WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Survival and Return on Investment of Stocked Walleye in Bayfield and Douglas Counties

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Executive Summary

Walleye are a critical species in northern Wisconsin that provide important subsistence and recreational fisheries and are of high socioeconomic value. In the past few decades, walleye populations have experienced declines in natural recruitment and abundance. In effort to increase walleye abundance, the Wisconsin Walleye Initiative (WWI) was developed in 2013, which significantly increased large fingerling (6-8 inch) walleye stocking. Despite increased stocking, walleye populations in many of these northern Wisconsin lakes have not responded as hoped. Therefore, we conducted a walleye stocking evaluation on five lakes in Douglas and Bayfield counties to estimate survival and cost returns on stocking. Survival of walleye from stocking as large fingerlings to maturity (4-5 years of age) ranged from a low of 0.17% (95% CI = 0.08-0.25%) to a high of 1.04% (95% CI = 0.63-1.45%). The low survival rates resulted in an expensive return, with estimated cost per adult fish that ranged from $101.77 (95% CI = $73.26-$166.59) - $640.01 (95% CI = $423.58-$1,308.70). The proportion of stocked fish and wild fish was also analyzed at age-1 and as adults. Proportion of stocked fish at age-1 was higher than as adults for the same cohort, which indicated potential differences in mortality or sampling gear catchability between stocked and wild fish. These results were comparable to other similar lakes in northwest Wisconsin and will be useful to help guide future management of walleye within these study lakes as well as other lakes with similar characteristics and fish communities.

Introduction

WALLEYE

Walleye are a cool water, biologically important predatory species and are a premier sportfish for anglers in Wisconsin. In recent decades there has been an overall declining trend in walleye natural recruitment often leading to a decline in the adult abundance within these waters. Many of the walleye fisheries in Bayfield and Douglas counties have experienced these declines. This has resulted in reduced fishing opportunities for walleye anglers, thus causing concerns for fisheries managers and stakeholders alike.

The Wisconsin Walleye Initiative (WWI) began in 2013. The goal of the initiative was to improve walleye populations by significantly increasing large fingerling walleye stocking. Several lakes in Bayfield and Douglas counties were included in this initiative.

STUDY LAKES

Upper Eau Claire Lake is part of the Eau Claire Chain of lakes and is located at the headwaters of the Eau Claire River watershed. It is a 996-acre complex-two story drainage lake with an adult walleye population density that has ranged between 1-2 fish/acre since the mid-1980s. Historically, natural recruitment was at moderate to high levels but has been relatively low in recent years. The average number of age-0 walleye captured/mile during fall electrofishing surveys was 5.7 in the 1990s, 15.2 in the 2000s and 3.8 since 2010.

Diamond Lake is located at the headwaters of the 18-mile Creek watershed within the Lake Superior basin. It is a 341-acre complex-two story drainage lake and has had an adult walleye population density of about 1 fish/acre since the early 1990s. There was minimal natural recruitment in Diamond Lake in the 1990s and 2000s and since 2008 no age-0 walleye have been observed in fall electrofishing surveys.

Lake Owen is located at the headwaters of the Long Lake Branch of the White River watershed within the Lake Superior basin. It is a 1,323-acre complex-two story drainage lake with an adult walleye population density that ranged from 1.0-1.5 fish/acre since the early 1990s. Natural recruitment was at moderate levels in the 1990s averaging 10.4 age-0/mile in fall electrofishing surveys but has declined since, averaging 1.9 age-0/mile in the 2000s and 2.9 age-0/mile since 2010.

Crystal Lake is located at the headwaters of the 18-mile Creek watershed within the Lake Superior basin. It is a 111-acre complex-cool-clear seepage lake with an adult walleye population density that ranged from 1.5-2.5 fish/acre since the early 1990s. Natural recruitment was at moderate levels in the 1990s and averaged 10.6 age-0/mile during fall electrofishing surveys but declined to 3.8 in the 2000s and since 2010 has averaged 1.3.

Lake Nebagamon is located in the Bois Brule River watershed within the Lake Superior basin. It is a 914-acre complex-cool-clear drainage lake with an adult walleye population that ranged from 1.5-2.5 fish/acre since the early 1990s. Natural recruitment was at moderate to high levels from the early 1990s to mid-2000s which averaged 18.7 age-0/mile during fall electrofishing surveys, then declined to 4.1 age-0/mile from 2006-2014 and since 2015 has averaged 12.0 age-0/mile.

These lakes were selected for this study because they were stocked with fin-clipped walleye and received an adult population estimate when those fish became mature at age-4 or age-5. The fin-clipped fish allowed us to differentiate between hatchery and wild fish which was necessary because these lakes had some level of natural recruitment. Although there are other lakes within Bayfield and Douglas counties that were stocked with large fingerling walleye as part of the WWI they were not included in this study because the stocked fish were not fin clipped.

OBJECTIVE

Through this evaluation, we aimed to estimate survival from stocking to adulthood and estimate cost per adult walleye that was stocked as a large fingerling. This information will be used to inform stakeholders and guide future management decisions.

