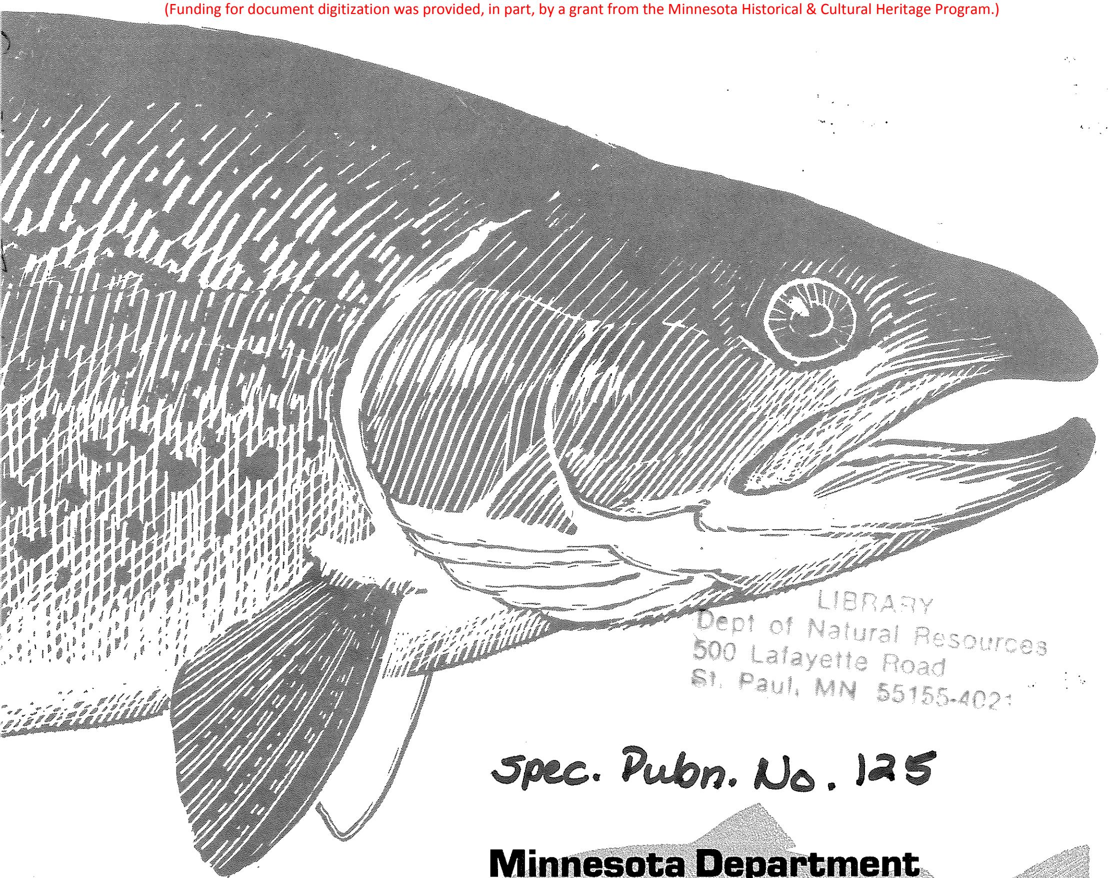
The Management of Lakes for Stream Trout and Salmon



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The Management of Lakes for Stream Trout and Salmon

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DIVISION OF
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MANAGED
STREAM TROUT
LAKE
FISHING PERMITTED DURING
TROUT SEASON ONLY
TAKING OF MINNOWS
PROHIBITED
MINNESOTA
CONSERVATION DEPT.

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Foreword

The purpose of this manual is to provide a comprehensive handbook of instruction on how to manage lakes for stream trout and salmon. Emphasis is placed on the conversion of lakes and ponds from warm-water fish populations to exclusive or near-exclusive salmonid populations. Much of the material presented here is drawn from research investigations and combined with personal management experience and observations beginning in 1957 and embracing about 20 years of work on the subject.

The early investigations were conducted under Federal Aid to Fish Restoration (Dingell-Johnson) Projects F-4-R and FW-1-R. Recent investigations have been conducted under Project F-26-R. The findings of the most recent study, No. 205, "Refinement of Management Techniques for Stream Trout Lakes" are incorporated with those from earlier studies in this manual which constitutes the final report of that study.

The author is indebted to Dennis H. Schupp, John E. Maloney, Robert C. Micklus, John G. Hale, John B. Moyle and Jerome H. Kuehn, who participated in the early investigations and to Donald E. Woods, W. J. Scidmore and Richard B. Sternberg for assistance and direction in the more recent studies and for editorial help. John L. Skrypek reviewed and updated the section on reclamation. Thanks are extended to the many seasonal assistants who aided on the creel census, population testnetting and in the laboratory, especially Mr. and Mrs. Frank A. Kulla who participated in the creel census since the studies were begun.

THE MANAGEMENT OF LAKES FOR STREAM TROUT AND SALMON

Introduction

The management of lakes for stream trout is an important part of the fisheries program in Minnesota. Currently about 130 lakes are managed for these species and there is potential for further expansion. The state has numerous lakes, many of small size, with physical and chemical conditions suitable for rainbow, brook, and other trout and salmon, mainly in central, northwestern and northeastern Minnesota. Many of these lakes contain warm-water fish populations of kinds and sizes of little interest to anglers. Stream trout and occasionally salmon have been substituted for, or to augment, existing fish populations in these lakes as a means of increasing both the volume and quality of the sport fishery.

Management of these lakes has the following objectives:

1. To substitute a salmonid fish population for an existing warm-water fish population to increase production and availability of fish to the angler and to improve the quality of the fishery.

2. To create a fishery where none exists and no preliminary fish removal is necessary as in a lake populated only by minnows.

3. To augment an existing fishery with trout or salmon. This usually requires stocking yearling-sized fish on top of a population of lake trout and/or warm-water fish.

4. To provide an immediate temporary fishery where lake reclamation (removal of existing fish with piscicides) has been undertaken preliminary to management for slower growing fish such as lake trout or walleye.

5. To provide "trophy" fish in addition to the natural, existing sport fishery. This consists of stocking of larger fish and is seldom undertaken except where occasional surplus brood stock are available from the hatcheries.

Most of the management effort has been directed at the first objective, the substitution of stream trout for existing warm-water fish populations.

The substitution of salmonid populations as an alternative to original fish populations has been widely practiced in the United States and Canada. In the U.S. the principal effort has been in New York, the New England states, the Great Lakes states and the Pacific Coast states.

Although there is a considerable literature on the management of stream trout and salmon in lakes, a comprehensive handbook addressed to the fisheries manager is not available. Minnesota studies on stream trout management in individual lakes include Johnson (1956), Micklus and Hale (1959), Micklus (1960, 1961-A, 1961-B) and Micklus and Johnson (1962). Micklus and Johnson (1965) also authored an evaluation of stream trout lake management in Minnesota with recommendations and instructions for managers based on a number of case histories. A useful, popularized publication concerning management of small intensively fished lakes for trout in Massachusetts has been issued by the Massachusetts Division of Game and Fish (Mullan and Tompkins, undated) and Cornell University has a publication for private pond owners (Eipper, 1964).

About two-thirds of the lakes managed for stream trout or salmon in Minnesota have been stocked with Rainbow trout *(Salmo gairdneri)*. In the remainder mostly brook trout *(Salvelinus fontinalis)* or brook trout and rainbow trout conbinations have been used. A few lakes have been managed for brown trout *(Salmo trutta)*, splake *(Salvelinus namaycush* x *Salvelinus fontinalis)*, coho salmo *(Oncorhynchus kisutch)* and kokanee salmon *(Oncorhynchus nerka.)* Experimental stockings of ohrid trout *(Salmo letnica)* and Arctic grayling *(Thymallus arcticus)* have also been made.

Atlantic (Landlocked) salmon *(Salmo salar)*, cutthroat trout *(Salmo clarki)* and chinook salmon *(Oncorhynchus tshawytscha)* have not yet been evaluated in Minnesota waters. References to their use in lakes are based on current literature.

Emphasis in this manual is placed on the management of stream trout and salmon in lakes. In the following sections criteria for selection of suitable lakes, lake types, removal of present fish populations, selection of species to be managed, stocking, monitoring the fishery created, regulations and suggestions for solving problems that may arise are presented.

Criteria for Management

A decision to manage a lake for stream trout or salmon must be based not only on the physiological requirements of the fish involved, but also on social and economic factors which include the need for a trout fishery, public acceptance, expected success in establishing a fishery, and costs in relation to expected benefits.

Lakes considered for stream trout and salmon management should meet the following criteria:

Physical and chemical criteria

1. Dissolved oxygen: A minimum of 5 ppm should be present in waters of 70° F (21° C) or lower during the warmest part of the summer. At least 4 ppm should be present under ice cover.
2. Water temperature: A minimum of two vertical feet of water with temperature(s) 70° F (21° C) or lower should be available in waters of at least 5 ppm dissolved oxygen during the warmest part of the summer for rainbow trout, brown trout or salmon. At least five feet of 65° F (18° C) water should be available at this minimum of dissolved oxygen for brook trout or splake.
3. Inlets and outlets: A lake managed for stream trout or salmon should have no inlets or outlets to prevent access by unwanted species and downstream migration of stocked fish. Hansen (1971) and others have documented the migrational tendencies of rainbow trout. Artificial barriers used to date have usually not been effective in preventing emigration or migration. The development of effective barriers would greatly expand the number of lakes potentially suitable for trout management.
4. Water chemistry: Ammonia and pH ranges encountered in Minnesota lakes have usually been well within those tolerated by trout. Lakes with a pH lower than 6.5 and lakes where detectable hydrogen sulphide is present should be avoided.

Social and economic criteria

These criteria require a judgement decision in which each factor is considered in relation to the others.

1. Evaluation of existing fish populations: The substitution of fast growing stream trout species that feed at a lower trophic level for the existing warm-water fish populations of a lake usually results in more fish of a higher quality in the angler's creel and a considerable increase

in fishing opportunity. However, there are situations where the destruction of an existing fish population cannot be justified. In each case a decision must be made balancing the quality and angler utilization of the existing fish populations against the other social and economic criteria. It should be pointed out that in lakes with suitable temperatures and dissolved oxygen, good indigenous fish populations including the larger predators are indicative of potentially good trout waters. If only minnows, bullheads, and sticklebacks are present, this may indicate that there is occasional winterkill, summerkill, or high levels of toxic products such as hydrogen sulfide or ammonia. In these waters an unsatisfactory trout fishery is likely.

2. Need for a trout or salmon lake: The relative need for trout or salmon fishing opportunity in an area must be considered in deciding whether to manage a particular lake. Greater consideration should be given to creating trout fishing in areas where none now exists than to those where trout fishing is presently available. In areas where there is little or no trout fishing, greater consideration can be given to marginally acceptable waters. An additonal important consideration is the degree of utilization expected once the fishery is created.

3. Public acceptance: It is elementary that the public must accept and approve a procedure where existing and sometimes acceptable kinds and sizes of fish are killed and the fishing characteristics of a lake are radically changed. This point cannot be overemphasized. Public opposition can make maintenance of satisfactory trout fishing difficult if not impossible. A few disgruntled people can easily negate management efforts by illegal stocking of unwanted species.

4. Public access: Minnesota law requires free access to lakes by the public before fish may be stocked by the Department of Natural Resources. Access to an intensively managed lake such as a reclaimed stream trout lake has some special requirements. Where these lakes are readily accessible, intensive fishing may be expected and adequate parking is required. The approach to the water does not necessarily have to be well developed since it is usually desirable to discourage the use of large boats and motors on a small intensively fished water.

5. Availability of trout: It is obvious that trout of the species needed be available both for introduction and maintenance of the fishery before the final decision to reclaim a lake is made. The manager should make certain that the kinds and sizes of fish required will be available when needed.

6. Cost: A large part of the cost of converting a lake from warm-water fish to a trout or salmon population is the initial treatment with fish

toxicants. This cost varies but is directly related to the volume of the lake and water hardness. Because of the cost, most lakes treated with fish toxicants in the past have usually been less than 100 acres in size. In recent years the techniques of toxicant application have improved and treatment of larger waters is feasible. However, a greater public relations effort is likely to be required since there is usually a greater amount of private development in the form of houses, cottages and resorts. In some areas larger lakes should be considered since it may be less costly to reclaim and maintain a few large lakes than many small ones. In any case, the expected benefits should justify the expenditures.

7. Expected success of treatment: Complete elimination of incompatible species is a prerequisite to the successful introduction and maintenance of stream trout or salmon populations. A thorough reconnaissance should be conducted to determine whether potential refuge areas such as dense stands of flooded timber or brush, floating bog shorelines or ground water spring flows or swamp seepages can be successfully treated. If thorough dispersal of the toxicant cannot be accomplished and a complete kill cannot be expected, reclamation should not be attempted since a few survivors in a nearly empty environment can quickly repopulate the lake with unwanted fish and drastically shorten the life of the trout fishery.

Types of Lakes Suitable for Management

The lakes of Minnesota are broadly classified as soft-water or hard-water. Moyle (1949) found that a total alkalinity of about 40 ppm seemed to be a natural separation point. The soft-water lakes tend to be oligotrophic while the hard-water lakes are usually mesotrophic or eutrophic. Moyle (1949) also developed indices of productivity for Minnesota lakes based on their chemical, physical and biological characteristics. Of these, water quality, particularly total alkalinity and phosphorus concentrations, appeared to be the best indicators of lake productivity.

Based on their physical and chemical characteristics, five relatively discrete lake types which have been successfully managed for stream trout are described. Four of the lake types are clear water. The fifth is the "dystrophic" or bog stained. In addition, two kinds of marginal lakes, which may be any of the clear water types, are discussed. Most of the lakes are small, ranging in size from about 10 to 100 acres. Micklus and Johnson (1965) described two types of lakes managed for stream trout in Minnesota. These types were based on geographic areas, northeastern and north central, but the classifications are too general for statewide management application.

Northeastern soft-water lakes

Most of the lakes of northeastern Minnesota counties (Cook, Lake and St. Louis) are depressions in the Laurentian shield and have soft-waters usually with total alkalinities of five to 25 ppm. These lakes generally have rock or gravel shorelines, clear water, relatively low fertility (total phosphorus less than 0.02 ppm) and range up to 100 feet in depth. Because of their lower fertility, sparser vegetation and less organic material than in lakes in other parts of the state, biological oxygen demand is lower and there is less production of toxic gases such as hydrogen sulfide. Because of this, lakes shallower and a little warmer than those in other parts of the state can be successfully managed for trout. There is also some indication from field observations that somewhat lower winter dissolved oxygen levels may be tolerated in these lakes. For lakes of this type, the previously mentioned criteria for temperatures in summer and dissolved oxygen in summer and winter can be regarded as slightly less exacting than for lakes in other parts of Minnesota.

Northcentral soft-water lakes

Many of the smaller lakes of northcentral Minnesota, found mostly in Aitkin, Crow Wing, Cass, Itasca and Hubbard Counties have soft waters. They are often associated with morainic hills of sand, gravel and boulders and have total alkalinities ranging from 10 to 25 ppm. Water levels are usually stable, waters are moderately clear, and shorelines are mostly sand and gravel. They are usually less than 80 feet in depth and submerged vegetation is sparse to moderately abundant.

These waters tend to be somewhat more fertile (total phosphorus about 0.03 ppm) than the northeastern soft-water lakes. Plankton and insect production is higher and they compare favorably with neighboring hard-water lakes in production of fish. These lakes are exceptions to the general regional patterns described by Moyle (1956) for Minnesota waters.

Hard-water lakes

Hard-water lakes (total alkalinity 40 ppm or greater, usually 50 to 150 ppm) are found throughout the state but few are in the northeastern part. The typical hard-water lakes suitable for trout are in the northcentral counties. They are characterized by sandy to gravelly shorelines, usually sand or silt bottoms covered by some detritus and have firm to boggy shorelines. Total phosphorus usually ranges from 0.03 to 0.05 ppm. If marl is present it is found in limited quantities. Quite often, these lakes have fluctuating water levels and drowned timber and brush may be found on the shoreline. Sometimes a zone of sedges and grasses is present following declining water levels. Waters range from clear to turbid but are without bog stain. Submerged vegetation is usually moderately abundant.

