WALLEYE STOCKING GUIDELINES FOR MINNESOTA FISHERIES MANAGERS

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Section of Fisheries
500 Lafayette Road
St. Paul, MN 55155

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The following Section of Fisheries employees developed and wrote this special publication:

Dean Beck, Fisheries Supervisor, Glenwood
Tim Brastrup, Project Coordinator, Brainerd
Henry Drewes, Program Coordinator, St. Paul
Dave Friedl, Fisheries Supervisor, International Falls
Bruce Gilbertson, Fisheries Supervisor, Spicer
Paul Glander, Fisheries Supervisor, Detroit Lakes
Steve Hirsch, Program Manager, St. Paul
Pete Jacobson, Research Biologist, Detroit Lakes
Roy Johannes, Program Coordinator, St. Paul
Doug Kingsley, Fisheries Supervisor, Ortonville
Joe Mix, Project Coordinator, Grand Rapids
Kit Nelson, Fisheries Supervisor, Aitkin
Brad Parsons, Research Biologist, Glenwood
Steve Persons, Fisheries Supervisor, Grand Marais
Hugh Valiant, Fisheries Supervisor, Waterville

The following Section of Fisheries employees edited and reviewed this special publication:

Charles Anderson, Fisheries Research Supervisor
Jack Wingate, Fisheries Research Manager

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Introduction

History of Walleye Management in Minnesota

Minnesota has been managing lakes and streams for walleye *Stizostedion vitreum* for more than a century. Walleye stocking has been used for many purposes including new introductions, population maintenance, and population supplementation. In the past, some walleye stocking was done in the absence of adequate information, and without adequate planning and evaluation. Historically, walleye stocking has been a topic of much debate.

Walleye propagation programs began in the United States in the late 1800s. The first recorded sites were located at Lake Oneida, New York, and Lake Erie at Sandusky, Ohio. Walleye propagation programs were started in Minnesota in 1887 (Cobb 1923).

In 1910, the first recorded fish trapping site in Minnesota was set up at Birchdale on the Rainy River. According to Cobb (1923), "there were many large pike and the average production was one quart of eggs per female and some fish produced as much as 2-1/2 quarts." The next major trapping site was established on the Pike River near Tower, MN in 1912. During the next several years many hatcheries and spawn-taking sites were developed, and by 1923 there were seven seasonal hatcheries used for walleye production. These first stations were at Baudette, Bemidji, Detroit Lakes, Jenkins, Tower, Glenwood, and Cut Foot Sioux.

The walleye management philosophy during the first part of the 1900s consisted of stocking walleye in almost all water bodies. Many fisheries managers felt that artificial stocking was required to maintain walleye populations. Little consideration was given to the existing fish community, natural reproduction, fish habitat, planning, or stocking evaluation. Stocking was more or less dictated by production numbers. Fry stocking was the most used management tool during this time period; however, in the 1920s fingerling stocking was tried in several lakes and streams.

Walleye fingerling stocking was expanded in the 1940s (Smith and Moyle 1943) as fish managers and biologists focused much of their efforts on learning and refining pond culture techniques. Drainable ponds and natural ponds were used for fingerling rearing. Many attempts were made to accelerate growth in rearing ponds by forage introduction or feeding, fertilization to stimulate plankton growth, experimentation with various pond sizes, and predator reduction. As modern techniques to harvest, transport, and hold fish became available, fingerling rearing moved from drainable ponds to natural ponds. During the late 1970s, natural rearing pond use was accelerated and fingerling production increased through the 1980s. Also during this period, more attention was given to the review and evaluation of the lake survey program. As a result, more scrutiny was placed on stocking recommendations and the evaluation of stocking programs.

In the late 1970s and early 1980s, there was increased effort to take a more systematic approach to walleye stocking and fish management. As a result, the Section of Fisheries published the Lake Management Planning Guide (Minnesota Department of Natural Resources 1983). The first fisheries lake management plans were prepared in 1984 and by 1995 over 2,700 lakes had management plans. A companion document, Fisheries Management Planning Guide for Streams and Rivers, was published in 1993. Evaluation of walleye stocking increased substantially as an outcome of lake and stream management planning.

During the first 100 years of walleye management, there have been various stocking rates, frequencies, and life stages utilized. Some of the best stocking practices have been learned through trial and evaluation and are still in use today.

Use of Walleye Stocking Guidelines

The lake and stream management planning process employed by the Section of Fisheries is designed to give Area Fisheries Supervisors flexibility in making management decisions. These walleye stocking guidelines are intended to provide recommended stocking norms that reflect our long history of walleye management in Minnesota, utilize the most recent information available, and incorporate a systematic approach to walleye management. Stocking and evaluation recommendations in this document are based largely on data from research and management evaluations. The recommended stocking strategies are limited to groups of lake classes with the understanding that precise predictions of success or failure on a specific lake or class of lakes are uncertain.

The guidelines in this document should be considered the standard for walleye stocking in the lake and stream management planning process. Specific circumstances on a given water body may warrant deviation from the "default" recommendations. In these cases, the management plan should justify the non-conforming stocking strategies and outline an evaluation plan to assess stocking results. Data collected from these evaluations will help refine future walleye stocking guidelines.

Management Goals for Walleye Stocking

The primary objective of stocking is to provide a fishery where natural reproduction and abundance are limited. In general stocking can be divided into three categories: introductory, maintenance, and supplemental. Introductory stocking would include new introductions into waters where a species was not previously found and reintroduction into waters which have been reclaimed or where water quality or habitat have been restored. Maintenance and supplemental stocking strategies are intended to enhance existing walleye populations. In Minnesota, most lakes stocked with walleye fall into the category of enhancement stocking.

Introductory stocking

Past walleye introductions in Minnesota resulted in a near statewide distribution of this species. As a result, there are limited opportunities to stock new waters. Most introductory stocking is intended to establish a self-sustaining population where continued stocking is unnecessary. New introductions will be closely reviewed as to the merit of adding additional walleye fishing opportunities at the risk of further altering existing fish community structures.

Maintenance Stocking

Maintenance stocking is used where natural reproduction is extremely limited or non-existent. This may include lakes or streams where walleye spawning habitat has deteriorated to the point where fish can no longer reproduce or waters where spawning habitat was never sufficient to support a walleye population. The latter category would include many lakes in the 100-750 acre size range which are ecologically best suited for centrarchid management. In situations where walleye stocking is being used to mitigate for failed recruitment related to habitat deterioration, stocking programs should be accompanied by a rigorous public education effort describing how the physical environment has changed and why stocking is necessary. Additional emphasis should be placed on watershed and shoreland management efforts to preserve habitat as well as to restore degraded habitat.

Laarman (1978) evaluated walleye stocking in 125 bodies of water over a 100 year period. He found that 32% of the maintenance stockings were successful compared to only 5% for supplemental stockings. Li et al. (1995), in a review of the Minnesota DNR walleye stocking program, concluded that stocking is most likely to contribute to walleye population abundance in lakes where reproduction is limited and otherwise suitable conditions (e.g. sufficient forage base) are available.

Supplemental Stocking

Supplemental stocking is intended to augment natural reproduction. Historically, many lakes have been stocked in Minnesota with this as the stated goal. In many cases, fisheries managers have employed alternate year stocking regimes in order to evaluate the relative contribution of stocked and naturally reproduced walleye to the fishery.

