2001 SUMMARY REPORT
of
CROOKED LAKE

Lake County, Illinois

Prepared by the

LAKE COUNTY HEALTH DEPARTMENT
ENVIRONMENTAL HEALTH SERVICES
LAKES MANAGEMENT UNIT
3010 Grand Avenue
Waukegan, Illinois 60085

Joseph Marencik
Michael Adam
Christina Brant
Mary Colwell
Mark Pfister

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EXECUTIVE SUMMARY

Crooked Lake has been plagued by a variety of lake quality problems for decades. These problems have brought about degradation in water quality that has led to some severe lake quality problems. The two biggest contributors to this decline in water quality are adjoining Slough Lake and an overabundant carp population. After years of phosphorus rich inputs from Slough Lake and the surrounding watershed, Crooked Lake has built up a high internal store of phosphorus. Slough Lake is the most significant contributor to this high internal store. Historical data shows that these phosphorus inputs may be declining since the closure of the duck farm in the mid 1980s. However, these inputs will not be substantially reduced unless problems in Slough Lake are addressed.

The excessive carp population in the lake is another major source of degraded water quality. Due to their feeding and spawning activities, carp resuspend nutrients and sediment which causes massive lake wide planktonic algae blooms and significantly reduces clarity. This turbidity caused by both the algae and suspended sediment have substantially reduced light penetration. This has led to a decline in the aquatic plant community of the lake. This too has negatively impacted the health of the Crooked Lake. A healthy aquatic plant population is crucial to good lake health. Aquatic plants provide sediment stabilization, habitat, food, and other water quality benefits. In recent years Eurasian water milfoil, an exotic invasive aquatic plant, has entered the lake (probably from Hastings Lake). Precautions should be taken to ensure that this plant does not become overabundant and dominate the lake.

However, all is not bad on Crooked Lake. Our shoreline analysis found that the presence of shoreline erosion on Crooked Lake is very low. This is due in large part to the high occurrence of naturalized buffered areas in addition to vast areas of undisturbed wetlands. Buffered areas and wetlands offer superior protection against wind and wave action, which can quickly eat away exposed, unprotected shorelines. Additionally, these beneficial shoreline types provide excellent wildlife habitat that provide refuge for a variety of water fowl and shoreline birds such as the common tern, which is a Illinois threatened species.

With some intensive management, Crooked Lake could be greatly improved. However, it will never be rehabilitated to the pristine glacial lake it once was. In recent years there have been efforts to reduce the carp population but these efforts have gone largely unsuccessful. Currently, carp removal techniques were reexamined and a more feasible plan is underway. Improvements to the fishery are also being implemented and include creation of fish structure and fish stocking. Additionally, in recent years (2000-2001) there has been a renewed interest in improving the lake. A loosely organized group of concerned lake residents have banned together in order to put together an improvement plan for the lake. Any major plan for improvement must include residents of the lake and surrounding watershed (including all subdivisions working as one), the Lake County Forest Preserve District, and possibly county, township, and city governments.

LAKE IDENTIFICATION AND LOCATION

Crooked Lake is a private lake located in unincorporated Lake Villa Township (with a portion within the village Lindenhurst) just northeast of intersection of Grand Avenue and Deep Lake Road (T46N, R10E, Section 34). Crooked Lake is an oblong, 137-acre glacial lake (Figure 1). The current maximum water depth is 26.5 feet with an average depth of 10.8 feet (LCHD-LMU morphometric data). Lake volume has been calculated to be approximately 1488 acre feet (LMU morphometric data). Crooked Lake is part of the North Mill Creek watershed, which is a drainage basin of the Des Plaines River watershed. Slough Lake (a.k.a. Douglas Lake) drains into Crooked via a creek from the south (Slough Lake drain). Crooked Lake receives water from Slough Lake during periods of high water (i.e., Spring/Fall rains). Crooked Lake drains into Hastings Lake via a dammed creek (Crooked Lake Drain), which is located directly east. Hastings Lake drains into Hastings Lake drain, which eventually drains into North Mill Creek and into the Des Plaines River. The watershed of Crooked Lake, which includes both Slough and Hastings Lake, is approximately 1174 acres (Figure 2).

BRIEF HISTORY OF CROOKED LAKE

Current historical records for Crooked Lake date back to the late 1890's. In C.F. Johnson's 1896 book titled *Angling in the Lakes of Northern Illinois: How and Where to Fish Them* there are several chapters dedicated to the lakes of Lake County including Crooked Lake. Although anecdotal, his accounts provide some insight into the condition of Crooked Lake at the turn of the last century. In his book he states that *"Crooked Lake affords very fine pickerel, perch and bass fishing. Its general characteristics regarding sport are something like those of Sand Lake, either big catches of large fishes or a total blank, but unlike Sand Lake in this respect – the blank days are not nearly so frequent."* He also adds that it was at Crooked Lake (and surrounding lakes) that then Cook County Commissioner James Munn came up with the idea of a weedless hook. Munn's love of area lakes also explains the origin of the road on the east side of Crooked Lake bearing his name. In addition to his verbal commentary, Johnson also includes a hand drawn map of Crooked Lake (Figure 3). On it one can clearly see areas where he has written fishing observations. He notes such things as areas of rushes (probably hard stem bulrush) that surround the entire lake perimeter, which are "*good bass grounds*." These rush areas still exist today but no where near the expanse described by Johnson. In addition to his angling comments, Johnson also hypothesizes as to where the lake's name originated:

> "I have asked several persons who are supposed to know: 'Why is Crooked Lake so named?' With the exception of one man, everybody I asked unhesitatingly answered 'Because it's so crooked of course.' The exception referred to was, I think, the only truthful one of my informants, for after pondering deeply for a few moments he turned around and frankly admitted he did not know and, furthermore, not feeling interested, didn't care a bean."

The truth may never be known. As late as 1841 it did not appear on maps of the area but according to historical record it appears to have been named sometime around 1860.

Figure 3. 1896 C.F. Johnson map of Crooked Lake.

The problems that Crooked Lake has had in the past, including nuisance algae blooms, excessive carp, and fish kills, can be traced back to the mid 1940's when reports of nuisance algae blooms started to surface. Reports of carp problems begin to appear in the 1950s. Infestation by carp more than likely is the result of poor oxygen conditions brought on by the nuisance algae blooms that started the previous decade. Carp control programs were tried seven times between 1961 and 1986. A large rotenone treatment was carried out in 1974 and a reported combined 100 tons of carp were removed out of Crooked, Slough, and Hastings (Figure 4). The treatment was short-lived due to misapplication of rotenone. All of these problems can be attributed to high nutrient concentrations in Crooked Lake (see *Limnological Data – Water Quality*). A large portion of this nutrient contamination has come from the operation of the Weber duck farm on adjacent Slough Lake from the mid 1940s through the mid1980s. During normal operation, the farm had 45,000-50,000 ducks (at times up to 100,000), which lived in and around Slough Lake. The waste from these ducks either directly deposited or washed into the lake, contain high levels of nutrients. These nutrients were eventually washed into Crooked Lake on a continual basis until the closure of the Duck farm in the mid 1980's. The farm was closed due to legal pressure by the East Shore Crooked Lake Improvement Association, Lake Villa Township, Illinois Environmental Protection Agency, and economic pressure. Additionally, in the past there was also three dairy farms in close proximity to Crooked Lake. The Walker farm closed in 1954, the Wolf farm closed in the early 1940's, and the third also closed in the 1940s. The sink of associated nutrient rich feedlot runoff was probably Crooked Lake. The effects of years of nutrient deposition will be discussed in the section titled *Limnological Data – Water Quality* later on in this report.

SUMMARY OF CURRENT AND HISTORICAL LAKE USES

Access to the lake is limited to lake and subdivision residents. There are four main access points on the lake (one for each subdivision)(Figure 1). The newest access is located at the far north end of the lake for the Emerald Shores subdivision. This access has a fishing/observation pier and a beach, which is used by residents of the subdivision. Additionally, there is also a place for non motorized watercraft (i.e., paddle boats, canoe, etc.). Another access point is located along the west shore and is the access point for the Crooked Lake Oaks subdivision. This area has a large beach with several boat mooring spots for the community use as well as storage for rowboats and canoes. This access site also has the only boat ramp on the lake, which is used by subdivision and other Crooked Lake residents (by permission). On the southwest portion of the lake is a third access point at Sedgewood Cove. This access site has a pier as well as a dozen boat mooring poles for Sedgewood Cove residents. There is also a licensed swimming beach and a small park at this location, which is monitored by the Lake County Health Department. Water samples are taken on a bimonthly basis and are tested for fecal coliform bacterial levels to ensure swimming safety. In 2001 this beach was tested seven times and was never closed due to high bacteria levels. The fourth access point on the lake is on the east shore of the lake. This area used to be open to all residents of the east shore but in recent years access has been limited to only a few homeowners.

Figure 4. Fish rehabilitation article from 1974.

1974

Lake rehabilitation appears successful

BY JOE KIRBY
Staff Writer

The major fish rehabilitation project undertaken a year ago in Crooked, Hastings and Slough (or Weber) Lakes in Lake Villa Township appears to be highly successful.

Township Supervisor Ronald Coles recently received the favorable report on current conditions in Crooked and Hastins Lakes from Gary Erickson, district fishery biologist for the Illinois Conservation Department. Slough Lake will be checked later in the year.

"The results were very encouraging," said Erickson after surveying Crooked Lake on June 24. "The largemouth bass stocked last year are averaging 6.5 inches and are in excellent shape. The northern pike are growing very rapidly and are in the six-inch size class. The sunfishes are averaging about three inches and they also are in excellent condition. Only two carp were seen and collected during the survey of 100 per cent of the shoreline."

In the report, Erickson commented on the increased clarity of both Crooed and Hastings Lakes. "The abundant filamentous algae now present on Crooked Lake is due to the absence of the rough fish and the greatly increased clarity of the water," the report said.

"Because there is a lack of rooted aquatic plants over the past years it will take some time before they again become established in the lake," the report continued. "But eventually they will take the place of the present algae foations and a more balanced system will then exist."

For some persons who use or live near Crooked Lake the most apparent improvement since the treatment last year is in the area of water clarity. Erickson points out that "the reading during the survey was 14 feet, 6 inches as compared to only 19 inches in 1973."

The Conservation Department team reported that the survey at Hastings Lake revealed similar conditions as far as fish were concerned and a clarity reading of 16 feet, 4 inches. Erickson said that "is the deepest reading I have ever seen in a lake in this part of the state."

The report concluded that "all in all everything looks excellent and I will be monitoring these areas in the future to keep on top of the situation."

Last August, after the fish had been removed from the lakes involved, Erickson sent Lake Villa officials a list of suggested guidelines to maintain the population of fish at desired levels. The lakes had been stocked with largemouth bass, bluegills, sunfish and northern pike. The fish were chosen for three principal reasons:

- 1. They are the most suitable species considering the size of the water area and the water quality involved.
- 2. The fewer the number of species, the easier it is to maintain a desireable balance in the lake.
- 3. To maintain the proper balance in the lake there has to be a strong predator population.

In addition to the four main access points for the subdivisions, there are also three other access points on Crooked Lake (Figure 1). Peacock Camp, which opened in 1930, is located on the western shore between Crooked Oaks and Sedgewood subdivisions. This is a children's day camp that has lake frontage with a licensed swimming beach, a pier, and non-motorized watercraft (canoes, rowboats, etc.). The Girl Scouts of America own a parcel of land on the northwest corner of the lake that also serves as a camp. A third organization, the White Feather Indian Club has lake access on the northeastern shore of the lake. Their access includes a beach, pier, and boat storage.

Currently there is no official governing body for the lake. Each subdivision has its own group that deals with lake issues. In 2000, the Crooked Lake Improvement Committee (CLIC) formed as an informal organization that is dedicated to improving Crooked Lake. It is made-up of concerned lake residents from all subdivisions. The CLIC meets every one to two months to discuss lake issues and develops plans for improvement.

The lake's main use is recreational boating and fishing. Gas motors are allowed on the lake with no restrictions on horsepower. However, Emerald Shores does not let their residents keep powerboats. The number of powerboats moored at Crooked Oaks is minimal. Sedgewood Cove has about a dozen power boat/jet skis moored at the park. A majority of the boats on the lake are docked at private residences on the east shore, which is made up of private lakefront lots, a feature that is largely absent on the rest of the lake. Fishing is also a major recreational use that is enjoyed by several lake and community residents. The lake is stocked yearly with a variety of sport fish (see *Limnological Data – Wildlife Assessment*). Nature presents several sources of enjoyment for residents of Crooked Lake. Numerous waterfowl and other birds can be viewed at different times of the year. In addition several other forms of life inhabit the lake and surrounding areas (see *Limnological Data-Wildlife Assessment*).

Historically, the uses of the lake have not changed over the last 100 years. In the past fishing was a large, if not the main, attraction on the lake. With the advent of powerboats, other recreational opportunities such as water skiing and leisure boating have become more widespread. In the past, two resorts operated on Crooked Lake. Grady's, which opened in the mid 1890's and closed in the mid 1960's. The original name of this resort was Joe & Helen's Resort. The second resort was Romie's Hideout (called the Hideout after 1963), which was located on the southeast shore and closed in the mid 1990s. Currently, there are two "resorts" on the lake, the White Indian Feather Resort (northeast shore, off Munn Road) and the Crooked Lake Resort (east shore, off Munn Road).

LIMNOLOGICAL DATA - WATER QUALITY

Water samples collected from Crooked Lake were analyzed for a variety of water quality parameters. Samples were collected at 3 feet and from 19-21 foot depths from May through September at the deep hole location in the lake (Figure 1). Crooked Lake thermally stratifies, which means the lake divides into warm upper water (epilimnion) and cool lower water (hypolimnion). This phenomenon occurred every month but May (had yet to stratify) and September (fall turnover had occurred). This stratification is due to the deep lake morphology of Crooked Lake (see *Interpreting Your Lake's Water Quality* for further explanation). Below is a discussion of highlights from the complete data set for Crooked Lake (Table 1, Appendix A).

Temperature stratification of the lake is reflected in the dissolved oxygen (D.O.) levels as well as other water quality data. D.O. concentrations were not problematic in Crooked Lake (see *Appendix C: Multiparameter Data for Crooked Lake*). During the five-month study D.O. was fairly consistent, averaging 8.08 mg/L, from the surface to about 11-12 feet. This means that approximately 80% of Crooked could support aquatic life. In the past, a small aerator was run off the east shore. The aerator was not run in 2001 and the D.O. levels were still acceptable. Based on volumetric calculations, a properly sized aerator for Crooked Lake would need to be 25-37 HP. Since this aerator is vastly undersized and ecologically unnecessary, it would be financially sensible that its operation be discontinued in the future. The only benefit of an aerator in Crooked Lake would be to prevent anoxic conditions from forming, which in turn would reduce the amount of phosphorus released into the entire lake volume in the. The approximate cost of a compressor unit of proper size would be approximately $14,000 – $20,000. However, since D.O. concentrations are good and only about 20% of Crooked Lake becomes hypoxic during the summer, an aeration system is unnecessary.

Secchi disk depth is a direct indicator of water clarity as well as overall water quality. In general, the greater the Secchi disk depth, the clearer the water and better the water quality. Secchi disk readings in Crooked Lake were fairly consistent over the five-month study ranging from 2.10 feet in May to 2.98 feet in August. The seasonal average was 2.5 feet, which is well below the Lake County median of 5.1 feet. However, this is an improvement over past average Secchi disk readings on Crooked Lake, which were 1.7 feet in 1995 and 1.1 feet in 1986. Lake wide algae blooms that were present throughout the study caused these poor Secchi disk readings. Lack of aquatic vegetation and high concentrations of nutrients, namely phosphorus (see below) cause these blooms. Additionally, a healthy aquatic plant population directly competes with algae for resources. Aquatic plants also stabilize nutrient rich sediment. With a balanced, healthy aquatic plant population, which Crooked Lake does not have, nutrient resuspension is reduced, occurrence of nuisance algal blooms are reduced, and water clarity increases. With no aquatic plants, sediment bound nutrients may become available (resuspended) and nuisance blooms can occur. Carp are also a major source of sediment/nutrient resuspension at Crooked Lake (see *Limnological Data – Wildlife Assessment*).

