STUDY FINAL REPORT

State: Michigan

Project No.: F-81-R-5

Study No.: 230681

Title: Development of multi-lake management strategies for Michigan's inland lakes.

Period Covered: October 1, 1998 - September 30, 2004

Study Objective: Develop a classification system for management of Michigan's inland lakes by determining how and why fish communities - and their response to management practices - vary among lakes (i.e., intersystem variability), along abiotic (e.g., longitudinal) and biotic (e.g., productivity) gradients, as well as across years (i.e., interannual variability).

Summary: Summaries of annual fish growth analysis surveys conducted by the Fisheries Division of the Michigan Department of Natural Resources were collected and entered into a central database. We collected and entered over 4,000 surveys over this four-year period. In a preliminary analysis, we examined temporal trends in mean length at age for eight warm and coolwater fish species. Preliminary weighted least squares regression analyses indicated there were significant temporal trends for age 2 pumpkinseed and ages 2 and 3 largemouth bass mean length at age, all demonstrating a decreasing trend over time. These findings are consistent with similar analyses conducted by others. If decreasing trends in mean length at age are present, these trends should be of concern for management. Such changes may lead to less-desirable recreational fisheries and have potentially detrimental population and community-level effects if few larger, faster growing individuals are present in the population. There is, however, a great amount of variability in the historical data used in these analyses and, although adequate data will not be available for several years, the implementation of the Status and Trends Program should provide further insight into any potential trends in fish growth rates. Ongoing analyses of these historical data will further assist with interpretation of long-term trends in fish mean length at age in Michigan inland lakes. Manuscripts giving results of this study were prepared, published, or are in the process of being published in a variety of journals. A listing of publications that resulted from from and summarize this research is provided.

Findings: Only Job 9, publish report, was scheduled for 2003-04. As findings will not be formally published, this Final Report is submitted.

Job 1: Title: <u>Assemble fish population assessment data</u>.-Summaries of annual fish growth analysis surveys conducted by the Fisheries Division of the Michigan Department of Natural Resources were collected and entered into a central database. Data acquisition started in 2000 and extended through 2003. We collected and entered over 4,000 surveys over this four year period. Data entered into the database included the survey date, lake name, county, gear type, species, age, mean length at age, the number of fish that were used to compute the mean, the person who collected the fish, and the person who aged the fish. Data were collected both from the Institute for Fisheries Research in Ann Arbor, MI (2,464 surveys) and regional Fish Division offices in the Upper Peninsula and upper Lower Peninsula (517 surveys), and data were downloaded from the Fish Collection System (1,041 surveys). Fish growth surveys span the years from 1952 to the present and represent 787 inland lakes. The number of surveys per species ranged from 1 – 2,498 (Table 1). The species with the most data include bluegill *Lepomis macrochirus*, pumpkinseed *L. gibbosus*, black crappie *Pomoxis nigromaculatus*, largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieu*, yellow perch *Perca flavescens*, walleye *Sander vitreus*, and northern pike *Esox lucius*.

Additional results of Job 1 are given in Nate and Bremigan (in review) [1].

Job 2: Title: Assemble abiotic, biotic, and meteorological data.-Results of Jobs 2 can be found in Wagner et al. (in prep) [1].

Job 3: Title: Determine the extent of intersystem and interannual variability in fish population parameters.-The elucidation of temporal trends in fish population demographics is of great interest to fisheries management. For example, long-term datasets enable managers to evaluate the effectiveness of regulatory changes, such as changes to minimum size limits. Furthermore, anglers can have a great influence on the size-structure of fish populations (Goedde and Coble1981), through size-selective harvesting. The effects of environmental changes on fish populations also may be detected with long-term datasets. Therefore, long-term trends in measures such as fish growth and the size structure of fish populations can lead to insights into any potential deleterious effects of high angling pressure or environmental change. Long-term datasets, however, are often not available and if they are, the data are often statistically messy, having been collected in a nonrandom fashion. However, if long-term datasets are available, even if the data were not collected under a standardized, statistically valid approach, they represent a unique opportunity to examine temporal trends in fish demographics and therefore represent a useful tool for managers.

