STUDY PERFORMANCE REPORT

State: Michigan **Project No.:** F-80-R-8

Study No.: 230547 **Title:** Quantifying the effects of anthropogenic development on lake foodwebs.

Period Covered: October 1, 2006 to September 30, 2007

Study Objective: Specific objectives are to: (1) analyze and publish data from a field study of Michigan lakes evaluating if residential shoreline development affects fish assemblages and energy flow between benthic and pelagic food webs, using stable isotope analysis, and (2) analyze data from lake monitoring programs to (a) explore relationships between anthropogenic activities and biological status of lakes, and (b) identify ecologically meaningful metrics with statistical power to detect trends.

Summary: Progress has been made on many fronts. Regarding Objective 1 (jobs 1 and 2), sample preparation has progressed well and analysis is underway to evaluate if lake food web dynamics vary predictably with residential development levels, as assessed by stable isotope analysis. Regarding Objective 2 (jobs 3, 4, and 5) much progress has been made. Several publications are underway at various stages of the publication process, a new graduate student has joined the work, and additional pertinent data continue to be gathered and integrated into our growing database.

Findings: Jobs 1 through 6 were scheduled for 2006-07, and progress is reported below.

Job 1. Title: Prepare samples.–We directed our initial efforts in sample preparation towards developing procedures for preparing snail, mussel, and fish tissue samples for stable isotope analysis. Toward that end, we conducted preliminary analyses to determine if lipids needed to be removed from the tissue samples to produce reliable results. This analysis indicated that lipid removal was not warranted, thus streamlining our subsequent efforts. Snail, mussel, and fish samples have been prepared by first isolating the desired tissue (foot samples for snails and native mussels, dorsal fin and muscle plug samples for fish, and the entire body contents (without shell) for zebra mussel), drying the tissue, grinding it with mortar and pestle until homogenized, and then weighing a standard amount into a small tin capsule. Samples are then sent to a lab for analysis of carbon and nitrogen stable isotopic signatures. To date we have data for 197 samples, representing roughly 5 samples per targeted taxa (snail, native mussel or zebra mussel, black bass, bluegill sunfish, and pumpkinseed sunfish) for each of 8 lakes.

Job 2. Title: Analyze isotope data.–As expected, snails, representing the isotopic signature for benthic production, were less depleted in the heavy C isotope than were mussels, representing the isotopic signature of pelagic production (Figure 1). Also, in Bruin Lake, our lowest development lake and the only lake that contained both the native mussel and the invasive zebra mussel, the carbon isotopic signature for these two indicators of pelagic production were extremely similar, indicating that the particular species of mussel present in each of our lakes does not bias our findings. Relative differences in N isotopic signatures between snails and mussels were less consistent across lakes (Figure 2). In some lakes snails were more depleted in the heavy N isotope, whereas in other lakes mussels were more depleted. Overall, we did not see a consistent relationship between N isotopic composition and dwelling density. (Increasing delta N values can be indicative of increasing human sewage in waters.) Our findings for nitrogen demonstrate why it is inappropriate to assume a constant baseline value across lakes for estimating trophic position of consumers. Rather, variation among lakes in baseline isotopic signatures must be taken into account when estimating trophic position of consumers or the relative contribution of various energy sources (i.e., benthic versus pelagic production) to fish diets. For the most part, our estimates of the proportion of fish production supported by benthic primary production ranged between 0 and 1, as would be expected (Figure 3). However, some estimates fell outside this range (both above and below) indicating that the use of snails and mussels as benthic and pelagic production baselines may not adequately capture the variation among prey isotopic values that occurs in these lakes. For example, in Bruin Lake, our lowest dwelling density lake, our estimate of the proportion of bluegill production (based on tissue content) supported by benthic production exceeded 1.0 because our bluegill tissue samples were less depleted in the heavy C isotope than were our snail samples. This could indicate that snails are not representative of the isotopic signal of all benthic prey. Snails are typically used as the benthic baseline in these sorts of studies because of their tendency to feed on periphyton (benthic primary producers). However, some snails are also known to feed on decomposing animal matter, which could result in an isotopic signature not fully representative of benthic primary production. It is more difficult to hypothesize as to why two situations resulted in an estimate of benthic contribution to fish diet being less than 0. In these cases, fish tissue was more depleted in heavy carbon than were the mussel tissue samples. Small sample size may play a role in these results and we are currently conducting more analyses to increase our sample size. We did not see a consistent relationship between proportion of fish production supported by benthic production and lake dwelling density. Similarly, we did not detect a relationship between fish trophic position and dwelling density, even though substantial variation occurred among lakes for each fish species (Figure 4). As expected, trophic position estimates for black bass, typically the top predators in north temperate lakes in this region, were higher than trophic position estimates for bluegill and pumpkinseed sunfish.

