

Wisconsin Department of Natural Resources

Fish Management Bureau

Management Report No. 28

AN EVALUATION OF THE
EFFECT AND EXTENT OF HABITAT LOSS
ON NORTHERN PIKE POPULATIONS
AND MEANS OF PREVENTION
OF LOSSES

By

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INTRODUCTION

The question covered in this paper is, "Do the recreational or other uses of the inland surface freshwaters significantly affect the northern pike fishery." And if they do, "What measures have prospect of alleviating the conflict." To answer these questions it is necessary to fully appreciate the characteristics of the physical resource and the demands of this fish species, and then to have knowledge of the effects of man's use of water and shore.

Much background on the physical resources in Wisconsin is available from an extensive inventory of the surface water resources of the whole state, and from more detailed information which became available through a water use planning project and some specific research. Completed surface waters inventories now cover most of the counties in the state. The lake use planning activity was primarily concentrated on the lakes in a single watershed in the southeastern part of the state where levels of use are the highest. Many of the thoughts which are advanced here are the result of those studies, for through them we have gained a substantial insight on the resource base and the relationship of users to it.

For knowledge of the habits of the various species of fish we are dependent upon the numerous studies of various aspects of life history in the literature. In many cases these studies are incomplete; consequently the impact of man's activities may not be fully appreciated. Also there are many unknowns in the relationship of a lower organism to a higher organism in the ecosystem, and the lower organism may be the one affected by recreation activities.

RELATIONSHIP OF HABITAT TO NORTHERN PIKE LIFE HISTORY STAGES

Stages to be considered are the spawning habitat, egg incubation, fry and fingerling stages, yearling stages, and adult stage. At each stage there are certain specific requirements, which if not met would cause either the death of the fish or a reduced competitive position with other species.

Spawning habitat is basically flooded emergent vegetation. The vegetation substrate is one of several stimuli necessary to induce spawning (Fabricius, 1950). According to Franklin and Smith (1963) they don't use cattails but do use all other types. Johnson and Moyle (1969) reported northern pike spawning on wild rice straw. Only in Lake Windemere (England) have they been reported using submergent aquatics as spawning substrate (Frost and Kibling, 1967). Adults normally seek out warmer influent waters in the early spring and once having reached these waters want the specific releaser of the flooded vegetation, (Svardson, 1948).

The situations in which they spawn are pictured in figures 1 and 2. Egg disposition occurs in very shallow water, 4 to 18 inches deep. In this shallow zone the eggs adhering to vegetation are particularly vulnerable to fluctuating water levels. Research has shown consistent relationships between strong year classes and prolonged high waters, at spawning time (Johnson, 1957) and Williams (1952) calls specifically for stable water levels for one month after spawning.

After hatching the sac fry attach themselves to vegetation by means of a sucker on their head, (Frost and Kibling, 1967) at which stage they are also highly vulnerable to water level fluctuations. With absorption of the yolk sac the alevin survival becomes much dependent upon the availability of plankton food. The marsh habitat in early spring with its warmer shallower water was reported to have 11-17 fold greater numbers of zooplankton than the equivalent colder lake waters (Kleinert, 1965).

A justifiable question which might be raised at this point is the space factor. Evidently this highly predatory fish from very young ages on has more food and space available to it in the flooded marsh and is less subject to either interspecific competition or intraspecific competition. Frost and Kibling (1967) noted that northern pike 2.3-10 cm. in aquarium tended to live a discrete distance from others and suggested that each fish needs a space around itself. As an example of interspecific competition Hunt and Carbine (1951) reported substantial perch predation on northern pike fingerling in the ditch systems, adjoining Houghton Lake. Also Franklin and Smith (1963) reported bluegill predation of northern pike fingerling in a slough outlet.

At the fingerling stage northern pike are normally seen near the surface throughout the shallows swimming about slowly contemplating the next meal of plankton organisms. When disturbed they dart for cover and cover is probably essential to their welfare. According to Franklin and Smith (1963), the alevins float out of the marsh on bright sunny days. It is very obvious at this point that they are highly vulnerable to predation and that if they have both space and cover and freedom from predation, their welfare would be enhanced accordingly. It appears that the flooded marsh vegetation offers just exactly this need. At this age they feed upon zooplankton organisms, particularly copepods (Kleinert, 1964). The copepods require a stable water supply to develop a strong pulse.

As advanced fingerlings, they will have migrated from the shallowest waters and now frequent the weed beds to seize invertebrates and small fish for prey. Fingerlings appear to leave the marsh spawning areas in greatest numbers when about two inches long. Obviously the accessible weed bed is an important feature in their welfare, for without it this small sliver of a fish, from $1\frac{1}{2}$ inches to a foot long, would be very vulnerable to predation. It is of interest to note that waters which have extensive marshlands and weed beds associated with them are the consistent producers of strong northern pike crops. Environments which give good protection to fingerlings as well as provide the spawning habitat seem to be most prolific.

It appears that northern pike control their own density to a substantial degree. Controlled spawning marshes do not produce proportional to stocking rates, but rather seem to have a ceiling on production. Those reports with density data (Table 1) noted maximum densities of less than 10,000 per acre from managed spawning marshes. Minnesota management measures rely upon a production of 3,000 per acre from managed spawning marshes. Thus, the relevant conclusion would be that the more habitat of desired types that can be provided, the stronger will be the northern pike population. Circumstantial evidence in support of this statement is strong.