Besides decreasing Secchi disk depth, lake wide algal blooms and resuspended sediment negatively impacted other water quality parameters. The average total suspended solids (TSS) during the study was 13.7 mg/L and remained consistent over the duration of the study (Table 1, Appendix A). This is over twice the County median of 5.7 mg/L (1995-2001 samples). TSS was slightly higher the first half of the study (May and June). This could be due to an increased amount of resuspended sediment due to carp spawning and greater intensity algae blooms (due to high phosphorus). Calculated average nonvolatile suspended solids (NVSS)[1] concentrations were 9.4 mg/L. This means that 69% of the average TSS can be related to sediment resuspension. Monthly NVSS calculations show that resuspended sediment account for 66-70% of TSS every month. This further supports the negative impacts that carp are having on Crooked Lake. Measurements of other types of solids, unaffected by algae growth, were below or near the County median. This further reinforces that the elevated TSS and decreased Secchi disk readings were due to algal blooms and carp activity. Historically, the average TSS concentration has decreased from 1995 (22 mg/L) to 2001 (13.7 mg/L). This could be attributed to a reduction in both carp populations and intensity of nuisance algae blooms over past years, which both significantly contribute to TSS.

Algae need light and nutrients, most importantly carbon, nitrogen (N) and phosphorus (P), to grow. Light and carbon are not normally in short supply (limiting). This means that nutrients (N&P) are the limiting factors in algal growth. To compare the availability of these nutrients, a ratio of total nitrogen to total phosphorus is used (TN: TP). Ratios <10:1 indicate nitrogen is limiting. Ratios of >15:1 indicate phosphorus is limiting. Ratios >10:1, <15:1 indicate that there is enough of both nutrients for excessive algal growth. Most lakes in Lake County are phosphorus limited. Crooked Lake had an average TN:TP ratio of 15:1. This means that phosphorus was a slightly limiting nutrient in the lake and any increases of phosphorus could trigger increased algae blooms. Phosphorus concentrations in Crooked Lake were *high* (average TP was 0.101 mg/L). These high TP concentrations are the cause of the nuisance algae blooms experienced year round on Crooked Lake. In May, June, and September phosphorus concentrations were near double the phosphorus concentrations the rest of the study. TP concentrations drastically decrease in July and then remain stable during August. This coincides with the dry period during the summer when inputs from Slough Lake decreased. Rain data supports this, with TP decreasing as rain amounts (and possibly flow from Slough) decreased (Figure 5). TP was highest in May with 0.145 mg/L, which is 3 times the County median concentration. This coincides with the greatest extent of observed algal blooms. There was another peak in TP in September. This was due to fall turnover, which mixed the released phosphorus that had built up in the hypolimnion during the summer months. Soluble reactive phosphorus (SRP), which is not normally detectable in the epilimnion in stratified lakes, was present in May, June, and September. The presence of SRP was probably due to the die off of curly leaf pondweed in the spring (May and June) and turnover in the fall (September). Additionally, other water quality parameters, which are closely linked to phosphorus levels and algae growth such as TSS and Secchi disk readings, were also at their worst in May (Table 1, Appendix A). Nitrogen (NH_3-N and NO_3-N) was nondetectable throughout the study in the epilimnion. Hypolimnetic NH_3-N and NO_3-N concentrations were also well below the County median. Total Kjeldahl nitrogen was present in above average concentrations in the epilimnion but was below average in the hypolimnion. This is due to periodic mixing of the hypolimnion and epilimnion during certain periods of the study (May and September).

[1] NVSS is the part of the TSS measurement that is nonvolatile suspended sediment that is not released at high temperature.

On a positive note, since the duck farm closed in the mid 1980's, the amount of phosphorus in Crooked Lake (and coming from Slough Lake) is slowly decreasing (Figure 6). LCHD tests in 1968 show that Slough Lake and Crooked Lake had a TP concentration of 11.00 mg/L and 2.0 mg/L, respectively. This is 41 times higher than concentrations found in Slough Lake during 2000 (0.263 mg/L) and 20 times higher than concentrations in Crooked Lake during 2001 (0.101 mg/L). Sampling of Slough Lake a decade later in 1978, while the duck farm was still in operation, yielded no change (11.41 mg/L). However, water quality testing of Slough Lake in 1990, after the duck farm had been closed, yielded a TP concentration of 0.587 mg/L (95% reduction from 1978). Similarly, sampling of Crooked in 1986, which was shortly after the duck farm closed, resulted in a TP of 0.64 mg/L, which is a reduction of 68% from 1968. Before this year, the most recent testing of Crooked Lake was in 1995. TP concentrations were 0.10 mg/L (the same as 2001 concentrations). So it appears that the phosphorus concentrations in Crooked Lake (and Slough) initially dropped off considerably after the closure of the duck farm and have now leveled off. This is not to say that they will not decrease further some day. If the carp problems were brought under control and the inputs from Slough Lake were stopped/controlled, phosphorus concentrations could drop further.

Another way to look at nutrient concentrations and how they affect productivity of a lake is the use of a Trophic State Index (TSI) based on average phosphorus concentrations. TSI can be based on phosphorus, chlorophyll *a*, and Secchi disk depth to classify and compare lake productivity levels (trophic state). The phosphorus TSI is setup so the higher the phosphorus concentration the greater amount of algal biomass and as a result, a higher trophic state. Based on a TSI phosphorus value of 70.8, Crooked Lake is classified as hypereutropic (>70 TSI). This means that the lake is a highly productive system that has excessive nutrient levels and high algal biomass (growth). Field observations reinforce that Crooked Lake is *hypereutrophic*. For comparison, most glacial lakes in the County are *eutrophic* (TSI values >50 <70). Out of all the lakes in Lake Country studied by the LMU since 1988, Crooked Lake ranks 82 out of 102 lakes based on average TSI (Table 2, Appendix A). For reference, Slough Lake is 100 and Hastings Lake is 77.

TSI values along with other water quality parameters can be used to make other analyses of Crooked Lake based on use impairment indexes established by the Illinois Environmental Protection Agency (IEPA). Using IEPA indexes, Crooked Lake is listed as having *Slight* use support impairment based on high levels of phosphorus. However, most overall use support impairment assessments were listed as *None*. Based on swimming use guidelines, Crooked Lake is categorized as providing only *Partial* support. This is due to poor Secchi disk readings and high phosphorus levels. Additionally, Illinois Department of Public Health recommends at least 48" Secchi disk depth for safe swimming (Crooked Lake's average was 30"). Under the recreational use impairment index, Crooked Lake was categorized as providing only *Partial* support. This is due to a high TSI value and high levels of suspended sediment, both of which result in poor visibility and contribute to an overall reduction in use of the lake. In the

case of aquatic life use impairment, Crooked Lake was categorized as providing *Full* support for aquatic life. Overall, Crooked Lake was listed as providing *Partial* overall support.

LIMNOLOGICAL DATA - AQUATIC PLANT ASSESSMENT

Floristic quality index (FQI) is a rapid assessment metric designed to evaluate the closeness that the flora of an area is to that of undisturbed conditions. It can be used to: 1) identify natural areas, 2) compare the quality of different sites or different locations within a single site, 3) monitor long-term floristic trends, and 4) monitor habitat restoration efforts (Nichols, 1999). Each submersed and floating aquatic plant species (emergent shoreline species were not counted) in the lake is assigned a number between 1 and 10 (10 indicating the plant species most sensitive to disturbance). Nonnative species were also counted in the FQI calculations for Lake County lakes. We then averaged these numbers and multiplied by the square root of the number of species present to calculate an FQI. A high FQI number indicates that there are a large number of sensitive, high quality plant species present in the lake. During the 2001 study, Crooked Lake had an FQI of 9.8. The Lake County average FQI for 2000-2001 was 14.0.

Aquatic plant surveys were conducted every month for the duration of the study (see *Appendix B* for methodology). Shoreline plants of interest were also observed (Table 3). However, no surveys were made of these shoreline species and all data is purely observational. The extent to which aquatic plants grow is largely dictated by light availability. Aquatic plants need at least 1% of surface light levels in order to survive. Based on the depth of the 1% light level, the depth at which plant growth could occur in Crooked Lake varied slightly on a monthly basis from 6-9 feet deep. Based on this light penetration level, aquatic plants could grow in about 50% of the lake. Surveys showed that plants did grow in these areas and were found to a maximum depth of 8.5 feet with average plant sample depth of 3.6 feet (Table 4, Appendix A). However, after May, plant growth in this zone was sporadic. Poor light penetration (and lack of aquatic plant growth) was due to the dominance of blue-green algae blooms. These blooms, dominated by the genera *Microcystis*, were present consistently from May through September with varying degrees of intensity with peak blooms occurring in May (observational). Furthermore, these blooms occur year round even during the winter under the ice (observational).

During May, curlyleaf pondweed (CLP) was the most abundant aquatic plant species and was found at 78% of sample sites. No other plants were noted in May. After May, plant diversity increased slightly to include five other species. However, plant density decreased during this same period. This was due to the die off of massive stands of curlyleaf pondweed that were present in May. This allowed light to reach other plants, thus the increase in diversity. CLP is a seasonal plant that thrives in cool waters and shorter days such as those found in the spring and fall.

As the study went on, the occurrence of the noxious aquatic weed Eurasian water milfoil increased. In May it was found at none of the sample sites but by September could be found at 25% of sample sites. This plant should be considered undesirable but currently is only sporadically located in a few areas of the lake (Figure 7). Eurasian water milfoil (EWM) densities should be closely monitored so they do not become problematic. If EWM populations do become problematic, management measures will have taken to prevent nuisance levels (see *Objective II: Aquatic Plant Management*). Excessive amounts of EWM can negatively impact fishery health as well as recreational activities.

Table 3. Aquatic and shoreline plants on Crooked Lake, May-September 2001.

Aquatic Plants	
Small Duckweed	*Lemna minor*
Eurasian Water Milfoil	*Myriophyllum spicatum*
Curlyleaf Pondweed	*Potamogeton crispus*
Sago Pondweed	*Stuckenia pectinatus*
White Water Lily	*Nymphaea tuberosa*
Yellow Pond Lily	*Nyphar advena*
Shoreline Plants	
Chairmaker's rush	*Scirpus pungens*
Purple Loosestrife	*Lythrum salicaria*
Reed Canary Grass	*Phalaris arundinacea*
Swamp Smartweed	*Polygonum coccineum*
Buckthorn	*Rhamnus cathartica*
Hardstem Bulrush	*Scirpus acutus*
Common Cattail	*Typha latifolia*

LIMNOLOGICAL DATA – SHORELINE ASSESSMENT

Shoreline assessments were conducted at Crooked Lake on July 26, 2001. Shorelines were assessed for a variety of criteria (*Appendix B* for methodology). Based on these assessments several important generalizations can be made. A majority of Crooked Lake's shoreline is developed (68%). The portion of the shoreline that was undeveloped was made up of cattail wetlands. Developed shoreline consisted of buffered areas (47%) and wooded lots (10%) (Figure 8). The high occurrence of these types of shoreline is encouraging, as they are less prone to erosion and provided good wildlife habitat. Shoreline types such as lawn (15%), beach (10%), seawalls (10%), and rip rap (9%) were also noted. The presence of manicured lawns and beach is normally considered undesirable. Manicured lawn is a poor shoreline water interface. This is due to the poor root structure of turf grasses, which are unable to stabilize soils and may lead to erosion. Beach makes a poor shoreline type due to the tendency of sand to be easily eroded and continually washed into the lake. Due to the recreational uses of the lake it is near impossible not to have some beach frontage. However, it would be advisable to try and limit the size of the beach frontage as much as possible. Since there is a very low occurrence of erosion on the lake (2% of the total shoreline), these shoreline types should not be considered problematic but should still be monitored for signs of erosion. Seawalls (and rip rap to an extent) are undesirable because of their tendency to reflect waves back into the lake. This can cause resuspension of near shore sediment, which can lead to a variety of water quality problems. Additionally, all four of these shoreline types; lawn, beach, rip rap and seawall, provide poor habitat. It is our recommendation that Crooked Lake Improvement Commission and individual neighborhood associations should promote the use of naturalized shoreline (native vegetation and buffer strips) and to minimize seawall, rip rap, and manicured lawns to the shoreline edge. Solutions to better protect Crooked Lake's shoreline against erosion are discussed in detail in *Options for Achieving the Lake Management Plan Objectives; Objective IV: Shoreline Erosion Control*.

LIMNOLOGICAL DATA – WILDLIFE ASSESSMENT

Wildlife observations were made on a monthly basis during water quality and plant sampling actives. All observations were visual. Several types of waterfowl were observed during the course of the study including the common tern, which is a State of Illinois endangered species (Table 5). There are healthy populations of mature trees that provide good habitat for a variety of bird species. There are also a few large dead trees that provide excellent habitat for Double Crested Cormorants. Additionally, there are several shrub and wetland areas that provide habitat for smaller bird and mammal species. Thirty-two percent of Crooked Lake's shoreline is undeveloped, which is encouraging especially for a residential lake in Lake County. Additionally, 47% of the developed shoreline consisted of buffered areas and wooded lots.

Table 5. Observed wildlife species on Crooked Lake, May – September 2001.

Birds	
Double Crested Cormorant	*Phalacrocorax auritus*
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhnchos*
Wood Duck	*Aix sponsa*
Ring-billed Gull	*Larus delawarensis*
Common Tern*****	*Sterna hirundo*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Red-tailed Hawk	*Buteo jamaicensis*
Red-Bellied Woodpecker	*Melanerpes carolinus*
Purple Martin	*Progne subis*
Barn Swallow	*Hirundo rustica*
American Crow	*Corvus brachyrhynchos*
Red Wing Blackbird	*Agelaius phoeniceus*
Amphibians	
Bull Frog	*Rana catesbeiana*
Leopard Frog	*Rana pipiens*
Reptiles	
Painted Turtle	*Chrysemys picta*

*Endangered in Illinois

There are two invasive plant species (purple loosestrife and buckthorn) that could be having negative impacts on the habitat around the lake and should be controlled/eliminated. Forty-eight percent of shoreline parcels had some invasive species growth. This means that some portion of roughly 9,300 lineal feet (66% of total shoreline) of Crooked Lake's shoreline is infested with one of these two species (Figure 9). These plants are seldom used by wildlife for food or shelter. They should be controlled/eliminated before they spread and displace other native and more desirable plant species (see *Objective III: Eliminate or Control Invasive Species*). In the summer of 2001, Wedgewood Cove initiated a buckthorn control program along their subdivision's lakefront property. In the spring of 2002 they will initiate a purple loosestrife control program in the cattail buffer areas along their shoreline. This is an example other groups on the lake should follow. Additionally, shoreline habitat should be improved with buffer strips and more naturalized shoreline areas (*see Objective V: Wildlife Habitat Improvement*).

Crooked Lake has an ongoing fish-stocking program. Fish species that are regularly stocked include largemouth bass, northern pike, and walleye. From 1998-2000 approximately 2,300 largemouth bass and 2,712 walleyes were stocked. In 2001, 260 northern pike and 1400 walleyes were stocked. For 2001, stocking plans include largemouth bass and channel catfish. IDNR recommendations regarding take and size limits should also be followed. Furthermore, a fishery survey was conducted in November of 2001 to determine the health of the fishery. In recent years there have not been any major fish kills. This is a welcome change since in the past, fish kills were quite frequent on Crooked Lake.

As stated above, one of the main sources of Crooked Lake's water quality problems is excessive number of common carp. The carp population of Crooked Lake has been negatively impacting Crooked Lake since the 1950's. Carp can cause a variety of water quality problems including resuspension of sediment and nutrients, disruption of the aquatic plant community, and low D.O. conditions. Additionally, this disruptive nature slowly deteriorates the quality of the lake's fishery until conditions are only suitable for their own (the carp) survival. Therefore, the carp in Crooked Lake should be eliminated/controlled. This has been the recommendation of the IDNR on several occasions. In 1961, a commercial fisherman was brought in and removed 50,000 pounds of carp. The lake has been seined for carp on at least five different occasions from 1982-1986. In the past, whole lake rotenone (fish poison) treatments have been unsuccessful. One possible explanation of past failures might be that rotenone was under applied and/or the entire lake (including cattail areas and outlet channel) was not treated completely. Treatment records from the 1974 rotenone application show that 2 parts per million (ppm) (1200 gallons) were used. The normal rate for removal of carp is 6 ppm, (3100 gallons). Additionally, the rotenone treatment of Slough and Hastings Lakes during the same time was also vastly under applied. The process of carp elimination is one of sacrifice. Currently, the levels of rotenone that are needed to kill carp are high enough to kill all of the other fish in Crooked Lake. Therefore, fishing opportunities on Crooked Lake would temporarily be lost. As a result, Crooked Lake would have to be restocked with fish after a rotenone treatment. To avoid this, Crooked Lake has been

using a rotenone baiting system since 1998. In this process, carp are fed poisoned bait after being trained with “fake” bait. The advantage of this system is that it can selectively remove carp and leave the rest of the fishery intact. After initial treatments, this baiting system has been unsuccessful and use has been discontinued. The feasibility of other carp removal plans is currently being investigated. The water quality and overall lake quality may not improve until Crooked Lake’s carp problem is brought under control.

EXISTING LAKE QUALITY PROBLEMS

Crooked Lake has a variety of problems and some are quite severe. These problems are not new to the lake. Several of these problems such as excessive carp and algae blooms date back over 50 years. However, there is hope for Crooked Lake. With some intensive management Crooked Lake could be greatly improved. Listed below are the most significant problems and best areas for improvement for Crooked Lake.

