STUDY PERFORMANCE REPORT

State: Michigan

Project No.: F-80-R-5

Study No.: 230714

Title: Managing Michigan lakes: evaluating effects of watersheds and habitat perturbation on lake resources.

Period Covered: October 1, 2003 - September 30, 2004

Study Objective:

1) To evaluate the ability of the Fisheries Division Status and Trends Program to actually detect changes in the status of Michigan lakes over time.
2) To investigate the effects of habitat perturbation on lake biota.
3) To conduct workshops designed to improve dialog within the Division regarding implementation of the Status and Trends program, and integration of the program with research and management efforts.

Summary: Analysis of existing data sets continued. Ongoing analysis of temporal trends in fish size at age indicates that in a few circumstances, size at age may have declined over the past 40 years. Small sample sizes currently constrain our ability to use historic data to estimate the power of the status and trends program to detect changes over time in fish size at age. Efforts are ongoing to rectify this situation if possible. Predictable relationships between shoreline development and littoral habitat have been documented at both the local (site) and lake level. In addition, results to date demonstrate that black bass nesting success declines with increasing lake dwelling density. Efforts to transfer findings to the Division in the form of interactive workshops have continued.

Findings: Jobs 1, 2, 3, 4, 5, and 7 were scheduled for 2003-04, and progress is reported below.

Job 1. Title: Analyze existing data sets.-Evaluation of the Status and Trends Program is composed of two steps (i) conduct temporal trend analysis, looking at trends in mean length at age over time, and (ii) use results from (i) to conduct a power analyses. To date, we have conducted preliminary temporal trend analysis and we have begun to develop methods for the power analysis.

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. Analysis 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

Temporal trends. For preliminary analyses, we used weighted linear least squares regression to examine temporal trends in mean length at age. Additional analyses are ongoing that are examining the presence/absence of autocorrelation within time series. Thus, future approaches will provide a more rigorous analysis of these data. 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 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 years in all analyses (i.e., 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 out of the 16 analyses. Age 2 pumpkinseed and ages 2 and 3 largemouth bass mean length at age demonstrate a decreasing trend over time (Table 1, Figures 1-4). For all age-species combination there was considerable variation in mean length at age over time. For the significant regressions, time accounted for between 19 and 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.

<u>Power analysis</u>. Power analysis is a useful tool for evaluating the performance of ecological monitoring programs (Hatch 2003). Power analysis can help answer questions such as the sufficient number of samples (in this case lakes) needed to detect a specified change in variable *X* and the probability of detecting a difference among groups or temporal trend if present. Ideally, a monitoring program should have high statistical power, the ability to detect a condition that differs from the null hypothesis. More formally, power is defined as $1 - \beta$, where β is the probability of a type II error (failing to reject the null hypothesis when it is actually false). Performing a power analysis requires the following information (1) knowledge of the statistical test to be used, (2) sample size, (3) an estimate of the variance of those measurements, (4) the effect size, that is the magnitude of the effect under the alternate hypothesis, (5) significance level (α, the probability of a type I error (rejecting the null hypothesis when it is actually true)), and (6) β.

Several statistical software packages are available for determining the power of various statistical tests (e.g., SAS®, NCSS Statistical Software, etc.). However, many of these software packages lack the flexibility to manipulate various aspects of an experimental design, thus limiting the ability to evaluate the statistical power under different hypothetical sampling regimes. Assuming that linear regression is the appropriate method for detecting temporal trends in fish growth rates, a Monte Carlo approach will be used to examine the power of various sampling scenarios. This analysis will likely be performed at the statewide level because sample sizes within the ST program strata are quite low, with sample sizes varying by species and stratum. This approach will allow for the flexibility to manipulate various aspects of the experimental design (i.e., the number of lakes sampled each year, the number of years sampled, etc). Briefly, the Monte Carlo approach is as follows: first, fish growth rates (dependent variable) are regressed against time (independent variable) to detrend the data. The distribution parameters are then estimated by taking the mean and standard deviation of the residuals. Next, random samples are generated from the study population by generating random values from a normal distribution with a mean of 0 and a standard deviation of 1 and multiplying these values by the observed standard deviation and adding the mean. After the set of random observations is generated from the above distribution, a trend of known magnitude is added, (e.g., an x% change in growth per year) and the test statistic is calculated and compared to a critical value. The above steps are then repeated (e.g., 5,000 times). Because the data generated depict a situation in which we know the null hypothesis is false, power can be estimated as the percentage of trials that rejected the null hypothesis (H_o: $\beta_1 = 0$). A similar approach was employed by Carpenter et al. (1995) to estimate the power of experiments to detect the effects of habitat manipulations on bluegill growth and population estimates. However, in their case, Carpenter et al. (1995) were not interested in temporal trends; rather, they were interested in detecting differences between controls and treatment lakes and therefore used a one-way analysis of variance design.

