

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE

IN THE MATTER OF THE PROPOSED ADOPTION OF
RULES FOR LAKE AERATION

STATEMENT OF NEED AND REASONABLENESS

July 12, 1988

Statement of Need and Reasonableness
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Preface

The DNR is responsible for managing Minnesota's aquatic resources for the purposes for which they are best suited. As the state's population grows greater demands for recreational and commercial use of lakes and wetlands will occur. Undoubtedly, aeration will continue to be a popular means of expanding fishing and recreational opportunities (see figure 1). These new demands may conflict with existing recreational uses or diminish some wildlife or fisheries values. Based on the potential for a continuing increase in the number of aeration systems (figure 2), greater public exposure to the hazard created by these systems, and the legislative mandate to promulgate rules, the DNR has prepared these rules for the regulation of aeration systems on protected waters.

Introduction

Winterkill of fish often occurs in ice covered lakes when dissolved oxygen is depleted and toxic gasses build up due to the decomposition of organic matter. Snow cover on frozen lakes reduces light penetration which limits photosynthesis, the major source of dissolved oxygen during the winter months. Under these conditions oxygen input is virtually eliminated but oxygen consumption by decomposition and plant and animal respiration continues. If demand exceeds the supply the oxygen concentration may drop below levels required by fish, resulting in winterkill.

Winterkill is seldom, if ever, complete. In some cases it can be beneficial by eliminating undesirable fish populations or reducing overcrowding in stunted panfish populations. More often it is detrimental because the more tolerant, less desirable fish species, such as the black bullhead, survive to repopulate the lake.

Scidmore (1970) estimated that approximately 2,600 of the 6,100 fishing lakes in Minnesota have the potential for winterkill. During the worst winterkill season of record (1955-56), 308 lakes or about 5% of all fishing lakes winterkilled. Although this does not appear to be a significant number on a statewide basis, the importance of winterkill in Minnesota is related not only to the number of lakes, but also to their location and the number of other quality fishing lakes nearby. In the winter of 1969-70, about 95 percent of the winterkill lakes were in the southern half of the state. This area contains only 35 percent of the state's fishing lakes, but has 75 percent of the state's population. "With most of the winterkill lakes concentrated in the region with the fewest number of fishing lakes and the majority of the population, the winterkill problem assumes considerable significance" (ibid.).

Several methods of alleviating winterkill have been tried. Snow removal or plowing has been used with some success on relatively small bodies of water (Paulin 1960). Clearing snow above large areas of vegetation may also work, but in years of frequent heavy snowfall this may not be cost effective (Woods 1961). Another serious disadvantage to plowing is that windrows of snow left by the plow act as snowfences and cause additional drifting. Snow removal, when snow and ice conditions allow, is still a common practice among private hatchery operators on small ponds used to rear bait and gamefish. Where water level manipulation is possible, raising water levels to increase lake volume, or releasing oxygen depleted bottom water commensurate with incoming flow have been successful in preventing winterkill.

Scidmore (1970) suggested that perhaps the most economical management of winterkill lakes is to open them to "promiscuous fishing" i.e. waiving catch limits and restrictions on methods of take when winterkill is imminent, allowing fishermen to maximize use of the fish available. The lake can then be restocked with selected fish species the following spring to take advantage of the reduced competition resulting from winterkill.

Promiscuous fishing and restocking is one way to manage winterkill lakes. In the southern half of the state, where fishing opportunities are limited and many lakes experience frequent winterkill, this alternative is much less appealing to anglers because fish stocked may barely reach acceptable size prior to the next winterkill. Unless winterkill is prevented there is no opportunity for anglers to take larger sized fish from these waters.

In recent years, lake aeration has become the most common and successful method of preventing winterkill. Four methods of aeration, listed below, are commonly used in Minnesota:

1. Sub-surface bubblers: Air is piped to a diffuser on the lake bottom through weighted plastic air lines from a shore-housed air compressor or high-volume, low-pressure blower.
2. Air injection systems: These pontoon-mounted, propellor-type aerators are driven by electric motors of various sizes. Air is injected just beneath the water surface and horizontal currents created by the propellor disperse the air entering the water.
3. Mechanical surface agitators: There are several types of mechanical surface agitators, but all are basically submersible or floating pumps which spray water into the air, producing a fountain-like effect.
4. Pump and baffle systems. These systems function through the direct aeration of a significant portion of the lake volume (Pederson 1982). Water is pumped from the lake to the top of a shore based chute, where it cascades back into the lake over a series of baffles, oxygenating the water and driving off harmful gases.