Li et al. (1995) reviewed walleye stocking records for 1,716 Minnesota lakes. Based on an assessment of natural reproduction, as determined by Area Fisheries Supervisors, he partitioned lakes into two categories: natural walleye lakes where reproduction occurs, and artificial walleye lakes where reproduction rarely or never occurs. Stocking in natural walleye lakes should be considered supplemental while stocking in artificial walleye lakes should be considered maintenance. Li et al. (1995) concluded that walleye stocking in artificial lakes (maintenance) was more likely to increase abundance than stocking in natural lakes (supplemental). He also found that fry stocking in natural lakes tended to decrease the average walleye weight while fingerling stocking tended to decrease the abundance of fish from year classes adjacent to the stocked year class.

Because the scientific literature shows the ineffectiveness of supplemental walleye stocking (Laarman 1978), a conclusion substantiated by research conducted in Minnesota (Parsons et al. 1994; Li et al. 1995), supplemental walleye stocking should be avoided.

Bio-manipulation

Stocking a top predator such as walleye to control population numbers of another species is referred to as bio-manipulation. In Minnesota, there have been few documented case histories from which to develop management goals for bio-manipulation. Some management areas have reported reductions in bullhead *Ameiurus spp.* correlated with increases in walleye; however, there is little quantitative information available to document these observations.

One of the two planned attempts at bio-manipulation was conducted on Lake Christina in west-central Minnesota. Walleye fry and fingerlings along with largemouth bass *Micropterus salmoides* were stocked following reclamation. Lake Christina is a large, shallow, wind-swept basin with extremely high value for waterfowl management. The goal of this stocking program was to control populations of buffalo *Ictiobus spp.*, carp *Cyprinus carpio*, and bullhead which were believed to have contributed to a decline in water quality and aquatic vegetation. Intensive predator stockings in combination with winter aeration were not successful at controlling undesirable fish species following the reclamation of Lake Christina (Dean Beck, MN DNR, personal communication).

Intensive walleye stocking was also a component of the ruffe *Gymnocephalus cernuus* control program in the St. Louis River estuary. There is no evidence to suggest that walleye stocking had any influence on ruffe population levels (John Lindgren, MN DNR, personal communication).

Stocking should be considered experimental if the stated goal is bio-manipulation. Management plans should include detailed evaluation plans to monitor the success or failure of this approach.

Social Considerations

At times, social and political pressure to stock fish in a given lake is enormous. Pressure may come from species advocates, lakeshore property owners, resort interests, private fish hatcheries, or local politicians. Controversies surrounding stocking are often associated with lakes that have a history of walleye stocking which have been discontinued. Stocking was discontinued on many of these waters due to the documented occurrence of natural reproduction or a long history of unsuccessful attempts to establish a fishery through stocking.

At times, the social pressure to stock may overwhelm a fisheries manager's ability to convey the ecological or fiscal merit of not stocking. When this is the case, the manager in the management plan should clearly delineate the reason fish are being stocked. Wherever possible, the public should be included in the evaluation of the stocking. This will improve DNR understanding of stakeholder concerns and public understanding that stocking is a management tool with biological limitations. While managers should strive to avoid compromising on biological principles, they cannot be deaf to their constituency. Greater involvement of the public in lake and stream management will place a larger burden on fisheries managers to effectively convey the science behind our decisions. This burden should also be viewed as an opportunity to focus public awareness, energy, and resources in areas with greater potential for improving fishing such as watershed and shoreland management.

Ecological Considerations

Stocking Effects on Fish Communities and Ecosystems

Inter-specific competition. According to Lyons and Magnuson (1987), major changes in existing fish assemblages often occur when piscivorous fishes are introduced into new locations. Piscivores play an important role in structuring aquatic ecosystems through modification of energy flow and nutrient cycling at lower trophic levels (Carpenter et al. 1985).

Walleye can affect small littoral zone fish, especially when the primary prey species yellow perch *Perca flavescens*, is low in abundance. In Sparkling Lake, Wisconsin, Lyons and Magnuson (1987) reported that predation by juvenile walleye accounted for approximately 100% of the mortality of adult Iowa darters *Etheostoma exile*, johnny darters *Etheostoma nigrum,* and logperch *Percina caprodes,* and 80% of the mortality of bluntnose minnows *Pimephales notatus*, mimic shiners *Notropus volucellus*, and six other uncommon species.

According to Colby et al. (1987), profound effects on community stability as well as the way energy and biomass are transported through the community can result from the addition or removal of a species from the community. It has been suggested that when intense interactions between species determine their abundance, these interactions occur during the very early life stages (Colby et al. 1987). Johnson (1975) found that the removal of white sucker *Catostomas commersoni* from Wilson Lake changed the energy flow through the aquatic community, appearing to benefit both yellow perch and walleye survival and growth rates.

Historical net catch records of many Minnesota bass-panfish lakes, and some lakes with relatively simple species assemblages in northeastern Minnesota, show a decline in yellow perch following walleye introductions (Figure 1). There is no cause and effect evidence linking walleye stocking to the decline in yellow perch populations; however, there is a strong relationship.

Several years of stocking of "winter rescue" northern pike *Esox lucius* had negative effects on the fish community of Horseshoe Lake, Crow Wing County, Minnesota (Anderson and Schupp 1986). The artificially induced increase in the northern pike population of Horseshoe Lake in 1979 was followed by a sharp decline in the yellow perch, largemouth bass and walleye populations, an eventual population explosion of bluegill *Lepomis machrochirus*, and changes in growth rates of bass, bluegill, pumpkinseed *Lepomis gibbosus*, yellow perch, and walleye. They reported that walleye preyed heavily on panfish and minnows following the dramatic decrease of the yellow perch population. The yellow perch population had not recovered as of 1994 (Tim Goeman, MN DNR, personal communication).

There is evidence both in literature and from the Minnesota Department of Natural Resources lakes data base that walleye management is likely to be less successful if either black crappie *Pomoxis nigromaculatus* or northern pike abundance is high (black crappie $\geq$ 1.0/gill net lift; northern pike $\geq$ 3.0/gill net lift), unless there are moderate to high numbers (8-30/gill net lift) of yellow perch present (Dennis Schupp, MN DNR, personal communication; Tables 1-5). Conversely, walleye management may succeed when yellow perch numbers are low ($<$2.0 per gill net lift) and black crappie numbers are high ($\geq$ 1.0/gill net lift) if there are high numbers of bullhead ($\geq$ 10/gill net lift).

Adequacy of forage fish populations. Walleye stocking should be contingent on the adequacy of a suitable prey base. Yellow perch abundance is the key forage indicator which should influence stocking decisions in most lakes. Yellow perch catch per unit effort (CPUE) should be at least 8/gill net lift or the equivalent in alternate sampling gear. Lakes with high northern pike numbers ($\geq$ 6.0/gill net lift) and low yellow perch numbers ($<$ 8.0/gill net lift) are particularly poor candidates for walleye stocking. Not only are yellow perch young-of-the-year not available as forage for walleye, but the buffering effect of yellow perch on northern pike predation on walleye fingerlings is lost.

Walleye growth can be affected by low density of prey species. Knight et al. (1984) found that walleye grew slower and were less selective for prey size in western Lake Erie when walleye density was high and prey density was low.

