# A Critical Review of the Young-of-Year Walleye Assessment Program on Leech Lake, Minnesota

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## Introduction

Minnesota's 10 largest natural walleye *Sander vitreus* lakes have a combined surface area of over 825,000 acres and account for approximately 40% of the statewide walleye harvest (MDNR 1997). These waters have significant economic importance and are among the state's most prized natural resources. Historical monitoring of these lakes generally followed the survey frequencies and procedures outlined in the lake survey manual (Scidmore 1970), but were also subject to infrequent lake-specific studies in response to perceived fisheries management problems (MDNR 1997). Recognizing the value of these resources, the Minnesota Department of Natural Resources Section of Fisheries increased its commitment to sustainable resource management by establishing the Large Lake Monitoring Program (LLP) in 1983. Annual collection, analysis, and reporting of fish population data, population trend analysis, development of management recommendations, and public outreach are mandated within the LLP framework.

Wingate and Schupp (1984) developed the sampling protocol for these lakes to improve identification of trends in fish stocks, which in turn facilitate biologically appropriate fisheries management actions. The Large Lake Sampling Guide (LLSG; Wingate and Schupp 1984) recommended minimum amounts of sampling effort using experimental gill nets, shoreline seine hauls, and bottom trawl hauls for annual fishery assessments as well as assessment of the recreational fishery using creel surveys. However, methods in the LLSG have since been modified on a lake-specific basis to enhance sampling precision and efficiency, to collect information on species that were not effectively sampled using recommended methods, and as fisheries science has improved (MDNR 1997). For example, electrofishing and trap netting have been added as supplements to many of the large lake surveys. Trap netting at ice-out has proven an effective method to collect population data on muskellunge *Esox masquinongy* and northern pike *E. luscius*; adequate data on these species cannot be collected using the recommended methods. Fall electrofishing on large lakes has been an invaluable tool for surveying centrarchid populations and age-0 walleye abundance. Additionally, aerial boat counts are also being evaluated for use during creel surveys as a possible means to improve estimates of recreational fishing effort (Rivers 2005). Sampling efficiency of methods outlined in the LLSG, including their revisions, are not equivocally effective or appropriate across lakes, due largely to differences in habitat types sampled. Therefore, the primary strength of the LLP has been the adaptive systematic collection of data in large lakes, as dictated by species targeted and habitats sampled, to develop the most biologically and statistically reliable methods for managing fish stocks on a lake-specific basis.

One of the most challenging aspects of the LLP has been determining the optimal method to predict walleye year class strength. As with most species, walleye recruitment in natural lakes is highly variable across years, and this variability has been attributed to a number of physical and biological effects. Stock-recruitment relationships (Madenjian et al. 1996; Beard et al. 2003), spring warming rates (Madenjian et al. 1996; Hansen et al. 1998), predation (Hansen et al. 1998; Beard et al. 2003), first-year growth and size specific mortality during the first winter (Madenjian et al. 1996), and other effects (Nate et al. 2001; Schupp 2002) all influence the survival of young walleyes both across years and among basins. For example, steadily increasing spring temperatures can result in shorter incubation periods and bountiful blooms of zooplankton, food necessary for the early growth and development of young fish. Cold fronts and spring rains during the reproductive period can disrupt spawning activities, extend incubation time and increase egg mortality, and alter the delicate timing for food availability, all of which result in poorer survival. Newly hatched fish that can take advantage of well-timed zooplankton blooms tend to grow faster and exhibit higher survival. By growing faster, these fish can shift their diet from zooplankton to larger prey sooner and escape predation windows more quickly while building energy reserves for their first winter. Therefore, establishment of a year class is not only determined by the number of fry that are successfully produced, but also through annual changes in YOY mortality sources and their respective rates among years.

An ongoing challenge for managers of walleye fisheries is to identify dependable early predictors of walleye recruitment while determining how recruitment variability can affect management outcomes (Isermann 2007). Accurate forecast of recruitment is often confounded because causes of young walleye mortality can operate either independently or concurrently during cohort establishment. Therefore, clarification of recruitment relationships can only be accomplished using consistently collected long-term data sets (Hansen et al. 1998; Quist 2007).

