Whole-lake Fluridone Effects

Work Plan 300FW1F10D39634

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EXECUTIVE SUMMARY

- The primary objectives of this study were to describe the effects of whole-lake fluridone treatments on the submersed plant community, and on largemouth bass growth and diet in Indiana natural lakes.

- Actual initial concentrations ranged from approximately 6 ppb at Bass, Crooked, Heaton, Lake of the Woods, and Wall Lakes to apparent concentrations much greater than that at Dewart and Shipshewana Lakes.

- EWM was effectively controlled by whole-lake fluridone treatments at all study lakes.

- Although all of the treatments conducted during this study had an impact on non-target species for at least one growing season, the lakes treated at a lower initial concentration (approximately 6 ppb) appeared to have less of an impact, and quicker recovery of natives.

- Certain species have been identified as being more susceptible to fluridone including: coontail, eel grass, Elodea sp., flat-stemmed pondweed, Illinois pondweed, large-leaf pondweed, naiad sp., northern watermilfoil, variable pondweed, and white-stemmed pondweed (RTE species) (Welling et al. 1997, Valley et al. 2006, Wagner et al. 2007, This Study).

- Species that are typically less impacted by fluridone and are likely to recover within one or two growing seasons include: Chara sp., curly-leaf pondweed, eel grass, Nitella sp., Richardson’s pondweed, sago pondweed, and water stargrass (Welling et al. 1997, Madsen et al. 2002, Valley et al. 2006, Wagner et al. 2007, This Study).

- Whole-lake fluridone treatments appeared to have little or no effect on largemouth bass growth.

- Whole-lake fluridone treatments appeared to have little or no effect on largemouth bass diet. The changes in largemouth bass diet were highly variable and no obvious patterns relating to vegetation removal were observed.

- Further water quality was not adversely affected by the whole-lake fluridone treatments. Average secchi disk depth declined similarly at all lakes from 2005 to 2006, and this decline was more likely the result of differences in weather conditions between years.

- Due to the possibility of significantly reducing susceptible native species, the DFW should continue to use caution when permitting whole-lake fluridone treatments with Sonar® AS on Indiana natural lakes. Submersed vegetation plays an important role in the diversity, distribution, and abundance of certain species and efforts to protect littoral zone habitat should be continued (Pratt and Smokorowski 2003).

- The DFW should continue to work towards development of lake selection criteria for selection of whole-lake fluridone applications.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum*) was introduced into North America in the 1940's. It has since spread throughout the United States and was discovered in Indiana by the 1960's. Eurasian watermilfoil (EWM) can grow rapidly and has the ability to produce extensive homogenous stands. Dense stands of EWM create problems for recreational lake users, and can have severe ecological impacts as well. EWM posses a competitive advantage against most native species, and natives are often displaced in its presence (Madsen 1991). Dense stands of EWM can also have an impact on predator prey interactions by reducing the foraging ability of largemouth bass and other piscivores (Engel 1995, Valley and Bremigan 2002a). This could potentially impact largemouth bass growth and recruitment and decrease growth rates of prey species (Engel 1995, Valley and Bremigan 2002b). Reductions in the biomass of invertebrates have also been associated with EWM density (Cheruvelil et al. 2001). However little research is available regarding what impacts EWM has on lake ecology when it does not form homogenous stands and is part of a diverse plant community. Furthermore, EWM may be beneficial to lake ecology if it occurs in lakes that typically do not support the growth of native species (Engel 1995, Valley et al. 2004).

Historically, populations of EWM in Indiana natural lakes had been controlled locally, most commonly by lake associations and property owners, typically along developed shorelines. In 2002, Indiana state legislature increased funding of the DNR Lake and River Enhancement Program (LARE) to help communities control invasive aquatic plants. With more money available for aggressive management of exotic species, more unique treatment options have become available. One such treatment option involves whole-lake treatments with fluridone, marketed as Sonar® AS.

The ability of fluridone to control EWM is based on a combination of the initial treatment concentration and adequate exposure time. Low initial treatment concentrations require a longer exposure time, but can be just as effective as high dose treatments with less exposure time (Netherland and Getsinger 1995a, Getsinger et al. 2001). When applied at a low dose fluridone has shown an ability to selectively control EWM in controlled environments. Initial treatments of 5 ppb and exposure times of 60 and 90 days in mesocosm experiments displayed a drastic reduction of EWM (>90%), while almost all non-target species increased when compared to reference tanks (Netherland et al. 1997). Results of residue analysis showed fluridone concentrations less than 2 ppb existed 56 days after treatment, and that some measurable concentration was still present 84 days after treatment. In contrast, treatment concentrations of 10 and 20 ppb in the same experiment reduced almost all plant species. Other laboratory studies have suggested that treatment rates as low as 4 ppb with an adequate exposure time of at least 60 days have been effective at controlling EWM (Netherland and Getsinger 1995a, 1995b).

While, multiple experiments have demonstrated the selectivity of fluridone to control EWM, several field studies have been completed with varying results. Studies conducted on Minnesota and Wisconsin lakes using various concentrations of fluridone ranging from 6 to 15 ppb have produced mixed results (Welling et al. 1997, Valley et al. 2006, Wagner et al. 2007). EWM and several native species were reduced to varying degrees in most lakes, while some natives increased following treatments. A study conducted on four Michigan lakes using an initial treatment concentration of 5 ppb, controlled EWM while native plant coverage and diversity increased (Madsen et al. 2002). This study used a very conservative approach, but documented what appears to be good selective control of EWM. Public pressure to control EWM has resulted in the increased use of fluridone on Indiana lakes over the past several years. The uncertainty of the effects of fluridone on aquatic ecosystems, and different treatment strategies among applicators has required the Division of Fish and Wildlife to use caution when approving such requests. The primary objectives of this study were to describe the effects of whole-lake fluridone treatments on the submersed plant community, and on largemouth bass growth and diet in Indiana natural lakes.

METHODS

Work Plan 300FW1F10D39634 was first initiated in 2005 to evaluate the effects of fluridone treatments using the following six study lakes: Big Chapman, Diamond (Kosciusko), Dewart, Heaton, Manitou, and Upper Long. Treatment lakes included Dewart and Heaton, and all other lakes were considered controls. However as the project developed one lake was added while two were eliminated from the study. Little Chapman was added to the study as a control lake in 2005 due to its proximity to Big Chapman. Upper Long was eliminated from the study due to the over abundance of control lakes following the 2005 sampling season, and Manitou was eliminated following the sampling season in 2006 due to the infestation of Hydrilla and the subsequent more aggressive treatment program. Several other Indiana natural lakes have been treated with fluridone outside the scope of this work plan. Those lakes that received whole-lake treatments and had adequate pre and post vegetation data were also included in this report. These lakes include, Bass (Starke), Crooked (Stueben), Lake of the Woods (Marshall), Shipshewana, and Wall.

Vegetation Sampling

Submersed aquatic plants were sampled during the summer (July 15 – August 31) at each lake from 2006 through 2007 according to the Tier II Aquatic Vegetation Survey Protocol (IDNR 2007). Vegetation sampling was also conducted during the spring (May 15 – June 15) at the original study lakes, but was not conducted at all lakes. Unless otherwise noted all vegetation data used throughout this report was collected during the summer survey. Vegetation sampling conducted at Diamond Lake during the summer of 2006 was excluded from this study due to lost voucher specimens. Sampling conducted at all lakes prior to 2006 was completed with slight differences in methodology including: differences in total number of rake tosses and number of rake tosses by contour. Due to these deviations, all analysis of vegetation data was completed using only two depth contours, 0-5 ft and >5 ft. It should also be noted that in some cases vegetation data collected by LARE approved contractors was used for the analysis of lakes although not part of the original work plan. Attempts to identify all plants to species were made however, certain plants were only identified to genus including: Chara sp., Elodea sp., naiad sp., and Nitella sp. (excluding spiny naiad at Heaton and Big Chapman Lakes, brittle naiad at Bass Lake and slender naiad at Wall Lake). A global positioning system device was used to record the location of submersed aquatic vegetation sampling locations. Plant species with a 10% frequency of occurrence for at least one sampling event were tested for significant shifts using a chi-squared test with an alpha level of 0.05 (Statistix 8®). Changes in total number of native species collected, native species diversity index, and species listed as rare, threatened, or endangered were also noted (IDNR 2007). Common plant names used in this report are consistent with the Tier II Aquatic Vegetation Survey Protocol (IDNR 2007).