Results for the power analysis are not yet available. However, results from the power analysis will allow for the construction of power curves that will inform management on the statistical power to detect temporal trends in mean length at age for various sampling designs. There are several issues with the fish growth database that need to be addressed prior to performing the power analysis. First, as described above, the temporal trend analyses will need to be performed while accounting for such issues as autocorrelation. Secondly, methods need to be developed that account for the fact that fish were sampled during different seasons and with different sampling gears. If such methods can be developed, our sample sizes should increase. If sample sizes cannot be increased, the power analysis will likely be performed at the state-level rather than for each stratum of the ST program. Historical sampling procedures also prohibit the evaluation of all strata. For example, historically very few, if any, ‘small’ or ‘medium’ size lakes were sampled, indicating a historical bias for sampling ‘large’ lakes. Therefore, the evaluation of strata that include small or medium lakes is not possible. Regardless of whether all strata of the ST program can be evaluated, knowledge of the ability to detect trends at the state level should provide valuable information.

Job 2. Title: Conduct fieldwork to investigate effects of habitat perturbation on lake biota.- Sampling was conducted on 15 lakes located in Washtenaw and Livingston counties in southeast Michigan, USA with varying amounts of residential lakeshore development. Across lakes, dwelling density ranges from 7.8 to 22.3 dwellings•km^{-1}. Lakes are mesotrophic and range in area from 28.8 to 100.5 ha. During summer of 2003, fish scales were collected from bluegill and largemouth bass using nighttime electrofishing. Using a subset of six lakes, we quantified substrate composition, coarse woody material abundance, and macrophyte cover along specific sites parallel to the lakeshore. In August 2003, we quantified whole-lake macrophyte cover and collected water chemistry and zooplankton samples from the 15 lakes. In the summer of 2004, additional bluegill and largemouth bass scale samples were collected using nighttime electrofishing, purse seining, and shoreline seining. Water chemistry and zooplankton were also collected again in 2004.

In addition, we monitored six of the lakes during May and June 2004 to assess the importance of nest locale and whole lake-scale habitat characteristics on black bass reproductive success.

Nest location and reproductive success. We surveyed the littoral area for black bass nests using boats powered by electric trolling motors. Each lake was surveyed at least biweekly for new nests and to examine the status of previously located nests. Once a new nest was located, it was marked with a numbered marker and its location was recorded using a differentiated global positioning system (GPS; Trimble GeoExplorer ®). After marking the nest, local nest characteristics were recorded (see below) and the presence/absence of a male bass, eggs, larvae, fry, and the species of bass (largemouth or smallmouth bass) were observed with either an aquascope or by snorkeling. A nest was considered successful if fry were observed actively swimming above the nest (Philipp et al. 1997).

Nest characteristics. Once a nest was located, the dominant substrate type (e.g., silt, sand, etc) and the presence of cover (boulders, woody debris, macrophytes) within a 1 m radius of the nest were recorded, along with the depth of the nest and, when possible, an estimate of the length of the brood-guarding bass. The development type of the nearest shoreline was also noted and recorded as either not developed, developed retained (a shoreline with riprap or a retaining wall), or developed maintained (developed, but with no retaining wall, e.g., a shoreline with a maintained lawn). Using the GPS locations, distance to shore and distance to nearest boat access point were calculated for each nest. Also, we determined the dominant shoreline vegetation type as either wetland or upland and the wind exposure for each nest from existing GIS coverages. Nest wind exposure was based on the location of the nest in relation to the prevailing wind direction and classified as high or low exposure.

Lake characteristics. Lake-scale characteristics included shoreline dwelling density and lake-wide estimates of angling pressure. Angling pressure was determined following the methods of Lockwood et al. (1999). Each lake was monitored twice weekly during May and June. One day during each week and each weekend was randomly selected and sampled at a randomly selected time of day (morning, mid-day, or evening). Surveys were conducted to determine the number of anglers potentially targeting nesting bass. Visual assessment of fishing activity was conducted by a researcher in a boat using binoculars. The number of anglers per boat, the location of the boat (near the shoreline or open water), shoreline characteristics (developed vs. undeveloped shoreline), and the gear type used were recorded when possible. Following Philipp et al. (1997), any angler that was determined to be using tactics (fishing near the shoreline and using appropriate lures or jigs) that could potentially catch nesting bass was recorded as targeting nesting bass.

Job 3. Title: Process field samples and analyze data.-Over 985 bluegill scale samples collected from the 15 study lakes were processed between 2003 and 2004. Scale annuli were measured using Optimas 6.51 imaging software. Back-calculated total length at the start of each growth increment was then determined for each fish. Nearly 750 largemouth bass scale samples will be processed using similar methods during fall 2004.

Littoral habitat data from the subset of six lakes were processed and analyzed during fall 2003. Mean number of coarse woody material transect intersections (Figure 5) and mean substrate size (Figure 6) were examined with relation to residential shoreline development.