The LLSG highlighted the need for robust data on Minnesota's large lakes. The LLSG recommended a minimum of five trawling stations totaling 100 minutes of sampling time to specifically target age-1 and age-2 walleye and yellow perch *Perca flavescens* (data on YOY fishes were considered secondary) and shoreline seine stations to target YOY percids (Wingate and Schupp 1984). However, lake-specific data has shown seining as an inferior gear when assessing walleye year class strength in most lakes because catch rates of YOY walleye are more variable. As a result, sampling methods targeting YOY walleye in the large lakes have been tailored from those originally suggested (Table 1). On lakes using alternative methods to assess YOY walleye abundance (e.g. bottom trawling and night electrofishing), sampling effort has been statistically refined to improve predictive power while mitigating logistical concerns.

Table 1. Summary of young-of-the-year assessment sampling for walleye in the 10 Large Lakes.

| Lake Name | Seine | Trawl | Night Electrofishing | Best Predictor |
|---|---|---|---|---|
| Cass | Yes | Yes | Yes | Electrofishing |
| Kabetogama | Yes | No | Yes | Electrofishing |
| Lake of Woods | Yes | Yes | No | Trawl |
| Leech | Yes | Yes | Yes | Trawl |
| Mille Lacs | No | Yes | Yes | Trawl |
| Pepin | Yes | Yes | Yes | All three |
| Rainy | Yes | No | Yes | Electrofishing |
| Red | Yes | Yes | No | Seine |
| Vermilion | Yes | No | Yes | Electrofishing |
| Winnibigoshish | Yes | Yes | No | Trawl |
| % that use technique | 90% | 70% | 70% | |

## Background

Leech Lake, with a surface area of 111,527 acres, is the third largest lake within state boundaries (MDNR 1997). Recreational angling effort on Leech Lake generally ranges between 1 to 1.2 million angler hours annually (Figure 1) and has been a substantial component of the local economy. Recent declines in walleye angler harvest rates, coupled with poor recruitment and reductions in angler effort, have raised concerns about the ability of the current sampling regime to predict walleye year class strength. Present methods utilize shoreline seine hauls to collect early information on YOY walleye growth and bottom trawl hauls at three stations for a total effort of 60 minutes to predict walleye year class strength based on trawl catch rates. Additional data collected using both gears includes: length and abundance of forage fishes necessary for growth and fitness of all walleye cohorts; length, weight, and condition of YOY walleye; and collection and examination of YOY walleye otoliths for biochemical marks during stocking evaluations.

