SPECIAL REPORT

Michigan Agricultural Experiment Station, Michigan State University

Status and Potential of Michigan Natural Resources

SAPMINR

Response of Fish and Wildlife Macrohabitat to Changes in Land Use and Land Cover

Final Report

March 2000 ■ Special Report 107

Reports on the Status and Potential of Michigan Natural Resources

This special research report is one of a series (listed on p. 3) prepared for a project of the Michigan Agricultural Experiment Station (MAES) called the Status and Potential of Michigan Natural Resources (SAPMINR).

The project, funded jointly by MAES and the Office of the Provost, was designed to inventory the current status of Michigan natural resources, identify emerging trends and appraise future opportunities. The purpose was to assist the MAES in establishing research priorities and planning programs.

Both overview and focused topic assessments have been made. The overview reports provide background information on the political, economic and social environments influencing Michigan natural resources. The focus reports examine specific resources, including timberland, fisheries and wildlife, parks and recreational, and land and water resources.

The SAPMINR project began in early 1993. At that time, interdisciplinary teams of MSU faculty members, graduate students, federal and state government officials, and others collaborated to develop preliminary reports. In March 1994, a SAPMINR conference during MSU's Agriculture and Natural Resources Week provided a public forum for discussion of the preliminary reports. Based on interaction with conference participants, the authors prepared the final drafts of the overview and focus reports listed below.

SAPMINR Reports

Overview Reports

SR 67 – SAPMINR Highlights
SR 68 – Michigan Natural Resources Policy
SR 69 – Demographic, Social and Economic Trends
SR 70 – Integrated Natural Resource Systems

Focus Reports

SR 71 – Timber and Timberland Resources
SR 72 – Lumber, Furniture, Composition Panels and Other Solidwood Products
SR 73 – Pulp, Paper, Allied Products and Wood Energy
SR 74 – Fisheries
SR 75 – Wildlife
SR 76 – Tourism
SR 77 – Boating and Underwater Recreation
SR 78 – Camping, Trails and Dispersed Recreation
SR 79 – Water Resources
SR 80 – Land Resources
SR 81 – Non-renewable Resources
SR 82 – Natural Resources and Communities

Once the trends and future opportunities were agreed upon, the MAES issued a call for research proposals to address issues and problems related to the highest priorities of Michigan's natural resources. Of the 38 pre-proposals received, the MAES selected 15 to be developed into full proposals. Ultimately, 10 were selected and funded at a total of almost $1.2 million over three years. The research findings of those SAPMINR projects were published as a series of Michigan Agricultural Experiment Station special reports (listed on p. 3)

To receive any of these SAPMINR research reports, contact the MSU Agricultural Experiment Station, 109 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039.

SAPMINR Research Projects – Published as Special Reports

SR 103 Perceptions, Preferences and Behaviors of Selected Outdoor Recreationists Concerning Michigan State Forest Campgrounds and Pathways

RR 568 The Role of Natural Resources in Community and Regional Economic Stability in the Eastern Upper Peninsula

SR 104 Spatial Distribution and Economic Impacts of Recreational Boating in Michigan

SR 105 Economic Consequences of Jack Pine Budworm Outbreaks

SR 106 Development of Methods and Guidelines for Local Wetland Protection and Related Land Use Planning

SR 107 Response of Fish and Wildlife Macrohabitat to Changes in Land Use and Land Cover

SR 108 Regional Michigan Travel Marketing Survey

SR 109 Foundations of Ecosystem Management: Integrating Sociological and Ecological Components

SR 110 Natural Resources and Tourism in Michigan: Potential Products, Satisfactions and Barriers

SR 111 Michigan's Mineral Wealth

SR 112 Waste: A Hidden Resource

SR 113 Hunting, Fishing and Wildlife-watching Expenditures in Michigan

SR 114 Michigan's Forest Products Industry

SR 115 Agricultural Production in Michigan

SR 116 Michigan's Tourist Industry

SR 117 Michigan's Natural Resources Endowment: A Summary

Acknowledgements

The authors of this report would like to thank all those who contributed to the SAPMINR projects and the final reports. Their efforts helped to produce the reports on a timely basis and contributed significantly to the success of the projects. In addition, we would like to thank the SAPMINR steering committee for its invaluable guidance and commitment to this endeavor. Finally, the authors would like to thank the staff of the MAES for their support and assistance throughout the SAPMINR process and ANR Communications for helping complete the reports in a timely fashion.