Adults are almost entirely fish eaters and they feed by sight during daylight hours. Observations indicate northern pike usually locate in some type of concealment from which they dash out after unsuspecting prey. No doubt they also make feeding forays, slowly moving about looking for unsuspecting schools of fish when they are hungry. Such behavior is not specifically detailed in available literature, but has been inferred from extensive angling observations and skin diving sightings. Beds of vegetation are considered vital to northern pike survival, and it is a matter of record that few lakes in Wisconsin have large northern pike populations that are lacking in

vegetation. Northern pike are especially adapted to judge distance and depth with veritable sighting grooves on their snouts in front of their eyes (Lagler, Bardack, and Miller, 1962). It would be difficult to effectively utilize such adaptations in turbid waters.

Northern pike are inhabitants of cool waters and shallow waters with vegetation (Greene, 1936), and they are not often common or abundant in very small lakes (less than 20 acres). They appear to reach their greatest abundance in lakes with inlets. This former contention will be borne out by the natural geographic distribution of northern pike with a southern limit in northern Indiana and a northern limit in Alaska. In mid-summer in southern Wisconsin, northern pike are known to frequent areas having ground water inflow for cooler water in preference to other parts of a lake with otherwise similar conditions. In shallow waters with large populations summer mortalities have been known to occur. Ridenhour (1957) reported a summer mortality in an Iowa marsh as probably being due to temperatures. Temperatures of 89-96 degrees F. were noted in marsh waters.

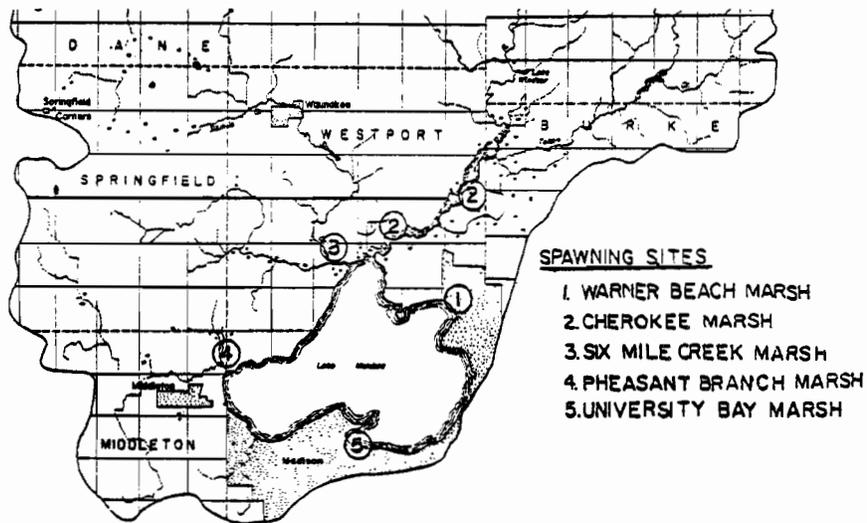


Fig. 1. Northern pike normally spawn in marshes of inlet streams and among the flooded emergent vegetation of the lee shores of lakes. Known spawning sites on 9,730-acre Lake Mendota are noted with arrows to indicate locations. An aerial view of one of the sites (part of Cherokee Marsh) illustrates the encroachment of buildings and shore improvements on lowland habitat.



Fig. 2. A typical spawning marsh for northern pike adjoining Lake Como, Walworth County.

Table 1. Densities of Northern Pike Produced in Spawning Marshes.

<u>Area</u>	<u>Size of Area</u>	<u>Number Produced</u>	<u>Average Size</u>	<u>Number Per Acre</u>
Lake Ripley Marsh, Wis.	10 acre marsh	703	2.1"	70.3
Valley City Hatchery, N. Dak.	(100,000 fry stocked)		2-2.5"	35,000
Ventura Marsh, Iowa	636 acres	26,958-31,654	12-15.5"	≈ 50
Laura Lake, Minn.	1,454 acres	52,699 (2,084 lbs)	(est. 12")	36.2
Valentine Fish Hatchery, Neb. (natural spawning)	2.6 acres	4,900	1.7"	1,895
	1 acre	1,946	2.3"	1,946
	1 acre	1,700	2.6"	1,700
	1.5 acres	5,050	1.5"	3,360
George Lake, Minn.	9 acre marsh	3,391	20 mm	377
		92,947	20 mm	10,327
		4,096	20 mm	455

It is appropriate to inquire about the significance of various types of aquatic vegetation in maintaining temperature. The thick weed bed prohibits vertical mixing, absorbs heat and provides cooler water. Certainly the clone of water lilies with leaves on the surface must have some effect on both heat absorption and water mixing locally.

Vegetation makes indirect contributions to the welfare of northern pike by acting as a substrate for strong invertebrate populations and nursery grounds for forage fish. Invertebrate populations are most abundant on plants with highly dissected surface area (Andrews and Hasler, 1942). Important food organisms like the amphipods Gammarus and Hyaella thrive amid vegetation and appear to be relatively rare in nonvegetated areas. In Franklin and Smith's (1963) work Hyaella replaced Cyclops as the dominant food when northern pike fingerlings reached 45 mm. The question that looms is this: Would northern pike have as good food resources without vegetation in the littoral?

MAN'S EFFECTS

Preservation of a northern pike fishery must, of course give adequate consideration to environment and habitat. The environment of northern pike has temperature aspects, oxygen requirements and water clarity requirements.

It can stand moderate fertility, low but not depleted oxygen; it should have some cool water and it needs moderately clear water.

As for habitat, the needs appear to be an adequate but not excessive crop of vegetation in the littoral, an abundance of flooded flats furnishing spawning habitat, food resources and protection for young fish. In what way, then, are man's activities interfering with northern pike welfare?