The oxygen provided to the lake through the operation of the first three systems comes primarily from oxygen transfer at the air-water interface due to the area of open water created (Johnson 1970; Skrypek and Shodeen 1977; Toetz et al. 1972; cited in Pederson 1982). Pump and baffle systems are provided by the Department of Natural Resources (DNR) to municipalities and

citizen groups through the Cooperative Opportunities for Resource Enhancement (CORE) program. In the winter of 1987-88, 30 CORE project pump and baffle systems were permitted statewide.

The first successful lake aeration project documented in Minnesota was in Lake Shetek, Murray County, during the winter of 1974-75 (Johnson and Skrypek 1975). The subsurface bubbler system in Lake Shetek consists of three 7.5 hp electric motor/blowers and 12 Helixor diffusers. By mid-winter this system had created approximately 60 acres of open water. DNR aeration permit records show that three other aeration systems were in operation in 1974.

Prior to 1978, aeration permits were issued by the DNR Division of Waters under the authority of Minnesota Statutes, Section 105.42, which require permits for activities which "... change or diminish the course, current or cross section of any public waters ... by any means, including ... placing of any materials in or on the beds of public waters". In 1978, permit authority was transferred from the DNR Division of Waters to the DNR Division of Fish and Wildlife under authority of Minnesota Statutes Section 84.027 (Commissioner of Natural Resources general powers). This was necessary because of the potential impact on the aquatic environment presented by aeration systems and the need for applicants to consult with fish and wildlife managers and biologists (Pederson 1982). In May 1978, Commissioner's Order (C.O.) 1996 was written, establishing permit and safety requirements for installation and operation of aeration systems. This C.O. has been revised several times, and C.O. 2194, as amended by C.O. 2258, currently regulates lake aeration.

With the advent of aeration, it is now possible to keep fish alive in basins that would frequently winterkill. Many of these basins that provide habitat for waterfowl and furbearers also have fish populations. Fish species such as black bullhead, which can tolerate high water temperature and low dissolved oxygen concentration are often the major component of the fish population in these basins. With virtually no competition these fish rapidly multiply to nuisance proportions and degrade habitat quality by increasing turbidity, which reduces light penetration and in turn growth of rooted vegetation. In shallow lakes frequent winterkill keeps these fish populations in check, benefiting the habitat for use by waterfowl and other wetland wildlife. Natural winterkills should be allowed to continue in many of these basins, particularly those with traditional waterfowl use because of the benefits to waterfowl and furbearer. Aeration should be closely scrutinized if it is to be considered in these shallow basins and then only as part of a comprehensive management plan, which may also include the use of fish toxicants to reclaim the lake, fish barriers to keep undesirable species out and special regulations to reduce user conflicts.

The success of aeration in preventing winterkill is well documented. Certain uses for water quality improvement also exist. Because of the open water hazard created by aeration systems during winter months and dramatic environmental changes which take place as a result of their operation, aeration systems generally should not be operated in lakes which have no history of winterkill or water quality problems.

The aeration program has grown considerably over the last 14 years, from three permits in 1974 to 183 in 1988. The first aeration systems were installed and operated for winterkill prevention only. Aeration systems are now operated for a variety of reasons. The western portion of the state, the "prairie pothole region," is dotted with small shallow ponds and wetlands. Many of these ponds and wetlands are used for commercial bait fish production (Peterson and Hennagir 1980). Twenty seven permits were issued during the winter of 1987-88, allowing private hatchery operators to aerate 126 bodies of water.

Permits were requested for aeration systems operated to protect shoreline property from ice damage on two lakes. One permit was issued to a resort on Leech Lake, Cass County; the other 12 systems are operated in Big Cormorant Lake, Becker County. These systems function by creating open water near shore and in front of the property to be protected. The open water area relieves the pressure normally placed on the shoreline as lake ice expands and contracts.