In the bass nesting component of the study, a total of 197 nests were located during the study period. The number of nests located in each lake ranged from 1- 52 nests per lake. The fate of the single nest on Blind Lake could not be determined and therefore this lake was excluded from further analyses. Bass initiated nest building in early May, with the number of nests peaking in all lakes in mid-May. The last nest was located on 8 June. Largemouth bass nests were the most commonly found nest during the study and were present in all study lakes. Smallmouth bass nests were only found in Bruin and Halfmoon lakes, with 11 and 6 located smallmouth bass nests, respectively. Initial analyses indicate that black bass nest success declines with increasing shoreline dwelling density (Figure 7).

Job 4. Title: Compare aquatic plant metrics.-We examined lake-wide macrophyte cover for the 15 study lakes using a point-intercept method (Table 2). While residential shoreline development did not affect the majority of total plant cover variables, littoral emergent and floating cover decreased as shoreline development increased. Macrophyte cover at the local scale was quantified for six of the 15 study lakes (Figure 8). Submersed, emergent, and floating macrophyte cover was greater at undeveloped and maintained sites than at retaining wall sites (all P-values <0.042)

Job 5. Title: Conduct Division-wide workshops.-Planning for the workshops has progressed in collaboration with Todd Wills. Workshops, primarily in the form of presentation and discussion at Basin Team meetings will be conducted in fall 2004 and winter 2005.

Job 7. Title: Prepare annual reports and manuscripts.-This annual report was completed as scheduled. Several manuscripts are currently in preparation.

Literature Cited

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Prepared by: M. Bremigan, P. Soranno, T. Wagner, and A. Jubar
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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*	1,349
Blackchin shiner	*Notropis heterodon*	1
Bluegill	*Lepomis macrochirus*	2,331
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*	2,085
Longear sunfish	*Lepomis megalotis*	14
Muskellunge	*Esox masquinongy*	110
Northern pike	*Esox lucius*	2,064
Other sturgeons	*Acipenser* spp.	2
Perches	*Percidae*	25
Pikes	*Esocidae*	2
Pumpkinseed sunfish	*Lepomis gibbosus*	1,614
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*	1,000
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*	1,467
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*	2,498

Table 2.–Macrophyte assemblage characteristics of the fifteen study lakes in southeast Michigan. Cover refers to the percentage of sampled points at which plants were present. Total plant cover indicates the percent occurrence of plants sampled of the entire lake, whereas littoral plant cover is the percentage of sampled points at which plants were present in the littoral zone. Littoral zone is defined as the area from shore to the depth at which plants consistently occurred. Plant data were collected during August 2003.

			Total		Littoral				
Lake	County	Dwellings/km	Plant Cover (%)	Dense Cover (%)	Plant Cover (%)	Dense Cover (%)	Emergent Cover[a] (%)	Floating Cover[a] (%)	EWM[b] Cover (%)
Crooked	Washtenaw	1.19	76	69	87	79	38	80	0
South	Washtenaw	2.42	48	24	93	46	18	12	18
Bruin	Washtenaw	7.76	31	9	63	17	27	7	12
Blind	Washtenaw	9.52	13	1	19	2	10	5	1
Woodburn	Livingston	12.70	36	13	71	28	40	48	0
West Crooked	Livingston	13.87	93	78	96	81	12	20	53
East Crooked	Livingston	14.55	49	24	82	40	8	9	41
Joslin	Washtenaw	17.64	94	89	94	90	4	6	24
Halfmoon	Livingston	17.71	19	5	60	17	22	14	7
Hiland	Livingston	18.61	53	34	70	45	21	41	7
North	Washtenaw	21.47	59	54	80	73	3	6	32
Strawberry	Livingston	22.18	26	13	69	34	31	24	14
Patterson	Livingston	22.31	26	14	71	38	28	21	32
Baseline	Livingston	22.76	26	11	87	36	2	3	11
Zukey	Livingston	28.78	35	12	48	17	7	7	5

[a] Indicates a significant response to residential shoreline development. (Emergent cover: $P<0.12$; Floating cover: $P<0.046$).

