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Division of Fish, Game and Enforcement

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Introduction

The muskellunge (Esox masquinongy immaculatus, Garrard) is Wisconsin's most highly regarded sport fish. Thus it has had management attention almost since the beginning of the sport fishery. In recognition of its status the Wisconsin legislature designated the muskellunge as the official state fish in 1955. The status and prominence of this fresh water trophy derives from its large size and fishing qualities. Wisconsin for a number of years retained the world angling record for this species until 1957. The purpose of this paper is to summarize management developments on the muskellunge in Wisconsin.

Little is known of the abundance of muskellunge in Wisconsin at the turn of this century, but the original distribution of this species in the state has been fairly well established (Green). Native muskellunge were apparently confined to the lakes and streams in the headwater basins of the Chippewa-Flambeau and Wisconsin River systems in the north-central part of the state (Oehmcke, 1965) with some scattered local populations. The present range of the muskellunge now covers 33 counties in all geographic areas except the southwest part of the state (Department of Natural Resources, 1968). This expanded muskellunge range is primarily a result of stocking.

The artificial propagation of muskellunge in Wisconsin was initiated in 1899 at Woodruff. For over 25 years little effort was directed to rearing muskellunge beyond the sac fry stage. Nearly all muskellunge were stocked shortly after hatching from eggs incubated in jars. The rearing of muskellunge to fingerling size in ponds was attempted at intervals from 1926 to 1938 with little success.

While propagation continued, a more sophisticated muskellunge management program evolved due to angling pressure, ecological changes and economic implications. Concurrent with the growth of the resort industry and accelerated sport fishing activity in the years following World War II, a decline in muskellunge populations was observed. Although the exploitation of muskellunge by anglers was not documented by general creel census, it was generally conceded that the annual harvest of this species exceeded the replenishment from natural reproduction. Resident and out-of-state anglers (mainly from Illinois) increased in number and it was reasonable to assume that muskellunge catches were commensurate with this increase in fishing pressure. License sales now number over 1,000,000.

Competition by northern pike for muskellunge food and spawning grounds was identified in a growing number of lakes. By 1947, the native muskellunge in several lakes was at such a low level that the spawning stock remaining was threatened by intruding northern pike (Esox lucius) (Threinen, 1950). Control

measures to reduce northern pike in muskellunge waters showed promising results in the late 1940s and this management approach has been used successfully since then.

Until 1940, the management of muskellunge waters in Wisconsin consisted of a regulation of the fishery (a large size limit, low bag limit and limited season) and a dubious fry stocking program. In the past three decades an improved propagation program has provided better quality planting stock and I suspect that the survival of such stock has contributed to the maintenance of fishable muskellunge populations.

For the practical fish manager, one of the best indicators of fishing success is the satisfied fisherman. Lacking valid creel census information on muskellunge fishing, a license stub survey was conducted by the Wisconsin Conservation Department in 1957 which revealed that approximately 54,000 legal muskellunge were harvested in Wisconsin during the previous season (Threinen, 1958). An apparent increase in harvest was reported by Churchill in 1968 for more recent years (Table 1).

The present status of muskellunge populations in Wisconsin, even in view of increased angling pressure, appears to be at an all time high. This situation may seem to be paradoxical considering the high fishing exploitation and the loss of muskellunge habitat from pollution and excessive human development on lake shores. The reasons for successful maintenance and/or improvement of Wisconsin muskellunge populations remains to be identified by studies. But, angler success throughout a newly extended range reflects a good fishery. Since muskellunge stocking is the most heavily used management tool, it looms as the most significant management factor.

Five major approaches to muskellunge management can now be identified in this State in order of their importance:

1. Habitat preservation and protection.
2. Regulation (angling restriction).
3. Stocking.
4. Population control and lake reclamation.
5. Classification of waters.

All of these measures are currently employed in Wisconsin's management program and will be discussed.

PROPAGATION DEVELOPMENTS

Fry Program

The artificial propagation of muskellunge fry in Wisconsin was reported several times in the past half century by Nevin (1901) and Webster (1929). For nearly fifteen years, until 1941, the production of muskellunge fry was performed in 18 seasonal hatcheries located in northern Wisconsin. The statewide production of muskellunge fry for stocking varied from several thousand to 28 million. Production of fry was at the mercy of natural water supplies, temperatures and quality of which varied substantially. While there were no studies made to determine the survival of fry, once stocked, it is very doubtful that many survived to legal size. The picture suggested the hatching operation and rearing pond operation required study.

Fingerling Rearing

The pond rearing of muskellunge to larger sized fingerling was initiated in 1926 (Webster, 1929). Numbers of muskellunge fingerling produced in rearing ponds was limited and erratic until more systematic procedures in handling fry and managing rearing ponds were developed (Oehmcke, 1949). The pond rearing sequence consists of providing plankton food initially, then forage of fry size, large fry forage and finally minnows. The effectiveness of rearing can break down at any of these points.

During the early success with muskellunge pond rearing, the emphasis was on numbers as well as size of fish. The efficiency of rearing pond production was determined largely by the percentage of fingerling produced from the initial fry stocking. Muskellunge fry stocked in ponds produced fingerling at an average survival rate of about 35%. Large numbers of fingerling muskellunge were reared at the two major muskellunge hatcheries located at Woodruff and Spooner. The magnitude of the muskellunge rearing program is reflected in annual production which ranged from 30,216 to 477,528 fingerling in a 10-year period, from 1950 to 1959 (Table 2).

