waters assessment sites varied from 1 mg/L to 12 mg/L with an average of 8 mg/L. The average dissolved oxygen concentration from the upper mixed zone of the lakes for the ambient lake monitoring program was 9.2 mg/L. The minimum dissolved oxygen (1 mg/L) occurred at multiple sites. Most of these sites were located in wetlands and are therefore expected to have periods of very low oxygen levels. The other

sites were associated with stormwater detention ponds or golf course ponds, which are also more susceptible to low dissolved oxygen levels than traditional lakes.

Figure 6. Median Dissolved Oxygen Concentration at IOWATER Standing Waters Sites (2001-2008).

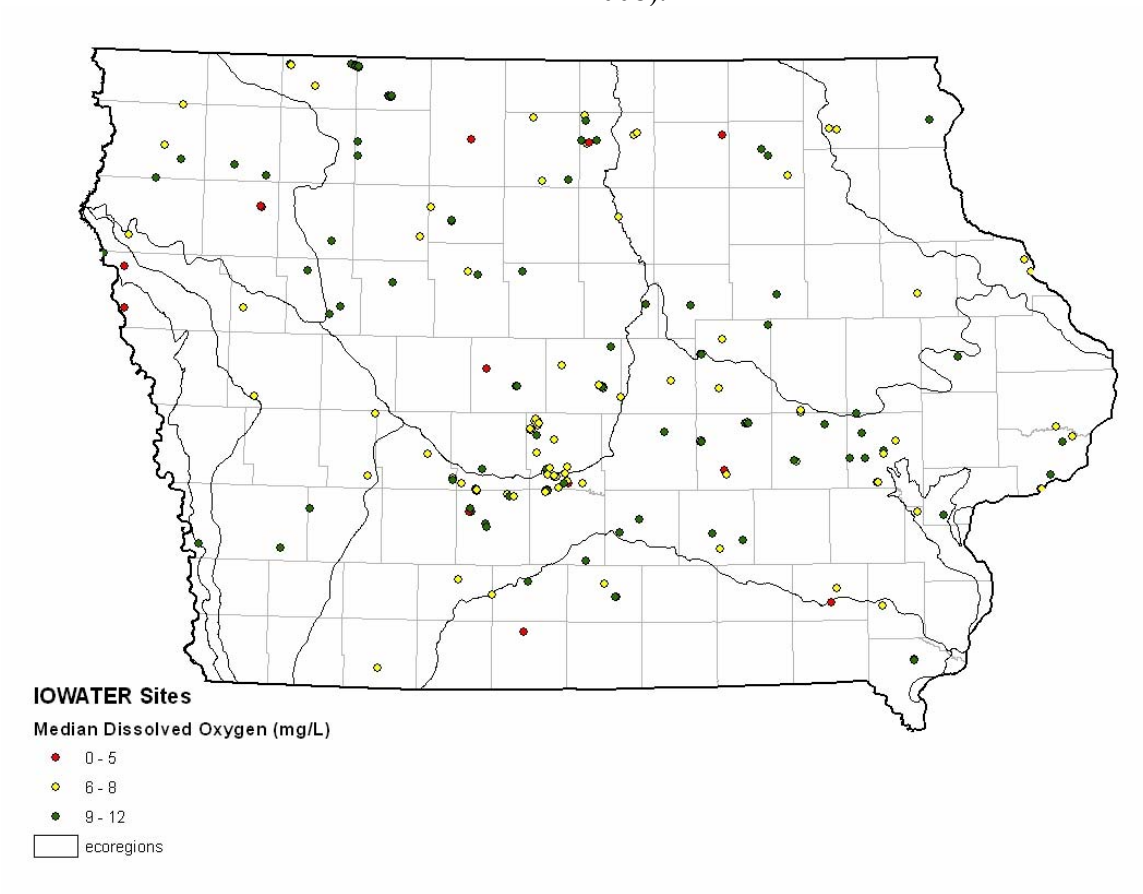


Figure 6 shows there were 12 sites with median dissolved oxygen concentrations that were 5 mg/L or less. Five of those 12 sites were wetland areas. Four of the 12 sites were farm ponds, which also may experience occasional low dissolved oxygen periods due to their shallow depth and nutrient enrichment. One of the sites was a pond on a golf course. The final two sites only had one assessment each and the samples appear to have been taken in shallow coves near the shore, based on photographs that accompanied the assessments.

pH

The pH of water is a measure of the concentration of hydrogen ions. The pH of water determines the solubility and biological availability of nutrients such as phosphorus, nitrogen and carbon, and heavy metals (lead, copper, cadmium, etc.). Like dissolved oxygen, pH can change during the day and at various depths due to photosynthesis, respiration, and decomposition.

There were 1,180 pH values reported in the 1,254 standing waters assessments submitted from 2001 through 2008. Results from IOWATER standing water assessments show that pH ranged

from 4 to 9 with an average of 8. The average pH concentration from the ambient lake monitoring program was 8.5, which was very similar to the average concentration from IOWATER volunteers.

Water Temperature

Temperature is measured and reported from just below the surface at each lake. The temperature near the surface of the lake is important because it influences biological activity and growth. Generally at higher temperatures there is more biological activity. Temperature also has a major influence on the amount of dissolved oxygen in the water. Colder water is able to hold more dissolved oxygen than warmer water.