[b] Eurasian Water Milfoil

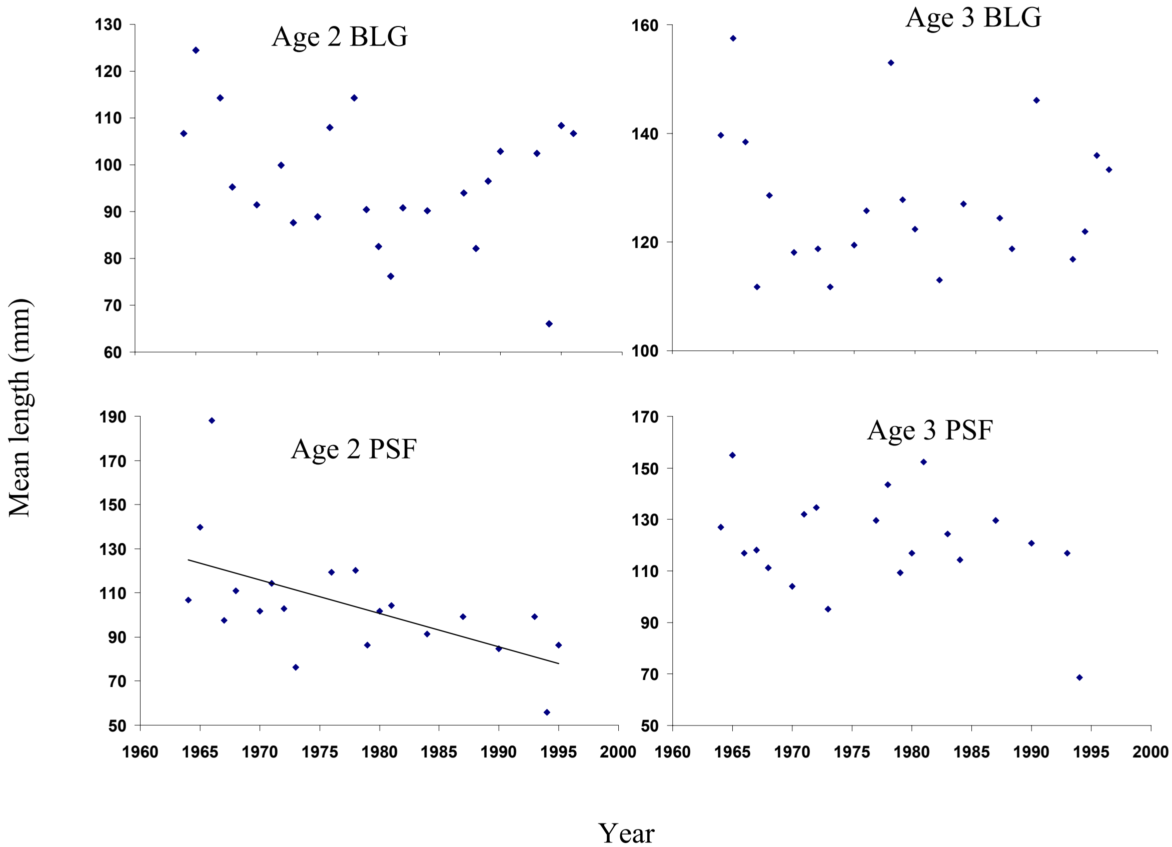

Figure 1.–Mean length at age for ages 2 and 3 bluegill (BLG) and pumpkinseed sunfish (PSF) versus time. Please note different Y-axis scales.