Hard-water marl lakes

Many of the hard-water lakes of central and northern Minnesota contain extensive deposits of marl. Total alkalinities on the average, are greater than in the other hard-water lakes. Shorelines are frequently soft and boggy or occasionally sandy. A shelf of marl often extends out a short distance from the shoreline resulting in a very soft bottom and an abrupt increase in depth at the outer margin of the shelf. A striking feature of these hard-water marl lakes is their usually very clear water which often has a greenish or blue-green cast. In these clear lakes, rooted, submerged vegetation is often dense with water lilies frequently abundant in the beds of marl.

It was once thought that lakes of this kind were less productive of trout than the hard-water or northcentral soft-water lakes because of the less suitable substrate for insect production and the somewhat lower total phosphorus levels. In practice, however, little difference in the survival and yield of trout in these Minnesota waters has been noted.

In these lakes with dense vegetation, snails are usually abundant and the parasites for which they are an intermediate host, such as *Neascus* and *Clinostomum,* are often common in the resident fish.

Shallow marginal lakes

Among each of the kinds of lakes just described (except bog-stained) there are shallow lakes which have marginal summer temperatures and dissolved oxygen levels for trout. They are of two general types, those which seldom winterkill and have adequate winter dissolved oxygen levels, (4.0 ppm D.O. or above) and those in which winterkill is usually an annual event. They are considered separately since they offer different possibilities for stream trout management.

In Minnesota a few of the shallow marginal type which seldom or rarely winterkill have been successfully managed for rainbow and brown trout. In New Jersey, Soldwedel and Pyle (1969A and 1969B) have reported that management of rainbows in marginal lakes is usually successful if no other species are present. Trojnar and Behnke (1974) in a paper on different races of cutthroat trout cite cases of these trout existing in shallow, warm, eutrophic, desert lakes and make the point that strict physical criteria in judging the suitability of waters for some genetic strains of trout should not be overemphasized.

In northeastern Minnesota, lakes of 15 to 20 feet maximum depth with temperatures of 70° F. to the bottom during the summer have consistently produced good rainbow fishing (Micklus and Johnson, 1965). Some success has been had in even shallower lakes in this area. In central and northern Minnesota, lakes have been moderately successful for rainbow trout with maximum depths of about 20 feet and with only a foot of water of suitable temperature during the summer months.

Although marginal lakes have been successfully managed for trout, some risks must be taken if rainbows are introduced into waters a little above the accepted limits of temperature. Poorer survival and summer growth may result and mortality may occur during the warmer summers. Although these lakes may seldom winterkill, the risk is greater than in the typical managed stream trout or salmon lake.

The advantages of managing marginal lakes for trout is obvious. It can extend trout fishing into areas where it is not now found and can supply trout fishing in lakes not usually considered for management because of marginal oxygen-temperature criteria.

Frequent winterkill lakes

Little effort has been made in Minnesota to manage lakes that frequently winterkill for stream trout. However, such lakes are sometimes successfully used for summer production of rainbow trout in the Canadian prairie provinces (Miller and Thomas, 1957). Typically, these lakes require stocking fingerling-sized rainbow trout in the spring and harvesting them as 10 to 15 inch fish in the fall. Winter carry-over is not wanted because of expected predation on newly stocked fingerlings, although experience in Minnesota in other types of lakes has not indicated that carry-over is a problem. Management could be either on a sport or commercial basis or for the production of large fish for use elsewhere and may have some limited value in Minnesota in suitable lakes. Lakes selected for such experimental management should be those that have suffered total or near total fish mortality with perhaps only minnows surviving and which have suitable or near suitable summer conditions for rainbow trout.

Bog-stain lakes

Some of the lakes of northeastern and northcentral Minnesota contain waters stained with dissolved tannins and associated material from the drainages of bogs and swamps. The waters are acid, of low productivity, and are usually soft. Limnologically they are often classed as "dystrophic lakes." Because sunlight penetration is low, submerged vegetation is scarce to low in abundance. The thermocline is shallow, sometimes beginning near the surface. Water temperatures remain cold at relatively shallow depths during the summer but dissolved oxygen may be found only in the top five or 10 feet of the lake. Often these lakes have abundant dissolved oxygen during the winter.

In lakes of this type waters of suitable temperature and dissolved oxygen for trout are limited and productivity is low. Some moderately successful management of these lakes has been carried out in Minnesota.

Reclamation Procedures

The terms "reclamation" and "rehabilitation" have been used extensively to describe the removal of an existing fish population before the introduction of more desirable species. The older term, "reclamation," is used throughout this manual.

Removal is usually accomplished with chemicals toxic to fish. Mechanical removal with nets or hook and line is usually impractical except in isolated cases and should be carried out only where alternative methods are not available and where the fish can be utilized. Regardless of how much removal is achieved by nets or hook and line, chemical treatment must follow to complete the eradication of fish. In Minnesota, lakes to be reclaimed with toxicants which contain species which may interest the angler are often opened to "promiscuous fishing" for an interval before reclamation. This provision in Minnesota law allows licensed anglers to take and utilize the fish with a minimum of restrictions. Permitting the removal of fish before reclamation helps create a rapport with the public that assists in what is sometimes a controversial fisheries activity.

The importance of the removal of non-trout species of fish from a lake to be managed for stream trout or salmon has been stressed many times in the literature from Minnesota and elsewhere, (Johnson, 1956; Micklus, 1960; Miller and Thomas, 1957; Micklus and Johnson, 1965). However, it should be recognized that different kinds of fish are not equally incompatible with stream trout and salmon. Since lake reclamation in this sense is removal of fish species that are incompatible with stream trout and salmon, the decision to remove fish will be governed by the species present.

Based on current information and past experience, the more common species of non-salmonid fresh-water fish of northern North America can be roughly divided into three groups; those that are incompatible with stream trout and salmon, those that are compatible and those whose relationship to stream trout and salmon is uncertain (Table 1). Failure to eradicate incompatible species and those whose relationship is uncertain will necessitate changes in management strategy. If only compatible species are present, no removal of fish may be required.

Fish toxicants

Fish toxicants, or piscicides, used in Minnesota and elsewhere have included rotenone, an organic insecticide derived from derris root; toxaphene, a mixture of chlorinated camphenes; copper sulphate, an inorganic chemical; and antimycin-A, a biological fungicide. Toxaphene, a persistent and dangerous chemical, is toxic to most forms of life and its use is no longer

Table 1. Compatibility of some common North American fishes to stream trout and salmon in lakes.

Not Compatible

Gars, *Lepisosteus spp.*
Bowfin, *Amia calva*
Northern pike, *Esox lucius*
Muskellunge, *Esox masquinongy*
Pickerel, *Esox americanus*
Chain pickerel, *Esox niger*
Carp, *Cyprinus carpio*
Longnose sucker, *Catostomus catostomus*
White sucker, *Catostomus commersoni*
Northern hog sucker, *Hypentelium nigricans*
Buffalo, *Ictiobus spp.*
Redhorse, *Moxostoma spp.*
Bullheads, *Ictalurus spp.*
Burbot, *Lota lota*
White bass, *Morone chrysops*
Rock bass, *Ambloplites rupestris*
Sunfishes, *Lepomis spp.*
Smallmouth bass, *Micropterus dolomieui*
Largemouth bass, *Micropterus salmoides*
White crappie, *Pomoxis annularis*
Black crappie, *Pomoxis nigromaculatus*
Perch, *Perca flavescens*
Sauger, *Stizostedion canadense*
Walleye, *Stizostedion vitreum*

Relationship Uncertain

Cisco, *Coregonus artedi*
Lake whitefish, *Coregonus clupeaformis*
Round whitefish, *Prosopium cylindraceum*
Mountain whitefish, *Prosopium williamsoni*
Rainbow smelt, *Osmerus mordax*
Central mudminnow, *Umbra limi*
Chubs and dace, *Hybobsis spp., Rhinichthys spp., semotilus spp.*
Logperch, *Percina caprodes*
Freshwater drum, *Aplodinotus grunniens*

Compatible

Dace, *Chrosomus spp.*
Golden shiner, *Notemigonus crysoleucas*
Shiners, *Notropis spp.*
Bluntnose minnow, *Pimephales notatus*
Fathead minnow, *Pimephales promelas*
Brook stickleback, *Culaea inconstans*

permitted by federal and state regulations. Copper sulphate is impractical and undesirable as a piscicide because of the quantity needed to achieve a fish kill and its toxicity to other kinds of life. Its use as a fish toxicant is also prohibited.

Rotenone and antimycin-A are, at present, the only substances registered for use as fish toxicants and are the only chemicals which can presently be used for fish eradication. Properly used, complete kills may be achieved with either product in most waters. At current prices antimycin-A is a little lower in cost in soft, neutral or slightly acid waters while rotenone formulations are less expensive in hard or alkaline waters.

A fish toxicant should not only be practical from a cost standpoint but should also be specific to fish. Antimycin-A is more specific than rotenone and will leave insect and plankton populations essentially intact (Beard, 1974). Therefore, it should be used where costs would be about equal since rotenone may severly reduce many of the fish food organisms. It has the added advantage in that it does not repel fish and its effect is irreversible. The cost of rotenone application is also usually greater since the preparations are heavier and bulkier and less easily applied.

Rotenone is presently available in an oil based liquid form with synergist and emulsifier and usually contains 2.5 to 5 percent active ingredient. It is also available as a dry formulation but is now seldom used in this form.

Antimycin-A has been available in three preparations with the brand names Fintrol-5, Fintrol-15 and Fintrol Concentrate.[1] Fintrol-5 and -15 are formulations adhering to sand grains. This preparation is scattered over the water and the active ingredient dissolves in about five or 15 feet as the sand settles. Fintrol Concentrate is an emulsifiable oil based liquid preparation.

Neither rotenone or antimycin-A is equally effective on all species. In general, perch, walleyes and centrarchids are most vulnerable; northern pike and suckers are less vulnerable and bullheads the most resistant to these chemicals.

The effectiveness of these toxicants is also influenced by water hardness (total alkalinity), pH and turbidity. As alkalinity and turbidity increase, greater concentrations are required.

More detailed information on fish toxicants and reclamation procedures may be found in a comprehensive review of fish toxicant use by Lennon, Schnick and Burress (1971) and in the material presented at a recent symposium on rehabilitation of fish populations edited by Eschmeyer (1975). Lennon and Berger (1970) have summarized field trial results with antimycin-A and Hassinger and Woods (1974) have described its effective use in deep, soft water lakes.

Determining fish toxicant concentrations

Once a lake has been selected for reclamation and its chemical and physical characteristics determined, the lake volume is calculated to determine the total amount of toxicant required. This should be done far enough ahead of the planned reclamation date to allow ample time for the purchase and delivery of materials.

In general, rotenone preparations usually require determination of the volume of three lake zones. These are: the shoreline out to three foot depth including adjacent marshes and areas of emergent vegetation; the remainder of the lake to the depth of the thermocline or 15 feet; and the portion of the lake below the thermocline or 15 feet.

Antimycin treatments require similar calculations but four zones are usually calculated since three formulations of the product are often used. These are: shorelines and marshes to five foot depth; five to 10 feet in depth; the ten to 15 foot depth; and areas deeper than 15 feet. Shoreline areas are sprayed with Fintrol Concentrate, the three to 8 foot depths are treated with Fintrol 5, the eight to 15 foot depths with Fintrol 15 and the deeper areas with Fintrol Concentrate.

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[1]Reference to brand names does not constitute endorsement by the State of Minnesota

The volume of each zone to be treated should be calculated separately. This requires an accurate map with contours preferably at 5 foot or lesser intervals. The area within the contour of each zone is calculated with a planimeter. The area is multiplied by the average depth to determine the volume of the zone in acre feet.

A simple illustration of a calculation procedure which is adequate for most situations is illustrated in Figure 1.

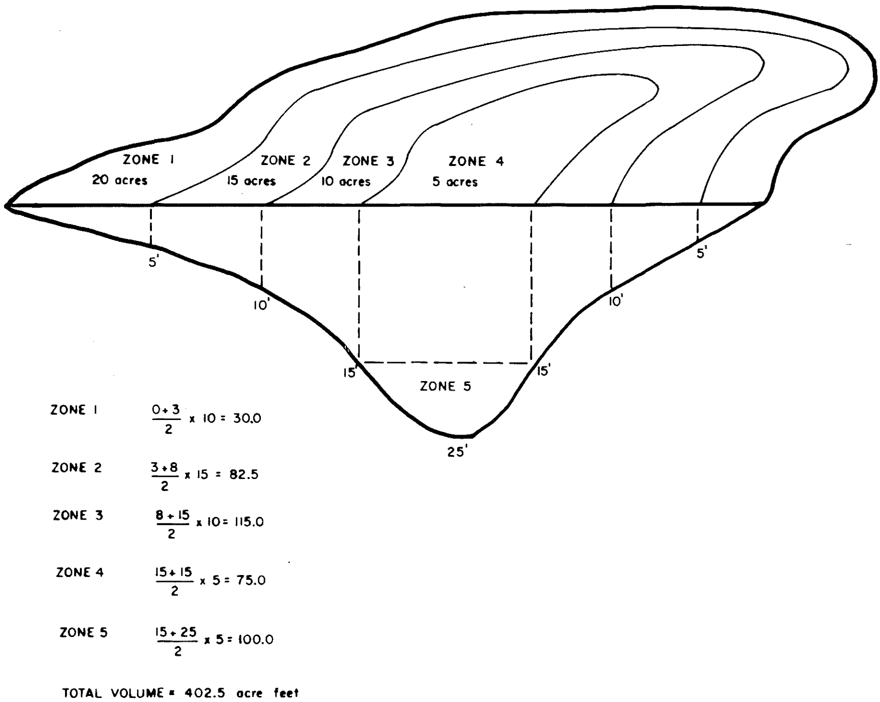

Figure 1. Calculation method for lake volume in acre feet.

Once the volume of the zones and the total lake volume in acre feet have been determined, the approximate total amount of toxicant needed can be estimated from Tables 2 and 3. The approximate concentration of active ingredient needed for the lake types described is shown in Table 2. These values can be used with Table 3 to determine the amount of total product required per acre-foot of water.

Table 2. Approximate concentrations of fish toxicants for use in different types of Minnesota lakes managed for stream trout

Lake type	Toxicant	Approximate parts per million of active ingredient required
Northeastern softwater	Antimycin	0.001 to 0.002
Northcentral softwater	Antimycin	0.002 to 0.003
Hardwater	Rotenone	0.050 to 0.100
Hardwater-marl	Rotenone	0.050 to 0.100
Bog-stain[1]	Rotenone	0.050 to 0.100
	Antimycin	0.002 to 0.003
Shallow marginal[1]	Rotenone	0.050 to 0.100
	Antimycin	0.001 to 0.003
Frequent winterkill[2]	Rotenone	0.050 to 0.100
	Antimycin	0.001 to 0.003

[1] Toxicant depends on hardness and pH.
[2] If necessary after winterkill.