Methods

Stocked fish were given a hatchery clip by removing one entire pectoral or ventral fin. This hatchery clip is noticeable for the entire lifespan of the fish so in subsequent sampling events we were able to determine stocked fish from natural fish. A mark-recapture population estimate survey was conducted for adult walleye 4 or 5 years after the stocking event. Hatchery marks were recorded at the time of capture and each fish was given a survey fin clip to show that it had been handled and used in the population estimate for that year. Population estimates were calculated using the Chapman modification of the Lincoln-Peterson estimator (Ricker 1975):

$$N=\frac{(M+1)(C+1)}{(R+1)},$$

where N = population estimate, M = number of fish marked during spring fyke net surveys, C = total number of fish captured during the recapture event which was a spring electrofishing survey sampling the entire shoreline and R = number of marked fish captured during the recapture event.

An aging structure was also collected from five fish per half-inch length bin per sex, dorsal spines from fish ≥ 12 inches and scales from fish < 12 inches. An age-length key was developed to assign ages to all unaged fish using the FSA package (alkIndivAge function; Ogle et al. 2023) in R version 4.2.3 (R Core Team 2023). All figures were created using the ggplot2 package in R version 4.2.3 (R Core Team 2023).

We evaluated one stocked age class for each lake. Depending on the timing of the population estimate survey, we selected either the age-4 or age-5 age class. Walleye in northern Wisconsin typically reach maturity at age-4, so the age classes with stocked hatchery fin-clipped fish were fully recruited to our sampling gear which targets spawning walleye. In Upper Eau Claire, a population estimate was conducted in 2017, so we evaluated fish stocked in 2013, age-4 at the time of the survey. For all other lakes we evaluated age-5 fish; Diamond Lake: stocked in 2013, population estimate conducted in 2018, Lake Owen: stocked in 2014, population estimate conducted in 2019, Crystal Lake: stocked in 2016, population estimate conducted in 2021, Lake Nebagamon: stocked in 2017, population estimate conducted in 2022. Hereafter, both naturally reproduced and stocked fish of these age classes that were evaluated are referred to as the ‘study age class’.

Survival of stocked fish through the first winter was assessed using catch-per-unit-effort (CPUE) data in fish/mile, collected during late spring electrofishing (SEII) surveys. The SEII surveys primarily target centrarchids, however, this survey is also a reliable index of age-1 walleye relative abundance. We determined age-1 walleye density (fish/acre) by imputing the SEII age-1 walleye CPUE into the Shaw Index calculator (Shaw and Sass 2020). Total abundance of age-1 walleye was then calculated by multiplying the density by the lake acreage. Total abundance of stocked age-1 walleye was determined from the proportion of hatchery clipped fish sampled in the SEII survey and compared to the total number of walleye stocked the previous fall to determine survival through the first winter. Data on age-1 hatchery clips were available from multiple SEII surveys so we calculated a mean survival rate through the first winter for each lake.

Survival to maturity was calculated using adult abundance from mark recapture population estimate surveys. For each lake we calculated the proportion of fish from all age classes captured in fyke nets that were of the study age class. Using that proportion, the total abundance of the study age class (natural and stocked fish) was calculated from the total adult population estimate. The proportion of fish in the study age class with hatchery clips was calculated and used to estimate the total abundance of stocked fish in the study age class. This abundance estimate of stocked fish was compared to the number of fish originally stocked for that age class, either 4 or 5 years prior to the population estimate survey. The proportion of stocked and natural fish at age-1 was compared to the proportion at an adult age class (i.e., age-7 for Crystal and Nebagamon, age-5 for Diamond and Owen and age-4 for Upper Eau Claire) for the same cohort to assess potential differences in mortality or catchability by life stage between stocked and natural fish. The cost per adult stocked fish was calculated based on the estimated survival to adulthood and the current cost to stock one large fingerling walleye ($1.06), similar to the analysis of Lake Owen (Olson 2015). The 95% confidence limits of the population estimate were used to estimate a 95% confidence limit associated with the estimated survival to adult and cost per adult stocked fish.

Results

SURVIVAL THROUGH FIRST WINTER

Average survival of stocked large fingerling walleye through the first winter ranged from a low of 2.45% in Crystal Lake to a high of 33.61% in Lake Nebagamon (Figure 1). Survival in Lake Owen and Upper Eau Claire Lake was relatively similar at 4.45% and 5.11%, respectively and survival in Diamond Lake was 15.24% (Figure 1).