Response of Fish and Wildlife Macrohabitat to Changes in Land Use and Land Cover

Authors

Daniel Hayes, Kurt Newman, Daniel Rutledge, Jianguo Liu, Christopher Lepczyk

Department of Fisheries and Wildlife

and Richard Groop

Department of Geography and Center for Remote Sensing
Michigan State University
East Lansing, MI 48824

MICHIGAN AGRICULTURAL EXPERIMENT STATION
Michigan State University

J. Ian Gray, Director
Michigan Agricultural Experiment Station
109 Agriculture Hall
Michigan State University
East Lansing, MI 48824
(517) 355-0123

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Executive Summary

The human population in the counties encompassing the Huron River watershed grew from about 750,000 in 1940 to more than 2.5 million in 1990. As a result of this growth, agricultural land cover in the watershed declined substantially, and the area of urban and suburban land cover increased proportionately. Concurrent with these changes in agricultural and urban land cover, the area of watershed in forested, non-forested, wetland and water coverages has shown relatively little net change since 1938. These land covers have shown increased fragmentation, however. Changes in land cover and degree of fragmentation have direct effects on the suitability of land in this watershed to support wildlife species. In particular, species tolerant of human disturbance and species preferring edge habitats are favored; species sensitive to human intrusion and species preferring central habitats have been reduced. Changes in watershed land coverage also have had a significant impact on the Huron River and its tributaries. Water flows have increased as the amount of impervious land cover has increased. These increased flows pose significant problems to people living in the watershed and have likely altered stream fish habitat. The fish species diversity has dropped dramatically since 1938. Sites sampled in the late 1930s averaged nearly 14 fish species; those same sites sampled in 1996 averaged fewer than 4 species. Changes in land cover in the Huron River watershed will likely continue to be driven by increases in the human population or redistribution of current residents. Continued conversion of agricultural lands to urban or suburban uses and continued fragmentation of existing habitats will likely result in further degradation of terrestrial and aquatic habitats.

Environmental and Economic Benefits to Michigan

This project was designed to provide fundamental information on the degree of environmental change experienced in a large Michigan watershed. Data on changes in the human population are readily available, but documenting the impact of population growth on landscape characteristics is much more important in understanding alterations to environmental quality. In the Huron River watershed, the human population increased approximately threefold from 1940 to 1990, but the area encompassed by urban and suburban land covers increased more than fivefold. Coincident with these changes are clear trends in the aquatic ecosystem. Changes to flow regime have a substantial effect on the suitability of the environment to support productive and diverse aquatic resources and have substantial implications for the potential loss of human life and property. Though many of the fish species showing declines in the Huron River are not game fish, their loss is symptomatic of the environmental damage that has occurred in the watershed. The effects of changing land use patterns on wildlife have proven to be difficult to document; it is likely, however, that increased urbanization and fragmentation of non-urban habitats has decreased the wildlife productivity of the watershed.