Table 3. Determination of amount of fish toxicants required for lake reclamation[1]

	Amount of Toxicant (Total Product) for Treatment									
	Fintrol-5		Fintrol-15		Fintrol Concentrate		Noxfish or Pro-noxfish		Rotenone 20% powder	
Required concentration of active ingredient (ppb)	Pounds per acre-foot	Acre-feet per 8.25# can	Pounds per acre-foot	Acre-feet per 7.0# can	M1. per acre-foot	Acre-feet per ½ pint	ppm	Gallons per acre-foot	ppm	Pounds per acre-foot
1.0	0.28	30.0	0.06	127.0	12.3	38.0				
2.0	0.55	15.0	0.11	63.5	24.5	19.0				
3.0	0.83	10.0	0.17	42.5	36.8	12.7				
4.0	1.10	7.5	0.22	31.7	49.0	9.5				
5.0	1.38	6.0	0.28	25.4	61.3	7.6				
6.0	1.65	5.0	0.33	21.2	73.5	6.3				
7.0	1.93	4.3	0.39	18.1	85.8	5.4				
8.0	2.20	3.75	0.44	15.8	98.0	4.7				
9.0	2.48	3.33	0.50	14.1	110.0	4.2				
10.0	2.77	3.0	0.55	12.7	122.5	3.8	0.2	0.07	.05	0.14
15.0	4.14	2.0	0.84	8.5	184.0	2.5	0.3	0.10	.075	0.20
20.0	5.54	1.5	1.10	6.3	245.0	1.9	0.4	0.14	.100	0.27
25.0	6.90	1.2	1.40	5.1	306.5	1.5	0.5	0.17	.125	0.34
50.0							1.0	0.34	.25	0.68
100.00							2.0	0.68	.50	1.36
150.0							3.0	1.02	.75	2.04
200.0							4.0	1.36	1.00	2.72

1.0 part per million (ppm) in water = .001 gram (1 milligram) per liter; or 1.0 ounce per 1,000 cubic feet; or 2.718 pounds per acre foot.
1.0 acre-foot = 43,560 cubic feet; or 325,851 gallons; or 2,718,000 pounds.

[1] From Minnesota Fisheries Managers Handbook, 1970.

The preceding calculations are intended to provide only a first estimate of the quantity of toxicant (total product) required. To insure that the proper concentrations of the toxicant are used, a bioassay must be conducted in the lake to be treated to insure that the actual concentrations necessary and the total amount of product needed to eradicate the fish present are used.

The following excerpt from the Minnesota Fisheries Managers Handbook (1970) describes the bioassay procedure.

"The first bioassay will be done about one week before treatment, using water and fish from the lake to be treated and the chemical formulation that is to be used as the toxicant. The fish to be tested should include the more resistant target species present in the lake as well as some of the more sensitive species.

The initial calculations for the concentrations of toxicant to be used are based upon the manufacturer's recommendations and water quality tests (such as total alkalinity, pH, and temperature) and are modified by experience in treating lakes of similar water quality. The toxicant concentrations used in the bioassay should start with the calculated concentration as the midpoint, and at least two weaker and two stronger concentrations to establish the lowest concentration at which all of the test fish are killed. One container should remain untreated to serve as a control. If little is known of the toxicity of the chemical, a broad range of concentrations should be used in one bioassay, followed by another bioassay using a narrower range of concentrations around the minimum lethal dose shown in the first bioassay. The amounts of chemical used to achieve the selected test concentrations of several formulations are shown in Table 4.

Table 4. Amount of fish toxicant stock solution to be used in 20-gallon bioassay

Concentration of active ingredient							
Parts per billion	Milligrams per 20 gallons	Fintrol[1] Bioassay kit stock solution	Fintrol[2] Concentrate (liquid) 1/530	Fintrol[3] (sand) 1/530	Fintrol 15[4] (sand) 1/530	Noxfish[5] (liquid) 5% rotenone 1/530	Rotenone[6] powder 20% 1/530
0.25	.0189	0.1 ml	0.1 ml	1 ml	0.2 ml		
0.5	.0378	0.2 ml	0.2 ml	2 ml	0.4 ml		
1.0	.0756	0.4 ml	0.4 ml	4 ml	0.8 ml		
2.5	.189	1.0 ml	1.0 ml	10 ml	2.0 ml		
5.0	.378	2.0 ml	2.0 ml	20 ml	4.0 ml		
7.5	.567	3.0 ml	3.0 ml	30 ml	6.0 ml		
10.0	.756	4.0 ml	4.0 ml	40 ml	8.0 ml	8 ml	2 ml
15.0	1.134	6.0 ml	6.0 ml	60 ml	12.0 ml	12 ml	3 ml
20.0	1.512	8.0 ml	8.0 ml	80 ml	16.0 ml	16 ml	4 ml
25.0	1.89	10.0 ml	10.0 ml	100 ml	20.0 ml	20 ml	5 ml
50.0	3.78					40 ml	10 ml
100.0	7.56					80 ml	20 ml
150.0	11.34					120 ml	30 ml
200.0	15.12					160 ml	40 ml

[1] Supplied with Fintrol bioassay kit as 0.0189% antimycin-A in acetone. For test concentrations below 5.0 ppb, the stock solution should be diluted to 1/10 and used at 10 times listed amount.
[2] Fintrol Concentrate (20% antimycin-A) mixed 50/50 with acetone and diluted: 1 ml on 530 water.
[3] Fintrol-5 (1% antimycin-A on sand): 1.0 gram dissolved in 530 ml water = 0.00189% antimycin-A.
[4] Fintrol-15 (5% antimycin-A on sand): 1.0 gram in 530 ml water = 0.00945% antimycin-A.
[5] Noxfish (5% rotenone) liquid: 1.0 gram in 530 ml water = 0.00945% rotenone.
[6] Rotenone powder, 20%: 1.0 gram in 530 ml water = 0.0378% rotenone.

Twenty-gallon plastic bags, or twenty-gallon plastic garbage cans with lock-on covers, are practical containers for most tests. Five-gallon jars can be used for very small fish and fifty-gallon (or larger) tanks may be necessary to test larger fish. About one-fourth pound of fish can be used for each twenty gallons of water. The containers should be immersed in lake water and inspected every hour for the first few hours, and again at least at the 24th hour and the 48th hour. At each inspection any dead fish should be removed and recorded. The minimum lethal dose is the lowest concentration in which all fish have died in 24 hours in warm water or 48 hours in cold water. The concentration selected for the lake treatment should be slightly higher than this to assure a complete kill, and is then translated in Table 3 into equivalent amounts of total product for several formulations of toxicants."

Pre-reclamation public relations

Killing fish in public waters requires an effective preliminary public relations effort. The program of managing suitable small lakes for trout has been successful and usually well received by the public but local residents and interested groups must be convinced of the desirability of the management effort in advance of reclamation. The facts that fish must be destroyed and angling interrupted and changed in its character should be told positively and with confidence. The probability that the reclamation will improve the quality of the fishery and the availability of acceptable fish will convince most people the program is worthwhile. Opposition is often based on misunderstanding and is usually the result of no or poor prior public informational effort.

The public should be invited to witness the treatment and assist in the clean-up. Public witness of the actual extent of the fish kill will help prevent uninformed and usually exaggerated rumors of vast destruction of game fish. No consumption of rotenone or antimycin-killed fish should be permitted because of possible health hazards.

Fish toxicant application

Rotenone and antimycin-A are both degradable and detoxify in a relatively short time. Antimycin-A loses its toxicity in 2 days to a week, while rotenone may detoxify in 2 days to two weeks. It is therefore imperative that these fish toxicants be carefully and thoroughly distributed to achieve a uniform concentration of the toxicant in all waters of the lake and all connected waters that might provide a refuge and source of fish re-entry. Application should be made in as short a period of time as possible. Vertical as well as horizontal dispersal must be achieved. Fish can detect rotenone and will attempt to avoid it. A pocket of untreated water will provide a refuge for fish and some will probably survive the treatment. While fish do not exhibit avoidance to antimycin, poor dispersal of the toxicant has resulted in failure to achieve complete fish eradication. In one case (Beauty Lake, Cass County, Minnesota) a few black crappies survived an antimycin treatment and re-established a population that precluded trout stocking a year later.

Zones of the lake to be treated should be well marked with buoys to help insure that the proper amount of the toxicant is applied to each area. Liquid rotenone can be applied to the surface of the water by mixing and diluting with water and pumping through a perforated boom distributor. Pumping the toxicant into the outboard motor propeller wash can also be done but this gives a more limited horizontal distribution. Distribution in deep water is achieved by pumping the toxicant through an appropriately long, weighted hose towed behind a boat at the desired depth.

Figure 2. Treating shoreline with fish toxicant.

The shoreline and adjacent marshes and beds of emergent or floating aquatic vegetation are sprayed with manual or motorized hand-held pumps containing diluted liquid rotenone. For larger waters and extensive marsh areas, application of liquid rotenone sprayed from a helicopter assures even distribution and has been the most effective means of application.

Water areas with dense vegetation pose some problems in the application of both rotenone and antimycin. When the toxicant mixture is sprayed over these areas, it can adhere to the leaves of emergent vegetation and the concentration of the toxicant reaching the surface of the water is reduced to an ineffective level. Lateral dispersal of the toxicant in plant choked waters is negligible and extra care is required to achieve uniform dispersal. Application during a light rain is ideal in these areas. If extensive areas of emergent vegetation are present, treatment in spring before vegetative growth begins may be preferable to summer or fall application.

Failures to achieve a complete fish kill are most often due to inadequate treatment of beds of vegetation, flooded terrestrial vegetation such as shrubs and trees, spring or swamp seepages, connecting marshes or poor horizontal or vertical dispersion of the chemical in the main body of water.

Liquid antimycin-A (Fintrol Concentrate) is applied similarly to liquid rotenone but it is considerably more concentrated and must be diluted more to assist in uniform dispersion.

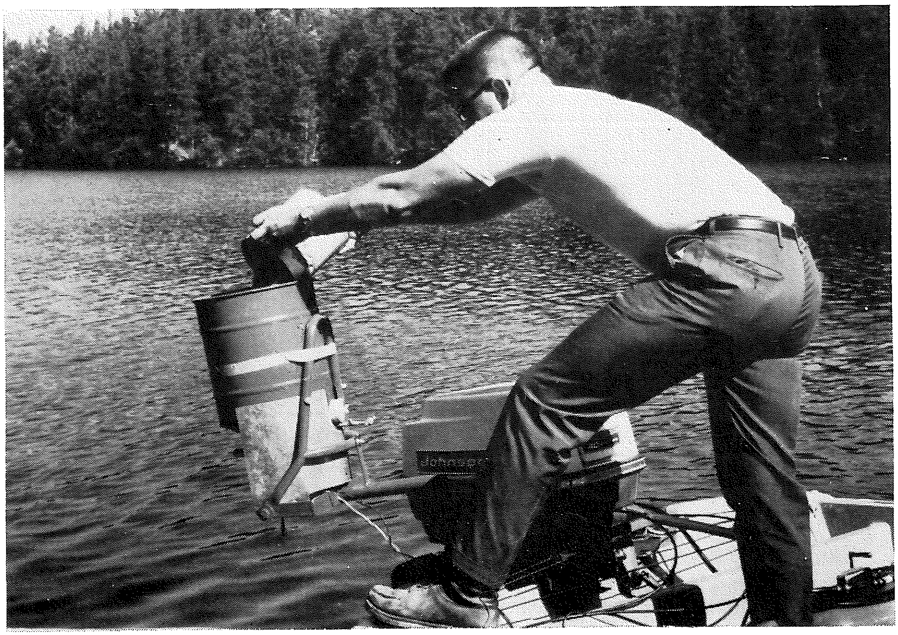

Figure 3. Loading spreader with sand coated fish toxicant.

Fintrol-5 and -15 coated sand formulations are applied to cover appropriate depths by scattering or "seeding" the granules with a manual or motor driven grass seeder or fertilizer spreader either hand-held or attached to the transom of a boat. Uniform distribution is relatively simple using this preparation. Diluted liquid Fintrol Concentrate is used to treat marsh and dense emergent vegetation areas and for treating waters too deep to be reached by the sand grain formulation. Deep waters are treated in the same manner as with rotenone.

In Minnesota dispersal of fish toxicants has been improved by taking advantage of the natural mixing action of the spring or fall "over-turn" of a dimictic, or two-layered lake to disperse the toxicant (Schneider, 1974). Most of Minnesota's managed stream trout lakes are between 25 and 75 feet maximum depth. In lakes of this type the depression of the thermocline and mixing of top and bottom waters during autumn takes about three days. Ideally, the fish toxicant should be applied on the first day of this period to insure mixing. However, Schneider (1974) found that a near homothermal condition was sufficient for uniform vertical dispersion of the chemical. He reported excellent mixing although treatment was made late in the turnover period under near homothermal conditions. During the spring, homothermality is very brief following ice break-up, but it can also be used to insure proper distribution of chemicals in a lake. Surface treatment may be sufficient during these two periods of natural mixing but pumping into deep waters will help insure thorough dispersion.

Because of the greater ease of application during the fall overturn, much of Minnesota's lake reclamation is now carried on at that time using either liquid antimycin-A or emulsified rotenone.

Post-treatment procedures

Collection and disposal of dead fish from shorelines is usually necessary after application of fish toxicants. Clean-up on the first and second day after treatment usually takes care of the problem. Birds, mammals and reptiles will make use of the remaining fish. Collection of fish by the public for home consumption should not be permitted. Product labels do not allow consumption of fish killed by fish toxicants because of possible health hazards. The public must be informed that this use is not permitted by personal contact and by warning signs posted around the lake.

Although rotenone and antimycin usually detoxify in a few days, physical and chemical conditions can shorten or lengthen the period of toxicity. Bioassay should always be made before fish are stocked to determine whether the treated waters have detoxified. In lakes treated with Fintrol, bioassay should begin about one week after treatment and with rotenone, about two weeks after treatment. Individuals of the same species and size that are to be stocked should be suspended in wire cages at various depths in the lake for 96 hours. If all individuals are alive and healthy after this period, it is safe to stock the fish. If fish of the species to be stocked are unavailable, it is best to use a species of similar or greater sensitivity to the toxicant used. With either rotenone or antimycin yellow perch, bluegills, or golden shiners are satisfactory test fish. Care should be taken to prevent escape of these fish.

Testnetting with gill-nets, trap-nets and seines should follow detoxification to determine whether the treatment was successful in eradicating the population. If incompatible species are taken in the nets, the stocking of trout should be planned for only one year or the lake should be retreated.

Selection of Species

The selection of species to be stocked and maintenance stocking are closely related and interdependent and although discussed separately, they must be considered in relation to each other.

The species of trout or salmon to be managed in a lake depends on such factors as its suitability to the year-around physical and chemical conditions of the lake, its growth and catchability in relation to the type of fishery desired, the expected fishing pressure, the availability of hatchery stock, and whether there is other local trout or salmon fishing.

The characteristics of the species of stream trout and salmon and their suitability relative to the above considerations are discussed in this section.

Brook trout

This species is preferred by many anglers because of their sporting qualities and their table excellence. Studies in Minnesota have shown that they are more easily caught early in the summer as six to 10 inch fish than are rainbows, but often furnish little angling later in the season. It has been noted in Minnesota (Micklus and Johnson, 1965) and in Michigan (Alexander, 1975; Alexander and Shetter, 1961, 1969) that they produce comparatively few larger fish during the second or third year of exploitation.

They are best suited for the softer waters and require at least five vertical feet of water with a temperature of 65° F. (18° C) or less during summer months. Dissolved oxygen levels should be at least 5.0 ppm in the warmest part of the summer and at least 4.0 ppm under winter ice cover.

Brook trout are produced at most state and federal hatcheries and availability is usually good. They are suitable for short term fisheries and have growth rates comparable to other stream trout. When stocked at fingerling size, they enter the fishery the following year.

If the physical conditions of a lake are suitable, brook trout may be preferable to rainbow since rainbow trout are generally more widely available.

Rainbow trout

This excellent sport fish has usually produced higher survival to catchable size from fingerling plants, better fishing in late summer and more fish of larger size in the second and third year of exploitation than brook trout. It also tolerates warmer water than brook trout.

Rainbow trout can tolerate waters up to 70° F. (21° C) where at least 5.0 ppm dissolved oxygen is present. In Minnesota waters they have survived summer conditions with as little as two feet of oxygenated water and temperatures up to 70° F. with no detectable losses. Water hardness has not been observed to have any notable effect on their growth or survival. Winter dissolved oxygen levels, as for brook trout, should be at least 4.0 ppm.