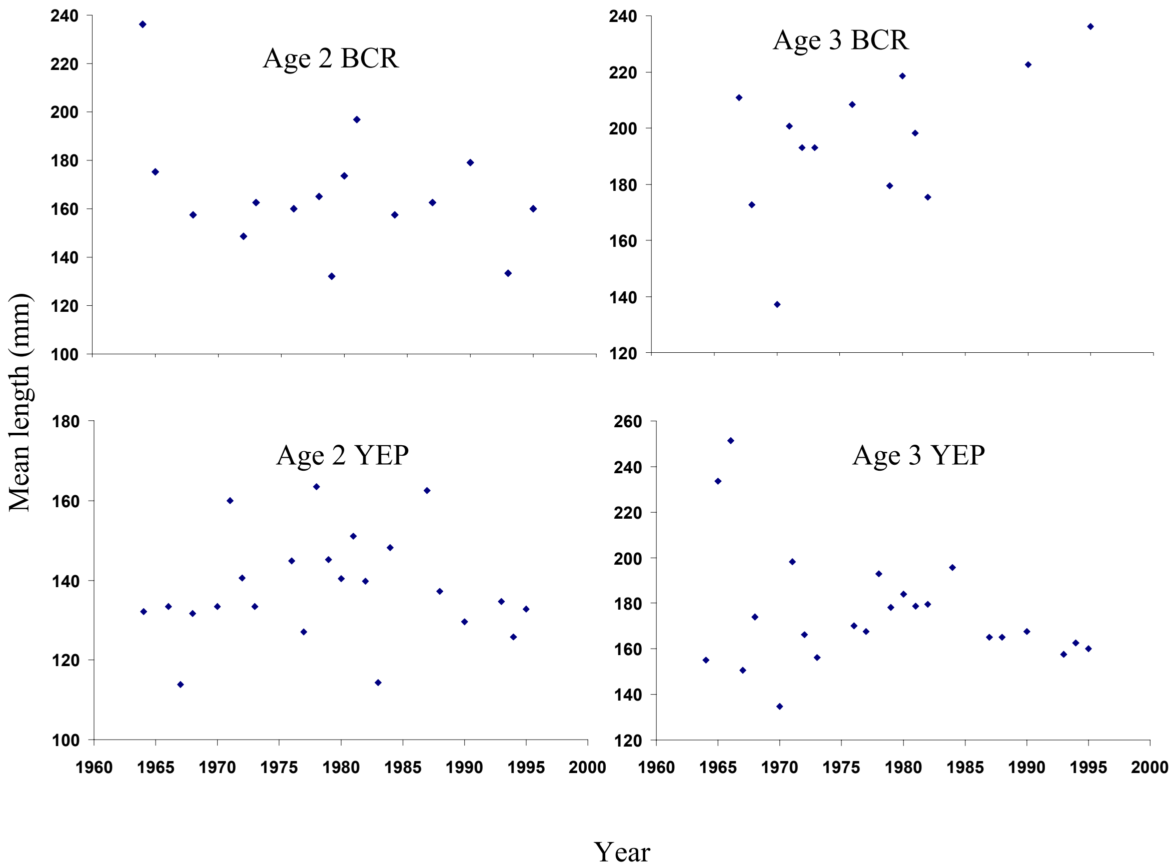

Figure 2.–Mean length at age for ages 2 and 3 black crappie (BCR) and yellow perch (YEP) versus time. Please note different Y-axis scales.

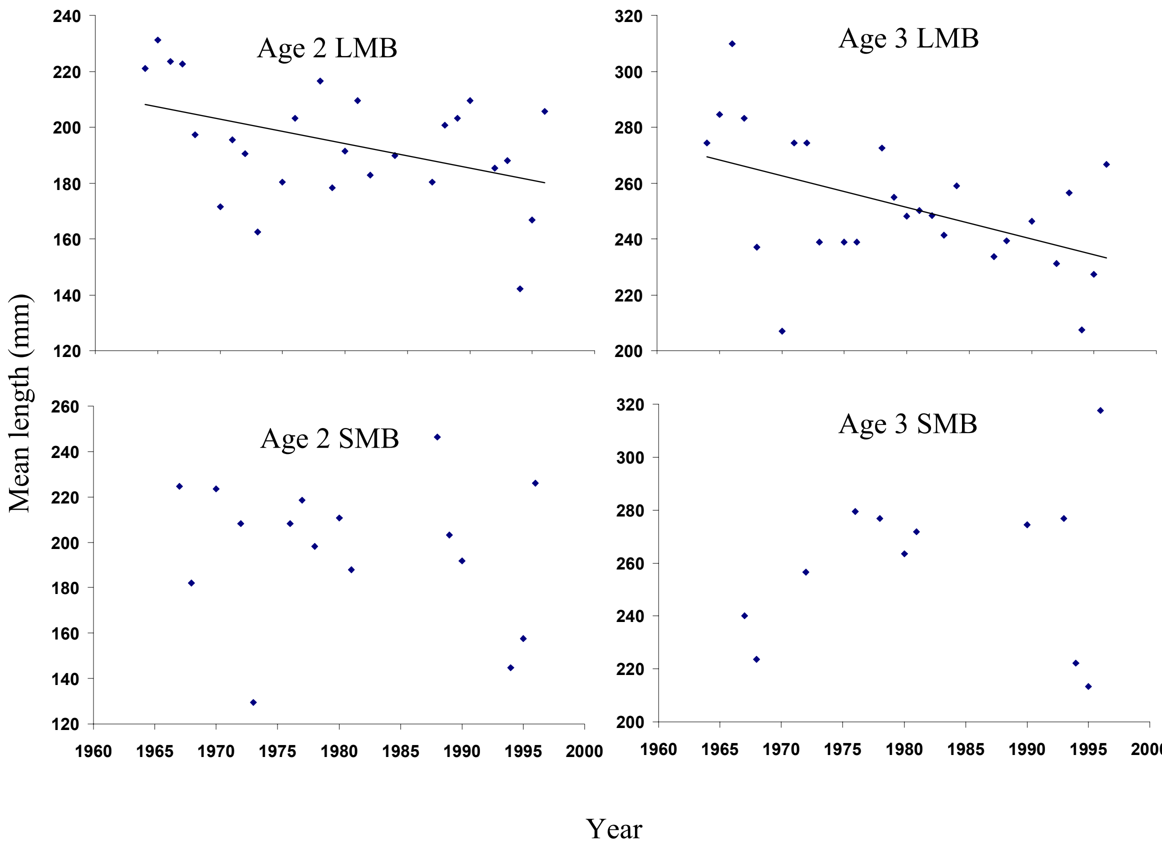

Figure 3.–Mean length at age for ages 2 and 3 largemouth bass (LMB) and smallmouth bass (SMB) versus time. Please note different Y-axis scales.