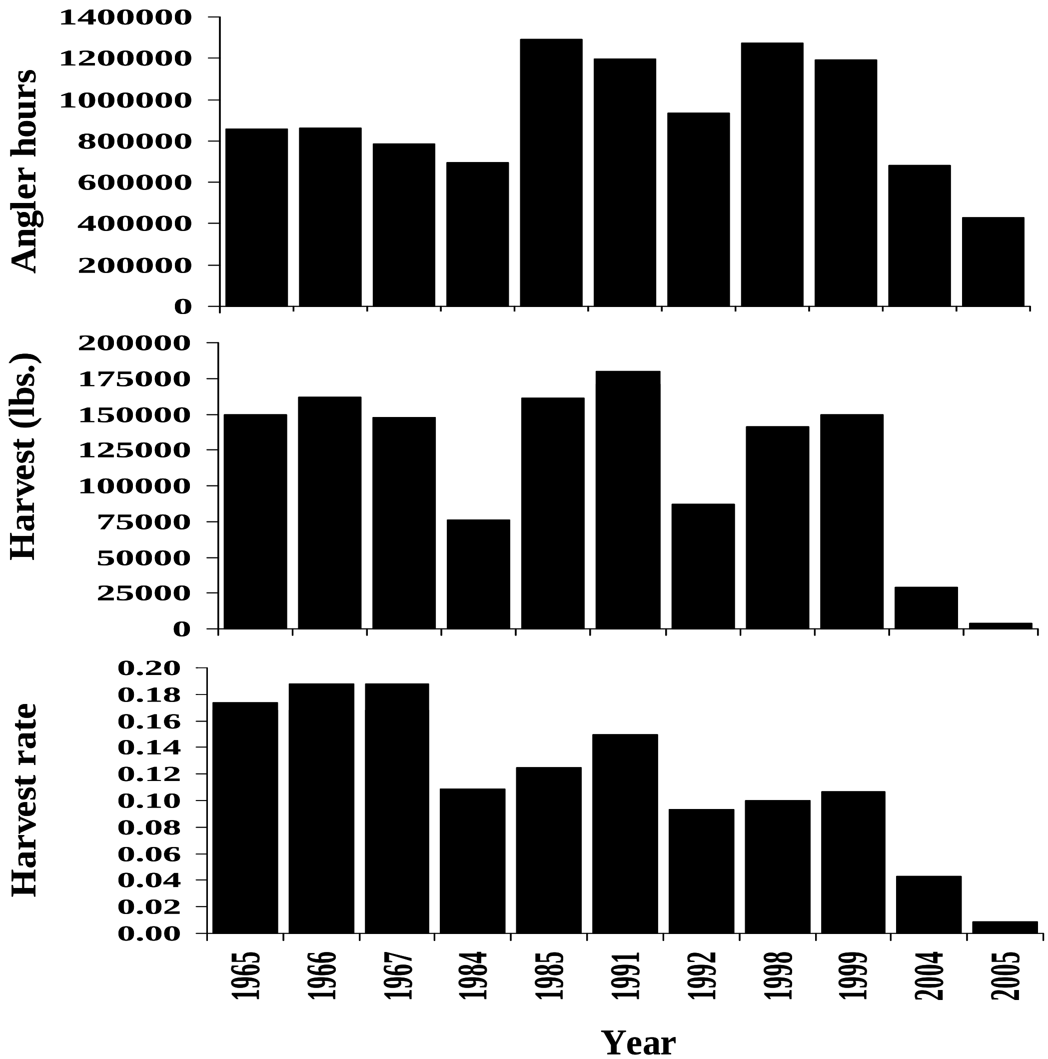


Figure 1. Estimated effort, walleye harvest, and walleye harvest rates (N/hour) of Leech Lake anglers during summer creel surveys conducted from 1965-2005 (Schupp 1972; Gustafson 1985, 1986; Haukos 1992, 1993; Sledge 1999, 2000; Rivers 2005, 2006).

Similar to the other lakes in the LLP, sampling methods targeting YOY walleye on Leech Lake have been adapted to optimize data integrity. However, modifications to the sampling protocol for Leech Lake have not been subjected to a rigorous review. Therefore, the objectives of this investigation are to: 1) provide a statistical review of deviations from the sampling protocol outlined in the LLSG, 2) to assess whether increased sampling effort can improve on current relationships between bottom trawl

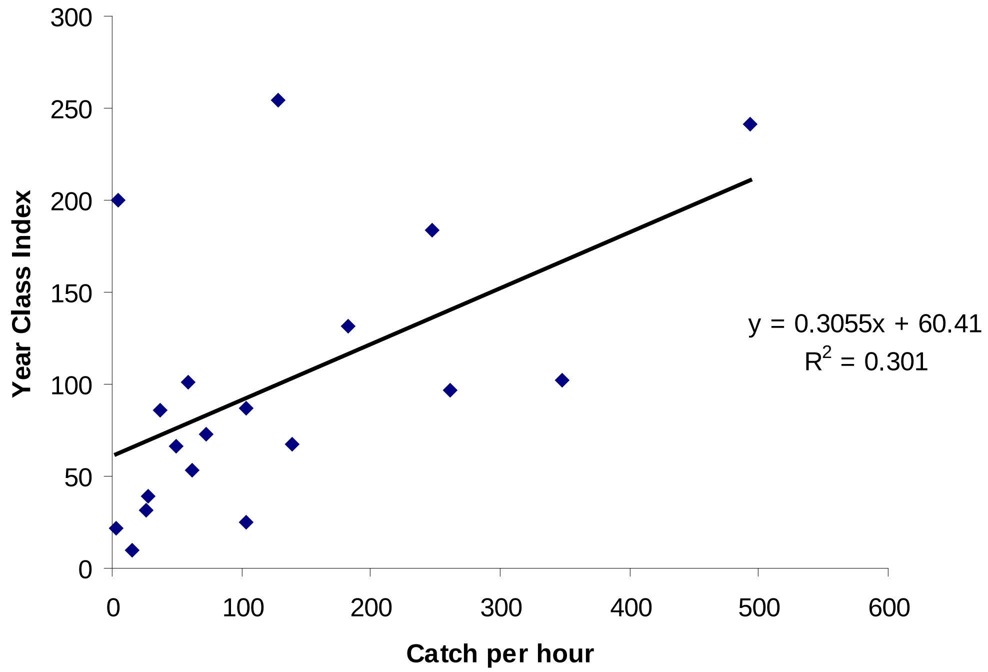


Figure 2. The relationship between catch rates of Leech Lake young-of the year walleye in trawl hauls at long-term sampling stations and ensuing year class index from 1987-2005.

catch rates of YOY walleye and ensuing walleye year class strength, and 3) to determine if other measures of cohort abundance or combinations thereof can strengthen preliminary estimates of year class strength.