In some cases an alternate to yellow perch forage may be available. There are several alternate prey species and various aquatic communities that are suitable in different ecoregions of the state. In southern Minnesota lakes and some winterkill situations, walleye may feed heavily on black bullhead *Ameiurus melas*. Davis (1975) found that walleye in Belle Lake, in southern Minnesota, fed extensively on yellow perch; however, their diet included substantial numbers of small bullhead (less than 4.0 inches total length) and crappie *Pomoxis spp*. (less than 5.0 inches total length).

There is evidence that walleye can feed at a lower trophic level, assuming the role of competitor with yellow perch. Colby et al. (1987) found that walleye, in addition to preying on yellow perch, may also compete with yellow perch for benthic food resources. In some northeastern Minnesota lakes, walleye populations seem to be functioning at a lower trophic level, occupying a niche or competing in a niche normally filled by yellow perch (Johnson 1975). These rocky infertile lakes often have excellent walleye reproduction in spite of their small size and are characterized by high density (greater than 20/gill net lift), slow growing walleye populations (Steve Persons, MN DNR personal communication). The fish community is often very simple and consists of relatively few species. Fish forage normally utilized by walleye is often lacking or scarce, and walleye diet is often composed of a high percentage of invertebrates. Stocking these lakes is often limited to introductions because maintenance stocking is usually not necessary.

The cisco *Coregonus artedii* is an important prey species for northern pike and walleye in coolwater fish communities (Ryder and Kerr 1978; Colby et al. 1979). Cisco have the potential to provide excellent forage for a trophy walleye fishery. Lakes which contain "dwarf" cisco populations are particularly good choices for trophy management. Colby et al. (1987) reported that in Lac des Mille Lac small and intermediate sized walleye preyed most heavily on yellow perch. However, the diet shifted to a greater proportion of coregonids as the walleye grew larger.

Smelt *Osmerus mordax* populations have been expanding across much of northeastern Minnesota and provide excellent forage. Lakes which contain smelt often have fast walleye growth rates. This is a mixed blessing, as with any exotic species introduction, there is the potential for ecological disruption and fish community instability. Goettl and Johnson (1994) found that smelt introductions greatly reduced the density of crustacean zooplankton and eliminated natural walleye recruitment within five years of introduction in Horsetooth Reservoir, Colorado. Walleye had recruited naturally for 15 years previous to smelt introduction. There is also mounting evidence that smelt introductions have impacted native coregonid populations in Minnesota (Joe Geis, MN DNR personal communication). Smelt should never be purposely introduced to lakes as an alternate forage species.

Other ecological effects. Fisheries managers should keep in mind that there are other possible ecological effects associated with stocking walleye. The Section of Fisheries requires that all walleye fry stocking proposals for new rearing ponds be reviewed by the Section of Wildlife. This policy became necessary in light of concerns over the potential effects of walleye management on wetland ecology.

Genetic Integrity

Protecting the genetic integrity of native fish stocks is an important factor which must be taken into account when planning and implementing all stocking programs. In selecting fish for stocking, every effort should be made to use strains of fish most suitable for the intended water body and to maintain the genetic integrity of the existing populations. In general this means using fish from local or regional sources within the same drainage (Fisheries Management Operational Guidelines, MN DNR 1994).

In northern Minnesota, there should be no mixing of walleye stocks between major drainages (Hudson Bay, Lake Superior and the northern part of the Mississippi River drainage). The Potlatch dam in Brainerd çan be used as the dividing line for the northern and southern portions of the Mississippi River drainage. Large natural walleye lakes where little stocking has occurred in the past should not be stocked to protect the genetic integrity of the existing population.

Statewide egg take, hatching, rearing, and stocking operations should be coordinated to ensure that walleye of proper genetic origin are used. For example, St. Louis River strain fish should be stocked in Lake Superior drainage lakes in Cook County, Pike River strain walleye should be stocked in Itasca County Lakes which drain to Hudson Bay, and Hudson Bay strain fish should not be stocked in lakes which are in the northern Mississippi River drainage. Area Supervisors should use their judgement in selecting strains for stocking in lakes with no outlets and with no evidence of natural reproduction. Generally, strains native to the watershed should be used in such isolated lakes.

Genetic integrity is also an important consideration in central and southern Minnesota watersheds with natural walleye populations. However, there are not enough Mississippi River strain walleye produced for all of the central, southern, and northern Minnesota lakes in the Mississippi drainage that are scheduled for stocking. As a result, southern and central Minnesota lakes with direct connections to the Mississippi River or other natural walleye waters should be given priority for stocking Mississippi River drainage strain walleye.

Genetic integrity must be considered in review and approval of private walleye stocking carried out by lake associations or other groups. To ensure that northern Minnesota walleye strains are widely available from private sources, only walleye eggs, fry or broodstock from northern Minnesota should be sold to private hatcheries or aquatic farms.

Social Considerations

Private Stocking

Most private stocking requests are routine and easily evaluated. However, some requests present tough decisions for fisheries managers because a denial may be controversial. Therefore, it is extremely important that private stocking requests are handled consistently on a regional and statewide basis.

Biological criteria used to evaluate private stocking requests are straightforward and should be consistent with the criteria DNR fisheries managers use to evaluate their own proposals. On the other hand, the social and economic criteria used to evaluate DNR stocking proposals often do not apply when looking at private requests. Fisheries managers have an obligation to give the public good information on the probability of success for a private stocking venture. If private stocking appears likely to fail, every effort should be made to inform the proposers and attempt to point them in a more productive direction. However, it is usually inappropriate to deny private stocking requests solely because success is unlikely or the economic costs outweigh the benefits. Similarly, private stocking requests should not be denied because the water body in question is a low management priority.

The single most important question to ask when reviewing a private stocking request is:

"Will the stocking conflict with the goals and objectives of the fisheries management plan?" The most important parameters to consider are the potential impacts to the fish community, the genetic integrity of existing fish stocks, and the status of ongoing evaluations.

Private stocking should not be approved if it would be incompatible with management of the primary or secondary species, or if there is potential for undesirable impacts to the fish community. Forage availability and inter-specific competition are valid concerns when reviewing private stocking requests.

Genetic integrity of native fish populations is an important concern when reviewing private stocking requests. For example, if a lake has not been stocked previously and has good natural reproduction of the species in question, private stocking requests should be denied. Where private stocking will be permitted, fisheries managers must verify that an appropriate strain will be used. Generally, only fish whose original source is from Minnesota or contiguous states should be allowed. In addition, walleye from south of Highway 210 should not be permitted for private stocking north of Highway 210. These criteria have to be applied to the lake requested for private stocking as well as the connected waters. Strain concerns are not as great for completely isolated waters where there is no chance of escapement and no pre-existing population, and for watersheds with artificial populations that are maintained by stocking.

Private stocking should not jeopardize ongoing evaluations by increasing stocking rates more than 5-10% or stocking in years where "blanks" are planned. Private stocking requests should be steered towards stocking within the confines of the evaluation plan.