Introduction

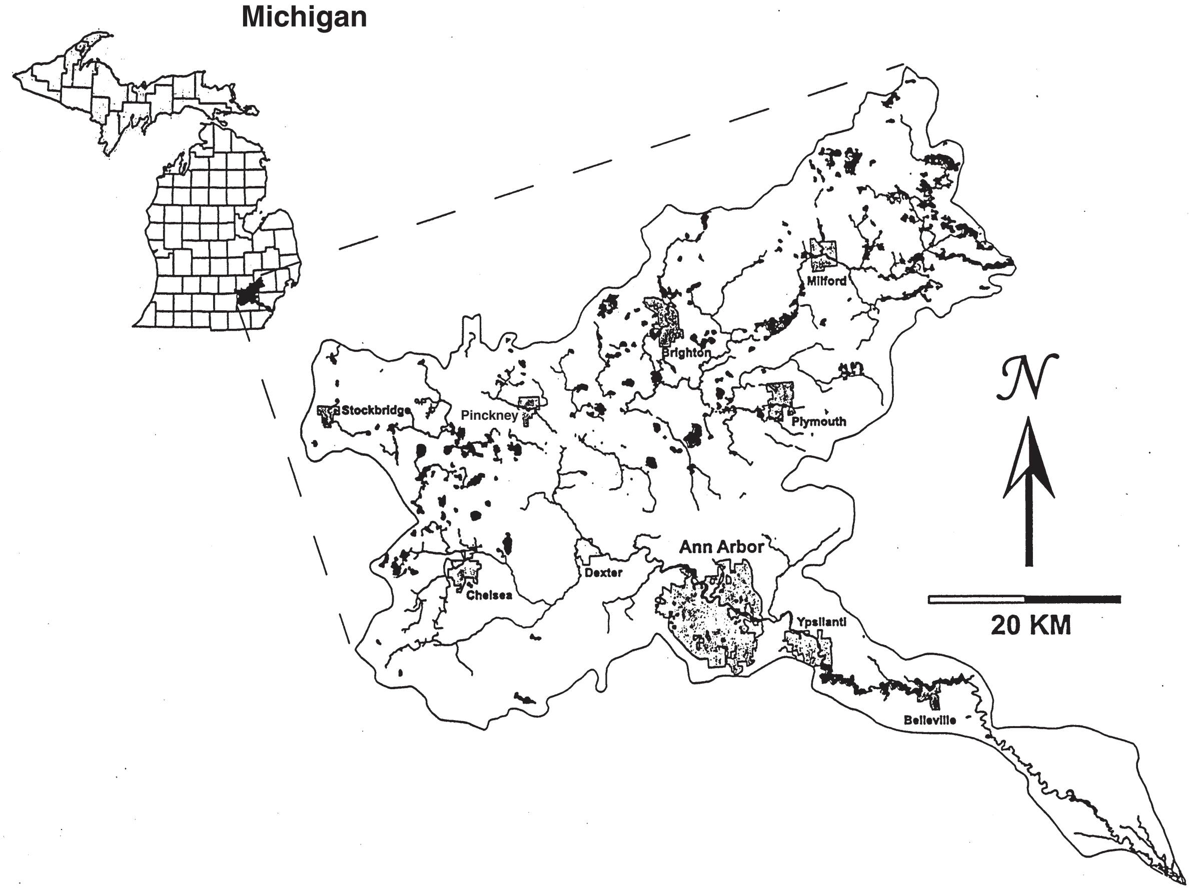
As the population of Michigan has grown over the past 150 years, so have the impacts of human land use on the natural vegetative cover of the landscape (Ferris and McVeigh, 1995). Though many studies have been conducted showing small-scale or short-term impacts of land cover change on fish and wildlife populations, few studies have been conducted evaluating the long-term impacts of these changes on a large scale. The negative effects of changing land use in Michigan on the quality of terrestrial and aquatic habitats were identified as a significant issue for fisheries (Garling et al., 1995), wildlife (Winterstein et al., 1995) and water resources (D'Itri et al., 1995) in the initial SAPMINR reports. Increases in urban land cover are of special concern because of the dramatic effects that urbanization may have on ecosystem functioning.

The goal of our research was to document how land cover has changed in the Huron River watershed (Figure 1) and to determine some of the impacts on fish, wildlife and water resources. Achieving this goal is of particular importance because the Michigan Department of Natural Resources is currently working toward implementing ecosystem management by taking a watershed approach. Our results will help managers accomplish ecosystem management objectives by providing concrete information on the linkages among land use, wildlife habitat and stream/watershed functioning. By providing information and new results and techniques to resource managers, we hope to improve environmental conditions for the citizens of Michigan, the ultimate beneficiaries of healthy ecosystems.

Objectives

- Project how land cover and land use have changed from presettlement to the present in the Huron River watershed.
- Determine how changes in historical land cover have affected the sediment transport rate and water flow regime in the Huron River.
- Determine the effect of land cover changes on the quality and quantity of wildlife habitat.
- Examine changes in the composition of the fish community that have occurred concurrently with changes in land cover, sedimentation and stream flow regime.

Figure 1. The Huron River watershed, Michigan.



Land Cover Changes

Procedures

Watershed boundaries were determined from 7.5-minute topographic maps available through the U.S. Geological Survey. Information on land cover from the presettlement period was provided through the cooperation of the Michigan Natural Features Inventory. Land cover was determined for five time periods following the presettlement period: 1938-1941, 1955, 1969, 1978 (1985 for Oakland, Livingston and Washtenaw counties) and 1992. Land cover for the first three of these time periods was determined by interpreting black and white aerial photographs obtained from the Center for Remote Sensing at Michigan State University. The 1978 and 1985 land cover was obtained from the Michigan Resource Inventory System (MIRIS) and was developed from color infrared aerial photography and ground verification. The 1992 land cover patterns were provided by the Huron River Watershed Council and were based on ground verification and interpretation of color aerial photography. All land cover patterns were digitized and analyzed with ARC/INFO software (Environmental Systems Research Institute).