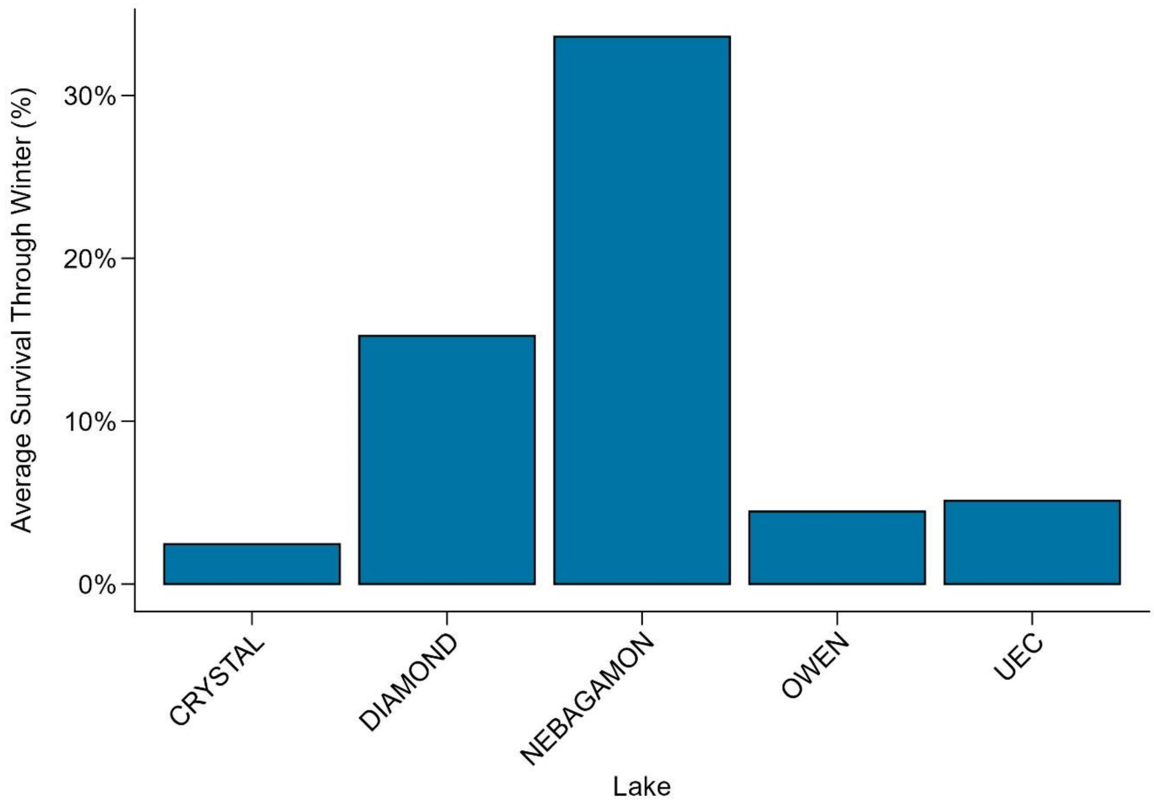

Figure 1. Average survival of stocked large fingerling walleye through the first winter.

SURVIVAL TO MATURITY

Survival to maturity ranged from a low of 0.17% (95% CI = 0.08-0.25) in Upper Eau Claire Lake to a high of 1.04% (95% CI = 0.64-1.45) in Diamond Lake (Figures 2 and 3). Survival to maturity among Crystal Lake, Lake Nebagamon and Lake Owen was relatively similar at 0.32% (95% CI = 0.21-0.43), 0.42% (95% CI = 0.35-0.50) and 0.33% (95% CI = 0.21-0.45), respectively (Figures 2 and 3).