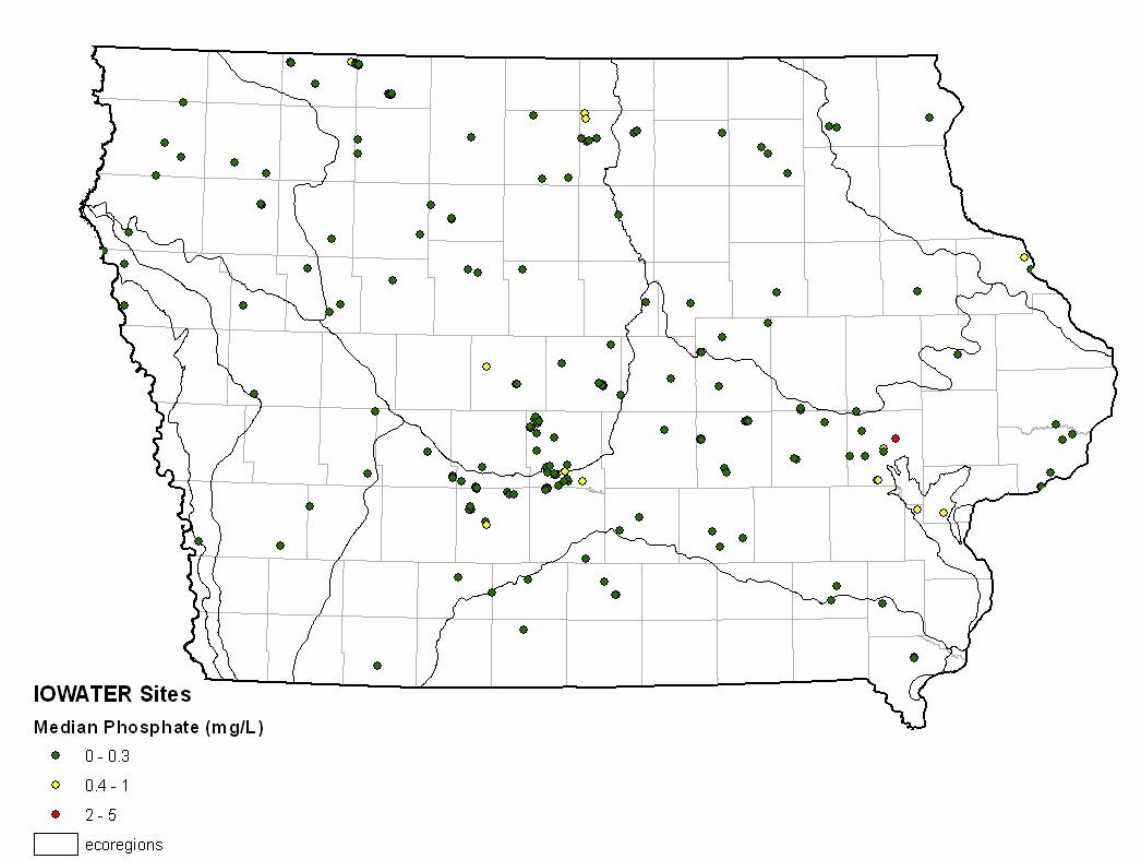
There were 1,126 temperature measurements submitted in the 1,254 standing waters assessments. Temperatures ranged from 14°F to 96°F with an average temperature of 66 °F.

Phosphate

Phosphorus is an essential nutrient for plant growth and many times in lakes is the limiting nutrient for plant growth. There are multiple different types of phosphorus found in surface waters. The IOWATER monitoring program test kits monitor orthophosphate (or soluble reactive phosphorus). This is the type of phosphorus that is readily used by plants.

There were 1,066 phosphate values reported in the 1,254 standing waters assessments in the IOWATER database. Phosphate concentrations ranged from 0 mg/L to 10 mg/L with an average of 0.2 mg/L. This is higher than the average orthophosphate concentration from the ambient lake monitoring program (0.03 mg/L). This is likely due to the differences in methods (IOWATER field test kit vs. laboratory analysis). While the IOWATER test kit is designed to measure orthophosphate, comparisons of IOWATER and laboratory data suggest that the amount of phosphate measured by the IOWATER test kit more closely resembles total phosphorus rather than orthophosphate. The maximum value for orthophosphate (10 mg/L) occurred at Harrier Marsh (Site # 908033) on October 13, 2003. Some possible explanations for this extremely high result could be: (1) during the process of sampling the volunteers may have stirred up sediment and phosphorus in this shallow wetland area, (2) the results were read incorrectly, (3) the result may have been entered into the database incorrectly, or (4) the result may be accurate. This site generally had high levels of phosphate (1 - 2 mg/L) from 2003 through 2008.

Figure 7. Median Phosphate Concentration at IOWATER Standing Waters Sites (2001-2008).