The artificial propagation of muskellunge in Wisconsin up to 1956 was well documented by Johnson (1958). Hatchery and pond culture procedures have since been revised and refined with an accompanying reduction in production costs. But muskellunge remain a difficult species to raise and a number of problems still confront fish culturists (Table 3).

In 1954, pond rearing goals were shifted to total weight produced rather than numbers of muskellunge fingerling reared. Small muskellunge fingerling (3"-6") are now regarded as a by-product of the rearing operation and are cropped as a rearing season progresses. In this manner a more adequate food supply is assured the fish remaining in the ponds so that larger specimens are reared (Table 4).

The new production goal forced full realization of supplying the demand for forage minnows to feed young muskellunge for it is still the primary key to successful fingerling production. An analysis of muskellunge pond production records at the Woodruff station shows that 4-5 pounds of minnows are required to produce one pound of muskellunge (Oehmcke, 1969). To achieve conversion ratios in this range requires a surplus of available forage minnows of required sizes throughout a 4½-month rearing season. Variations in size of forage conversion are undoubtedly a result of either feeding different minnow species and perch or size and availability of forage. For example, it appears that fewer pounds of perch and fathead minnows are required to produce one pound of muskellunge (Table 5).

Although the effort to supply the mass forage requirements for any given rearing season is of high priority, a basic requirement is the feeding of proper sized forage fish at each critical stage in the development of fingerling muskellunge. The fourth and fifth week of rearing has been identified as one of the weakest points in our muskellunge pond program. At this stage muskellunge fry require forage species which are intermediate between advanced sucker fry (1/2"-3/4") and larval panfish or small minnows (3/4"-1"). A technique has been developed in Wisconsin for procuring larval and fingerling perch which aid in feeding at a time when 2" muskellunge fingerling require small sized forage fish. The collecting is done by boat at night with the aid of propane gas lights (Schuman, 1963). Several million perch fingerling have been gathered in one night of work using this method.

The efficiency of rearing pond production in Wisconsin is reflected in the results of 15 acres of rearing pond area at Woodruff which have produced an average of 7,577 muskellunge fingerling per acre. Weight of muskellunge fingerling produced in Wisconsin rearing ponds has ranged from 231 pounds to 800 pounds per acre per year. It is to be remembered that the rearing ponds do not produce the food required for muskellunge and that all food consumed by these fish are placed in them daily throughout the rearing season.

Hatching Improvements

The two major warmwater game fish hatcheries in Wisconsin are supplied with water from natural lakes and streams. Water from this source has presented problems in erratic temperatures and quality for incubation of muskellunge eggs. High mortalities resulted from weak fry and differential hatching resulted from excessively high and low water temperatures. To prevent future muskellunge mortalities, Wisconsin constructed a hatchery at Woodruff with equipment designed to overcome some of these problems. Installation of similar equipment is planned for the Spooner hatchery.

Initial studies in 1957 with a closed circuit hatching battery for the incubation and hatching of muskellunge eggs showed that it was feasible to achieve temperature control in a jar-type hatchery system (Klingbiel, 1958). In 1962, a 12-jar experimental battery, equipped with an electrically controlled valve, mixed hot water of a constant temperature so that cold lake water of a varying temperature in the proper amounts could provide a desired minimum temperature. After three years of experimental incubating and hatching of northern pike and muskellunge eggs, hatching batteries were designed using the temperature control equipment which had proved successful. This new equipment was incorporated in a new 1200-jar warmwater game fish hatchery which was constructed and completed in 1961-64 at Woodruff. The new hatchery can be supplied with a maximum of 2,350 gallons of water per minute. It has a total capacity of 1,140 jars, but the present operating capacity is 1,020 jars. The main feature is a control temperature muskellunge hatching battery consisting of 60 jars which collectively receive 120 g.p.m. of water. Both hot and cold water are forced to this battery by a centrifugal pump and automatic temperature control equipment regulates the desired temperatures for effective incubating and hatching.

By fine regulation of water temperature, closer coordination of the hatching and rearing functions in muskellunge and northern pike propagation was achieved. Providing consistent hatches of strong, healthy muskellunge fry regardless of weather conditions followed. Since excessive and catastrophic mortalities of the past have been avoided in the last four years, this development is regarded as an outstanding achievement.

Muskellunge hatches can be regulated to coordinate with other events in the rearing process. The hatchery man can plan ahead and prepare rearing ponds because fry hatching dates can be calculated and the exact time required for yolk sac assimilation determined to facilitate stocking in rearing ponds. Fry stocking can thus be accomplished when the plankton pulse is on the increase and be timed to relate to the hatching of suckers and other forage fishes so essential to their early welfare.

The temperature control measures permit operation of a better pond feeding regimen also. After a short cycle of feeding on zooplankton, young muskellunge consume large numbers of sucker fry. Since larval suckers grow rapidly in rearing

ponds after hatching, it is necessary to time the stocking of swim-up muskellunge fry so that the sucker fry can be readily captured and eaten by them. The control temperature battery also allows timing of the sucker hatch to coincide with feeding requirements.

Bringing off an earlier hatch in cold spring weather by regulating water temperatures during incubation also provides for a longer rearing period. From one to two weeks of additional growth can be gained by early hatching of muskellunge. It is estimated that the extra one to two weeks of growth on 30,000 muskellunge fingerling reared until mid-October would produce approximately an extra ton of muskellunge flesh and from 1"-1½" of length per fingerling. Since size is a critical factor in the success of muskellunge stocking, the extra rearing time is regarded as being particularly advantageous.