The rainbow trout is the best choice for lakes with heavy fishing pressure. Investigations in Minnesota and elsewhere have shown that a higher percentage of rainbow are creeled from a given stocking than are brook trout or other salmonids. (Micklus and Johnson, 1965; Alexander, 1975; Alexander and Shetter, 1961 and 1969). This species is regularly produced at most state and federal hatcheries and in most areas is probably the most readily available stream trout. Either rainbow or brook trout are a good choice for lakes that may winterkill since a large percentage are harvested the first summer following introduction. Johnson and Hasler (1954) found rainbows were also more suitable than brook trout for dystrophic (bog-stain) lakes. Hatch and Webster (1961) rated rainbows superior to the native brook trout in New York because of their more efficient use of food organisms but pointed out their lesser "sporting values." Since rainbow trout are adaptable to a wide variety of conditions, they are presently stocked in about two-thirds of Minnesota's managed stream trout lakes.

Brown trout

This species has been introduced and maintained in lakes to a much more limited extent in Minnesota and other states than have brook and rainbow trout although they are generally produced in most state and federal trout hatcheries. They are more tolerant of warm waters than rainbow trout but do not seem to furnish as many fish to the creel from equal stockings. When small they appear to be as easily caught as rainbow trout but as large fish they are more difficult to catch particularly where regulations prohibit night fishing. It is probable that a stock of brown trout would furnish more trophy-sized fish than would rainbows because of their greater survival to larger size.

Brown trout appear to be more piscivorous than brook trout or rainbow trout and may be able to better utilize populations of minnows that often become abundant in managed stream trout lakes. Boles and Borgeson (1966) suspected that large brown trout were responsible for the poor survival of subsequently stocked rainbow and brown trout fingerlings in a California lake.

Splake

The splake is a hybrid with female lake trout and male brook trout parents. Their growth is influenced by their lake trout parentage and in Minnesota waters is slower than that of rainbow or brook trout. Because of their slower growth, splake require an extra year before fully entering the fishery. They are thus subject to predation for a longer time than other salmonids. However, the splake is an attractive fish and excellent eating. They can be successfully managed in lakes, often in combination with faster growing brook or rainbow trout. Catch data in Minnesota indicates that they do not compare favorable with brook and rainbow trout in yield to the angler but usually furnish more larger fish a few years after stocking. They should not be used in heavily fished lakes except as an addition to rainbow or brook trout.

Splake, like the lake trout and brook trout, are best suited to soft waters and require at least five vertical feet of water with temperatures 65° F. (18° C) or less.

Advance planning is essential in the management of a lake for splake since fish may not be readily available from the hatcheries.

Kokanee salmon

Kokanee, coho and chinook, the Pacific salmon species, have not always provided satisfactory fishing in the small inland lakes. They may be used instead of rainbow trout to furnish an exotic and unusual fish for the angler, but this should generally be limited to experimental use until their growth and catch characteristics in reclaimed lakes is better defined. They appear to be best suited to lakes of a type suitable for rainbow trout. Their availability from hatcheries may be limited in many areas.

The kokanee is a dwarfed, landlocked form of the sockeye salmon *(Oncorhynchus nerka)* with a four year life cycle. Because of their tendency to feed pelagically, they have been stocked in deep lakes in an attempt to make more efficient use of open water forage such as the cisco. In Minnesota trials, their growth rate was slow and the return to the angler was low and of small fish.

Coho salmon

Coho salmon have a three year life cycle. In some cases they have not grown well, and, at best, have not exceeded the rainbow in return to the creel in Minnesota trials. Hassinger (1974) summarized coho management in Minnesota and concluded rainbow trout were a better choice for small inland lakes. McKnight and Serns (1974) reported that the food habits of coho in a Wisconsin lake were similar to those of rainbow trout.

Chinook salmon

The chinook is the largest of the salmon species and matures in four years. They have recently been stocked in a Minnesota lake on an experimental basis and there have been some angler catches of two-year old fish, but there is yet not enough data to evaluate this introduction.

Atlantic (landlocked) salmon

The Atlantic salmon is a stream trout that is usually anadromus and resembles the brown trout in inland waters. It grows a little slower than brown or rainbow trout and most individuals enter the fishery as two year olds, and contribute to the catch for two or three years. These fish generally produce fewer numbers and pounds per acre than would rainbow or brook trout.

Although not currently stocked in Minnesota, this trout has been widely and successfully used in inland Maine lakes. Maine's experience with the Atlantic salmon has been reported by Havey (1973), Havey and Andrews (1973), Warner (1972) and Warner, et.al (1968). Havey and Warner (1970) have authored a publication on the management of this species. Judging from Maine's experience, it appears that the landlocked salmon can be used in lakes where a longer lived fish is desired.

Cutthroat trout

The cutthroat are managed in lakes in some western states and provinces and have been introduced elsewhere. They have not been used in Minnesota. Trojnar and Behnke (1974) discuss the performance of two strains of cutthroat trout in a Colorado lake. They cite the Snake River strain's ability to withstrand eutrophic conditions and report the use of populations of different strains to more efficiently utilize the various food resources of a lake. Cutthroat trout management in an Oregon lake has been discussed by Hansen (1971). The fish were stocked in the presence of centrarchids, yellow perch and bullheads as well as stocked rainbow trout, coho salmon and kokanee salmon. Survival was poor except for those stocked at "legal" size just before the angling season. Migration down an outlet was at least 10 percent.

Other references concerning cutthroat trout include Donaldson, Hansler and Buckridge (1957) and Erving (1955).

Grayling

The grayling are neither stream trout nor salmon but deserve mention. They have been stocked on a limited basis in Minnesota but are regarded as an exotic and interesting fish not deserving of a large management effort. Micklus (1961-A) reported that most of the grayling creeled were taken in their first season in a Minnesota lake. Securing grayling for stocking in most states or provinces would probably be difficult.

Combinations of species of trout and salmon

Combinations of different kinds of trout and salmon can be managed in the same lake. However, in Minnesota no case has been recorded where more fish were produced to the angler by stocking two or more species together than by managing for one species alone.The most effective multi-species trout management would appear to be the combination of fast growing and slow growing species. Fast growing species such as rainbow and brook trout should produce satisfactory angling within a year. The slower growing species such as lake trout or splake would provide fish acceptable to the angler following the initial harvest of the faster growing species and would prolong and stabilize fishing success. Investigations have shown that a slower growing and longer lived fish will contribute to the catch over a longer period of time and will produce more trophy sized individuals. However, survival of slow growing fish to the creel is usually lower primarily because of longer exposure to predation.

Another possible multi-species management technique might be stocking a common proven species with an exotic or trophy producing fish. For example, a rainbow trout stocked with a salmon species or brown trout. One species would sustain the fishery in numbers and pounds while the other would increase interest and produce trophies.

Stocking

The introduction and maintenance of populations of stream trout or salmon in lakes of the kind discussed in this manual almost always depends on annual stocking since the spawning habitat required by salmonids is rarely found in these lakes. Attempts in Minnesota to provide artificial spawning beds, usually placed in spring water flows, have been unsuccessful. In New York and the New England states, reproduction of brook trout may occur in coldwater tributary streams and contribute to the populations of lakes. Such tributary streams are rare in the Minnesota lakes usually managed for stream trout. It is assumed that no reproduction occurs in these lakes and that following introduction of the desired species, stocking will be required on an annual basis to maintain a fishery.

Assuming that fishing pressure and regulations remain constant, the number and size of trout creeled can be regulated by four factors: time of stocking, size of fish stocked, strain of trout, and stocking rate. The cost and availability of trout must also be considered in stocking plans.

Time of stocking

Trout and salmon are usually stocked either in the spring or in the fall (preferably October) because of high summer surface water temperatures. Stocking lakes during winter ice cover is not recommended because of the difficulty in tempering fish to low temperatures. Substantial mortality has been noted in wintertime plants in Minnesota lakes.

Micklus and Johnson (1965) have shown that rainbows and brook trout stocked in the fall, usually October, had a higher survival to the creel than did those stocked in spring.

Although direct evidence was lacking it was found during an investigation in Minnesota of possible causes of fingerling trout mortality, that predation primarily by birds was probably the chief cause of mortality among stocked fingerling brook and rainbow trout. Diver observation of newly stocked trout, stomach contents of large fish and food habits of small trout indicated that mortality from stocking, predation by larger trout, and food availability were not major causes of trout mortality. Loons and other bird predators were present on these lakes and the absence of other major factors implicates them as the major source of fingerling mortality. Analysis of loon, great blue heron, mergansers and other vertebrate predator diets by Alexander (1976) in Michigan showed that avian predators consumed substantial numbers of trout. Myers and Peterka (1976) also observed that trout populations in four prairie pothole lakes were substantially smaller where avian predators were present.

Fingerling trout stocked in the fall are subject to only a short period of predation before freeze up and fish surviving to the following spring are apparently not as seriously reduced by avian or mammal predators.

If the fall stocked fish are too small to be retained by the angler at the beginning of the season, the fishery will depend on older fish during early season and recruited fish from the fall stocking later in the season. Fishing success will be relatively uniform throughout the summer.

If the fall stocked fish are large enough to be acceptable to the angler the following spring, an early season fishery will result with few fish available after June or July. To remedy this situation, it is recommended that a combination stocking of catchable or nearly catchable size fish with smaller three to five inch fingerlings be made in the fall. The smaller fish should recruit to the angler later in the summer and replace the depleted larger fish.

Rainbow trout stocked as fingerlings during the spring will enter the catch in late summer of the same year and contribute to the catch mostly during the following summer unless there is a winter fishery. If angling occurs during the first winter, a spring planted stock will be substantially cropped if fishing pressure is significant.

Size of fish stocked

The fisheries manager usually has the choice of stocking spring fingerlings, fall fingerlings or yearlings. Because spring fingerlings are subject to high mortality from bird predators for nearly the entire open water season and fall fingerlings are exposed for only a short time, the fall fingerlings usually show good survival and attain a significant weight gain in the lake. Yearling stocking is an expensive practice and the fish are usually removed by anglers during the first summer in the lake.

In Minnesota it has been found when brook or rainbow trout are stocked at a size of 100 to the pound or smaller there is usually a substantial mortality. It is therefore recommended that fingerlings larger than this be used for any stocking.

Strain of trout stocked

When managing a lake for rainbow trout, the fisheries manager has a choice of several strains from which to choose. The Madison strain is the common strain produced in Minnesota hatcheries and has been very adaptable to conditions in Minnesota lakes. The Kamloops strain, sometimes considered a geographic race, is now widely distributed in the United States and Canada. It has been stocked to limited extent in Minnesota lakes, and has shown a tendency to contribute to the fishery for a larger period and has produced larger fish than the Madison or Donaldson strain under similar fishing pressure. The Donaldson strain, developed by Dr. Lauren Donaldson at the University of Washington, is a product of over 40 years of selective breeding. Donaldsons are capable of surviving in slightly warmer waters than the other strains and have shown outstanding growth in lakes with abundant food supplies and not subject to heavy fishing pressure. In Minnesota's experience the Donaldsons have been very vulnerable to angling and heavy fishing pressure has depleted stocks during the first summer. Because they are readily caught, their potential growth is often not realized and few fish are left for succeeding years.

Stocking rates

The number of fish to be stocked per unit of lake area depends on species, size of fish, productivity of the lake, time of year stocked, expected intensity of fishing pressure, cost and availability of fish and the mechanical problems of hauling and stocking the fish. Ideally, stocking rates should be governed by biological factors, but budget limitations and production capabilities often necessitate modifications in stocking plans.

The stocking recommendations in this section are based on recorded returns to the creel from various stocking rates used in Minnesota lakes over the past 20 years. Most of these case histories concern rainbow and brook trout. Experience with splake, brown trout, grayling and various species of salmon has been limited and the recommendations are best estimates based on these experiences and the literature. Suggested stocking rates for the various species for each lake type and their expected levels of fishing pressure are discussed below and summarized in Tables 5, 6, and 7.

Since lakes within a type will vary somewhat in their fish producing capability, the suggested rates are considered initial trial rates and require modification to meet specific conditions.

It should be pointed out that increasing the stocking rate will only partially compensate for increases in fishing pressure. In Minnesota it has been found that there were significant increases in mortality and slower growth for fingerling and yearling rainbow when stocked at rates of 500 to 1000 per acre (unpublished data).

Rainbow trout — A guide to stocking rates for various sizes of rainbow trout in lakes with different productivity and fishing pressure is given in Table 5. Donaldson strain rainbows should be stocked at a lower rate since they are of a larger size in October than are rainbows of the other strains.

Brook trout — Fish available for planting in the fall are smaller than rainbow trout and should be stocked at a higher rate. Because brook trout are unsuitable for the marginal lake types, recommendations are presented for only four types of Minnesota lakes in Table 6.

Table 5. **Recommended stocking rates for rainbow trout in number per surface acre for three levels of fishing pressure by Minnesota lake type.**

	Expected Fishing Pressure		
	Light [1]	Moderate [2]	Heavy [3]
Rainbows of more than 100 to the pound (small fingerlings)			
Northeastern softwater	150	225	300
Northcentral softwater	175	250	350
Hardwater	225	300	400
Hardwater-marl	225	300	400
Bog stain	150	225	300
Shallow, marginal	150	225	300
Frequent winterkill	75	150	300
Rainbows of 10 to 100 to the pound (medium to large fingerlings)			
Northeastern softwater	100	150	200
Northcentral softwater	125	175	225
Hardwater	150	200	250
Hardwater-marl	150	200	250
Bog stain	100	150	200
Shallow marginal	100	150	200
Frequent winterkill	50	100	200
Rainbows of less than 10 to the pound (yearlings)			
Northeastern softwater	50	75	100
Northcentral softwater	65	85	115
Hardwater	75	100	125
Hardwater-marl	75	100	125
Bog stain	50	75	100
Shallow marginal	50	75	100
Frequent winterkill	25	50	100

[1] Less than 100 man-hours per surface acre.
[2] Between 100 and 200 man-hours per surface acre.
[3] Over 200 man-hours per surface acre.

Brown trout — These trout have seldom been used in lakes in Minnesota and little information is available on their performance. Tentative stocking rates are therefore based on the recommendations for rainbow trout in Table 5.

Splake — The recommended stocking rates for splake are shown in Table 7. Because they tend to persist for a longer period of time in a lake, stocking rates for splake should be about one-half that of brook trout.

Atlantic salmon — Minnesota has had no experience with Atlantic salmon in inland lakes and no stocking rates can be recommended. However, fingerlings and yearlings stocked at about 10 per acre in a Maine lake with populations of pickerel, smallmouth bass, brook trout, smelt and eel had a reported return to the creel of five to 15% (Havey and Andrews, 1973).

Coho salmon — Coho are no longer being stocked in Minnesota lakes. When used in small lakes, the stocking rates should approximate those for rainbow trout (Table 5).

Table 6. Recommended stocking rates for brook trout in numbers per surface acre for three levels of fishing pressure by Minnesota lake type.

	Expected Fishing Pressure		
	Light[1]	Moderate[2]	Heavy[3]
Brook trout of over 100 to the pound (small fingerlings)			
Northeastern softwater	200	250	300
Northcentral softwater	300	400	500
Hardwater	300	400	500
Hardwater-marl	300	400	500
Brook trout of 10 to 100 to the pound (large fingerlings)			
Northeastern softwater	150	200	250
Northcentral softwater	200	300	400
Hardwater	200	300	400
Hardwater-marl	200	300	400
Brook trout of less than 10 to the pound (yearlings)			
Northeastern softwater	100	125	150
Northcentral softwater	150	200	250
Hardwater	150	200	250
Hardwater-marl	150	200	250

[1] Less than 100 man-hours per acre.
[2] Between 100 and 200 man-hours per acre.
[3] More than 200 man-hours per acre.

Table 7. Recommended stocking rates for splake in number per surface acre for three levels of fishing pressure by Minnesota lake type.