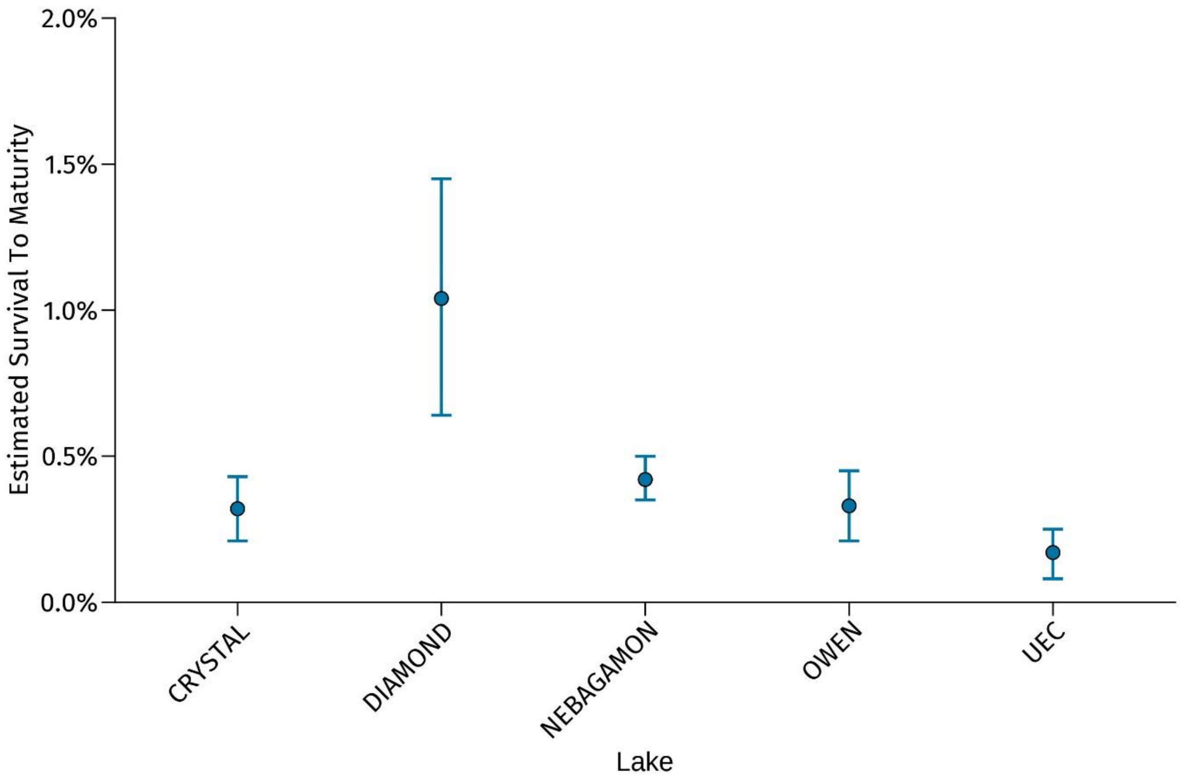

Figure 2. Survival of stocked large fingerling walleye to maturity (± 95% CI). *Age-4 was used in Upper Eau Claire Lake and age-5 was used for all other lakes.*

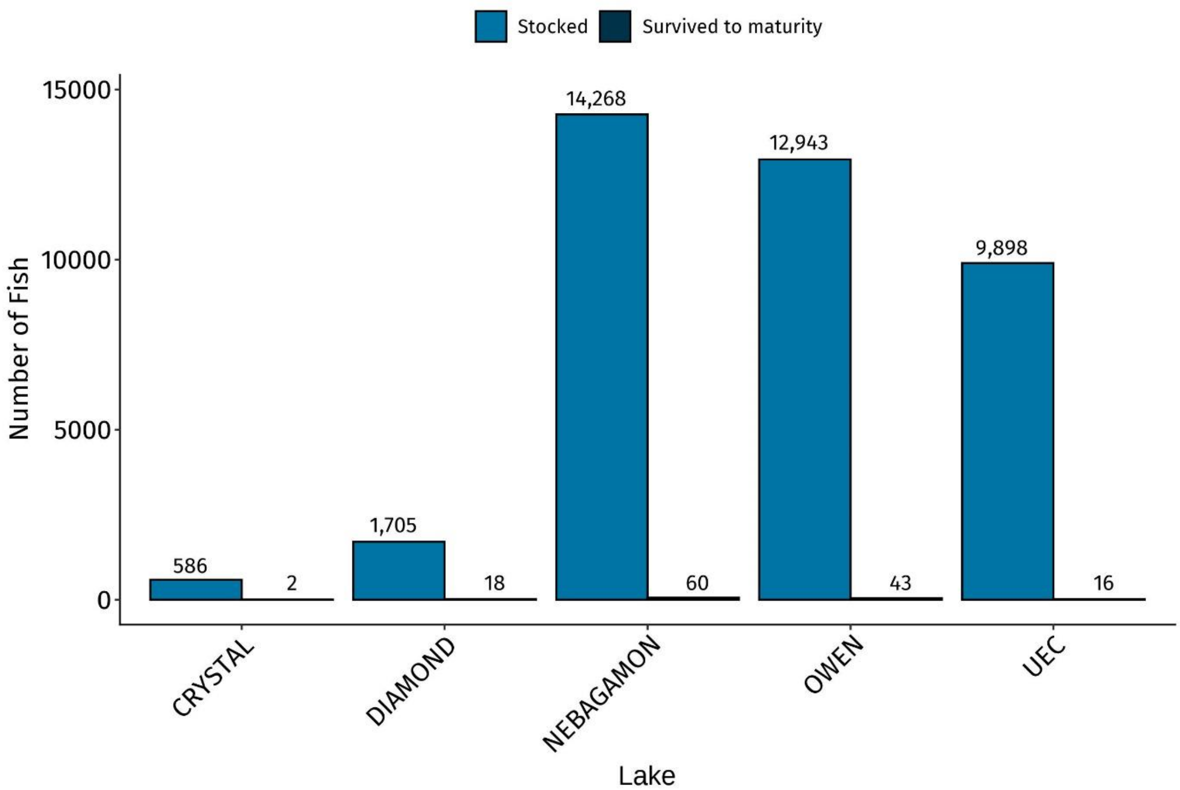

Figure 3. Number of large fingerling walleye stocked (light blue bars) compared to estimated number that survived to maturity (dark blue bars). Number of fish is shown above the bars.