Our land cover classification system consisted of seven general categories: urban, agriculture, non-forested (herbaceous and shrub cover), forested, water, wetlands and barren (beach, sand dune and exposed rock). Land cover patterns and watershed boundaries were treated as polygons. All digitized coverages were converted to a standardized geographic reference scale (Michigan State Plane North American Datum of 1927) to permit spatial overlays of any coverage type (i.e., polygon, line or point) during analyses.

Results

The Huron River watershed encompasses just over 236,000 hectares. During the presettlement period, the watershed was predominantly forested, with substantial areas of water and wetland. By the late 1930s, more than 50 percent of the watershed had been converted to agriculture (Table 1), and the percentage of forested land cover had been reduced to only 16 percent of the watershed. Since the 1930s, there has been a steady trend of declining agricultural land cover and increasing urban land cover. This trend is consistent with our initial prediction that the large increase in population in the

Table 1. Percentage of land cover types in the Huron River watershed.

	Presettlement	1938	1955	1969	1978	1992
Barren	0%	0%	0%	0%	0%	0%
Wetlands	12%	7%	7%	7%	7%	7%
Water	3%	4%	4%	4%	4%	4%
Forest	56%	16%	19%	19%	18%	17%
Non-forest	29%	11%	13%	18%	20%	18%
Agriculture	0%	56%	46%	34%	29%	27%
Urban	0%	5%	11%	18%	22%	27%

watershed would generate an increase in urban land cover, largely at the expense of agricultural land cover. Forested and non-forested land covers both increased from the 1930s to the mid-1960s but have declined slightly since then. Water area has increased slightly over time, likely because of the construction of dams and other water control structures.

In addition to changes in land cover, the mean sizes of patches within each land cover category have changed over time. Most striking is the decline in mean size of agricultural patches and the increase in mean size of urban land cover types (Table 2). With the exception of barren lands and wetlands, the mean patch size showed a net decline from 1938 to 1992. Although patch sizes have declined, these declines have not been as steady as for agricultural land covers.

Table 2. Mean patch size (hectares) for each land cover category in the Huron River watershed.

	1938	1955	1969	1978	1992
Barren	0.6	11.2	2.7	3.2	3.2
Wetlands	8.6	7.8	7.6	7.3	7.1
Water	15.6	15.8	14.5	14.2	13.8
Forest	12.6	14.7	15.5	14.1	13.5
Non-forest	13.9	14.0	15.3	15.2	12.4
Agriculture	317.6	183.8	101.0	67.9	43.4
Urban	5.3	9.4	17.3	22.6	17.9

Changes in Sediment Transport and Water Flow

Procedures

Data on river discharge and precipitation were obtained from the U.S. Geologic Survey and the National Climatic Data Center. Total water flow was determined on an annual basis for each of the river gauging stations in the Huron River. Precipitation was determined by mean rainfall equivalents for stations in or near the watershed, multiplied by the watershed area. Annual water yield was computed as the percent of rainfall exiting the watershed via the river.

Sedimentation rates were examined from Baseline and Portage lakes, which are naturally occurring in-stream lakes located on the mainstem of the Huron River. Sediment samples were collected from soft-bottomed, midlake areas with a Wildco sediment core sampler. Sediment cores up to 0.75 m in length could be extracted from these areas. Sediment particle sizes, water content and percentage of organic matter were determined at 1-cm intervals throughout the length of the cores.

Results

Data on river discharge were available at eight sites within the watershed. Annual patterns of water yield were similar at all sites. We present here the water yield for the Ann Arbor site, which has the longest time series. Since the 1920s, water yields have increased from approximately 22 percent to about 30 percent (Figure 2). Such an increase in water yield is consistent with previous research indicating that urbanization and deforestation tend to increase runoff and total water yield. For comparison, we have presented water yield summaries for the Muskegon and Au Sable rivers. The trends in water yield are similar between the Huron River and the Muskegon River, though yield was consistently higher in the Muskegon River (Figure 2). In contrast, water yields in the Au Sable River do not show a strong trend over time and are similar to the present water yield in the Huron River. These results illustrate the fact that watershed characteristics and climatic factors play a major role in determining water yield, but land use practices can cause substantial shifts in water yield over time.

In addition to increasing the overall water yield, changes in land use in the Huron River watershed have resulted in general increases in river discharge, particularly for the summer period (Figure 3). This is in contrast to results from other systems where peak flows were increased but low flows were diminished. It is difficult to determine why the Huron River has responded differently than other systems, but it is possible that its nearly 100 dams and water control structures tend to maintain steadier flows through the summer months than less regulated systems experience.