In our current intensive quest for aquatic recreation and use of water and land, we are, without question, interfering. Waters are being made more fertile and more turbid with northern pike less able to get their food needs or to survive either seasonal or diurnal oxygen fluctuations in their environment. It is also true that more fertility has prospect of increasing food resources in infertile waters--possibly a benefit if not carried to excess. Means of making them more fertile and turbid arise from the open, bare, erodable lands of farm or subdivisions, the location of housing on shorelands and increments of sewage from individual houses and communities. More detail on man's interference follows.

Pollution

Pollution is defined specifically for purposes of this discussion as depletion of oxygen as a result of wastes contributed to the lake or stream and poisons which adversely affect fish life or fish food resources. Pollution as a result of oxygen depletion occurs where there are excessive organic loadings of the natural waters. This can occur below major cities, below paper mills and in conjunction with food processing plants. Major cities, those over 50,000 have an impact on the rivers that flow through them for some distance downstream except in the largest rivers (i.e., Mississippi) although almost all cities have at least secondary waste treatment.

Perhaps more important is the fertilization they contribute, a subject discussed under a separate heading. We can say that northern pike populations are adversely affected by pollution in river systems for several miles below major cities.

Food processing plants typically have high BOD wastes. The wastes in Wisconsin are in all cases either consigned to the city sewerage treatment systems or confined to oxidation ponds. Outside of occasional accidents, food processing plants are not a significant threat to fish populations of any kind. Paper mills are another matter. They have wastes with oxygen demands equivalent to a very large city (i.e., over 100,000); thus, they affect river and impoundment systems for many miles downstream--as many as 100 miles downstream in the Wisconsin River. Northern pike are normally abundant in waters affected by paper mills wastes, but their abundance probably stems in part from their mobility and tolerance of low oxygen levels. Possibly 50,000 acres of the inland surface water (5 percent of the total excepting the Great Lakes) is affected by paper mill wastes. One ingredient in paper mill wastes, the wood sugars could be particularly devastating to any type of fish eggs as pointed out by Colby and Smith (1967) for the sugars foster growth of the fungus Sphaerotilus, which smothers eggs. In their case it was walleye eggs.

Out of the many heavy metal poisons, alkalies or acids, none is known to cause any significant or lasting effects on fish populations in Wisconsin. However, accidents from the many industrial plants may occur. Pesticides must be suspect, however. Analyses of the flesh of northern pike for DDT and analogues from many Wisconsin lakes indicates they contain substantial amounts, commonly in the range of 15-30 ppm on a fat basis and 0.1-0.2 on a whole fish basis (Kleinert, 1967). However, the impact of pesticides is insidious and seldom directly observed. A number of fish kills have been reported from thiodan, a chlorinated sulphonated hydrocarbon, and the fish population in the Milwaukee River became depauperate in an area subjected to gentle release of dieldrin, a chlorinated hydrocarbon in conjunction with a wool treating operation. Insecticides appear to affect all species and they can be both chronic and short term accidental. Kleinert et al (1968) reported 400,000 acres of Wisconsin lands are subjected to total agricultural insect pest control, so the extent of use is great.

Pollution can seriously affect welfare of the fingerlings in their shallow water marsh habitat. These waters inherently have high oxygen demands which cannot be accentuated by pollutants of any kind if fish are to survive. Franklin and Smith (1963) noted toxic concentrations of iron and excessively rapid temperature changes were correlated with fingerling mortalities. McCarragher (1962) noted that northern pike did not survive where the total alkalinity exceeded 1,200 ppm. He noted 95 percent of Nebraska's lakes supporting northern pike have less than 600 ppm bicarbonate.

Turbidity should be lumped with pollution because it is a deleterious substance in water. Turbidity levels so far as is known are never enough to kill northern pike, in Wisconsin waters, but they are great enough to substantially decrease light penetration and sight distance in the water. For a species of fish dependent upon sight for feeding the effects can be unfortunate. Distribution and abundance data indicate northern pike are a common fish in the relatively turbid Mississippi River. With its extensive marshes one would expect greater abundance. By way of contrast relatively clear northern Wisconsin streams have large northern pike populations. Mississippi River waters commonly have sustained periods when the turbidity exceeds 100 units. Activity of carp contributes to sustained turbidity and in silty carp infested lakes secchi disk readings of as little as 15 inches are common (Threinen and Helm, 1954). Turbidity is a negative factor for all species of

fish because it limits light penetration and affects production. Many fold differences in production have been reported in the literature between turbid and unturbid waters. Silt erosion, would therefore be listed as another act of man affecting northern pike abundance.

Turbidity is accentuated by turbulence. Natural turbulence from wave action has to be accepted and cannot be of concern. But turbidity created by man is another matter. With large numbers of motorboats numbering more than one for every 10 acres of water on the inland lakes of southeastern Wisconsin on a peak activity day, there is unquestionably greater levels of turbidity. Observers report that the waters of many lakes are turbid on weekends and tend to be much clearer during the week. Motorboats in a displacement travel status are capable of generating wake waves equivalent to those generated by strong winds, namely a height of 8 inches.

Motorboats can be sources of pollution. Surber et al (1962), in a field trial reported the tainting of fish flesh by outboard motor exhaust. Although northern pike were not included it is assumed they would be effected. Tainting occurred with as little as 2.6 gallons of fuel per acre foot of water. The amount of oil wasted in surface waters must be nothing short of prodigious because there is estimated gasoline consumption by boats amounting to 44 million gallons per year in the entire state of Wisconsin.¹ Just exactly what impact these potential pollutants have has never been accurately measured.

Quite apart from the known direct effects on the fish itself are the effects of wastes on the eating qualities of fish including northern pike. Baldwin and Strong (1961) in scoring cooked northern pike through a taste test panel found them to have off flavors and aromas in three of four seasons when taken from waters affected by paper mill wastes.