Job 3. Title: <u>Collect biological data from monitoring programs.</u>–We have made progress gathering biological data from monitoring programs in 6 northeastern states. For these states, we have a growing database that includes water chemistry data for approximately 2500 lakes, as well as landscape data including regionalization frameworks (e.g., ecoregions or hydrologic units), lake morphometry (i.e., area and depth), lake origin (natural or impoundment), lake hydrology (e.g., seepage versus drainage), lake catchment characteristics (e.g., catchment size), and anthropogenic factors (e.g., human population density, as well as agricultural and urban land use in the catchment). This year we focused our efforts on obtaining data on lake fish assemblages in these states. Our emphasis is on amassing data on fish species composition and relative abundance. To date, we have data for 127 lakes in Iowa (collectively containing ~45 fish species), 2073 lakes in Maine (collectively containing ~55 fish species), 98 lakes in Michigan (collectively containing ~80 fish species), and 472 lakes in Wisconsin (collectively containing ~90 fish species). We determined that fish data available for Ohio do not meet the needs of this project (only sport fish were collected). We are still in the process of gathering fish data for New Hampshire lakes. We have also assessed the availability of zooplankton data for lakes in these states and will continue with those efforts into the coming year.

Job 4. Title: <u>Assess biological condition gradients.</u>–We have been reading the literature and conducting preliminary analyses in this area, but the bulk of the analyses will occur after the data collection has been completed.

Job 5. Title: Coordinate variance components analysis.–We have been reading the literature and conducting preliminary analyses in this area, but the bulk of the analyses for the six state database will occur after the data collection has been completed. This year we published findings (see Job 6) from analyses conducted on Michigan and Wisconsin data regarding fish size at age. This manuscript identified unique patterns of variance components between the two states, with important implications regarding the statistical power of monitoring programs to detect changes over time in fish size at age.

Job 6. Title: Prepare annual report and publications.–This report was completed. In addition, the manuscript, "An empirical evaluation of the nutrient-color paradigm for lakes," is being reviewed for publication in Limnology and Oceanography. Findings for Job 5 are being published as "Regional trends in fish mean length at age: components of variance and the power to detect trends" in the *Canadian Journal of Fisheries and Aquatic Sciences*.