- *Slough Lake*

  As stated several times in this report, Crooked Lake's single biggest problem is excessive phosphorus concentrations. The source of this phosphorus is both external and internal. The largest potential external source is Slough Lake. Management of external sources can be difficult. However, in Crooked's case this source is easily identifiable, which possibly makes management a little easier. These external inputs from Slough have been occurring for over 60 years. This has led to a large internal source of phosphorus in Crooked Lake. The phosphorus inputs form Slough Lake must be brought under control to possibly start to see any appreciable changes in water quality in Crooked Lake. This will be an expensive, ongoing process and should involve Crooked Lake residents, Lake Villa Township, and most importantly the Lake County Forest Preserve District (the owner of Slough Lake).

- *Excessive Number of Carp*

  Carp are another major management concern Crooked Lake is currently facing. Crooked Lake's problems with carp are not a new one and has existed for over 50 years. Whole lake rotenone treatments have been unsuccessful in the past. This is probably due to poor execution and reinfestation from remaining carp, Slough and Hastings Lakes. In the recent past, efforts to selectively remove carp using a rotenone baiting system also proved to be ineffective. Currently, the Crooked Lake Improvement Committee is investigating alternative methods to selectively reduce carp populations. The water quality of Crooked Lake may not substantially improve until this carp problem is brought under control.

- *Exotic Species*

  During the study of Crooked Lake three exotic invasive plant species, purple loosestrife, buckthorn, and Eurasian water milfoil, were found on the shores and in the lake. Loosestrife and buckthorn are particularly problematic shoreline species as they very quickly displace and outcompete native wetland plants and offer little value in terms of shoreline stabilization or wildlife habitat. Eurasian water milfoil is one of the most problematic aquatic weeds in the United States (especially the Midwest). It can quickly take over a body of water displacing other beneficial aquatics and creating a monoculture that is of no benefit to the lake or its associated wildlife. These invasive plant species should be controlled/eliminated before they become more widespread and further impact the Crooked Lake ecosystem.

- *Nuisance Algae Blooms*

  Severe algal blooms occurred during the entire study of Crooked Lake. Blooms consisted largely of planktonic blue-green algae. High phosphorus concentrations and the lack of aquatic vegetation cause these blooms. Aquatic vegetation competes with algae for available resources, stabilize sediment, and therefore minimize high phosphorus concentrations. The growth of nuisance or excessive algae can cause a number of problems. The increase in algal blooms over the course of the summer leads to the drastic decrease in water clarity, decrease in light penetration, and increased TSS. This can lead to several major problems such as loss of aquatic plants, decline in fishery health, and interference with recreational activities. Health hazards, such as skin irritations have been linked to excessive algal growth. Additionally, algae have been both directly and indirectly linked with fish kills by either toxin release or oxygen depletion. Normally, excessive algal growth is a sign of larger problems such as excessive nutrients and/or lack of aquatic plants. Solving the problem of excessive algal growth involves treating these larger problems not the algae it self.

- *Poor Aquatic Plant Diversity*

  One key to a healthy lake is a healthy aquatic plant population. Crooked Lake has poor plant densities as well as poor diversity. Lack of quality aquatic plants, and subsequent loss of water quality, is mainly due to low light penetration caused by lakewide algae blooms (which itself is partly due to a lack of aquatic plants). The negative impacts associated with lack of a quality aquatic plant community are numerous including those on water quality and fishery health. In the spring, the only aquatic plant in the lake is curlyleaf pondweed, which can be considered undesirable. After curly leaf pondweed dies back other plants, including Eurasian water milfoil, were able to grow in certain parts of the lake. The presence of Eurasian water milfoil is of some concern. While absent in past studies of the lake, it now occurs sporadically in a few areas of the lake. The milfoil was probably introduced from adjoining Hastings Lake, which has substantial infestation. Eurasian water milfoil densities should be closely monitored and so they do become more widespread and cause problems.

POTENTIAL OBJECTIVES FOR CROOKED LAKE MANAGEMENT PLAN

I. Controlling Excessive Number of Carp
II. Nuisance Algae Management
III. Aquatic Plant Management
IV. Eliminate or Control Invasive Species
V. Shoreline Improvement and Erosion Control
VI. Wildlife Habitat Improvement
VII. Create Bathymetric Map with Morphometric Table
VIII. Illinois Volunteer Lake Monitoring Program

OPTIONS FOR ACHIEVING THE LAKE MANAGEMENT PLAN OBJECTIVES

Objective I: Controlling Excessive Numbers of Carp

A frequent problem that plagues many of the lakes in the County is the presence of common carp (*Cyprinus carpio*). Common carp were first introduced into the United States from Europe in the early 1870's, and were first introduced into Illinois river systems in 1885 to improve commercial fishing. The carp eventually made their way into many inland lakes and are now so wide spread that many people do not realize that they are not native to the U.S. Crooked Lake is not an exception to this trend. The carp population of Crooked Lake has been negatively impacting Crooked Lake since the 1950's. Therefore, the carp in Crooked Lake should be eliminated/controlled. *Additionally, for any plan to be effective, the carp in Slough and Hastings Lakes must also be addressed.*

Carp prefer warm waters in lakes, streams, ponds, and sloughs that contain high levels of organic matter. This is indicative of many lakes in Lake County. Carp feed on insect larvae, crustaceans, mollusks, and even small fish by rooting through the sediments. Immature carp feed mainly on small crustaceans. Because their feeding habits cause a variety of water quality problems, carp are very undesirable in lakes. Rooting around for food causes resuspension of sediments and nutrients, which can both lead to increased turbidity. Additionally, spawning, which occurs near shore in shallow water, can occur from late April until June. The spawning activities of carp can be violent further contributing to turbidity problems. Adult carp can lay between 100,000 –500,000 eggs, which hatch in 5-8 days. Initial growth is rapid with young growing 4 ¾" to 5" in the first year. Adults normally range in size from 1-10 lbs., with some as large as 60 lbs. Average carp lifespan is 7-10 years, but they may live up to 15 years.

There are several techniques to remove carp from a lake. However, rarely does any technique completely eradicate carp from a lake. Commonly, once a lake has carp, it has carp forever. However, it is up to the management entity to dictate how big the problem is allowed to become. Rotenone is the only reliable piscicide (fish poison) on the market at this time, but it kills all fish that is comes into contact with. Currently, there is a rotenone laced baiting system that can selectively remove carp. While the process is a step in the right direction, several factors still need to be worked out in order for it to be a viable alternative to the whole lake treatment. Until this baiting technique is further developed and produces consistent results, it is not being recommended by the LMU at this time.

Option 1: No Action

By following a no action management approach, nothing would be done to control the carp population of the lake. Populations will continue to thrive at epidemic proportions as they have years. Until recently the no action plan has been the prevailing attitude/action plan on Crooked Lake for decades.

Pros
There are very few positive aspects to following a no action plan for excessive carp populations. The only real advantage would be the money saved by taking no action.

Cons
There are many negative aspects to a no action management plan for carp management. The feeding habits of carp cause most of the associated problems. As carp feed they root around in the lake sediment. This causes resuspension of sediment and nutrients. Increased nutrient levels can lead to increased algal blooms, which, combined with resuspended sediments, lead to increased turbidity (reduced clarity). As a result there is a decrease in light penetration, negatively impacting aquatic plants. Additionally, the rooting action of the carp causes the direct disruption of aquatic plants. Loss of aquatic plants can further aggravate sediment and nutrient loads in the water column due to loss of sediment stabilization provided by the plants. Additionally, the fishery of the lake may decline and/or become stunted due to predation issues related to decreased water clarity and loss of habitat. Other wildlife, such as waterfowl, which commonly forage on aquatic plants and fish, would also be negatively impacted by the decrease in vegetation.

The loss of aquatic plants and an increase in algae will drastically impair recreational use of the lake. Swimming could be adversely affected due to the increased likelihood of algal blooms. Swimmers may become entangled in large mats of filamentous algae, and blooms of planktonic species, such as blue-green algae, can produce harmful toxins and noxious odors. Fishing would also be negatively affected due to the decreased health of the lake's fishery. The overall appearance of the lake would also suffer from an increase in unsightly algal blooms, having an unwanted effect on property values.

Costs
There is no direct monetary cost associated with the no action option. However, the aesthetic impacts that the carp caused have undoubtedly brought about indirect negative costs.

<u>Option 2: Rotenone</u>

Rotenone is a piscicide that is naturally derived from the stems and roots of several tropical plants. Rotenone is approved for use as a piscicide by the USEPA and has been used in the U.S. since the 1930's. It is biodegradable (breaks down into CO_2 and H_20) and there is no bioaccumulation. Because rotenone kills fish by chemically inhibiting the use of oxygen in biochemical pathways, adult fish are much more susceptible than fish eggs (carp eggs are 50 times more resistant). Other aquatic organisms are less sensitive to rotenone. However, some organisms are effected enough to reduce populations for several months. In the aquatic environment, fish come into contact with the rotenone by a different method than other organisms. With fish, the rotenone comes into direct contact with the exposed respiratory surfaces (gills), which is the route of entry. In other organisms this type of contact is minimal. More sensitive nonfish species include frogs and mollusks but these organisms typically recover to pretreatment levels within a few months. Rotenone has low mammalian and avian toxicity. For example, if a human consumed fish treated with normal concentrations of rotenone, approximately 8,816 lbs. of fish would need to be eaten at one sitting in order to produce toxic effects. Furthermore, due to its unstable nature, it is unlikely that the rotenone would still be active at the time of consumption. Additionally, warm-blooded mammals have natural enzymes that would break down the toxin before it had any effects.

Rotenone is available in 5% and 2.5% concentrations. Both concentrations are available as synergized formulations. The synergist (piperonal butoxide) is an additive that inhibits fish detoxification of rotenone, making the rotenone more effective. Rotenone has varying levels of toxicity on different fish species. Some species of fish can detoxify rotenone quicker than it can build up in their systems. Unfortunatly, concentrations to remove undesirable fish, such as carp, bullhead and green sunfish, are high enough to kill more desirable species such as bass, bluegill, crappie, walleye, and northern pike. Therefore, it is difficult to selectively remove undesirable fish while leaving desirable ones. Typically, rotenone is used at concentrations from 2 ppm (parts per million) – 12 ppm. For removal of undesirable fish (carp, bullhead and green sunfish) in lakes with alkalinities in the range found in Lake County, the target concentration should be 6 ppm. Sometimes concentrations will need to be increased based on high alkalinity and/or high turbidity. Rotenone is most effectively used when waters are cooling down (fall) not warming up (spring) and is most effective when water temperatures are $<50^{o}$F. Under these conditions, rotenone is not as toxic as in warmer waters but it breaks down slower and provides a longer exposure time. If treatments are done in warmer weather they should be done before spawn or after hatch as fish eggs are highly tolerant to rotenone.

Rotenone rarely kills every fish (normally 99-100% effective). Some fish can escape removal and rotenone retreatment needs to occur about every 10 years. At this point in time, carp populations will have become reestablished due to reintroduction and reproduction by fish that were not removed during previous treatment. To ensure the best results, precautions can be taken to assure a higher longevity. These precautions include banning live bait fishing (minnows bought from bait stores can contain carp) and making sure every part of the lake is treated (i.e., cattails, inlets, adjoining lakes, and harbored shallow areas). Restocking of desirable fish species may occur about 30-50 days after treatment when the rotenone concentrations have dropped to sub-lethal levels. Since it is best to treat in the fall, restocking may not be possible until the following spring. To use rotenone in a body of water over 6 acres a *Permit to Remove Undesirable Fish* must be obtained from the Illinois Department of Natural Resources (IDNR), Natural Heritage Division, Endangered and Threatened Species Program. Furthermore, only an IDNR fisheries biologist licensed to apply aquatic pesticides can apply rotenone in the state of Illinois as it is a restricted use pesticide.

Pros
Rotenone is one of the only ways to effectively remove undesirable fish species. This allows for rehabilitation of the lake's fishery, which will allow for improvement of the aquatic plant community, and overall water quality. By removing carp, sediment will be left largely undisturbed. This will allow aquatic plants to grow and help further stabilize the sediment. As a result of decreased carp activity and increased aquatic plant coverage, fewer nutrients will be resuspended, greatly reducing the likelihood of nuisance algae blooms and associated dissolved oxygen problems. Additionally, reestablishment of aquatic plants will have other positive effects on lake health and water quality, increases in fish habitat and food source availability for wildlife such as waterfowl.

Cons
There are no negative impacts associated with removing excessive numbers of carp from a lake. However, in the process of removing carp with rotenone, other desirable fish species will also be removed. The fishery can be replenished with restocking and quality sport fishing normally returns within 2-3 years. Other aquatic organisms, such as mollusks, frogs, and invertebrates (insects, zooplankton, etc.), are also negatively impacted. However, this disruption is temporary and studies show that recovery occurs within a few months. Furthermore, the IDNR will not approve application of rotenone to waters known to contain threatened and endangered fish species. Another drawback to rotenone is the cost. Since the whole lake is treated and costs per gallon range from $50.00 - $75.00, total costs can quickly add up. This can be off-set with lake draw down to reduce treatment volume. Unfortunately, draw down is not an option on all lakes.

Costs
As with most intensive lake management techniques, a good bathymetric map is needed so that an accurate lake volume can be determined (for costs see *Objective VI: Create Bathymetric Map with Morphometric Table*). To achieve a concentration of 6 ppm, which is the rate needed for most total rehabilitation projects (remove carp, bullhead and green sunfish), approximately 3000 gallons of rotenone would be needed. This would come to a total cost of between $150,400 – 225,000. *This is just the cost for Crooked Lake*. Additional treatments would have to made to Slough and Hastings Lake to reduce the chance of reintroductions form one of these bodies of water. In waters with high turbidity and/or planktonic algae blooms, the ppm may have to be higher which will further increase costs. If the lake were lowered five feet, which would reduce the lake volume to 908 acre feet, the cost could be lowered by approximately 40% ($91,800 – $137,000).

Objective II: Nuisance Algae Management

The growth of nuisance or excessive algae can cause a number of problems. Excessive algal growth can cause decreases in water clarity and light penetration. This can lead to several major problems such as loss of aquatic plants, decline in fishery health, and interference with recreational activities. Health hazards, such as swimmer's itch and other skin irritations have been linked to nuisance algae growth. Normally, excessive/nuisance algae growth is a sign of larger problems such excessive nutrients and/or lack of aquatic plants. Some treatment methods, such as copper sulfate, are only quick remedies to the problem. Solving the problem of nuisance algal growth involves treating the factors that cause the growth not the algae itself. Long-term solutions typically include an integrated approach such as alum treatments, revegetation with aquatic plants, and limiting external sources of nutrients. Interestingly enough, these long-term management strategies are seldom used, typically because of their high initial costs. Instead, the cheap, quick fix of using copper sulfate, though temporary, is much more widely used. However, the costs of continually applying copper sulfate over years, even decades, can eventually far exceed the costs of a slower acting, eventually more effective, integrated approach.

As with aquatic plant management techniques, algae management practices have both positive and negative characteristics. If used properly, they can be beneficial to a lake's well being. If misused or abused, they all share similar outcomes - negative impacts to the lake. Putting together a good management plan should not be rushed. Plans should consist of a realistic set of goals well thought out before implementation. The plan should be based on the management goals of the lake and involve usage issues (beaches, boat ramps, etc.), habitat maintenance/restoration issues, and nutrient levels. For an algal management plan to achieve long term success, follow up is critical. The management of the lake's algae problem does not end once the blooms and/or mats have been reduced/eliminated. It is critical to continually monitor problematic areas for regrowth and treat as necessary. An association or property owner should not always expect immediate results. A quick fix of the algal problem may not always be in the best interest of the lake. Sometimes the best solutions take several seasons to properly address the problem. The management options covered below are commonly used techniques and those that are coming into wider acceptance, and have been used in Lake County. There are other algae management options that are not covered below as they are not very effective, unproven, unfounded, or are too experimental to be widely used.

Option 1: No Action

With a no action management plan nothing would be done to control the nuisance algae regardless of type and extent. Nuisance algae, planktonic and/or filamentous, could continue to grow until epidemic proportions are reached. Growth limitations of the algae and the characteristics of the lake itself (light penetration, nutrient levels.) will dictate the extent of growth. Unlike aquatic plants, algae are not normally bound by physical factors such as substrate type. The areas in which filamentous and thick surface planktonic blooms (scum) occur can be affected by wind and wave action if strong enough.

However, under normal conditions, with no action, both filamentous and planktonic algal blooms can spread to cover 100% of the surface. This could cause major inhibition of the lakes recreational uses and impact fish and other aquatic organisms adversely.