## Methods and Results

*Deviation from the LLSG*

The Large Lake Sampling Program on Leech Lake began in 1983. Bottom trawling was soon determined to be more effective for sampling YOY walleye than shoreline seining on Leech Lake. After several years of sampling, DNR staff discontinued stations that were either difficult to sample (e.g. rocks or submerged trees that destroyed trawling equipment or heavy vegetation that reduced gear efficiency), or stations that caught few age-0 fish (Table 3). The long-term stations retained include three different habitat types: break line (Whipholt), sand flats (Goose), and chara flats (Five Mile). Each station is sampled once per week over a two week period. Within each station, two five minute trawl hauls are completed, yielding a total sampling effort of 20 minutes per station per year. The combined catch per effort (CPE) of these three long-term stations has been a good index of YOY walleye abundance in any given year and correlates well with ensuing year class index (YCI; D. Schupp, unpublished) (Figure 2).

We used linear regression to describe the relationship between trawl CPE of YOY walleye and walleye YCI for all stations trawled from 1984-1989 (includes discontinued stations) and between trawl CPE and YCI for the three long-term stations used from 1990-present. Stations that were discontinued increased catch rate variability and the relationship using these stations was not statistically valid ($F$ = 0.59; df = 1,4; $P$ = 0.4865) (Figure 3). Conversely, YCI was well described by bottom trawl catch rates at the long-term sampling stations ($F$ = 8.45; df = 1,14; $P$ = 0.0115).

Table 3. Stations trawled in Leech Lake from 1984-2006.

| | Station (bold indicates a Long-term station) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | **Whipholt** | **Goose** | **Five Mile** | Traders | Duck Point | Sand Point | South Walker Bay | Cedar Point | Steamboat |
| 1984 | **x** | **x** | | x | | x | | | |
| 1985 | **x** | **x** | | x | | x | | | x |
| 1986 | **x** | **x** | | x | | x | | | |
| 1987 | **x** | **x** | **x** | x | x | x | | | |
| 1988 | **x** | **x** | **x** | x | x | x | x | x | |
| 1989 | **x** | **x** | **x** | x | x | x | x | x | |
| **1990-2006** | **x** | **x** | **x** | Abundant Chara | Difficult to sample | Few fish caught | Difficult to sample | Difficult to sample | Abundant vegetation |

Figure 3. Bottom trawl catch rates of age-0 walleye describing walleye year class index (YCI; D. Schupp, unpublished) for all stations trawled from 1984-1989 (dashed line) and for stations used from 1990-present (Fivemile, Goose, and Whipholt; solid line) in Leech Lake, Minnesota.

This analysis verifies that statistically appropriate, management-based decisions were made when the number of sampling stations was reduced to the current three long-term stations. Furthermore, this analysis highlights that re-incorporation of discontinued stations or the addition of new sampling stations via expanded sampling effort would reduce the efficacy of bottom trawl YOY walleye catch rates for predicting walleye year class strength. Consequently, future walleye management actions on Leech Lake could be compromised if expanded trawling effort is incorporated.

*Increasing sampling effort*

Increases to current sampling efforts have the potential to improve the relationship between trawl CPE and YCI. Therefore, we analyzed data collected at the long-term stations using a non-parametric bootstrap model. Data were sampled with replacement 2,000 times within each station and year to create a range of effort at these stations. Confidence intervals (95%) were calculated for the resampled data set to assess the degree of sampling precision that could be attained by increasing effort from the current 60 minutes of trawling time to the suggested 100 minutes of trawling time.

A shift from 60 to 100 minutes of total trawling effort at the long-term stations would not appreciably improve the ability to predict year class strength (Figure 4). Catch rates at the three long-term stations serve as an index of age-0 walleye abundance in that they reflect relative changes in abundance (i.e. higher abundance usually results in higher catch rates); they do not estimate true abundance. Therefore, as an index, it not the CPE values that are relevant, but how those values relate to later measures of year class strength.