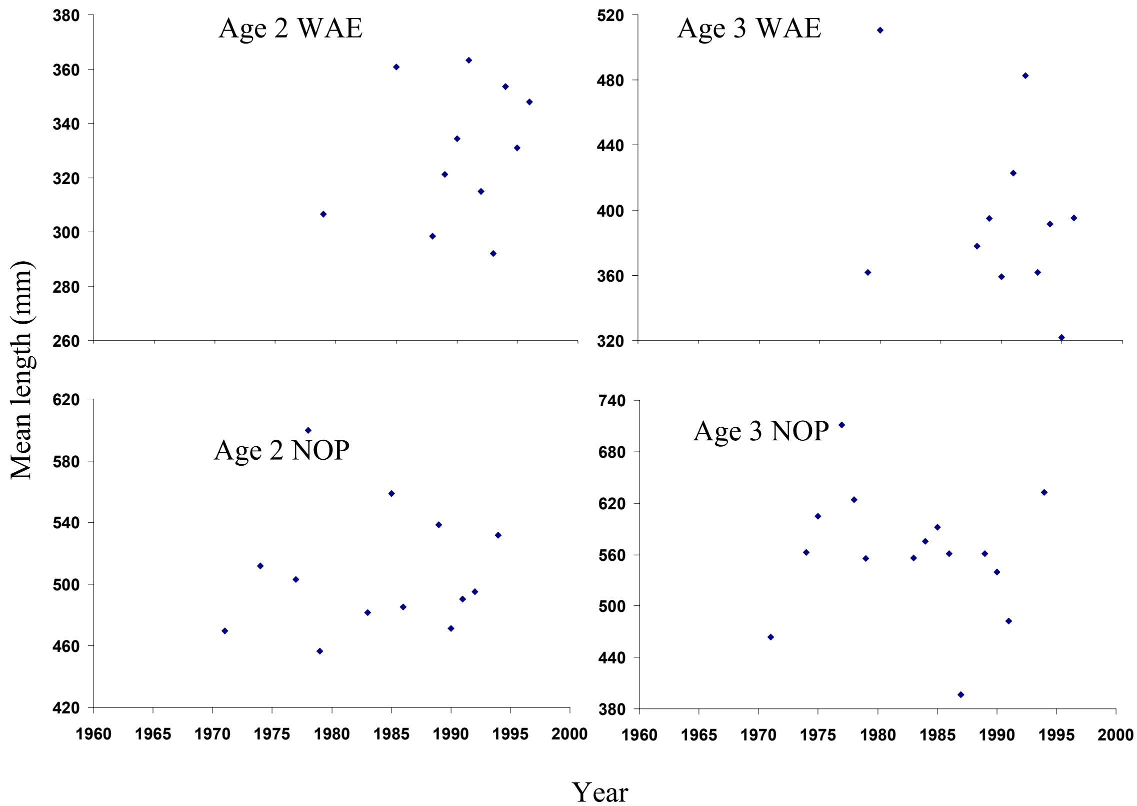

Figure 4.–Mean length at age for ages 2 and 3 walleye (WAE) and northern pike (NOP) versus time. Please note different Y-axis scales.

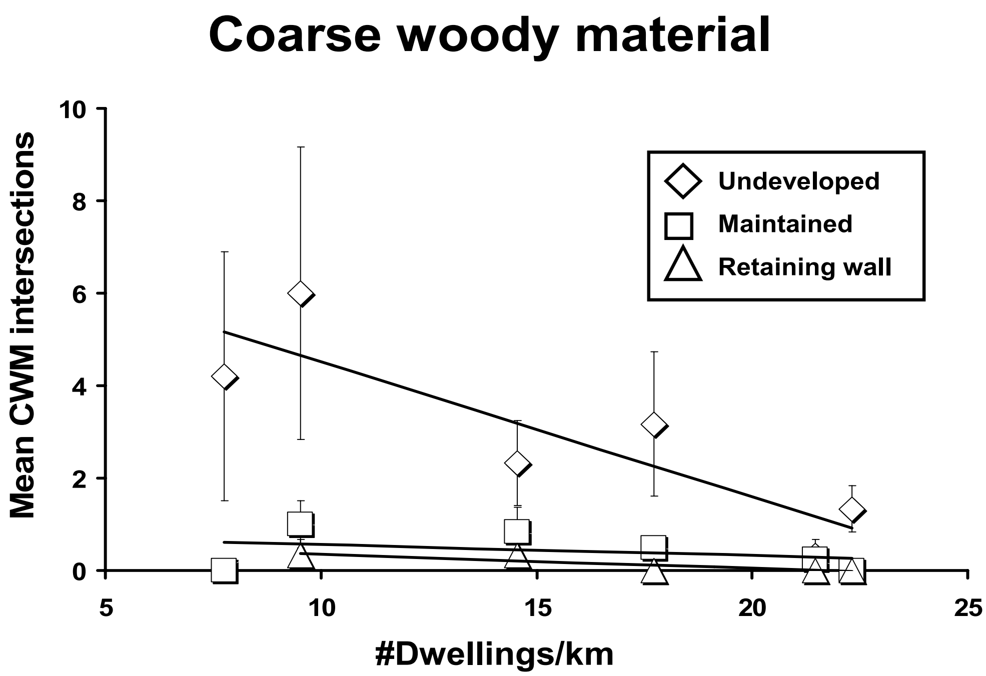

Figure 5.–Coarse woody material intersections (>5cm in diameter) for three different levels of shoreline modifications in six study lakes. Survey sites were 40m long and conducted parallel to shore, at the 0.5m depth contour.