Aeration systems operated to improve water quality have had some success and can improve several water quality parameters. The water quality parameters that have shown improvement most consistently are dissolved oxygen, ammonium, pH, hydrogen sulfide, and the trace nutrients iron and manganese (Cooke, et al, 1986). The effect of aeration on phosphorous concentration and water transparency is much less predictable. Cooke (1986) noted that in 65% of the lakes he examined there was either no significant change or the phosphorous concentration increased after

aeration. He also found that in over half of the cases studied water transparency worsened after aeration and only 21% showed any improvement. Most often, aeration systems operated to "improve water quality" are of the subsurface bubbler type. These systems break down thermal stratification allowing the lake to "mix" distributing dissolved oxygen throughout the water column. Hypolimnetic aeration systems function in a similar manner; however, hypolimnetic aeration systems are designed to maintain thermal stratification.

During the winter of 1987-88, aeration permits were also issued to provide open water for captive waterfowl and to test experimental systems. However, winterkill prevention is still the primary reason for operating aeration systems. Table 1 provides a breakdown of aeration system operation by region for the winter of 1987-88. Aeration permit issuance by region from 1978 to 1987 is shown in figure 3. Figure 4, displays DNR geographic regions.

Due to heavy recreational use of lakes for ice fishing, snowmobiling, skating, etc., open water areas and or thin ice pose a serious public safety hazard. Water temperatures in winter are very near freezing and can quickly cause hypothermia. From 1974 through 1988, six people have died because of accidents at the site of aeration systems. At least seven other non-fatal accidents have occurred when vehicles broke through thin ice or were driven into the open water at an aeration system site. Numerous other incidents have been reported where people have fallen into the open water while fishing along its edge. The

exact number of accidents that have taken place at aeration sites is unknown because accidents that do not result in serious injury or death are not often reported.

In summary, lake aeration is a tool which has the potential to provide benefit to the resource but poses a serious threat to public safety. It can also create conflicts among lake user groups. If misused, aeration has the potential to degrade waterfowl, furbearer and non-game habitat. Used properly aeration can improve the fishery resource. The fundamental purpose of this rule is to ensure the safe and appropriate use of this technology.

These proposed rules were drafted by a committee representing those disciplines within the DNR that have responsibilities related to aeration. Information used included the foregoing historical data, public input received from 10 public meetings and numerous letters and telephone calls received in response to a mailing to about 1,000 individuals and organizations. The following narrative explains the need and reasonableness of each provision of these proposed rules.

General Provisions

6116.0010 Definitions

This section contains two types of definitions; those that are defined by Minnesota Statutes or rules, and those terms that may not be generally recognized and to which specific meanings are given for the purposes of this rule.

Subpart 2. "Aeration system" is defined to include only those types of equipment designed for and intended to create currents that increase dissolved oxygen concentration and/or maintain open water during periods of ice cover. It is not the intent of this rule to regulate those activities or businesses that may create open water incidentally or as a secondary result of their operation.

The uses for aeration described in subpart 2., items A to E are included to clarify the definition of aeration system and intended uses as pertains to this rule.

Subpart 3. "Commissioner" is defined in Minnesota Statutes, section 93.46, subdivision 8.

Subpart 4. "Management Plan" is a plan approved by the Commissioner that identifies specific management actions that will be used by public agencies or private interests to improve fish, wildlife, water and recreational resources. A management plan is necessary to ensure that an aeration system is a compatible practice because aeration systems can make long-term changes in the biological characteristics and recreational uses of public waters.

Subpart 5. "Protected waters" is defined in Public Water Resources Rules Chapter 6115.0030 item G. [Clarifies the scope of the rule, and MnDNR jurisdiction].

Subpart 6. "Public access" is defined to describe those areas where the general public can legally gain access to protected water.

Subpart 7. "Structures" are defined in Public Water Resources Rule 6115.0170, Subp. 37.

Permit Requirements

6116.0020 PERMIT.

Permit requirements need to be described because there are many different reasons for operating aeration systems and a wide variety of waters where they are used. This section identifies those activities and waters requiring a permit from the Department of Natural Resources before an aeration system is installed and operated. It also identifies those activities and bodies of water where aeration will not be allowed, and those aeration activities that do not require a permit.

Subpart 1. Required.

A permit is required for all aeration systems operated in protected waters because of the potential hazard the public is exposed to during winter months; Department of Natural Resources water resource management responsibilities; and to enforce the posting and public notice regulations established by Minnesota Statute 378.22.