PROPORTION OF STOCKED AND NATURAL FISH

Crystal Lake was the only lake where the percent of hatchery fish within a cohort increased from the age-1 age class to the adult age class although it was relatively similar going from 20.0% at age-1 to 23.1% at age-7 for the 2014 year class (Figure 4). More substantial changes in the percent of hatchery fish were observed in the other lakes, 100.0% at age-1 to 72.7% at age-5 for the 2013 year class in Diamond Lake, 59.8% at age-1 to 26.2% at age-7 for the 2015 year class in Lake Nebagamon, 44.4% at age-1 to 17.4% at age-5 for the 2014 year class in Lake Owen and 61.9% at age-1 to 20.0% at age-4 for the 2013 year class in Upper Eau Claire Lake (Figure 4).

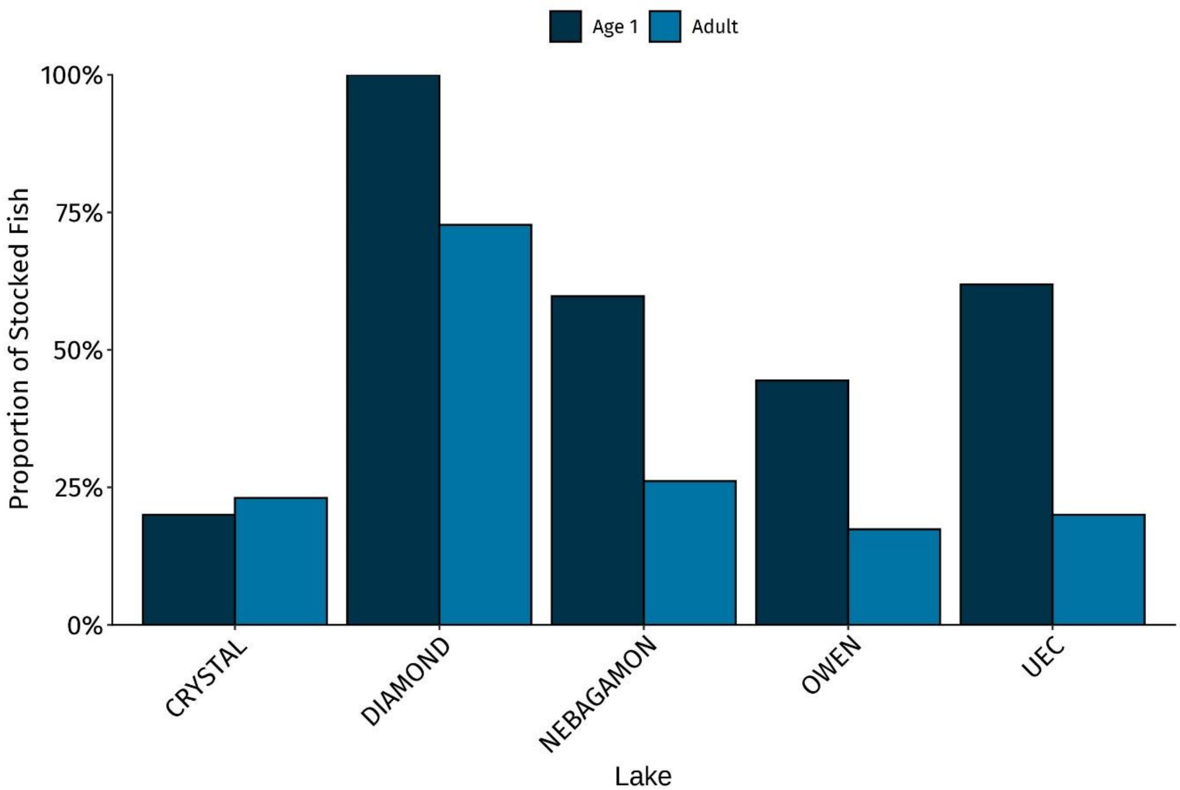

Figure 4. Proportion of fish at age 1 that were stocked compared to the proportion of adult fish from the same cohort that were stocked. Crystal Lake and Lake Nebagamon compare to age-7 adult fish, Diamond Lake and Lake Owen compare to age-5 adult fish and Upper Eau Claire Lake compares to age-4 adult fish.

COST PER ADULT RECRUIT

The cost per adult stocked walleye ranged from a low of $101.77 (95% CI = $73.26-$166.59) in Diamond Lake to a high of $640.01 (95% CI = $423.58-$1,308.70) in Upper Eau Claire Lake (Figure 4). The cost per adult stocked walleye in Lake Nebagamon, Lake Owen and Crystal Lake were relatively similar at $250.46 (95% CI = $213.16-$303.58), $318.28 (95% CI = $234.51-$495.16) and $331.52 (95% CI = $244.15-$516.26), respectively (Figure 4).