Though sediments could be readily collected, dating the various layers proved to be problematic. Though differences in organic content and particle size were apparent among depths, these differences were not consistent among core samples taken at different locations within each lake. Unfortunately, we did not have sufficient funds to use radioisotope methods to date core samples to estimate annual sediment transport rates.

Figure 2. Mean water yields for the Huron, Muskegon and Au Sable river watersheds. Means for the 1990s are based on preliminary data.

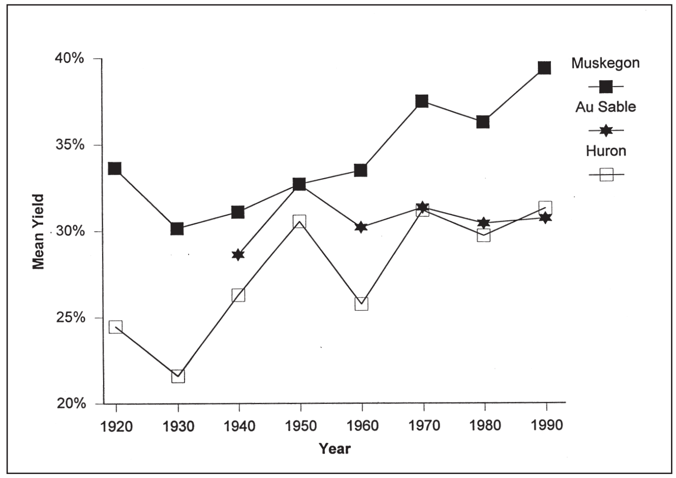
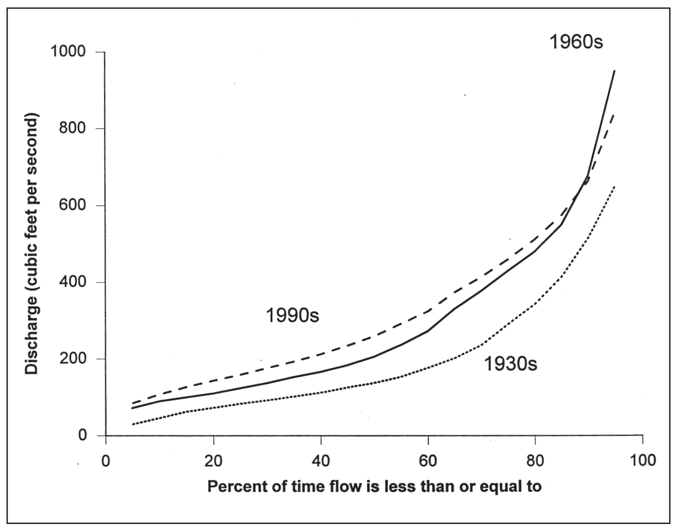


Figure 3. Flow duration curves for the Ann Arbor gauging station on the Huron River for May-September. Each curve illustrates the percent of time that a discharge is less than or equal to a given value. For example, during the 1930s, discharge was less than 400 cfs approximately 80 percent of the time. Thus, a higher curve represents greater discharge most of the time.



Wildlife Habitat

Procedures

We developed a list of vertebrate species that occur within the watershed, including mammals, birds, reptiles and amphibians (Baker, 1983; Harding and Holman, 1990a; Harding and Holman, 1990b; Harding and Holman, 1990c; Brewer et al., 1991). For each species, we determined whether it historically ranged within the watershed and assessed, based on available data, its current status. We also examined data from four routes of the Breeding Bird Survey (BBS) that ran through the Huron River watershed and were surveyed from 1965 to 1997. The BBS consists of roadside surveys of bird populations and provides information on general trends of game species and general patterns of non-game species observed over at least two decades. Because BBS surveys occur along roadsides, they tend to be biased toward edge, human-associated and generalist species. Furthermore, there can also be observer bias, depending on the experience and knowledge of the surveyor (Erskine, 1978; Sauer et al., 1994). Despite these potential limitations, a wide number of studies and applications have effectively used BBS data (e.g., Flather and Sauer, 1996), and these data can provide useful indices for birds that are interior and specialist species.

Results

The Huron River watershed supported 289 vertebrate species in presettlement times (Table 3). Bird species accounted for 62 percent of this number, with the remainder split evenly between mammals and herpetofauna (reptiles and amphibians). Of the original suite of species, 26 have either become extinct (e.g., passenger pigeon) or been locally extirpated (e.g., yellow-bellied sapsucker). Of the remaining 263 species, Michigan lists 34 as endangered, threatened or of special concern (Table 3).