Pros

There are positive aspects associated with the no action option for nuisance algae management. The first, and most obvious, is that there is no cost. However, if an active management plan for algae control were eventually needed, the cost would be substantially higher than if the no action plan had been followed in the first place. Another benefit of this option would be the lack of environmental manipulation. Under the no action option, chemicals or introduction of any organisms would not take place. Use of the lake would continue as normal unless blooms worsened. In this case, activities such as swimming might have to be suspended due to an increase in health risks. Other problems such as strong odors (blue-green algae) might also increase in frequency.

Cons

Under the no action option, if nuisance algae becomes wide spread and able to reach epidemic proportions, there will be many negative impacts on the lake. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation. This will cause an explosion in the small fish population and with food resources not increasing, growth of fish will be reduced. Fish kills can result from toxins released by some species such as some blue-green algae. Blue-green algae can also produced toxins that are harmful to other algae. This allows blue-green algae to quickly dominate a body of water. Decreased dissolved oxygen levels, due to high biological oxygen demand from the excessive algae growth, will also have negative impacts on the aquatic life. Wildlife populations will also be negatively impacted by dense growths of algae. Birds and waterfowl will have difficulty finding quality plants for food or in locating prey within the turbid green waters. Additionally, some species, such as blue-green algae, are poor sources of food for zooplankton and fish.

Water quality could also be negatively impacted with the implementation of a no action option. Decomposition of organic matter and release of nutrients upon algal death is a probable outcome. Large nutrient release with algae die back could lead to lake-wide increases of internal nutrient load. This could in turn, could increase the frequency or severity of other blooms. In addition, decomposition of massive amounts of algae, filamentous and planktonic, will lead to a depletion of dissolved oxygen in the lake. This can cause fish stress, and eventually, if stress is frequent or severe enough, fish kills. All of the impacts above could in turn have negative impacts on numerous aspects of the lake’s ecosystem.

In addition to ecological impacts, many physical lake uses will be negatively impacted. Boating could be nearly impossible without becoming entangled in thick mats of filamentous algae. Swimming could also become increasingly difficult and unsafe due to thick mats and reduction in visibility by planktonic blooms. Fishing could become more and more exasperating due in part to the thick mats and stunted fish populations. In addition, the aesthetics of the lake will also decline due to large areas of the lake covered by large green mats and/or blooms of algae and the odors that may develop, such as with large blue-green blooms. The combination of above events could cause property values on the lake to suffer. Property values on lakes with algae problems have been shown to decrease by as much as 15-20%.

Costs

No cost will be incurred by implementing the no action management option.

Option 2: Algicides

Algicides are a quick and inexpensive way to temporarily treat nuisance algae. Copper sulfate ($CuSO_4$) and chelated copper products are the two main algicides in use. These two compounds are sold by a variety of brand names by a number of different companies. They all work the same and act as contact killers. This means that the product has to come into contact with the algae to be affective. Algicides come in two forms, granular and liquid. Granular herbicides are spread by hand or machine over an effected area. They can also be placed in a porous bag (such as a burlap sack) and dragged though the water in order to dissolve and disperse the product. Granular algicides are mainly used on filamentous algae where they are spread over the mats. As the granules dissolve, they kill the algae. Liquid algicides, which are much more widely used, are mixed with a known amount of water to achieve a known concentration. The mixture is then sprayed onto/into the water. Liquid algicides are used on both filamentous and planktonic algae. Liquid algaecides are often mixed with herbicides and applied together to save on time and money. The effectiveness of some herbicides is enhanced when mixed with an algicide. When applying an algicide it is imperative that the label is completely read and followed. If too much of the lake is treated at any one time an oxygen crash may occur. This may cause fish kills due to decomposition of treated algae. Additionally, treatments should never be made when blooms/mats are at their fullest extent. It is best to divide the lake into at least two sections depending on the size of the lake. Larger lakes will need to be divided into more sections. Then treat the lake one section at a time allowing at least two weeks between treatments. Furthermore, application of algicides should never be done in extremely hot weather (>90^{o}F) or when D.O. concentrations are low. This will help lessen the likelihood of an oxygen crash and resulting fish kills. When possible, treatments should be made as early in the season as possible when temperature and D.O. concentrations are adequate. It is best to treat in spring or when the blooms/mats starts to appear there by killing the algae before they become a problem.

Pros

When used properly, algicides can be a powerful tool in management of nuisance algae growth. A properly implemented plan can often provide season long control with minimal applications. Another benefit of using algicides is their low costs. The fisheries and waterfowl populations of the lake would greatly benefit due to a decrease in nuisance algal blooms. By reducing the algae, clarity would increase. This in turn would allow the native aquatic plants to return to the lake. Newly established stands of plants would improve spawning habitat and food source availability for fish. Waterfowl population would greatly benefit from increases in quality food sources, such as large-leaf pondweed (*Potamogeton amplifolius*) and sago pondweed (*Potamogeton pectinatus*). Additionally, copper products, at proper dosages, are selective in the sense that they do not affect aquatic vascular plants and wildlife.

By implementing a good management plan, usage opportunities for the lake would increase. Activities such as boating and swimming would improve due to the removal of thick blooms and/or mats of algae. Health risks associated with excessive algae growth (toxins, reduced visibility, etc.) The quality of fishing may recover due to improved habitat and feeding opportunities. In addition to increased usage opportunities, overall aesthetics of the lake would improve, potentially increasing property values.

Cons

The most obvious drawback of using algicides is the input of chemicals into the lake. Even though the United States Environmental Protection Agency (USEPA) approved these chemicals for use, human error and overuse can make them unsafe and bring about undesired outcomes. By continually killing particular algal species, lake managers may unknowingly be creating a larger problem. As the algae are continuously exposed to copper, some species are becoming more and more tolerant. This results in the use of higher concentrations in order to achieve adequate control, which can be unhealthy for the lake. In other instances, by eliminating one type of algae, lake managers are finding that other species that are even more problematic are filling the empty gap. These species that fill the gap can often be more difficult to control due to an inherent resistance to copper products. Additionally, excessive use of copper products can lead to a build up of copper in lake sediment. This can cause problems for activities such as dredging. Due to a large amount of copper in the sediment, special permits and disposal methods would have to be utilized.

Costs

Lake wide algae treatments would be extremely costly and would only bring short term control on Crooked Lake. This is due to lake volume and intensity of the blooms. Spot treatments for surface scums and filamentous algae along select areas (i.e. beach and boat areas) of the shoreline are more practical. Cost for these types of treatments will vary with size of treatment areas and intensity of the blooms.

Option 3: Alum Treatment

A possible remedy to excessive algal growth is to eliminate or greatly reduce the amount of phosphorus. This can be accomplished by using aluminum sulfate (alum). Alum does not directly kill algae as copper sulfate does. Instead, alum binds phosphorus making it unavailable, thus reducing algal growth. Alum binds water-borne phosphorus and forms a flocculent layer that settles on the bottom. This floc layer can then prevent sediment bound phosphorus from entering the water column. Phosphorus inactivation using alum has been in use for 25 years. However, cost and sometimes unreliable results deterred its wide spread use. Currently, alum is commonly being used in ponds and small lakes, and its use in larger lakes is increasing. Alum treatment typically lasts 1 to 20 years depending on various parameters. Lakes with low mean depth to surface area ratio benefit more quickly from alum applications, while lakes with high mean depth to surface area ration (thermally stratified lakes) will see more longevity from an alum application due to isolation of the flocculent layer. Lakes with small watersheds are also better candidates because external phosphorus sources can be limited. Alum treatments must be carefully planned and carried out by an experienced professional. If not properly done, there may be many detrimental side effects.

Pros

Phosphorus inactivation is a possible long-term solution for controlling nuisance algae and increasing water clarity. Alum treatments can last as long as 20 years. This makes alum more cost effective in the long-term compared to continual treatment with algaecides. Studies have shown reductions in phosphorus concentrations by 66% in spring and 68% in summer. Chlorophyll *a*, a measure of algal biomass, was reduced by 61%. Reduction in algal biomass caused an increase in dissolved oxygen and a 79% increase in Secchi disk readings. Effects of alum treatments can be seen in as little as a few days. The increase in clarity can have many positive effects on the lake’s ecosystem. With increased clarity, plant populations could expand or reestablish. This in turn would improve fish habitat and provide improved food/habitat sources for other organisms. Recreational activities such as swimming and fishing would be improved due to increased water clarity and healthy plant populations. Typically, there is a slight invertebrate decline immediately following treatment but populations recover fully by the following year.

Cons

There are several drawbacks to alum. External nutrient inputs must also be reduced or eliminated for alum to provide long-term effectiveness. With larger watersheds this could prove to be physically and financially impossible. Phosphorus inactivation may be shortened by excessive plant growth or motorboat traffic, which can disturb the flocculent layer and allow phosphorus to be released. Also, lakes that are shallow, non-stratified, and wind blown typically do not achieve long term control due to disruption of the flocculent layer. If alum is not properly applied toxicity problems may occur. Typically aluminum toxicity occurs if pH is below 6 or above 9. Most of Lake County’s lakes are in this safe range. However, at these pHs, special precautions must be taken when applying alum. By adding the incorrect amounts of alum, pH of the lake could drastically change. Due to these dangers, it is highly recommended that a lake management professional plans and administers the alum treatment.

Costs
Alum treatments can be very expensive, especially on the a lake as big as Crooked Lake. Furthermore, carp populations would have to be greatly reduced/eliminated to achieve any long term control. Additionally, external inputs, such as Slough Lake, would need eliminated. Based on a lake volume of 1488.83-acre feet, approximately 60 tons of dry alum would be needed to treat Crooked Lake. This would cost approximately $42,000 - $72,000. This is just the cost of the alum and does not include transportation or application labor costs.

<u>Option 4: Revegetation With Native Aquatic Plants</u>

A healthy native plant population can reduce algal growth. Many lakes with long-standing algal problems have a very sparse plant population or none at all. This is due to reduction in light penetration brought about by years of excessive algal blooms and/or mats. Revegetation should only be done when existing nuisance algal blooms are under control using one of the above management options. If the lake has poor clarity due to excessive algal growth or turbidity, these problems must be addressed before a revegetation plan is undertaken. Without adequate light penetration, revegetation will not work. At maximum, planting depth light levels must be greater than 1-5% of the surface light levels for plant growth and photosynthesis. If aquatic herbicides are being used to control what vegetation does exist there use should be scaled back or abandoned all together. This will allow the vegetation to grow back, which will help in controlling the algae in addition to other positive impacts associated with a healthy plant population.

There are two methods by which reestablishment can be accomplished. The first is use of existing plant populations to revegetate other areas within the lake. Plants from one part of the lake are allowed to naturally expand into adjacent areas thereby filling the niche left by the nuisance algae. Another technique utilizing existing plants is to transplant vegetation from one area to another. The second method of reestablishment is to import native plants from an outside source. A variety of plants can be ordered from nurseries that specialize in native aquatic plants. These plants are available in several forms such as seeds, roots, and small plants. These two methods can be used in conjunction with one another in order to increase both quantity and biodiversity of plant populations. Additionally, plantings must be protected from herbivory by waterfowl and other wildlife. Simple cages made out of wooden or metal stakes and chicken wire are erected around planted areas for at least one season. The cages are removed once the plants are established and less vulnerable. If large-scale revegetation is needed it would be best to use a consultant to plan and conduct the restoration. Table 6 (*Appendix A*) lists common, native plants that should be considered when developing a revegetation plan. Included in this list are emergent shoreline vegetation (rushes, cattails, etc) and submersed aquatic plants (pondweeds, *Vallisneria*, etc). Prices, planting depths, and planting densities are included and vary depending on plant species.

Pros

By revegetating newly opened areas that were once infested with nuisance species, the lake will benefit in several ways. Once established, expanded native plant populations will help to control growth of nuisance algae by shading and competition for resources. This provides a more natural approach as compared to other management options. In addition, using established native plants to control excessive invasive plant growth is less expensive than other options. Expanded native plant populations will also help with sediment stabilization. This in turn will have a positive effect on water clarity by reducing suspended solids and nutrients that decrease clarity and cause excessive algal growth. Properly revegetating shallow water areas with plants such as cattails, bulrushes, and water lilies can help reduce wave action that can lead to shoreline erosion. Increases in desirable vegetation will increase the plant biodiversity and also provide better quality habitat and food sources for fish and other wildlife. Recreational uses of the lake such as fishing and boating will also improve due to the improvement in water quality and the suppression of weedy species.

Cons

There are few negative impacts to revegetating a lake. One possible drawback is the possibility of new vegetation expanding to nuisance levels and needing control. However, this is an unlikely outcome. Another drawback could be high costs if extensive revegetation is needed using imported plants. If a consultant were used costs would be substantially higher. Additional costs could be associated with constructing proper herbivory protection measures.

Costs

See Table 6 (*Appendix A*) for pricing.

Objective III: Aquatic Plant Management Techniques

Crooked Lake does not have an organized aquatic plant management program nor does it need one at the current time. Currently, Crooked Lake has started to see growth of the exotic Eurasian water milfoil in the lake. The extent of this growth was minimal during the study and may not currently warrant action since Crooked Lake has no real aquatic plant population so the EWM is a welcome habitat provider for the moment (some plants may be better than no plants). However, EWM densities/extent should be closely monitored so to ensure that it does not become a management problem in the future. This is especially important if EWM starts to grow in areas with high motor boat traffic as plants can be fragmented and spread to other parts of the lake. This objective has been included in this report in order to provide guidance if aquatic plant management does become a concern/need in the future. Another species, curly leaf pondweed, is a nuisance in the spring time. Several groups on the lake remove large stands of curly leaf pondweed in the late spring/early summer by hand, which is probably the best way to remove this plant (at least in Crooked Lake's case). Ways to improve upon this current practice are also covered under this objective

All aquatic plant management techniques have both positive and negative characteristics. If used properly, they can all be beneficial to a lake's well being. If misused or abused, they all share similar outcomes - negative impacts to the lake. Putting together a good aquatic plant management plan should not be rushed. Plans should consist of a realistic set of goals well thought out before implementation. The plan should be based on the management goals of the lake and involve usage issues, habitat maintenance/restoration, and limitations of the lake. For an aquatic plant management plan to achieve long term success, follow up is critical. A good aquatic plant management plan considers both the short and long-term needs of the lake. The management of the lake's vegetation does not end once the nuisance vegetation has been reduced/eliminated. It is critical to continually monitor problematic areas for regrowth and remove as necessary. An association or property owner should not always expect immediate results. A quick fix of the vegetation problems may not always be in the best interest of the lake. Sometimes the best solutions take several seasons to properly solve the problem. The management options covered below are commonly used techniques that are coming into wider acceptance and have been used in Lake County. There are other plant management options that are not covered below as they not are very effective, unreliable, or are too experimental to be widely used.

<u>Option 1: No Action</u>

If the lake is dominated by *native*, *non-invasive* species, the no action option could be ideal. Under these circumstances native plant populations could flourish and keep nuisance plants from becoming problematic. However, if a no action aquatic plant management plan in a lake with non-native, invasive species, nothing would be done to control the aquatic plant population of the lake regardless of the type and extent of the vegetation. Nuisance vegetation could continue to grow until epidemic proportions are reached. Growth limitations of the plant and the characteristics of the lake itself (light penetration, lake morphology, substrate type, etc.) will dictate the extent of infestation. Rooted plants, such as curly leaf pondweed (*Potamogeton crispus*) and elodea (*Elodea canadensis*), will be bound by physical factors such as substrate type and light availability. Plants such as Eurasian watermilfoil and coontail, which can grow unrooted at the surface regardless of water depth, could grow to cover 100% of the water's surface. This could cause major inhibition of the lakes recreational uses and impact fish and other aquatic organisms adversely.

Pros

There are positive aspects associated with the no action option for plant management. The first, and most obvious, is that there is no cost. However, if an active management plan for vegetation control were eventually needed, the cost would be substantially higher than if the no action plan had not been followed in the first place. Another benefit of this option would be the lack of environmental manipulation. Under the no action option, no chemicals, mechanical alteration, or introduction of any organisms would take place. This is important since studies have shown that nuisance plants are more likely to invade disrupted areas. If the lake contains native, non-invasive plant species, expansion of the native plant population would increase the overall biodiversity and health of the lake. Habitat, breeding areas, and food source availability would greatly improve. Use of the lake would continue as normal and in some cases might improve (fishing) if native plants keep "weedy" plants under control.

An additional benefit of the no action option is the possible improvement in water quality. Turbidity could decrease and clarity should increase due to sediment stabilization by the plant's roots. Algal blooms could be reduced due to decreased resource availability and sediment stabilization. However, the occurrence of filamentous algae may increase/remain stable due to their surface growth habitat. The lake's fishery could improve due to habitat availability, which in turn would have numerous positive effects on the rest of the lake's ecosystem.