Private stocking has its best applications on smaller lakes which are a low management priority or lakes with no public access. However, one difficult situation that occasionally arises is a request to stock a lake for which there is little or no information. The Area Fisheries Supervisors should rightfully be reluctant to stock a lake until more is known about it, but budget limitations and more important priorities may preclude collecting the desired information. If there is strong interest in such a lake, the Area Supervisor should try to get information before deciding on the stocking request. If this is not possible, an Area Supervisor, in consultation with the Regional Manager, may consider approval of the stocking in the absence of information.

Recreation

Fisheries managers need to consider the kinds of fishing that anglers want. It is reasonable to assume that almost all anglers want to catch fish in a daily outing, but beyond that there is a diversity of desires and expectations. Some anglers fish for food, some for a trophy, some for number or kinds of fish, and some just for fun and relaxation. The relative proportion of these desires needs to be considered when determining the recreation "needs" of anglers. There is no one lake which will satisfy the numbers, size structure, catch rates, etc. desired by all anglers. A satisfactory walleye population is related to management goals matched with angler perceptions. Providing walleye populations which will satisfy the varied angler desires requires different management strategies for different lakes.

Does added recreation justify stocking? Low angler success or harvest will normally result in discontinuation of walleye stocking. In some cases, walleye stocking at a reduced rate or frequency may be justified even though walleye harvest is limited. Examples where this type of management may be justified include:

- Naturally occurring walleye populations are not present in the area
- Urban areas where presence of walleye provides increased recreational use and adds another dimension to the angling experience
- High numbers of resorts, parks, and campgrounds are present
- Other large predators are not available in the managed water

- Stocking results in a low walleye population, but good growth and large average size produces quality or trophy sized fish
- Where fishing opportunity can be provided for children, physically challenged people, and the elderly, or other groups which may be limited in their ability to participate in more traditional walleye angling

In most of these situations, the management goal is to provide anglers with the opportunity to catch walleye in recognition of the fact that these waters will not typically produce a level of angling experienced on "traditional" walleye waters.

Distribution of fishing pressure. Distribution of fishing pressure has been used as a criteria for walleye management. However, documentation of success is lacking for this approach and it should not be used as a reason by itself to stock walleye in unsuitable waters.

Economics

The 1991 National Survey of Fishing, Hunting, and Wildlife Associated Recreation indicates a 141% nationwide increase in participation in fishing from 1955-1990 (Aiken 1995). Total expenditures for sport fishing in Minnesota in 1991 approached $1 billion. Angler surveys indicate the single greatest portion of fishing participation in Minnesota waters is directed at walleye (Aitkin 1995; Leitch and Baltezore 1987).

Departmental funding to manage and sustain sport fishing in Minnesota lakes and streams has decreased in recent years. The challenge of "doing more with less" issued to fisheries managers in the decade of the 1980s seems even more appropriate for the 1990s. Currently, 15% of the Section's budget dollars are allocated to fish production and stocking programs. With decreased funding, there is a greater need than ever to evaluate walleye production costs in relationship to economic benefits resulting from this management program.

The benefit/cost ratio of the walleye program should be balanced with angler demand, while maintaining both biological and economic benefits. The cost of artificially producing walleye for the creel will generally be higher than manipulating natural populations through habitat protection and regulations; however, a favorable benefit/cost ratio may still be achieved. Knowledge of that point is part of the art of fish management.

Benefits derived from a comprehensive economic evaluation of stocking can be numerous. The most obvious benefits are trust and fiscal responsibility. Economic evaluations of the impact of walleye stocking may be valuable in leveraging support and funding for stocking programs or other important management alternatives. The Department's ecosystem-based management approach stresses consideration of the user, community, and economic sustainability, as well as the resource in formulating and implementing management programs. Perhaps the greatest potential benefit of economic assessment of walleye stocking is that fisheries resource values and management programs may gain equal footing with other economic considerations that may be incompatible with or detrimental to fish management programs.

At present, fisheries program reviews have included economic evaluations designed to measure direct angler expenditures in relationship to Department expenditures, and to assess internal program efficiency such as the cost to produce and distribute walleye versus the contribution of stocked walleye to the angler's creel. As an example of the latter, Parsons et al. (1994) estimated the Section of Fisheries costs to put a single stocked fingerling into the creel of anglers fishing Ida, Mary, and Miltona lakes. Total expenditures ranged from $4.02 per stocked walleye harvested in Lake Miltona to $16.35 per stocked walleye harvested from Lake Mary. Based on these and additional research findings that indicated natural reproduction contributed more to the creel than fingerling stocking, stockings in Mary and Miltona lakes have been discontinued or greatly modified. Annual Section of Fisheries program savings from discontinuing fingerling stockings in Lake Miltona are in excess of $15,000 during those years in which fry are not stocked. Such economic evaluations must continue so that the Department can become increasingly efficient and effective in delivering services at minimal cost, as well as more credible in justifying management actions.

Stocking decisions should not be based on internal costs alone. Successful integration of ecosystem management will involve consideration of more complex social and economic interactions of fish management programs before implementation of a management decision. Questions that will need to be asked when assessing values and impacts of a walleye stocking program may include:

- What is the economic activity generated by the use of the resource itself
- What is the economic activity stimulated by stocking
- How much value do people place on the resource

According to Rockland (1986), categorization of economic impacts and meaningful evaluation of walleye stocking should include:

- Direct impacts or those initial purchases made by the recreational angler to participate in fishing
- Indirect impacts or purchases on inputs by the directly impacted businesses to produce the goods and services demanded by anglers. These indirect purchases have further indirect impacts as the suppliers to the direct businesses make purchases to produce their products
- Induced impacts or the purchase of goods and services by households resulting from wages paid to households by the directly and indirectly impacted businesses. Induced impacts have additional indirect and induced impacts as well.

Such comprehensive evaluations can be extremely complex and are beyond the ability of most fisheries managers and biologists. Economic models are available to assist in this effort. Ideally, the Department will provide support, training, and additional funding for such economic evaluations if the concept of ecosystem management is to be fully employed and addressed.

Stocking Strategies

Use of the Lake Classification System

Lake Class is an important variable to consider when deciding whether to stock walleye, or what stocking strategy to use. Li et al. (1995) examined changes in average walleye CPUE in several lake classes two, three, four, and five years after stocking. Stocking apparently resulted in significant increases in walleye CPUE in some lake classes and significant declines in others, although the presence or absence of natural reproduction may have explained much of the difference between classes. A review of lake assessment data by Schupp in 1994 (unpublished) shows that in some lake classes walleye gill net CPUE tended to be higher in lakes stocked with fry or fingerlings than it was in unstocked lakes, while in other classes walleye CPUE was not higher in stocked lakes (Figures 2-4). Other variables, such as the level of natural walleye reproduction, limnological factors, forage availability, and abundance of predators and competitors should also be considered when planning a walleye stocking program.

In order to obtain additional information regarding stocking successes, failures, and potential causative factors we conducted a survey of Minnesota fisheries managers. A questionnaire was sent to all Minnesota DNR Area Fisheries Offices in October 1994 to collect data that might allow the effects of other variables on stocking to be determined. Fisheries managers were asked to evaluate the success of stocking programs on lakes in their area for which walleye was the primary or secondary management species. Data were collected on lake area, littoral area, stocking size (fry or fingerling), stocking frequency, stocking rate, evaluation method, and success or failure of the stocking program for over 1,300 stocking case-histories. Stocking success or failure was clearly defined for 753 lakes in 42 Lake Classes. Questionnaire data were combined with Lake Class and assessment data to allow identification of any potential influences of Lake Class, Lake Class groupings, and fish communities on stocking success. No data on the extent of walleye natural reproduction were included in the analysis. It should be noted that responses to the stocking questionnaire were probably biased toward cases of successful stocking. Questionnaire data cannot be used to show the actual success rate for stocking programs; however, they can be used as in index to stocking success when comparing Lake Classes or Lake Class groups.