Fertility

Consequences of high and excessive fertilization must be considered also. High nutrient loadings push fish production in the direction of the rough fish species to the detriment of angling. As Moyle (1956) noted, the low fertility lakes tend to be trout lakes, while high fertility lakes tend to be rough fish lakes. Frost and Kibling (1967) reported that Lake Windemere (England) experienced increases of pike and perch at the expense of trout with an increase in productivity. If the entire littoral becomes a tangle of aquatic plants and filamentous algae, anglers have difficulty. Thus, in considering a development policy, factors affecting a lake basin's fertility must be given consideration.

In Wisconsin, one of the more flagrant abuses of lentic systems is to dump sewage effluents into streams entering lakes. Even small communities seriously and significantly affect lakes. Use of herbicides or algicides normally follows with uncertain and temporary benefits. A list of Wisconsin natural lakes known to be affected by sewage effluent is provided to illustrate the impact of communities, (Table 2).

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1969 estimate developed from data of the Outboard Boating Club.

It is well to remember that present methods of sewage treatment reduce the BOD and solids to very low levels, but they do little with dissolved solids. Seventy-five percent of the nutrients flow right through under normal operations. The nutrient contributions of 1 person are considerable and over a year period amount to 1.1 pounds (525 grams) of phosphate. This amount is enough phosphate to feed a nuisance bloom of algae at as low a level as .10 ppm in 21.7 acre feet of water. According to Lackey and Sawyer (1949), nuisance blooms of algae will develop with as little as .01 ppm.

Specifically we should point to the impact of fertility on specific aspects of the northern pike's welfare. Northern pike are sight feeders. Therefore, waters cannot be excessively turbid from either algae or sediment if the northern pike is to feed effectively. Lux and Smith (1960) noted when turbidity from algae blooms in late summer was highest, angling success for northern pike was poor. Northern pike are quite tolerant of low oxygen conditions and will withstand levels as low as 0.3 and 0.4 ppm in winter (Cooper and Washburn, 1949). But they do succumb to winterkill when the oxygen is depleted (Hanson, 1958). Excessively fertile environments that cause winterkill are therefore not in the best interest of survival of northern pike. Ball (1950) artificially fertilized a Michigan lake inhabited by northern pike and thereby caused a winterkill. He specifically warned against high production of filamentous algae. Northern pike have also been known to succumb to summerkill and perhaps algae-produced toxins. Mackenthune et al (1948) noted a mass fish mortality which included northern pike on the Yahara River (south central Wisconsin) as a result of the decomposition of algae in early fall.

Table 2. Some Wisconsin Lakes Directly Affected by Waste Contributions from Communities.

Lake	County	Area of Lake Acres	Maximum Depth	Effluent Source	Population of Source ⁴
Beaver Dam	Barron	1,112	106	Cumberland	1,900
Beaver Dam	Dodge	5,440	11	Fox Lake and Randolph	4,000
Coleman	Marquette	234	64	Goodman	700
Delavan	Walworth	2,072	56	Elkhorn	3,600
Eagle ⁵	Racine	520	15	Kansasville	200 [±]
Kegonsa ²	Dane	2,716	31	Madison and Deerfield	126,800
Koshkonong	Jefferson	10,480	6	Fort Atkinson and Jefferson	12,400
Mendota	Dane	9,730	82	Waumakee and De Forest	3,800
Minocqua ¹	Oneida	1,285	60	Minocqua	1,000
Nagawicka	Waukesha	917	90	Hartland	2,100
Snake	Oneida - Vilas	12	22	Woodruff	600
Waubesa ³	Dane	2,113	34	Madison	126,000
Winnebago	Winnebago	137,708	21	Oshkosh and Fond du Lac	77,700
Yellow	Burnett	2,287	32	Spooner	2,400

1 Sewage effluent bypassed about 1965 but effects still linger.

2 Sewage effluent from Madison area bypassed in early 1960 but effects still linger and a small community still dumps effluent in an influent stream.

3 Sewage effluent bypassed in early 1960 but effects still linger.

4 1960 population data

5 A dense rural population plus a milk plant is present within the Eagle Lake Watershed.

Organically enriched water such as deriving from sewage disposal plants and from ground disposal units has a very low pH. Unless sufficiently buffered, it will readily dissolve minerals, and should they be heavy metals, mortalities can result. Outright mortalities of muskellunge fry in a hatchery have been associated with low oxygen and high zinc concentrations (Johnson, 1966). Organic wastes are, therefore, considerably more of a threat in the welfare of fish species than their oxygen demands alone would suggest.

Space Competition From Cultural Developments on Shorelands

The shore activities of man may compete directly with northern pike when the marsh is used for a dumping ground and when the marsh edge is filled in or cut off in land reclamation. The user of shorelands usually leaves a disciplined, antiseptic site which allows little littoral vegetation and no emergent vegetation. With these demands spawning and nursery areas may be in jeopardy. The size of a northern pike crop is directly proportional to the amount of spawning grounds and nursery grounds available to it. Lakes with a high fraction of open water tend to be poor lakes. Carbine and Applegate (1948) lamented the ditching of extensive marshland adjoining Houghton Lake, Michigan.

Some idea of the extent of shoreland changes may be seen from statistics on permits issued by the Department of Natural Resources. A review of the permits provided for shore improvements indicates the Department granted 1,250 permits for sand blankets, 213 dredging permits, 213 lagoon permits in recent years. Most of these were granted for southeastern Wisconsin lakes.