Some aeration bubblers are operated exclusively to de-ice manmade structures in the water to protect them from ice damage. Operations of this type are monitored closely and operated so that the open water does not extend beyond the structure. Due to the privacy of the site, and small area affected, public exposure is minimized. These systems do not have and are not intended to have resource management implications, and may be regulated by local units of government. It is reasonable that they be excluded from the permit process.

Subpart 2. Issuance prohibited. Describes those waters and circumstances where the commissioner shall not allow aeration.

Subpart 2. A. It is state and federal practice not to interrupt or delay the migration of waterfowl except where this technique is used to improve the status of an endangered species or other beneficial waterfowl management practice.

Subpart 2.B. Waters designated for wildlife management are best suited for that purpose. They are generally shallow, and very productive. Water levels fluctuate annually and in some years they are dry. Management objectives are directed towards improved aquatic vegetation and invertebrate production to benefit waterfowl, furbearers and many nongame species. These objectives are often obtained by water level management. Winterkill of fish is usually desirable. These lakes also have high waterfowl use during migration and breeding periods and, therefore, efforts to increase fishing opportunities can encourage conflicts between anglers and waterfowl hunters. It is reasonable to exclude these lakes from aeration unless the management plan clearly identifies that the aeration system will be beneficial to fish without any deterioration to waterfowl and furbearer resources.

Subpart 2.C. Waterfowl lake designation is a lengthy process involving public meetings and extensive watershed management planning. The inventory and designation process results in a management plan that is presented to the public at a public hearing. Upon concurrence from the public, the Commissioner of Natural Resources designates the lake for wildlife management purposes. Actions to improve the lake's natural resources and recreational opportunities are identified in the plan. Premature installation of an aeration system within these lakes will limit the Department's ability to make long-term natural resource improvements for the public good.

Subpart 2.D. This section is based on Minnesota Rule 6135.4800, subp. 2, which states "It is unlawful for any person to destroy injure, damage molest or remove any natural resources within scientific and natural areas including but not limited to.....fish..., and MN Rule 6135.4900 which prohibits fishing in scientific and natural areas. It is reasonable to keep natural areas natural.

Subpart 2. E. It is necessary and reasonable that there be a management plan for an aerated body of water so that identifiable goals can be established and assessed, and to ascertain if these goals can be achieved, whether or not they are compatible with resource management, and if they merit the risk of exposing the public to the open water hazard during the winter. The information required on a hatchery license, fish farm permit and aeration permit application contains some of the essential elements of a management plan. Part 6116.0030. Subp. 3, item E gives the commissioner authority to request any necessary additional information he may require.

Subpart 3. "Winter operation". The operation of an aeration system during the winter creates open water around the device and can also reduce ice thickness. The effectiveness of many aeration systems operated to prevent winterkill is directly related to the size of the open water area maintained. For safe and efficient operation, these systems should create only one open water area. However, there may be certain situations, such as lakes with complex basin morphology, where more than one open water area is required to prevent winterkill. This shall be determined on an individual basis for each body of water.

6116.0030 APPLICATION FOR PERMIT

Rules relating to the operation of aeration systems in protected waters are established primarily to reduce the risk of water-related accidents and to ensure that the operation of the system is appropriate for the body of water in question. The information contained in an application will enable the commissioner to make these determinations.

Subpart 1. Term. There are many variables involved with the operation of an aeration system which are subject to change on an annual basis. Among these variables are: permittee, operator, system type, system location, and operating schedule. Each of these variables has an affect on the safe

and effective operation of the aeration system. Because close cooperation between the permittee and the DNR is necessary for the effective operation of these systems, an annual permit application is necessary.

Subpart 2. Criteria for granting a permit. This subpart and items A and B establish performance criteria for granting an aeration permit. Because aeration systems can cause dramatic changes to the aquatic environment and pose a serious public safety hazard it is reasonable and necessary that the benefit provided outweigh the risk. It is also necessary that the aeration system be installed and operated in a manner which minimizes the public safety hazard, effectively accomplishes its intended purpose, and is compatible with natural resource management goals in the area.

Subpart 3. Form contents. Items A-E describe the information required from the applicant and what constitutes an acceptable form.

Subpart 4. Public Input. Because of the potential hazard and environmental implications area residents need to be informed of, and given the opportunity to, express their support or opposition to the project.