Prepared by: Mary Bremigan
Date: September 30, 2007

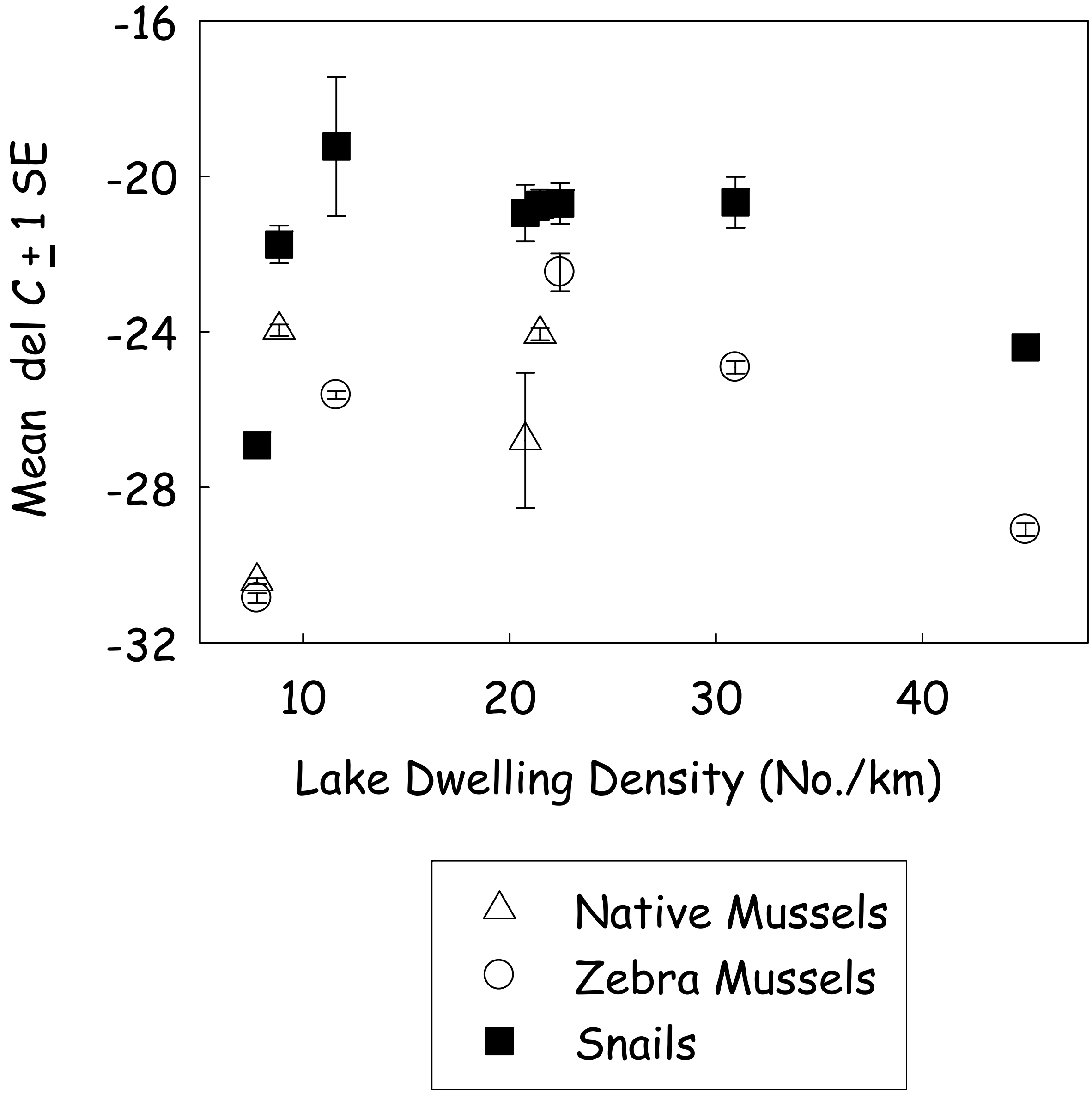

Figure 1.–Carbon isotopic signatures for snails, native mussels, and zebra mussels in eight southeastern Michigan lakes samples during summer 2006. Lakes are ordered according to increasing dwelling density (number of dwellings per km of shoreline). 'Del C' refers to the stable carbon isotope ratio or $\delta^{13}C$ which is defined as parts per thousand deviation from a standard material, i.e., $([R_{sample}/R_{standard}]-1)x1000)$ where $R={}^{13}C/{}^{12}C$.