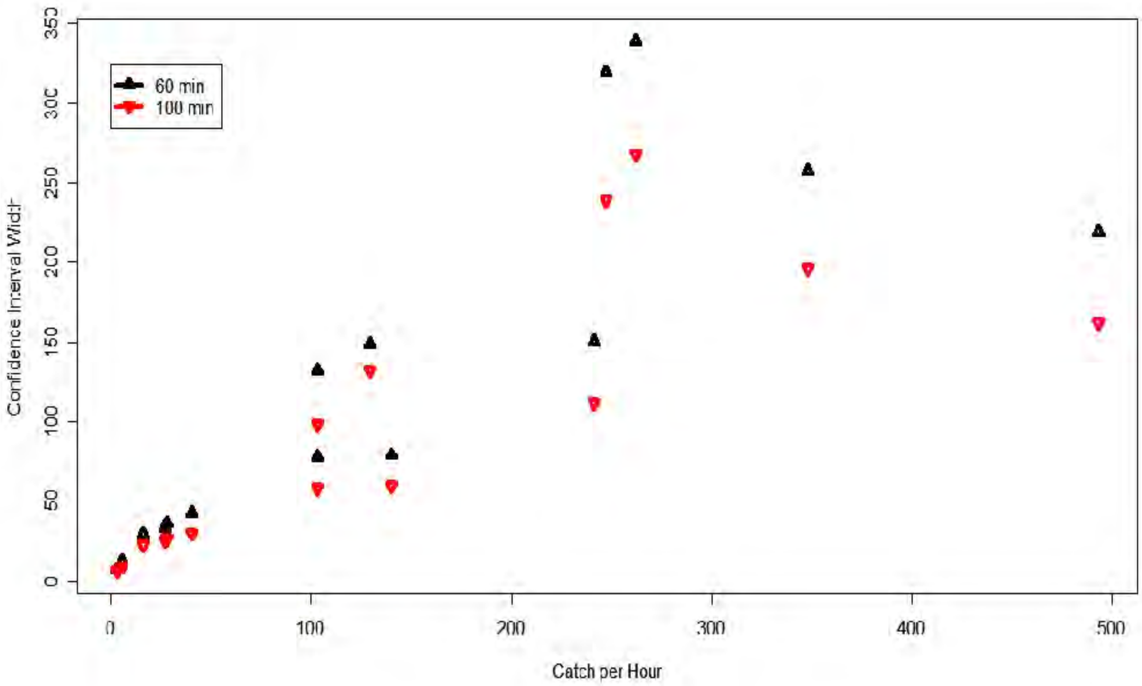


Figure 4. Confidence interval widths (95%) of trawl catch rates calculated for 60 and 100 minutes of total effort at the long-term sampling stations in Leech Lake, Minnesota.

As an example, we have 16 years of data to calibrate the relationship between trawl CPE at the long-term stations and YCI on Leech Lake. Catch rates below 100 fish/hour at the long-term stations usually suggest a relatively low abundance of age-0 walleye in the lake and that the pending YCI for that cohort could be average (YCI = 100) or lower based on survival (Figure 5). However, the proportion of fish surviving from year to year changes because the causes of walleye mortality and the amount of influence they have on a cohort also change among years. As a result, while low trawl CPE in a given year may indicate a low abundance of YOY walleye, unusually high survival can result in a large year class; such was the case in 1997 (CPE = 5 fish/h, YCI = 200). Similarly, unusually high mortality can suppress what initially appeared to be a promising cohort (1992: CPE = 102 fish/h, YCI = 25). This uncertainty between trawl catch rate and YCI increases as CPE increases because of the differing changes in age-0 walleye mortality among years (Figure 5). Early life-history mortality processes, such as growth rates and predation, drive walleye recruitment (Madenjian et al. 1996; Hansen et al. 1998). Consequently, establishment of all cohorts, particularly during the first year, is inherently uncertain. Therefore, increasing effort at existing stations would not improve this relationship, and any addition of new stations would change this relationship and would require another 10 years of repetitive sampling before the new relationship can be evaluated.