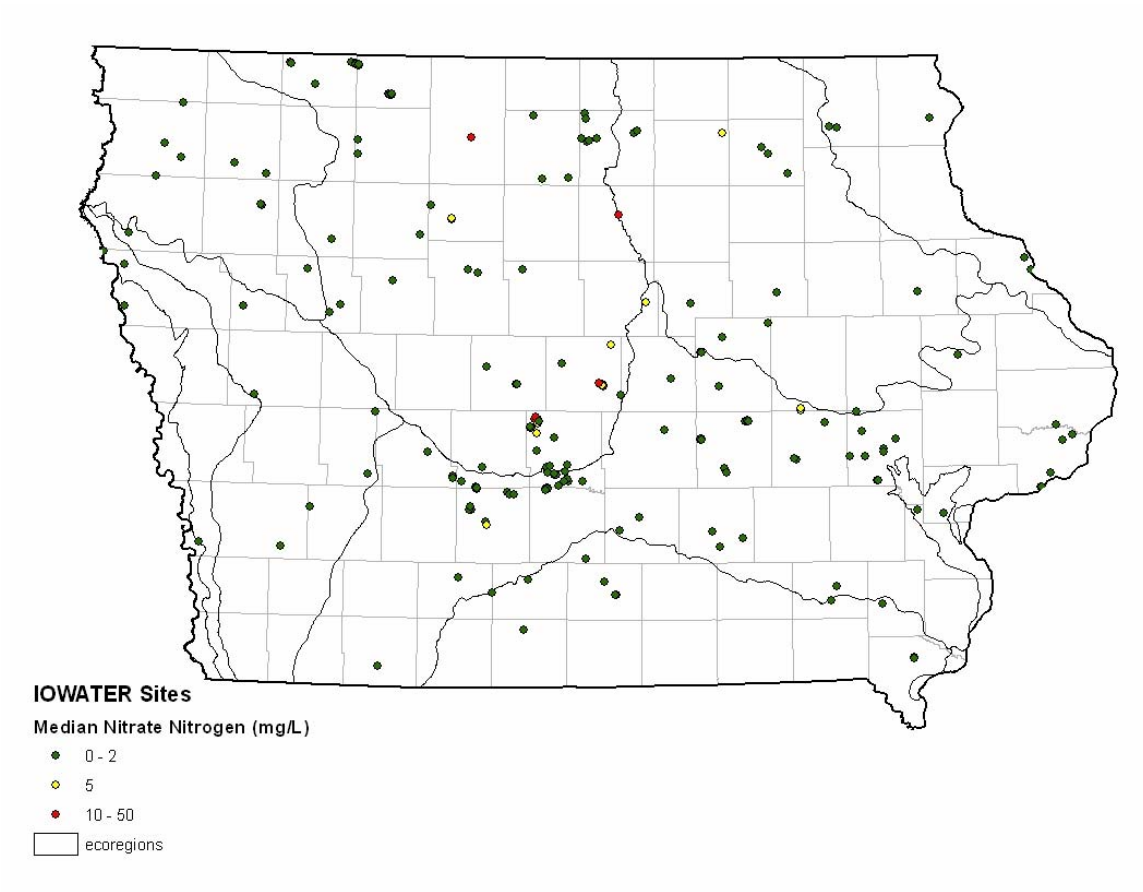


Nitrate/Nitrite

Nitrogen is another essential nutrient for plant growth. Nitrogen is very abundant in the environment and found in many forms. Inorganic forms in the water include nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3). Nitrogen is also found in many organic compounds including amino acids, proteins, and peptides. The IOWATER monitoring program measures nitrate and nitrite nitrogen in the surface waters.

There were 1,141 nitrite values reported in the 1,254 standing waters assessments. Nitrite concentrations ranged from 0 mg/L to 3 mg/L with an average of 0.1 mg/L. There were 1,146 nitrate values reported in the 1,254 standing waters assessments. Nitrate concentrations ranged from 0 mg/L to 50 mg/L with an average of 1.4 mg/L. Through the ambient lake monitoring program nitrate and nitrite nitrogen are measured together. The average nitrate + nitrite concentration from the ambient lake monitoring program was 1.4 mg/L. Nitrate and nitrite concentrations tend to be highest in the spring when fertilizers are being applied to the land and precipitation is common. Nitrate and nitrite are water soluble compounds that are readily transported when it rains.

Figure 8. Median Nitrate Nitrogen Concentrations at IOWATER Standing Waters Sites (2001-2008).

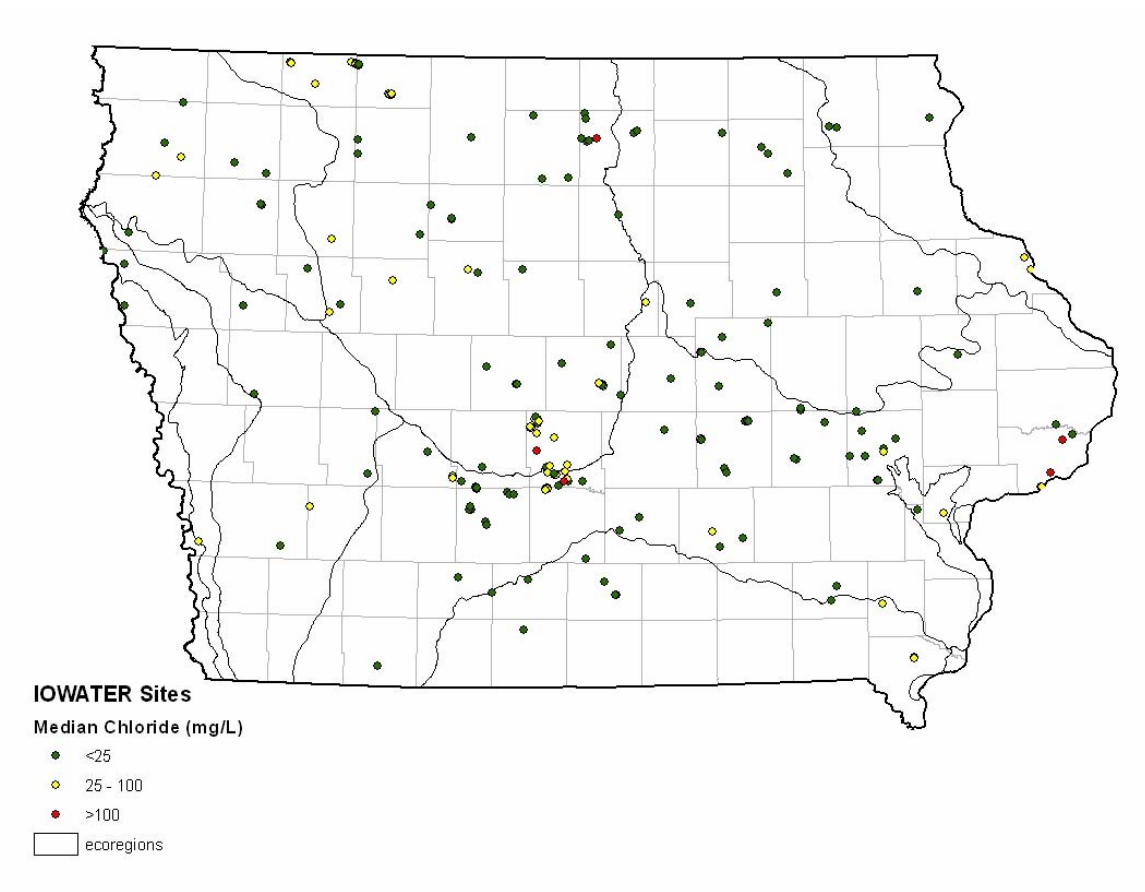


Chloride

Chloride is a chemical found in salts, which tend to dissolve easily in water. In lakes, elevated levels of chloride may indicate inputs of human or animal waste, or inputs of fertilizers, many of which contain salts. Chloride may also occur due to runoff of road salt during winter months. Chloride is used as a "conservative" measure of water contamination as many natural processes, such as breakdown by bacteria, do not affect it.