The Huron River watershed has undergone two distinct phases of development that have had different impacts on wildlife habitats and, consequently, on wildlife species. The first phase, the agricultural phase, occurred from presettlement times until the end of World War II. During this time, the watershed changed from a mixture of predominantly forest and open grasslands/savannas (Comer et al., 1995) to predominantly agricultural. The second phase, the urbanization phase, began after World War II and included the expansion of suburban and urban areas, primarily in the northeastern lobe and the southeastern neck of the watershed. Also of significance was the development of the interstate highway system beginning in the mid-1950s.

Table 3. Status of wildlife species in the Huron River watershed.

	Number of species	
	Range includes watershed	Michigan endangered, threatened or special concern species
Birds	180*	13
Mammals	57*	3
Herptofauna	52	9
Frogs	12	1
Lizards	2	0
Salamanders	11	1
Snakes	17	3
Turtles	10	4
Total	289	34

*13 species of birds and 13 species of mammals are extinct or have been extirpated from the watershed.

The patterns of development during these two phases have different implications for wildlife. Presettlement vegetation generally consisted of large, contiguous tracts that followed naturally occurring environmental gradients, particularly topographic gradients (Comer et al., 1995). Forests, openlands and wetlands had average tract sizes of 700, 756 and 79 hectares. The largest forest tract, approximately 4,230 hectares, covered 20 percent of the watershed. By 1938, the first year of the current study, the landscape had changed substantially. Fifty-six percent of the watershed supported some type of agriculture. Forests, openlands and wetlands declined 71, 62 and 42 percent in area (Table 1), and average patch sizes for each of these types declined significantly (Table 2). Moreover, landscape patterns now followed the regular grid of land ownership boundaries established by the township and range survey system used throughout most of the United States.

These changes, including the reduction and fragmentation of forests, open grasslands and wetlands habitat, contributed to the decline and eventual extirpation of many of the top predators and herbivores from the watershed, including: the gray wolf, black bear, mountain lion, wolverine, marten, fisher, moose and elk. Some of these animals were quite common, whereas others were already rare within southeastern Michigan even before European settlement. For example, the Huron River watershed lies at the southern end of the moose's former range within Michigan's Lower Peninsula. Consequently, the wildlife species still present in the watershed by the late 1930s either adapted to or persisted in the predominantly agricultural landscape that existed at the time.

The second phase of development, the urbanization phase, exhibited a much different pattern from the first phase. The largest changes consisted of transfers from agriculture to urban land covers (Table 1). Urban development increased in the northeastern portion of the watershed, and most towns within the watershed expanded, especially the larger communities of Ann Arbor, Ypsilanti and Brighton. The western portion of the watershed showed a relatively smaller degree of change. An extensive highway network developed throughout the watershed. Conversely, the total area in forests, grasslands and wetlands stabilized during this time period (Table 1).

For wildlife, the consequences of increasing urbanization depend on the species and their requirements. For many species, urbanization brings negative impacts. First, urbanization, especially highways and roads, can reduce dispersal among remaining areas of suitable habitat (Forman, 1995). Second, urbanization typically leads to higher levels of pollutants that can degrade the quality of the remaining wildlife habitats, such as increased sediment loads in aquatic environments. Third, urbanization is associated with higher levels of human population, which increases the probability of human disturbance within the remaining habitats. Current information indicates that species with declining population levels are typically sensitive to these types of impacts. For example, Michigan has designated six species of reptiles and amphibians as species of special concern, one as threatened and two as endangered. The total number of state-listed reptiles and amphibians (nine) is disproportionately high relative to the overall number of such species in the watershed. Reptiles and amphibians have highly specialized habitat requirements for reproduction and early development and limited dispersal ability and so would not be expected to fare well within highly urbanized landscapes. Similarly, bird species with specialized habitat requirements, such as large, contiguous tracts of forest (e.g., cerulean warbler) or old field grasslands (e.g., dickcissel), showed consistently low abundance or inconsistent occurrences during BBS sampling (Brewer et al., 1991).

On the other hand, increasing urbanization and development can benefit wildlife species capable of exploiting such changes. Increasing levels of development can generate more edge habitat, which is useful to many species, or can provide resources to generalist species. Generalist species such as the raccoon and opossum have done well, as have many non-game bird species that are edge species, generalists or species that tolerate human presence and disturbance. For example, the BBS showed stable or increasing populations of American robins, blue jays and mourning doves during the past 30 years. Some game birds, such as the northern bobwhite and the ring-necked pheasant, have shown population cycling between highs and lows but appear to be steady overall. The white-tailed deer, in particular, has thrived within the agricultural/urban/woodland mix now found within the watershed.