Largemouth Bass Sampling

Pulsed D.C. night electrofishing with two dippers was used to collect approximately 100 largemouth bass at each lake. Collections were made during a single sampling event during June or July from 2005 to 2007. Total length and weight of all bass were measured to the nearest 0.1 in and 0.01 lb, respectively. Five scales per half-inch group were collected for age determination and back-calculated lengths-at-age. Scales were not collected for Dewart Lake in 2005, age data collected during a 2003 general survey were substituted. Mean relative growth increments (RGI) were calculated for all ages collected, except age 1. Mean RGI was calculated as (Lt2-Lt1)/Lt1, where Lt2 is length at most recent annulus formation and Lt1 is length at previous annulus formation. Relative weights (Wr) were calculated for all bass ≥6 in and for bass stock to quality size. The weight and diet data collected from Big and Little Chapman Lakes in 2005 were combined. A two-way analysis of variance (ANOVA, $\alpha = 0.05$) was used to test for significant differences in mean RGI for select ages and Wr for bass stock to quality size (Statistix 8®). Tukey's Honestly Significant Difference (HSD) test was used to determine which sample means were significantly different. Little Chapman was excluded in the RGI analysis due to a low sample size, and the same Wr values were used for Big and Little Chapman in 2005. Stomach contents were removed by intubation through the esophagus and stored on ice. Stomach contents of each fish were identified and separated into five categories (fish, invertebrate, crayfish, vegetation, and unknown) and weighed to the nearest 0.01 g.

Water Quality Sampling

Attempts to measure selected water quality parameters at each lake were made bi-monthly during June through September and monthly during all other months from March through October. However due to other priorities water quality sampling was not completed as frequently as planned. Adequate samples from almost every month were attained during 2006 and 2007. However no samples were collected from March through June during 2005. Water quality parameters that were of primary interest were secchi disk depth, and orthophosphate. All water quality parameters were collected at each lakes deepest point using a Hydrolab Quanta®.

RESULTS

Heaton Lake

Heaton Lake was treated with fluridone at an estimated rate of 6 ppb on May 25, 2006 (Table 1). The exposure goal for Heaton was to maintain an approximate concentration of 3 ppb for a minimum of 45 days. FasTESTs conducted on water samples collected on May 27 (2 days after treatment) and June 8 (14 days after treatment) indicated an average concentration of 6.4 and 5.2 ppb, respectively (Table 2). Based on the 14 day FasTEST results, a bump of 1.46 ppb of fluridone was applied on June 16 to return the concentration of fluridone in Heaton to 6 ppb. FasTESTs conducted on water samples collected on June 29 (13 days after bump) and July 31 (45 days after bump, 67 days after initial treatment) indicated an average concentration of 3.6

and 3.9 ppb, respectively. Approximately 1 acre of EWM was treated at Heaton Lake the following spring.

During the 2005 spring survey the frequency of occurrence of EWM was 17% and 10% within the 0-5 ft and >5 ft depth contours, respectively. Following EWM spot treatments, no EWM was detected during the summer survey of that year (Table 3, Table 4). Following the fluridone treatment in the spring of 2006, no EWM was identified in either survey conducted during 2006 and 2007. Significant reductions in eel grass, northern watermilfoil, and white-stemmed pondweed from the 2005 to the 2006 survey were also identified (Table 3, Table 4). The frequency of occurrence of these species remained low during 2007. The native species diversity index declined from 0.75 in 2005 to 0.64 in 2006, but then increased to 0.84 in 2007. The total number of natives collected also declined from 9 in 2005 to 5 in 2006, but then increased to 11 in 2007. Species that were present before the treatment but were not collected following the treatment included: EWM, Illinois pondweed, and northern watermilfoil. Species that were present in 2007, but were not collected prior to treatment included: leafy-pondweed, Nitella sp., Richardson's pondweed, sago pondweed, and water stargrass. Plant species that appeared to benefit or were not affected by the fluridone treatment included: Chara sp., common bladderwort, coontail, curly-leaf pondweed, leafy-pondweed, naiad sp., Nitella sp., Richardson's pondweed, sago pondweed, and spiny naiad. Of those species, naiad sp., Richardson's pondweed, and spiny naiad significantly increased at depths >5 ft from 2006 to 2007 (Table 4).

The mean Wr of largemouth bass ≥6 in remained stable from 2005 to 2007 at Heaton Lake (Table 5). The mean Wr of stock to quality sized largemouth bass increased from 2005 to 2006. The mean RGI of age-2 and age-3 largemouth bass was not significantly different between years at Heaton Lake (Figure 1). The diet of largemouth bass at Heaton Lake consisted mainly of fish and invertebrates. The frequency of fish in the diet ranged from 0.39 in 2007 to 0.46 in 2005 (Table 6). The frequency of invertebrates in the diet ranged from 0.27 in 2007 to 0.52 in 2005.

The average secchi disk depth and average orthophosphate level declined at Heaton Lake from 2006 to 2007 (Table 7).

<u>Wall Lake</u>

Wall Lake was treated with fluridone at an estimated rate of 6 ppb on May 23, 2005 (Table 1). The exposure goal for Wall was to maintain an approximate concentration of 3 ppb for an undefined number of days. FasTESTs conducted on water samples collected on May 25 (2 days after treatment) and June 6 (14 days after treatment) indicated an average concentration of 5.0 and 4.8 ppb, respectively (Table 2). Based on the 14 day FasTEST results, a bump of fluridone was applied on June 10 to return the concentration of fluridone in Wall Lake to 6 ppb. FasTESTs conducted on water samples collected on June 17 (7 days after bump) and July 25 (45 days after bump, 63 days after initial treatment) indicated an average concentration 3.8 and 2.5 ppb, respectively. A small amount of EWM was treated following the whole-lake treatments in both 2006 (≤ 5 acres) and 2007 (≤ 20 acres).

During the 2004 survey the frequency of occurrence of EWM was 0% and 32% within the 0-5 ft and >5 ft depth contours, respectively (Table 3, Table 4). Following the fluridone treatment in the spring of 2005, no EWM was identified in surveys conducted from 2005 to 2007 within the 0-5 ft contour. During the 2005 to 2007 surveys the frequency of occurrence of EWM was 7%, 6%, and 3% at depths >5 ft, respectively. Significant reductions in coontail following the treatment were identified within both depth contours, and the frequency of occurrence remained low through 2007 (Table 3, Table 4). Illinois pondweed displayed a significant reduction immediately following the treatment at depths >5 ft, however a decline within the 0-5 ft depth contour was not identified until the 2007 survey (Table 3, Table 4). Significant reductions in slender naiad following the treatment were identified within both depth contours (Table 3, Table 4). While the frequency of occurrence of slender naiad increased in subsequent surveys following this decline, it remained below pretreatment levels. The native species diversity index declined from 0.81 in 2004 to 0.79, 0.75, and 0.79 in 2005 through 2007, respectively. Total number of natives collected also declined from 10 in 2004 to 9, 7, and 9 in 2005 through 2007, respectively. All natives present in the 2004 survey, were collected in at least one survey following the treatment in 2005. Plant species that appeared to benefit or were not affected by the fluridone treatment included: Elodea sp., Nitella sp., sago pondweed, and variable pondweed. Both Elodea sp. and Nitella sp. were present in the 2007 survey, but were not collected from 2004 through 2006. Significant increases in sago pondweed immediately following the treatment were identified within both depth contours, and remained above pretreatment levels through 2007 (Table 3, Table 4). Variable pondweed significantly increased at depths ≤5 ft from 2006 to 2007 (Table 3). The response by eel grass to the fluridone treatment at Wall Lake was variable (Table 3, Table 4). Eel grass significantly increased from 2004 to

2005 within both depth contours, and then significantly decreased from 2005 to 2006. Eel grass significantly increased at depths >5 ft from 2006 to 2007, and was greater than pretreatment levels. However eel grass remained below pretreatment levels at depths ≤5 ft following the initial increase observed immediately following the treatment.