Cons

Under the no action option, if nuisance vegetation is dominant in the lake and were uninhibited and able to reach epidemic proportions, there will be many negative impacts on the lake. By their weedy nature, the nuisance plants would out-compete the more desirable native plants. This could eventually, drastically reduce or even eliminate the native plant population of the lake and reduce the lake's biodiversity. The fishery of the lake may become stunted due the to lack of quality forage fish habitat and reduced predation. Predation will decrease due to the difficulty of finding prey in the dense stands of vegetation. This will cause an explosion in the small fish population and with food resources not increasing, growth of fish will be reduced. Decreased dissolved oxygen levels, due to high biological oxygen demand from the excessive vegetation, will also have negative impacts on the aquatic life. Wildlife populations will also be negatively impacted by these dense stands of vegetation. Birds and waterfowl will have difficulty finding quality plants for food or in locating prey within the dense plant stands.

Water quality could also be negatively impacted with the implementation of the no action option. Deposition of large amounts of organic matter and release of nutrients upon the death of the massive stands of vegetation is a probable outcome of the no action option. These dead plants will contribute to the sediment load of the lake and could accelerate its filling in. The large nutrient release when the plants die back in the fall could lead to lake-wide algae blooms and an overall increase of the internal nutrient load. In addition, the decomposition of the massive amounts of vegetation will lead to a depletion of the lakes dissolved oxygen. This can cause fish stress, and eventually, if the stress is frequent or severe enough, fish kills. All of the impacts above could in turn have negative impacts on numerous aspects of the lake's ecosystem.

In addition to the ecological impacts, many physical uses of the lake will be negatively impacted. Boating could be nearly impossible without becoming entangled in thick stands of plants. Swimming could also become increasingly difficult due to thick vegetation that would develop at beaches. Fishing could become more and more exasperating due in part to the thick vegetation and also because of stunted fish population. In addition, the aesthetics of the lake will also decline due to large areas of the lake covered by tangled mats of vegetation and the odors that will develop when they decay. The combination of the above events could cause property values on the lake to suffer. Property values on lakes with weedy plant/algae problems have been shown to decrease by as much as 15-20%.

Costs

No cost will be incurred by implementing the no action management option. However, if in the future a management plan was initiated, costs might be significantly higher since a no action plan was originally followed.

Option 2: Aquatic Herbicides

Aquatic herbicides are the most common method to control nuisance vegetation/algae. When used properly, they can provide selective and reliable control. Products can not be licensed for use in aquatic situations unless there is less than a 1 in 1,000,000 chance of any negative effects on human health, wildlife, and the environment. Aquatic herbicides are not allowed to be environmentally persistent, bioaccumulate, or have any bioavailability. Prior to herbicide application, licensed applicators should evaluate the lake's vegetation and, along with the lake's management plan, choose the appropriate herbicide and treatment areas, and apply the herbicides during appropriate conditions (i.e. low wind speed, D.O. concentration, temperature).

There are two groups of herbicides: contact and systemic. Contact herbicides, like their name indicates, kill on contact. These herbicides affect only the above ground portion of the plant that they come into contact with and therefore do not kill the root system. An example of a contact herbicide is diquat. Systemic herbicides are taken up by the plant and disrupt cellular processes, which in turn cause plant death. These herbicides kill both the above ground portions of the plant as well as the root system. An example of a systemic herbicide is fluridone. Both types of herbicides are available in liquid or granular forms. Liquid forms are concentrated and need to be mixed into water to obtain the desired concentration. The solution is then sprayed on the water's surface or injected into the water in the treatment areas. Granular herbicides are broadcast in a known rate over the treatment area where they sink to the bottom. Some granular products slowly release the herbicide, which is then taken up by the plant. These are referred to as SRP formulations (Slow Release Pellet). Other granular herbicides come in crystal form and dissolve as they come in contact with water. This is typical of herbicides such as copper sulfate. Many herbicides come in both liquid and granular forms to fit the management needs of the lake. Herbicide applications can either be done as whole lake treatments or as more selective spot treatments. Multiple herbicides are often mixed and applied together. This is called a tank mix. This is done to save time, energy, and cost.

Aquatic herbicides are best used on actively growing plants to ensure optimal herbicide uptake. For this reason, herbicides are normally applied mid to late spring when water temperatures are above 60^0F. This is the time of year when the plants are most actively growing and before seed/vegetative propagule formation. Follow up applications should be done as needed. When choosing an aquatic herbicide it is important to know what plants are present, which ones are problematic, which plants are beneficial, and how a particular herbicide will act upon these plants. The herbicide label is very important and should always be read before use. There may be more than one herbicide for a given plant. As with other management options, proper usage is the key to their effectiveness, benefits, and disadvantages.

Pros

When used properly, aquatic herbicides can be a powerful tool in management of excessive vegetation. Often, aquatic herbicide treatments can be more cost effective in the long run compared to other management techniques. A properly implemented plan can often provide season long control with minimal applications. Ecologically, herbicides can be a better management option than using mechanical harvesting or grass carp. When properly applied, aquatic herbicides may be selective for nuisance plants such as Eurasian watermilfoil but allow desirable plants such as American pondweed (*Potamogeton nodosus*) to remain. This removes the problematic vegetation and allows native and more desirable plants to remain and flourish with minimal manipulation.

The fisheries and waterfowl populations of the lake would benefit greatly due to an increase in quality habitat and food supply. Dense stands of plants would be thinned out and improve spawning habitat and food source availability for fish. Waterfowl population would greatly benefit from increases in quality food sources, such as large-leaf pondweed (*Potamogeton amplifolius*). Another environmental benefit of using aquatic herbicides over other management options is that they are organism specific. The metabolic pathways by which herbicides kill plants are plant specific which humans and other organisms do not carry out. Organisms such as fish, birds, mussels, and zooplankton are generally unaffected.

By implementing a good management plan with aquatic herbicides, usage opportunities of the lake would increase. Activities such as boating and swimming would improve due to the removal of dense stands of vegetation. The quality of fishing may improve because of improved habitat. In addition to increased usage opportunities, the overall aesthetics of the lake would improve, potentially increasing property values on the lake.

Cons

The most obvious drawback of using aquatic herbicides is the input of chemicals into the lake. Even though the United States Environmental Protection Agency (USEPA) approved these chemicals for use, human error can make them unsafe and bring about undesired outcomes. If not properly used, aquatic herbicides can remove too much vegetation from the lake. This could drastically alter biodiversity and ecological. Total or over-removal of plants can cause a variety of problems lake-wide. The fishery of the lake may decline and/or become stunted due predation issues related to decreased water clarity. Other wildlife, such as waterfowl, which commonly forage on aquatic plants, would also be negatively impacted by the decrease in food supply.

Another problem associated with removing too much vegetation is the loss of sediment stabilization by plants, which can lead to increased turbidity and resuspension of nutrients. The increase in turbidity can cause a decrease in light penetration, which can further aggravate the aquatic plant community. The resuspension of nutrients will contribute to the overall nutrient load of the lake, which can lead to an increased frequency of noxious algal blooms. Furthermore, the removal of aquatic vegetation, which compete with algae for resources, can directly contribute to an increase in blooms.

After the initial removal, there is a possibility for regrowth of vegetation. Upon regrowth, weedy plants such as Eurasian water milfoil and coontail quickly reestablish, form dense stands, and prevent the growth of desirable species. This causes a decrease in plant biodiveristy. Additionally, these dense stands of nuisance vegetation can lead to an overpopulation of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fisheries can have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl and other wildlife. Additionally, some herbicides have use restrictions regarding their use in relation to fish, swimming, irrigation, etc.

Over removal, and possible regrowth of nuisance vegetation that may follow will drastically impair recreational use of the lake. Swimming could be adversely affected due to the likelihood of increased algal blooms. Swimmers may become entangled in large mats of filamentous algae. Blooms of planktonic species, such as blue-green algae, can produce harmful toxins as well produce noxious odors. If regrowth of nuisance vegetation were to occur, motors could become entangled making boating difficult. Fishing would also be negatively impacted due to the decreased health of the lake's fishery. The overall appearance of the lake would also suffer due to an increase in unsightly algal blooms and massive stands of vegetation. This in turn could have an unwanted effect on property values. Studies have shown that problematic algal blooms can decrease property values by 15-20%.

Costs
Total cost to spot treat the main areas of Eurasian water milfoil with 2,4-D would cost approximately $4,900 – $5,700. This includes an area of approximately 10 acre in the north part of the lake and a 3.5 acre areas in the south part of the lake. Spot treatment of the spring infestation of curly leaf pondweed (about 54 acres) would cost approximately $23,000. These treatments would, especially the treatment of curly leaf pondweed, would need to be done yearly.

Option 3: Mechanical Harvesting

Mechanical harvesting involves the cutting and removal of nuisance aquatic vegetation by large specialized boats with underwater cutting bars. Plants are cut below the water at a level that will restore use of the lake. Typically, problematic areas are harvested and other areas are left alone. However, some management plans call for more widespread harvesting, especially when nuisance plants such as Eurasian watermilfoil become dominant. The total removal or over removal (neither of which should never be the plan of any management entity) of plants by mechanical harvesting should never be attempted. To avoid complete or over removal, the management entity should have a harvesting plan that determines where and how much vegetation is to be removed.

Pros
Mechanical harvesting can be a selective means to reduce stands of nuisance vegetation in a lake. Typically, plants cut low enough to restore recreational use and limit or prevent regrowth. This practice normally improves habitat for fish and other aquatic organisms. Some plant species such as curlyleaf pondweed, if harvested at the right time, do not grow back to nuisance proportions after harvesting. Plant clippings are high in nutrients and can be used as fertilizer or compost. Additionally, use of the lake is uninterrupted while harvesting is occurring.

By removing large quantities of plant biomass the overall quality of the lake may improve in many ways. The decrease in vegetative biomass will reduce the dissolved oxygen (D.O.) demand on the lake. This will cause increased dissolved oxygen levels. Some nuisance vegetation such as coontail have extremely high oxygen demands. Dense stands of these plants can quickly deplete a lake of D.O. during certain periods of the day. This can cause fish stress. Additionally, a decrease in plant density will improve the lake's fishery of the lake by creating better opportunities for predation, which is essential in creating a balanced fish population. By removing nuisance vegetation, recreational uses of the lake will improve. The quality of activities such as boating, swimming, and fishing would greatly improve. By removing dense stands of vegetation the possibility of entanglement will decrease thereby increasing opportunities for boating and swimming. Paths cut by the harvester will open fishing areas especially if networks of fish "cruising lanes" are created.

Cons

Once widespread, mechanical harvesting is becoming a less attractive management technique for a variety of reasons. Many applicators that regularly employed mechanical harvesting no longer use or even offer this service due to low public demand. In addition, high initial investment, extensive maintenance, and high operational costs have also led to decreased use. Since many applicators no longer offer harvesting services, a lake association would have to purchase and maintain their own harvester. Many associations do not even have the financial resources to cover the maintenance and operational cost involved with owning a harvester. Harvester costs can range from $50,000-$150,000. Beside the financial limitations there are also physical limitations. Mechanical harvesters cannot be used in less than 2-4 feet of water (depending on draft of the harvester) and can not maneuver well in tight places. The harvested plant material must be disposed of properly to a place that can accommodate large quantities of plants and prevent any from washing back into the lake. Fish, mussels, turtles and other aquatic organisms are commonly caught in the harvester and injured or even removed from the lake in the harvesting process.

After the initial removal, there is a possibility for vegetation regrowth. Upon regrowth, weedy plants such as Eurasian watermilfoil and coontail quickly reestablish, form dense stands, and prevent the growth of desirable species. This causes a decrease in plant biodiveristy. Additionally, these dense stands of nuisance vegetation may lead to an overpopulation of stunted fish due to a decrease in predation of forage species by predatory fish. This disruption in the fishery will have negative impacts throughout the ecosystem from zooplankton to higher organisms such as waterfowl.

If complete/over removal does occur several problems can result. One problem is the loss of sediment stabilization by plants, which can lead to increased turbidity and resuspension of nutrients.   The increase in turbidity can cause a decrease in light penetration, which can further aggravate the aquatic plant community. The resuspension of nutrients will also contribute to overall nutrient load of the lake, which can lead to increased frequency of algal blooms. Furthermore, the removal of aquatic vegetation, which competes with algae for resources with algae, can directly contribute to an increase in algal blooms. Removal of plants may lead to increased turbidity and decreased clarity. The fishery of the lake may decline and/or become stunted due changes in predation related to decreased water clarity. Other organisms, such as waterfowl, which commonly forage on native aquatic plants, would also be negatively impacted by the removal of these plants.

Another problem with mechanical harvesting, even if properly done, is that it can be a nonselective process. In the areas where harvesting is being conducted, one plant can not be removed and another left. All the plants are removed from that area. After the initial removal, regrowth of desirable plants does not typically occur in these harvested areas. Due to their weedy nature, plants such as Eurasian water milfoil, are able to grow more quickly than native plants and become more established in harvested areas. This will create a monoculture of nuisance vegetation. This causes an overall decrease in plant biodiversity, which can have detrimental effects to the entire ecosystem. Depending on the plant species, frequent harvesting might be required (typically 2-4 times per season). Along with this increased harvesting frequency come increased operational costs (labor, gas, maintenance, etc.). Nuisance plants such as coontail and Eurasian watermilfoil can spread by vegetative fragments that may escape collection during the harvesting process and spread to uninfested parts of the lake. In addition to the release of plant fragments, as the plants are cut, there is a possibility of plant associated nutrients being released into the lake. This could cause an increase is algal blooms whenever harvesting in conducted. Short-term turbidity may also be created by the harvester paddle wheels stirring up sediment in harvested area.

Cost

Depending on the type of the harvester (cutting width, payload capacity, hull material, HP of the motor, trailer options, etc) prices range from $50,000 to $150,000. Operational and maintenance cost typically range from $161.00-$445.00/acre.

Option 5: Hand Removal

Hand removal of excessive aquatic vegetation is a commonly used management technique. Hand removal is normally used in small ponds/lakes and limited areas for selective vegetation removal. Areas surrounding piers and beaches are commonly targeted areas. Typically tools such as rakes and cutting bars are used to remove vegetation. These are easily obtainable through many outdoor supply catalogs or over the internet. Some rakes are equipped with tines as well as cutting edges. Tools can also be hand made by drilling a hole in the handle of a heavy-duty garden rake and tying it to a length of rope. Weights may be needed in order to provide forceful contact with the plants. In many instances, homeowners on lakes with near shore vegetation problems simply cut swaths through the weeds to create pathways to open water. Due to the limited amount of biomass removed, harvested plant material is often used as fertilizer and compost in gardens.

Hand Removal is probably the best option for control of curly leaf pondweed on Crooked Lake. Removal should be done before the curly leaf forms its reproductive structures (called turions), which normally occurs late May-early Jun so removal should take place early May. It is from these turions that the next few seasons of growth originate. Curly leaf plants should be totally removed from the lake, not just ripped out/cut and left to float in the lake. This prevents nutrient release back into the lake from dead plant material. Additionally, any turions that have already formed will be removed. Studies have shown that after a few seasons of pre-turion removal of curlyleaf pondweed, plant densities are drastically reduced. This will greatly improve early season light penetration in Crooked Lake and possibly allow more beneficial, native plants to reinhabit the lake. Currently, there are several areas on Crooked Lake that practice hand removal. These programs should be continued and efforts should be made to encourage other residents to participate.

Pros

Hand removal is a quick, inexpensive, and selective way to remove nuisance vegetation. Hand removal is an activity in which all lake residents could participate. The work involved in removing plants can provide a rewarding sense of accomplishment. By removing excess vegetation, use of beaches and piers would be improved. Many of the improved water quality benefits of a well-executed herbicide program or harvesting program are also shared by hand removal. Wildlife habitat, such as fish spawning beds, could be greatly improved. This in turn would benefit other portions of the lake's ecosystem.

Cons

There are few negative attributes to hand removal. One negative implication is labor. Depending on the extent of infestation, removal of large amount, of vegetation can be quite tiresome. Another drawback can be disposal. Finding a site for numerous residents to dispose of large quantities of harvested vegetation can sometimes be problematic. However, individual homeowners would be removing limited quantities of plant material so there would not be much to dispose of. Another drawback is possible nonselective removal by hand harvesting. By throwing a rake blindly into the depths, it is impossible to determine what plants are removed and which ones are not until the rake is pulled up. Even in shallow depths, untrained persons might mistakenly remove desirable vegetation and/or disrupt valuable habitat (fish spawning beds). Over removal could also be a problem but is not normally a concern with hand removal.

Costs

Plant removal rakes can range in price from $50-150 and cutting tools commonly range in price from $50-200. Both are available from numerous catalogs and from the internet.. A homemade rake would cost about $20-40.