In a preliminary analysis, we examined temporal trends in mean length at age for eight warm and coolwater fish species. The eight species included black crappie, bluegill, pumpkinseed, largemouth bass, smallmouth bass, northern pike, walleye, and yellow perch. These species were chosen because they had a fairly large number of surveys (i.e., larger sample sizes) and they are economically and ecologically important species. Analyses were restricted to mean length at ages 2 and 3 for each species. We restricted our analyses to these earlier age classes because the reliability of fish aging decreases with increasing age (Ricker 1975) and because the growth of early age classes of fishes is an important factor in determining predator-prey and competitive interactions, which can affect species distributions, size-structure, and population dynamics (Eklöv and Hamrin 1989; Diehl and Eklöv 1995; Persson et al. 1996).

For preliminary analyses, we used weighted linear least squares regression to examine temporal trends in mean length at age. Additional analyses are ongoing to examine the presence/absence of autocorrelation within the time series. Thus, future analyses will provide a more rigorous analysis of these data. For this analysis, yearly average mean length at age was the dependent variable and year was the independent fixed factor. Yearly means were calculated by averaging the mean length at age estimates for each lake within the state that was sampled in a given year. The number of lakes that were used to calculate the mean was then used as the weighting factor in the regression analysis. No lake was represented more than once during the time series to avoid having frequently sampled lakes having more influence on the analysis compared to less frequently sampled lakes. Additionally, year was grand-mean centered to aid in the interpretation of the intercept. In an effort to control for season of sampling and sampling gear type effects, the season and gear-type combination with the most data was used in the analysis. For all analyses, except walleye, fish that were sampled during summer months (June and July) with electrofishing (EF) gear were used in the analyses. For walleye, fish sampled in the fall (August and September) with EF gear were used in the analyses.

The number of years that were available for analysis ranged from 11 for ages 2 and 3 walleye to 26 for ages 2 and 3 largemouth bass. Although there were missing values in all analyses (i.e.,

[1] See Job 8 for full citations.

there were years with missing data), this did not represent a problem because regression approaches do not require that the response variable for all years be observed.

Preliminary weighted least squares regression analyses indicated there were significant temporal trends for three of the 16 analyses. Age 2 pumpkinseed and ages 2 and 3 largemouth bass mean length at age demonstrated a decreasing trend over time (Table 2, Figures 1-4). For all age-species combinations there was considerable temporal variation in mean length at age. For the significant regressions, time accounted for between 19 – 28 percent of the variation in mean length at age. For the remaining 13 nonsignificant analyses, 8 had negative coefficients for the time effect and 5 had positive coefficient estimates.

Although three significant trends were detected, due to the preliminary nature of our analyses caution must be used in the interpretation of these results. For example, autocorrelation is often present in time series analyses, where data exhibit serial correlation in which consecutive residuals are correlated to one another (Hirsch et al. 1982). The effects of not accounting for autocorrelation include (1) an increased probability of type I errors (i.e., finding a significant trend when no trend actually exists) and (2) producing less efficient estimates of parameters compared to estimates that are made when accounting for autocorrelation (Bence 1995).

Although our analyses are preliminary, they still provide insight into potential trends in mean length at age that may exist in the state of Michigan. Overall, the analyses suggest that if trends do in fact exist, they are likely negative, with mean length at age decreasing over time for certain species-age combinations. Beard and Kampa (1999) examined trends in mean size of bluegills, yellow perch, and black crappies in Wisconsin lakes. They found that mean size of bluegills and yellow perch in fyke net samples decreased over the time period from 1976 – 1991; however, they did not find a significant trend for black crappie. Grant et al. (2004) examined temporal trends in mean weight of black crappies, ciscoes *Coregonus artedi*, northern pike, walleye, white suckers *Catostomus commersonii*, and yellow perch over the time period from 1983 – 1997. Grant et al. (2004) found a significant trend in mean weight for walleye, with mean weight increasing significantly over the 15 yr period. No trends were detected for any other species.

Beard and Kampa (1999) also examined trends in the size of fish harvested and total catch and harvest for the abovementioned species. For all three species, Beard and Kampa (1999) found that total catch and harvest decreased from 1980 – 1991. The mean size of bluegill and yellow perch harvested, however, did not change over the same time period, but the proportion of large bluegills harvested decreased. Results from Beard and Kampa (1999) suggest that the size-selective nature of angling, with anglers removing the larger individuals, may be a possible mechanism for the decreasing temporal trends in mean fish size. Goedde and Coble (1981) studied the effects of angling on a waterbody in Wisconsin that was previously closed to all fishing and found that after angling was allowed, length and age-frequency distributions shifted towards smaller sizes and younger ages. Furthermore, mean age and life-spans decreased. These trends were evident for species such as yellow perch, pumpkinseed, bluegill, largemouth bass, and northern pike (Goedde and Coble 1981). Coble (1988) also concluded that due to the size-selective nature of angling, that angling could substantially change the size-structure of bluegill populations, resulting in a size-distribution with few larger fish.