Lake of the Woods

Lake of the Woods was treated with fluridone at an estimated rate of 6 ppb on May 5, 2005 (Table 1). The exposure goal for Lake of the Woods was to maintain an approximate concentration of 6 ppb for a minimum of 60 days. FasTESTs conducted on water samples collected on May 26 (21 days after treatment) indicated an average concentration of 2.2 ppb (Table 2). Based on the 21 day FasTEST results, a bump of fluridone was applied on June 2 to return the concentration of fluridone in Lake of the Woods to 6 ppb. FasTESTs conducted on water samples collected on June 7 (5 days after bump) indicated an average concentration 3.8 ppb. No treatments were necessary at Lake of the Woods during 2006, and approximately 17 acres of EWM was treated during 2007.

During the 2004 survey the frequency of occurrence of EWM was 44% and 21% within the 0-5 ft and >5 ft depth contours, respectively (Table 3, Table 4). Following the fluridone treatment in the spring of 2005, no EWM was identified during surveys conducted during both 2005 and 2006. During the 2007 survey, the frequency of occurrence of EWM was 4% and 3% within the 0-5 ft and >5 ft depth contours, respectively. Significant reductions in naiad sp. from the 2004 to the 2005 survey were also identified within both depth contours (Table 3, Table 4). The frequency of occurrence of naiad sp. remained low during 2006 and 2007. The native species diversity index declined from 0.39 in 2004 to 0.23 in 2005, but then increased to 0.41 and 0.53 in 2006 and 2007, respectively. The total number of natives collected also declined from 4 in 2004 to 2 in 2005, but then increased to 4 and 6 in 2006 and 2007, respectively. Species that were present in 2007, but were not collected prior to treatment included: curly-leaf pondweed, flat-stemmed pondweed, and Richardson's pondweed. Plant species that appeared to benefit or were not affected by the fluridone treatment included; Richardson's pondweed and sago pondweed. Of those species, sago pondweed significantly increased within the 0-5 ft contour from 2004 to 2005 (Table 3).

Bass Lake

Bass Lake was treated with fluridone at an estimated rate of 8 ppb on May 14, 2007 (Table 1). The exposure goal for Bass Lake was to maintain an approximate concentration of 3 ppb for a minimum of 60 days. FasTESTs conducted on water samples collected on May 16 (2 days after treatment), May 28 (14 days after treatment), and June 10 (27 days after treatment) indicated an average concentration of 5.1, 5.5, and 3.0 ppb, respectively (Table 2). Based on the FasTEST results, a bump of fluridone was applied on June 15 to return the concentration of fluridone in Bass Lake to 6 ppb. No FasTESTs were conducted following the bump.

During the 2006 survey the frequency of occurrence of EWM was 32% and 47% within the 0-5 ft and >5 ft depth contours, respectively (Table 3, Table 4). Following the fluridone treatment in the spring of 2007, the frequency of occurrence of EWM was 5% and 16% within the 0-5 ft and >5 ft depth contours, respectively. A significant reduction in variable pondweed was identified within the 0-5 ft contour, while a significant reduction in Chara sp. was displayed at depths >5 ft following the treatment (Table 3, Table 4). The native species diversity index declined from 0.53 in 2006 to 0.28 in 2007. The total number of natives collected also declined from 5 in 2006 to 1 in 2007. Species that were present before the treatment, but were not collected in 2007 following the treatment included: brittle naiad, Elodea sp., Nitella sp., and variable pondweed.

Crooked Lake

The third basin of Crooked Lake was treated with fluridone at an estimated rate of 8 ppb on May 14, 2007 (Table 1). The exposure goal for Crooked was to maintain an approximate concentration of 3 ppb for a minimum of 90 days. FasTESTs conducted on water samples collected on May 17 (3 days after treatment) indicated an average concentration of 6.6 ppb (Table 2). Based on the 3 day FasTEST results, a bump of fluridone was applied on May 23 to return the concentration of fluridone in Crooked Lake to 8 ppb. FasTESTs conducted on water samples collected on June 6 (14 days after bump) and June 26 (34 days after bump) indicated an average concentration of 5.4 and 4.7 ppb, respectively. Based on the FasTEST results, a second bump of fluridone was applied on July 2 to increase the concentration of fluridone in Crooked Lake to reach the desired goal for exposure time. FasTESTs conducted on water samples collected on July 18 (16 days after second bump) and August 6 (35 days after second bump, 84 days after initial treatment) indicated an average concentration of 5.0 and 3.5 ppb, respectively.

It should also be noted that EWM was also treated with 2,4-D in the first and second basin of Crooked Lake during 2007, and that the third basin was the only basin in which fluridone was applied.

During the 2005 survey the frequency of occurrence of EWM was 55% and 47% within the 0-5 ft and >5 ft depth contours, respectively (Table 3, Table 4). Following the fluridone treatment in the spring of 2007, the frequency of occurrence of EWM was 67% and 100% within the 0-5 ft and >5 ft depth contours, respectively. Although EWM appeared to have increased following the fluridone treatment, all of the EWM observed during the 2007 survey had fallen out of the water column and was dying. Green or living sections of each plant were observed and were recorded as being present. No significant reductions of any species occurred following the treatment. However minimal changes in frequency of occurrence were identified in several species. The native species diversity index declined from 0.74 in 2005 to 0.66 in 2007. The total number of natives collected also declined from 8 in 2005 to 5 in 2007. Species that were present before the treatment, but were not collected in 2007 included: common bladderwort, flat-stemmed pondweed, naiad sp., and water stargrass. Eel grass was the only species that was present following the treatment that was not collected in 2005. Illinois pondweed was the only other species aside from EWM to significantly increase in frequency following the treatment (Table 4).

Dewart Lake

Dewart Lake was treated with fluridone at an estimated rate of 6 ppb on May 25, 2006 (Table 1). The exposure goal for Dewart was to maintain an approximate concentration of 6 ppb for a minimum of 60 days. FasTESTs conducted on water samples collected on June 9 (15 days after treatment) indicated an average concentration of 8.1 ppb (Table 2). Due to the concentration measured on June 9, no bump of fluridone was required. Only 3 acres of EWM was treated in a man-made channel at Dewart Lake the following spring.

During the 2005 survey the frequency of occurrence of EWM was 25% and 72% within the 0-5 ft and >5 ft depth contours, respectively (Table 8, Table 9). Following the fluridone treatment in the spring of 2006, no EWM was identified in either survey conducted during 2006 and 2007. Significant reductions in Illinois pondweed, naiad sp., and variable pondweed at depths ≤5 ft from the 2005 to the 2006 survey were also identified (Table 8). The frequency of occurrence of these species remained low during 2007. Coontail was still abundant during the

2006 survey, but had lost much of its color following the fluridone treatment. A significant decline in coontail was measured from the 2006 to the 2007 survey at depths >5 ft (Table 9). The native species diversity index declined from 0.84 in 2005 to 0.71 and 0.74 in 2006 and 2007, respectively. The total number of natives collected also declined from 15 in 2005 to 9 and 11 in 2006 and 2007, respectively. Species that were collected at low levels (<10% frequency of occurrence) before the treatment, but were not collected following the treatment included: common bladderwort, Elodea sp., floating-leaf pondweed, and northern watermilfoil. Plant species that appeared to benefit or were not affected by the fluridone treatment included: Chara sp., curly-leaf pondweed, sago pondweed, and water stargrass. Sago pondweed declined significantly at depths >5 ft following the treatment in 2006, but had increased beyond pretreatment levels within both contours by 2007 (Table 8, Table 9). Water stargrass increased significantly within the 0-5 ft contour from 2005 to 2006 (Table 8). Both Chara sp. and curly-leaf pondweed displayed significant increases at depths >5 ft from 2006 to 2007 (Table 9).

The mean Wr of largemouth bass ≥6 in and largemouth bass of stock to quality size declined from 2005 to 2007 at Dewart Lake (Table 5). The mean RGI of age-2 largemouth bass was not significantly different between years at Dewart Lake (Figure 2). However, the mean RGI of age-3 largemouth bass in 2006 was significantly ($F = 4.03$, $df = 6$, $p < 0.001$) greater than 2003. Although the difference was not significant, the mean RGI of age-3 largemouth bass in 2006 was also greater than 2007. The diet of largemouth bass at Dewart Lake consisted mainly of fish and invertebrates. The frequency of fish in the diet ranged from 0.37 in 2007 to 0.61 in 2006 (Table 6). The median weight of fish in the diet remained relatively stable between years, as did the frequency of invertebrates (Table 6, Table 10).

The average secchi disk depth and average orthophosphate level declined at Dewart Lake from 2006 to 2007 (Table 7).