Option 6: Water Milfoil Weevil

Euhrychiopsis lecontei (*E. lecontei*) is a biological control organism used to control Eurasian water milfoil (EWM). *E. lecontei* is a native weevil, which feeds exclusively on milfoil species. It was originally discovered while investigating declines of EWM in a Vermont lake in the early 1990s. It was discovered in northeastern Illinois lakes by 1995. Another weevil, *Phytobius leucogaster,* also feeds on EWM but does not cause as much damage as *E. lecontei*. Therefore, *E. lecontei* is stocked as a biocontrol and is commonly referred to as the Eurasian water milfoil weevil. Currently, the LCHD-Lakes

Management Unit has documented weevils (*E. lecontei* and/or *P. leucogaster*) in 23 Lake County lakes. Many of these lakes have seen declines in EWM densities in recent years. It is highly likely that *E. lecontei* and/or *P. leucogaster* occurs in all lakes in Lake County that have excessive EWM growth. Adjoining Hastings Lake, which has substantial EWM densities, has a resident population of weevils (both *E. lecontei* and *P. leucogaster*). Certain parts of Hastings Lake experienced substantial declines in EWM during the LMU's 2001 study. Other parts of the lake were unaffected. No weevils were found during the 2001 Crooked Lake study but they are suspected to be present but in low numbers. In the future, if EWM densities were to increase, weevils would probably inhabit the lake.

Weevils are stocked in known quantities to achieve a density of 1-4 weevils per stem. As weevil populations expand, EWM populations may decline. After EWM declines, weevil populations decline and do not feed on any other aquatic plants and die back. When EWM starts to grow again in the spring, the weevil populations respond by keeping the increasing milfoil under control before it becomes a problem. Once the weevil is established, EWM should no longer reach nuisance proportions and begins to become more sparse. Best results are achieved in lakes that have shallow EWM infestations in areas where it is undisturbed by recreational and management actives. Weevils need proper overwintering habitat such as leaf litter and mud, which are typically found on naturalized shorelines or shores with good buffer strips. Additionally, water temperatures need to be 68-70°F for maximum weevil activity. For this reason, weevils are typically stocked in late spring/early summer. Currently only one company, EnviroScience Inc., has a stocking program (called the MiddFoil® process). The program includes evaluation of EWM densities of current weevil populations (if any), stocking, monitoring, and restocking as needed.

Pros

The milfoil weevil can provide long-term control of EWM. Typically, by the end of June EWM stands are starting to decline due to weevil damage. In many situations, EWM beds might not reach the surface before weevil damage causes declines. *E. lecontei* is also a selective means to control EWM. Studies have shown that *E. lecontei* has a strong preference for EWM and the only other plant it possibly will feed on is northern water milfoil. Since milfoil weevils are found to naturally occur in several lakes in Lake County, weevil stocking would be an augmentation rather than an introduction, making it a more natural control option.

If control with milfoil weevils were successful, the quality of the lake would be improved. Native plants could then start to recolonize. Fisheries of the lake would improve due to more balanced predation and higher quality habitat. Waterfowl would benefit due to increased food sources and availability of prey. Recreational activities such as fishing, swimming, and boating would be easier and more enjoyable with the removal of inhibiting stands of EWM.

Cons
Use of milfoil weevils does have some drawbacks. Control using the weevil has been inconsistent in many cases. EWM has been reduced one year, only to be unaffected the next. Reasons for these inconsistencies are under investigation. One possible explanation is lack of suitable overwintering habitat. The highly developed, manicured shorelines of many lakes in the County are not suitable habitat for weevil overwintering. Another possible explanation is cooler than normal summer water temperatures. Studies have shown that cooler water temperatures reduce weevil feeding and egg production.

Milfoil control using weevils may not work well on plants in deep water. Plants are able to compensate for weevil damage on upper portions of the plant by increasing growth on lower portions where weevil does not feed. Furthermore, weevils do not work well in areas where plants are continuously disturbed by activities such as powerboats and swimming, harvesting or herbicide use. In areas where weevils are to be stocked, activity should be reduced as much as possible. This may either limit the extent to which the weevils can be used or limit recreational use of the lake.

One of the most prohibitive aspects to weevil use is price. Typically weevils are stocked to achieve a density of 1-4 weevils per stem. This translates to 500-3000 weevils per acre. At a cost of $1 per weevil plus labor, a EWM management program using weevils can be expensive. Additionally, there is no guarantee that weevils will provide long term control or even produce any results at all.

Costs
EnviroScience, Inc.
3781 Darrow Road
Stow, Ohio 44224
1(800) 940-4025

Weevils are sold in units of 1000 bugs/unit and stocking rates must be at least 1 unit/stocked area. Normally there is a minimum purchase of 5-10 units. The cost of the weevils does not include the labor involved in initial surveys, stocking, and monitoring, which typically run an additionally $3,500-$4,500.

Option 7: Reestablishing Native Aquatic Vegetation
An established aquatic plant community is a crucial part in achieving good lake quality. If the lake has poor clarity due to excessive algal growth or turbidity, these problems must be addressed before a revegetation plan is undertaken. Without adequate light penetration, revegetation will not work. At maximum, planting depth light levels must be greater than 1-5% of the surface light levels for plant growth and photosynthesis. If a reestablishment project were undertaken at Crooked Lake, water clarity must fist be significantly improved. This means reducing carp populations and nutrient levels.

There are two methods by which reestablishment can be accomplished. The first is use of existing plant populations to revegetate other areas within the lake. Plants from one part of the lake are allowed to naturally expand into adjacent areas thereby filling the niche left by the nuisance plants. Another technique utilizing existing plants is to transplant vegetation from one area to another. This technique is not an option for Cooked Lake due to the lack of suitable aquatic plants. The second method of reestablishment is to import native plants from an outside source, which is the option Crooked would have to utilize if revegetation was attempted. A variety of plants can be ordered from nurseries that specialize in native aquatic plants. These plants are available in several forms such as seeds, roots, and small plants. These two methods can be used in conjunction with one another in order to increase both quantity and biodiversity of plant populations. Additionally, plantings must be protected from herbivory by waterfowl and other wildlife. Simple cages made out of wooden or metal stakes and chicken wire are erected around planted areas for at least one season. The cages are removed once the plants are established and less vulnerable. If large-scale revegetation is needed it would be best to use a consultant to plan and conduct the restoration. Table 6 (*Appendix A*) lists common, native plants that should be considered when developing a revegetation plan. Included in this list are emergent shoreline vegetation (rushes, cattails, etc) and submersed aquatic plants (pondweeds, *Vallisneria*, etc). Prices, planting depths, and planting densities are included and vary depending on plant species.

Pros

By revegetating newly opened areas that were once infested with nuisance species, the lake will benefit in several ways. Once established, expanded native plant populations will help to control growth of nuisance vegetation. This provides a more natural approach as compared to other management options. In addition, using established native plants to control excessive invasive plant growth can be less expensive in the long run than other options. Expanded native plant populations will also help with sediment stabilization. This in turn will have a positive effect on water clarity by reducing suspended solids and nutrients that decrease clarity and cause excessive algal growth. Properly revegetating shallow water areas with plants such as cattails, bulrushes, and water lilies can help reduce wave action that can lead to shoreline erosion. Increases in desirable vegetation will increase the plant biodiversity and also provide better quality habitat and food sources for fish and other wildlife. Recreational uses of the lake such as fishing and boating will also increase due to the improvement in water quality and the suppression of weedy species.

Cons

There are few negative impacts to revegetating a lake. One possible drawback is the possibility of new vegetation expanding to nuisance levels and needing control. However, this is an unlikely outcome. Another drawback could be high costs if extensive revegetation is needed using imported plants. If a consultant is used costs would be substantially higher. Additional costs could be associated with constructing proper herbivory protection measures.

Costs

See Table 6 (*Appendix A*) for plant pricing. Additional costs will be incurred if a consultant/nursery is contracted for design and labor.

Objective IV: Eliminate or Control Exotic Species

Numerous exotic plant species have been introduced into our local ecosystems. Some of these plants are aggressive, quickly out-competing native vegetation and flourishing in an environment where few natural predators exist. Plants such as purple loosestrife (*Lythrum salicaria*), buckthorn (*Rhamnus cathartica*), and reed canary grass (*Phalaris arundinacea*) are three examples. The outcome is a loss of plant and animal diversity. This section will address terrestrial shoreline exotic species. Currently, purple loosestrife and buckthorn have been found on Crooked Lake. There are some groups on the lake that have taken the initiative and will or have implemented control programs for these nuisance species.

Purple loosestrife is responsible for the "sea of purple" seen along roadsides and in wetlands during summer. It can quickly dominate a wetland or shoreline. Due in part to an extensive root system, large seed production (estimates range from 100,000 to 2.7 million seeds per plant), and high seed germination rate, purple loosestrife spreads quickly. Buckthorn is an aggressive shrub species that grows along lake shorelines as well as most upland habitats. It shades out other plants and is quick to become established on disturbed soils. Reed canary grass is an aggressive plant that if left unchecked will dominate an area, particularly a wetland or shoreline, in a short period of time. Since it begins growing early in the spring, it quickly out-competes native vegetation that begins growth later in the year. Control of purple loosestrife, buckthorn, and reed canary grass are discussed below. However, these control measures can be similarly applied to other exotic species such as garlic mustard (*Allilaria officianalis*) or honeysuckle (*Lonicera* spp.) as well as some aggressive native species, such as box elder (*Acer negundo*).

Presence of exotic species along a lakeshore is by no means a death sentence for the lake or other plant and animal life. If controlled, many exotic species can perform many of the original functions that they were brought here for. For example, reed canary grass was imported for its erosion control properties. It still contributes to this objective (offering better erosion control than commercial turfgrass), but needs to be isolated and kept in control. Many exotics are the result of garden or ornamental plants escaping into the wild. One isolated plant along a shoreline will probably not create a problem by itself. However, problems arise when plants are left to spread, many times to the point where treatment is difficult or cost prohibitive. A monitoring program should be established, problem areas identified, and control measures taken when appropriate. This is particularly important in remote areas of lake shorelines where the spread of exotic species may go unnoticed for some time.

Option 1: No Action

No control will likely result in the expansion of the exotic species and the decline of native species. This option is not recommended if possible.

Pros

There are few advantages with this option. Some of the reasons exotics were brought into this country are no longer used or have limited use. However, in some cases having an exotic species growing along a shoreline may actually be preferable if the alternative plant is commercial turfgrass. Since turfgrass has shallow roots and is prone to erosion along shorelines, exotics like reed canary grass or common reed (*Phragmites australis*) will control erosion more effectively. Native plants should take precedent over exotics when possible. Table 6 in Appendix A lists several native plants that can be planted along shorelines.

Cons

Native plant and wildlife diversity will be lost as stands of exotic species expand. Exotic species are not under the same stresses (particularly diseases and predators) as native plants and thus can out-compete the natives for nutrients, space, and light. Few wildlife species use areas where exotic plants dominate. This happens because many wildlife species either have not adapted with the plants and do not view them as a food resource, the plants are not digestible to the animal, or their primary food supply (i.e., insects) are not attracted to the plants. The result is a monoculture of exotic plants with limited biodiversity.

Recreational activities, especially wildlife viewing, may be hampered by such monocultures. Access to lake shorelines may be impaired due to dense stands of non-native plants. Other recreational activities, such as swimming and boating, may not be effected.

Costs

Costs with this option are zero initially, however, when control is eventually needed, costs will be substantially more than if action was taken immediately. Additionally, the eventual loss of ecological diversity is difficult to calculate financially.

Option 2: Biological Control

Biological control (bio-control) is a means of using natural relationships already in place to limit, stop, or reverse an exotic species' expansion. In most cases, insects that prey upon the exotic plants in its native ecosystem are imported. Since there is a danger of bringing another exotic species into the ecosystem, state and federal agencies require testing before any bio-control species are released or made available for purchase.

Recently two beetles (*Galerucella pusilla* and *G. calmariensis*) and two weevils (*Hylobius transversovittatus* and *Nanophyes marmoratus*) have offered some hope to control purple loosestrife by natural means. These insects feed on either the leaves or juices of purple loosestrife, eventually weakening or killing the plant. In large stands of loosestrife, the beetles and weevils naturally reproduce and in many locations, significantly retard plant densities. The insects are host specific, meaning that they will attack no other plant but purple loosestrife. Currently, the beetles have proven to be most effective and are available for purchase. There are no designated stocking rate recommendations, since using bio-control insects are seen as an inoculation and it may take 3-5 years for beetle populations to increase to levels that will cause significant damage. Depending on the size of the infested area, it may take 1,000 or more adult beetles per acre to cause significant damage.

Pros

Control of exotics by a natural mechanism if preferable to chemical treatments. Insects, being part of the same ecological system as the exotic (i.e., the beetles and weevils and the purple loosestrife) are more likely to provide long-term control. Chemical treatments are usually non-selective while bio-control measures target specific plant species. This technique is beneficial to the ecosystem since it preserves, even promotes, biodiversity. As the exotic dies back, native vegetation can reestablish the area.

Cons

Few exotics can be controlled using biological means. Currently, there are no bio-control techniques for plants such as buckthorn, reed canary grass, or a host of other exotics. One of the major disadvantages of using bio-control is the costs and labor associated with it.

Use of biological mechanisms to control plants such as purple loosestrife is still under debate. Similar to purple loosestrife, the beetles and weevils that control it are not native to North America. Due to the poor historical record of introducing non-native species, even to control other non-native species, this technique has its critics.

Costs

The Department of Natural Resources at Cornell University (607-255-2821) sells overwintering adult beetles (which will lay eggs the year of release) for $2 per beetle and new generation beetles (which will lay eggs beginning the following year) at $0.25 per beetle. Some beetles may be available for free by contacting the Illinois Natural History Survey (217-333-6846).

Option 3: Control by Hand

Controlling exotic plants by hand removal is most effective on small areas (< 1 acre) and if done prior to heavy infestation. This would be effective on several areas or Crooked Lake such as private shorelines where there are only a few plants. Some exotics, such as purple loosestrife and reed canary grass, can be controlled to some degree by digging, cutting, or mowing if done early and often during the year. Digging may be required to ensure the entire root mass is removed. Spring or summer is the best time to cut or mow, since late summer and fall is when many of the plant seeds disperse. Proper disposal of excavated plants is important since seeds may persist and germinate even after several years. Once exotic plants are removed, the disturbed ground should be planted with native vegetation and closely monitored. Many exotic species, such as purple loosestrife, buckthorn, and garlic mustard are proficient at colonizing disturbed sites.

Pros
Removal of exotics by hand eliminates the need for chemical treatments. Costs are low if stands of plants are not too large already. Once removed, control is simple with yearly maintenance. Control or elimination of exotics preserves the ecosystem's biodiversity. This will have positive impacts on plant and wildlife presence as well as some recreational activities.

Cons
This option may be labor intensive or prohibitive if the exotic plant is already well established. Costs may be high if large numbers of people are needed to remove plants. Soil disturbance may introduce additional problems such as providing a seedbed for other non-native plants that quickly establish disturbed sites, or cause soil-laden run-off to flow into nearby lakes or streams. In addition, a well-established stand of an exotic like purple loosestrife or reed canary grass may require several years of intense removal to control or eliminate.

Costs
Cost for this option is primarily in tools, labor, and proper plant disposal.

Option 4: Herbicide Treatment
Chemical treatments can be effective at controlling exotic plant species. However, chemical treatment works best on individual plants or small areas already infested with the plant. In some areas where individual spot treatments are prohibitive or unpractical (i.e., large expanses of a wetland or woodland), chemical treatments may not be an option due to the fact that in order to chemically treat the area a broadcast application would be needed. Since many of the herbicides that are used are not selective, meaning they kill all plants they contact; this may be unacceptable if native plants are found in the proposed treatment area. On Crooked Lake using herbicides to control purple loosestrife and buckthorn would be very effective due to the distribution and densities of these plants in several areas around the lake (large infestations of purple loosestrife in the cattails on the northeast and south west shores).

Herbicides are commonly used to control nuisance shoreline vegetation such as buckthorn and purple loosestrife. Herbicides are applied to green foliage or cut stems. Products are applied by either spraying or wicking (wiping) solution on plant surfaces. Spraying is used when large patches of undesirable vegetation are targeted. Herbicides are sprayed on growing foliage using a hand-held or backpack sprayer. Wicking is used when selected plants are to be removed from a group of plants. The herbicide solution is wiped on foliage, bark, or cut stems using a herbicide soaked device. Trees are normally treated by cutting a ring in the bark (called girdling). Herbicides are applied onto the ring at high concentrations. Other devices inject the herbicide through the bark. It is best to apply herbicides when plants are actively growing, such as in the late spring/early summer, but before formation of seed heads. Herbicides are often used in conjunction with other methods, such as cutting or mowing, to achieve the best results. Proper use of these products is critical to their success. Always read and follow label directions.

