The Homogenizing of Minnesota Lake Fish Assemblages

By Paul J. Radomski and Timothy J. Goeman

ABSTRACT

The loss of unique fish assemblages in Minnesota lakes was evaluated by comparing species presence in historical and most-recent surveys of both stocked and unstocked lakes. Fish stocking resulted in greater species richness but reduced fish assemblage diversity among stocked lakes. No significant changes occurred among unstocked lakes. Short-term goals of additional fishing opportunities were partially achieved through stocking by creating more opportunities to fish for walleye in more lakes. However, the resulting loss of fish assemblage diversity within a local management area was apparently not considered. Fisheries managers should consider the potential for loss of community diversity and preserve unique fish communities where they still exist.

F isheries biologists have initiated steps to protect biodiversity by counteracting forces acting on imperiled species (Moyle and Yoshiyama 1994; Warren and Burr 1994). However, other kinds of diversity also need to be addressed, especially in management areas with no endemic species. Diversity can be defined two ways (Cairns and Lackey 1992): α-diversity (the number of species in a specific area) and β-diversity (the turnover of species across space or between-habitat diversity). *Community diversity*, as measured by β-diversity indices, refers to the variability of communities within a region.

Community diversity in natural lakes is related to drainage patterns, drainage connectivity, physical barriers to migration, local species richness, habitat diversity, and interspecific interactions (Barbour and Brown 1974; Tonn and Magnuson 1982; Minns 1989). In addition, anthropic factors such as species introductions, transfers, and habitat alteration and degradation also affect community diversity.

Many human factors contributing to the loss of diversity are beyond the control of the local fisheries manager since many problems relate broadly to human culture and activities; other losses stem from purposeful management actions that may have unexpected consequences. Fish stocking is one such activity that has only recently been evaluated in a broader ecological context.

Stock transfers may decrease genetic diversity within the recipient stock, which would reduce that stock's adaptive capability (Philipp et al. 1993). Fish stocking may have effects on diversity beyond the species' gene pool. Introductions may harm diversity and stability of fish communities by increasing the rate of species immigration and extinction (Magnuson 1976).

Our objective was to quantify changes in fish assemblage diversity during a 50-year period when central Minnesota lakes were actively managed for recreational fishing by the Minnesota Department of Natural Resources (MDNR). Additionally, we examined the implications and broader ecological effects on β-diversity.

Methods

Lentic fish assemblages in the Brainerd, Minnesota, area (Fig. 1) were compared during two periods. Of the area's 300 natural lakes, 70% had been stocked. Fifty-four

stocked lakes had a MDNR fisheries survey conducted from 1940 to 1955 and 1985 to 1992, with a mean time between surveys of 43 years. The median number of years stocked per lake between the earliest and most recent survey was 10 (range: 1–46). Most of the 54 lakes also were stocked prior to being surveyed; however, documentation of stocking was poor before 1940. Stocked lake differences in assemblage similarity and species richness between the two periods were compared to differences in unstocked lakes between the first and last surveys. Eighteen unstocked lakes had at least two surveys, with the mean time of 22 years between the first and last survey. Although the stocked lakes were generally larger than the unstocked lakes, the lakes had similar geomorphological characteristics.

The MDNR has been conducting fisheries surveys using standard experimental gill nets since the late 1930s. Moyle and Burrows (1954) and Scidmore (1970) documented the procedures for gill net sampling. Gill nets of linen mesh were used until the 1960s, after which multifilament nylon gill nets were used. The differences in catch efficiencies between linen and nylon gill nets varied by species (Scidmore and Scheftel 1958); thus, fish assemblage comparisons were made using species presence and absence. We compared the first and

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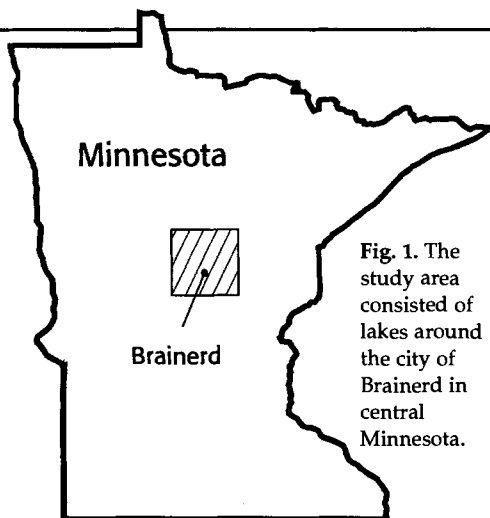
Brainerd

Fig. 1. The study area consisted of lakes around the city of Brainerd in central Minnesota.

last survey for both stocked and unstocked lakes and assumed that the standard sampling, which involved similar effort in both surveys, equally defined species richness.