With a decrease in mean size as observed by Beard and Kampa (1999), it can be hypothesized that compensation would lead to larger mean size at age for remaining fish in the population. However, in our preliminary analysis, we observed decreasing trends in mean size at age. If the mean size of fish in Michigan lakes is also decreasing for some species, this would imply that the compensatory ability of these populations is less than previously acknowledged.

[1] See Job 8 for full citations.

If decreasing trends in mean length at age are present, these trends should be of concern for management. Such changes may lead to less-desirable recreational fisheries and have potentially detrimental population and community-level effects if few larger, faster growing individuals are present in the population. There is, however, a great amount of variability in the historical data used in these analyses and, although adequate data will not be available for several years, the implementation of the Status and Trends Program should provide insight into any potential trends in fish growth rates. Furthermore, ongoing analyses of these historical data will further assist with interpretation of long-term trends in fish mean length at age in Michigan inland lakes.

Additional results of Job 3 can be found in Wagner et al. (in prep) [1].

Job 4: Title: Combine historic fisheries data with abiotic, biotic, and meteorological data.- Results of Job 4 can be found in Wagner et al. (in prep) [1].

Job 5: Title: Conduct field research to evaluate management actions.-Results of Job 5 can be found in Hayes et al. (2003) [1], Valley and Bremigan (2002) [1], and Wills et al. (2004) [1].

Job 6: Title: Participate in assessment and inventory committee.-Fisheries Division Research Inventory and Assessment committee meetings were regularly attended. Collectively, the efforts of this committee laid the foundation for the Division's Status and Trends sampling program of inland lakes and streams.

Job 7: Title: Expand research into related areas.-Several proposals were submitted in order to allow expansion of this research into related areas:

- Fisheries Division, Michigan Department of Natural Resources: "Developing a lake classification system for Michigan inland lakes". 2003. Duration: 2 years. $80,000 with 3 co-PIs.

- Fisheries Division, Michigan Department of Natural Resources: "Managing Michigan lakes: evaluating effects of watershed and habitat perturbation on lake resources". 2002. Duration: 4 years. $221,663 with 1 co-PI.

- Michigan Agriculture Experiment Station Research Competitive Grants Program: "Predicting chemical and biological characteristics of lakes using landscape-context features from multiple spatial scales". 2001. Duration: 3 years. $90,000 with 1 co-PI.

- United States Geological Survey: "A multiscaled landscape-context model to predict abiotic and biotic lake characteristics". 2000. Duration: 1 year. $15,000 with 1 co-PI.

- Michigan Habitat Improvement Fund: "Evaluation of habitat improvement structures in Au Sable River impoundments". 1999. Duration: 3 years. $159,342 with 1 co-PI.

- Aquatic Ecosystem Restoration Foundation/Aquatic Plant Management Society: "The indirect effects of Sonar® application on lake food webs: a multi-lake experiment". 1999. Duration: 2 years. $34,000.

[1] See Job 8 for full citations.

Job 8: Title: <u>Publish results and prepare annual reports</u>.-Reports were prepared as scheduled. Publications, theses, dissertations, and manuscripts in preparation that include findings from this project are:

Cheruvelil, K. S. 2004. A field test of the unimodal relationship between fish growth and macrophyte cover in north temperate lakes. *Chapter 1 in:* Examining lakes at multiple spatial scales: predicting fish growth, macrophyte cover and lake physio-chemical variables. PhD. Dissertation. Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI.

Hanson, S. M. 2001. The effects of Eurasian watermilfoil reductions on largemouth bass diet and growth. MS Thesis. Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI.

Hayes, D., E. Baker, R. Bednarz, D. Borgeson, Jr., J. Braunscheidel, J. Breck, M. Bremigan, A. Harrington, R. Hay, R. Lockwood, A. Nuhfer, J. Schneider, P Seelbach, J. Waybrant, and T. Zorn. 2003. Developing a standardized sampling program: the Michigan experience. Fisheries 28(7):18-74.

Nate, N. A., M. Bozek, M. Hansen, C. Ramm, M. Bremigan, and S. Hewett. 2003. Predicting the occurrence and success of walleye populations from physical and biological features of northern Wisconsin lakes. North American Journal of Fisheries Management 23:1206-1213.