<u>Shipshewana</u>

Shipshewana Lake was treated with fluridone at an estimated rate of 6 ppb on May 5, 2007 (Table 1). The exposure goal for Shipshewana was to maintain an approximate concentration of 6 ppb for a minimum of 60 days. FasTESTs conducted on water samples collected on May 17 (12 days after treatment) and June 8 (34 days after treatment) indicated an average concentration of 9.1 and 2.3 ppb, respectively (Table 2). Due to the concentration measured on June 8, no bump of fluridone was required.

During the 2006 survey the frequency of occurrence of EWM was 64% and 10% within the 0-5 ft and >5 ft depth contours, respectively (Table 8, Table 9). Following the fluridone treatment in the spring of 2007, no EWM was detected during the subsequent survey. A significant reduction in coontail was observed within both depth contours following the treatment (Table 8, Table 9). The native species diversity index declined from 0.23 in 2006 to 0.21 in 2007. The total number of natives collected also declined from 3 in 2006 to 2 in 2007. Leafy pondweed was the only species present prior to treatment that was not collected during the 2007 survey.

<u>Control Lakes</u>

All control lakes received some amount of vegetation treatment from 2005 through 2007. Approximately 30 acres of Big Chapman were treated annually from 2005 through 2007. The bulk of these treatments were targeted towards EWM, and it can be assumed that the treatments had some effect on the overall plant community. No treatments were conducted at Little Chapman in 2005, and 2 to 7 acres were treated in 2006 and 2007, respectively. Unlike Big Chapman, treatments at Little Chapman covered less acreage and it can be assumed that the treatments had minimal effect on the overall plant community. Approximately 20 acres of Diamond Lake were treated during 2005 and 2006. Due to the timing of these treatments and the fact that most of littoral zone was treated, it is assumed that the treatments had some effect on the overall plant community. Some decline in non-targeted species is expected, but it is difficult to say specifically how much decline was a result of the treatments. No treatments were conducted at Diamond Lake during 2007.

A significant reduction in eel grass and a significant increase in variable pondweed were observed from 2005 to 2006 at Big Chapman (Table 11, Table 12). Significant reductions in variable pondweed, spiny naiad, naiad sp., coontail, and Chara sp. were observed within at least one depth contour from 2006 to 2007 (Table 11, Table 12). Significant increases in eel grass and EWM were also observed from 2006 to 2007 (Table 11, Table 12). Nitella sp. and sago pondweed were the only two species that remained somewhat stable during the study period at Big Chapman. The native species diversity index declined from 0.87 in 2005 to 0.84 and 0.83 in 2006 and 2007, respectively. The total number of natives collected also declined from 15 in 2005 to 11 and 8 in 2006 and 2007, respectively. Only minor fluctuations in frequency of occurrence were observed at Little Chapman from 2005 through 2007 (Table 11, Table 12). The native species diversity index increased annually from 2005 through 2007, 0.66, 0.71, and 0.74, respectively. The total number of natives collected increased from 5 to 7 from 2005 to 2006, and then declined to 6 in 2007. Significant reductions in coontail and water stargrass were observed from 2005 to 2007 at Diamond Lake (Table 11). Significant increases in EWM, leafy pondweed, and sago pondweed were also observed from 2005 to 2007 (Table 11). The native species diversity index increased from 0.82 in 2005 to 0.84 in 2007. The total number of natives collected declined from 10 in 2005 to 9 in 2007. Minimal changes in frequency of Chara sp., Eel grass, Illinois pondweed, naiad sp., and variable pondweed were observed at Diamond Lake from 2005 to 2007.

The mean Wr of largemouth bass ≥6 in declined from 2005 to 2006 at all three control lakes (Table 5). Increases in the mean Wr of largemouth bass ≥6 in were observed from 2006 to 2007 at Big Chapman and Little Chapman Lakes. The mean Wr of stock to quality sized largemouth bass at Big and Little Chapman Lakes declined from 2005 to 2006, and increased in 2007 (Table 5). The decline in the mean Wr of stock to quality sized largemouth bass observed at Big Chapman from 2005 to 2006 was significant ($F = 4.23$, $df = 8$, $p < 0.001$). The exact opposite trend in mean Wr of stock to quality sized largemouth bass was observed at Diamond Lake when compared to Big and Little Chapman. Mean Wr of stock to quality sized largemouth bass increased from 2005 to 2006, and declined in 2007.

The mean RGI of age-2 and age-3 largemouth bass was not significantly different between years at either Big Chapman or Diamond lakes (Figure 3, Figure 4). Mean RGI of age-2 largemouth bass at both lakes increased from 2005 to 2006, and declined in 2007. Mean RGI of age-3 largemouth bass declined from 2005 through 2007 at Big Chapman Lake. Where as the mean RGI of age-3 largemouth bass at Diamond Lake declined from 2005 to 2006, and increased in 2007.

The diet of largemouth bass at all three control lakes consisted mainly of fish and invertebrates. The frequency of fish in the diet at each lake fluctuated annually, with the greatest variation observed at Diamond Lake from 2005 (31%) to 2006 (55%) (Table 6). The frequency of invertebrates in the diet showed a similar amount of fluctuation as fish. Again the greatest amount of variation was observed at Diamond Lake from 2005 (36%) to 2006 (16%).

The average secchi disk depth and average orthophosphate level declined at all control lakes from 2006 to 2007 (Table 7).

DISCUSSION

EWM was effectively controlled by whole-lake fluridone treatments at all study lakes. The length of control expected following fluridone treatments of less than 10 ppb can range anywhere from 0 to 4 growing seasons (Welling et al. 1997, Madsen et al. 2002, Valley et al. 2006, Wagner et al. 2007). EWM has been controlled (<10% frequency of occurrence) at Lake of the Woods and Wall Lake for three growing seasons, and with continuing spot treatments in 2008, chances are good that EWM will be controlled for another season. Similar conclusions can be made for Dewart and Heaton Lakes, where EWM has been controlled for two growing seasons. The treatments at Crooked, Bass, and Shipshewana Lakes appear to have been effective and could provide control of EWM over the next couple of growing seasons. Although the frequency of EWM remained high following treatments at Crooked Lake, the plants observed were dying and the presence of EWM is expected to be low in 2008. Although the frequency of EWM at Bass Lake was 16% at depths >5 ft, the majority of plant growth occurs within the 0-5 ft depth contour, which was clear of EWM following the treatment (Table 3, Table 4). Extensive spot treatments to kill the remaining EWM and extend the effectiveness of the fluridone treatment are planned for 2008.

Although the initial concentrations and exposure time of fluridone varied considerably at each lake, all prescriptions appeared to be effective at controlling EWM. The lack of FasTESTs or timing of FasTESTs made it very difficult to determine the concentration and exposure time of fluridone at all lakes. Actual initial concentrations ranged from approximately 6 ppb at Bass, Crooked, Heaton, Lake of the Woods, and Wall Lakes to apparent concentrations much greater than that at Dewart and Shipshewana Lakes. Although Bass, Crooked, Heaton, Lake of the Woods, and Wall Lakes were treated with a lower concentration than the other two it appears that the length of exposure to fluridone was adequate, and therefore just as effective. Discrepancies in FasTEST results documenting increases in fluridone concentrations over time were observed at more than one lake during this study. These increases could be due to poor distribution of the chemical by the applicator creating “hot spots” within the lake, or may have resulted from mistakes made during the collection and testing of water samples. Either way these discrepancies question the methods and accuracy of these tests, making it more difficult to interpret fluridone efficacy.

Although all of the treatments conducted during this study had an impact on non-target species for at least one growing season, the lakes treated at a lower initial concentration (approximately 6 ppb) appeared to have less of an impact, and quicker recovery of natives. This observation is consistent with a Michigan study that documented the selectivity of low dose (<6 ppb) fluridone for EWM (Madsen et al. 2002). Certain species have been identified as being more susceptible to fluridone including: coontail, eel grass, Elodea sp., flat-stemmed pondweed, Illinois pondweed, large-leaf pondweed, naiad sp., northern watermilfoil, variable pondweed, and white-stemmed pondweed (RTE species) (Welling et al. 1997, Valley et al. 2006, Wagner et al. 2007, This Study). It is difficult to determine if or when impacted species will recover. The time it takes a species to recover to levels equal to or greater than pretreatment levels may depend greatly upon the species, the concentration of fluridone, and the recovery of EWM in the lake. Most studies documenting the effects of fluridone on non-target species have yet to document long-term benefits to native species diversity and abundance from the reduction of EWM (Welling et al. 1997, Madsen et al. 2002, Valley et al. 2006). Wagner et al. (2007) attempted to document long-term (4 – 7 years) benefits to natives at Potter Lake in Wisconsin following fluridone treatments; however the reduction of EWM was short lived, and limited certain species ability to return to pretreatment levels.