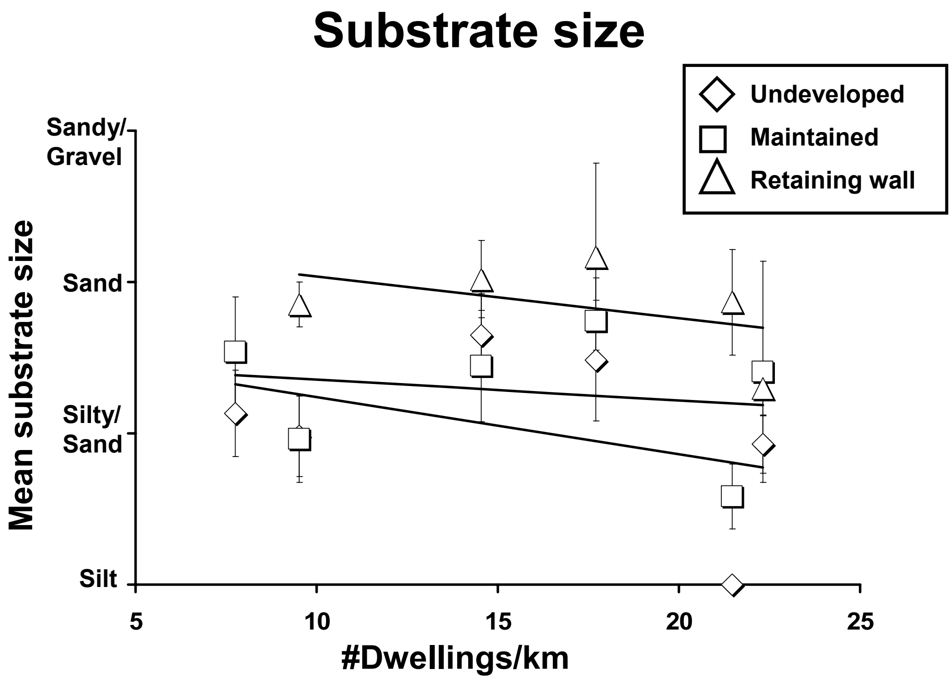

Figure 6.–Substrate size for three different shoreline modifications in six study lakes. Survey sites were 40m long and conducted parallel to shore, at the 0.5m depth contour.