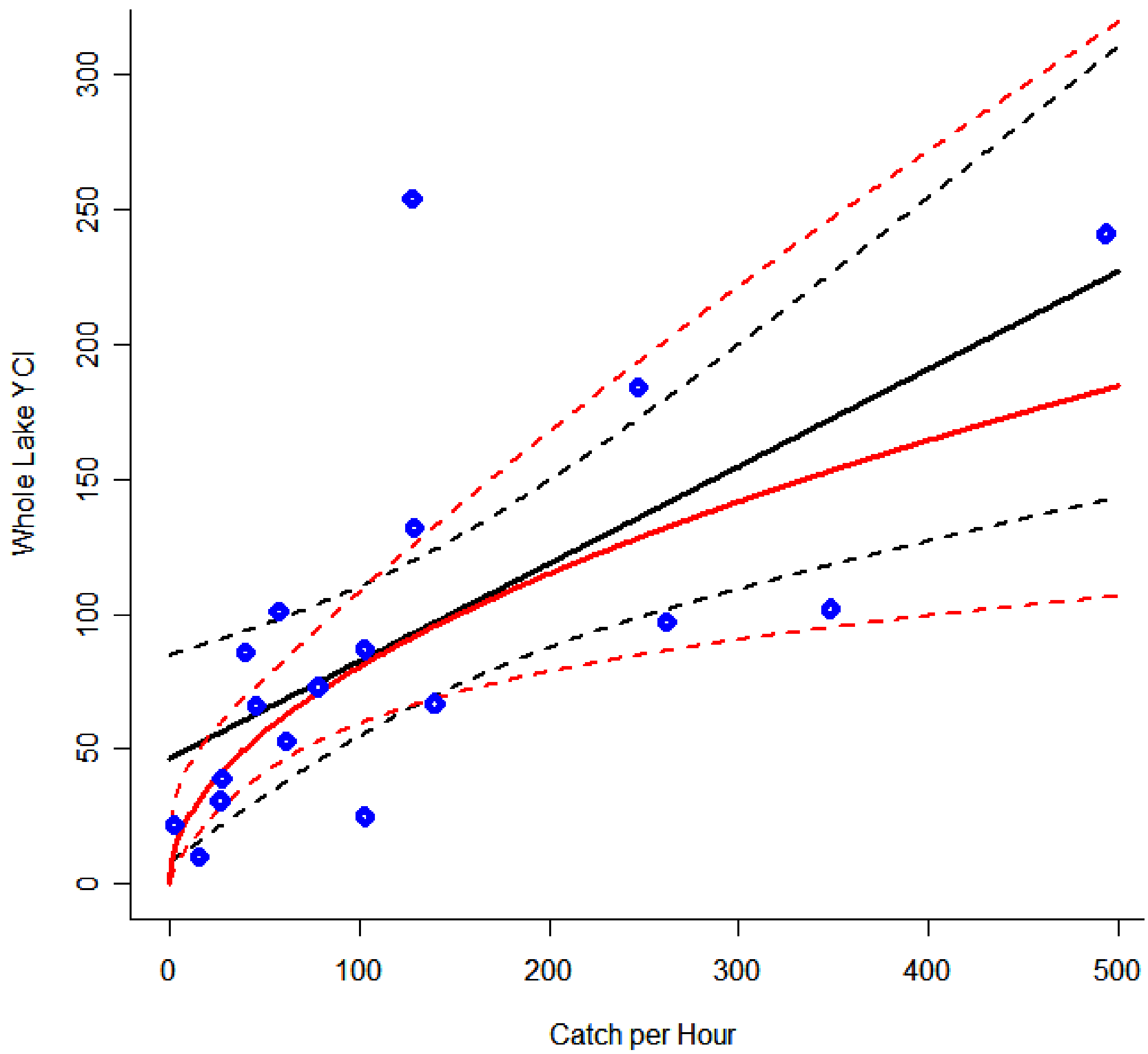


Figure 5. Regression model (solid black line) and log-transformed regression (solid red line) with associated 95% confidence bands for the mean value of year class index (YCI) for a given catch rate.

*Additional measures of cohort abundance*

We further examined existing data to determine if other metrics could improve on early estimates of year class strength. We used Akaike's Information Criterion to select the best-fit model for predicting YCI using data collected at long-term stations from 1987-2005. Model variables included catch rates (fish/h) of YOY walleye in bottom trawls, mean total length (TL) of age-0 walleye captured in trawls, and respective catch rates (fish/net) of the same cohort as age-1 and age-2 fish in experimental gill nets during standard lake surveys. Mean TL of age-0 walleye were standardized to observations during the 34$^{th}$ Julian week, which was when annual trawling surveys were generally completed across years. Catch rates of age-0 walleye in gill nets were not included because of gear bias. Catches of YOY walleye in trawl hauls served as indicators of initial relative abundance, mean TL was included to account for potential influences of first-year growth and size-specific winter mortality, and catches of age-1 and age-2 fish in experimental gill nets were used as early approximations of year class strength (finalized at age 4; D. Schupp, unpublished) before entering the recreational fishery, although gear bias still exists with age-1 fish. Models described both raw and $\log_{10}$ ($x$ +

1)-transformed catch data to determine the best analytical method for future assessments; YCI data were not transformed for this analysis.