The examination of lakeshores today on private land areas would show most if not all frontage being converted to housing, marinas or other intensive use of shoreland. As an example of the intensity of cultural developments we can point to the amount of housing located on the 47 significant lakes in three southeastern counties. There were 5,914 houses located on 209 miles of shoreline. With only 186 feet per unit there is little space left on the shore for anything else (Threinen and Poff, 1964). Boats in themselves are highly consumptive of space when parked on the shore. In the three county corner of southeastern Wisconsin with a large boat population the 13,654 registered boats would use 5.6 percent of the shore if moored beam to beam. Only where there are public lands is the picture different. Lake shores are being converted to urban areas and the fish species perhaps most affected by these trends is the northern pike. A Minnesota forecast stated, "Trends indicate that all north-central Minnesota lakeshore will be fully developed by the mid-1970's" (Skrypek, 1968).

An appreciation of the impact of these trends may be gained by noting the number of species of amphibians and reptiles in a suburban area which was developed. Since many of these species are amphibians, such developments would be expected to influence fish species through loss of potential food resources. Before development, there were 2 species of salamanders, 6 anurans, 6 turtles and 7 species of snakes, most of which were terrestrial and semi-aquatic of broad ecological tolerance. After development, only 2 species of anurans, 1 species of turtle and 4 species of snakes were recorded and there was no evidence of amphibian breeding. We can also deplete the desirable invertebrate aquatic organisms by a systematic attack on their habitat and degradation of their environment. As an example Bratley (1969) reported the swimming beach of Ottawa Lake had a much lower density of mayfly larvae than other sampling locations where swimming did not take place.

Dams

There is evidence that northern pike will wander extensively and they frequently show up below barriers such as dams (Priegel, 1968, Snow, 1965, Carbine and Applegate, 1948). Priegel reported 2.4 and 2.8 percent of the recoveries from 965 and 1,689 tagged stocked northern pike showed up below the Neenah-Menasha dam, 22 to 35 miles distant from the planting site and below huge Lake Winnebago. Snow estimated as much as 25-30 percent of the 8,534 northern pike stocked in Murphy Flowage, a 155 acre impoundment, ended up below the dam. The large exodus apparently occurred during a high water period and could have occurred in response to rapid by-passing of high waters. Northern pike are known to respond to currents. Impassable dams apparently do not act as a barrier to downstream movement but they do act as barriers to upstream movement. What we do not know is how much of this movement or exodus is a density adjustment to an overpopulation. Favorite fishing grounds for upstream migrants seeking spawning grounds in the spring are often the waters below dam sites. Carbine and Applegate (1948) reported 5 out of 230 recovered northern pike were caught below the dam at Houghton Lake.

Dams tend to be one way--allowing downstream movement but blocking upstream movement if they are high enough. The rather considerable movement reported in studies suggests that northern pike populations will be advantaged by having opportunities to move both ways in a stream system. In this way, predator populations tend to balance out.

In Wisconsin during the early years of dam building, state law¹ and policy required the construction of fishways in conjunction with new dams. Such a policy is no longer enforced. Since almost every stream in the state has one or more dams on it, the significance of dams to the distribution of northern pike can be realized.

Quite apart from the negative effects of dams, is the positive aspects. Northern pike habitat is created where it did not exist before when the small stream is converted to a lake. Since impoundments always have extensive shallows and marshy spawning habitat, they are invariably good northern pike habitat. Certainly this space created in impoundments vastly outweighs the negative losses over dams.

Ditching and Dredging

These two actions have the potential for taking spawning grounds and nursery grounds. The manner in which this occurs in the case of ditching is to remove the meander in a stream and eliminate back water ponds and marshes that were an outgrowth of the meandering stream. If the ditch system remains sluggish, it could still contribute to northern pike welfare but a fast stream will likely rule out successful effective safe spawning and nursery grounds. A levee system which cuts off former marsh lands would be just as detrimental.

Dredging would deepen shallows and create filled land out of former marsh edge. This act would cut off spawning grounds and if dug deeply, would also reduce nursery grounds. Pike fry and fingerlings would be highly subject to predation if this occurred.

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Section 31.02 (4) of the Wisconsin Statutes states, "The Department may order and require any dam heretofore and hereafter constructed to be equipped and operated. . . with good and sufficient fishway or fishways. . ."

Ditching, of course, is widely prevalent in agricultural areas. Given a choice, a farmer normally will ditch a stream running through his lands to avoid flooding of croplands. This move reduces length by $\frac{1}{4}$ to $\frac{1}{2}$ on a meandered stream and increases the gradient an equivalent amount. Under the circumstances, a less stable environment would be provided. Iowa experience with modern ditching has been to provide straight, wide and shallow streams coupled with control of shore vegetation. The straightened streams have neither depth nor cover to support game fish.¹ A waters inventory for Jefferson County, a southeastern Wisconsin county, reported 47.7 miles of stream (50 percent of the total mileage) had been ditched. Much less ditching has occurred in forested areas of northern Wisconsin. Ditching and tiling have resulted in losses of wetlands amounting to 9,000 acres (11.7 percent of the total) in this farm county in a 15-year span. Loss of wetlands to this extent is certain to have considerable effect on northern pike when it is known that fingerling production is proportional to the water area available. In the state as a whole there were approximately 5,000,000 acres of wetlands and in the 1955 inventory it was estimated that half of this total had been lost (USFWS, 1959).

Much worse than the farm ditching, where at least a stream channel remains, is the channeling of water courses in metropolitan areas. The sole objective is to get rid of water as fast as possible, thus creating the most unstable conditions. Quotes from a resolution of the Milwaukee Metropolitan Sewage District sound like a death warrant to any fish species. "Whereas. . . Commission. . . is presently engaged in flood control by deepening, widening and improving main water courses. . . and whereas. . . flooding of property along the Menomonic River Basin. . . caused extensive damage. . . with resultant hazards to health, comfort and welfare. . . And whereas the. . . Commission has undertaken the work of widening and deepening of the channel. . . with constructing a sheet piling wall. . . And whereas the proposed improvement of Honey Creek will increase the volume of storm waters discharging into the Menomonic River. . . Now therefore, be it resolved. . . to make an engineering investigation of the flood carrying capacity to provide additional capacity for increased flows."