There were 761 chloride values reported in the 1,254 standing waters assessments. Chloride concentrations ranged from <25 mg/L to 510 mg/L with an average of 30 mg/L. Chloride is not measured as part of the ambient lake monitoring program. Because chloride contamination is generally associated with human impacts, many times it is highest around cities. This can be seen in Figure 9, which shows the highest concentrations of chloride near Des Moines and Davenport.

Figure 9. Median Chloride Concentrations at IOWATER Standing Waters Sites (2001-2008).



E. coli

E. coli are a type of bacteria that can be found in the water. Indicator *E. coli* bacteria does not make people sick, however high levels of *E. coli* indicate that the water has come into contact with fecal material and other pathogens or disease causing organisms may be present. IOWATER volunteers must take an advanced workshop to learn how to test for *E. coli*. There were 156 *E. coli* samples collected on the IOWATER standing waters sites. *E. coli* concentrations ranged from 0 colony forming units (CFU)/100 mL to 6,533 CFU/100 mL. The average *E. coli* concentration was 378 CFU/100 mL.

CARLSON'S TROPHIC STATE INDEX

The large amount of water quality information collected by many lake monitoring programs can be confusing to evaluate. In order to analyze all of the data collected it is helpful to use a trophic state index (TSI). A TSI condenses large amounts of water quality data into a single, numerical index. Different values of the index are assigned to different concentrations or values of water quality parameters.

The most widely used and accepted TSI, called the Carlson TSI, was developed by Bob Carlson (1977). Carlson found statistically significant relationships among summertime total phosphorus, chlorophyll a, and Secchi transparency for numerous lakes. He then developed

mathematical equations to describe the relationships between these three parameters, which are the basis for the Carlson TSI. Using this method, a TSI score can be generated by just one of the three measurements. Carlson TSI values range from 0 to 100.

The Carlson TSI is divided into four main lake productivity categories: *oligotrophic* (least productive), *mesotrophic* (moderately productive), *eutrophic* (very productive), and *hypereutrophic* (extremely productive). Mesotrophic lakes, for example, generally have a good balance between water quality and algae/fish production. Eutrophic lakes have less desirable water quality and an overabundance of algae or fish. The productivity of a lake can therefore be assessed with ease using the TSI score for one or more parameters.

The Carlson TSI does not apply to all lakes. The relationship between transparency, chlorophyll a, and total phosphorus can vary based on factors not observed in Carlson's study lakes. For example, high concentrations of suspended sediments will cause a decrease in transparency from the predicted value based on total phosphorus and chlorophyll a concentrations.

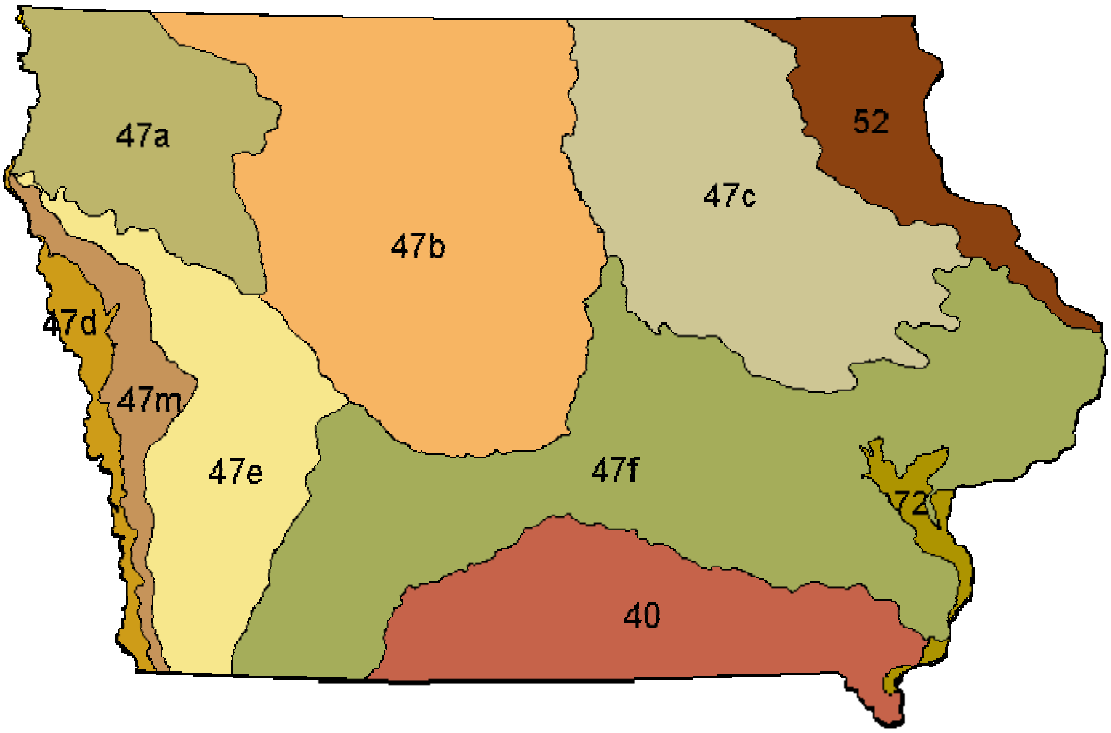
The only parameter collected through IOWATER Standing Waters Assessments that can be used to calculate Carlson's Trophic State Index values is Secchi depth. Only 104 sites had a Secchi depth result associated with at least one assessment and only 380 Secchi depth measurements were taken. Therefore, information on Secchi depth and the associated trophic state is limited for the IOWATER standing waters assessments. Using the median Secchi depth for the 104 sites with readings, 12 sites were in the *mesotrophic* category, 60 sites were in the *eutrophic* category, and 32 sites were in the *hypereutrophic* category. These results suggest many lakes have poor water transparency that is, according to Carlson's TSI relationships, associated with high levels of nutrients and algae blooms.