Table 4. Akaike's Information Criterion scores, change from the minimum score ($\Delta_{min}$), coefficients of determination, and respective variables selected for the top ten best-fit models used describe walleye year class strength in Leech Lake. Variables used included catch rates of young-of-year walleyes in bottom trawls (TRL), mean total length (TL) of young-of-year walleyes collected in trawl hauls during the 34$^{th}$ Julian week of each year, and catch rates of age-1 (GN1) and age-2 (GN2) walleyes of the respective cohort in experimental gillnets during standard lake surveys.

| Model | Rank | AIC score | $\Delta_{min}$ | $R^2$ | Variables |
|---|---|---|---|---|---|
| Raw data | 1 | 108.01 | . | 0.68 | GN2 |
| | 2 | 109.42 | 1.41 | 0.69 | GN1, GN2 |
| | 3 | 109.64 | 1.63 | 0.69 | TRL, GN2 |
| | 4 | 110.00 | 1.99 | 0.68 | GN2, TL |
| | 5 | 111.22 | 3.21 | 0.69 | GN1, GN2, TL |
| | 6 | 111.40 | 3.39 | 0.69 | TRL, GN1, GN2 |
| | 7 | 111.55 | 3.54 | 0.69 | TRL, GN2, TL |
| | 8 | 111.78 | 3.77 | 0.63 | TRL, GN1, GN2 |
| | 9 | 113.19 | 5.18 | 0.70 | TRL, GN1, GN2, TL |
| | 10 | 113.57 | 5.56 | 0.64 | TRL, GN1, TL |
| $Log_{10}(x+1)$-transformed catch rates | 1 | 104.02 | . | 0.76 | GN2 |
| | 2 | 105.73 | 1.71 | 0.76 | GN1, GN2 |
| | 3 | 105.99 | 1.97 | 0.76 | GN2, TL |
| | 4 | 106.02 | 2.00 | 0.76 | TRL, GN2 |
| | 5 | 107.62 | 3.60 | 0.76 | TRL, GN1, GN2 |
| | 6 | 107.73 | 3.71 | 0.76 | GN1, GN2, TL |
| | 7 | 107.95 | 3.93 | 0.76 | TRL, GN2, TL |
| | 8 | 109.60 | 5.58 | 0.76 | TRL, GN1, GN2, TL |
| | 9 | 111.06 | 7.04 | 0.65 | TRL, GN1 |
| | 10 | 112.00 | 7.98 | 0.57 | GN1 |

Model selection using raw and $\log_{10}(x + 1)$-transformed data determined gillnet catch rates of age-2 walleyes was the best predictor of cohort strength (Table 4). However, this can be attributed to recruitment of age-2 fish to experimental gill nets while experiencing comparatively low exploitation. The addition of other variables, such as gill net catch rates of age-1 walleyes or catch rates of YOY walleyes in bottom trawls, did not appreciably improve model fit over using age-2 CPE independently.

Year class strengths were then predicted for cohorts from 1987 to 2005 using catch rates of age-0 walleyes in bottom trawls and catch rates of age-1 and age-2 walleyes in experimental gill nets. Year class indices were $\log_{10}$-transformed and catch rates were $\log_{10}(x+1)$-transformed to linearize relationships and to reduce residual error in regression models. Predicted YCIs were plotted against realized YCIs to further assess the utility of these models (Figure 6).