Subpart 5. Applicants. Because of the varied applications for lake aeration it is reasonable and necessary that the opportunity to operate an aeration system be available to private individuals as well as municipalities.

Subpart 6. Financial responsibility. Because of the open water hazard artificially created by the operation of aeration systems during the winter months and the potential for an accident involving fatalities or serious injuries to occur, it is necessary and reasonable that permittees be financially responsible for their actions. The \$500,000 combined single limit of liability was chosen because it is a standard coverage commonly used by the insurance industry, and it provides meaningful coverage.

The Tort Claims Act was amended by the 1987 legislature to exclude the State of Minnesota and municipalities from liability at permitted aeration systems.

Subpart 6, items A and B, describe the limits of financial responsibility and options for the permittee to provide proof of financial responsibility.

6116.0040 PERMIT CONDITIONS

This section describes those conditions with which the permittee agrees to comply when granted a permit to operate an aeration system.

Subpart 1. Objective. Because of the diversity of lake types and unique (physical, chemical and biological) characteristics and attributes of each body of water it is reasonable and necessary that the commissioner have the ability to evaluate each proposal for lake aeration and make those conditions which will increase the effectiveness, efficiency and safety of the operation.

Subpart 2. Workshops. Many aeration systems are operated by groups such as sportsmens clubs and lake associations whose membership and duties assigned to members change over the course of the year. Therefore it is necessary to explain the requirements and intent of the rule to avoid misinterpretations. Because of the difficulties involved in maintaining signing requirements it helps to have permittees who have successfully overcome these difficulties discuss their ideas with other permittees. It is also necessary to explain permit requirements to new permittees prior to the operation of an aeration system.

Subpart 3. Inspections. It is the commissioner's responsibility to enforce the regulations governing aeration systems pursuant to this rule, and it is therefore reasonable and necessary that the commissioner or his designee be allowed to inspect aeration systems to monitor, assist and enforce this rule and terms of the permit, and to

check equipment performance where public resources are at stake. Due to extremes in weather and the changing conditions of ice cover it is reasonable and necessary that the permittee inspect the aeration system not less than once every seven days to insure that posting requirements are met and any discrepancies immediately corrected.

Subpart 4. Aeration periods. In order to decrease the public's exposure to the open water hazard during the winter, aeration systems operated for winterkill prevention should not be operated unnecessarily. Therefore, the regional fisheries manager will determine when the aeration system shall be operated. Aeration systems operated to prevent shoreline property damage and to prevent winterkill of commercially reared fish shall be operated at the discretion of the permittee. Because of the heavy recreational use Minnesota's lakes receive during the winter months it is necessary to mark the area of the hazard prior to operation.

Subpart 5. Hold harmless. The operation of an aeration system is strictly voluntary and a permit to install and operate is permissive only. Therefore, it is necessary and reasonable that the permittee accept all responsibility for this activity.

Subpart 6. Revocations. It is necessary to provide the commissioner the authority to revoke a permit when, in his opinion it is necessary to protect human life or natural resources, or for violation of this rule or permit issued hereunder.

6116.0050 MARKING REQUIREMENTS AND PUBLICATION OF NOTICE OF OPERATION.

This section refers to Mn. Statutes 378.22 Subdivisions 1 and 2 as amended by laws 1988 Chapter 588, section 15, in order to assure that these statutory safety requirements are not overlooked.

6116.0060 WAIVER. Because of the unpredictable and urgent nature of the winterkill problem it is essential that there be an alternative to the terms of this rule if circumstances dictate immediate action to protect the natural resources of the state.

Aeration has also been shown to be an effective method of reducing shoreline property damage caused by ice expansion. The "waiver" provides a means to expedite the operation of a system for this purpose if circumstances dictate.

The waiver does not relieve the individual of his responsibility but provides the commissioner a means to allow the operation until the emergency is over and the permittee can meet permit requirements.

The commissioner can not waive those portions of the rule which are statutory requirements.

6116.0070 APPEAL. This provision provides the applicant an opportunity for a due process review of a permit condition or denial.