The number of Lake Classes and the minor differences between some classes make it difficult to establish walleye stocking recommendations based on individual classes. Lake Class recommendations should be based on a history of evaluations within the class, but in many classes the number of lakes with good evaluations was very small. When Area Fisheries Supervisors in Minnesota were asked to evaluate the success of walleye stocking programs in their areas, there were 12 Lake Classes in which only five or less clear examples of success or failure could be identified (Table 6). Cluster analysis was used to group Lake Classes to allow stocking recommendations to be made on an ecological basis, while reducing the complexity of the task. Eight Lake Class groups were identified: three groups in northeastern Minnesota (Lake Classes 1-19); and five elsewhere in the state (Table 7).

For all lakes statewide, Chi-square and logistic regression analysis of questionnaire data indicated that stocking success appeared to be related to Lake Class group, percent littoral area, size of walleye stocked, stocking frequency, crappie (black and white combined) abundance, northern pike abundance, and yellow perch abundance (Table 8). Increased stocking success appeared to be related to higher Lake Class group number, higher percent littoral area, fingerling instead of fry stocking, and higher abundance of crappie and yellow perch. Lower stocking success appeared to be related to more frequent stocking and higher northern pike and cisco abundance.

Within Lake Class groups, small sample sizes made identification of significant relationships more difficult. Stocking success appeared to be related to surface acreage in Lake Class groups 1 and 2, to size of walleye stocked and stocking frequency in Lake Class group 4, to yellow perch abundance in Lake Class group 5, and to northern pike abundance in Lake Class group 7 (Table 8). Increased surface acreage appeared to be associated with decreased stocking success in Lake Class groups 1 and 2.

Stocking Guidelines

Management Plan. An approved lake or stream management plan is required for all waters stocked with walleye. The management plan must include a stocking chronology and information pertaining to rates, sizes, and weight (or numbers) of fish to be stocked. For example: a lake will be stocked triennially with walleye fingerlings beginning in 1996 at a rate of 1.0 pound/littoral acre (500 lbs). The management plan should also include a discussion of past stocking history and the results of past stocking evaluations. Plans for walleye introductions should include a thorough discussion of available forage and potential effects on the fish community.

In some situations, annual stocking proposals may not match the current management plan. This is often the case in situations where annual stocking proposals may precede the submission of revised management plans to the central office. The Area Supervisor should accompany the stocking proposal with an explanation of why the proposed stocking is not consistent with the current management plan when this occurs.

Deviations from the walleye stocking guidelines should be accompanied by a thorough explanation in the lake or stream management plan. Evaluations of alternative stocking scenarios are encouraged; however, managers should avoid "reinventing the wheel." There is an ever-increasing wealth of information to help fisheries managers avoid stocking regimes which are likely to fail. All new stocking recommendations should include a detailed evaluation plan. This would apply to newly stocked waters as well as those waters where the stocking frequency, size or rate is changed.

Stocking frequency. Annual walleye stocking is usually unnecessary. Walleye should be stocked biennially if mortality and growth rates are moderate to high, or triennially if mortality and growth rates are low. Extremely high exploitation may justify annual stocking if growth rates and survival are high enough to supply the necessary recruitment. Preliminary analysis of the stocking questionnaire data indicated that higher stocking frequencies were generally not associated with an increased probability of stocking success. In fact, there appeared to be an inverse relationship between stocking frequency and success (Table 8). Li et al.'s (1995) analysis of stocking effectiveness indicated that groups of lakes with multiple stockings over a 3-5 year period did not have significantly higher mean walleye CPUEs than groups of lakes with a single stocking during a similar period. Increased stocking frequency was associated with a decrease in the mean weight of walleye collected in assessments.

Fry versus fingerlings. Managers should use their experiences on the lake in question when making a choice between fry and fingerlings for most Lake Class groups. If no prior stocking evaluations have been done on a lake, fry stocking should be attempted first, due to the lower cost. Fingerling stocking may be an option if fry stocking is not successful. Fry and fingerling stocking strategies have had mixed success in all Lake Class groups (Table 9). The highest fry stocking success rate was reported in Lake Class group 8, and the lowest success rate in Lake Class group 3. Fingerling stocking success tended to be higher than fry stocking success for lakes in Lake Class groups 1, 2, 3, 4, and 7.

Stocking fry and fingerlings within the same season is strongly discouraged. Evaluation is impossible when different life stages have been stocked within the same year, unless there has been an attempt to evaluate the fry stocking success before fingerlings are stocked. Fall electrofishing for young-of-the-year walleye in lakes with no natural reproduction has proven to be a useful indicator of fry stocking success. Not all fry stockings should be expected to contribute strong year classes and it should not be deemed necessary to fill in weak year classes with fingerlings.

A management plan which calls for alternate stocking of fry and fingerlings such as fry-fingerling- blank, also complicates evaluation. Timing of future gill netting assessments is more difficult and may be biased toward one life stage stocking over another due to the variation in gill net selectivity for different fish ages. Errors in aging, especially for older fish, can confuse the evaluation more than if either fry or fingerlings alone are used. In general, a single life stage stocking strategy should be used.

Stocking rate. Li et al. (1995) found that walleye abundance was not linearly related to stocking density and recommended that high density stocking not be done. Preliminary Chi-square analysis of the stocking success questionnaire data showed little indication of a significant relationship between stocking rate and stocking success. Success rates for high-density fry or fingerling stocking were not higher than success rates for "standard" rate stocking (0.5-1.0 lb fingerlings/acre, 1,000 fry/littoral acre; Table 10). High-density walleye fingerling stocking (2.9-6.8 lb/littoral area) in two west-central Minnesota lakes yielded mixed results (Parsons et al. 1994). Stocked walleye contributed to the walleye population and harvest in both lakes, but in one lake (Lake Mary) there was no improvement in gill net CPUE compared to periods of no stocking, probably due to replacement of natural reproduction by stocked fish. Angling success and walleye yields were lower three to five years after the stocking than they had been before the high density stocking. Stocking established one strong year class in the other lake (Lake Ida), which improved walleye angling success and yield for two years. However, subsequent stockings did not prevent a decline in success and yield to pre-stocking levels.

Managers should avoid stocking walleye fry at rates higher than 1,000 fry/littoral acre, and avoid stocking fingerlings at rates higher than 1.0 lb/littoral acre except in unusual circumstances. Lower rates may be effective and should be considered (and evaluated) whenever there is an opportunity to do so. In northeastern Minnesota, ongoing evaluations of fry stocking at 1,000/surface acre should be completed. Stocking rates should be changed to 1,000 fry/littoral acre (or less) and evaluated, unless the lower rate has been found unsuccessful or unless there is a valid reason to maintain the higher rate. In lakes under 250 acres, walleye fingerlings may be stocked at a rate of 15 fingerlings/littoral acre to a maximum rate of 3.0 lb/littoral acre, if the fingerlings are larger than 10.0/lb and there is a concern that a rate of 1.0 lb/littoral acre would result in too few fish being stocked.