Pros

Herbicides provide a fast and effective way to control or eliminate nuisance vegetation. Unlike other control methods, herbicides kill the root of the plant, which prevents regrowth. If applied properly, herbicides can be selective. This allows for removal of selected plants within a mix of desirable and undesirable plants.

Cons

Since most herbicides are non-selective, they are not suitable for broadcast application. Thus, chemical treatment of large stands of exotic species may not be practical. Native species are likely to be killed inadvertently and replaced by other non-native species. Off target injury/death may result from the improper use of herbicides. If herbicides are applied in windy conditions, chemicals may drift onto desirable vegetation. Care must also be taken when wicking herbicides as not to drip on to non-targeted vegetation such as native grasses and wildflowers. Another drawback to herbicide use relates to their ecological soundness and the public perception of them. Costs may also be prohibitive if plant stands are large. Depending on the device, cost of the application equipment can be high.

Costs

Two common herbicides, triclopyr (sold as Garlon™) and glyphosate (sold as Rodeo®, Round-up™, Eagre™, AquaPro™), cost approximately $100 and $65 per gallon, respectively. Only Rodeo® is approved for water use. A Hydrohatchet®, a hatchet that injects herbicide through the bark, is about $300.00. Another injecting device, E-Z Ject® is $450.00. Hand-held and backpack sprayers costs from $25-$45 and $80-150, respectively. Wicking devices are $30-40. A low cost alternative to specialized spray equipment is the use of household spray bottles (commonly used for window and bathroom cleaners). These bottles can be purchased at department stores for minimal costs. However, after there use for herbicide application they should not be used for anything else. Similarly, spray canisters like those used to apply lawn chemicals also provide lower costs alternatives to commercial spray equipment.

Objective V: Shoreline Improvement and Erosion Control

Erosion is a potentially serious problem to lake shorelines and occurs as a result of wind, wave, or ice action or from overland rainwater runoff. While some erosion to shorelines is natural, human alteration of the environment can accelerate and exacerbate the problem. Erosion not only results in loss of shoreline, but negatively influences the lake's overall water quality by contributing nutrients, sediment, and pollutants into the water. This effect is felt throughout the food chain since poor water quality negatively affects everything from microbial life to sight feeding fish and birds to people who want to use the lake for recreational purposes. The resulting increased amount of sediment will over time begin to fill in the lake, decreasing overall lake depth and volume and potentially impairing various recreational uses. The occurrence of erosion on Crooked Lake is low. However, precautions should be made to ensure that erosion does not become a problem.

Option 1: No Action

Pros

There are no short-term costs to this option. However, extended periods of erosion may result in substantially higher costs to repair the shoreline in the future.

Eroding banks on steep slopes can provide habitat for wildlife, particularly bird species (e.g. kingfishers and bank swallows) that need to burrow into exposed banks to nest. In addition, certain minerals and salts in the soils are exposed during the erosion process, which are utilized by various wildlife species.

Cons

Taking no action will most likely cause erosion to continue and subsequently may cause poor water quality due to high levels of sediment or nutrients entering a lake. This in turn may retard plant growth and provide additional nutrients for algal growth. A continual loss of shoreline is both aesthetically unpleasing and may potentially reduce property values. Since a shoreline is easier to protect than it is to rehabilitate, it is in the interest of the property owner to address the erosion issue immediately.

Costs

In the short-term, cost of this option is zero. However, long-term implications can be severe since prolonged erosion problems may be more costly to repair than if the problems were addressed earlier. As mentioned previously, long-term erosion may cause serious damage to shoreline property and in some cases lower property values.

Option 2: Install Rock Rip-Rap

Rip-rap is the term for using rocks to stabilize shorelines. Size of the rock depends on the severity of the erosion, distance to rock source, and aesthetic preferences. Generally, four to eight inch diameter rocks are used. Rip-rap can be incorporated with other erosion control techniques such as plant buffer strips. If any plants will be growing on top of the rip-rap, fill will probably be needed to cover the rocks and provide an acceptable medium for plants to grow on. Prior to the initiation of work, permits and/or surveys from the appropriate government agencies need to be obtained (see costs below). There is no real need for the use of rip rap on Crooked Lake. Most shoreline property in very flat and could easily be rehabilitated using buffer strips (see Option 3).

Pros

Rip-rap can provide good shoreline erosion control. Rocks can absorb some of the wave energy while providing a more aesthetically pleasing appearance than seawalls. If installed properly, rip-rap will last for many years. Maintenance is relatively low, however, undercutting of the bank can cause sloughing of the rip-rap and subsequent shoreline. Areas with severe erosion problems may benefit from using rip-rap. In all cases, a filter fabric should be installed under the rocks to maximize its effectiveness.

Fish and wildlife habitat can be provided if large boulders are used. Crevices and spaces between the rocks can be used by a variety of animals and their prey. Small mammals, like shrews can inhabit these spaces in the rock above water and prey upon many invertebrate species, including many harmful garden and lawn pests. Also, small fish may utilize the structure underwater created by large boulders for foraging and hiding from predators.

Cons

A major disadvantage of rip-rap is the initial expense of installation and associated permits. Installation is expensive since a licensed contractor and heavy equipment are generally needed to conduct the work. Permits are required if replacing existing or installing new rip-rap and must be acquired prior to work beginning. If any fill material is placed in the floodplain along the shoreline, compensatory storage may also be needed. Compensatory storage is the process of excavating in a portion of a property or floodplain to compensate for the filling in of another portion of the floodplain.

While rip-rap absorb wave energy more effectively than seawalls, there is still some wave deflection that may cause resuspension of sediment and nutrients into the water column.

Small rock rip-rap is poor habitat for many fish and wildlife species, since it provides limited structure for fish and cover for wildlife. As noted earlier, some small fish and other animals will inhabit the rocks if boulders are used. Smaller rip-rap is more likely to wash away due to rising water levels or wave action. On the other hand, larger boulders are more expensive to haul in and install.

Rip-rap may be a concern in areas of high public usage since it is difficult and possibly dangerous to walk on due to the jagged and uneven rock edges. This may be a liability concern to property owners.

Costs
Cost and type of rip-rap used depend on several factors, but average cost for installation (rocks and filter fabric) is approximately $30-45 per linear foot. The steeper the slope and severity of erosion, the larger the boulders that will need to be used and thus, higher installation costs. In addition, costs will increase with poor shoreline accessibility and increased distance to rock source. Costs for permits and surveys can be $1,000-2,000 for installation of rip-rap, depending on the circumstances. Additional costs will be incurred if compensatory storage is needed. Contact the Army Corps of Engineers, local municipalities, and the Lake County Planning and Development Department.

Option 3: Create a Buffer Strip
Another effective method of controlling shoreline erosion is to create a buffer strip with existing or native vegetation. Native plants have deeper root systems than turfgrass and thus hold soil more effectively. Native plants also provide positive aesthetics and good wildlife habitat. Cost of creating a buffer strip is quite variable, depending on the current state of the vegetation and shoreline and whether vegetation is allowed to become established naturally or if the area needs to be graded and replanted. Allowing vegetation to naturally propagate the shoreline would be the most cost effective, depending on the severity of erosion and the composition of the current vegetation. Non-native plants or noxious weedy species may be present and should be controlled or eliminated. Stabilizing the shoreline with vegetation is most effective on slopes no less than 2:1 to 3:1, horizontal to vertical, or flatter. Usually a buffer strip of at least 25 feet is recommended, however, wider strips (50 or even 100 feet) are recommended on steeper slopes or areas with severe erosion problems. Areas where erosion is severe or where slopes are greater than 3:1, additional erosion control techniques may have to be incorporated such as biologs, A-Jacks®, or rip-rap.

Buffer strips can be constructed in a variety of ways with various plant species. Generally, buffer strip vegetation consists of native terrestrial (land) species and emergent (at the land and water interface) species. Terrestrial vegetation such as native grasses and wildflowers can be used to create a buffer strip along lake shorelines. Table 6 (*Appendix A*) gives some examples, seeding rates and costs of grasses and seed mixes that can be used to create buffer strips. Native plants and seeds can be purchased at regional nurseries or from catalogs. When purchasing seed mixes, care should be taken that native plant seeds are used. Some commercial seed mixes contain non-native or weedy species or may contain annual wildflowers that will have to be reseeded every year. If purchasing plants from a nursery or if a licensed contractor is installing plants, inquire about any guarantees they may have on plant survival. Finally, new plants should be protected from herbivory (e.g., geese and muskrats) by placing a wire cage over the plants for at least one year.

A technique that is sometimes implemented along shorelines is the use of willow posts, or live stakes, which are harvested cuttings from live willows (*Salix* spp.). They can be planted along the shoreline along with a cover crop or native seed mix. The willows will resprout and begin establishing a deep root structure that secures the soil. If the shoreline is highly erodible, willow posts may have to be used in conjunction with another erosion control technique such as biologs, A-Jacks ®, or rip-rap.

Emergent vegetation, or those plants that grow in shallow water and wet areas, can be used to control erosion more naturally than seawalls or rip-rap. Native emergent vegetation can be either hand planted or allowed to become established on its own over time. Some plants, such as native cattails (*Typha* sp.), quickly spread and help stabilize shorelines, however they can be aggressive and may pose a problem later. Other species, such as those listed in Table 6 (*Appendix A*) should be considered for native plantings. It is the recommendation of the LMU that Crooked Lake Improvement Committee and the individual associations promote the use of buffer strips on all applicable lakefront properties (including beaches, seawalls, and rip rap). *The use of buffer strips is the best option for erosion control/prevention on Crooked Lake.*

Pros

Buffer strips can be one of the least expensive means to stabilize shorelines. If no permits or heavy equipment are needed (i.e. no significant earthmoving or filling is planned), the property owner can complete the work without the need of professional contractors. Once established (typically within 3 years), a buffer strip of native vegetation will require little maintenance and may actually reduce the overall maintenance of the property, since the buffer strip will not have to be continuously mowed, watered, or fertilized. Occasional high mowing (1-2 times per year) for specific plants or physically removing other weedy species may be needed.

The buffer strip will stabilize the soil with its deep root structure and help filter run-off from lawns and agricultural fields by trapping nutrients, pollutants, and sediment that would otherwise drain into the lake. This may have a positive impact on the lake's water quality since there will be less "food" for nuisance algae. Buffer strips can filter as much as 70-95% of sediment and 25-60% of nutrients and other pollutants from runoff.

Another benefit of a buffer strip is potential flood control protection. Buffer strips may slow the velocity of flood waters, thus preventing shoreline erosion. Native plants also can withstand fluctuating water levels more effectively than commercial turfgrass. Many plants can survive after being under water for several days, even weeks, while turfgrass is intolerant of wet conditions and usually dies after several days under water. This contributes to increased maintenance costs, since the turfgrass has to be either replanted or replaced with sod. Emergent vegetation can provide additional help in preserving shorelines and improving water quality by absorbing wave energy that might otherwise batter the shoreline.

Calmer wave action will result in less shoreline erosion and resuspension of bottom sediment, which may result in potential improvements in water quality.

Many fish and wildlife species prefer the native shoreline vegetation habitat. This habitat is an asset to the lake's fishery since the emergent vegetation cover may be used for spawning, foraging, and hiding. Various wildlife species are even dependent upon shoreline vegetation for their existence. Certain birds, such as marsh wrens (*Cistothorus palustris*) and endangered yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) nest exclusively in emergent vegetation like cattails and bulrushes. Hosts of other wildlife like waterfowl, rails, herons, mink, and frogs to mention just a few, benefit from healthy stands of shoreline vegetation. Dragonflies, damselflies, and other beneficial invertebrates can be found thriving in vegetation along the shoreline as well. Two invertebrates of particular importance for lake management, the water-milfoil weevils (*Euhrychiopsis lecontei* and *Phytobius leucogaster*), which have been shown to naturally reduce stands of exotic Eurasian water-milfoil (*Myriophyllum spicatum*). Weevils need proper over wintering habitat such as leaf litter and mud which are typically found on naturalized shorelines or shores with good buffer strips. Many species of amphibians, birds, fish, mammals, reptiles, and invertebrates have suffered precipitous declines in recent years primarily due to habitat loss. Buffer strips may help many of these species and preserve the important diversity of life in and around lakes.

In addition to the benefits of increased fish and wildlife use, a buffer strip planted with a variety of native plants may provide a season long show of various colors from flowers, leaves, seeds, and stems. This is not only aesthetically pleasing to people, but also benefits wildlife and the overall health of the lake's ecosystem.

Cons

There are few disadvantages to native shoreline vegetation. Certain species (i.e. cattails) can be aggressive and may need to be controlled occasionally. If stands of shoreline vegetation become dense enough, access and visibility to the lake may be compromised to some degree. However, small paths could be cleared to provide lake access or smaller plants could be planted in these areas.

Costs

If minimal amount of site preparation is needed, costs can be approximately $10 per linear foot, plus labor. Cost of installing willow posts is approximately $15-20 per linear foot. To establish buffer areas on slightly eroded shorelines the cost wold be approximately $2,110. However it is the recommendation of the LMU to establish buffer strips on all applicable parcels of land surrounding the lake. The labor that is needed can be completed by the property owner in most cases, although consultants can be used to provide technical advice where needed. This cost will be higher if the area needs to be graded. If grading is necessary, appropriate permits and surveys are needed. If filling is required, additional costs will be incurred if compensatory storage is needed. The permitting process is costly, running as high as $1,000-2,000 depending on the types of permits needed.

Option 5: Install Biolog, Fiber Roll, or Straw Blanket with Plantings

These products are long cylinders of compacted synthetic or natural fibers wrapped in mesh. The rolls are staked into shallow water. Once established, a buffer strip of native plants can be planted along side or on top of the roll (depending if rolls are made of synthetic or natural fibers). They are most effective in areas where plantings alone are not effective due to already moderate to severe erosion. In areas of severe erosion, other techniques may need to be employed or incorporated with these products.

Pros

Biologs, fiber rolls, and straw blankets provide erosion control that secure the shoreline in the short-term and allow native plants to establish which will eventually provide long-term shoreline stabilization. They are most often made of bio-degradable materials, which break down by the time the natural vegetation becomes established (generally within 3 years). They provide additional strength to the shoreline, absorb wave energy, and effectively filter run-off from terrestrial sources. These factors help improve water quality in the lake by reducing the amount of nutrients available for algae growth and by reducing the sediment that flows into a lake.

Cons

These products may not be as effective on highly erodible shorelines or in areas with steep slopes, as wave action may be severe enough to displace or undercut these products. On steep shorelines grading may be necessary to obtain a 2:1 or 3:1 slope or additional erosion control products may be needed. If grading or filling is needed, the appropriate permits and surveys will have to be obtained.

Costs

Costs range from $25 to $35 per linear foot of shoreline, including plantings. This does not include the necessary permits and surveys, which may cost $1,000 – 2,000 depending on the type of earthmoving that is being done. Additional costs may be incurred if compensatory storage is needed.

Option 6: Establish a "No Wake" Zone, Horsepower Limit, or Boat Speed Limit

Establishing a "No Wake" zone, boat horsepower limit, or boat speed limit will not solve erosion problems by itself. However, since shoreline erosion is generally not caused by one specific factor, these techniques can be effective if used in combination with one or more of the techniques described above. Given the multisubdivision nature of Crooked Lake establishing a horsepower limit or speed limit might prove to be difficult let alone enforce. A No Wake zone might be easier and could be marked with buoys.

Pros

These techniques can reduce wave activity along shorelines susceptible to erosion. Limiting boat activity, particularly near shorelines, may also have an additional benefit by improving water quality since less sediment will be disturbed and resuspended in the water column. Disturbed sediment contribute to poor water clarity, which can negatively effect sight feeding fish and wildlife and limit the available light needed for plant growth. Nuisance algae also benefit from disturbed sediment since this action makes available nutrients in the sediment that otherwise would stay settled on the bottom.

Less motorboat disturbance will benefit wildlife and may encourage many species to use the lake both during spring and fall migration and for summer residence. This may add to the lake's aesthetics and increasing recreational opportunities for some lake users.

Cons

Enforcement and public education are the primary obstacles with these techniques. Public resistance to any regulation change may be strong, particularly if the lake is open to the public and has had no similar regulations in the past. Depending on the regulations implemented, there may be some loss of recreational use for some users, particularly powerboating. However, if the lake is large enough, certain parts of the lake (i.e. the middle or deepest) may be used for this activity without negatively influencing other uses.

Costs

Costs are limited to purchase and placement of signs and enforcement. No wake or speed limit buoys cost approximately $30-150 each.

Objective VI: Wildlife Habitat Improvement.