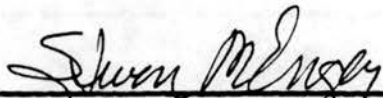
Small Business Consideration In the Rulemaking Process

Minnesota Statutes, section 14.115 (supp. 1983) requires that state agencies adopting rules consider and incorporate rule language to reduce the impact of the rules on small business to the extent that doing so would not be contrary to the statutory objectives that are the basis of the proposed rule. According to the definition of "small business" in Minnesota Statutes, section 14.115, subdivision 1, all commercial aquaculture operations in the state are small business.

The fundamental purpose of this rule is to ensure that public safety is not unduly compromised by the winter operation of aeration systems, and to ensure that the operation of these systems in protected waters

is compatible with DNR resource management objectives. Therefore it is reasonable and necessary that all sections of this rule apply to all protected waters of the state where the public can gain legal access. However, on those protected waters where the public cannot gain legal access and a single individual owns all of the riparian land or all of the possessory rights to the riparian lands or has leased all access rights to the protected water, public exposure and therefore the risk of accident is greatly reduced. Provision has been made to exclude the insurance requirement from permittees and protected waters meeting these criteria.

Prepared by:



Steven Enger, Aquatic Biologist
Ecological Services Section
Division of Fish and Wildlife

Approved by:

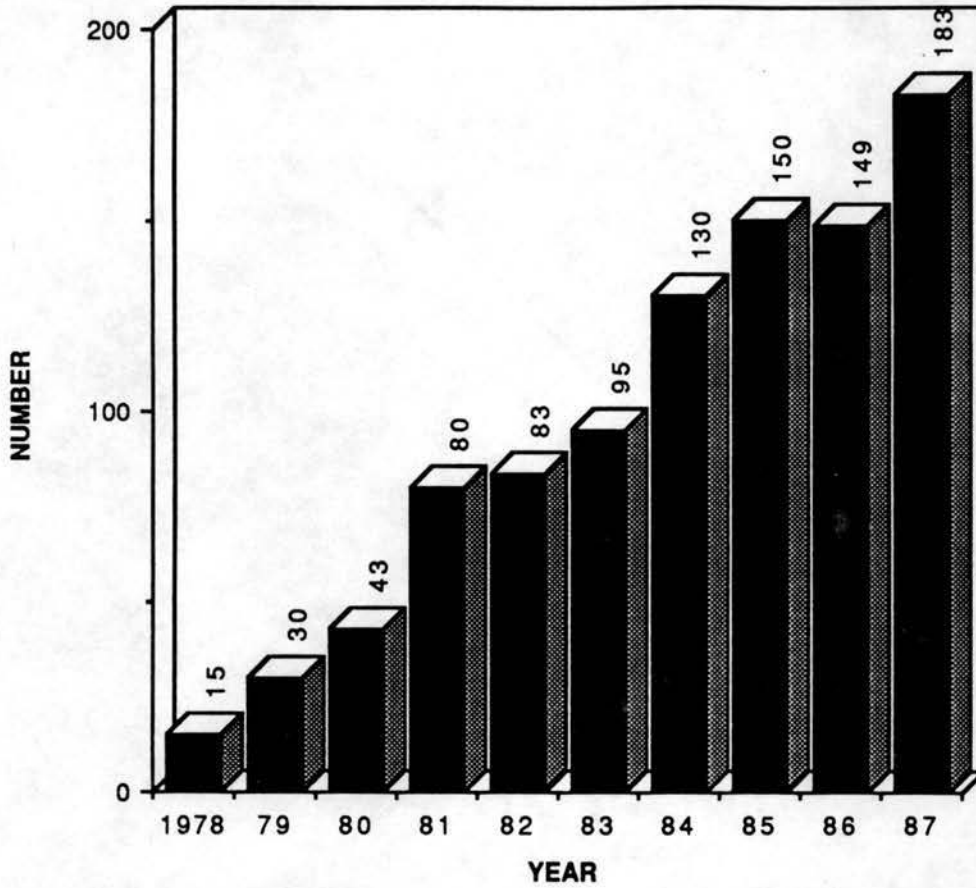


John L. Skrypek, Chief
Ecological Services Section
Division of Fish and Wildlife

Table 1. Purpose of Aeration System Operation 1987-88

Purpose	REGIONS						Overall
	1	2	3	4	5	6	
Winterkill Prevention	13	1	10	63	2	26	115
Improve Water Quality						2	2
Winterkill Prevention & Improve Water Quality			5	4	1	11	21
Provide Open Water for Captive Waterfowl	2		1			1	4
Shoreline Protection	13						13
Experimental						2	2
Winterkill Prevention & Provide Open Water for Waterfowl						1	1
Private Hatchery Operations	18		6	1			25
TOTAL	46	1	22	68	3	43	183

TOTAL NUMBER OF AERATION PERMITS, 1978-87



1978 F&W PERMITS REQUIRED

1984 BAIT DEALERS REQUIRED PERMITS

FIGURE 1.