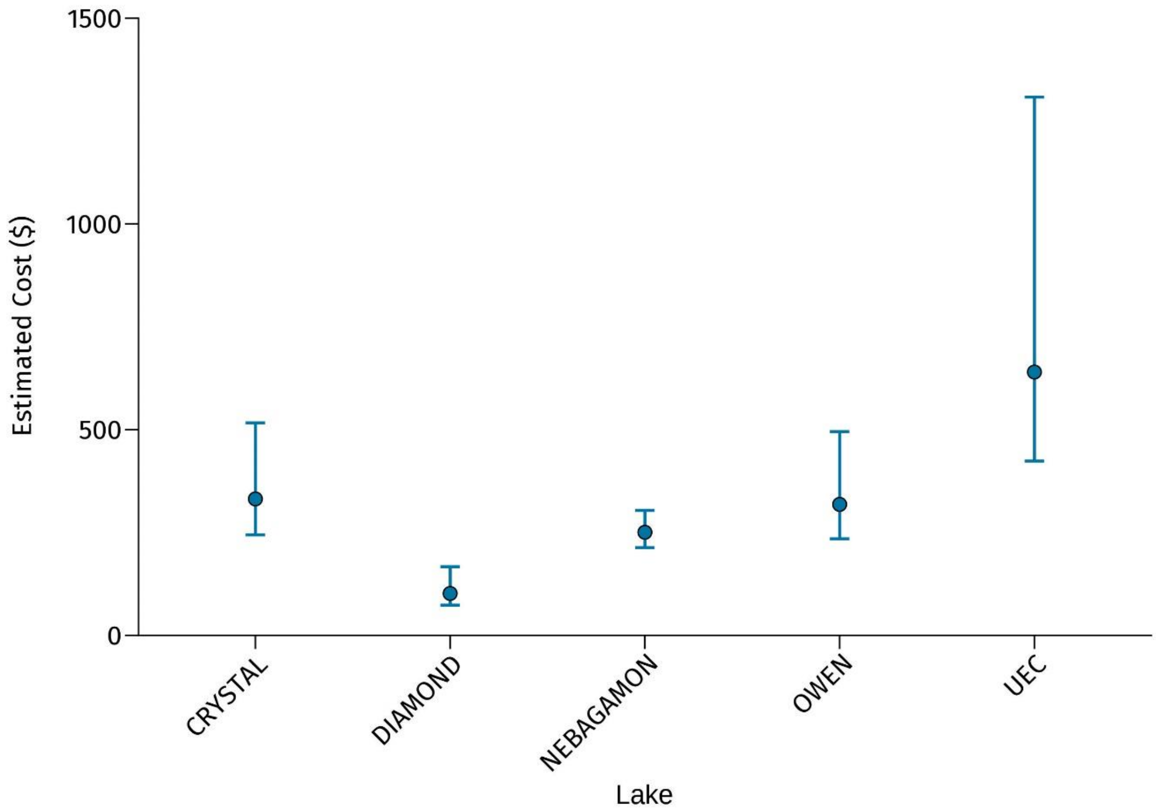

Figure 5. Estimated cost range per stocked adult walleye (± 95% CI). *Cost of stocking calculated using $1.06 per large fingerling walleye.*

Discussion

Results from this study show three generally disparate ranges of stocked walleye survival to maturity and cost per recruit estimates for these five study lakes. Upper Eau Claire Lake had the lowest survival to maturity and Crystal Lake, Lake Owen and Lake Nebagamon were all relatively similar with survival rates to maturity about twice as high as upper Eau Claire Lake. Diamond Lake had substantially higher survival to maturity relative to the other lakes, about six times higher than Upper Eau Claire Lake and about three times higher than Crystal Lake, Lake Owen and Lake Nebagamon.

Furthermore, a comparison to other lakes in northwest Wisconsin was made to provide context for survival in nearby waterbodies with similar and differing characteristics (Kyle Broadway personal communication, Broadway and Wagester 2023, Roberts 2019a, Roberts 2019b, Roberts 2020, Roberts 2023, Table A1). Lakes were selected based on availability of data. The six additional lakes include: Big Butternut Lake (Polk County), Beaver Dam Lake (Barron County), Lake Nancy (Washburn County), Long Lake (Washburn County), Middle McKenzie Lake (Washburn County) and Slim Lake (Washburn County).

The stocked walleye survival to maturity in Big Butternut Lake was significantly higher than all other lakes at 16.7%. The survival to maturity in Slim Lake was also quite high relative to the other study lakes at 10.0%. Long Lake and Middle McKenzie Lake had slightly higher survival to maturity than the Bayfield and Douglas County lakes, 3.2% and 2.5%, respectively. Beaver Dam Lake and Lake Nancy had an estimated survival to maturity similar to those in Bayfield and Douglas County, 0.9% and 0.8%, respectively.

Cost per recruit estimates for these additional lakes ranged from a low of $6.00/adult stocked walleye in Big Butternut Lake to a high of $130.32/adult stocked walleye in Lake Nancy. The cost per recruit estimate in Slim Lake was relatively low, similar to Big Butternut Lake, at $9.99/adult stocked walleye. Long Lake and Middle McKenzie Lake had a cost per recruit estimate similar to each other: $31.47 and $40.71/adult stocked walleye, respectively. Beaver Dam Lake had a similar cost/recruit to Lake Nancy as well as the Bayfield and Douglas County lakes, estimated at $106.38/adult stocked walleye.