Controlled water temperatures at the Woodruff hatchery during a four-year period has assured a steady production of strong muskellunge swim-up fry. Methods of controlling temperatures by heating and mixing water and fry production have proven highly effective, but there are still some facts to be learned. The optimum temperature ranges from incubating and hatching muskellunge eggs need to be determined (Oehmcke, 1969).

Overcoming Water Quality Problems

Massive muskellunge fry mortalities at the Woodruff hatchery occurred several times during the 20 year interval from 1943 to 1963. It was suspected that these mortalities were caused by an abnormal water temperature and possibly water quality. The presence of copper and zinc in the hatchery water supply was reported by Radonski (1964 and 1965). Copper appears to be toxic at the relatively low concentration of 100 p.p.b. (Radonski, 1967).

Since copper and zinc go into solution with a low pH and are more toxic in soft water than hard water, Radonski (1965) suggested a change in pH could alter the toxicity of these metals. The temperature control system warmwater outlet provided waters with a higher pH than natural cold waters, thus neutralizing the effect of the toxins. The maintenance of minimum water temperatures (above 50°F.) by automatic temperature control thus provides an additional safeguard in muskellunge egg incubation. The disappearance of muskellunge fry mortalities at the Woodruff hatchery in the past four hatching seasons testify to the elimination of this cause of mortality. Hatchery innovations are responsible.

Yearling Program

The parameters of rearing of yearling muskellunge have been explored at the Woodruff station also. For 15 years (until 1962) a number of yearling were reared (Oehmcke, 1950) to provide larger sized muskellunge for stocking since it appeared that better survival of yearling fish was obtained than from fingerling. Prior to 1962, the average size of muskellunge fingerling stocked was much smaller (average 6"-9") than those being stocked under the present program. Although provided with adequate supplies of feed, yearling muskellunge did add appreciable growth over winter (from fall to spring). Muskellunge yearling generally averaged 11 inches in length and 3 to 6 fish per pound in weight at time of stocking.

The newer techniques, namely hatching muskellunge at an earlier date and intensified feeding, has now resulted in the production of large sized muskellunge fingerling which average greater than 12 inches in length in 4½ months of rearing.

The muskellunge yearling program was discontinued since the production of a larger sized fingerling in a one season operation has reduced the high cost of holding fish for a one year period.

Trough Rearing

Wisconsin fish culturists have also attempted to rear muskellunge in tanks and troughs,much like that used for trout, in search of a better system than pond rearing. Although rearing methods for trout offers considerable promise as a muskellunge rearing procedure and apparently provides higher survival rates than for muskellunge fry reared in ponds, growth rates of pond reared muskellunge have been found to be more rapid (Walker, 1958 and Klingbiel, 1959). The trough rearing system used in Wisconsin involved the use of live food such as daphnia, sucker fry and minnows. Adequate supplies were provided at all times, but labor costs for the operation were prohibitive. It is believed that space was a factor in limiting the growth in tanks. The area that young muskellunge can range in rearing ponds is extensive and permits greater activity of the fish. Whether improvement of vigor and subsequent growth is increased has not been confirmed.

Attempts have been made in Wisconsin to feed artificial food such as liver, combinations of yeast, flour and meat, pellets, and other non-living material without success. We watch with interest the progress being made in Pennsylvania in experiments with the feeding of artificial dry diets to Esocid fishes and walleye (Sorenson, 1968). Without a doubt the economical production of large numbers of quality muskellunge fingerling hinges on a breakthrough in this type of feeding routine. High costs in rearing muskellunge in ponds are primarily accrued from forage gathering activities. At such a time when minnow seining for muskellunge forage can be eliminated, costs of production will be drastically reduced. In the writer's opinion, the ultimate success of an ecomomical muskellunge fingerling rearing program will be found in a feeding technique of this nature.

In summary, progress in the refinement and techniques of hatching and rearing muskellunge have led to a quality product at a greatly decreased cost in Wisconsin. Future improvement along these lines hinges on a more economical method of obtaining feed and of feeding young muskellunge fingerling.

MANAGEMENT MEASURES

The control of angling harvest of muskellunge through fishing regulations has been consistent and is perhaps the oldest and most well known tool in muskellunge management. However, other new management measures are now used which are equally, if not more significant than regulation.

Habitat Preservation and Protection

Wetland areas adjacent to shorelands of northern Wisconsin lakes are important to the natural reproduction potential of Wisconsin muskellunge. In the past 20 years the sale of lake frontage of many prime northern Wisconsin muskellunge waters has reached the point where very little, if any, public land with unimproved frontage remains. Subsequent development of private lake frontage property has resulted in the destruction and alteration of muskellunge spawning grounds. Although a considerable amount of lake frontage is still held in public ownership (federal, state and county), firm measures are necessary to stop the degradation of muskellunge spawning and rearing habitat. A land acquisition program of the Wisconsin

Department of Natural Resources incorporates lake and stream fish habitat purchases as one of its primary aims. The acquisition of critical lake frontage on muskellunge lakes to protect this type of habitat has been limited but is most effective (Hacker, 1968).

The Wisconsin legislature passed a broad, new Water Resources Act aimed at the control of all forms of water pollution and preservation of scenic and ecologic values. This new statute strengthens enforcement provisions to facilitate the prevention and abatement of pollution. Through the establishment of water quality standards and the regulation of development on shorelands, the prospect of assuring the water quality necessary for the perpetuation of muskellunge is brightened. The use of lands adjacent to any body of water determines the quality and utility of those waters. It is expected that in 1969 all Wisconsin counties will have zoned all navigable water shorelands. Present shoreland zoning requirements are applicable within 1000 feet of any lake, pond or flowage in the state. Suitable setbacks for dwellings, septic tanks and dry wells, and spacing of buildings are established to prevent pollution and to protect shorelands adjacent to such water. A particularly important requirement is to have wetlands zoned as conservancy and withheld from development.