Nate, N. A., and M. T. Bremigan. In review. Comparison of mean length at age and growth parameters of bluegill, largemouth bass and yellow perch from length-stratified sub-samples and samples in Michigan lakes. Submitted to North American Journal of Fisheries Management.

Nate, N. A. 2004. A lake classification scheme for fish species richness and fish growth in Michigan and Wisconsin lakes. *Chapter 2 in:* Variability in fish growth rates in relation to physical and landscape characteristics of Michigan and Wisconsin inland Lakes. PhD Dissertation, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI.

Valley, R. D. and M. T. Bremigan. 2002. Effects of selective removal of Eurasian watermilfoil on age-0 largemouth bass piscivory and growth in southern Michigan lakes. Journal of Aquatic Plant Management 40:79-87.

Wagner, T., M. T. Bremigan, K. S. Cheruvelil, P. A. Soranno, N. A. Nate, and J. E. Breck. In prep. Comparing multi-scale predictors of fish growth: towards a regional framework for fish management. To be submitted to Canadian Journal of Fisheries and Aquatic Sciences.

Wills, T. C., M. T. Bremigan, and D. B. Hayes. 2004. Variable effects of habitat enhancement structures across species and habitats in Michigan reservoirs. Transactions of the American Fisheries Society 133:398-410.

[1] See Job 8 for full citations.

Literature Cited

Beard, T. D. Jr., and Kampa, J. M. 1999. Changes in bluegill, black crappie, and yellow perch populations in Wisconsin during 1967-1991. North American Journal of Fisheries Management 19:1037-1043.

Bence, J. R. 1995. Analysis of short time series: correction for autocorrelation. Ecology 76: 628-639.

Coble, D. W. 1988. Effects of angling on bluegill populations: management implications. North American Journal of Fisheries Management 8:277-283.

Diehl, S., and Eklöv, P. 1995. Effects of piscivore-mediated habitat use on resources, diet, and growth of perch. Ecology 76: 1712-1726.

Eklöv, P., and Hamrin, S. F. 1989. Predatory efficiency and prey selection: interactions between pike Esox lucius, perch Perca fluviatilis, and rudd Scardinus. Oikos 56: 149-156.

Goedde, L. E., and Coble, D. W. 1981. Effects of angling on a previously fished and an unfished warmwater fish community in two Wisconsin lakes. Transactions of the American Fisheries Society 110:594-603.

Grant, G. C., Schwartz, Y., Weisberg, S., and Schupp, D. H. 2004. Trends in abundance and mean size of fish captured in gill nets from Minnesota lakes, 1983-1997. North American Journal of Fisheries Management 24:417-428.

Hirsch, R. M., Slack, J. R., and Smith, R. A. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18:107-121

Prepared by: M. Bremigan, N. Nate, T. Wagner, and P. Soranno
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Table 1.–The number of annual fish growth summary surveys collected and entered into the Michigan State fish growth database. The numbers of surveys are listed by species (or family if species information was not reported). Fish are listed in alphabetical order according to common name.

Common name	Scientific name	Number of surveys
Alewife	*Alosa pseudoharengus*	2
Atlantic salmon	*Salmo salar*	8
Black bullhead	*Ameiurus melas*	6
Black crappie	*Pomoxis nigromaculatus*	1349
Blackchin shiner	*Notropis heterodon*	1
Bluegill	*Lepomis macrochirus*	2331
Bowfin	*Amia calva*	1
Brook trout	*Salvelinus fontinalis*	109
Brown trout	*Salmo trutta trutta*	173
Bullhead catfishes	*Ameiurus spp.*	1
Burbot	*Lota lota*	1
Carps and minnows	*Cyprinidae*	1
Channel catfish	*Ictalurus punctatus*	14
Chinook salmon	*Oncorhynchus tshawytscha*	8
Cisco	*Coregonus spp.*	111
Coho salmon	*Oncorhynchus kisutch*	7
Common carp	*Cyprinus carpio carpio*	9
Common shiner	*Luxilus cornutus*	1
Crappie (unspecified)	*Pomoxis spp.*	42
Creek Chubsucker	*Erimyzon oblongus*	2
Freshwater drum	*Aplodinotus grunniens*	1
Gizzard shad	*Dorosoma cepedianum*	2
Golden shiner	*Notemigonus crysoleucas*	10
Goldfish	*Carassius auratus auratus*	2
Grass pickerel	*Esox americanus vermiculatus*	3
Green sunfish	*Lepomis cyanellus*	75
Herrings	*Clupeidae*	1
Hybrid sunfish	–––	59
Lake chub	*Couesius plumbeus*	1
Lake chubsucker	*Erimyzon sucetta*	1
Lake herring	*Coregonus artedi*	31
Lake sturgeon	*Acipenser fulvescens*	1
Lake trout	*Salvelinus namaycush*	63
Lake whitefish	*Coregonus clupeaformis*	49
Largemouth bass	*Micropterus salmoides*	2085
Longear sunfish	*Lepomis megalotis*	14
Muskellunge	*Esox masquinongy*	110
Northern pike	*Esox lucius*	2064
Other sturgeons	*Acipenser spp.*	2
Perches	*Percidae*	25
Pikes	*Esocidae*	2
Pumpkinseed sunfish	*Lepomis gibbosus*	1614
Rainbow darter	*Etheostoma caeruleum*	1
Rainbow smelt	*Osmerus mordax*	8