In summary, the impact of land cover changes depend on the habitat requirements and life history characteristics of the affected species. Species with specialized or large-area habitat requirements respond poorly to increasing urbanization. To retain or restore these species will require active management of habitat and wildlife populations. Conversely, those species capable of adapting to the changes brought about by human development will likely continue to persist without active intervention.

Fish Habitats and Changes in Fish Community Composition

Procedures

To determine changes in fish community composition, we based our sampling on a previous survey that characterized the fish species assemblage in the watershed in 1938 (Brown and Funk, 1945). In the 1938 survey, samples were collected with a 3-meter by 1.2-meter seine net with a 0.42-centimeter square mesh. Though Brown and Funk (1945) identified 121 sites sampled in the previous survey, we found clear fish species and location information for only 90 of those sites on the original data sheets. In their survey, Brown and Funk recorded information on fish species and the size range of individuals caught. Therefore, we were limited to analyses on species richness and percentage of sites occupied by each species. In the 1996 survey, we resampled the 90 sites identified above, employing the same sampling methods and sampling the same stream areas reported on the original data sheets. This allowed us to directly compare the results between the two surveys under the assumption that each survey was subject to the same limitations imposed by the gear used. A paired t-test was performed to determine the significance of differences in species richness between the two surveys.

Data on fish habitat were collected at each site, providing broad coverage of stream conditions across the watershed. We evaluated stream width, depth, temperature and substrate conditions at each site.

Results

For the watershed as a whole, Brown and Funk (1945) observed 65 fish species. In 1996, we observed 47 fish species, a net loss of 18 species (Table 4).

Table 4. Changes in the distribution of fish species observed in the Huron River between the 1938 and 1996 faunal surveys.

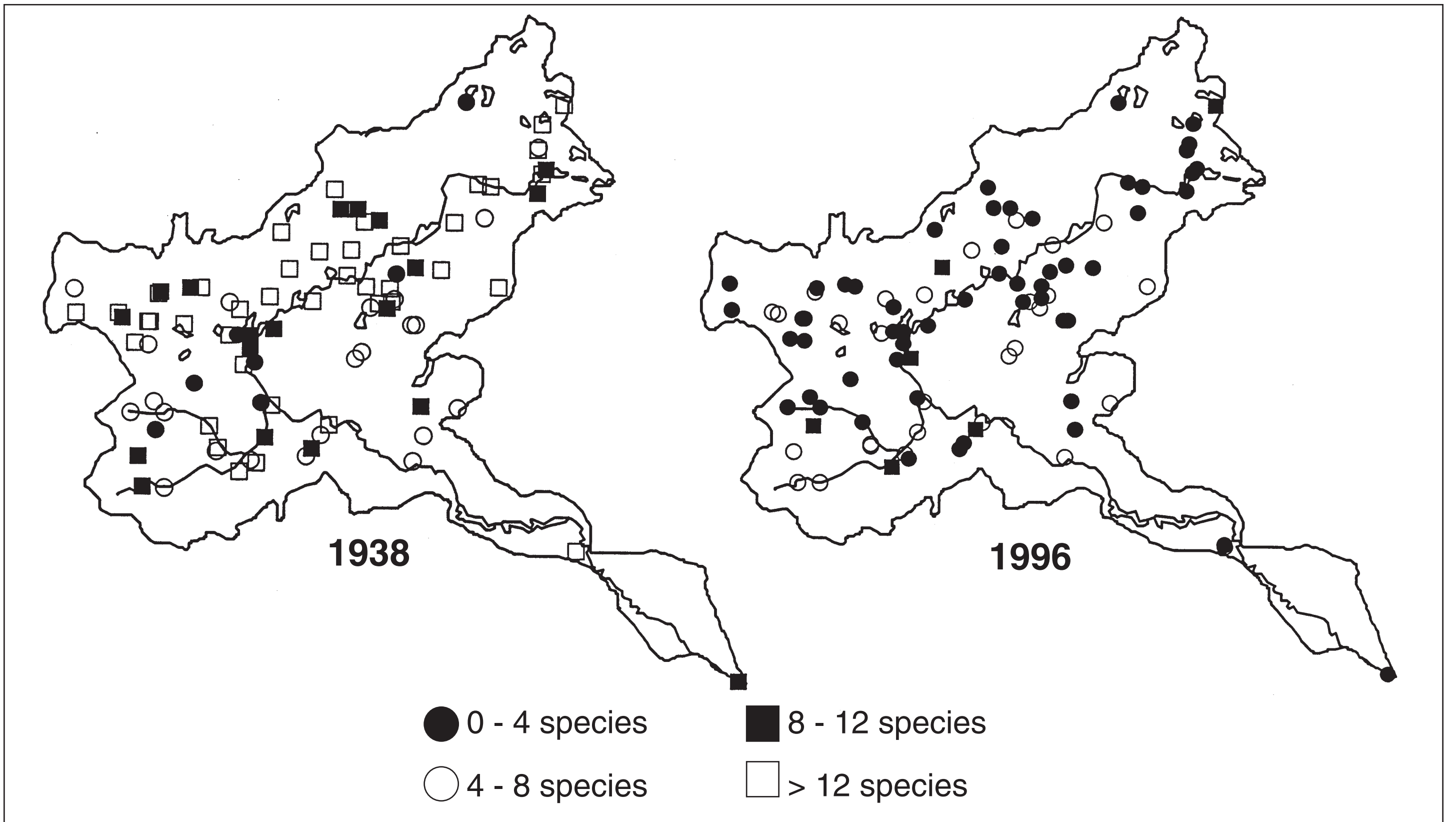
Fish species	1938	1996
Newly observed since 1938 survey	—	6
Expanded range since 1938 survey	3	3
No change in range since 1938 survey	3	3
Reduced range since 1938 survey	35	35
Lost since 1938 survey	24	—
Total fish species richness	65	47