It is obvious the engineers with their straight cemented channels are not thinking of the fish resource. This same river estuary, now part of the harbor of the City of Milwaukee, when first settled supported a fine northern pike fishery and spearing of northern pike was common (Gregory, 1931). Obviously the northern pike lost all their spawning grounds to urban expansion and any remaining died off in the subsequent pollution. A comparative picture of a partially improved stream as the engineer views it is provided (Fig. 3).

Since lands surrounding most of our lakes, particularly in the southeastern part of the state, are becoming urban, habitat here is in serious jeopardy. Loss of spawning grounds on lakeshores was detailed by Brynildson (1958). The tendency in all our water management programs to get rid of water rather than hold it is a serious deterrent to northern pike prosperity.

Water Level Controls

As we have noted in the habitat requirements, northern pike have a very specific spawning habitat requirement--flooded emergent vegetation. If this form of habitat can be furnished, there is apparently no problem with survival of egg and fry. Water level fluctuations can, however, seriously affect this zone where there is use of water for other purposes or if the needs of fish species are not considered in the water level manipulations.

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Personal communication with Harry Harrison, State Conservation Comm. of Iowa.

On the one hand we regularly note the correlation of strong year classes with high water (Johnson, 1957) and, on the other hand, we note the work of Sychena (1965) who reported decreasing pike catches in the face of water level fluctuations in an impoundment. It is easy to see how northern pike eggs could become stranded in the shallows with short term water level fluctuations.

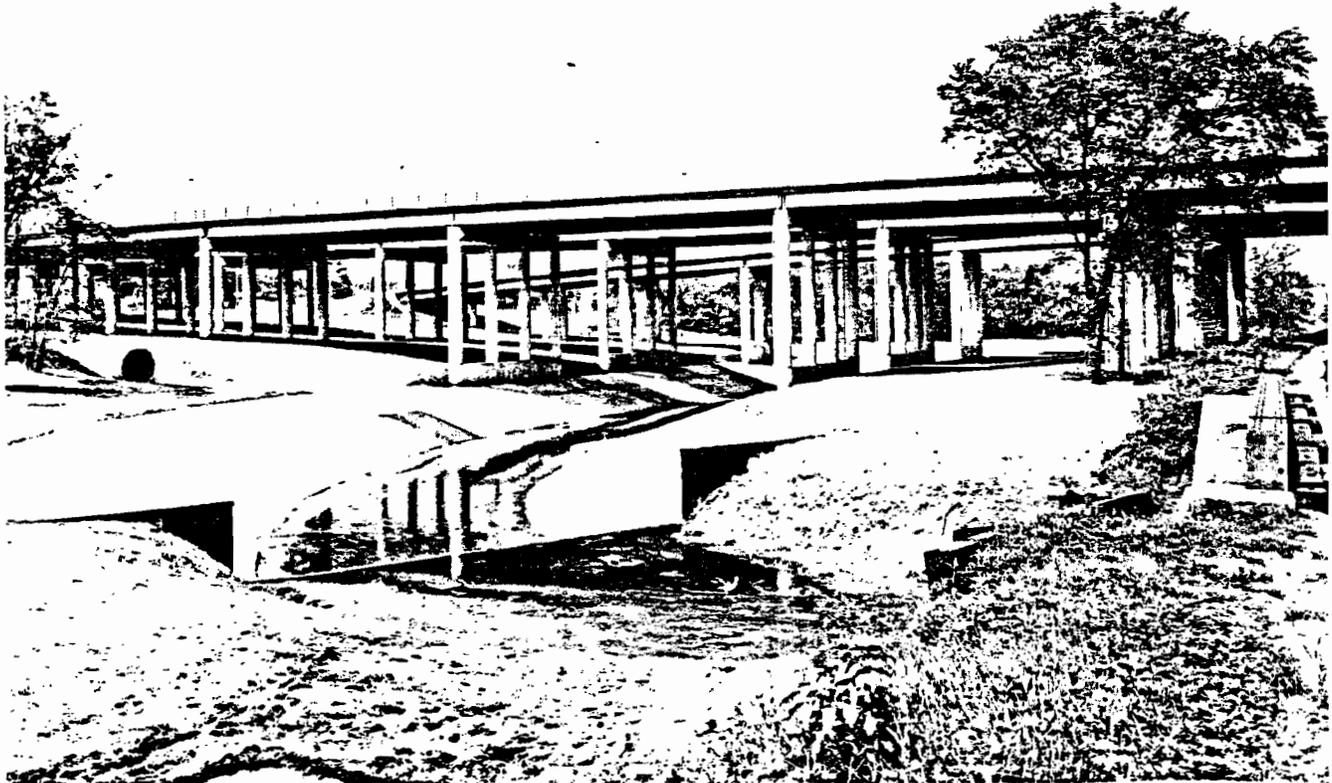
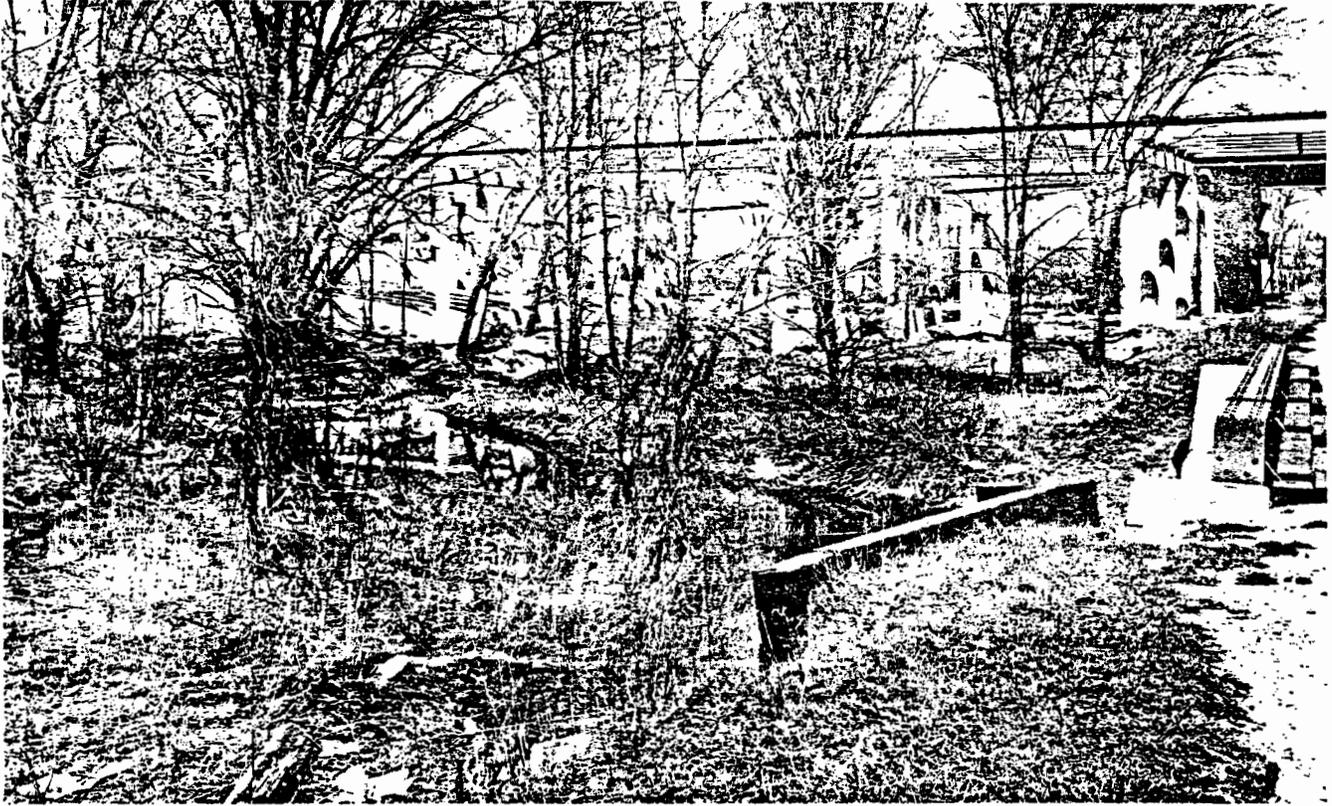