Species that are typically less impacted by fluridone and are likely to recover within one or two growing seasons include: Chara sp., curly-leaf pondweed, eel grass, Nitella sp., Richardson’s pondweed, sago pondweed, and water stargrass (Welling et al. 1997, Madsen et al. 2002, Valley et al. 2006, Wagner et al. 2007, This Study). Species that produce overwintering propagules such as tubers or turions (e.g. curly-leaf pondweed, eel grass, and sago pondweed) typically recover much more quickly than species that overwinter in an evergreen state (Netherland et al. 1997). The increases in curly-leaf pondweed following fluridone treatments are troubling. An extensive amount of effort is spent on curly-leaf pondweed control through out the natural lakes region, and increases in this species following fluridone treatments are a major concern.

Whole-lake fluridone treatments appeared to have little or no effect on largemouth bass growth. The only significant increase in growth was documented at Dewart Lake for the mean RGI of age-3 bass following the treatment. Although, a similar shift was observed at Heaton Lake, this increase was not significant. The mean RGI of age-3 bass increased slightly at Little

Chapman, but declined at the other control lakes. The removal of vegetation at Dewart Lake was greater than at Heaton, and could explain why similar increases in growth were not observed. Studies have shown that removal of vegetation can improve bass foraging efficiency and growth (Valley and Bremigan 2002a, Dibble et al. 1996). However, the amount of vegetation that needs to be removed in order for these changes to occur is highly variable (Valley et al. 2004). Similar increases in growth were observed in Michigan lakes, however changes in growth were only observed for bass <8 in (Bremigan et al. 2005). This size range would include both age-1 and age-2 largemouth bass in Indiana natural lakes, and no significant changes were observed in the mean RGI of age-2 bass during this study. The mean RGI of age-1 bass was not evaluated during this study due to low sample size. Other possible explanations in the differences observed at the two treatment lakes point to differences in year class strength and prey availability (Valley and Bremigan 2002b). It is possible that the inconsistent changes in growth were more density related, than a result of vegetation removal.

Whole-lake fluridone treatments appeared to have little or no effect on largemouth bass diet. The changes in largemouth bass diet were highly variable and no obvious patterns relating to vegetation removal were observed. An increase in the frequency of fish in the bass diet was documented at Dewart Lake in 2006, but this increase was also observed in all three control lakes. Due to largemouth bass variability more in depth analysis, over a longer period of time would be needed to document any significant changes resulting from vegetation control practices. The original design of this study was not to extensively document the diet, but was intended as a “quick and dirty” approach to document any extreme negative impacts resulting from these treatments. A more extensive study conducted on Michigan lakes following fluridone treatments did not document any significant effects on age-0 largemouth bass piscivory and growth (Valley and Bremigan 2002b). This study did not document any positive or negative changes to largemouth bass food habits or growth following fluridone treatments.

Further, water quality was not adversely affected by the whole-lake fluridone treatments. Average secchi disk depth declined similarly at all lakes from 2006 to 2007, and this decline was more likely the result of differences in weather conditions between years. Impacts to water clarity are likely related to the timing and magnitude of vegetation removal, and consequently also related to the dosage concentration of fluridone applied (Cromwell et al. 1997, Bremigan et al. 2005, Wagner et al. 2007). For lakes in which the abundance of EWM is high or the overall plant community is expected to be significantly reduced, water clarity can be expected to decline following whole-lake fluridone treatments. These declines are the result of increased nutrient availability to algae and resuspension of sediments by wave action (Wagner et al. 2007). Declines in water quality in eutrophic lakes can also inhibit the recovery of native plants following vegetation treatments and caution should be used in such cases (Valley et al. 2006).

RECOMMENDATIONS

Due to the possibility of significantly reducing susceptible native species, the DFW should continue to use caution when permitting whole-lake fluridone treatments with Sonar® AS on Indiana natural lakes. Submersed vegetation plays an important role in the diversity, distribution, and abundance of certain fish species and efforts to protect littoral zone habitat should be continued (Pratt and Smokorowski 2003). Unless justified, initial concentrations of fluridone should be applied within the range of 5 to 6 ppb, and a concentration of at least 5 ppb should be maintained for a minimum of 2 to 3 weeks. The initial concentrations should be followed by an exposure of ≥2 ppb for a minimum of 60 to 90 days. If necessary PlanTESTs should be utilized to justify higher treatments and a minimum of three FasTESTs should be conducted post treatment. The first FasTEST should be conducted within the first 5 days following the initial treatment and the second within 20 days after treatment. This should provide enough data to determine if a bump application is necessary to meet the concentration and application goals set. The third FasTEST should be conducted within 40 days post treatment, unless a bump has been applied. FasTESTs should be conducted within 10 days following all bump applications. When whole-lake treatments are applied to lakes that contain curly-leaf pondweed, plans to treat curly-leaf pondweed the following spring should be prepared. Furthermore, spot treatments are essential in controlling EWM and extending the effectiveness of the whole-lake treatment and should always be utilized.

The DFW should continue to work towards development of lake selection criteria for determining when whole-lake fluridone applications should be applied. These criteria should be based on current and future literature as well as this study. Whole-lake fluridone treatments using Sonar® AS should be avoided, or at a minimum approached with caution, for lakes that meet the following criteria:

- Have a high abundance of fluridone sensitive species.

- Have a high amount of flow and low retention time.
- Contain vascular plant species that are listed as rare, threatened, or endangered.
- Do not typically support much growth of native vegetation.
- EWM is not at nuisance levels.

It is recommended that Work Plan 300FW1F10D39634 be terminated. Summer vegetation sampling should be continued by LARE approved applicators at Dewart, Heaton, Lake of the Woods, and Wall Lakes through 2009.

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Date: May 1, 2008

Table 1. Lake characteristics, fluridone treatment date, and target concentration at all study lakes.

Lake	County	Acres	Max Depth	Treatment Date	Target Concentration
Bass	Starke	1345	28	5/14/2007	8 ppb
Big Chapman	Kosciusko	512	39	Control	NA
Crooked	Stueben	802	77	5/14/2007	8 ppb (3rd basin only)
Dewart	Kosciusko	551	82	5/25/2006	6 ppb
Diamond	Kosciusko	79	39	Control	NA
Heaton	Elkhart	87	22	5/25/2006	6 ppb
Lake of the Woods	Marshall	416	48	5/5/2005	6 ppb
Little Chapman	Kosciusko	177	31	Control	NA
Shipshewana	Lagrange	202	14	5/5/2007	6 ppb
Wall	Lagrange	141	34	5/23/2005	6 ppb

Table 2. Timing and results (ppb) of FasTESTs conducted following initial fluridone treatments.

	Number of days following initial treatment			
Lake	0-3 days	12-21 days	23-43 days	≥ 63 days
Bass	5.1	5.5	3.0	NA
Crooked	6.6	NA	5.4, 4.7	5.0, 3.5
Dewart	NA	8.1	NA	NA
Heaton	6.4	5.2	3.6	3.9
Lake of the Woods	NA	2.2	3.8	NA
Shipshewana	NA	9.1	2.3	NA
Wall	5.0	4.8	3.8	2.5