	Expected Fishing Pressure		
	Light[1]	Moderate[2]	Heavy[3]
Splake of over 100 to the pound (small fingerlings)			
Northeastern softwater	100	125	150
Northcentral softwater	150	200	250
Hardwater	150	200	250
Hardwater-Marl	150	200	250
Splake of 10 to 100 to the pound (medium to large fingerlings)			
Northeastern softwater	75	100	125
Northcentral softwater	100	150	200
Hardwater	100	150	200
Hardwater-marl	100	150	200
Splake of less than 10 to the pound (yearlings)			
Northeastern softwater	50	65	75
Northcentral softwater	75	100	125
Hardwater	75	100	125
Hardwater-marl	75	100	125

[1] Less than 100 man-hours per acre.
[2] Between 100 and 200 man-hours per acre.
[3] More than 200 man-hours per acre.

Kokanee salmon — This species is no longer used in Minnesota. If trials are contemplated it is suggested that 100 to 500 fingerlings or 50 to 250 yearlings per acre be stocked on an experimental basis, depending on the forage available.

Chinook salmon — Chinook salmon have been stocked experimentally in only one Minnesota lake. The success of this introduction has not yet been evaluated and stocking rates have not been established.

Grayling — Since most of the grayling stocked in two Minnesota lakes were taken during their first summer in the lake and there were no further trials, not enough information was gathered to develop stocking rates. Since difficulty is probable in securing grayling for stocking in most states or provinces, it is unlikely the cost and difficulties of procurement would be offset by their value as a novelty or trophy in most areas.

Combination of species — Minnesota lakes managed for more than one species have not shown a better production of trout than those managed for a single species. If more than one species is used, the total stocking rate for the combinations of salmonids in lakes should not exceed the total for one species alone.

To illustrate how stocking rates and sizes may be used to influence the number and size of fish creeled, four different types of rainbow trout fisheries are described, each based on a different stocking program. These hypothetical fisheries, based on a number of case histories, assume single annual stockings, angling only during the open water season and relatively heavy fishing pressure with anglers willing to accept eight inch fish.

1. Madison or kamloops strain rainbow fingerlings of 30 to 100 per pound, stocked annually in the spring: These fish will enter the fishery, depending on initial size, between July and September. Most of their contribution to the catch will be during their second summer in the lake. Heavy losses will often occur during the first summer, primarily to avian predators such as the loon. One to 10 percent of the stocked fish will be creeled. The fishery will follow a pattern of fair success during the early season, primarily on 10 to 12 inch fish carried over from the previous year with a switch to six to eight inch fish from the spring plant by mid- or late-season. Angling success will likely be relatively constant and not high at any one time.

2. Madison or Kamloops rainbow fingerlings of 20 to 70 per pound stocked in the fall: This fishery will be somewhat similar to one where spring stocked fingerlings are used. Some growth will occur over winter but most of the fish will be too small to be retained by the angler at the beginning of the season. The trout should recruit to the fishery in about July. The spring catch will depend on 12 to 15 inch

fish from the previous year's stocking. These fish will be rapidly cropped off and mid- and late-summer success will depend on the fall planted fish recruiting to the fishery as seven to ten inch fish. Many of these fish will survive to the fishery the following spring. Usually 20 to 60 percent of the number stocked will be creeled over a two year period.

3. Donaldson rainbow stocked in the fall, six to seven months after hatching, eight to 15 per pound: Most of these fish will be acceptable to anglers the following spring. Heavy catches will be made during the early season of seven to 11 inch fish with progressively lower catches as the summer passes. The often spectacular opening day catches will increase the early season angling pressure and by fall, 50 to 80 percent of the number stocked will be harvested. Little of this species potential growth will be realized since up to 90 percent of the annual harvest usually occurs during the first month of the season.

4. Madison or Kamloops rainbow yearling stocked annually in spring or fall: This type of stocking should be used where the return to the creel of stocked fingerlings is very low or where one initial stocking is needed for immediate angling in a newly reclaimed lake. The fishery which results will be similar to that from stocking Donaldsons although the catch may not be quite as high at the start of the season because of the Donaldson's greater vulnerability to angling. However, most fish will be caught relatively early in the season, fewer during mid- and late-season and very few in subsequent years. Little growth will be realized in the lake since up to 90% of the annual harvest may be expected to occur during the first month of the season. Fifty to 80 percent will be creeled from each stocking.

Cost and availability of trout

The actual cost per fish or per pound of fish stocked can be roughly determined by adding direct hatchery costs, pro-rated administrative costs and transportation costs.

Cost per fish stocked is probably lowest for Donaldsons because of their rapid growth in the hatchery. Fingerling trout are considerably less expensive than yearlings and should be used in most cases. Calculations based on hatchery costs in Minnesota have shown that it was more economical to stock fingerling rainbow trout unless survival to the creel was less than 15% in which case yearlings were more economical (Unpublished data. Section of Fisheries).

Most rainbow trout are available as fingerlings of 20 to 70 per pound from the hatcheries in the fall. They are also available as yearlings the following spring and early summer. Donaldson fingerlings are somewhat larger at 8 to 15 per pound. Some may reach catchable size by October after hatching in March. They are also sometimes available as small fingerlings in late spring. Brook trout are available at somewhat smaller sizes both as fingerlings in the fall and yearlings in the spring.

The introduction and maintenance of trout or salmon in lakes requires close coordination between the fish manager and the production supervisor since needs must be carefully planned for a period of years. Unexpected or unpredictable needs may often be adjusted if close communication is maintained.

Harvest

Lakes managed for stream trout and salmon are usually harvested by sport fishing and this manual deals only with the sport fisheries. However, commercial production of trout in ponds and lakes is also practical and is currently being undertaken in private waters. The planting and harvest of trout from frequent winterkill lakes for commercial production is being carried out in some prairie pothole lakes in Manitoba, Saskatchewan and Alberta. For further information on management for commercial purposes, the reader is referred to Miller and Thomas (1957); Johnson, Lawler and Sunde (1970); and Sunde, Whitaker and Lawler (1970).

Sport fishing harvest is affected by the productivity of the water, species stocked, survival to catchable size and fishing pressure and is usually measured in terms of number or pounds of fish taken by anglers per acre per year. Fishing success is commonly measured in terms of number of fish caught per man-hour of fishing or fish per trip.

The usual harvest characteristics for the various species of stream trout or salmon are discussed below and typical angling catches for the various lake types at different levels of fishing pressure are shown in Tables 8-17.

Figure 4. Catch from a lake successfully managed for stream trout.

Rainbow trout

In Minnesota lakes it has been found that rainbow trout usually return a higher percentage of stocked fish to the creel than other trout or salmon and will sustain a fishery until the stocks are nearly exhausted. They are relatively easy to catch and only moderate experience is required of the angler. Compared to brook trout, rainbows show a higher percentage of second and third year fish in the creel. Alexander (1975) and Alexander and Shetter (1961 and 1969) compared rainbow and brook trout stocked as yearlings and found that the rainbows had better survival and better growth resulting in a better yield to the angler. Johnson and Hassler, (1954) found rainbow trout more suitable than brook trout for dystrophic (bog-stained) lakes.

Other studies which document results of rainbow trout management for a sport fishery have been reported by Burdick and Cooper (1956), Rawstron (1972), Smith (1957) and Hatch and Webster (1961).

Characteristic harvests from various lake types managed for rainbow trout in Minnesota are shown in Tables 8-12.

Brook trout

A large percentage of the fingerling brook trout stocked the previous fall are harvested the first few weeks of the angling season as six to seven inch fish if fishing pressure is high. Fishing success then declines and few fish are caught during the summer months. Only in lakes where angling pressure is light or where recruitment occurs later in the season will fishing success hold up in late summer. The average size of fish is larger in lakes with less fishing pressure,

Table 8. Mean annual harvest of rainbow trout from five types of Minnesota lakes managed for stream trout.

Lake	County	Surface area Acres	Years Censused	Mean Annual Harvest N/Acre	Lbs/Acre
Northeastern soft-water:					
Kimball	Cook	79	3	15.8	9.9
Divide	Lake	65	3	2.8	2.9
Northcentral soft-water:					
Allen	Crow Wing	46	5	42.5	25.0
Hard-water:					
Willard	Cass	7	7	145.9	103.8
Hard-water marl:					
Strawberry	Crow Wing	16	9	89.0	39.1
Pleasant	Crow Wing	22	3	30.8	19.8
Bog stain:					
Surprise	Itasca	9	1	5.3	5.3

Table 9. Harvest of stocked rainbow trout year classes from Minnesota lakes as related to fishing pressure

Lake	Acreage	N/Acre Stocked	Harvest (percent of numbers stocked) 1st Yr.	2nd Yr.	3rd + 4th Yr.	Total
Heavy fishing pressure: [1]						
Willard	7	1392	8.1	4.6	2.1	14.8
Willard	7	144	32.8	27.7	10.0	70.5
Willard	7	143	44.4	17.8	13.9	76.1
Willard	7	777	24.3	8.2	1.2	33.7
Strawberry	16	268	17.7	8.5	0.4	26.6
Strawberry	16	270	9.6	7.9	2.0	19.5
Strawberry	16	209	59.1	2.6	0.2	61.9
Moderate fishing pressure: [2]						
Allen	46	54	57.7	8.8	2.2	68.7
Allen	46	218	15.3	2.3	1.1	18.7
Light fishing pressure: [3]						
Kimball	79	68	14.6	1.8	0.4	16.8
Divide	65	88	3.1	1.2	0.2	4.5

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

Table 10. Catch of rainbow trout per man-trip during summer angling seasons in Minnesota lakes managed for stream trout.

Lake	Year	Opening Weekend	May	Catch per man-trip June	July	August	September
Lakes with heavy fishing pressure: [1]							
Willard	1962	1.2	1.2	1.7	0.6	0.6	1.2
Pleasant	1959	0.5	0.4	1.5	0.9	0.9	0.3
Strawberry	1973	0.9	0.5	1.1	0.6	0.3	0.3
Lakes with moderate fishing pressure: [2]							
Allen	1973	3.0	2.0	1.1	1.0	1.0	0.2
Pleasant	1960	0.4	1.2	0.9	0.3	0.04	0.2
Lakes with light fishing pressure: [3]							
Kimball	1961	—	0.3	0.9	0.2	0.1	0.4
Divide	1961	—	0.2	0.4	0.6	0.3	0.2

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

but the percentage of stocked fish creeled is less because of greater losses to causes other than angling. Total production of brook trout per acre is less than in lakes managed for rainbow trout and average size is smaller.

Brook trout at six to 10 inches appear to be more vulnerable to the angler in the spring than are rainbow trout, but seem to be more difficult to take at

Table 11. Average total length (inches) of rainbow trout creeled during summer angling seasons in Minnesota lakes managed for stream trout.

Lake	Year	Opening Weekend	May	June	July	August	September
			Total length				
Lakes with heavy fishing pressure: [1]							
Willard	1962	9.2	8.8	9.2	10.2	9.2	8.5
Pleasant	1959	12.9	12.9	9.3	9.7	9.6	8.4
Strawberry	1973	9.7	9.2	9.8	10.7	10.8	11.2
Lakes with moderate fishing pressure: [2]							
Allen	1973	10.0	9.9	10.0	11.1	11.5	12.9
Pleasant	1961	9.7	9.7	10.2	12.1	12.1	12.1
Lakes with light fishing pressure: [3]							
Kimball	1961	—	12.1	12.4	13.7	13.7	13.9
Divide	1961	—	12.5	12.4	13.6	14.1	14.1

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

Table 12. Average weight (pounds) of rainbow trout creeled during summer angling seasons from Minnesota lakes managed for stream trout.

Lake	Year	Opening Weekend	May	June	July	August	September
			Weight				
Lakes with heavy fishing pressure: [1]							
Willard	1962	0.3	0.3	0.2	0.4	0.4	0.2
Pleasant	1959	1.0	1.0	0.4	0.4	0.5	0.3
Strawberry	1973	0.4	0.3	0.4	0.5	0.6	0.5
Lakes with moderate fishing pressure: [2]							
Allen	1973	0.4	0.4	0.4	0.6	0.7	1.0
Pleasant	1961	0.4	0.4	0.5	0.6	0.6	0.6
Lakes with light fishing pressure: [3]							
Kimball	1961	—	0.7	0.7	0.9	0.9	0.9
Divide	1961	—	0.7	0.7	0.9	0.9	0.9

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

larger sizes. This may be due to the brook trout's preference for colder water and less active feeding habits during the summer months.

The harvest characteristics of brook trout in Minnesota lakes have been reported by Micklus and Hale (1959), Micklus (1960) and Micklus and Johnson (1965). Production and harvest of brook trout in softwater, subalpine Adirondack Mountain lakes has been described by Hatch and Webster

(1961). In these lakes standing crops were seven to 18 pounds per acre, harvests were 3.5 to 5.8 pounds per acre and exploitation rates were 15 to 43 percent. In Minnesota brook trout lakes yields have been both higher and lower than this range (Table 13) but exploitation rates were usually higher. Latta (1963) described brook trout management in small Michigan lakes where he found a good carry-over to a second year of harvest for each stocked class of large fingerlings.

Flick and Webster (1964) discussed brook trout production in New York ponds and compared differences in performance between domestic and wild strains. They found a higher total return to the creel of the wild strain.

Harvest data from Minnesota brook trout lakes of various types is shown in Tables 13-17.

Brown trout

Brown trout have been used in few managed stream trout lakes in Minnesota and there has been no documentation of their survival or harvest. General observations suggest that while the smaller brown trout are readily caught in these lakes, the older, larger individuals are difficult to harvest. Consequently, this species will not provide as great a harvest as would rainbow trout when stocked in comparable numbers. The reluctance to use brown trout in lake management is also due to the reputation the larger fish have as predators on younger trout.

These general observations agree with those reported in studies from other areas. Brynildson and Kempinger (1973) report that rainbow trout had higher survival, growth rates and yields than brown trout in a Wisconsin lake managed for both species. The brown trout did provide a few trophy-sized fish in subsequent years while the rainbow stock was depleted in two years. Boles and Borgeson (1966) found that young brown trout are caught as readily as

Table 13. Mean annual harvest of brook trout from Minnesota lakes managed for stream trout.

Lake	County	Area (acres)	No. years Censused	Mean annual harvest N/acre	Lbs./acre
Northeastern soft-water:					
Benson	Lake	20	3	9.2	5.4
Divide	Lake	65	3	5.6	2.6
Surber	Cook	7	3	42.6	14.0
Duck	Lake	9	1	32.4	14.0
Northcentral soft-water:					
Perch	Cass	13	3	131.7	26.5
Hard-water-marl:					
Pleasant	Crow Wing	22	1	6.0	3.0

Table 14. Harvest of stocked brook trout year classes from Minnesota lakes managed for stream trout as related to fishing pressure.

Lake	Acreage	N/Acre Stocked	Harvest (percent of numbers stocked) 1st Yr.	2nd Yr.	3rd + 4th Yr.	Total
Heavy fishing pressure:[1]						
Perch	13	526	34.9	0.5	0	35.4
Pleasant	22	100	63.4	0.4	0	63.8
Moderate fishing pressure:[2]						
Benson	20	105	11.4	1.9	0.1	13.4
Surber	7	147	19.7	4.4	0.9	25.0
Perch	13	438	21.3	0.9	0	22.2
Light fishing pressure:[3]						
Divide	65	130	8.1	1.8	0.3	10.2
Benson	20	347	1.1	0.2	0	1.3

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

rainbow trout but subsequent stockings had poor survival. They felt that this was due to predation by older brown trout.

Cutthroat trout

There is no record of the cutthroat trout being used in Minnesota lakes. From the literature it would not appear that they would perform and yield better than the rainbow trout. Trojnar and Behnke (1974) discuss the per-

Table 15. Catch per man-trip of brook trout during summer angling seasons in Minnesota lakes managed for stream trout.

Lake	Year	Catch per man-trip: Opening Weekend	May	June	July	August	September
Lakes with heavy fishing pressure:[1]							
Pleasant	1959	5.8	2.6	0.1	Trace	0.1	0
Perch	1959	3.3	3.5	1.7	1.6	0.7	0
Lakes with moderate fishing pressure:[2]							
Benson	1961	—	0.6	0.5	0.4	0.2	0.1
Surber	1962	2.5	0.7	0.2	0.1	0	0.1
Perch	1957	9.0	4.0	1.9	0.9	0.8	0.3
Lakes with light fishing pressure:[3]							
Benson	1963	1.1	0.4	0.3	0.1	0.1	0.3
Divide	1962	0.3	0.3	0.6	0.4	0.2	0.2

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

Table 16. Average total lengths (inches) of brook trout creeled during summer angling seasons in Minnesota lakes managed for stream trout.