Fig. 3. The fate of urban streams spells complete ruination of a stream and associated marshes for fish spawning. These pictures of "improved" urban streams were taken in Milwaukee County, a completely urbanized area.

The handling of flood control releases could be just as devastating. Flooded lands at spawning could be quickly dried out with massive releases immediately thereafter. Schmitz (1953) in his description of spawning grounds in Lake Mendota offered caution against dewatering for he observed a 13 cm (5.1 in.) drop in water levels during the spawning period. Lake Mendota is a 9,730 acre lake with 250-square-mile drainage area. Gate capacity at the outlet is such that the lake can be dropped quickly following a storm event. When northern pike as reported by Kleinert (1965) have a 177.6 degree day hatching period (approx. 10-20 days when 40-50°) the drawdown can significantly affect the pike eggs or sac fry not yet independent.

While in some cases, handling high waters can be a detriment, it could also be a decided advantage. If reservoirs or lake basins controlled by a dam are allowed to hold water for a period during spawning and early development of fry, northern pike could be advantaged. Studies of marshes and management of northern pike rearing ponds (Franklin and Smith, 1965) indicate migration of northern pike fingerlings takes place when fingerlings average 20 mm (1.79 inches) long, a size attained in 18 to 24 days in Minnesota. Thus, to benefit northern pike optimally the water levels in marshes should be stable until this time.

An evaluation of water level effects calls for a full appreciation of the kinds of water level fluctuations occurring. These have been summarized for Wisconsin in Table 3. Flooding and water level fluctuations are not all bad. The regimen that allows water level increases and holds them reasonably steady during key reproduction periods is performing a service to northern pike. The success of these water level management programs is best illustrated by the consistent crops of Esocids produced by water storage reservoirs and by game impoundments which have summer drawdowns. Maloney and Johnson (1957) called Winnibigosh, a 48,000 acre lake with a 4 foot annual fluctuation a "good" northern pike lake.

Temperature

While not a cold water species, northern pike do like cool water. Fish distribution texts make note of the northern pike's occurrence in cool to moderately warm waters such as occurs in northern U.S. (Hubbs and Lagler, 1947). Privolney (1963) reported the northern pike had a much increased oxygen threshold in warm waters-- 1.4 mg/l at 84.2° F. How do man's activities affect them?