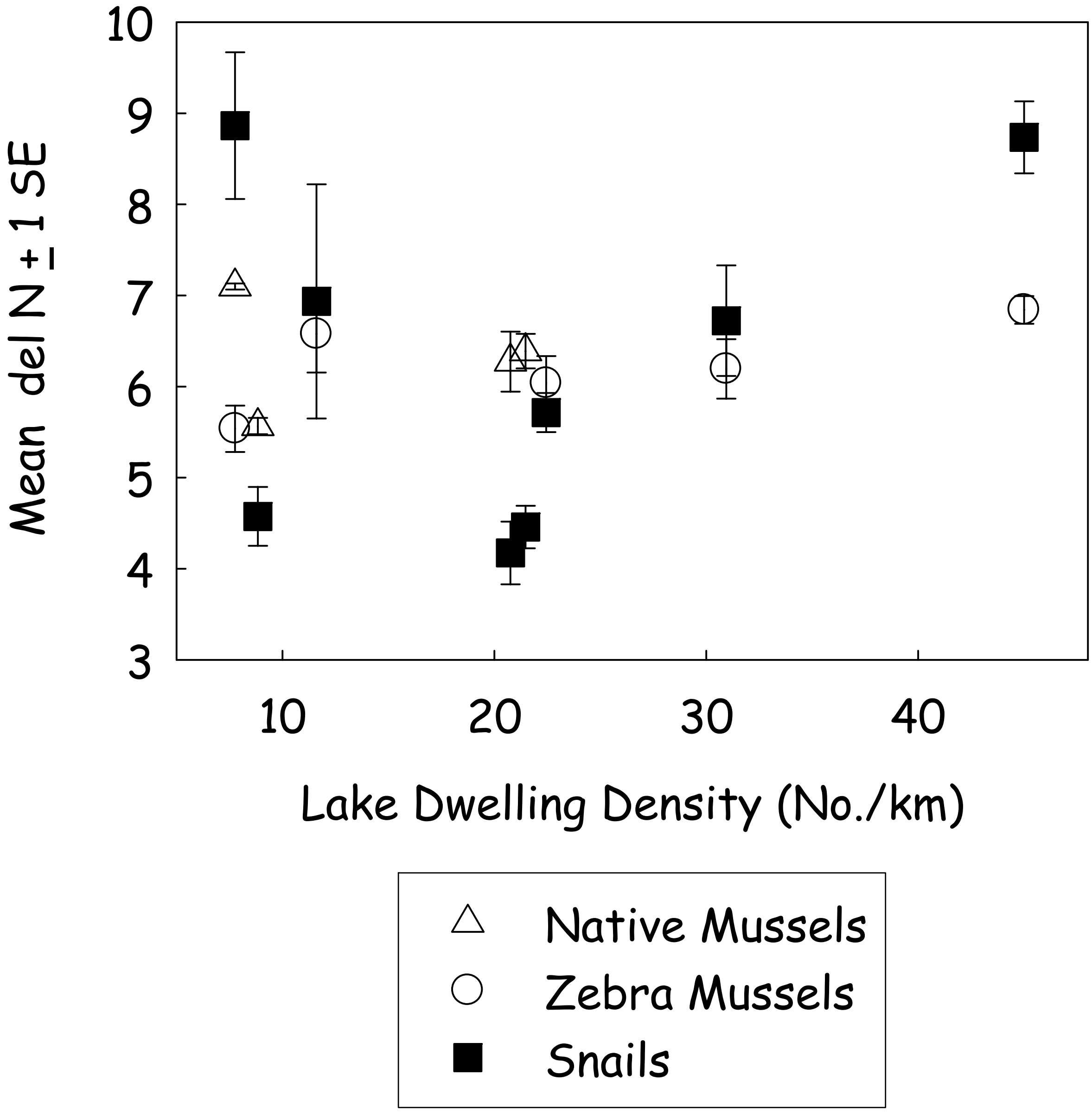

Figure 2.–Nitrogen isotopic signatures for snails, native mussels, and zebra mussels in eight southeastern Michigan lakes samples during summer 2006. Lakes are ordered according to increasing dwelling density (number of dwellings per km of shoreline). 'Del N' refers to the stable nitrogen isotope ratio or $\delta^{15}N$ which is defined as parts per thousand deviation from a standard material, i.e., $([R_{sample}/R_{standard}]-1)x1000)$ where $R={}^{15}N/{}^{14}N$.