We calculated a matrix of similarities among stocked and unstocked lakes for each period to test for changes in β-diversity. We used Jaccard's similarity index (Pielou 1984), which ranges from 0 (no species in common) to 1 (identical species lists). Significant differences in similarity values (Wilcoxon rank sum test) and species richness (number of species; Wilcoxon signed rank test) between periods were examined.

To determine which species maximized differences between periods in stocked lakes, we constructed null data sets. For the matrix of presence/absence data with rows representing lakes in both periods (two rows for each lake) and columns representing species, the null data set and quantities of interest were calculated as follows: (i) shuffle the rows (a survey for a lake) into a period randomly, with half the surveys in each period; (ii) for each species, count the number of lakes with species present in each assigned period and calculate the difference between these two values; (iii) repeat steps i and ii 100 times and then for each

species determine the probability that the difference was greater than or equal to (or less than or equal to) the original difference in the number of lakes with the species present between periods. In other words, was the difference greater than random? In addition, to test if the co-occurrence of two species was independent, we used the chi-square test statistic. Correlation analysis was used to test for a relationship between years of stocking and species richness. The level of significance for all tests was $P = 0.05$.

Changes in the Fish Assemblages

Changes in the distribution of similarity values between periods represent changes in diversity of communities within an area. Higher similarity values indicate an increase in the predictability of species composition and the number of ubiquitous species. The distributions of fish assemblage similarities between periods were different for stocked lakes ($P < 0.05$; Fig. 2) but not for unstocked lakes ($P > 0.05$). For stocked lakes, fish assemblages were more similar in the recent period than they were earlier. The decrease in β-diversity coincided with extensive fish stocking.

Species richness was significantly greater in the recent surveys for stocked lakes ($P < 0.05$). No significant difference was found in species richness between surveys in unstocked lakes ($P > 0.05$). Most stocked lakes increased their richness by one to three species (Fig. 3). Recent species richness in stocked lakes was positively correlated with the number of years stocked ($P < 0.05$, Fig. 4). The more often a lake was
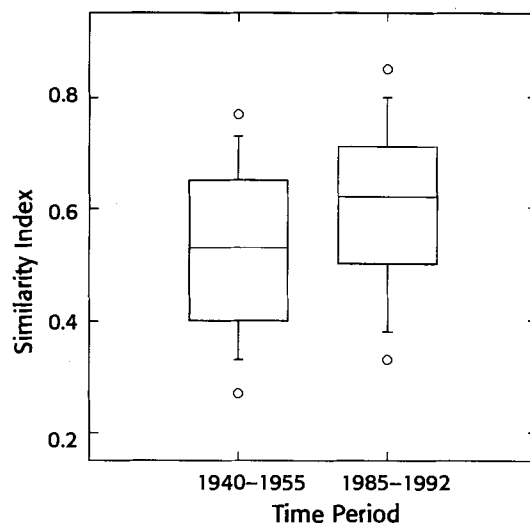

Fig. 2. Fish assemblage similarities were derived for 54 stocked lakes and 18 unstocked lakes in first and last surveys. Data are median (solid horizontal line), 25th and 75th percentiles (box), 10th and 90th percentile (capped vertical lines), and 5th and 95th percentile points (circles).

stocked, the greater the chance it had high species richness. Also, partial correlations of the number of years stocked with the number of species gained between surveys and the difference in species richness between surveys, controlling for the effect of lake surface area, were significant ($P < 0.05$).

Simulation results were used to determine which species contributed most to the differences in fish assemblage similarity and species richness in stocked
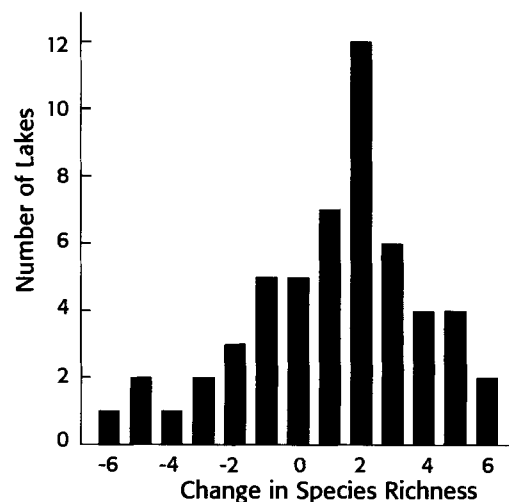