TREND IN LAKE AERATION PERMIT ISSUANCE 1978-87

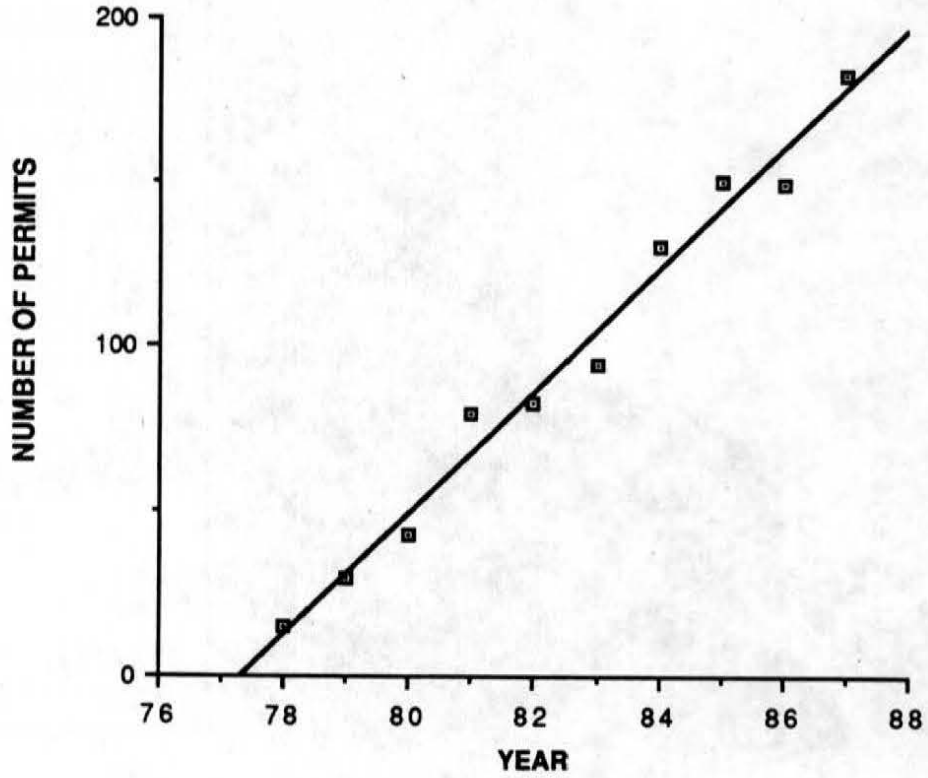


FIGURE 2.