The key to increasing wildlife species in and around a lake can be summed up in one word: *habitat*. Wildlife need the same four things all living creatures need: food, water, shelter, and a place to raise their young. Since each wildlife species has specific habitat requirements, which fulfill these four basic needs, providing a variety of habitats will increase the chance that wildlife species may use an area. Groups of wildlife are often associated with the types of habitats they use. For example, grassland habitats may attract wildlife such as northern harriers, bobolinks, meadowlarks, meadow voles, and leopard frogs. Marsh habitats may attract yellow-headed blackbirds and sora rails, while manicured residential lawns attract house sparrows and gray squirrels. Thus, in order to attract a variety of wildlife, a mix of habitats are needed. In most cases quality is more important than quantity (i.e., five 0.1-acre plots of different habitats may not attract as many wildlife species than one 0.5 acre of one habitat type).

It is important to understand that the natural world is constantly changing. Habitats change or naturally succeed to other types of habitats. For example, grasses may be succeeded by shrub or shade intolerant tree species (e.g., willows, locust, and cottonwood). The point at which one habitat changes to another is rarely clear, since these changes usually occur over long periods of time, except in the case of dramatic events such as fire or flood.

In all cases, the best wildlife habitats are ones consisting of native plants. Unfortunately, non-native plants dominate many of our lake shorelines. Many of them escaped from gardens and landscaped yards (i.e., purple loosestrife) while others were introduced at some point to solve a problem (i.e., reed canary grass for erosion control). Wildlife species prefer native plants for food, shelter, and raising their young. In fact, one study showed that plant and animal diversity was 500% higher along naturalized shorelines compared to shorelines with conventional lawns (University of Wisconsin – Extension, 1999).

Option 1: No Action

This option means that the current land use activities will continue. No additional techniques will be implemented. Allowing a field to go fallow or not mowing a manicured lawn would be considered an action.

Pros

Taking no action may maintain the current habitat conditions and wildlife species present, depending on environmental conditions and pending land use actions. If all things remain constant there will be little to no effect on lake water quality and other lake uses.

Cons

If environmental conditions change or substantial land use actions occur (i.e., development) wildlife use of the area may change. For example, if a new housing development with manicured lawns and roads is built next to an undeveloped property, there will probably be a change in wildlife present.

Conditions in the lake (i.e., siltation or nutrient loading) may also change the composition of aquatic plant and invertebrate communities and thus influence biodiversity. Siltation and nutrient loading will likely decrease water clarity, increase turbidity, increase algal growth (due to nutrient availability), and decrease habitat for fish and wildlife.

Costs

The financial cost of this option may be zero. However, due to continual loss of habitats many wildlife species have suffered drastic declines in recent years. The loss of habitat effects the overall health and biodiversity of the lake's ecosystems.

Option 2: Increase Habitat Cover

This option can be incorporated with Option 3 (see below). One of the best ways to increase habitat cover is to leave a minimum 25 foot buffer between the edge of the water and any mowed grass. Allow native plants to grow or plant native vegetation along shorelines, including emergent vegetation such as cattails, rushes, and bulrushes (see the table in Appendix B for costs and seeding rates). This will provide cover from predators and provide nesting structure for many wildlife species and their prey. It is important to control or eliminate non-native plants such as buckthorn, purple loosestrife, garlic mustard, and reed canary grass, since these species outcompete native plants and provide little value for wildlife.

Occasionally high mowing (with the mower set at its highest setting) may have to be done for specific plants, particularly if the area is newly established, since competition from weedy and exotic species is highest in the first couple years. If mowing, do not mow the buffer strip until after July 15 of each year. This will allow nesting birds to complete their breeding cycle.

Brush piles make excellent wildlife habitat. They provide cover as well as food resources for many species. Brush piles are easy to create and will last for several years. They should be place at least 10 feet away from the shoreline to prevent any debris from washing into the lake.

Trees that have fallen on the ground or into the water are beneficial by harboring food and providing cover for many wildlife species. In a lake, fallen trees provide excellent cover for fish, basking sites for turtles, and perches for herons and egrets.

Increasing habitat cover should not be limited to the terrestrial environment. Native aquatic vegetation, particularly along the shoreline, can provide cover for fish and other wildlife.

Pros

Increased cover will lead to increased use by wildlife. Since cover is one of the most important elements required by most species, providing cover will increase the chances of wildlife using the shoreline. Once cover is established, wildlife usually have little problem finding food, since many of the same plants that provide cover also supply the food the wildlife eat, either directly (seeds, fruit, roots, or leaves) or indirectly (prey attracted to the plants).

Additional benefits of leaving a buffer include: stabilizing shorelines, reducing runoff which may lead to better water quality, and deterring nuisance Canada geese. Shorelines with erosion problems can benefit from a buffer zone because native plants have deeper root structures and hold the soil more effectively than conventional turfgrass. Buffers also absorb much of the wave energy that batters the shoreline. Water quality may be improved by the filtering of nutrients, sediment, and pollutants in run-off. This has a "domino effect" since less run-off flowing into a lake means less nutrient availability for nuisance algae, and less sediment means less turbidity, which leads to better water quality. All this is beneficial for fish and wildlife, such as sight-feeders like bass and herons, as well as people who use the lake for recreation. Finally, a buffer strip along the shoreline can serve as a deterrent to Canada geese from using a shoreline. Canada geese like flat, open areas with a wide field of vision. Ideal habitat for them are areas that have short grass up to the edge of the lake. If a buffer is allowed to grow tall, geese may choose to move elsewhere.

Cons

There are few disadvantages to this option. However, if vegetation is allowed to grow, lake access and visibility may be limited. If this occurs, a small path can be made to the shoreline. Composition and density of aquatic and shoreline vegetation are important. If vegetation consists of non-native species such as or Eurasian water milfoil or purple loosestrife, or in excess amounts, undesirable conditions may result. A shoreline with excess exotic plant growth may result in a poor fishery (exhibited by stunted fish) and poor recreation opportunities (i.e., boating, swimming, or wildlife viewing).

Costs

The cost of this option would be minimal. The purchase of native plants can vary depending upon species and quantity. Based upon 100 feet of shoreline, a 25-foot buffer planted with a native forb and grass seed mix would cost between $165-270 (2500 sq. ft. would require 2.5, 1000 sq. ft. seed mix packages at $66-108 per package). This does not include labor that would be needed to prepare the site for planting and follow-up maintenance. This cost can be reduced or minimized if native plants are allowed to grow. However, additional time and labor may be needed to insure other exotic species, such as buckthorn, reed canary grass, and purple loosestrife, do not become established.

Option 3: Increase Natural Food Supply

This can be accomplished in conjunction with Option 2. Habitats with a diversity of native plants will provide an ample food supply for wildlife. Food comes in a variety of forms, from seeds to leaves or roots to invertebrates that live on or are attracted to the plants. Plants found in the table in Appendix B should be planted or allowed to grow. In addition, encourage native aquatic vegetation, such as water lily(*Nuphar* spp. and *Nymphaea tuberosa*), sago pondweed (*Stuckenia pectinatus*), largeleaf pondweed (*Potamogeton amplifolius),* and wild celery (*Vallisneria americana*) to grow. Aquatic plants such as these are particularly important to waterfowl in the spring and fall, as they replenish energy reserves lost during migration.

Providing a natural food source in and around a lake starts with good water quality. Water quality is important to all life forms in a lake. If there is good water quality, the fishery benefits and subsequently so does the wildlife (and people) who prey on the fish. Insect populations in the area, including beneficial predatory insects, such as dragonflies, thrive in lakes with good water quality.

Dead or dying plant material can be a source of food for wildlife. A dead standing or fallen tree will harbor good populations of insects for woodpeckers, while a pile of brush may provide insects for several species of songbirds such as warblers and flycatchers.

Supplying natural foods artificially (i.e., birdfeeders, nectar feeders, corn cobs, etc.) will attract wildlife and in most cases does not harm the animals. However, "people food" such as bread should be avoided. Care should be given to maintain clean feeders and birdbaths to minimize disease outbreaks.

Pros

Providing food for wildlife will increase the likelihood they will use the area. Providing wildlife with natural food sources has many benefits. Wildlife attracted to a lake can serve the lake and its residents well, since many wildlife species (i.e., many birds, bats, and other insects) are predators of nuisance insects such as mosquitoes, biting flies, and garden and yard pests (such as certain moths and beetles). Effective natural insect control eliminates the need for chemical treatments or use of electrical "bug zappers" that have limited effect on nuisance insects.

Migrating wildlife can be attracted with a natural food supply, primarily from seeds, but also from insects, aquatic plants or small fish. In fact, most migrating birds are dependent on food sources along their migration routes to replenish lost energy reserves. This may present an opportunity to view various species that would otherwise not be seen during the summer or winter.

Cons

Feeding wildlife can have adverse consequences if populations become dependent on hand-outs or populations of wildlife exceed healthy numbers. This frequently happens when people feed waterfowl like Canada geese or mallard ducks.

Feeding these waterfowl can lead to a domestication of these animals. As a result, these birds do not migrate and can contribute to numerous problems, such as excess feces, which is both a nuisance to property owners and a significant contribution to the lake's nutrient load. Waterfowl feces are particularly high in phosphorus. Since phosphorus is generally the limiting factor for nuisance algae growth in many lakes in the Midwest, the addition of large amounts of this nutrient from waterfowl may exacerbate a lake's excessive algae problem. In addition, high populations of birds in an area can increase the risk of disease for not only the resident birds, but also wild bird populations that visit the area.

Finally, tall plants along the shoreline may limit lake access or visibility for property owners. If this occurs, a path leading to the lake could be created or shorter plants may be used in the viewing area.

Costs

The costs of this option is minimal. The purchase of native plants and food and the time and labor required to plant and maintain would be the limit of the expense.

Option 4: Increase Nest Availability

Wildlife are attracted by habitats that serve as a place to raise their young. Habitats can vary from open grasslands to closed woodlands (similar to Options 2 and 3).

Standing dead or dying trees provide excellent habitat for a variety of wildlife species. Unless there is a safety navigational issue, dead trees and dead fall should be left alone. Birds such as swallows, woodpeckers, and some waterfowl need dead trees to nest in. Generally, a cavity created and used by a woodpecker (e.g., red-headed or downy woodpecker, or common flicker) in one year, will in subsequent years be used by species like tree swallows or chickadees. Over time, older cavities may be large enough for waterfowl, like wood ducks, or mammals (e.g., flying squirrels) to use. Standing dead trees are also favored habitat for nesting wading birds, such as great blue herons, night herons, and double-crested cormorants, which build stick nests on limbs. For these birds, dead trees in groups or clumps are preferred as most herons and cormorants are colonial nesters.

In addition to allowing dead and dying trees to remain, erecting bird boxes will increase nesting sites for many bird species. Box sizes should vary to accommodate various species. Swallows, bluebirds, and other cavity nesting birds can be attracted to the area using small artificial nest boxes. Larger boxes will attract species such as wood ducks, flickers, and owls. A colony of purple martins can be attracted with a purple martin house, which has multiple cavity holes, placed in an open area near water.

Bat houses are also recommended for any area close to water. Bats are voracious predators of insects and are naturally attracted to bodies of water. They can be enticed into roosting in the area by the placement of bat boxes. Boxes should be constructed of rough non-treated lumber and placed >10 feet high in a sunny location.

Pros

Providing places were wildlife can rear their young has many benefits. Watching wildlife raise their young can be an excellent educational tool for both young and old.

The presence of certain wildlife species can help in controlling nuisance insects like mosquitoes, biting flies, and garden and yard pests. This eliminates the need for chemical treatments or electric "bug zappers" for pest control.

Various wildlife species populations have dramatically declined in recent years. Since, the overall health of ecosystems depend, in part, on the role of many of these species, providing sites for wildlife to raise their young will benefit not only the animals themselves, but the entire lake ecosystem.

Cons

Providing sites for wildlife to raise their young have few disadvantages. Safety precautions should be taken with leaving dead and dying trees due to the potential of falling limbs. Safety is also important when around wildlife with young, since many animals are protective of their young. Most actions by adult animals are simply threats and are rarely carried out as attacks.

Parental wildlife may chase off other animals of its own species or even other species. This may limit the number of animals in the area for the duration of the breeding season.

Costs

The costs of leaving dead and dying trees are minimal. The costs of installing the bird and bat boxes vary. Bird boxes can range in price from $10-100.00. Purple martin houses can cost $50-150. Bat boxes range in price from $15-50.00. These prices do not include mounting poles or installation.

Option 5: Limit Disturbance

Since most species of wildlife are susceptible to human disturbance, any action to curtail disturbances will be beneficial. Limiting disturbance can include posting signs in areas of the lake where wildlife may live (e.g., nesting waterfowl), establish a "no wake" area, boat horsepower or speed limits, or establish restricted boating hours. These are examples of time and space zoning for lake usage. Enforcement and public education are needed if this option is to be successful. In some areas, off-duty law enforcement officers can be hired to patrol the lake.

Pros
Limiting disturbance will increase the chance that wildlife will use the lake, particularly for raising their young. Many wildlife species have suffered population declines due to loss of habitat and poor breeding success. This is due in part to their sensitivity to disturbance.

This option also can benefit the lake in other ways. Limited boat traffic may lead to less wave action to batter shorelines and cause erosion, which results in suspension of nutrients and sediment in the water column. Less nutrients and sediment in the water column may improve water quality by increasing water clarity and limiting nutrient availability for excessive plant or algae growth.

Recreation activities such as canoeing and paddleboating may be enhanced by the limited disturbance.

Cons
One of the strongest oppositions to this option would probably be from the powerboat users and water skiers. However, this problem may be solved if a significant portion of the daylight hours and the use of the middle part of the lake (assuming the lake is deep enough) are allowed for powerboating. For example, powerboating could be allowed between 9 AM and 6 PM within the boundaries established by “no wake” restricted area buoys.

Costs
The costs of this option include the purchase and placement of signs and public educational materials as well as enforcement. Off-duty law enforcement officers usually charge $25/hour to enforce boating laws or local ordinances.

Objective VII: Create Bathymetric Map with Morphometric Table.

A bathymetric (depth contour) map is an essential tool for effective lake management since it provides critical information on the morphometric features of the lake (i.e., acreage, depth, volume, etc.). This information is particularly important when intensive management techniques (i.e., chemical treatments for plant or algae control, dredging, fish stocking, etc.) are part of the lake's overall management plan. Some lakes in Lake County do have a bathymetric map, but they are frequently old, outdated and do not accurately represent the current features of the lake. If management activities intensify, Crooked Lake should consider having a more detailed bathymetric map made. Crooked Lake's most recent map was produced in October of 1986 but is limited as depth contours are in 5 foot intervals.

Maps can be created by agencies like the Lake County Health Department - Lakes Management Unit or other companies. Costs vary, but can range from $3,000-10,000 depending on lake size.

Objective VIII: Illinois Volunteer Lake Monitoring Program

In 1981, the Illinois Volunteer Lake Monitoring Program (VLMP) was established by the Illinois Environmental Protection agency (Illinois EPA) to gather fundamental information on Illinois inland lakes, and to provide an educational program for citizens. Annually, 150-200 lakes (out of 3,041 lakes in Illinois) are sampled by approximately 250 citizen volunteers. The volunteers are primarily lake shore residents, lake owners/managers, members of environmental groups, public water supply personnel, and citizens with interest in a particular lake.

The VLMP relies on volunteers to gather a variety of information on their chosen lake. The primary measurement is the Secchi disk transparency or Secchi depth. Analysis of the Secchi disk measurement provides an indication of the general water quality condition of the lake, as well as the amount of usable habitat available for fish and other aquatic life.

Microscopic plants and animals, water color, and suspended sediments are factors that interfere with light penetration through the water column and lessen the Secchi disk depth. As a rule, one to three times the Secchi depth is considered the lighted or euphotic zone of the lake. In this region of the lake there is enough light to allow plants to survive and produce oxygen. Water below the lighted zone can be expected to have little or no dissolved oxygen. Other observations such as water color, suspended algae and sediment, aquatic plants, and odor are also recorded. The sampling season is May through October with volunteer measurements taken twice a month. After volunteers have completed one year of the basic monitoring program, they are qualified to participate in the Expanded Monitoring Program. In the expanded program, selected volunteers are trained to collect water samples that are shipped to the Illinois EPA laboratory for analysis of total and volatile suspended solids, total phosphorus, nitrate-nitrite nitrogen and ammonia nitrogen. Other parameters that are part of the expanded program include dissolved oxygen, temperature, and zebra mussel monitoring. Additionally, chlorophyll *a* monitoring has been added to the regiment of selected lakes. These water quality parameters are routinely measured by lake scientists to help determine the general health of the lake ecosystem.

It is to Crooked Lakes benefit to enroll in this program. The data gathered by the VLMP program could be prove to be valuable information to the residents of Crooked Lake as well as providing a historical record on the condition (improving quality) of the lake. For more information about the VLMP contact the northeast Illinois VLMP Coordinator:

Holly Hudson
Northeast Illinois Planning Commission
222 S. Riverside Plaza, Suite 1800
Chicago, IL 60606
(312) 454-0400