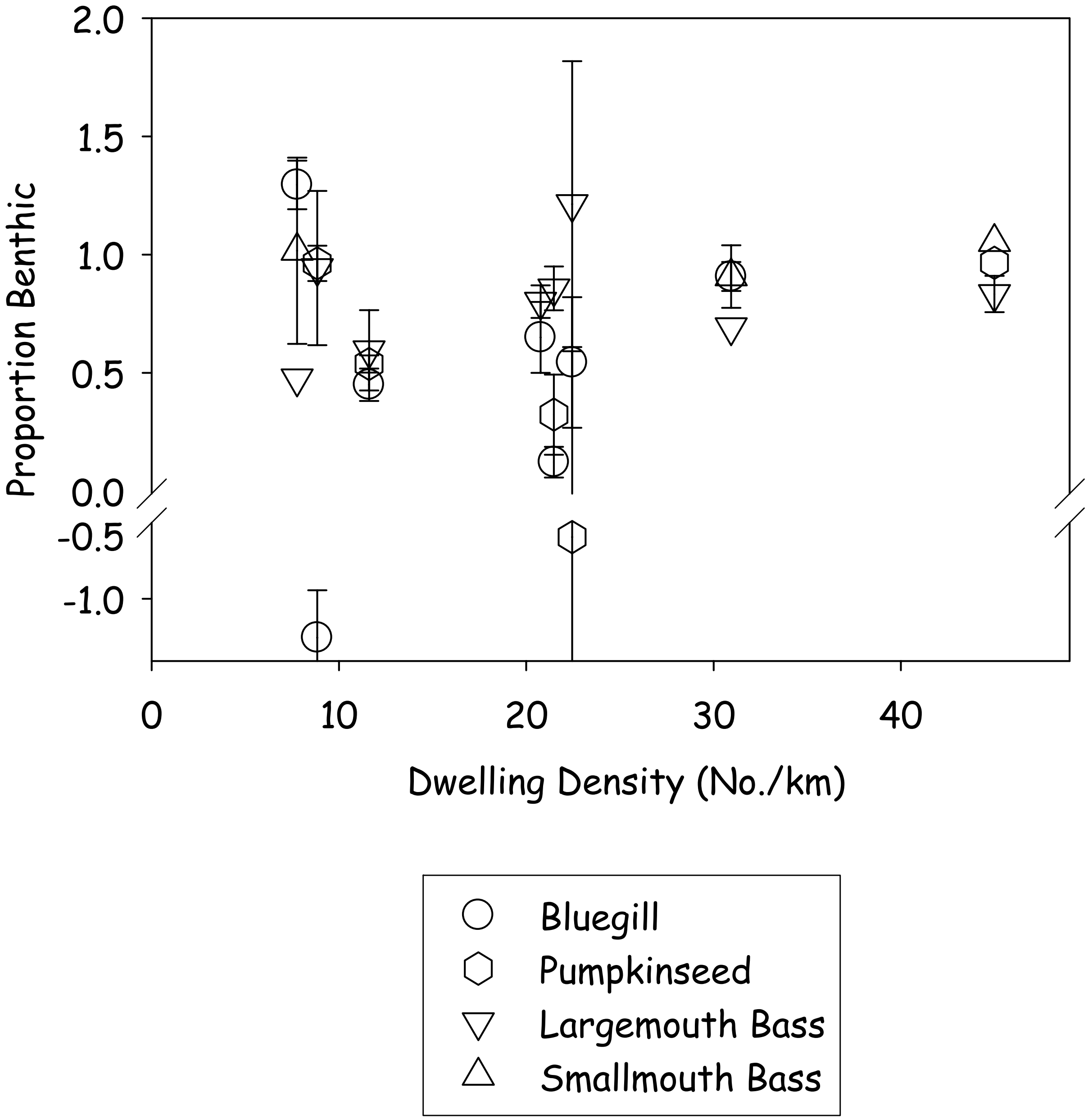

Figure 3.–Estimated proportion benthic contribution to fish production (tissue composition) for four species of fish in eight southeastern Michigan lakes. Proportion benthic was calculated by comparing $\delta^{13}C$ values for fish to values for snails (benthic production baseline) and mussels (pelagic production baseline) using the equation: proportion benthic = $(\delta^{13}C_{fish} - \delta^{13}C_{mussels})/(\delta^{13}C_{snails} - \delta^{13}C_{mussels})$.