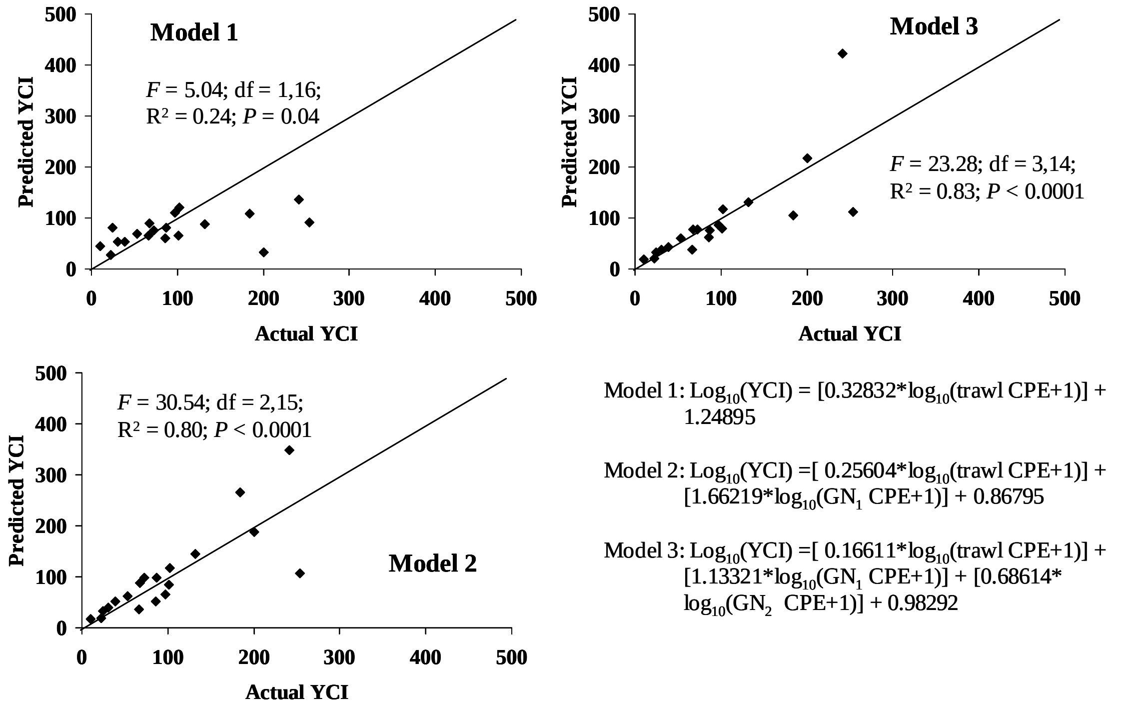


Figure 6. Actual and predicted year class indices (YCI) for walleye cohorts in Leech Lake from 1987 to 2005. Regression relationships were determined using $\log_{10}$-transformed YCIs and $\log_{10}(x + 1)$-transformed catch rates of age-0 walleyes in bottom trawl hauls and age-1 and age-2 walleyes in experimental gill nets. Lines have an approximate slope of 1.0.

Catch rates of age-0 walleyes in bottom trawls serve as a good preliminary predictor of YCI; however, this index is still subject to the numerous processes driving recruitment variability. Incorporation of additional cohort abundance indices, such as catch-at-age in experimental gill nets, can improve YCI forecasting ability as the cohort ages. Furthermore, fall sampling of YOY walleye using nighttime electrofishing, which was initiated in 2005 and has proven to be an effective gear for assessing early walleye cohort abundance in other large lakes, could strengthen the current trawl-only relationship. Sampling with this gear should continue and its utility as a complement to bottom trawl and gill net catch rates should be evaluated following several years of continuously collected data. The "Expanded YOY Sampling" document provides spatial details on historical and current young-of-year walleye sampling in Leech Lake.

## Conclusions and Management Recommendations

- A strength of the Large Lake Monitoring Program has been lake-specific adaptation of sampling methods to improve biological and statistical precision as dictated by species targeted and habitats sampled.

- Walleye recruitment is strongly influenced by early mortality processes. As a result, year class establishment is inherently highly variable and therefore difficult to predict during the first year.

- Seining is not a reliable indicator of walleye year class strength on Leech Lake. However, this method should be continued for the expressed purpose of providing additional data on age-0 walleye growth rates and condition as well as forage abundance.

- Trawling protocols used to index age-0 walleye abundance is a good preliminary indicator of cohort strength pending atypical mortality rates occur.

- Refinement of the YOY walleye sampling protocol on Leech Lake to its current form using trawling has improved statistical precision, increased logistical efficiency, and reduced negative effects on aquatic habitat.

- Increasing sampling effort, either by re-visiting previously discontinued stations, by adding new stations, or by increasing trawling effort at long-term stations, will not increase our ability to predict year class strength because of the many mechanisms regulating walleye mortality. While statistical precision always increases with increased sampling, the increased precision from expanded trawling (from 60 to 100 minutes) will not substantially improve or change management decisions.

- Increasing sampling effort via additional stations could compromise future management decisions by changing the relationship between the trawling CPE and realized year class strength. Adding stations would require an additional 10 years of repetitive sampling before new relationships could be evaluated.

- Incorporation of catch-at-age in experimental gill nets improved predictions of walleye year class strength. These data should be included as collected when assessing year class strength and when basing walleye management decisions in Leech Lake on recruitment indices.

- Fall electrofishing, initiated in 2005, should be sustained and with time may serve as an additional useful tool for early prediction of walleye year class strength. Electrofishing should complement trawling as a predictor of walleye year class strength if proven statistically valid.

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