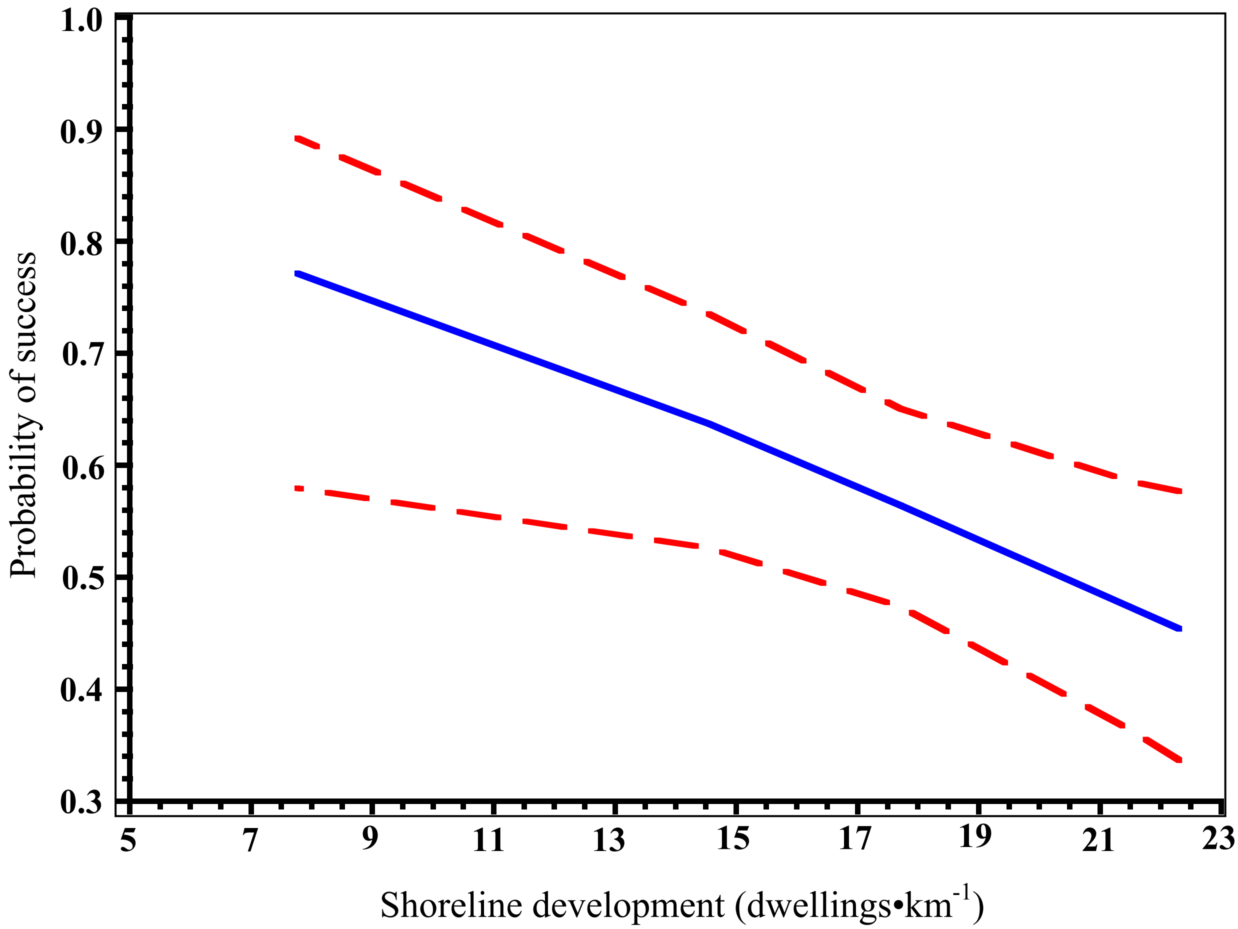

Figure 7.–Predicted probability of success (solid line) and 95% confidence intervals (dashed line) for black bass nests in relation to residential shoreline development.

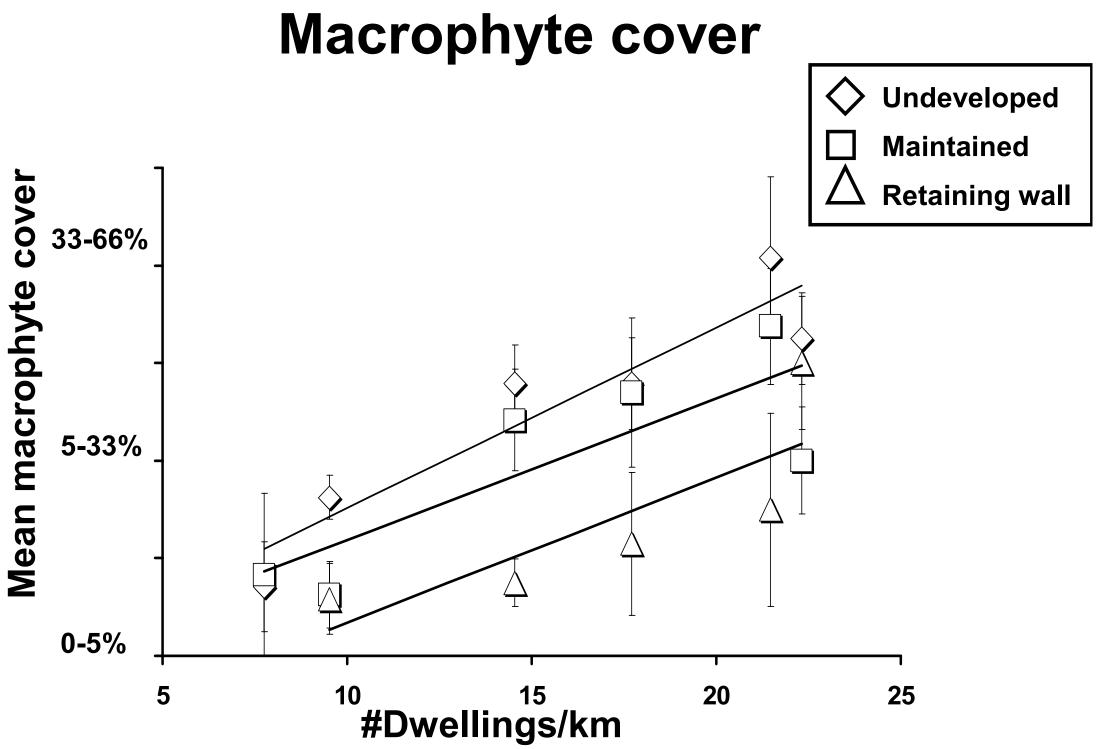

Figure 8.–Macrophyte cover for three different shoreline modifications in six study lakes. Survey sites were 40m long and conducted parallel to shore, at the 0.5m depth contour.