Table 1.–Continued.

Common name	Scientific name	Number of surveys
Rainbow trout	*Oncorhynchus mykiss*	253
Redear sunfish	*Lepomis microlophus*	104
Redhorse	*Moxostoma carinatum*	7
Rock bass	*Ambloplites rupestris*	836
Round whitefish-menominee	*Prosopium cylindraceum*	3
Shorthead redhorse	*Moxostoma macrolepidotum*	1
Silver redhorse	*Moxostoma anisurum*	1
Smallmouth bass	*Micropterus dolomieu*	1000
Smelts	*Osmeridae*	39
Splake	*Salvelinus fontinalis*	88
Suckers	*Catostomidae*	51
Sunfishes	–––	3
Tiger musky	*Esox lucius × E. masquinongy*	113
Trouts	*Oncorhynchus spp.*	1
Walleye	*Sanders vitreus*	1467
Warmouth	*Lepomis gulosus*	25
White bass	*Morone chrysops*	24
White crappie	*Pomoxis annularis*	25
White perch	*Morone americana*	8
White sucker	*Catostomus commersoni*	80
Yellow perch	*Perca flavescens*	2498

Table 2.–Weighted linear regression analysis results. Mean length at age was the dependent variable, year was the independent factor, and the number of lakes contributing to the yearly mean was the weighting factor. β_0 is the intercept, β_1 is the estimated coefficient for the year effect, s.e. = standard error, *n* = the number of years used in the analysis. Each lake was sampled once during the analysis period and year was grand-mean centered. Significant trends are shown in bold. All fish were sampled during summer months (June and July) with electrofishing (EF) gear, except for walleye which were sampled during fall months (August and September) with EF gear. Units for the intercept and slope are in mm.

Species (age)	β_0 (s.e.)	β_1 (s.e.)	*n*	*P*-value	R^2
Black crappie (2)	163.4 (5.78)	-0.64 (0.65)	15	0.34	0.07
Black crappie (3)	198.3 (5.78)	1.44 (0.72)	13	0.07	0.27
Bluegill (2)	96.3 (2.49)	-0.18 (0.52)	23	0.52	0.02
Bluegill (3)	126.8 (2.73)	0.006 (0.29)	23	0.98	0.00
Pumpkinseed (2)	**102.4 (4.42)**	**-1.19 (0.45)**	**20**	**0.02**	**0.28**
Pumpkinseed(3)	120.3 (3.84)	-0.20 (0.43)	20	0.65	0.01
Largemouth bass (2)	**192.7 (3.42)**	**-0.86 (0.36)**	**26**	**0.026**	**0.19**
Largemouth bass (3)	**251.2 (3.79)**	**-0.97 (0.39)**	**26**	**0.019**	**0.21**
Northern pike (2)	509.97 (12.88)	-0.06 (1.80)	13	0.98	0.00
Northern pike (3)	567.8 (17.40)	-0.69 (2.62)	15	0.80	0.01
Smallmouth bass (2)	197.6 (7.36)	-0.37 (0.74)	16	0.63	0.02
Smallmouth bass (3)	255.7 (8.52)	0.59 (0.80)	12	0.48	0.05
Walleye (2)	331.3 (6.31)	2.08 (1.36)	11	0.16	0.21
Walleye (3)	388.3 (13.24)	-1.80 (2.72)	11	0.53	0.05
Yellow perch (2)	138.7 (2.46)	0.13 (0.28)	23	0.65	0.01
Yellow perch (3)	174.5 (4.05)	-0.19 (0.49)	23	0.70	0.00