With the implementation of the 1965 Water Resources Act, the preservation of key muskellunge habitat areas will be maintained. It is estimated that a large percentage of the state's muskellunge harvest results from natural reproduction. Thus, the prevention of loss of critical spawning habitat and maintenance of high water quality is a high priority management goal.

Regulation

The regulation of muskellunge harvest is considered second in importance to habitat preservation. Current angling regulations are directed toward protection of muskellunge brood stock by the establishment of season. Within the north and south limits of Wisconsin muskellunge range, spawning quite consistently runs from April 15 to mid-May. The peak of spawning usually occurs several weeks before the opening of fishing season on the second Saturday in May. The closing date of the season is somewhat arbitrary and is perhaps based on the characteristics of angling for this species. Most muskellunge fishing ceases after ice forms on the lakes. Very few muskellunge are captured through the ice although occasional specimens are taken. If the season were extended through February 15 with the regular open season for big game fish, it is doubtful that any serious exploitation would occur. Muskellunge are not caught readily on hook and line with conventional ice fishing methods (Kempinger, 1969). Closed season is mandatory before and during the spawning season to protect brood fish in their migration and during the spawning act.

Low population densities are characteristic of the Wisconsin muskellunge fishery. Some of the prime lakes run as high as two adult muskellunge per acre, but the average is less than one. Without size limits, a heavy exploitation of brood fish and a contingent decline in average size of fish captured can develop. An 18 year record of harvest from the Northern Highland Research Station on Escanaba Lake, Vilas County, where all angling restrictions have been removed, provides data which substantiates this (Table 6).

Fishery managers in New York learned years ago the effect of low size limits on a muskellunge fishery (Heacox, 1946). Under a 24-inch size limit many female muskellunge were taken before they had an opportunity to spawn, but when size limits were raised to 32 inches on Chatauqua Lake, the standing crop of muskellunge increased dramatically. Wisconsin follows this principle by maintaining

a 30-inch size limit on this valued trophy fish. Muskellunge reach a legal length of 30 inches in 3 to 5 years in Wisconsin and, normally, reach sexual maturity before reaching the legal length. The 30-inch size limit has been well tested over 40 years in Wisconsin and is considered one of the most important factors in protecting its native spawning stock. The 30-inch minimum size takes advantage of the period of most rapid growth.

The lower bag limit of one fish per day is a reflection of the trophy character and low density of this species. Bag restrictions spread the total harvest over a greater number of fishermen and excessive harvest tends to be avoided.

Angling for muskellunge is restricted to hook-and-line fishing with artificial and live baits. The use of spears, nets and guns is prohibited. Motor trolling (illegal in most waters since 1923) is not legal on nearly all of Wisconsin's prime muskellunge water. However, pressures are being exerted to permit motor trolling in these areas. The effects of trolling with motor have never been studied on prime muskellunge waters in Wisconsin, but the results of trolling with metal lines and the extensive harvest from such methods on Chatauqua Lake in New York has been reported by Heacox (1946). Current management sentiment calls for prohibiting motor trolling on high quality muskellunge waters.

Wisconsin fish managers conclude that existing regulations for taking muskellunge on hook and line meet the high standards necessary to maintain a sustained fishery. More liberalized regulations for muskellunge would relegate this species to a position far below its present trophy status and might very well result in the demise of this species in a competitive environment.

Stocking Practices

Modest numbers of high quality muskellunge fingerling are stocked in Wisconsin lakes and streams annually (Table 3). Less than 30% of a total of 312,048 acres of muskellunge waters is stocked annually. At first glance this appears to be a meager attempt to sustain muskellunge populations by this management method. However, refinements in stocking procedures have limited plantings to critical problem waters. These specialized stocking situations include waters faced with heavy depletion by angling, excessive competition by northern pike, loss of spawning areas, natural catastrophes, and stocking of waters that have been reclaimed with toxicants.

Stocking rates vary with management requirements. Biologists and fish managers determine the recommended stocking rate for individual bodies of water based on such factors as available forage, exploitation rates and general conditions of the fishery. When the actual catch from a given lake is known, a fingerling stocking of twice the annual harvest is recommended. Otherwise, a standard rate of two fingerling per acre is used. A certain amount of maintenance stocking is conducted at this rate to assure the perpetuation of spawning stock in prime muskellunge waters.

Large sized fingerling, ranging in size from 8"-15", are used in all high priority muskellunge plantings. Although small sized fingerling (2"-6") are stocked, such procedures are merely a by-product of a necessary intermediate cropping routine before the final harvest of large fingerling. Although lower returns are expected from fingerling stocked in small sizes, this procedure is

followed on the theory that these fish would be lost through cannibalism if they are retained in rearing ponds. Even a small return on this type of stocking would be an added bonus.

Various studies of the survival of stocked muskellunge have provided differing results, but with the advent of large sized fingerling stocking some encouraging information is now available.