Elevated stocking levels. The use of elevated stocking levels to improve walleye populations has generally been ineffective in Minnesota (Li et al. 1995). Parsons et al. (1994) found that four years of high density fingerling stocking did not increase the walleye population in Lake Mary beyond levels found with normal density fingerling stocking or no stocking. Only one of four high density fingerling stockings produced a strong year class in Lake Ida (Parsons et al. 1994). Hansen and Lucchesi (1991) found that increased fry stocking density did not result in greater abundance of age-0 walleye in South Dakota lakes. Conversely, Schweigert et al. (1977) concluded that success of fry stocking was related to stocking density. The low density fry stocking they used ranged from less than 250 fry/surface acre to 950 fry/surface acre.

Despite these results, there may be narrowly defined situations where the use of elevated stocking densities is appropriate. A possible option is increased density stocking with reduced frequency of stocking. An example would be changing from annual fingerling stockings of 1 lb/littoral acre to 3 lb/littoral acre in one of three years. Elevated stocking rates should only be tried after failure to achieve management goals using "standard" stocking densities. Experimental high density stocking should be accompanied by a thorough evaluation.

Reduced stocking levels. Lower stocking densities may be appropriate in some situations. Some lakes, particularly in southern Minnesota, experience infrequent but extensive winterkills. With few surviving predators and little competition, survival of stocked walleye fry is usually excellent. Initial stocking rates may be reduced to 250-500/littoral acre in these cases.

A lake's productivity may be inadequate to sustain numbers of walleye associated with a "normal" stocking regime in some cases. This is usually identified by declines in abundance and increases in growth and condition of forage fishes, or declines in growth and condition of walleye. The best management strategy is probably to reduce walleye stocking rates or frequency in these situations. Survival and success of walleye fry stockings is usually quite good in lakes with high primary productivity which can result in extremely large year classes. Even in these highly productive waters, the resulting walleye abundance may have negative effects on the forage base and reduced stocking rates may be appropriate. These effects have been observed in some Lake Class 41 and other Lake Class group 8 lakes.

Finally, some waters may be managed primarily for other species and secondarily for walleye, or to provide only an incidental or trophy fishery for walleye. The management goals in these situations would call for low abundance, faster growth, and large size and good condition of individual fish. These goals could best be achieved by reducing stocking rates or frequency.

Annual and consecutive year stocking. Although several studies have indicated that annual or consecutive years of stocking (primarily fingerlings) may result in lower survival or weaker year classes, in some situations it may be appropriate to increase the frequency of fry stockings. Lakes with little or no natural reproduction, good survival of stocked fish, and high mortality (particularly angling mortality) of recruited walleye are strong candidates for annual or consecutive year stocking. These conditions are often characteristic of Lake Class group 8. Waters chosen for annual or consecutive year stocking should also have a good forage base and walleye should exhibit fast growth rates and good condition. Under such circumstances, annual or consecutive year stockings might help reduce extreme fluctuations in abundance which could be associated with stocked and non-stocked year classes or climatic influences, by increasing the odds of establishing a strong year class. Annual or consecutive year stocking should be done cautiously. Evaluation of the initial survival or contribution of stocked fish, and their effects on the fish community should be carefully evaluated.

A strong year class of walleye is needed if the management goal for a lake is to improve walleye fishing (Parsons et al. 1994). Annual fingerling stocking generally does not create strong year classes (Parsons et al. 1994) and may suppress the strength of adjacent year classes (Li et al. 1995). Johnson et al. (1994) found declining survival of annual fingerling stockings and suggested that walleye surviving the initial stocking may cannibalize subsequently stocked fingerlings.

Use of carry-over walleye. It is virtually impossible to harvest all the walleye fingerlings from a natural pond and these ponds do not always winterkill. These conditions combine to create “carry-over” walleye, which have survived one or more winters in the rearing pond. These fish are generally harvested and stocked at age 1+, although they may be older.

Carry-over walleye can seriously compromise stocking evaluations by making it appear that natural reproduction occurred, or that a previous stocking was more successful than it actually was if they are stocked following a blank year or a fry stocking. Therefore, carry-over walleye should not be stocked in waters where a stocking evaluation is underway.

However, when no stocking evaluation is underway, carry-over walleye can be a beneficial management tool for stocking in waters with high predator densities and low forage abundance. Predation by adult walleye or other predators is one possible reason for the failure of a walleye stocking. Cannibalism by older walleye is most intense on the smaller individuals the following year classes (Chevalier 1973). Northern pike will also eat small walleye (Parsons et al. 1994). Johnson et al. (1994) found that 33% of the mortality of walleye fingerlings from October 1988 to May 1989 could be accounted for by walleye and northern pike predation. Carry-over walleye are generally larger than fingerlings and may be less susceptible to predation. This is particularly important when yellow perch, which can act as a buffer to predation on walleye (Forney 1974), are low in abundance. Stocking large carry-over walleye could also bypass a growth bottleneck in waters with low densities of small prey fish such as young of the year yellow perch. The lack of suitably sized prey fish can affect the growth of predatory fish (Colby et al. 1987).

Due to their large size, it may be better to use stocking quotas based on numbers when carry-over walleye are used, as described for large fingerlings in the stocking rate section of this document.

Use of surplus fish. Walleye fry or fingerlings may occasionally be available in quantities over and above those needed to complete approved stocking quotas. Several methods are available to use such "surplus" walleye in a way which is biologically and socially acceptable. Surplus walleye should be utilized in ways which do not compromise the genetic integrity of natural walleye populations, ongoing evaluation and management objectives, or other aspects of the fisheries management plan for an individual water body.

Accurate projection of egg take needs and hatching rates coupled with statewide coordination of egg take operations limits the production of surplus walleye fry. Minnesota Statute 97C.203 indicates how collected walleye eggs can be distributed. This includes meeting the State's needs, transfer to other government agencies or private fish hatcheries in exchange for other fish, sale to the private sector, and transfer to other government agencies. Surplus fry should be returned to the parent lake where the eggs were collected once lake and rearing pond quotas have been met.

The nature of extensive walleye culture in natural ponds is such that fingerling surpluses occur. Several means exist to use surplus walleye fingerlings:

- Stocking quotas can be increased up to 10% for lakes previously approved for fingerling stocking. Stocking quotas are occasionally not met, so it is acceptable to exceed the target occasionally by a small amount. This should be considered only where it would not compromise an ongoing evaluation.
- Surplus fingerlings may be used to "hedge" against next years planned stockings for lakes that are on an alternate or every third year stocking cycle. Such shifting among years helps to "balance out" walleye production needs given the variability in annual fingerling production. Lakes where this type of flexibility applies should be identified in lake management plans.
- Surplus fingerlings may be used following a recent assessment or survey which shows a need for walleye stocking in a "new" lake not currently being stocked. As with all stocking proposals, approval by the Regional Fisheries Manager should be obtained first and a modified lake management plan should be written as soon as possible.
- Surplus fingerlings may be used on lakes where fall electrofishing showed poor survival of fry stocked earlier that year. This should only be done if it does not compromise ongoing evaluations and there are at least two consecutive weak year classes.
- Certain lakes may be designated as "surplus lakes" where stocking surplus fingerlings would not have undesirable effects on the existing fish community or compromise evaluation and management objectives. Fisheries lake management plans should identify such "surplus lakes".