Environmental characteristics and presence or absence of walleye natural reproduction are likely influencing the survival of stocked fish in these lakes. Walleye do well in relatively productive and darker water. Big Butternut Lake had significantly higher survival of stocked fish than all lakes analyzed and is the only lake classified in the “dark” water clarity category of the lake classification system. Additionally, Big Butternut Lake had the most eutrophic TSI Values (Secchi: 56, Chlorophyll-a: 61, Total Phosphorus: 60). Slim Lake also had a high survival rate although it is similar in characteristics to the Bayfield and Douglas County lakes, it does not have natural reproduction, which is likely why we saw higher survival of stocked fish in this lake. Long Lake and Middle McKenzie Lake had somewhat better survival than the lakes in Bayfield and Douglas counties. Beaver Dam Lake and Lake Nancy had low survival, similar to the lakes analyzed in Bayfield and Douglas counties. This could be due to many factors such as lake productivity, predation, habitat, harvest to name a few, but this is outside of the scope of this analysis.

Despite the relatively low survival to maturity for all lakes analyzed in Bayfield and Douglas counties, Lake Nebagamon and Diamond Lake experienced higher survival through the first winter compared to the other lakes. Lake Nebagamon was particularly interesting as the average survival through the first winter was high at 33%. It is difficult to determine what caused this decrease in survival after the first winter from age-1 to age-5. Typically, most mortality occurs in the first year but stocked walleye in Lake Nebagamon appear to be experiencing higher levels of mortality after the first winter or fish behavior could be influencing our survey results. There could potentially be some emigration of these fish from Lake Nebagamon. Minnesuing Creek (inlet) and Nebagamon Creek (outlet) could allow age 2+ walleye to leave Lake Nebagamon, however, these streams are small with limited habitat. Harvest could cause some mortality, but it is probably minimal because there is a conservative 18-inch minimum length limit on Lake Nebagamon and exploitation by tribal spearing was only 7% in 2022. The higher survival through the first winter in Diamond Lake could be a result of the walleye recruitment history. Natural recruitment has not been documented in Diamond Lake since 2008 meaning there was no competition between stocked and natural age-0 fish whereas the other lakes all had some level of natural recruitment. Additionally, the increased mortality from age-1 to age-5 could be a result of size selective predation by high size structure populations of northern pike and walleye which are present in Diamond Lake.

The analyses evaluating contribution of stocked fish versus natural fish at age-1 and maturity produced both expected and unexpected results. For the four lakes with mixed recruitment, Crystal, Nebagamon, Upper Eau Claire and Owen, the adult population appears to be largely comprised of naturally recruited fish, ~25% of the adult age class analyzed came from stocking and ~75% came from natural reproduction. Conversely, contribution of stocked fish to the adult age class was substantially higher at just under 75% in Diamond Lake, which is the only lake we did not detect natural reproduction in juvenile surveys. This difference in contribution to the adult population could be attributed to higher competition between naturally reproduced fish and stocked fish. Interestingly, and contrary to our hypotheses, the contribution of stocked fish noticeably decreased from age-1 to adults for all lakes besides Crystal Lake. This points to higher mortality or changes in catchability of stocked fish than naturally reproduced fish from age 1 to maturity in these lakes. This could be due to several factors. One hypothesis is that there could be a sample bias driven by a difference in behavior between stocked and wild walleye. Stocked walleye may not be exhibiting the same spawning behavior as wild fish and therefore the adult fish are not as susceptible to capture in spring fyke netting surveys. Age-1 stocked walleye may also be selecting for nearshore habitat more than wild walleye in the fall, making them more susceptible to electrofishing surveys. These behaviors could cause sampling bias leading to inflated catches of natural fish relative to stocked fish in the fyke net surveys or inflated catches of stocked fish relative to natural fish in the fall electrofishing surveys. Another hypothesis is that stocked walleye may be more susceptible to predation during juvenile years than wild walleye, which could explain this difference in contribution to the adult population.

Survival to age 1 was also calculated to compare the study lakes with other lakes in northwest Wisconsin. Age-1 fish from Beaver Dam Lake, Big Butternut Lake, Lake Nancy, Middle McKenzie Lake and Slim Lake were assumed to be from stocking origin because of minimal or no natural recruitment documented in fall electrofishing surveys. Due to the Shaw Index calculator limitations with catch rates of 0 fish/mile, we used 0.1 fish/mile when analyzing surveys where no stocked fish were collected. Slim Lake had a high survival estimate (26.18%), Middle McKenzie Lake was also relatively high (12.57%). Beaver Dam Lake, Lake Nebagamon, Diamond Lake, Lake Nancy and Long Lake all had similar survival to each other (2.72%, 3.97%, 4.62%, 4.99%, 5.10%, respectively). Lake Owen, Upper Eau Claire Lake, Crystal Lake and Big Butternut Lake together made up the lowest tier of survival to age 1 (0.54%, 0.57%, 1.12%, 1.38%, respectively).