Lake	Year	Opening Weekend	May	June	July	August	September
			Total length				
Lakes with heavy fishing pressure: [1]							
Pleasant	1969	8.4	9.4	8.5	8.5	8.2	8.2
Perch	1959	8.5	7.8	8.0	8.9	9.8	–
Lakes with moderate fishing pressure: [2]							
Benson	1961	–	10.3	9.5	11.2	13.2	12.2
Surber	1962	8.8	8.4	10.1	12.1	–	13.5
Perch	1957	7.4	7.9	9.3	10.3	12.2	12.8
Lakes with light fishing pressure: [3]							
Benson	1963	9.7	8.4	8.6	8.6	11.6	11.0
Divide	1962	12.6	11.3	9.4	10.7	11.2	12.4

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

Table 17. Average weight (pounds) of brook trout creeled during summer angling seasons in Minnesota lakes managed for stream trout.

Lake	Year	Opening Weekend	May	June	July	August	September
			Weight				
Lakes with heavy fishing pressure: [1]							
Pleasant	1959	0.2	0.2	0.2	0.3	0.3	0.3
Perch	1959	0.2	0.2	0.2	0.3	0.5	–
Lakes with moderate fishing pressure: [2]							
Benson	1961	–	0.4	0.3	0.5	0.8	0.7
Surber	1962	0.3	0.2	0.4	0.7	–	0.9
Perch	1957	0.1	0.2	0.3	0.4	0.7	0.8
Lakes with light fishing pressure: [3]							
Benson	1963	0.4	0.2	0.3	0.3	0.6	0.5
Divide	1962	0.7	0.5	0.3	0.4	0.5	0.7

[1] More than 200 man-hours per acre per year.
[2] Between 100 and 200 man-hours per acre per year.
[3] Less than 100 man-hours per acre per year.

formance of two strains of cutthroat trout in a Colorado lake. They cite the Snake River strain's ability to withstand eutrophic conditions and report the use of populations of different strains to more efficiently utilize food resources of a lake. Hansen (1971) also discusses cutthroat trout management in an Oregon lake. The fish were stocked in the presence of centrarchids, yellow perch and bullheads as well as stocked rainbow trout, coho salmon and kokanee salmon. Survival was poor except for those stocked at "legal" size just before the angling season. Migration down an outlet was at least 10 percent. This seems moderate in comparison with migratory tendencies of rainbow trout observed in Minnesota.

Atlantic (landlocked) salmon

The landlocked form of the Atlantic salmon is used extensively in Maine and other northeastern North American areas. It was stocked in Minnesota waters near the turn of the century, apparently without success. Physically, it closely resembles the brown trout and can be considered a stream trout that is usually anadromous.

Our knowledge of the management of lakes for the landlocked salmon comes mostly from several publications from Maine. Havey and Warner (1970) published a comprehensive study of the life history and management of the landlocked salmon, and Warner (1972) recommended the fish for a "quality" sport fishery in inland lakes. He indicated that some two-year old fish are creeled but the fishery relies mostly on three, four and five year-old salmon of about 12 to 20 inches total length. These sizes are similar to rainbow trout in lakes at one to three years of age.

Havey (1973) studied the harvest of landlocked salmon stocked at different ages in a Maine lake and presented additional data on their performance that largely supports the findings of Warner (1972). Havey and Andrews (1973) reporting on the population dynamics of hatchery reared landlocked salmon in the same lake found that the yields from different stockings ranged from 1.4 to 3.5 pounds per acre. They also pointed out the accelerated mortality for landlocked salmon after age five.

From the experience in Maine, it appears the landlocked salmon could be used in suitable lakes where a longer lived fish is desired.

Splake

Minnesota has used the hybrid of the female lake trout and male brook trout with some apparent success in inland lakes but no detailed evaluation has been made. The food habits and growth of splake in a Wisconsin lake was reported by Brynildson and Kempinger (1970) who found that the growth of this hybrid was quite variable and harvest was low. Martin and Baldwin (1960) also found a low harvest in most Ontario lakes where less than two percent of each stocking of splake were recovered by the anglers.

Observations of splake catches from Minnesota lakes indicate that their characteristics are somewhere between those of the lake trout and brook trout parent stocks. Growth of the first cross has been faster than lake trout but significantly slower than brook trout. The hybrid becomes acceptable to the angler at age two as compared to age one for the brook trout. In a moderate to heavily fished lake, splake will contribute to the catch for two or three years instead of the one or two provided by brook trout.

Coho salmon

Coho salmon have been stocked in inland lakes in Minnesota and Lake Superior. Hassinger (1974) summarized Minnesota's experience in Lake Superior and in two inland lakes with this Pacific salmon. Management of one inland lake failed because of out-migration and the other lake produced a return of 21 percent and 14.9 pounds per acre. He concluded that coho salmon did not compare favorably with the rainbow trout in Minnesota's inland lakes.

However, Wigglesworth and Rawstron (1974) concluded that in a California lake coho salmon compared favorably with rainbow trout for lake management. Stocked in a large reservoir, coho salmon produced a return to the angler of 38 and 39 percent with average weights of three and six pounds. They calculated a cost to the angler of $0.44 per pound of fish creeled. Advantages over rainbow trout were the attainment of a larger size and a lesser vulnerability to angling immediately after stocking.

Kokanee salmon

Kokanee salmon have been stocked in Minnesota lakes as a pelagically feeding fish with the intent of increasing the sport fishery in deep lakes of limited productivity and limited shoal areas. Although some fish were caught, their sizes and the small number harvested did not justify continued management. No further management is contemplated and no recommendations are made for this species.

Grayling

The arctic grayling is not a trout or salmon but since it has been stocked and managed in lakes, it is discussed here. Micklus (1961-A) described the experimental management of grayling in Minnesota. In a nine day season, fishing pressure amounted to 54 man-hours per acre and the harvest was about 16 fish and 10 pounds per acre. Most of the grayling creeled were taken in their first season in the lake.

Grayling are usually expensive to obtain and rear and in most areas they must be regarded as an exotic species valuable principally as an unusual trophy.

Evaluation Procedures

The establishment and maintenance of a stream trout or salmon population in a reclaimed lake is an expensive management practice and the resulting fishery should be evaluated to determine whether it justifies the cost. To determine whether a satisfactory fishery has been established, a monitoring program is required. If problems develop, a monitoring program will usually define them. Remedies for some common problems are discussed in the next section.

Ideally, monitoring procedures should consist of a full season creel census, pre-season and post-season population estimates and periodic checks of temperature and dissolved oxygen profiles and the abundance of food organisms. Although budget and man-power limitations usually necessitate sampling techniques requiring less time and money, monitoring of some type for each year class of stocked fish should continue as long as that year class remains in the fishery if a reasonable assessment of the success of the fishery is to be made.

The evaluation program should answer the following questions: (1) has survival of stocked fish to catchable size been sufficient to provide a satisfactory sport fishery? (2) has growth been sufficient so that fingerling trout reach an acceptable size and older trout provide an occassional trophy? (3) has angler utilization and harvest been great enough to justify the expense of establishing the fishery? (4) are the fish produced of good quality in regard to taste, odor, visible parasites and sporting appeal?

Evaluation procedures used on study lakes in Minnesota have been described by Micklus and Hale (1959) and Micklus (1960). Micklus and Johnson (1965) also evaluated management efforts on a statewide basis and described population estimate procedures and creel census methods applicable to these waters. Waters (1960) has described and evaluated population estimate procedures for trout in small lakes.

Population estimates

Numerical estimates of fish populations have been made for many years, probably starting with Petersen (1896). Various methods of estimation and criteria governing their use have been developed and are detailed in a number of publications. One of the most comprehensive is that by Ricker (1975).

Population estimates in these lakes are intended primarily to determine survival of a stocked year class of fish and to determine whether the total fish population is large enough to sustain a satisfactory fishery in numbers, pounds and size of fish.

The usual technique used in the evaluation of lakes managed for stream trout in Minnesota to determine the number of fish present at a given time is the simple unmodified "Petersen" or single census method (Ricker, 1975). A sample of fish are captured, marked and released unharmed at random or at a central release point. After an interval of time which allows for redistribution of the marked fish and a resumption of usual habits (a week or two is adequate in these small lakes), a recapture effort is made. The ratio of marked fish in the recaptured sample to the total fish in the sample should then be the same as the ratio of total marked fish in the lake to the total population of fish in the lake.

The population estimate

where: M = number of fish marked
C = total fish caught in recapture effort
R = marked fish in recapture sample
N = unknown total population

is then: $\frac{R}{C} = \frac{M}{N}$ or

$$N = \frac{MC}{R}$$

Somewhat better "Petersen" estimates may be obtained using the modification of Chapman (1951) and Bailey (1951), but in practice where values of R are usually large, there is little improvement in the estimate.

Confidence limits for the Petersen estimates are easily calculated from the tables in Appendix II of Ricker (1975).

This method will give unbiased estimates of the population only if several conditions are met. These are: (1) that mortality of the marked fish is no different than the unmarked, (2) that marked and unmarked fish are equally vulnerable to the fishing gear, (3) that marked fish do not lose their mark and that all marks are recognized among recaptured fish, (4) that marked fish become randomly mixed with the unmarked population and (5) that there is no or negligible recruitment to the population.

Estimating the numbers of trout or salmon in small lakes or ponds can be relatively simple and free from bias compared with larger waters with more complex distribution of the fish populations. Usually these small bodies of water are discreet, with no movement of the target species in or out. With little or no natural reproduction recruitment is not a problem or is controlled by stocking. Since the lakes are small, the fish populations can be rather intensively sampled.

The recapture sample can represent the sum of several samples such as individual trap-net catches taken over a short period of time, provided that any fish captured more than once is counted only once in the catches. To exclude this possibility a temporary mark applied to each fish (marked or unmarked) will permit their identification so that they can be excluded from the catch if captured in later samples (Robson and Regier, 1971).

The principal problem in making unbiased estimates in these lakes is the differential vulnerability of fish of different sizes to the gear. This can be avoided if fish of distinctly different sizes are estimated separately and there is no growth between the time of marking and the time of recapture. Where growth occurs between the time of marking and the time of recapture, it is best to use the most non-selective gear available.

Trap-nets are the usual gear used in Minnesota stream trout lakes to collect trout for population estimates, although electrofishing and the angler's catch have also been used. The trap-net has a 50 foot lead, a six by three foot entrance with internal wings and 30 inch steel hoops containing two throats. It is emptied at the cod end. Mesh sizes are uniform throughout the net and are usually one-fourth inch, one-half inch, three-fourths or one inch bar measure. It has been found during netting in Minnesota lakes that 5.5 to 7.5 inch rainbow trout will be gilled in three-fourths inch bar mesh trap nets and that 4.0 to 5.2 inch rainbows will be gilled in one-half inch bar mesh trap-nets. It follows that trout of about 8 inches would be vulnerable to injury or death in one-inch mesh nets. Mesh sizes must be carefully selected to avoid this problem. The trap-nets are fished from shore out to a depth of two to eight feet and are effective in capturing stream trout in lakes during spring and fall when the fish frequent shoal waters.

Electrofishing is also an effective method frequently used for collecting in stream trout or salmon lakes. The usual gear is a boom shocker mounted on a square-bowed pram with a 220-volt A.C. or pulsed current 220-volt D.C. generator. There is, however, some potential selectivity with this kind of gear. For example, in a small lake it was found possible to obtain an adequate sample of the eight to twelve inch trout in one night of fishing, but the proportion of larger trout was less than that obtained from trap-netting. This indicated that the larger fish were not as vulnerable to the gear either because they were more adept at escaping the field of the shocker or were at depths that could not be effectively sampled.

Seining is a relatively non-selective method of capture but is not always possible since these small lakes often have soft bottoms and abundant vegetation. It also requires more man power. Seining may also physically damage the fish and thus effect mortality especially if large amounts of mud or vegetation are brought in with the fish. In some waters, however, a large seine can be an effective means of securing samples for population estimates.

Gill-netting is usually not recommended for making recapture since excessive numbers of fish may be killed or injured in the process. However, if a high mortality can be tolerated, a large sample can be taken using the proper mesh sizes. Because of their body shape and their tendency to force their way through obstructions, stream trout are highly vulnerable to gill-nets.

Waters (1960) indicated that it is preferable to make recaptures with a different type of sampling gear since some members of the trout population may be more attracted, or repelled, by a particular type of gear than others. However, for management purposes, the bias in the estimate resulting from the use of the same recapture gear does not appear to be serious. Population estimates in seven acre Willard Lake in Cass County, Minnesota, using the same recapture gear and two other methods of recapture were very similar suggesting that bias using the same gear was negligible. Using trap-nets, a total of 524 rainbow trout were captured, marked and released in late September and early October of 1962. Four different samples were taken by three methods in April and May, 1963, and estimates were made. Assuming no overwinter mortality, the estimates are shown in the following table.

Method of Capture	**C**	**R**	**N**	**95% Confidence limits**
Trap-netting	515	270	999	888 - 1124
Electrofishing 1	116	54	1126	868 - 1482
Electrofishing 2	146	67	1142	900 - 1443
Angler catch, month of May	179	90	1042	845 - 1285

These estimates do not vary much and are adequate for management purposes.

The time required to capture and mark sufficient trout or salmon for a population estimate varies greatly with amount of gear and the size of the lake. For example, in small lakes (less than 100 acres), it is usually possible to capture and mark enough fish for a population estimate in three days netting (two 24-hour series) if the trout population is fairly abundant.

In practice an attempt is made to mark 30% or more of the population. While this may be more marking than is required for estimates for management purposes, it serves to insure that the available habitat is well sampled in an attempt to reach this level and to insure that some segments of the population which may be localized are not missed.

Marking fish by removal of all or part of a fin has been the standard marking technique used in the Minnesota studies. No problems of mark recognition or survival of marked fish have been encountered. Since the number of trout surviving to a catchable size and their survival following the first season of angling is the fisheries manager's main concern, a temporary mark which persists for about 6 months is normally sufficient.

Fin removal in recent years has been done with a toenail clipper which pinches the fin off and closes most of the blood vessels. This method leaves a cleaner cut than shearing the fin off with scissors which often leaves the tissues with a raw open edge.

When removing fins from trout or salmon, it is best to clip the less vital fins first. Usually one fin is enough. If one or more marks is required the following order of fin removal is suggested: (1) the adipose fin, (2) either pelvic fin, (3) part of either lobe of the caudal fin and (4) no more than one half of either pectoral.

Population estimate procedures used in other studies of stocked trout and salmon in lakes have been described by several investigators. Alexander and Shetter (1961 and 1969) used trap-nets to collect trout for marking and used other methods including angling and electrofishing for recoveries. Latta (1963) using fin clips as marks also used a variety of methods for capture and recapture. Rawstron (1972) using both carlin tags and fin clips as marks found voluntary tag returns were not entirely satisfactory as a method of recovery. Stauffer and Hansen (1969) compared different jaw tags and fin clips on rainbow trout. They found some effect on growth by jaw tags and from five to 15 percent loss of these tags. Fin clipped trout were not affected and 95% of the marks were recognizable after two years.

Creel census

Creel census is the final evaluation procedure for the fishery and provides the measure of the end product of the management effort. Anglers are interviewed, their catch is examined and fishing pressure and total catch is then determined.

A season-long creel census, whether full-time or a sampling type, such as used in the Minnesota studies, is an expensive procedure. Three full days out of each eight day period were censused on the Minnesota study lakes. In most cases, all fishing trips originated from a single access and a day's data could be regarded as complete. Anglers were interviewed at the end of their fishing trip and their fish were examined. This procedure provided a sample of 37.5 percent of the days in the fishing season. Recently, to save manpower and expense, three sample stratifications were used: 50% of the opening weekend days, 50% of the remaining weekend days and holidays and 10% of the weekdays. Because of the higher pressure on weekend days and holidays, this stratified sampling which sampled 24 percent of the days in the season sampled 30 percent of the anglers. Calculations for the final estimates were made separately for the three samples and then totaled.