In analyzing the muskellunge fishery of Little Green Lake, Wisconsin, a reclaimed lake, Hacker (1966) reported for the period 1963-65, 471 muskellunge caught, weighing 4,215.8 pounds, in a voluntary creel census. Known age muskellunge from the September, 1960 plant comprised 298 or 63.3% of all fish caught during the voluntary creel census. It is interesting to note that in the original planting, these muskellunge ranged in total length from 8.4"-13.3" and weighed a total of 266.5 pounds. The harvest from the 1960 planting was 2,574.2 pounds which represented a 966% increase in weight in the five year period since stocking. Hacker emphasizes that the numbers of fish caught and total annual weights from this stocked fishery are minimum harvest figures only.

Other experimental stocking studies on High Lake, Vilas County, and Escanaba Lake, Vilas County, describe returns of 3% to 25% (Kempinger, 1969) (Klingbiel, 1954). There is some evidence that from 20% to 30% of this total estimated state harvest of 100,000 fish may be due to the stocking effort (Hacker, 1966; Snow, 1968). Since Churchill (1966 and 1968) reports a fairly high and sustained yield from 1964 through 1967, part of the success can be attributed to stocking.

Results of stocking non-native muskellunge waters on a maintenance basis is reflected in a 15-year cooperative creel census on Wabicon Lake in Forest County. New and highly productive musky fisheries have been created in several large reservoirs: Caldron Falls, Marinette County (1,180 acres), Gile Flowage, Iron County (3,384 acres), Chute Pond, Oconto County (600 acres), and the Townsend and Wheeler Flowages, Oconto County (519 acres). Years of high harvest appeared to coincide with years of previous heavy stocking . Each increment of additional evidence accumulated from studies and management observations gives more encouragement to the stocking of large sized muskellunge fingerling.

Much information is needed as to the proper stocking methods. Limited evidence is available which indicates that stocking muskellunge in late fall when water temperatures are lowest is more desirable than mid-summer and late August stocking. If large sized muskellunge fingerling are planted after the first fall lake turnover, most predators and/or competitors will have settled down and it can be assumed that predation is at a low level. A research effort has been initiated to test the probability that a higher survival of stocked fish during this period will result (Johnson, 1967). Due to the cost factors much of Wisconsin's fingerling stocking is currently done in September and early October.

Considerable care and attention is paid to handling of muskellunge fingerling during the stocking operation. Young muskellunge are removed from rearing ponds with extreme care and clean aerated water is available in tank transportation equipment. Secondary infections from bruises and possible mishandling are prevented by the addition of several grams of acriflavin to transportation tanks. Although both spot planting and scatter planting of muskellunge fingerling have been practiced, present stocking procedures call for scatter planting whenever

possible to eliminate concentrations of small fish. Muskellunge fingerling are in a traumatic condition from handling and transportation, and could be easy prey for other big game fish.

Population Control and Lake Reclamation

The northern pike (Esox luscius), another prime Wisconsin game fish, is regarded as a direct competitor of the muskellunge. Competition and ultimate domination by northern pike has forced consideration of pike control measures. The range of northern pike has expanded into many exclusively muskellunge waters. (Threinen, 1950). A pike removal program was tried in several waters. Nets set on muskellunge spawning grounds during the pike spawning season gave good results. The evaluation of this type of northern pike removal work by district fish managers shows that northern pike populations can be decimated then. Concentrated stocking of large sized fingerling follows pike control and results in restoring the muskellunge population.

Since northern pike are unwanted in prime muskellunge waters, special regulations have been imposed and have been partially effective in controlling northern pike populations to benefit the muskellunge. These regulations call for a year-round season with a bag limit of 25 fish per day and no size limit. In some counties these regulations have been so effective that they have been discontinued.

Muskellunge have been successfully introduced into landlocked, soft water lakes containing stunted panfish populations in an effort to reduce slow growing perch and panfish by predation. Positive results have been obtained in reducing stunted perch populations after yearling muskellunge were stocked in a 92-acre soft water lake in Vilas County (Gammon, 1965). Muskellunge were ineffective in improving the growth of stunted bluegills in Clear Lake, Sawyer County, within five years after stocking large sized fingerling, but the growth rate of muskellunge was high (Snow, 1968).

It has been my personal observation that large sized muskellunge fingerling stocked in landlocked lakes in the presence of stunted panfish and perch have made definite inroads on the total numbers of small fish, but no positive evidence has turned up which indicates that the growth rate of panfish has been improved. Nevertheless, the quality of fishing in these lakes has definitely been enhanced by the presence of muskellunge. The conversion of large numbers of unusable watchfob-sized panfish to muskellunge flesh is regarded as sound utilization of this resource.

A most promising muskellunge management technique is reflected in the successful establishment of spawning muskellunge populations in lakes which have been treated with toxicants. The muskellunge appear to provide sufficient predation to maintain balanced game and panfish populations in such lakes. There are two classic examples: A productive, well balanced sport fishery has been reported over the past ten years in Tug Lake, Lincoln County. This 168-acre lake was treated with toxicants in 1957 and subsequently stocked with walleyes, muskellunge, suckers, and largemouth bass (Wendt, 1964-67); previously mentioned Little Green Lake, Green Lake County, (466 acres) was stocked with yellow perch, bluegill, largemouth bass, smallmouth bass, walleye, and muskellunge. High angler returns are reported for all these species and a balanced sport fishery has been maintained.

The question is frequently asked why northern pike removal is conducted in favor of chemical treatment since lake reclamation procedures have been so successful. The answer is that almost all Wisconsin muskellunge lakes which have been invaded by northern pike are drainage lakes which have either/or outlet or inlet streams which make them difficult to treat with chemicals. In addition, the spectre of thousands of pounds of large northern pike killed from treatment procedures would rose most sport fishermen and thereby negate such an operation. In any case the introduction of muskellunge in reclaimed landlocked waters holds the greatest promise in this category of management.