Table 3. Changes in frequency of occurrence of submerged vegetation within the 0 - 5 ft contour following whole-lake fluridone treatments with initial concentrations of approximately 6 ppb. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Heaton Lake					Wall Lake							Lake of the Woods							Bass Lake			Crooked Lake		
Plant	2005	SIG	2006	SIG	2007	2004	SIG	2005	SIG	2006	SIG	2007	2004	SIG	2005	SIG	2006	SIG	2007	2006	SIG	2007	2005	SIG	2007
Chara sp.	100.0	NS	90.0	NS	90.0	69.0	NS	83.9	NS	92.9	NS	85.7								27.4	NS	19.3	55.0	NS	80.0
Common Bladderwort	16.7	NS	10.0	NS	10.0																		15.0	NS	0.0
Coontail	26.7	NS	10.0	NS	10.0	13.8	-	0.0	NS	0.0	NS	0.0													
Eel Grass	23.3	-	0.0	NS	10.0	20.7	+	45.2	-	14.3	NS	7.1											0.0	NS	13.3
Eurasian Watermilfoil													44.4	-	0.0	NS	0.0	NS	4.3	32.3	-	5.3	55.0	NS	66.7
Flat-stemmed Pondweed						10.3	NS	19.4	NS	21.4	NS	0.0													
Illinois Pondweed						48.3	NS	25.8	NS	42.9	-	7.1											10.0	NS	33.3
Leafy Pondweed	0.0	NS	0.0	NS	10.0																				
Naiad sp.	3.3	NS	20.0	NS	0.0								52.8	-	0.0	NS	4.7	NS	0.0				10.0	NS	0.0
Nitella sp.	0.0	NS	0.0	NS	10.0																				
Northern Watermilfoil	10.0	NS	0.0	NS	0.0																				
Richardson's Pondweed	0.0	NS	0.0	NS	10.0								0.0	NS	0.0	NS	7.0	NS	13.0						
Sago Pondweed	0.0	NS	0.0	NS	10.0	3.4	+	25.8	NS	7.1	NS	7.1	11.1	+	40.0	NS	41.9	NS	50.0				5.0	NS	13.3
Slender Naiad						34.5	-	0.0	+	21.4	NS	21.4													
Spiny Naiad	10.0	NS	0.0	NS	0.0																				
Variable Pondweed						0.0	NS	0.0	NS	0.0	+	35.7								11.3	-	0.0	40.0	NS	20.0
White-stemmed Pondweed	10.0	NS	0.0	NS	0.0																				

Table 4. Changes in frequency of occurrence of submerged vegetation within the > 5 ft contour following whole-lake fluridone treatments with initial concentrations of approximately 6 ppb. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Heaton Lake					Wall Lake							Lake of the Woods							Bass Lake			Crooked Lake		
Plant	2005	SIG	2006	SIG	2007	2004	SIG	2005	SIG	2006	SIG	2007	2004	SIG	2005	SIG	2006	SIG	2007	2006	SIG	2007	2005	SIG	2007
Chara sp.	22.2	NS	18.8	NS	13.3	61.3	NS	60.0	NS	43.8	NS	44.4								21.1	-	4.7	13.3	NS	30.0
Coontail	33.3	NS	40.6	NS	40.0	6.5	NS	10.0	-	0.0	NS	2.8													
Curly-leaf Pondweed	0.0	NS	6.3	NS	10.0																				
Eel Grass						25.8	+	50.0	-	14.6	+	47.2													
Elodea sp.						0.0	NS	0.0	NS	0.0	+	11.1													
Eurasian Watermilfoil						32.3	-	6.7	NS	6.3	NS	2.8	20.9	-	0.0	NS	0.0	NS	2.9	47.4	-	16.3	46.7	+	100.0
Flat-stemmed Pondweed						9.7	NS	23.3	NS	18.8	-	0.0													
Illinois Pondweed						32.3	-	10.0	NS	8.3	NS	8.3											0.0	+	30.0
Naiad sp.	0.0	NS	3.1	+	20.0								18.6	-	0.0	NS	0.0	NS	5.9						
Nitella sp.						0.0	NS	0.0	NS	0.0	+	22.2													
Northern Watermilfoil	11.1	-	0.0	NS	0.0																				
Richardson's Pondweed	0.0	NS	0.0	+	13.3																				
Sago Pondweed						9.7	+	40.0	-	16.7	NS	11.1													
Slender Naiad						64.5	-	6.7	NS	0.0	+	8.3													
Spiny Naiad	0.0	NS	0.0	+	13.3																				
White-stemmed Pondweed	33.3	-	6.3	NS	0.0																				

Table 5. Mean relative weight and standard error for largemouth bass ≥ 6 inches and for largemouth bass stock to quality (S-Q) size collected from northern Indiana lakes in 2005 through 2007.

Lake	Year	N	Wr ≥ 6 in	SE	Wr S-Q	SE
			Treatment lakes			
Dewart	2007	93	89.2	0.9	91.0	1.1
Dewart	2006	84	92.5	1.0	92.5	2.1
Dewart	2005	60	93.6	1.0	95.5	1.3
Heaton	2007	85	83.5	0.7	83.0	0.8
Heaton	2006	71	84.9	1.0	84.0	1.2
Heaton	2005	72	84.8	1.3	81.1	1.6
			Control Lakes			
Big Chapman	2007	76	87.5	0.9	87.6	1.0
Big Chapman	2006	62	82.4	0.8	82.4	0.8
Chapman Lakes	2005	87	89.4	0.7	89.0	0.7
Diamond	2007	87	86.0	0.8	86.1	0.8
Diamond	2006	44	89.2	1.3	89.1	1.2
Diamond	2005	69	91.5	4.5	88.2	2.6
Little Chapman	2007	20	93.2	1.4	93.7	1.6
Little Chapman	2006	18	84.5	1.7	82.8	2.4

Figure 1. Mean relative growth increments of Largemouth Bass collected at Heaton lake in 2005 through 2007. Error bars represent standard error. Bars within each age group with the same letter denote no significant difference (p > 0.05).

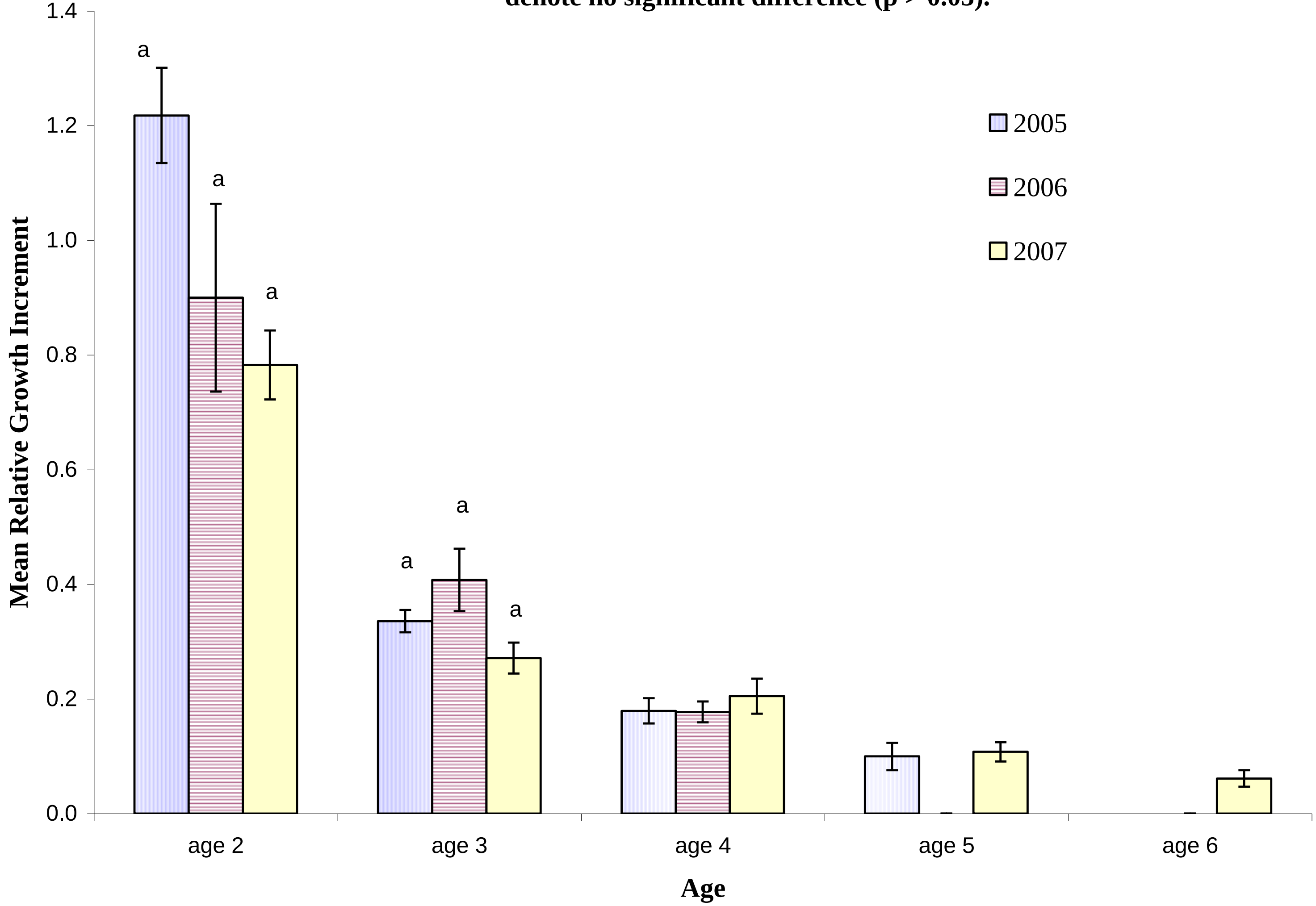

Table 6. Frequency of occurrence of prey items removed from largemouth bass stomachs collected from northern Indiana lakes in 2005 through 2007.