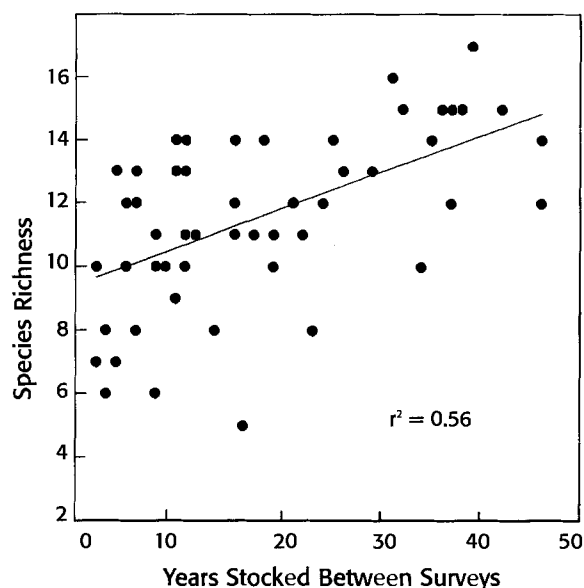Fig. 3. Stocked lakes were evaluated by changes in species richness between time periods.

Fig. 4. Number of years stocked between surveys was compared to species richness at last survey for 54 lakes.
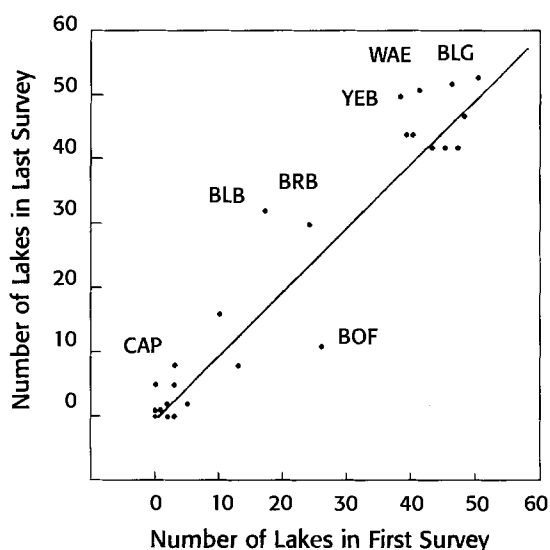

Fig. 5. Species presence in first survey (x-axis) was plotted against the last survey (y-axis) for stocked lakes. Significant differences of the following species were noted: BLG = bluegill, WAE = walleye, YEB = yellow bullhead, BRB = brown bullhead, BLB = black bullhead, BOF = bowfin, and CAP = carp. Points above the line correspond to an increase in occurrence and points below the line to a decrease in species occurrence.

favorite sportfish in the area and were stocked in most lakes. Walleye are typically raised to fingerling size in natural ponds and then harvested and stocked into area lakes. Using this technique, there is a substantial, though undocumented, transfer of nontarget species, including ictalurids and centrarchids (Tim Rosinger, MDNR, personal communication). In these lakes, walleye and black bullhead (*Ictalurus melas*) were significantly associated with each other ($P < 0.05$).

Fisheries Management Objectives and Implications

An implicit objective of inland recreational fisheries management is better angling or at least more angling opportunity (Heidinger 1993). The last 50 years of stocking in central Minnesota lakes likely had this same objective, though no explicit historical documentation is available. Although fish management agencies probably attempted to increase α-diversity, we doubt that they specifically attempted to decrease β-diversity. However, the cumulative effects of several decades of fisheries management with an emphasis on stocking resulted in changes beyond those original objectives. Because management in this area was not unique in the state or the region, β-diversity has probably decreased across a large geographical area.

The association between changes in fish assemblage diversity and stocking does not conclusively prove cause-and-effect. Other pressures—development, bait bucket discharges, pollution, habitat alteration, and eutrophication—have also occurred in the area, but these pressures were similar in both stocked and unstocked lakes. Although stressed ecosystems may be less resistant to species invasions (Pimm and Hyman 1987), our results suggest that extensive, well-intentioned fish transfer played an important role in this homogenizing

process. Magnuson (1976) also cited stocking as a major factor in altering species richness in Lake Wingra, Wisconsin. His discussion of island biogeography indicated that human actions would reduce the isolation of lakes. In Minnesota, this reduced isolation translated to fewer unique fish assemblages.