Related to the intra-specific competition from northern pike is the natural hybridization between northern pike and native muskellunge. Natural hybrids are caught frequently in several large Vilas County muskellunge lakes where northern pike have entered the native fishery. We estimate that 40%-50% of the "muskellunge" caught annually from Lac Vieux Desert, a 2,853-acre lake on the Michigan-Wisconsin boundary, are natural hybrids. Fred A. Aman, taxidermist at Conover, Wisconsin, mounts many muskellunge specimens from this lake and is reported handling an average of 12 hybrids a year from it. The specimens he has worked on range from 31 inches to 49½ inches, and from 7 pounds to 32 pounds. Evidence that this hybridization has been taking place for some time is found in the national Field and Stream Fishing Contest records for 1950 when the fourth-place winner was a 50 pound, 53-inch muskellunge (hybrid) caught by Delores O. Lapp in Lac Vieux Desert Lake. The exact significance of this cross-breeding and its impact on native muskellunge populations is not really known at this time. However, observations by fish managers in the major musky counties show that natural hybridization between the two species is rising in all muskellunge waters where northern pike are now present. This cross-breeding of a native species is of definite management concern and presently begs for research attention.

Classification of Muskellunge Waters

A recent tabulation in Wisconsin lists 692 lakes, streams and flowages as having muskellunge. This classification includes all native and introduced muskellunge populations in lakes and streams (Wisconsin Department of Natural Resources, 1968). I estimate that about 25% of all these muskellunge populations in Wisconsin were created through stocking.

In the list of muskellunge waters the capability of these waters to reproduce muskellunge was designated. This new classification system forms a basis for more precise management planning and provides fishermen with specific information on the quality of muskellunge waters. Three major classes of muskellunge waters are as follows:

Class A - Prime muskellunge waters are placed under the "A" classification. Most of these are native muskellunge waters, particularly those located in the northern part of the state. These waters consistently support good muskellunge populations and are considered among the top muskellunge producers.

Class B - Waters in this list provide very good muskellunge fishing, but, in general, muskellunge are not the principal species or as abundant as in waters listed in the Class A category.

Class C - Waters in this list do not produce muskellunge as regularly as those in the first two categories and have minimal, if any, natural reproduction.

Of the 692 waters identified in the Muskellunge Waters classification bulletin, the majority, 309, are Class A waters. Class B waters include 195 lakes, streams and flowages, while 188 comprise the Class C category. A total of 312,048 acres of all three classes of muskellunge water is present in Wisconsin.

The heaviest concentration of muskellunge lakes is located in the extreme north central portion of the state (Appended Map). This area is also the original native muskellunge range. Four counties in this region contain 414 muskellunge waters and comprise 62% of the state's total. Fifty-five percent of the latter total are considered Class A musky lakes and streams.

Research

Early research on muskellunge in Wisconsin was brief and was limited to age-growth (Schloemer, 1936), spawning habits and artificial hybridization (Black, 1947).

Intensive studies of propagation were started in 1953 which culminated in a handbook on pond culture (Johnson, 1958). The important steps in Wisconsin's muskellunge propagation procedures were documented in this bulletin. This study contributed a more thorough understanding of the requirements for the production of natural forage in rearing ponds and the means by which cultures of zooplankton could be improved through fertilization. Detailed steps in the propagation of muskellunge were described and the sequence of natural food requirements for young muskies in ponds was clearly delineated.

The Department of Natural Resources actively pursued muskellunge studies as a part of its fishery research program. A statewide fishery research project is aimed at obtaining information on five major areas important to muskellunge management:

1. Muskellunge spawning and reproduction.
2. Feeding habits of muskellunge.
3. Muskellunge age and growth studies.
4. Water quality of muskellunge habitat.
5. Evaluation of muskellunge stocking.

Muskellunge spawning and reproduction research is directed toward the determination of behavioral patterns of muskellunge that influence their survival. Such studies will explore how muskellunge locate spawning grounds; whether spawning habitat is optimum; patterns of dispersion of stocked fingerling and movement of native fingerling in lakes; migration of muskellunge to and from spawning areas; behavior of muskellunge in the spawning area; development of eggs in relation to lake bottom soils, and location and dispersion of newly hatched fry.

The knowledge of the food of muskellunge is important because of our limited information on its preferred forage, and the possible effect of muskellunge as a predator on the fish population of lakes. A research study on the feeding habits of muskellunge is directed toward this end. Its objectives are to determine the number, quantity, size, and kind of food items that are taken by muskellunge and to relate, where known, the foods consumed to their availability.

Muskellunge age and growth studies have been conducted since 1955 when all muskellunge over five inches in length, which were stocked in northwest area lakes and some of the muskellunge stocked in northeast area lakes, were fin clipped to designate the year they were stocked. This study will determine the rate of growth of known age muskellunge from fingerling to adult stages and to validate age determination methods using fin sections and scales. It will also be possible to make some comparative growth data on northern pike in Lac Court Oreilles, a famous muskellunge lake.

The importance of water quality of muskellunge habitat is emphasized in a project which seeks to detect the effect of water quality as it pertains to heavy metals and antagonistic alkaline earth materials, has upon the survival of muskellunge eggs and lakes. Water samples from a series of twelve Wisconsin lakes and two hatcheries were collected during three spring spawning seasons (1966, 1967 and 1968) and analyzed to determine if naturally occurring zinc and copper were factors causing muskellunge egg and fry mortality. Results to date indicate that no correlation of egg mortalities to chemical content was observed. Correlations appeared to exist between low temperatures, below 50°F., and egg mortalities. Survival of fry was high at water temperatures of 55-60°F. both at the Woodruff hatchery and in the lakes.