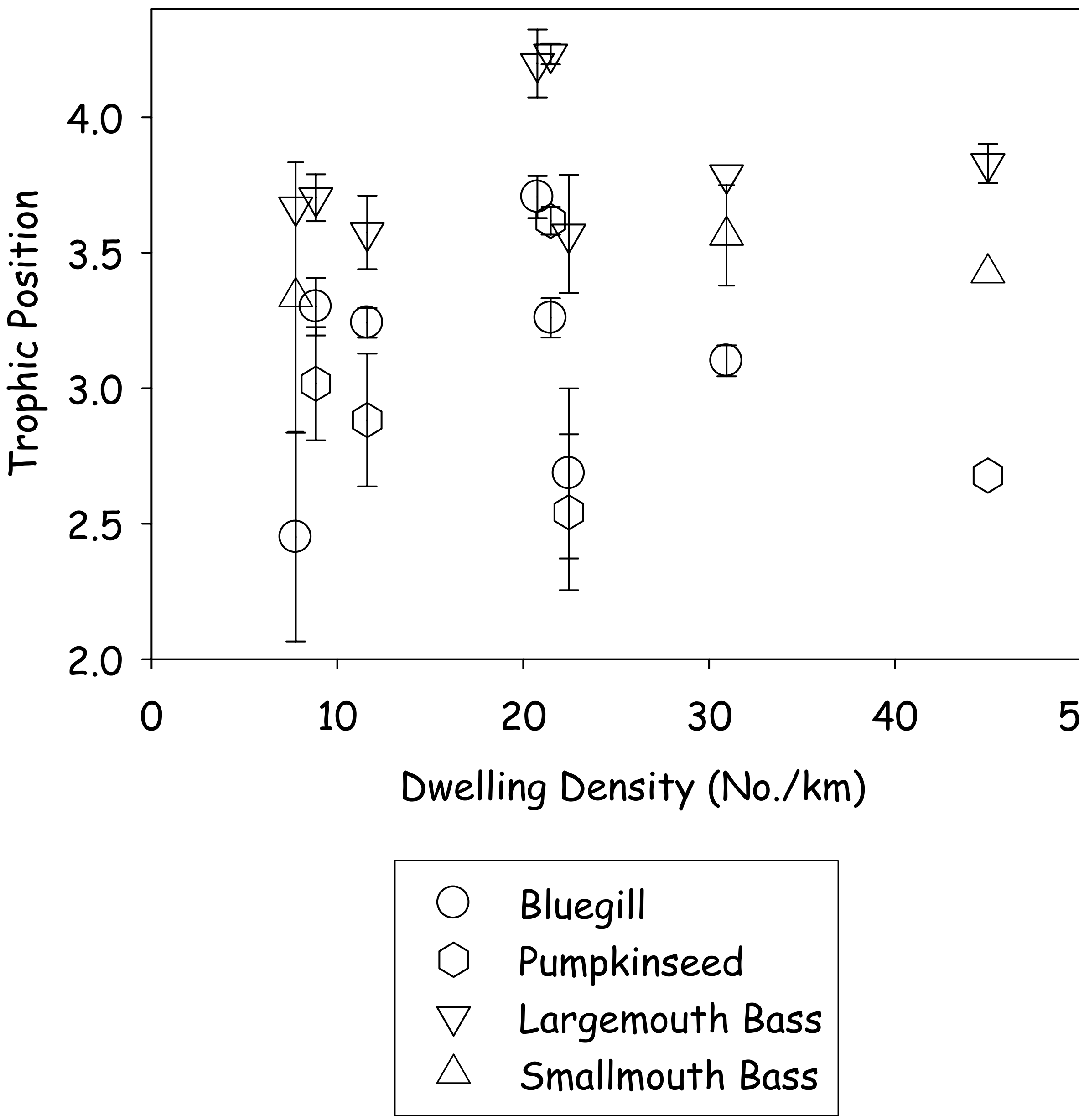

Figure 4.–Estimated trophic position for four species of fish in eight southeastern Michigan lakes. Trophic position was calculated by comparing $\delta^{15}N$ values for fish to values for snails (benthic production baseline) and mussels (pelagic production baseline) using the equation: trophic position = $((\delta^{15}N_{fish} - \delta^{15}N_{baseline})/3.4)+2$.