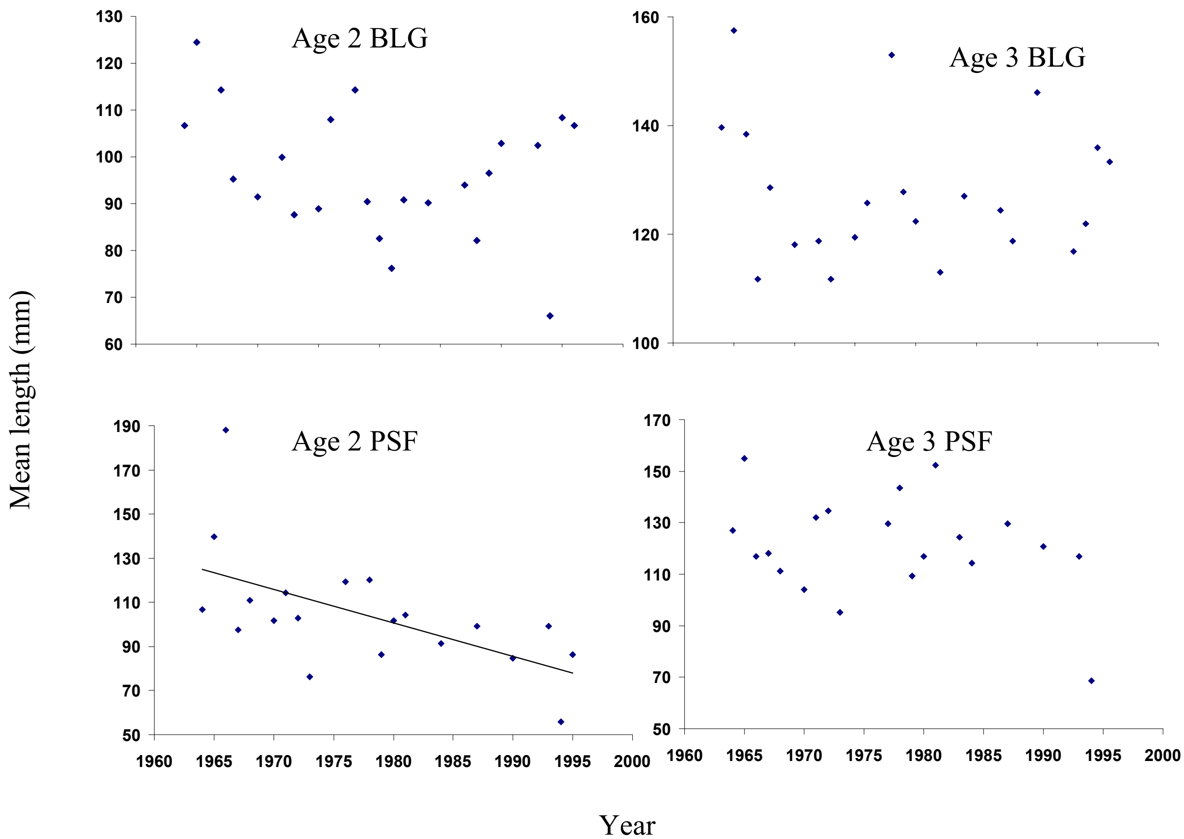

Figure 1.–Mean length at age for ages 2 and 3 bluegill (BLG) and pumpkinseed sunfish (PSF) versus time. Please note different Y-axis scales.