ECOREGIONS

Ecological regions (ecoregions) are areas in which there is relative homogeneity in ecological systems and relationships between organisms and their environment. Ecoregions were delineated in the late 1980s (Omernik 1987) to provide a geographic framework for more efficient management of ecosystems and their components. This concept recognizes that land features such as bedrock geology, topography, soil type, vegetation, land use, and human impacts interact to form specific ecological regions or ecoregions. The relative importance of individual factors and the complexity with which these factors interact varies from one ecoregion to another.

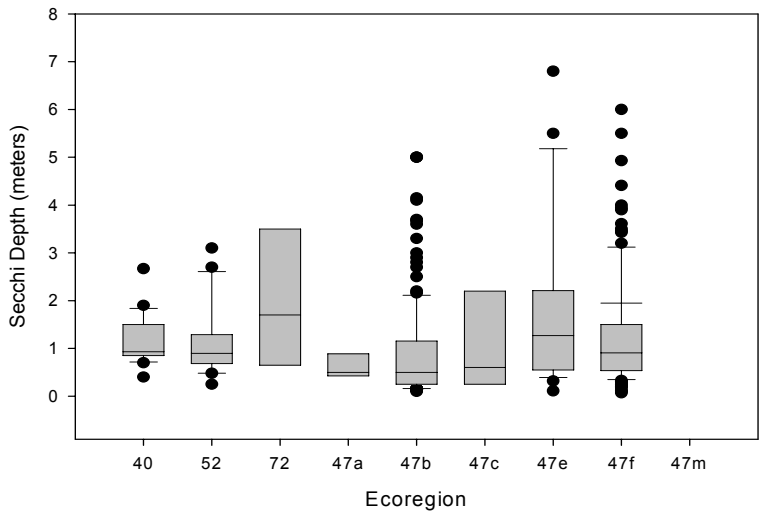
Ecoregions can be recognized and defined at different scales to suit a variety of purposes (Omernik 1995). Omernik's Level III ecoregion delineations (1987) created 4 ecoregions in Iowa: the Western Corn Belt Plains (47), the Central Irregular Plains (40), the Driftless Area (52), and the Interior River Lowland (72). In 1993, the U.S. EPA and IDNR completed an ecoregion refinement project to facilitate biocriteria development (Griffith et al., 1994). This project further refined the ecoregions in Iowa. Currently there are 10 Level IV ecoregions or subecoregions within the state of Iowa. Nine of these ecoregions have lakes within them.

Figure 10. Ecoregions and Subregions of Iowa. (Modified from Griffith et al., 1994)



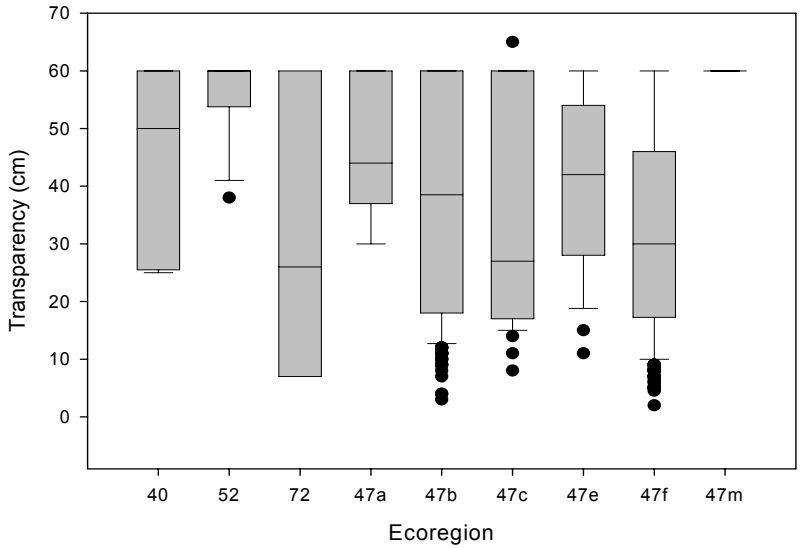
Median Secchi depth transparency varied greatly among the ecoregions of Iowa (Figure 11). The Interior River Lowland Ecoregion (72) had the highest median Secchi depth transparency (1.7 m), however only two sites were monitored in this ecoregion, which may not be representative of the entire ecoregion. No Secchi depth measurements were taken in the Missouri Alluvial Plain Ecoregion (47d) and only two measurements were taken in the Loess Hills Ecoregion (47m). The lowest median Secchi depth transparency (0.5 m) was found in both the Des Moines Lobe Ecoregion (47b) and the Northwest Iowa Loess Prairies Ecoregion (47a). These two ecoregions are characterized by shallow, natural lakes. The shallow depth of these lakes results in greater amounts of sediment and nutrient resuspension leading to poor water transparency.

Figure 11. Secchi Depth Transparency by Ecoregion.



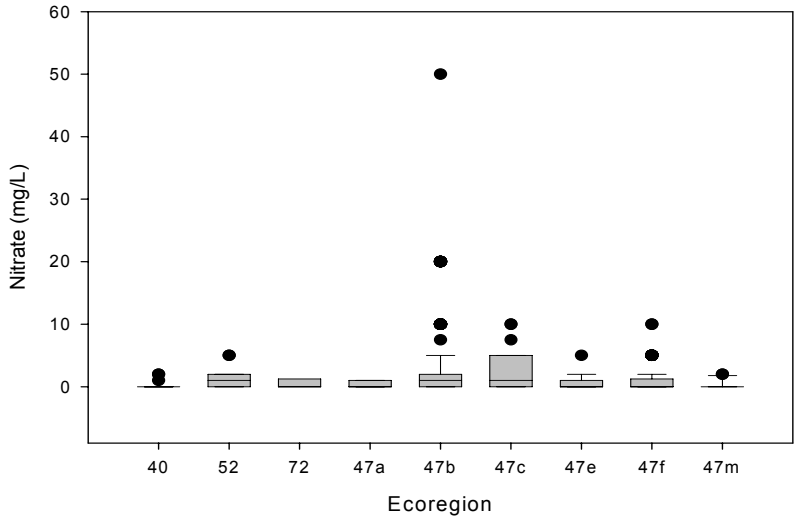
Median water transparency using the transparency tube method also varied greatly among ecoregions (Figure 12). The Loess Hills Ecoregion (47m) and Paleozoic Plateau Ecoregion (52) had the highest median transparency (60 cm). Both of these ecoregions, however, had few sites monitored and a limited number of measurements. The Interior River Lowland Ecoregion (72) had the lowest median transparency (26 cm), however there were only 3 transparency measurements taken in this ecoregion. Overall it is difficult to evaluate the transparency tube data due to the limited number of measurements and the fact that the maximum measurement allowable is 60 cm.