Using the original system, the total time necessary to census a lake during Minnesota's former 21 week season was about 770 man-hours. Using the stratified sample under the present (1975) 19 week season, the time required would be about 380 man-hours, resulting in a substantial reduction in costs.

The fisheries manager will probably not regard it as necessary to run a season long creel census on all lakes he manages for trout or salmon. Much data, which will provide insight into the quality and use of the fishery, can be secured from a sample of trout collected during periods of peak fishing pressure such as the opening weekend or a holiday weekend like Memorial Day or July 4th. Data required can include: fish per man-hour, mean length and weight of fish in the catch, their size distribution, the ratio of young recently stocked fish to older fish and an indication of angler interest and acceptance of the trout lake management.

Another evaluation of the success of fisheries management of a lake is a measurement of utilization. Crude estimates of fishing pressure can be obtained from a series of counts of anglers made from the air or from the ground. This procedure was described by Micklus and Johnson (1962) wherein about 30 randomly scheduled counts were made on a number of lakes during the former 21 week Minnesota stream trout season. Since the fishing day averaged about 16 hours for the 147 day season, the season total was 2,352 hours. Then, 2,352 multiplied by the average of the thirty angler counts would equal the total estimated man-hours. This technique provides a useful index of use especially where large numbers of lakes are involved.

It has been found during the Minnesota studies that in trout lakes with a history of moderate to heavy fishing, a lack of angler use usually indicates unsatisfactory angling. Poor angling is nearly always due to low fish populations which are usually the result of poor survival of stocked trout.

Other monitoring procedures

It has been concluded from the studies conducted in Minnesota that the single most important element in successful management of a lake for trout or salmon is the survival of the stocked fingerlings to a total length of about eight inches. It is therefore desirable to monitor the stocked fish until they enter the fishery. If substantial mortality is indicated, a remedial stocking can be made. If there is a loss of fish immediately following stocking, it can often be determined by inspection of the shoreline and shallow water areas. When possible, observations of the bottom in deeper water should be made to get a more complete assessment of losses.

Survival and growth of spring stocked fingerling rainbow trout in Minnesota has been most successfully determined by sampling with gill-nets of appropriate mesh size. Short-term daylight sets (two hours) made at intervals throughout the summer, did not over-sample the population and the fish were alive with stomach contents intact. Growth and condition factors can be calculated if the nets are not selective within the size range of fish encountered.

Foods available to young trout were also sampled with bottom dredges and plankton tows during open water seasons on a number of Minnesota lakes but little relationship to survival or mortality was apparent. Some authors, however, have stressed food availability. These include Micklus (1961) who compared productivity of a bog lake and an oligotrophic lake in northeastern Minnesota, Cordone and Nicola (1970) who fertilized a California lake to increase its productivity and Warner (1972) who was concerned with forage species available to landlocked salmon.

Since a major cause of mortality among stocked fingerling trout is predation by birds, monitoring efforts should also include estimates of the activities and impact of such avian predators as loons, mergansers, ospreys, great blue herons and kingfishers. The presence of such mammalian predators as mink and otter should be noted as well.

Problems And Remedies

If problems develop on a lake managed for stream trout or salmon, they are usually brought to light by dissatisfied anglers, local residents or through monitoring by the fisheries manager.

Usually, the problems are much easier to define than to solve. Problems commonly associated with the management of lakes for stream trout and salmon can be grouped into four categories: (1) poor angling success, (2) small fish, (3) fish of poor quality and (4) people problems.

Poor angling success

A low catch rate is nearly always caused by a low population of trout. The causes of low populations of trout or salmon experienced during the Minnesota studies or encountered in the literature include: (1) oxygen depletion during the period of winter ice and snow cover, (2) oxygen depletion or high temperatures during the summer, (3) predation by or competition with other fish species, (4) loss to predators other than fish, (5) incomplete detoxification following reclamation and (6) loss of sub-catchable trout from hooking and release by anglers. In some cases a lake that is subject to winter oxygen depletion or high summer temperatures and algae blooms has been selected through error or as a deliberate risk.

There are no easy remedies for these problems in most lakes. In small lakes or ponds, winter oxygen depletion can be prevented by aeration devices. Summerkill from high temperatures or low dissolved oxygen may be prevented by pumping cold water from the hypolimnion to the surface to absorb oxygen. (Smith, Knauer and Worth, 1975). However, these authors point out that if the lake is totally destratified, the entire water mass may become too warm for trout or salmon. The application of alum to reduce phosphorus availability and thus reduce algae blooms and subsequent oxygen depletion has also been demonstrated (Peterson, et al. 1973). These techniques are generally expensive and in most cases the benefit is unlikely to justify the expense.

Competition with, or predation by other fish species is a common cause of trout mortality. Generally, fingerling trout stocked in Minnesota waters containing northern pike, walleyes, perch and various centrarchids suffer total or nearly total mortality in the sub-catchable stage. Rainbow or brook trout stocked as yearlings (about eight inches) have shown a higher survival and have often produced a fishery in spite of the presence of other fish populations. However, this is an expensive procedure and is generally not recommended.

Investigations reported in the literature emphasize the importance of predation by other species on stocked trout or salmon. Warner, et al., (1968) and Havey (1973) documented predation on stocked landlocked salmon by chain pickerel, lake trout, yellow perch and burbot and found it advisable to stock yearling or older salmon. Keith and Barkley (1970) reported substantial predation on rainbow trout by chain pickerel and largemouth bass in Arkansas. Micklus (1960) found heavy losses of brook, rainbow and lake trout to smallmouth bass. In several Minnesota lakes, the re-establishment of a substantial yellow perch population has resulted in total mortality of stocked rainbow trout and brook trout fingerlings.

Often, reclaimed lakes develop fish populations incompatible with trout through the use of live bait, from deliberate illegal introductions or from the activities of birds. In most cases, the only solution is complete eradication of the population with toxicants and a new start made with trout or salmon. If only minnow species are present, eradiction is not required.

As previously noted in the section on stocking, losses of small trout to predators other than fish is an important factor in non-angling mortality. These loses occur during the open-water season and are mostly of trout less than eight inches in total length. It has been noted earlier that birds appear to be the principal predator. Loons followed by mergansers are the most numerous bird predators in Minnesota's stream trout lakes. Other active bird predators observed were osprey, great blue heron and kingfisher. The latter two are, of course, limited to shallow waters. Non-bird predators observed on the lakes included mink, otter and snapping turtles.

The importance of bird and animal predation as a factor in mortality of small trout in lakes has been reported by several investigators. Alexander (1976) rated the loon, American merganser, great blue heron, otter, mink and water snake as the chief predators on trout in Michigan. Alexander and Shetter (1961 and 1969) also cited the importance of bird and mammal predation in managed stream trout lakes. Johnson and Hassler (1954) assigned most of the mortality of trout in Wisconsin lakes to mergansers, kingfishers, great blue herons, ospreys, loons, snapping turtles and otters. Latta and Sharkey (1966) who studied the feeding habits of mergansers found them to be efficient fish predators.

Elimination of the predators is the obvious, but often not feasible, remedy for predation. Elimination or reduction measures may include shooting, trapping or harassment. However, most of the bird predators are protected by state or federal law which precludes shooting or harassment. In Minnesota the loon also enjoys added status as the state bird.

Some losses of stream trout or salmon have occurred in the past when lakes were stocked following reclamation before the water had completely detoxified. With the present day toxicants and bioassay procedures, this should no longer be a problem.

Losses of sub-catchable trout to hooking and release by anglers is a definite but not a major part of the total mortality of stream trout in lakes. These losses are usually greater for ice fishing because of the added damage to fish exposed to winter temperatures.

Mason and Hunt (1967) found in many cases a high mortality among hooked and released trout. Losses of hooked and released trout of up to 11 percent in a Colorado lake has been reported by Klein (1966). Shetter and Allison (1958) also found a definite but variable mortality among trout hooked and released in Michigan waters.

As previously mentioned, observations in Minnesota have indicated that transportation, handling, stocking, failure of the trout to adapt to the new environment, or failure to utilize wild food organisms, were not usual factors in loss of trout. Newly stocked rainbow trout fingerlings were observed by a diver to immediately begin feeding, rapidly disperse from the stocking site, penetrate the thermocline and within a week acquire "wild" defensive characteristics. No dead fingerling rainbow trout were observed when stocking was properly executed. No evidence is available to suggest that brook trout were more or less susceptible than rainbow trout to the rigors of transportation and stocking.

Losses of stocked rainbow and brook trout fingerlings to predation by larger trout in Minnesota stream trout lakes were also minor. Food consumption data was collected for rainbow and brook trout most years between 1957 and 1974 from angler caught fish. Very few small trout were found in the stomachs. However, larger trout (over 16 inches) may be more predaceous on smaller trout. Johnson, Lawler and Sunde (1970) felt that large rainbows posed a threat to stocked fingerling trout and Eipper (1964) also warned about predation by older trout. Boles and Borgeson (1966) indicated that brown trout were more predaceous on small trout than were rainbow and brook trout.

Small fish

A lake managed for stream trout or salmon that does not produce fish of a size acceptable to the angler may have one or more of the following problems: (1) productivity so low that growth is poor even with minimal stocking, (2) excessive stocking accompanied by high survival, (3) vulnerability to angling when the fish are small or (4) excessive stress during the growing season from prolonged periods of high water temperatures or low dissolved oxygen.

Stream trout stocked in Minnesota study lakes have usually shown good to excellent growth, with or without good survival. Indications are that the standing crop seldom reaches the maximum because of substantial mortality and angling removal before the potential growth of the trout is realized. In these lakes, except some marginal lakes, rainbow trout or brook trout stocked at 100 to 300 per acre have not shown slow growth. In marginal waters such as dystrophic (bog-stain) lakes or lakes too shallow and warm for rainbow trout, poor growth occurs more often than in the lakes more suitable for trout.

Unsatisfactorily small stream trout or salmon from lakes is usually a result of harvest at an early age. This occurs commonly in heavily fished lakes where there is no legal size limit and where most of the previous year's stock of fish were removed. In some Minnesota lakes, the majority of brook trout and rainbow trout are removed at an average weight of less than one-half pound. Another summer's growth would have produced one to two pound fish.

Remedies for over-cropping of the smaller fish include stocking expensive catchable-sized fish and regulations to restrict the harvest of small fish. Regulations could include size limits with the attendant additional mortality on hooked and released fish or restrictions on creel limits, season opening and length, and gear used to reduce the catch until fish have grown to acceptable size.

In some cases, stocking of another strain or species will produce a larger fish to the angler. For example, rainbow trout will do well in water a little too warm for brook trout or splake. Rawstron (1972) has reported that different strains of rainbow trout showed different performances in one lake. Trojnar and Behnke (1974) also pointed out the different performances of different species and the value of preserving and utilizing the different strains of cutthroat trout.

Introduction of forage into managed stream trout lakes can sometimes improve growth of the fish. Crayfish were successfully introduced in Willard Lake, Cass County, Minnesota, where they were not previously found and were heavily utilized by rainbow trout. Growth of these trout was good. Minnows can improve growth of rainbow trout, brook trout and coho salmon during the second and third years but this may not be entirely beneficial since they also compete for many of the same food organisms. Burdick and Cooper (1956) regarded such an introduction as more harmful than beneficial. In Minnesota it was found that sticklebacks were utilized by rainbow trout and are a useful forage species. The introduction of a forage species for better growth of landlocked salmon has been recommended by Warner (1972) and Speirs (1974).

Poor quality trout or salmon

Trout or salmon of poor quality are usually the result of parasites, poor flavor or poor appearance. These problems are not as common as poor fishing success or fish of small size but can be detrimental to a sport fishery or the commercial production of trout.

Problems of visible parasitism encountered during work in Minnesota have included the black spot *(Neascus spp.)* cyst in brook trout and rainbow trout and the yellow grub *(Clinostomum spp.)* cyst in rainbow trout. In all cases the problems were temporary in nature but troublesome during the period of infestation. *Neascus* seemed to infect only the smaller trout up to about 12 inches total length while *Clinostomum* was found in all sizes of rainbow trout. These two parasites have snails as intermediate hosts. Snails can be killed without danger to trout by using copper sulfate at dosages of 45 — 130 pounds per acre in the shallows inhabited by the snails. The dosage required is less in the softer waters and greater in hard waters where precipitation of the copper sulfate is faster.

Poor flavor has not often been encountered in Minnesota lakes. Off-flavor is usually due to poor handling of trout or salmon by the angler. In some lakes, however, a true off-flavor can occur especially during the warm part of the summer. Johnson, Lawler and Sunde (1970) partially ascribed muddy odors and tastes in some rainbow trout from Canadian prairie pothole lakes to the saprophytic soil bacteria *Streptomyces.* Bad flavors and odors are usually intermittent and there are no known remedial procedures. In time the problem usually subsides.

Poor appearance of trout or salmon, when not involving diseased fish or accident, usually means white flesh instead of the more desirable pink to golden brown colored flesh. Apparently, true flavor differs little between the white fleshed and the colored fleshed trout but anglers usually attach great importance to this characteristic.

The abundance of crustaceans in the diet of the trout or salmon usually determines the level of color in the flesh. This color is caused by an excess of carotids deposited in the flesh. If trout flesh does not achieve a satisfactory degree of color, an introduction of crustaceans such as crayfish, *Hyalella* or *Gammarus* may help if they are not already present in the lake.

People problems

It is beyond the scope of this manual to recommend solutions to all problems caused by people. However, the impact of the public on an intensively fished lake managed for stream trout or salmon and some of the more common problems that occur will be discussed.

In most cases, lakes reclaimed and stocked with stream trout or salmon will be fished more intensively than before reclamation. More intensive fishing means greater use of access roads, parking areas and the lake itself. The fisheries manager cannot ignore the consequences of creating an intensive sport fishery.

Public relations problems develop when roads or trails are inadequate or parking is too limited to accommodate vehicles during peak fishing days. Litter develops from intensive angler use and often the aesthetic appeal of the lake is lost. A management plan for a lake that involves trout or salmon and intensive fishing must be accompanied by adequate development of access and parking facilities with regularly scheduled maintenance.

Maintenance of adequate facilities for human use at the site of an intensive fishery is time consuming and may require cooperative agreements for assistance by county or local governments or if possible parks and recreational agencies. These arrangements could include construction and maintenance of access, parking, water supply and sanitary facilities. Campgrounds, if properly supervised and maintained, are an ideal association with managed trout or salmon lakes.

The fisheries manager must also consider the impact of intensive angler use of waters on private shorelines or private property adjacent to heavily used accesses. Adequate development and maintenance of the access areas can minimize trespass and littering on private areas.

Other literature of a general nature concerning problems encountered in managing lakes for stream trout or salmon includes Micklus and Johnson (1965) dealing with public waters and Eipper (1964) for private waters.

Regulations

The prerogative of formulation and imposition of fishing regulations rarely rests with the fisheries manager even though regulations are an integral part of the management process. In most cases the manager can only recommend through the structure of his organization. Changes may or may not require legislative action. Often there is a framework established by legislation which allows the fisheries administrator some latitude in making adjustments.

Fishing regulations should be designed to provide the maximum amount of satisfactory recreation even if the maximum production of fish is not always attained. This goal can be approached by achieving the following: (1) maximum yield of satisfactorily large fish, (2) making available a variety of sizes of fish, and (3) distribution of satisfactory catches among a maximum number of fishermen.

Use of regulations

Regulations are imposed to achieve these goals and include: (1) season time and length restrictions, (2) restrictions on daily hours of fishing, (3) creel limits, (4) gear and bait restrictions and (5) size limits.