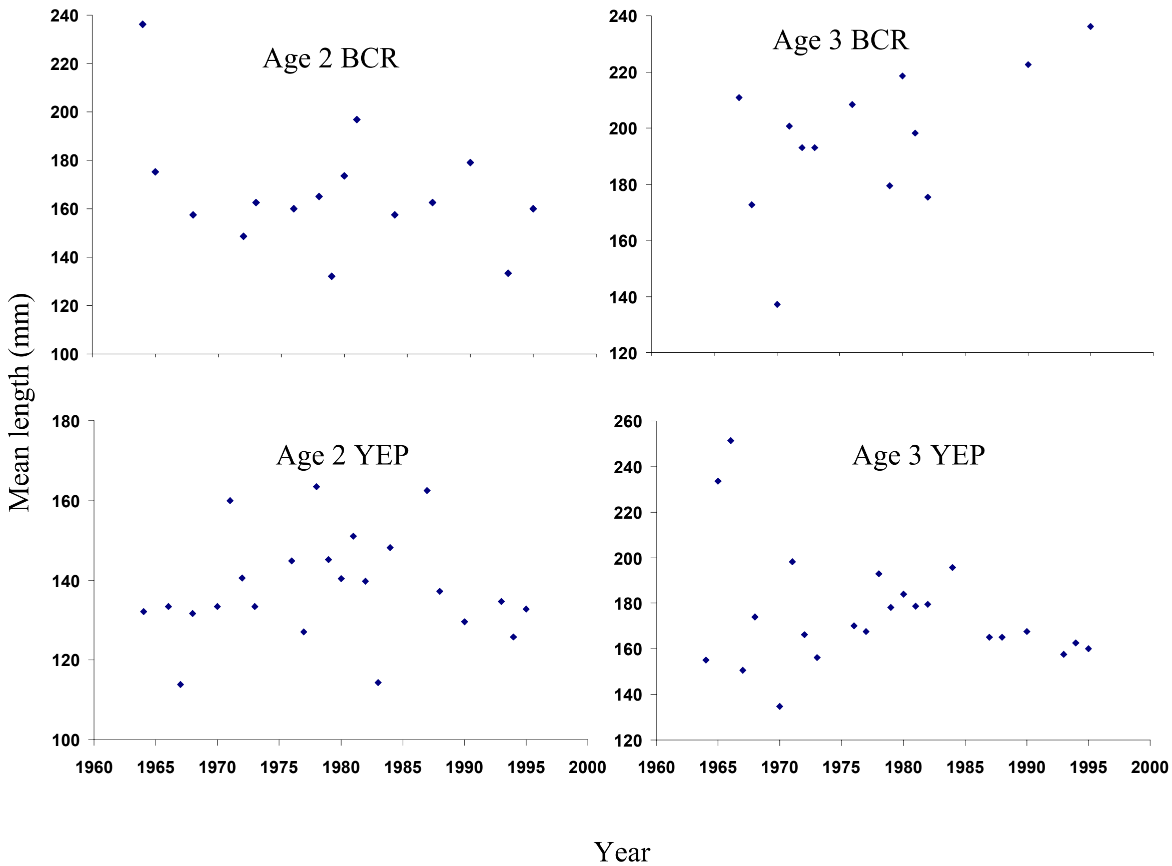

Figure 2.–Mean length at age for ages 2 and 3 black crappie (BCR) and yellow perch (YEP) versus time. Please note different Y-axis scales.