Lake	Year	N	Fish	Invertebrate	Crayfish	Vegetation	Unknown	Empty
				Treatment Lakes				
Dewart	2007	100	0.37	0.50	0.11	0.04	0.04	0.18
Dewart	2006	98	0.61	0.52	0.11	0.17	0.04	0.12
Dewart	2005	75	0.45	0.41	0.00	0.04	0.01	0.31
Heaton	2007	100	0.39	0.27	0.00	0.05	0.11	0.27
Heaton	2006	91	0.45	0.43	0.04	0.15	0.08	0.19
Heaton	2005	87	0.46	0.52	0.00	0.25	0.02	0.24
				Control Lakes				
Big Chapman	2007	76	0.36	0.54	0.07	0.05	0.07	0.18
Big Chapman	2006	64	0.50	0.47	0.09	0.06	0.00	0.23
Little Chapman	2007	20	0.65	0.30	0.00	0.05	0.05	0.25
Little Chapman	2006	20	0.90	0.40	0.00	0.15	0.00	0.10
Chapman Lakes	2005	95	0.58	0.33	0.05	0.21	0.02	0.25
Diamond	2007	99	0.56	0.14	0.03	0.09	0.03	0.30
Diamond	2006	100	0.55	0.16	0.00	0.39	0.02	0.28
Diamond	2005	84	0.31	0.36	0.00	0.36	0.23	0.25

Table 7. Average secchi disk depth and average orthophosphate levels collected from northern Indiana lakes in 2006 through 2007.

	Average Secchi Depth (ft)		Orthophosphate (ppm)	
Lake	2006	2007	2006	2007
Dewart	13.23	10.80	0.73	0.33
Heaton	9.32	7.62	0.90	0.20
Diamond	5.10	3.69	0.75	0.29
Big Chapman	9.06	8.86	0.67	0.25
Little Chapman	4.50	4.16	0.68	0.33

Table 8. Changes in frequency of occurrence of submerged vegetation within the 0 - 5 ft contour following whole-lake fluridone treatments with initial concentrations of approximately 8 ppb. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Dewart Lake					Shipshewana Lake		
Plant	2005	SIG	2006	SIG	2007	2006	SIG	2007
Chara sp.	79.5	NS	80.0	NS	83.9			
Coontail	13.6	NS	10.0	NS	3.2	96.0	-	42.0
Eurasian Watermilfoil	25.0	-	0.0	NS	0.0	64.0	-	0.0
Illinois Pondweed	20.5	-	0.0	NS	3.2			
Naiad sp.	25.0	-	3.3	NS	0.0			
Sago Pondweed	4.5	NS	0.0	+	16.1	14.0	NS	6.0
Variable Pondweed	25.0	-	3.3	NS	6.5			
Water Stargrass	0.0	+	10.0	NS	9.7			

Table 9. Changes in frequency of occurrence of submerged vegetation within the > 5 ft contour following whole-lake fluridone treatments with initial concentrations of approximately 8 ppb. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Dewart Lake					Shipshewana Lake		
Plant	2005	SIG	2006	SIG	2007	2006	SIG	2007
Chara sp.	18.8	NS	16.9	+	42.4			
Coontail	59.4	NS	59.3	-	16.9	50.0	-	10.0
Curly-leaf Pondweed	3.1	NS	3.4	+	35.6			
Eurasian Watermilfoil	71.9	-	0.0	NS	0.0	10.0	NS	0.0
Sago Pondweed	17.2	-	0.0	+	45.8			
Water Stargrass	21.9	NS	20.3	NS	20.3			

Figure 2. Mean relative growth increments of largemouth bass collected at Dewart Lake in 2003, 2006, and 2007. Error bars represent standard error. Bars within each age group with the same letter denote no significant difference ($p < 0.05$).

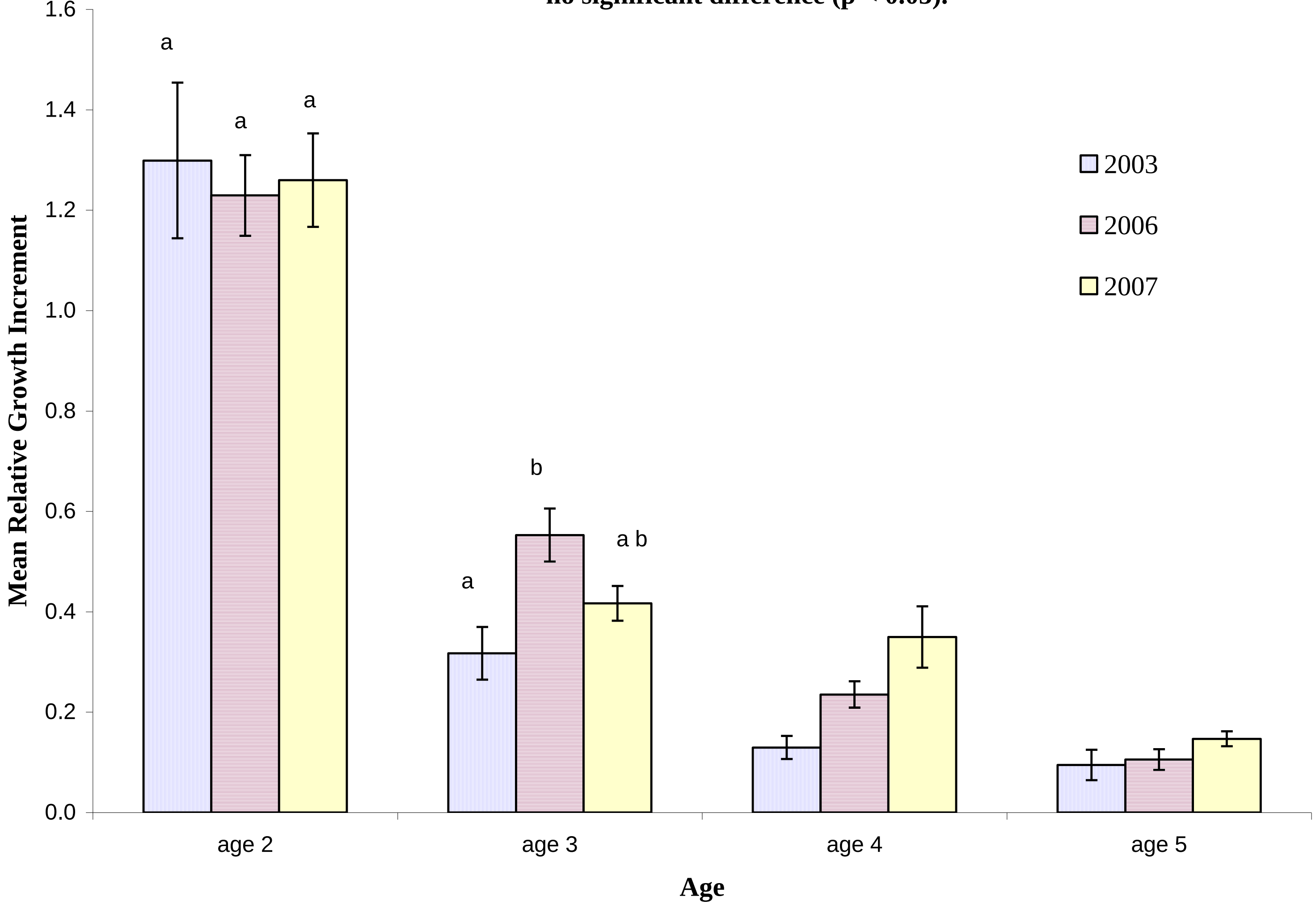

Table 10. Median weight of prey items removed from largemouth bass stomachs collected from northern Indiana lakes in 2005 through 2007.