Figure 12. Transparency using the Transparency Tube Method by Ecoregion.



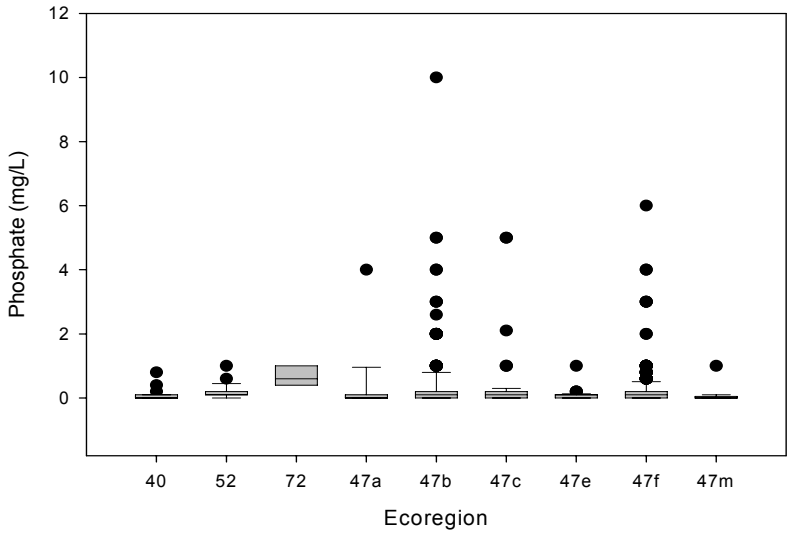
The Paleozoic Plateau Ecoregion (52), the Des Moines Lobe Ecoregion (47b), and the Iowan Surface Ecoregion (47c) all had the highest median nitrate nitrogen concentration (1 mg/L). The median for the remaining ecoregions (47a, 47e, 47f, 47m, 72, and 40) was 0 mg/L. High nitrate nitrogen concentrations are common in the Des Moines Lobe Ecoregion (47b) due to the large amount of artificial tile drainage and row crop agriculture in this region.

Figure 13. Nitrate Nitrogen Concentrations by Ecoregion.



The median phosphate concentration was highest in the Interior River Lowland Ecoregion (72) (0.6 mg/L). However, only 5 samples were collected in this region. Phosphorus levels were generally low in each ecoregion and did not vary greatly. The median phosphate concentration for ecoregions 52, 47b, 47c, and 47f was 0.1 mg/L, while the median phosphate concentration for ecoregions 40, 47a, 47e, and 47m was 0 mg/L.

Figure 14. Phosphate Concentrations by Ecoregion.



TRENDS

The amount of data collected through the IOWATER standing waters assessments makes trend analysis difficult. Only one site had at least one data record collected in all 8 years (2001-2008). This site was located at Swan Lake in Dickinson County. Figures 15 and 16 show that transparency and phosphate levels, respectively, show a stable trend since 2001.

Figure 15. Transparency Trend at Gemm 2 Site, Swan Lake, Dickinson County.
(NOTE: The black line in the following graphs represents the trend line using linear regression. The trend line shows whether the values for each parameter have increased, decreased, or stayed relatively the same. The trend lines below are not considered statistically significant; however, visual inspection can show changes in these parameters over time.

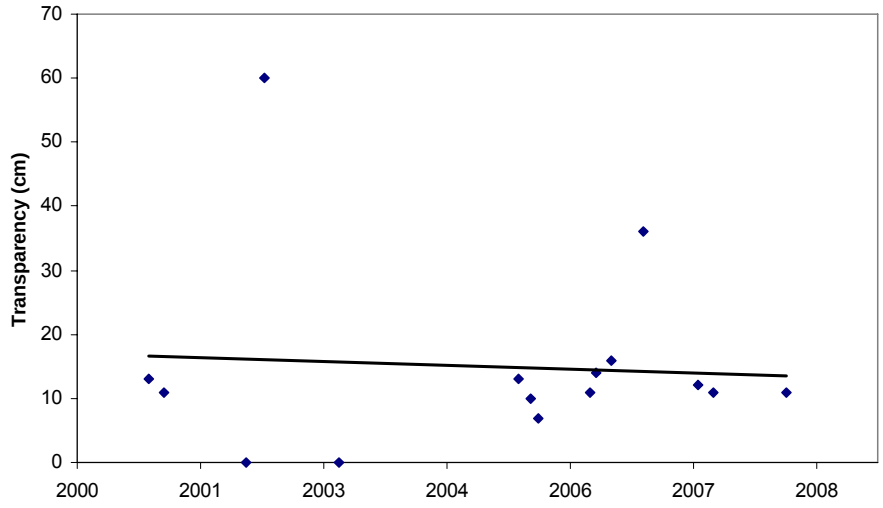
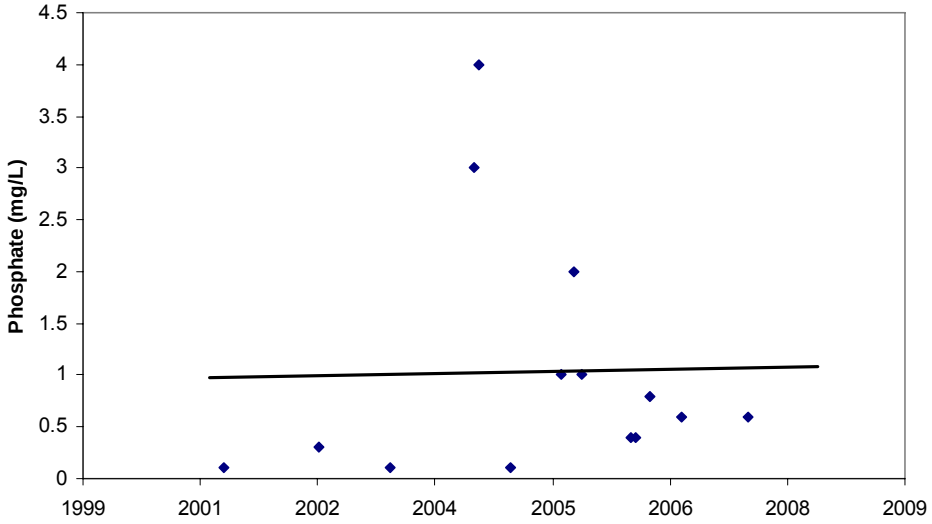


Figure 16. Phosphate Trend at Gemm 2 Site, Swan Lake, Dickinson County.