Rearing pond harvest can be managed to reduce the production of surplus fingerlings. Employees involved in the pond harvest operation and the public should be informed as to the economics of extensive walleye fingerling production. The major cost of production comes from harvesting the rearing ponds. The initial investment of fry stocking is relatively small. Therefore, it is acceptable to let some ponds go un-harvested if fingerling quotas have been met. However, social factors must be considered and "co-op ponds" or ponds where a private group has financed the lease of access rights should be harvested early in the fall.

Walleye rearing pond harvest operations should cease when catch rates markedly decline. This is especially important in years where fingerling survival is good and there is potential for a surplus. Rearing ponds containing carry-over walleye should generally not be harvested when a fingerling surplus may occur, unless there is a special need for large fish.

In some circumstances, it may be possible to promote angling in rearing ponds where surplus walleye were not removed. Care must be taken not to create adverse public relations through such use of surplus fingerlings. All rearing ponds promoted for fishing must have public access.

Transferring fish to other states or agencies after meeting private sector needs is another way to utilize surplus walleye. Priority should be given to states or agencies which have provided fish to us in the past. Fingerlings from co-op or sponsored ponds should not be transferred outside the state.

Stocking in rivers and flowage lakes. Stocking walleye fry or fingerlings in rivers is generally not necessary in Minnesota. Habitat protection and enhancement are preferable management techniques for rivers which currently contain walleye. Rivers which historically never had walleye should be managed for other fish species.

Walleye stocking programs in reservoirs and "flowage" lakes should consider possible upstream and downstream movement in deciding on what life stage to stock and stocking site. Use of fall fingerlings could be considered if high spring flows could carry fry downstream. Stocking cycles should be synchronized in connected water bodies to eliminate possible difficulties in evaluation of natural reproduction and stocking success.

Recommendations for Walleye Stocking

Guide to making stocking decisions. The stocking decision key (Appendix B) provides general guidelines to use when making walleye stocking decisions for Minnesota lakes. The key assumes that stocking will only be done if all access (as defined in *Fisheries Management Operational Guidelines* 1995), economic, genetic, and fish community concerns have been adequately addressed. At each evaluation cycle, these factors should be reexamined. If any have changed, the stocking program should be reconsidered. The decision key incorporates the following general principals:

- No stocking should be done if regular natural reproduction occurs in the lake (Li et al. 1995).
- Walleye fry should be stocked triennially or two consecutive years out of four at a rate of 500-1,000/littoral acre if the reproductive status of the walleye population is unknown. Walleye fingerlings may be stocked, at the same frequency, at a rate of 0.5-1.0 lb/littoral acre if walleye fry stocking in the lake has been ineffective. Consecutive stocking blanks should be left if there is any doubt about the reproductive status of walleye in a lake so that natural reproduction can be assessed in years that have not been affected by suppression due to stocked year classes.
- Walleye fry may be stocked biennially at a rate of 500-1,000/littoral acre if walleye reproduction has been shown to be lacking or sporadic and weak (no strong year classes over a typical four-year period).
- Walleye fingerlings may be stocked biennially at a rate of 0.5 to 1.0 lb/acre if reproduction has been shown to be lacking or weak and sporadic and walleye fry stocking has been unsuccessful.
- Stocking rate or frequency should be reduced if declines in growth or condition of walleye are noted, or declines in forage abundance (and increased forage growth rates) occur. This may occur in lakes with low productivity or in lakes with high survival of stocked fish.
- Stocking frequency may be increased if walleye growth is fast, initial survival of stocked fish is high, and angling mortality is high (walleye recruit to fishery at age 2, most harvested by age 3 or 4).

Use of the stocking decision key. Use the key as you would any taxonomic key, picking the most correct statement as you go. When stocking strategies are listed, use the strategy list at the end of the key to determine what size, rate, and frequency have been recommended. You will often be given several choices - use your knowledge to select the strategy best suited to the lake in question. Unsuccessful stocking programs may lead to a choice of a different stocking strategy, or they may lead to a recommendation that no further stocking effort be made ("STOP"). Programs where success (or failure) cannot be clearly established may require additional evaluation, or a change in strategy which would make evaluation easier.

Evaluation

Importance of Evaluation

One of the most important steps in any management planning process is the evaluation of what was done. Whether fisheries managers are evaluating the success of a fish stocking program or an experimental regulation, the primary evaluation tool is the lake (or stream) survey. Standardized survey data collected over a period of time yields a wealth of information relative to trends in fish population abundance and size distribution. Age and growth data collected from important game fish species can also be used to determine the extent of natural reproduction or the relative contribution of stocked fish. Fisheries managers may also conduct specialized assessments such as fall electrofishing, trawling, tagging studies, or creel surveys. Ideally, an evaluation strategy should be chosen concurrently with the selection of a stocking strategy.

Evaluation plans should be clearly identified in the operational plan and discussed in the evaluation section of the fisheries lake or stream management plan. Upon completion of the evaluation period, which generally includes several stocking cycles, the data are reviewed and, if necessary, the management plan is updated to reflect the success or failure of the operational plan at achieving the established goal. It may also be necessary to adjust the management goals if evaluations indicate that they were not realistic.

Evaluation of Natural Reproduction

Evaluation of walleye natural reproduction is one of the most important steps for efficient fisheries management of stocked lakes. Stocking walleye in lakes with sufficient natural reproduction is not only a waste of money and time, but a detriment to naturally reproduced walleye year classes (Li et al. 1995). The most direct way to evaluate if natural reproduction can sustain a walleye population is to quit stocking and monitor the population with lake surveys. However, if practical concerns make this an impossibility, you should switch to a stocking regime that includes some years with no stocking, or you may directly assess natural reproduction by annual fall electrofishing, shoreline seining, or 1/4 inch mesh trap netting.

Since a large walleye year class can suppress the size of the next year class, naturally reproduced year classes can be suppressed in stocking cycles with only one blank year (e.g. every other year stocking) and natural reproduction can be seriously underestimated. A more appropriate cycle would be one or two years of stocking followed by two blanks. At least three full stocking cycles should be completed for a thorough evaluation. However, if good naturally reproduced year classes are documented after one or two stocking cycles, this may be sufficient evidence that significant natural reproduction is occurring. If you choose to quit stocking, you should continue to monitor the population to confirm your findings.

Lake surveys or population assessments should be conducted at least every third or fourth year if natural reproduction is to be evaluated effectively. Accurate aging is critical. It is recommended that dorsal spines (the second dorsal spine cut at the base) be used for aging and that only the younger year classes of walleye (through age 7) be used for the analysis. Fingerlings from ponds that have carry-over should not be used because that would mask naturally reproduced year classes.

The correct interpretation of the lake survey data is very important. Managers should remember that even in healthy walleye populations, not every natural year class is large; therefore, large year classes should not be expected in every blank year. In fact, one large year class out of four blank years may be sufficient evidence that natural reproduction is adequate to sustain a walleye population. For example, only three large year classes of walleye occurred in Mille Lacs Lake (a lake with excellent natural reproduction) from 1977 through 1991 (Figure 6).