Lake	Year	N	Fish	Invertebrate	Crayfish	Vegetation	Unknown
Dewart	2007	100	0.60	0.04	3.50	0.04	0.04
Dewart	2006	98	0.59	0.03	0.15	0.03	0.09
Dewart	2005	75	0.70	0.12	0.00	0.01	2.45
Heaton	2007	100	0.50	0.40	0.00	0.10	0.10
Heaton	2006	91	0.65	0.13	0.49	0.02	0.02
Heaton	2005	87	0.21	0.10	0.00	0.03	0.02
Big Chapman	2007	76	0.60	0.02	0.60	0.07	0.60
Big Chapman	2006	64	0.56	0.08	0.26	0.02	0.00
L. Chapman	2007	20	0.60	0.07	0.00	0.20	0.10
L. Chapman	2006	20	0.94	0.10	0.00	0.04	0.00
Chapman Lakes	2005	95	0.37	0.03	4.64	0.05	0.04
Diamond	2007	99	0.57	0.21	12.40	0.23	0.10
Diamond	2006	100	0.31	0.04	0.00	0.05	0.04
Diamond	2005	84	1.03	0.04	0.00	0.04	0.10

Table 11. Changes in frequency of occurrence of submerged vegetation within the 0 - 5 ft contour at lakes that did not receive whole-lake fluridone treatment. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Big Chapman Lake					Little Chapman Lake					Diamond Lake		
Plant	2005	SIG	2006	SIG	2007	2005	SIG	2006	SIG	2007	2005	SIG	2007
Chara sp.	93.8	NS	78.6	NS	87.1	28.6	NS	17.4	NS	26.1	33.3	NS	27.8
Coontail						47.6	NS	52.2	NS	34.8	51.1	-	22.2
Curly-leaf Pondweed											13.3	NS	0.0
Eel Grass	25.0	-	0.0	NS	0.0	38.1	NS	30.4	NS	30.4	11.1	NS	5.6
Eurasian Watermilfoil	3.1	NS	3.6	NS	9.7	38.1	NS	52.2	NS	56.5	0.0	+	11.1
Illinois Pondweed											17.8	NS	22.2
Leafy Pondweed											2.2	+	22.2
Naiad sp.	12.5	NS	0.0	NS	0.0						46.7	NS	27.8
Sago Pondweed	31.3	NS	28.6	NS	16.1	14.3	NS	13.0	NS	21.7	0.0	+	11.1
Spiny Naiad	43.8	NS	46.4	-	12.9								
Variable Pondweed	12.5	+	57.1	-	9.7						2.2	NS	11.1
Water Stargrass											33.3	-	0.0

Table 12. Changes in frequency of occurrence of submerged vegetation within the > 5 ft contour at lakes that did not receive whole-lake fluridone treatment. Species with a 10% frequency of occurrence for at least one survey were tested for significant shifts using a x-squared test. Changes were measured as the difference in the number of occurrences between surveys. Direction of change indicated by + (increase $p < 0.05$) or - (decrease $p < 0.05$). Nonsignificant changes are indicated by NS (Wagner et al. 2007).

	Big Chapman Lake					Little Chapman Lake					Diamond Lake		
Plant	2005	SIG	2006	SIG	2007	2005	SIG	2006	SIG	2007	2005	SIG	2007
Chara sp.	32.4	NS	33.9	-	13.6								
Coontail	32.4	NS	41.9	-	16.9	34.3	NS	14.8	NS	22.2	13.3	NS	4.5
Eel Grass	30.9	-	0.0	+	35.6								
Eurasian Watermilfoil	20.6	NS	17.7	+	45.8	14.3	NS	7.4	NS	25.9			
Naiad sp.	10.3	NS	8.1	-	0.0						13.3	NS	18.2
Nitella sp.	11.8	NS	9.7	NS	3.4								
Sago Pondweed	35.3	NS	24.2	NS	22.0								
Spiny Naiad	30.9	NS	32.3	NS	42.4								
Variable Pondweed	5.9	+	40.3	-	11.9								

Figure 3. Mean relative growth increments of largemouth bass collected at Big Chapman Lake in 2005 through 2007. Error bars represent standard error. Bars within each age group with the same letter denote no significant difference (p > 0.05).

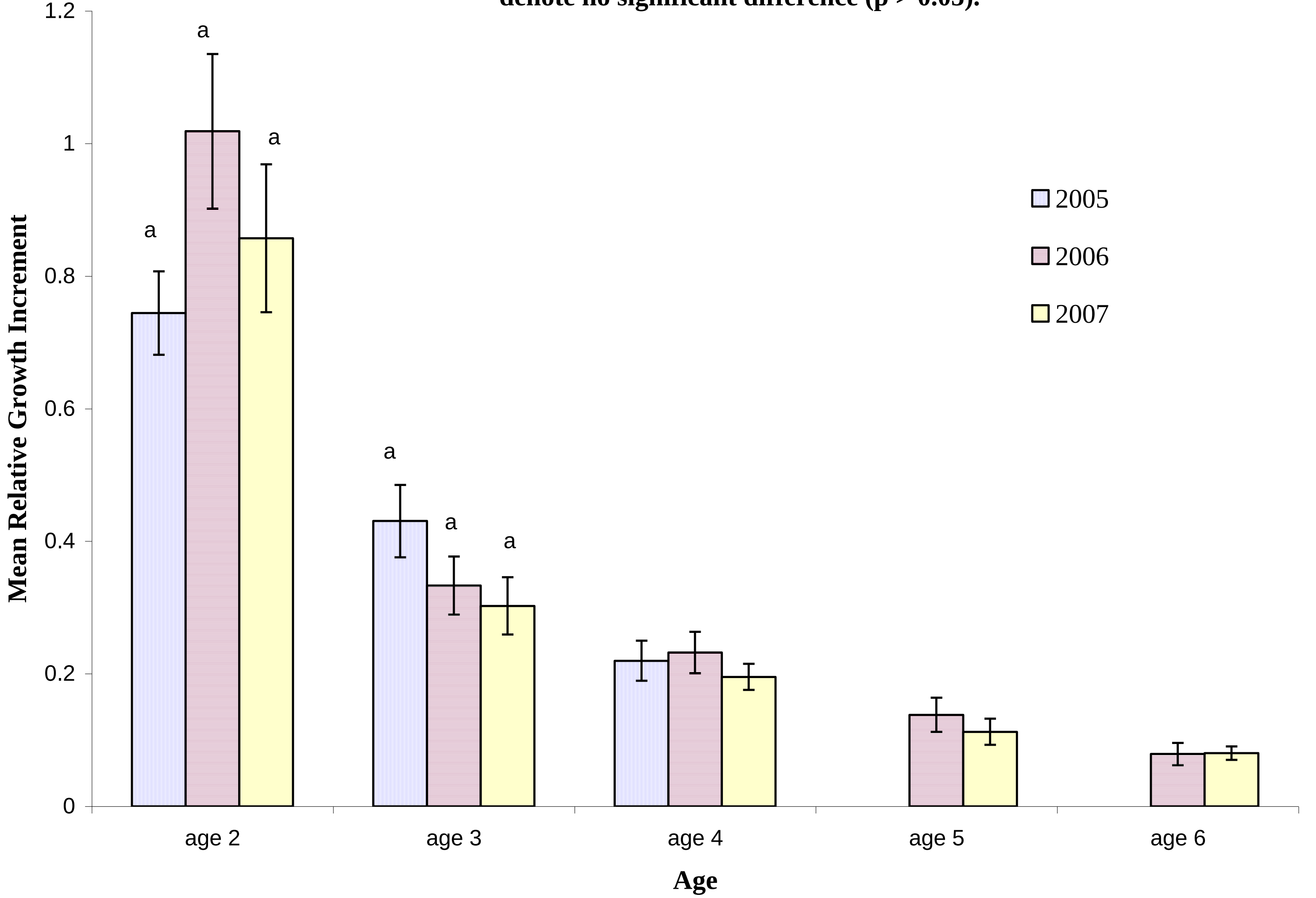

Figure 4. Mean relative growth increments of Largemouth Bass collected at Diamond Lake in 2005 through 2007. Error bars represent standard error. Bars within each age group with the same letter denote no significant difference (p > 0.05).