Regulations on length of season are imposed to limit the total harvest of fish or to delay harvest until fish have attained satisfactory growth and tend to limit the recreation to traditionally acceptable periods, such as during the normal open water or ice fishing seasons. Restrictions on the daily hours of fishing like seasonal restrictions are intended to limit the harvest of fish. They protect some species during hours of greatest vulnerability but this is often a matter of tradition. Limits on numbers of fish creeled are also designed to restrict the harvest and are intended to distribute available stocks more evenly among fishermen. These are effective only when limit catches are easily obtained. Gear and bait restrictions have the intent of conserving fish by eliminating overly-efficient methods. Minimum size limits are intended to protect the smaller individuals and increase the average size of the fish creeled by increasing the number of large individuals in the population.

Effectiveness of regulations

Regulation of the sport fishing harvest from lakes is consistently effective only when regulations are specifically tailored to each lake. However, regulations tailored to every individual trout or salmon lake are generally impractical, especially when many lakes are involved. Nevertheless, regulations should be as specific as possible to insure a reasonable harvest. Angling restrictions on trout in streams may not always be appropriate for trout in lakes.

The prohibition of the more efficient gear is an important regulation in conserving trout and salmon. Nets, electrofishing gear, poisons and explosives have long been prohibited in sport fishing. The inefficiency of hook and line angling serves to insure that a relatively large number of fishermen can compete for a limited resource. This may be further restricted by prohibiting baits or lures that tend to injure fish which may have to be returned to the water.

Changes in the angling season lengths and opening dates and in creel limits are most often used to distribute harvests equitably. These regulations are usually the easiest to enforce and can be changed on relatively short notice.

Minimum size limits on trout and salmon are used in some states and provinces, but not others. These are controversial regulations and have been the subject of much study and debate. Theoretically, a minimum size length will protect the small, young fish, allow them to grow and thereby increase the average size of fish creeled. Where natural reproduction occurs, a size limit is also imposed to increase survival to maturity. Warner (1972) advocated size limits to help provide a quality fishery for landlocked salmon.

Where sub-legal sized trout or salmon are vulnerable to the fishery, some losses occur to hooked and released fish due to injury, shock from handling or abrupt changes in water temperature while hooked. If a high percentage of fish released after hooking die, this can negate the intention of a size limit. Shetter and Allison (1958) reporting on the mortality of hooked and released sub-legal trout found that hardware lures and flies were about equal in causing mortality. It is generally accepted that natural baits will cause more mortality than will artificial lures because of the tendency of the fish to swallow the bait which results in deeper hooking and greater injury to the fish. Klein (1966) found deaths of up to 11 percent among released trout taken by artificial lures, and Mason and Hunt (1967) reported mortalities of 35 to 95 percent among deeply hooked and released trout.

The use of size limits must be related to other measures such as bait and lure restrictions and to the desirability for a fishery of relatively high numbers of smaller fish in the creel versus a "quality" fishery for lower numbers of larger fish.

The number and size of fish available for stocking, fishing pressure and efficiency of angling gear are subject to change and regulations should be flexible enough to adapt to these changes. The fisheries manager must keep currently informed through his monitoring procedures on the effects regulations are having on the fishery since changes in regulations require time, sometimes years, if statutory changes are required, to put into effect.

Literature Cited

Alexander, G. R. 1976. Diet of vertebrate predators on trout waters in North Central Lower Michigan. Mich. Dep. Nat. Resour. Fish. Res. Rpt. 1839. 18 pp.

__________. 1975. Growth, survival, production and diet of hatchery reared rainbow and brook trout stocked in East Fish Lake under different stock densities, cropping regimes and competition levels. Mich. Dep. Nat. Resour. Fish. Res. Rpt. 1828. 24 pp.

Alexander, G. R. and D. S. Shetter. 1961. Seasonal mortality and growth of hatchery reared brook and rainbow trout in East Fish Lake, Montmorency County, Michigan, 1958-59. Mich. Acad. Sci. Arts and Lett. Vol. 46.

__________. 1969. Trout production and angling success from matched plantings of brook trout and rainbow trout in East Fish Lake, Michigan. J. Wildl. Mgmt. 33 (3): 682-692.

Bailey, N. J. J. 1951. On estimating the size of mobile populations from recapture data. Biometrika 38: 293-306.

Beard, Thomas P. 1974. Impact of repeated antimycin treatments on the zooplankton and benthic organisms in Camp, Larveriau and Nancy Lakes, Bayfield County, Wisconsin. Wisc. Dep. Nat. Resour. Res. Rpt. 78. 10 pp.

Boles, H.D. and D. P. Borgeson. 1966. Experimental brown trout management in Lower Sardine Lake, California. Calif. Fish and Game. 52 (3): 166-172.

Brynildson, O. M. and J. J. Kempinger. 1970. The food and growth of splake. Wisc. Dep. Nat. Resour. Res. Rpt. 59. 41 pp.

__________. 1973. Production, food and harvest of trout in Nebish Lake, Wisconsin. Wisc. Dep. Nat. Resour. Tech. Bull. 65. 20 pp.

Burdick, M. E. and E. L. Cooper. 1956. Growth rate, survival and harvest of fingerling rainbow trout planted in Weber Lake, Wisconsin. J. Wildl. Mgmt. 20 (3): 233-239.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample census. Univ. Calif. Publ. Stat. 1: 131-160.

Cordone, A. J. and S. J. Nicola. 1970. Influence of molybdenum on the trout and trout fishing of Castle Lake. Calif. Fish and Game. 56 (2):96-108.

Donaldson, Lauren R., Donald D. Hansler and Terry N. Buckridge. 1957. Interracial hybridization of cutthroat trout, *Salmo clarkii,* and its use in fisheries management. Trans. Am. Fish. Soc. 86: 350-360.

Eipper, Alfred W. 1964. Growth, mortality rates and standing crops of trout in New York farm ponds. Cornell Univ. Agr. Exp. Station Memoir 388. July, 1964. 67 pp.

Eschmeyer, Paul H. Editor, 1975. Rehabilitation of fish populations with toxicants: A Symposium. North Cent. Div. Am. Fish. Soc. Spec. Publ. 4. 74 pp.

Flick, W. A. and D. A. Webster. 1964. Comparative first year survival and production in wild and domestic strains of brook trout, *Salvelinus fontinalis.* Trans. Am. Fish. Soc. 93 (1): 58-69.

Hansen, D. J. 1971. Evaluation of stocking cutthroat trout, *Salmo clarkii,* in Munsel Lake, Oregon. Trans. Am. Fish. Soc. 100 (1): 55-60.

Hassinger, Richard. 1974. Evaluation of coho salmon *(Oncorhynchus kisutch)* as a sport fish in Minnesota. Minn. Dep. Nat. Resour. Fish. Invest. Rpt. 328. 28 pp.

Hassinger, Richard and D. E. Woods. 1974. Evaluation of fintrol as a fish toxicant in deep softwater lakes. Minn. Dep. Nat. Resour. Fish. Invest. Rpt. 325. 13 pp.

Hatch, R. W. and D. A. Webster. 1961. Trout production in four central Adirondack Mountain lakes. Cornell Agr. Exp. Station Memoir 363. 83 pp.

Havey, K. A. 1973. Relative recoveries of hatchery reared landlocked salmon planted at different ages at Schoodic Lake, Maine. Trans. Am. Fish. Soc. 102 (1): 121-124.

Havey, K. A. and P. S. Andrews. 1973. Population dynamics of hatchery reared salmon, *Salmo salar*, at Schoodic Lake, Maine. Trans. Am. Fish. Soc. 102 (4): 728-738.

Havey, K. A. and Kendall Warner. 1970. The landlocked salmon (*Salmo salar*): Its life history and management in Maine. Joint Publ. Sport. Fish. Inst. and Maine Dep. Inland Fish and Game. 129 pp.

Irving, Robert B. 1955. Ecology of the cutthroat trout in Henrys Lake, Idaho. Trans. Am. Fish. Soc. 84: 275-296.

Johnson, F. H. 1956. Notes on the harvest and fishing mortality of rainbow trout in a rehabilitated Minnesota lake. Minn. Dep. Conserv. Fish. Invest. Rpt. 170. 6 pp.

Johnson, L., F. H. Lawler and L. A. Sunde. 1970. Rainbow trout farming in central Canada. J. Fish. Res. Board Can. Tech. Bull. 165.

Johnson, W. E. and A. D. Hassler. 1954. Rainbow trout production in dystrophic lakes. J. Wildl. Mgmt. 18 (1): 113-134.

Keith, W. E. and S. W. Barkley. 1970. Predation on stocked rainbow trout by chain pickerel and largemouth bass in Lake Quachita, Arkansas. Presented to Annual S. E. Assoc. Game and Fish Comm. Sep. 28-30, 1970.

Klein, W. D. 1966. Mortality of trout caught on artificial lures and released by fishermen. Trans. Am. Fish. Soc. 95 (3): 326-328.

Latta, W. C. 1963. Semi-annual estimates on natural mortality of hatchery brook trout in lakes. Trans. Am. Fish. Soc. 92 (1): 53-59.

Latta, W. C. and R. F. Sharkey. 1966. Feeding behavior of the American merganser in captivity. J. Wildl. Mgmt. 30 (1): 17-23.

Lennon, R. E., J. B. Hunn, R. A. Schnick and R. M. Burress. 1971. Reclamation of ponds, lakes and streams with fish toxicants: A Review. FAO Fish. Tech. Paper 100. Reprinted by U.S. Fish and Wildl. Serv. Bur. Sport Fish. and Wildl. 99 pp.

Lennon, Robert E. and Bernard L. Berger. 1970. A resume on field applications of antimycin-A to control fish. Invest. Fish Control. U.S. Fish and Wildl. Serv. No. 40. 19 pp.

Martin, N. V. and N. S. Baldwin. 1960. Observation on the life history of the hybrid between eastern brook trout and lake trout in Algonquin Park, Ontario. J. Fish. Res. Board Can. 17 (4): 541-551.

Mason, J. W. and R. L. Hunt. 1967. Mortality rates of deeply hooked rainbow trout. Prog. Fish. Cult. 29 (1): 87-91.

McKnight, T. C. and S. L. Serns. 1974. Food habits of coho salmon (*Oncorhynchus kisutch*) in an inland Wisconsin lake. Trans. Am. Fish. Soc. 103 (1): 126-130.

Micklus, R. C. 1960. Sport fishing success and yield from a natural trout lake, Echo Lake, Lake County. Minn. Dep. Conserv. Fish. Invest. Rpt. 219. 4 pp.

____________.1961 (A). A report on Minnesota's first grayling season, Twin Lake, Lake County, September 21-29, 1957. Minn. Fish and Game Invest. Fish Series 3: 63-68.

____________. 1961 (B). Limnological study of Hare and Echo Lakes in Superior National Forest, Lake County, Minnesota. Minn. Dep. Conserv. Fish. Invest. Rpt. 237. 26 pp.

Micklus, R. C. and J. G. Hale. 1959. Fishing harvest and population estimate for brook trout, Duck Lake, Lake County. Minn. Dep. Conserv. Fish. Invest. Rpt. 223. 6 pp.

Micklus, R. C. and M. W. Johnson. 1962. Evaluation of fishing pressure on 30 Minnesota stream trout lakes with associated angling catches, summer, 1961. Minn. Dep. Conserv. Fish. Invest. Rpt. 248. 10 pp.

____________. 1965. An evaluation of the management of reclaimed trout lakes. Minn. Dep. Conserv. Fish. Invest. Rpt. 287. 48 pp.

Miller, R. B. and R. C. Thomas. 1957. Alberta's "Pothole" trout fisheries. Trans. Am. Fish. Soc. 86 (1956): 261-268.

Moyle, John B. 1956. Relationships between the chemistry of Minnesota surface waters and wildlife management. J. Wildl. Mgmt. 20 (3): 303-320.

____________. 1949. Some indices of lake productivity. Trans. Am. Fish. Soc. 76 (1946): 322-334.

Mullan, J. W. and W. A. Tomkins. No Date. Trout pond management in Massachusetts. Comm. of Massachusetts, Div. Fish and Game. 132 pp.

Myers, G. L. and J. J. Peterka. 1976. Survival and growth of rainbow trout (*Salmo gairdneri*) in four prairie lakes, North Dakota. J. Fish. Res. Board Can. 33: 1192-1195.

Petersen, C. G. J. 1896. The yearly immigration of young plaice into the Limfjord from the German Sea. Rep. Danish Biol. Sta. 6 (1895): 1-77. (Original Not Examined by Author.)

Peterson, J. O., J. P. Wall, T. L. Wirth and S. M. Born. 1973. Nutrient inactivation by chemical precipitation at Horseshoe Lake, Wisconsin. Tech. Bull. 62. Wisc. Dep. Nat. Resour.

Rawstron, R. R. 1972. Harvest, survival and cost of two domestic strains of tagged rainbow trout stocked in Lake Berryessa, California. Calif. Fish and Game. 58 (1): 44-49.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. 191. Fish. Res. Board of Can. 382 pp.

Robson, D. S. and H. A. Regier. 1971. Estimation of population number and mortality rates. In: Methods for assessment of fish production in freshwaters, 2nd Ed. W. E. Higher Ed. IBP Handbook No. 3 Blackwell Scientific Publications, Oxford and Edinburgh.

Schneider, James A. 1974. Dispersion of a fintrol concentrate-dye mixture applied to the surface ofa dimictic lake at fall overturn. Prog. Fish. Cult. 36 (4): 192-195.

Shetter, D. S. and L. H. Allison. 1958. Mortality of trout caused by hooking with artificial lures in Michigan waters, 1956-1957. Mich. Dep. Conserv. Inst. Fish Res. Misc. Publ. 12. 15 pp.

Smith, S. A., D. R. Knauer and T. L. Worth. 1975. Aeration as a lake management technique. Tech. Bull. 87. Wisc. Dept. Nat. Resour.

Smith, S. B. 1957. Survival and growth of wild and hatchery rainbow trout (*Salmo gairdneri*) in Corbett Lake, British Columbia. Can. Fish. Cult. 20: 7-12.

Soldwedel, Robert and A. B. Pyle. 1969(A). The survival and growth of three strains of rainbow trout (*Salmo gairdneri*) under conditions of high natural temperatures with and without other fishes. New Jersey Dep. Conserv. and Ec. Dev. Fish. Misc. Rpt. 29. 10 pp.

____________. 1969(B). Aspects of trout management employing reclamation and restocking with fingerling rainbow trout in a marginal trout pond. New Jersey Dep. Conserv. and Ec. Dev. Fish. Misc. Rpt. 30. 20 pp.

Speirs, G. D. 1974. Food habits of landlocked salmon and brook trout in a Maine lake after introduction of landlocked alewives. Trans. Am. Fish. Soc. 103 (2): 396-399.

Stauffer, T. M. and M. J. Hansen. 1969. Mark return, survival and growth of jaw tagged and fin clipped rainbow trout. Trans. Am. Fish. Soc. 98 (2): 225-229.

Sunde, L. A., J. Whitaker and G. H. Lawler. 1970. Rainbow trout production in winterkill lakes. In: Symposium on management of winterkill lake. Edw. Schneberger, Ed. Spec. Publ. North Central Div. Am. Fish. Soc. 57-63.

Trojnar, J. R. and R. J. Behnke. 1974. Management implications of ecological segregation between two introduced populations of cutthroat trout in a small Colorado lake. Trans. Am. Fish. Soc. 103 (3): 423-430.

Warner, Kendall. 1972. Development of a sport fishery for landlocked salmon in a reclaimed pond. Prog. Fish. Cult. 34: 133-140.

Warner, Kendall, R. P. Auclair, S. E. Deroche, K. A. Havey and C. F. Ritze. 1968. Fish predation on newly stocked landlocked salmon. J. Wildl. Mgmt. 32 (4): 712-717.

Waters, T. F. 1960. The development of population estimate procedures in small trout lakes. Trans. Am. Fish. Soc. 89 (3): 287-294.

Wigglesworth, K. A. and R. R. Rawstron. 1974. Exploitation, survival, growth and cost of stocked silver salmon in Lake Berryessa, California. Calif. Fish and Game. 60 (1): 36-43.