Heated water discharges which warm the waters over temperatures preferred then probably drive northern pike out of warmed waters. If summer surface water temperatures reach into the seventies, an additional 10° could be critical. The lethal temperature of northern pike probably approximates that of other cool water fish, namely about 80°F. None of the warm water game fish apparently survive at water temperatures exceeding 100°F as reported in the Wurtz and Renn (1965) review. Thus, power plants with large condenser cooling water discharges no doubt locally influence distribution because they may raise temperatures as much as 25°F. (Trembley, 1960). It might also be argued that they benefit northern pike by warming cold waters in winter. This act might very well be advantageous on Lake Michigan because it could convert some parts of the basin to better habitat for northern pike. In studies of condenser cooling water discharges the common conclusion is that temperature changes are local and that they are dissipated rapidly, water temperatures coming into balance with the atmosphere. One of the known large concentrations of spawning northern pike occurs in Peshtigo Harbor off Green Bay, a marshy estuary area partially warmed by waste discharges.

We have many times seen the effects of temperature change when a spring pond has been dammed up ostensibly to benefit trout and the warmer water thus created results in a good crop of northern pike. Actual mortalities of northern pike have been reported in the summer in Wisconsin, one in a shallow lake in the southeast and one in a shallow flowage in northwestern Wisconsin (Snow, 1965). The latter mortality occurred in June and most fish picked up had a Myxobolus infection. Conceivably the warm waters accentuate the prospect of disease. Lawler (1965) found growth of northern pike in a shallow Manitoba lake was less in years with warm summers.

Table 3. Types of Water Level Fluctuations Experienced in Wisconsin.

	Nature of Effect on Water Levels	Effect on Fish
Diurnal power demand	Daily fluctuations of as much as 5 feet.	Unreliable spawning habitat and nursery grounds. If low variations no problem.
Storage reservoir for low flow augmentation	Rapidly rising waters in spring with loss in late summer and late winter.	Probably good spawning and early season nursery conditions.
Built-in temporary flood storage	Dissipate high runoff accumulation in a matter of days. High and rapid fluctuations of as much as 20 feet.	Can be advantageous for spawning depending upon speed of drawdown. Generally rapid and unstable.
Natural flood storage of lake	Modest slow rises and gentle lowering of increased levels. Three foot maximum fluctuation most commonly in the spring.	Generally advantageous depending upon speed of drawdown. Both good spawning and nursery grounds provided.
Game management impoundment	Late spring drawdown with summer following reflooding in the fall.	Good spawning conditions and early nursery conditions.
Seepage lakes affected by groundwater	Closely related to precipitation and long term groundwater conditions. Potentially affected by groundwater withdrawals.	Good spawning and nursery conditions in high water years. Poor in low water years.
Channel and floodplain storage	Meandered rivers with low gradient spill out of their banks and gradually accumulate flood flows and just as gradually release them.	Advantageous if prolonged but unstable and unreliable on small streams.

QUANTITATIVE ASPECTS

What appears most important of the many acts of man which affect habitat? The ditching and blocking of marshlands far exceeds in quantity any of the other acts. It has occurred on large numbers of lakes particularly in the southeastern part of the state where all lakeshores have been subjected to intensive development and it is spreading in the north. In my opinion, the second level of significance is the disturbances of shallows. When weedy shallows are converted to either antiseptic sandy beaches or open waters, by aquatic plant control of one kind or another, many hundreds of acres of nursery grounds are lost. Pollution problems follow for they have most certainly ruled off any significant fish production in some waters. In certain other waters known for northern pike populations, affected by paper mill wastes, the flavor of fish flesh has been tainted to the point where they are disregarded as eating fish by anglers.

Action Program

The only answer to successful preservation of habitat is some means of reservation of critical habitat. Critical habitat I regard to be the estuaries and wet marshes plus an adequate undisturbed littoral zone. An official recommendation of the Wisconsin Department of Natural Resources is that 25 percent of the shore remain wild. I would feel more comfortable if 50 percent remained wild.

Habitat preservation measures include use of the land and water zoning tool and acquisition to reserve flood plains and wetlands. Since zoning is always continuously subject to molding and modification by economic activity, the only certain means of habitat protection is public land acquisition. At this point in time it is economic to improve low-land shorelines for human occupancy. Fish get little consideration in the face of economic pressures. The state with a strong shoreland acquisition program has prospects of maintaining abundant northern pike.

The most significant thrust of an action program will be to preserve habitat. Habitat consists of both the spawning marsh and nursery areas. For large lakes preservation of marshy estuary areas is essential; for smaller lakes preservation of the marshy western sides of basins is desirable. The habitat preservation package which has been prescribed by the Wisconsin Department of Natural Resources is to preserve 25 percent of the shore in a wild state. A strong land acquisition program coupled with zoning are essential action tools. The State of Wisconsin enacted a shoreland zoning law in 1965 (Water Use and Planning Committee, 1969) and State of Minnesota enacted a similar law in 1969. These laws have the potential to reduce the rate of loss of spawning grounds by protecting wetlands.

States have water regulatory agencies that control what is done with their navigable waters. If water regulatory measures can be exercised with the welfare of northern pike in mind a much better northern pike crop may be realized. Regulatory decisions in recent years in Wisconsin have tended to give consideration to habitat needs but have not been refined enough to provide the best water level controls. Part of the difficulty is lack of knowledge of the effects of the water regimen.

Water level manipulation appears to have potentially rich rewards. Wherever possible, recognition of the northern pikes' needs for flooded vegetation and protected fingerling nursery grounds is needed. These circumstances create the large year classes. Summertime water levels may be much lower. We have seen how game management impoundments seem to have consistently high production of northern pike.

As with most fisheries, avoidance of pollution is necessary. However, since northern pike are a hardy fish, they are not so seriously affected as other species and in some cases may be benefited by differential survival. More important is the excessive fertility which apparently tends to favor other species over northern pike.

Since the northern pike is a prolific fish and a reasonably tolerant fish, its future will be well assured if it can be provided with ample spawning and nursery grounds with good water quality.

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