Interestingly, Big Butternut had very low survival to age 1 but survival to maturity was much higher than all of the other lakes. Perhaps this is due to difficult sampling conditions in the fall electrofishing survey. Or perhaps the age-1 fish were simply not occupying shallow water habitat at the time of the survey. Slim Lake's survival decreased significantly from age 1 to age 5 but remained relatively high in comparison to other lakes. Middle McKenzie Lake's relatively high survival at age 1 decreases substantially by maturity but remains above the levels seen in Bayfield and Douglas County lakes. All other lakes analyzed had relatively low survival to age 1, which stayed relatively low to maturity. All lakes, except for Big Butternut Lake, exhibited a decrease in survival from age 1 to maturity, as you would expect.

Although Lake Nebagamon and Diamond Lake had moderate to high levels of survival through the first winter, survival to maturity was still low. Ultimately, the survival to maturity is most important as this metric describes the effect of stocking on the adult population and cost per adult fish.

Low estimates of survival equate to high costs per adult walleye (Figure 5). These high costs should question the cost: benefit ratio of these stockings and what a stocked walleye is worth to anglers. A Wisconsin angler would have to buy a resident fishing license (currently $20) for 5-32 years to cover the cost of one stocked walleye in these lakes. To maximize the cost: benefit ratio, stocking efforts should focus on lakes where stocked fish exhibit higher survival to adults and support a viable fishery.

CONCLUSION

Stakeholders and fisheries managers are eager to find a solution to declining walleye populations throughout the state of Wisconsin. Stocking is one of the primary tools that biologists have in managing a fishery to achieve a desired population objective, however, stocking lakes where survival of stocked fish is poor, results in a low return on the investment. Evaluating stocking contribution to the adult population is valuable to determine if this management action is worthwhile from a resource availability (e.g., monetary, personnel, hatchery infrastructure) standpoint and understanding if it will have the desired population response. The results of these analyses indicate survival of stocked walleye in these study lakes is low, resulting in a high cost to achieve management objectives for walleye. Depending on fishery objectives, managers may need to implement other management actions such as restricting walleye harvest and providing harvest opportunities for other species. Additionally, managers should reevaluate if managing for walleye is still feasible and accept if a lake is no longer conducive for sustaining a walleye fishery either through stocking or natural reproduction. Results from this study will be integral to inform public stakeholders regarding walleye stocking practices and the overall management of stocked fisheries.

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Appendix

Table A1. Lake class, lake area (acres), mean and max depth (ft), lake productivity (trophic state index (TSI) values for chlorophyll-a (Chl-a), water clarity (Secchi depth in feet) and total phosphorous (Total P)), walleye recruitment (mixed = stocked and natural reproduction), stocking density (fish/acre) and adult density (fish/acre) for walleye stocking evaluation study lakes in Bayfield, Douglas, Barron, Polk, Washburn, and Burnett Counties.

LAKE	COUNTY	LAKE CLASS	LAKE AREA	MEAN DEPTH	MAX DEPTH	PRODUCTIVITY (TSI)			WALLEYE RECRUITMENT	YEAR STOCKED	STOCKING DENSITY	PE YEAR	COHORT AGE	ADULT DENSITY
						Chl-a	Secchi	Total P						
Crystal Lake	Bayfield	Complex-Cool-Clear	111	17	29		36.77	48.5	Mixed	2016	5	2021	5	1.5
Diamond Lake	Bayfield	Complex-Two Story	341	33	83	41.89	40.82	47.79	Stocked	2013	5	2018	5	1.2
Lake Nebagamon	Douglas	Complex-Cool-Clear	914	20	56	47.84	48.51	51.31	Mixed	2017	15	2022	5	1.6
Lake Owen	Bayfield	Complex-Two Story	1323	27	95	36	31.2	49.25	Mixed	2014	10	2019	5	1.1
Upper Eau Claire Lake	Bayfield	Complex-Two Story	996	29	92	40.35	36.27	47.8	Mixed	2013	10	2017	4	0.8
Beaver Dam Lake	Barron	Complex-Two Story	1163	3	106	41.63	38.65	46.45	Stocked	2015	15	2019	4	0.5
Big Butternut Lake	Polk	Complex-Warm-Dark	384	13	19	61.12	55.75	59.64	Stocked	2017	10	2022	5	6
Slim Lake	Washburn	Complex-Two Story	210	22	42	46.92	45.16	51.94	Stocked	2015	15	2019	4	2.6
Long Lake	Washburn	Complex-Two Story	3290	26	74	51.3	48.25	52.37	Mixed	2018	10	2022	4	1.9
Middle McKenzie Lake	Washburn	Complex-Two Story	527	20	45	39.85	41.19	48.92	Stocked	2014	10	2018	4	1.2
Lake Nancy	Washburn	Complex-Warm-Clear	772	11	39	41.99	38.74	48.77	Stocked	2014	20	2019	5	0.7