In order to develop a method to improve the survival of stocked muskellunge, an evaluation of muskellunge stocking is being carried out by the statewide fishery research unit. The main objective is to determine the survival of fin clipped and unmarked muskellunge in selected experimental lakes and hatchery ponds and to make population estimates of native muskellunge and northern pike (where they are present) based on recaptured, marked fish. Based on population and survival estimates fromfish recaptured with electro-fishing gear and fyke nets, it was established that stocked muskellunge have low survival in lakes but still contributed from 2-60% of muskellunge caught. It was found that the highest mortalities most often occurred within two weeks after stocking.

Throughout northern Wisconsin are found hundreds of small landlocked lakes of low fertility which have populations of slow growing and stunted perch and panfish. For several years fish managers have been introducing muskellunge in lakes of this type to reduce large populations of slow growing fish and to try to improve growth rates.

Gammon (1965) studied the predator-prey interaction of muskellunge on resident fish populations of two bog lakes. The lakes contain resident populations of yellow perch and largemouth bass, and within a year after the introduction of muskellunge yearling, the perch population in one lake declined drastically. At the time of muskellunge stocking, it was estimated that 31,000 perch were present and after one year the population density of perch was too low to estimate. In the second lake, three years elapsed before a comparable reduction occurred. Population levels of largemouth bass also decreased but growth rates were not improved. The growth rate of one and three-year old perch increased after the reduction in the number of perch. About 25% of the yearling muskellunge died shortly after introduction. After this initial loss, a relatively constant annual mortality of 10-15% was observed. The rate of growth was below the average for Wisconsin muskellunge in both lakes. It is believed that this drop in growth rate was brought about when prey species of proper sizes were eliminated.

In a most recent Department of Natural Resources research study, Snow (1968) reports the results of stocking muskellunge and walleye fingerling in a lake

containing an extremely abundant and slow growing bluegill population. The lake selected (Clear Lake, Sawyer County) is a 77-acre seepage lake with a maximum depth of 32 feet, a pH range of 6.8-7.8, and methyl purple alkalinity range of 27-35 p.p.m. Aquatic vegetation was very sparse and scattered. Throughout the period of study, 1960-1967, after muskellunge were stocked, there were no significant changes in the growth rates of the bluegill. A minimum return to the creel of 7% of the initial number of muskellunge stocked, based on a voluntary creel census, was reported to be of above-average growth and survival.

Comprehensive reports on the Department of Natural Resources research studies are being compiled and will be published in the near future. In general, research studies on muskellunge stocking continue to show that survival of stocked muskellunge fingerling is low but, nevertheless, stocked fish make up a substantial portion of the adult muskellunge population in some lakes.

ECONOMIC ASPECTS

The impact of muskellunge fishing on the recreation industry in Wisconsin is difficult to measure, but the state's leadership in the sale of nonresident fishing licenses attests to the overall popularity of all types of fishing as a summer recreational pursuit.

The lure of the muskellunge as a trophy fish to nonresident fishermen is also considered a big factor in the large number of nonresident fishing licenses sold. While an estimated 10%-15% of all nonresident fishermen fish for muskellunge, it is assumed from tourist sampling that many nonresident fishermen choose to fish Wisconsin waters in the hope of catching a muskellunge incidental to other fishing activity. Wisconsin has led the nation in nonresident fishing license sales for the past 10 years.

Extensive use of the muskellunge for attracting out-of-state and resident fishermen is made by Chambers of Commerce, resorts, sporting goods shops, and newspapers. Fishing derbies and contests sponsored by all of these organizations and expensive prizes are offered for record catches. Participation is heavy in the musky lake areas.

An outstanding promotion, specifically aimed at muskellunge fishing, is the "Musky Marathon" sponsored by the Vilas County Chamber of Commerce. This marathon has been conducted for three years and has attracted over 4,000 participants. An established set of rules guide the marathon and grand prizes are awarded for the first three largest muskies caught and every tenth fish. Each fisherman receives recognition in the form of a parchment certificate. A total of 4,510 fish have been entered in the contest for a three-year period, from 1966 to 1968. These fish weighed a total of 53,966 pounds. This form of voluntary creel census provides some indication of the harvest and of the economic significance of the muskellunge in one of Wisconsin's best muskellunge counties. Wisconsin's muskellunge are rated as excellent food fish and, therefore, their contribution in protein has some economic significance.

The University of Wisconsin Department of Commerce reported in an early research study that 21% of the tourists preferred muskellunge fishing (Lanning, 1949). Later surveys in 1955 and 1957 by the Wisconsin Conservation Department sampled licensees. This survey revealed that 9% of residents and 10% of licensed nonresidents had fished for muskellunge (Threinen, 1958).

An up-to-date summary of information on muskellunge fishing in Wisconsin was drawn from three separate sources by Churchill (1968). There were 2,600 responses to a mail questionnaire sent to a random sample of Wisconsin licensed fishermen in 1966. Two other sources included data from the "Musky Marathon" sponsored by the Vilas County Chamber of Commerce, and a similar survey in northwestern Wisconsin in 1961. A 1961 survey was conducted by the Department of Natural Resources with more intensive coverage but on fewer lakes. The report notes that nonresident fishermen did 41% of the muskellunge fishing and caught 41% of the muskellunge harvest. In 1966, Churchill reported that "statewide, 157,000 fishermen made almost a million muskellunge fishing trips and caught 94,000 legal muskellunge. One-sixth of all licensed anglers fished one or more times for muskellunge, averaging six trips apiece. One-third of these caught one or more legal sized muskellunge with an average of 1.8 for each successful angler. Less than 2% of all who fished for muskellunge caught more than four; the largest number reported for a season catch was 24."