Species richness among the sites sampled in each survey was highly variable, but changes from 1938 to 1996 show an alarming trend. In 1938, fish species richness at individual sites ranged from 3 to 45 species, with a mean species richness ± one standard error of 13.7 species ± 0.8 across all sites. In 1996, fish species richness ranged from 0 to 12 species, with a mean of 3.7 species ± 0.3 across all sites. Results of a paired t-test indicate that the decline in species richness that occurred with changing land cover from 1938 to 1996 was highly significant ($P < 0.0001$).

Maps of fish species richness at individual sites show that the loss in species richness was spread across the watershed, but some areas experienced greater losses than others. In 1938, the highest species richness values were observed in the northeastern lobe of the watershed and in the extreme southern arm of the drainage (Figure 4). In contrast, relatively moderate or low species richness values were observed in the central and southwestern lobe of the watershed. Just the opposite pattern was observed in 1996: relatively low species richness values were recorded in the northeastern lobe and the extreme southern arm of the watershed, while higher species richness values were recorded in the central part and the southwestern lobe of the drainage (Figure 4). Overwhelmingly, we observed high losses in species richness (75 to 100 percent) in those areas where urban cover increased the most. Conversely, smaller losses or slight gains in species richness were observed near the center and in the southwestern lobe of the watershed where land cover has changed less than in other portions of the watershed.

Several changes in the distribution of individual fish species were observed across the Huron River watershed between the two surveys (Table 4). Though six new fish species were observed in the 1996 survey and a few fish species either expanded their range or remained unchanged since 1938, the majority of the changes observed were either complete losses or reductions in the ubiquity of fish species since 1938 (Table 4).

Figure 4. Maps showing fish species richness at 90 sites sampled in the Huron River watershed during 1938 and 1996.



Recommendations

Though changing land use in the Huron River watershed has substantially reduced environmental quality, it is unrealistic to expect that this is sufficient to halt or reverse the population trends in this part of Michigan. Assuming that the trends in changing land cover that we have observed will continue, it will become increasingly important to develop methods for minimizing environmental impacts where development does occur and for protecting critical habitats. Examples of such actions include:

- Sediment management in agricultural settings and in areas of active urban and suburban construction.
- Maintenance of riparian forests and herbaceous cover to minimize bank erosion and reduce solar heating of stream water.
- Careful management of water flows to avoid destruction of human property and of valuable fish and wildlife habitat.

SAPMINR Project Results: A catalyst for additional funding and research

Though the Michigan Agricultural Experiment Station provided primary funding for this research project, the Michigan DNR provided support for faculty salaries for D. Hayes and J. Liu through the Partnership for Ecosystem Research and Management (PERM) agreement. This project has also received $25,000 from the Wildlife Division of the Michigan Department of Natural Resources for additional graduate student support. By building on this project, three MSU faculty members — Jianguo Liu, Patricia Soranno and Angela Mertig — are integrating ecological and human dimensions to predict how land use and land cover changes will affect both terrestrial and aquatic ecosystems. The expanded four-year project is being supported by the College of Agriculture and Natural Resources and the College of Social Sciences.

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