AERATION PERMITS BY DNR REGION 1978-87

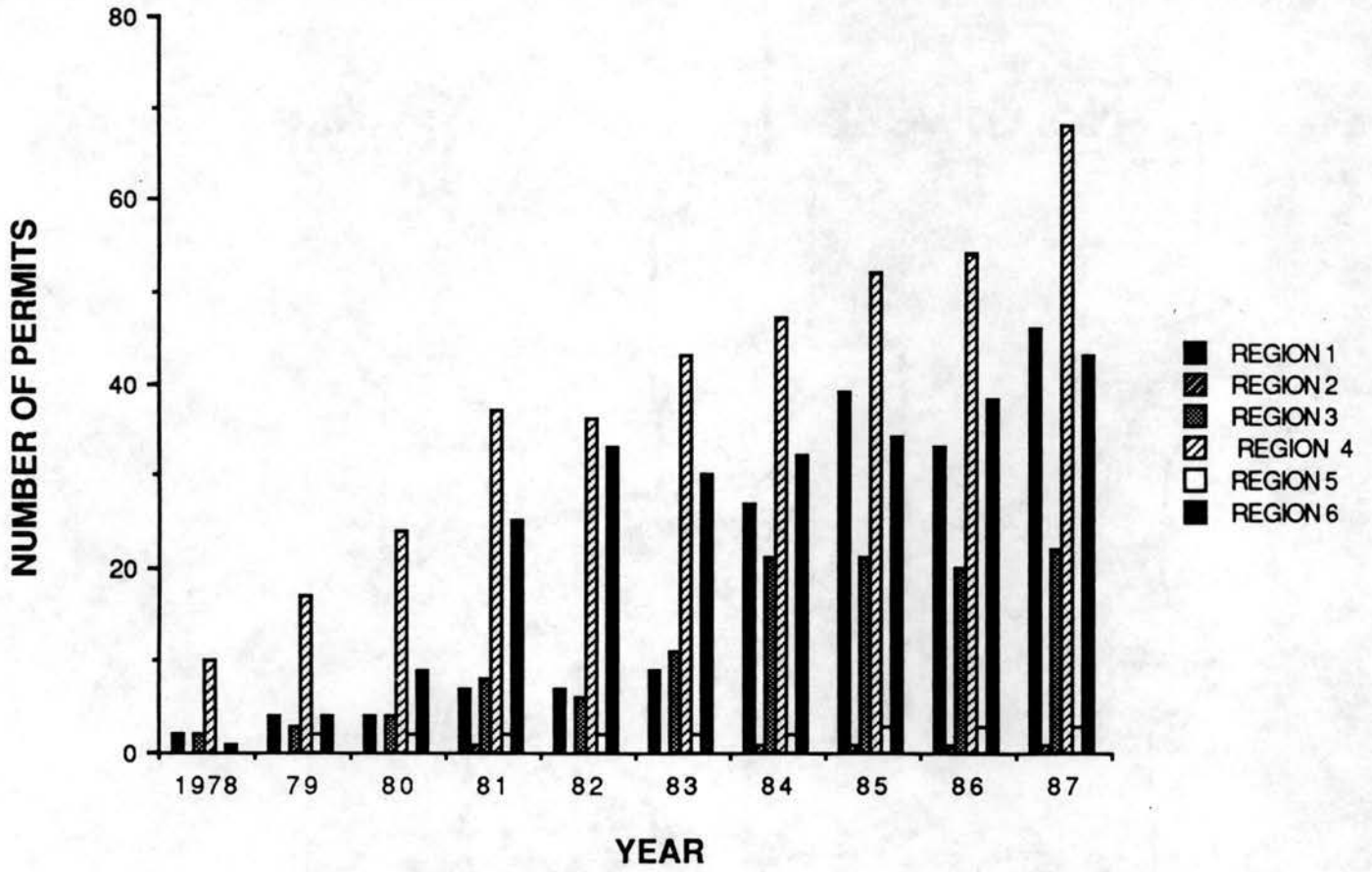


FIGURE 3.

BIBLIOGRAPHY

- Cooke, G.D., E.B. Welch, S.A. Peterson and P.R. Newroth. 1986. Lake and reservoir restoration. Butterworth Publishers, Stoneham, Massachusetts. 392 pages.
- Paulin, F.L. 1960. Snow removal heads off winterkill. Wis. Conserv. Dept. Bull., 25 (2): 24-25.
- Pederson, D.W. 1982. Aeration and mixing systems in Minnesota lakes. Minn. Dept. Nat. Res., Div. Fish Wildl., Spec. Pub. No. 133.
- Peterson, D.L., and F. Hennagir 1980. Minnesota live bait industry assessment report. Minn. Dept. Nat. Res., Div. Fish Wildl., Sec. Fish. Invest. Rep. No. 367.
- Johnson, R., and J. Skrypek. 1975. Prevention of winterkill of fish in a southern Minnesota lake through use of a Helixor aeration and mixing system. Minn. Dept. Nat. Res., Div. Fish Wildl., Sec. Fish. Invest. Rep. No. 336.
- Scidmore, W.J. 1970. Using winterkill to advantage. Pages 47-51 in: E. Schneberger, ed. A symposium on the management of midwestern winterkill lakes. Am. Fish. Soc. Spec. Publ., North Central Div.
- Woods, D.E. 1961. The effects of compressed air on winter oxygen levels in a fertile southern Minnesota lake. Minn. Dept. Nat. Res., Div. Fish Wildl., Sec. Fish. Invest. Rep. No. 230.