Expenditures for lodging, meal and fishing equipment expended specifically on muskellunge fishing excursions can only be estimated. Research by Fein and Werner (1960) was directed toward the contribution made by all fishermen to the economy of the state. Their study showed that resident and nonresident fishermen spent an estimated $188,455,218.00 in 1960. If the conservative estimate of 10% can be applied to all licensed fishermen who fish for muskellunge, the economic impact of the fishery is quite obvious.

In summary we feel this important fishery is being supported by adequate management measures to assure its future preservation. Long range resource planning projections anticipate thousands of additional fishermen by the year 2000. The program reported here will permit Wisconsin to keep abreast of this growth only if commensurate funds are made available.

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Table I. Muskellunge Fishing in Wisconsin - 1964-67.

	1964	1965	1966	1967
Total licenses sold	1,041,000	1,054,000	1,067,000	1,098,000
Number who fished for muskellunge	114,000	150,000	157,000	- -
Percent of total	11	14	15	- -
Number who caught muskellunge	- -	50,000	52,000	39,000
Percent of total	- -	5	5	4
Number of muskellunge caught	110,000	110,000	94,000	92,000

(Source: Churchill, 1968)

Table 2. Wisconsin Annual Muskellunge Fingerling Production - Statewide - 1950-59.

Year	Number of Fingerling Produced	Year	Number of Fingerling Produced
1950	143,844	1955	250,240
1951	238,022	1956	30,216
1952	259,912	1957	477,528
1953	201,098	1958	96,867
1954	65,706	1959	118,192

Table 3. Muskellunge Fingerling Production and Costs in Wisconsin (1957-1967)

Muskellunge Fingerling Produced			Cost	
Year	Number	Pounds	Fingerling	Pounds
1957	476,718	4,700	.16	16.45
1958	96,867	3,290	1.05	30.96
1959	118,192	3,074	.73	23.26
1960	216,460	3,987	.38	20.85
1961	190,167	4,582	.49	20.34
1962	334,935	12,160	.26	7.28
1963	103,816	9,410	.96	10.57
1964	294,740	15,834	.35	6.66
1965	418,771	18,125	.26	5.96
1966	157,937	20,774	.82	6.27
1967	93,258	21,300		
1968	77,619*	17,664*		
Total	2,580,480	134,900		

Table 4. Size of Muskellunge Fingerling Produced at Woodruff Fish Hatchery (1962-68).

	Size Range					
	3"-6"		7"-9"		10"-15"	
Year	Number	Weight	Number	Weight	Number	Weight
1962	218,877	372	21,998	2,222	21,876	5,723
1963	2,435	54	-	-	6,507	1,508
1964	174,204	656	8,891	1,258	26,717	6,540
1965	230,462	578	18,558	994	39,235	7,263
1966	37,138	1,147	7,198	976	36,781	9,243
1967	4,138	54	21,715	2,217	29,123	8,625
1968	33,401	273	2,509	386	24,709	9,005
Total	700,655	3,134	80,869	8,053	184,948	47,907

Source: Wisconsin Department of Natural Resources, Bureau of Fish Management Annual Reports.

Table 5. Summary of Forage used in Muskellunge Rearing - Woodruff Fish Hatchery (1962-68)

Year	Total Pounds of Forage	Total Pounds of Fingerling Produced	Conversion Ratio
1962	54,300	10,714	5.07
1963	6,681	3,854	4.33
1964	35,800	8,455	4.23
1965	43,683	9,660	4.52
1966	51,750	11,507	4.50
1967	46,500	10,896	4.27
1968	42,550	9,664	4.40

Table 6. Harvest of Muskellunge - Escanaba Lake, Wis. (1946-68)

	Year 46	47	48	49	50	51	52	53
Number	14	7	5	11	34	21	52	20
Weight	91	68	38	74	257	85	200	133

	Year 54	55	56	57	58	59	60	61	62
Number	14	9	6	13	16	11	18	24	74
Weight	117	32	30	78	80	45	90	88	210
Av.T.L.	29.1	27.3	26.0	26.7	24.8	25.0	26.4	21.5	22.3
% Stocked	*	*	*	*	*	*	*	17	18

	63	64	65	66	67	68**
Number	57	22	23	22	21	24
Weight	173	131	112	153	105	76
Av.T.L.	23.0	28.7	25.6	29.2	25.3	23.7
% Stocked	35	25	26	27	14	8

*No date
** Summer only

Muskellunge Rearing Chronology (Generalized)

Approximate date or time	Activity
April 15 - May 1	Spawning.
12-15 days	Egg development and hatching.
April - May	Prepare ponds for fry. Fertilize and innoculate for zooplankton.
6-8 days after hatching.	Stock muskellunge swim-up fry into ponds.
8-10 days after muskellunge.	Stock sucker fry.
June 15	Stock minnow and perch fry for forage.
June 22	Crop 3" muskellunge fingerling for transfer to other ponds and distribution.
June 22	Stock small sized forage species.
June 22 - August 1	Cropping of muskellunge fingerling for distribution.
August 1	Stock forage species (all size).
September 1 - October 15	Harvest large muskellunge fingerling.