Multiple sites have been monitored for 6 years. Mallard Marsh East has been monitored since 2003 and shows trends toward increasing phosphate and decreasing water transparency based on visual inspection (Figures 17 and 18). While these trends are not statistically significant, they may point to possible areas where water quality is degrading. Additional samples taken each year would assist in analyzing trends.

Figure 17. Transparency Trend at Mallard Marsh East, Cerro Gordo County.

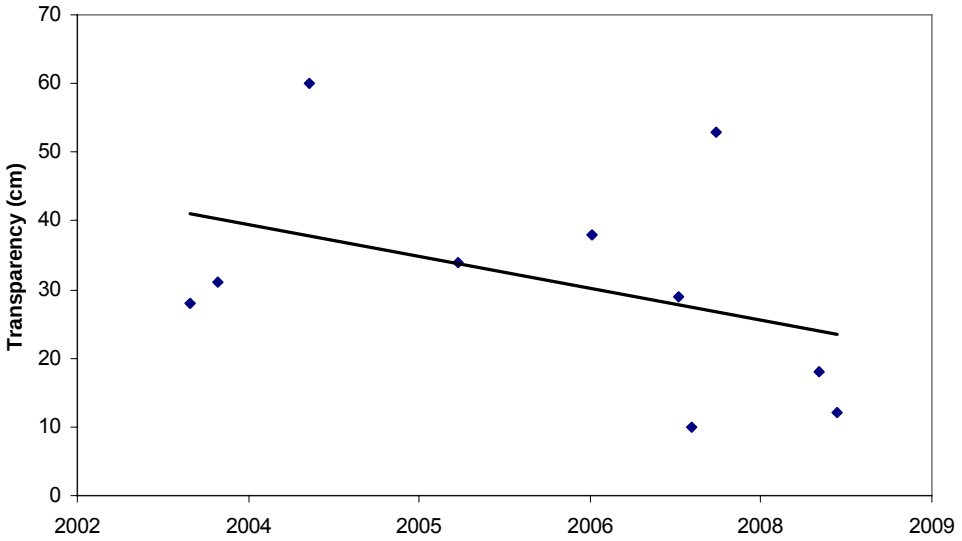
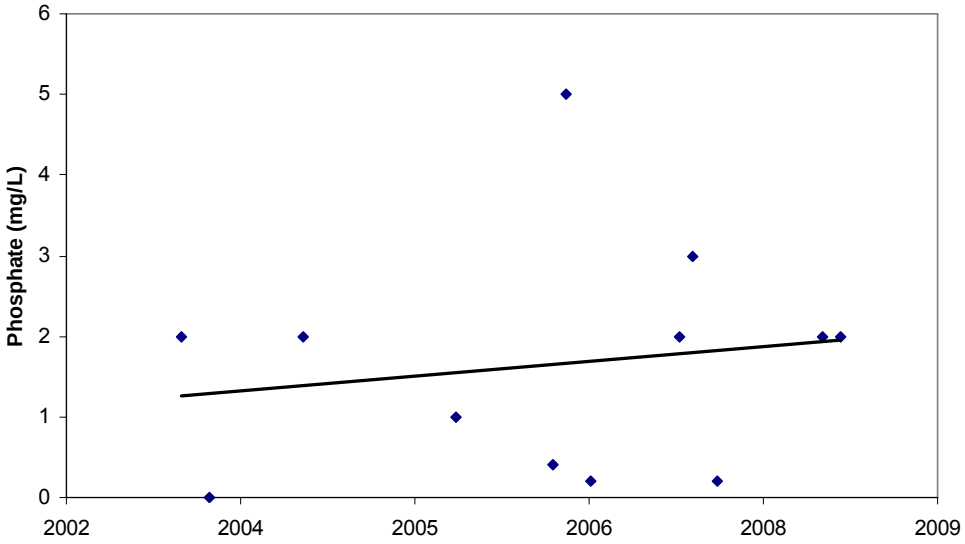


Figure 18. Phosphate Trend at Mallard Marsh East, Cerro Gordo County.



Overall, additional data are needed to assess long-term trends at the IOWATER standing waters assessment sites. A minimum of monthly samples from May through September would be necessary to ensure that the water quality at a site is accurately characterized and can be compared from year to year with a relatively high level of confidence.

SUMMARY

The standing waters assessments completed through the IOWATER program have provided a start on gathering additional information on Iowa's lakes and wetlands. The IOWATER program monitors many lakes and ponds that are not otherwise monitored through DNR programs. Overall, the results from these sites show that most chemical physical parameters are similar to those seen through the DNR's ambient lake monitoring program.

Additional analysis shows that the majority of lakes where Secchi depth was collected are considered eutrophic or hypereutrophic based on Carlson's trophic state index. This is also similar to results from professional lake monitoring in Iowa and indicates that Iowa's lakes are nutrient rich systems.

Analysis of the IOWATER standing waters data by ecoregion shows that there are some differences in water quality based on location in the state. Standing waters on the Des Moines Lobe (Ecoregion 47b) tended to have shallower Secchi depths and higher nitrate concentrations when compared to other ecoregions. This is likely due to the large number of shallow, natural lakes, ponds, and wetlands in this area.