The broad objective of stocking to produce better fishing was partially successful. Walleye stocking provided some additional recreational fishing opportunity, but only a small portion of Minnesota's total walleye harvest (roughly 4%) can be attributed to any stocking (Dennis Schupp, MDNR, personal communication). The underlying question is whether this increase in harvest and fishing opportunities justified broad changes in fish communities and the loss of β-diversity.

We suspect that highly visible and widespread stocking programs have altered angler expectations (Hudgins and Davies 1984; Spencer 1993). This could explain the constant public demand for walleye stocking in Minnesota, even in lakes not well-suited for such management. Even close proximity to excellent natural walleye lakes does not satiate the desires of many anglers for more walleye stocking in their favorite lakes. This demand has been created by historical management practices. Many recreational anglers are neither aware of nor concerned about a loss in β-diversity. Rather, extensive stocking has clouded public understanding of the more beneficial resource management priorities such as habitat protection and restoration. For many anglers, high-profile activities such as stocking appear more important than less visible but more effective long-term initiatives.

The cost of providing additional opportunity and a small increase in harvest has never been fully assessed in Minnesota and likely is not possible. The calculated cost of US$0.24 per walleye fingerling (Paul J. Wingate,

lakes. Results from the simulation indicated that six species were significantly more common recently, and one species was less common ($P < 0.05$, Fig. 5). Walleye (*Stizostedion vitreum*), bullhead (*Ictalurus* spp.), bluegill (*Lepomis macrochirus*), and carp (*Cyprinus carpio*) were more likely to be present in a stocked lake now than in the 1940s, and bowfin (*Amia calva*) were collected less often than before. Walleye are a

MDNR, personal communication) accounts only for immediate production and stocking costs and does not consider more long-term ecological consequences nor the value of diversity. Typically, ecological values are difficult to quantify and are often ignored because they cannot be placed on a cost-benefit balance sheet. However, our results demonstrate that potential changes in fish community diversity within a management area should be considered when planning stocking activities. Fisheries managers should consider the value of β-diversity (i.e., unique lakes) and be cognizant of management activities that may irreversibly alter this diversity. This is not a call for fisheries managers to stop stocking but to preserve unique fish assemblages where they still exist. ⟫➤

References

Barbour, C. D., and J. H. Brown. 1974. Fish species diversity in lakes. Am. Nat. 108:473–489.

Cairns, M. A., and R. T. Lackey. 1992. Biodiversity and management of natural resources: the issues. Fisheries 17(3):6–10.

Heidinger, R. C. 1993. Stocking for sport fisheries enhancement. Pages 309–333 *in* C. C. Kohler and W. A. Hubert, eds. Inland fisheries management in North America. American Fisheries Society, Bethesda, MD.

Hudgins, M. D., and W. D. Davies. 1984. Probability angling: a recreational fishery management strategy. N. Am. J. Fish. Manage. 4:431–439.

Magnuson, J. J. 1976. Managing with exotics—a game of chance. Trans. Am. Fish. Soc. 105:1–9.

Moyle, J. B., and C. R. Burrows. 1954. Manual of instructions for lake survey. Minnesota Dept. Natural Resources, Div. Fish Wildl. Sect. Fish. Spec. Publ. No. 1.

Minns, C. K. 1989. Factors affecting fish species richness in Ontario lakes. Trans. Am. Fish. Soc. 118:533–545.

Moyle, P. B., and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries 19(2):6–18.

Philipp, D. P., J. M. Epifanio, and M. J. Jennings. 1993. Point/counterpoint: conservation genetics and current stocking practices—are they compatible. Fisheries 18(12):14–16.

Pielou, E. C. 1984. The interpretation of ecological data. John Wiley & Sons, New York.

Pimm, S. L., and J. B. Hyman. 1987. Ecological stability in the context of multispecies fisheries. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2):84–94.

Scidmore, W. J. 1970. Manual of instructions for lake survey. Minnesota Dept. Natural Resources, Div. Fish Wildl. Sect. Fish. Spec. Publ. No. 1 (Revised).

Scidmore, W. J., and Z. Scheftel. 1958. Relative efficiency and selectivity of experimental nets of linen and nylon. Minnesota Dept. Natural Resources, Div. Fish Wildl. Sect. Fish. Fish Ser. 1:46–53.

Spencer, P. D. 1993. Factors influencing satisfaction of anglers on Lake Miltona, Minnesota. N. Am. J. Fish. Manage. 13:201–209.

Tonn, W. M., and J. J. Magnuson. 1982. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. Ecology 63:1149–1166.

Warren, M. L., and B. M. Burr. 1994. Status of freshwater fishes of the United States: overview of an imperiled fauna. Fisheries 19(1):6–18.