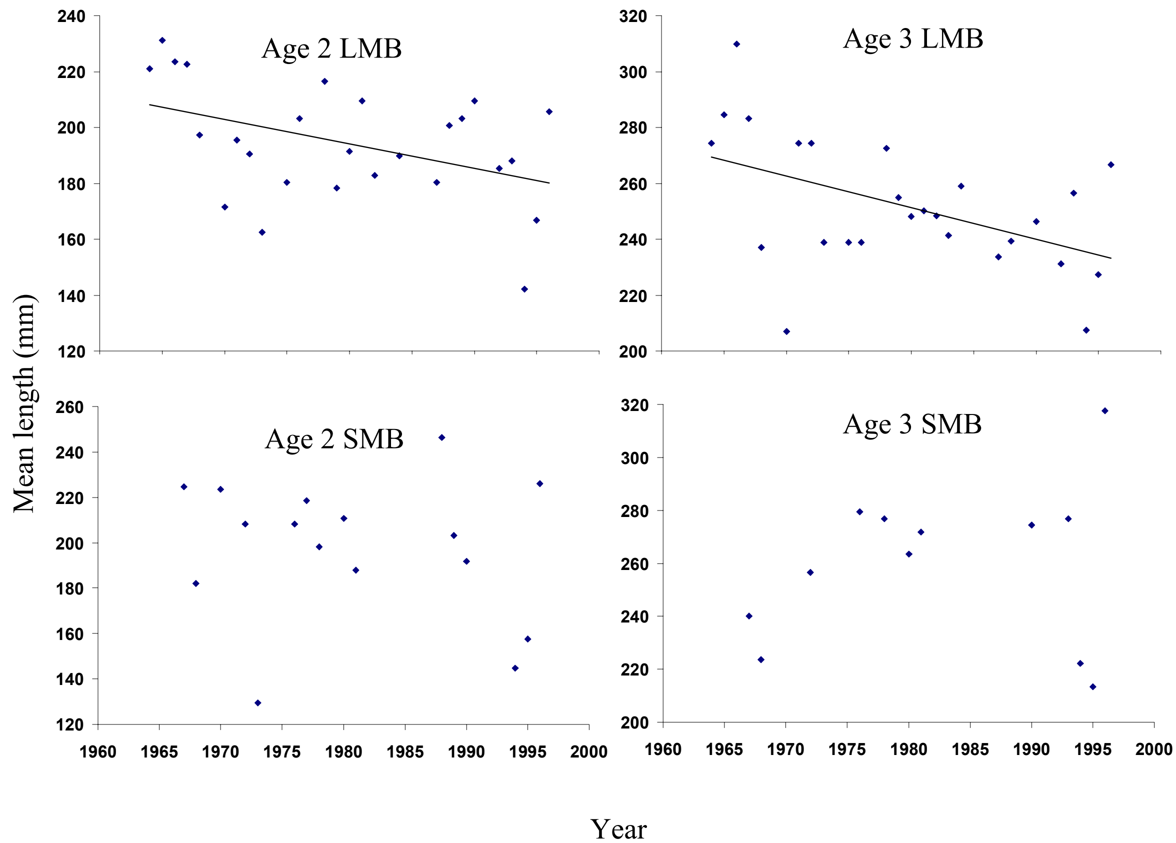

Figure 3.–Mean length at age for ages 2 and 3 largemouth bass (LMB) and smallmouth bass (SMB) versus time. Please note different Y-axis scales.

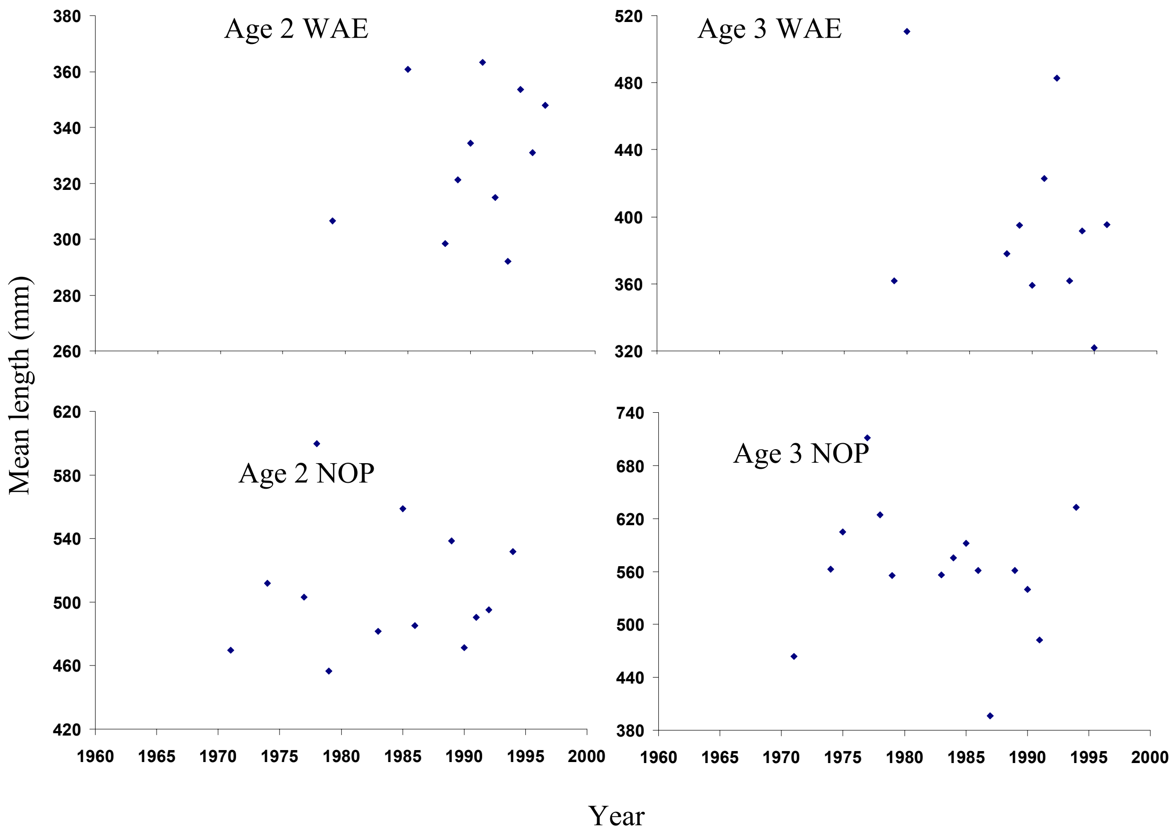

Figure 4.–Mean length at age for ages 2 and 3 walleye (WAE) and northern pike (NOP) versus time. Please note different Y-axis scales.