While only 8 years of data have been collected at most at standing water sites, some sites are beginning to show trends in the data. Additional data collection at these sites and other sites will continue to provide information on whether water quality is improving, staying the same, or worsening at individual sites. Further data collection by IOWATER volunteers will provide valuable information on the standing waters of Iowa.

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APPENDIX – IOWATER STANDING WATERS ASSESSMENT SUMMARY STATISTICS

ALL DATA	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	970	380	730	1126	1180	1136	1141	1146	1066	761	156
mean	0.1	1.1	36	66	8	8	0.1	1.4	0.2	30	378
std dev	0.4	1.1	18	13	1	3	0.2	3.3	0.6	41	935
min	0	0.1	2	14	4	1	0	0	0	<25	0
25th	0	0.4	19	59	8	6	0	0	0	<25	0
median	0	0.8	35	68	8	8	0	0	0.1	<25	100
75th	0	1.4	57	76	9	10	0.15	2	0.2	32	300
max	4.5	6.8	60	96	9	12	3	50	10	510	6533

2001	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	18	12	6	20	20	20	18	20	15	1	0
mean	0.1	1.4	22	63	8	8	0.0	1.0	0.5	<25	
std dev	0.3	1.0	10	14	1	3	0.0	1.2	1.3		
min	0	0.3	11	34	7	5	0	0	0	<25	0
25th	0	0.5	15	53	8	6	0	0	0	<25	
median	0	0.9	21	60	9	8	0	1	0.1	<25	
75th	0	2.0	28	76	9	10	0	1	0.3	<25	
max	1.1	3.1	38	89	9	12	0.15	5	5	<25	0

2002	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	35	24	16	42	34	36	50	51	38	6	1
mean	0.1	1.1	50	67	9	10	0.1	4.6	0.2	<25	200
std dev	0.2	0.9	17	14	1	3	0.2	7.9	0.6	8.6	
min	0	0.1	15	19	6	1	0	0	0	<25	200
25th	0	0.5	51	55	8	8	0	1.5	0	<25	200
median	0	0.9	60	70	9	10	0.15	2	0.1	<25	200
75th	0	1.2	60	76	9	12	0.15	5	0.2	<25	200
max	1	3.7	60	89	9	12	1	50	4	34	200

2003	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	126	55	89	153	156	149	161	161	153	18	9
mean	0.1	1.0	34	65	8	9	0.1	1.2	0.2	<25	329
std dev	0.2	1.0	20	14	1	3	0.3	2.8	0.9	9.2	256
min	0	0.1	2	35	5	1	0	0	0	<25	133
25th	0	0.3	15	56	8	6	0	0	0	<25	167
median	0	0.7	34	67	9	9	0	0	0.1	<25	233
75th	0	1.5	54	76	9	10	0.15	2	0.1	<25	300
max	1	4.9	60	90	9	12	3	20	10	28	833

2004	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	200	102	104	206	215	215	220	219	203	136	64
mean	0.1	1.1	41	67	8	8	0.1	2.9	0.2	<25	177
std dev	0.5	1.0	18	12	1	3	0.1	4.2	0.4	43	380
min	0	0.1	9	14	5	1	0	0	0	<25	0
25th	0	0.5	25	62	8	6	0	0	0	<25	0
median	0	0.8	40	69	8	8	0	2	0.1	<25	33
75th	0	1.4	60	75	9	10	0.15	5	0.15	28	200
max	4	5.0	60	85	9	12	1	20	4	510	2533

2005	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	141	47	93	150	154	153	153	153	145	101	30
mean	0.2	1.3	36	66	8	9	0.0	0.7	0.2	<25	243
std dev	0.4	1.3	19	14	1	3	0.1	1.4	0.6	22	587
min	0	0.2	7	30	4	1	0	0	0	<25	0
25th	0	0.4	16	56	7	8	0	0	0	<25	0
median	0	1.0	36	66	8	10	0	0	0.1	<25	50
75th	0.1	1.7	60	76	9	12	0.15	1	0.2	30	292
max	2	5.5	60	96	9	12	0.3	10	4	148	3233

2006	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	147	49	123	168	180	177	166	167	158	170	19
mean	0.1	1.1	35	66	8	9	0.0	0.8	0.2	38	903
std dev	0.4	1.5	17	14	1	3	0.1	2.8	0.6	49	1675
min	0	0.1	5	34	6	1	0	0	0	<25	0
25th	0	0.4	22	55	8	6	0	0	0	<25	0
median	0	0.7	31	68	9	8	0	0	0.1	<25	167
75th	0.1	1.3	52	78	9	10	0	0	0.2	43	533
max	4.5	6.8	60	91	9	12	0.3	20	5	315	5300

2007	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	191	46	201	260	266	234	228	228	216	200	16
mean	0.2	1.2	33	69	8	8	0.1	0.7	0.3	32	1060
std dev	0.4	1.1	18	11	1	3	0.2	1.2	0.7	42	1790
min	0	0.2	4	33	5	1	0	0	0	<25	0
25th	0	0.4	17	62	8	6	0	0	0	<25	25
median	0	0.9	29	70	9	8	0	0	0.1	<25	150
75th	0.1	1.2	49	79	9	10	0	1	0.3	36	1350
max	2	5.0	60	90	9	12	1.5	5	6	320	6533

2008	Precipitation 24 hours (inches)	Secchi Depth (meters)	Transparency (centimeters)	Water Temperature (°F)	pH	Dissolved Oxygen (mg/L)	Nitrite Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Phosphate (mg/L)	Chloride (mg/L)	E. coli (CFU/100 mL)
N	112	45	98	127	155	152	145	147	138	129	17
mean	0.2	1.0	39	64	8	9	0.0	1.2	0.2	33	180
std dev	0.5	0.9	17	10	1	2	0.1	2.1	0.5	40	202
min	0	0.1	3	37	6	2	0	0	0	<25	0
25th	0	0.5	25	60	7	8	0	0	0	<25	33
median	0	0.8	41	65	8	8	0	0	0.1	<25	100
75th	0.1	1.1	56	71	9	10	0	2	0.2	36	233
max	4	4.0	60	83	9	12	1.5	10	4	321	700