Evaluation of Stocking Success Using Gill Net Data

Background information. Gill nets are a valuable and practical sampling tool for evaluating walleye stocking. Moyle (1950) called the use of gill nets for sampling fish populations in northern waters "a matter of practical necessity." Experimental gill nets have been the standard lake survey tool used in Minnesota since the 1940s.

Gill net CPUE can be used in two ways to evaluate walleye stocking: 1) Gill net CPUE can be compared with the Lake Class inter-quartile range to look for gross deviations from typical catches for that lake class (Schupp 1992); and 2) Gill net catches can be statistically analyzed for significant differences, and probability statements can be made about changes in abundance (Moyle and Lound 1960). With either of these methods, investigators can make inferences about the effectiveness of a stocking program.

Schupp (1992) used limnological variables to classify Minnesota's lakes into 43 Lake Classes. Gill and trap net catch indices within Lake Classes were used to characterize fish communities for each Lake Class. Gill and trap net CPUE quartiles were calculated by Lake Class, providing a useful tool for comparing net catches. In his study, Schupp recommended that inter-quartile ranges be used as benchmarks for quick examinations of survey net catches. He cautioned that the use of quartiles is a statistically conservative approach and that it is not a substitute for statistical testing. However, this method does have the advantage of aiding rapid identification of gross departures from more typical catches.

The failure to consider the statistical significance of differences in gill net catches has probably led to many erroneous conclusions (Schupp 1992). Fisheries managers have many options available for analyzing gill net catches. This document is not intended to be all inclusive in its coverage of statistical testing of CPUE, but does provide managers with a few quick and easy statistical testing tools.

Two types of statistical tests are typically used to test for differences in means, medians, or distribution between two samples. Parametric tests are used to test for differences between means of two samples. An assumption when using parametric tests is that the data have an approximately normal distribution. Since fisheries gill net catch data are usually not normally distributed, testing for normality and a transformation to make the data distribution normal are usually required. Non-parametric tests are used to test for differences in medians, other central values, or distributions between samples. Medians are less sensitive to extreme observations than are means. However, Moyle and Lound (1960) pointed out that the median has the important disadvantage of being zero if more than half the nets in a sample series do not take fish of the kind considered. Non-parametric tests are not as powerful as parametric tests. However, non-parametric tests require fewer assumptions about data distribution and are, therefore, easier and probably safer to use for fisheries work.

A note of caution about statistical testing. While investigators can make probability statements about the medians or means of samples, and make inferences about the parent populations from which the samples were drawn, the nature of most of our investigations and sampling does not allow us to say with much statistical confidence why changes in CPUE may be occurring. In other words, statistical testing may show that change has occurred, but not why it has occurred. We must use other sources to infer the causes, or seek additional information to discover the mechanisms for change.

Two examples of statistical testing of net catches (Moyle and Lound 1960) and two modern equivalents using *Statistix* software are described in Appendix A. These tests can be used to detect differences between any two samples with either pooled or unpooled data as described in the cases that follow. If the experimental design for an evaluation will allow it, two groups of years (two or more surveys in each group) could be pooled by net set to eliminate some of the noise associated with fish sampling. The two pooled groups could then be treated as two samples and tested as such.

Comparing or testing walleye gill net CPUE for the purpose of evaluating a stocking program is necessary but has limitations. Gill nets are selective to certain sizes and ages of walleye. Knowledge of this selectivity is essential for correct interpretation of catch information. Stocking evaluations must consider the changes in gill net CPUE over time and the contribution of stocked and natural year classes to the gill net catch.

In general, most stocking evaluations can be categorized into two cases. The first case is where two management strategies are applied and evaluated over two extended periods by comparing CPUE data. The second case is where a single management strategy employing an intermittent stocking regime is applied and year class analysis is used to compare stocked and unstocked year classes (or one stocking method with another).

Case 1. Comparing large blocks of continuous management. In this case, comparisons can be made between surveys with catches that contain mostly age classes produced under one management strategy and catches that contain mostly age classes produced under a second management strategy. Bigger blocks of each treatment give more confidence in the results of the evaluation and pooled data can eliminate some of the noise associated with biological sampling. Needless to say, many evaluations require several years and many surveys to get enough data points from each treatment to compare for differences. Evaluations of this type allow managers to say with greater certainty that stocking has or has not worked, since there is less need to worry about aging errors, replacement, gill net selectivity, or year class suppression. Unfortunately, most lake's stocking history prevent this type of analysis.

Example A. Using Schupp's Lake Class inter-quartile ranges to compare CPUE data for two management strategies. Using Schupp's Lake Class method to compare gill net CPUE simply involves comparing a lake's gill net CPUE with the inter-quartile CPUE range for the same Lake Class. A hypothetical example can be used to illustrate this approach. A lake has had 10 surveys over a 15 year period. Due to a well thought out stocking strategy, the first five surveys catch contained mostly age classes associated with stocked years. The second five surveys catch contained mostly natural age classes. Walleye gill net CPUE varied for all 10 assessments, however, all fell within the Lake Class inter-quartile range. If all other known variables that affect CPUE were equal, fisheries managers might conclude that there were no unusual catches and, therefore, stocking probably made no real difference in gill net CPUE. Conversely, if mean CPUE of one of the assessment series had been outside the inter-quartile range, a more detailed examination would have been merited. It should be mentioned again that this method is conservative since statistically significant differences can exist within the inter-quartile range. The value of this method may be greatest when no further testing is planned or when it is used as a first test for possible changes.

Example B. Using statistics to compare two series of gill net CPUE data. Using the same data available in example A, statistical tests outlined in Appendix A might be able to detect significant differences in CPUE, even if comparisons with inter-quartile ranges failed to show such a difference. Statistical tests can also be used to evaluate changes in stocking strategies (frequency, rate, or size) using this method.

Example C. Using statistics to compare a period of varied management with a period of consistent management. Many lakes have a history of variable stocking regimes, and do not appear to fit into Case 1. For example, a lake may have been managed from 1975 through 1985 with a random program of fry and fingerling stockings at various rates with few or no blank years. Carry-over fingerlings also clouded the picture. Surveys were conducted in 1979 and 1984. In 1986, a management strategy using alternate year fry stockings was initiated. Surveys were conducted in 1989 and 1994. A Mann-Whitney test (Appendix A) indicated no significant difference between the median gill net catches of the two survey groups. The manager could then conclude that eliminating fingerling stocking and increasing the frequency of blank years improved the cost-effectiveness of the stocking program without harming the walleye population.

Case 2. Evaluating smaller intervals of varied management. Only statistical comparisons of gill net catches between surveys will work for this case (cannot use Lake Class inter-quartile range comparisons). If stocking has occurred more frequently, and only small gaps are present between stocked years, a strategy for analyzing age specific information is necessary. For example, one strategy would be to statistically test for differences in CPUE of the first fully recruited stocked age class and the first fully recruited natural age class, from several surveys. An equal number of surveys should be timed to catch either the stocked or natural age class as they first fully recruit to the gill net catch. This method may require that the ages and numbers of walleye caught during a survey be recorded by net or mesh size, since many statistical methods require individual net information.

Example A. Using statistics to compare two series of age specific gill net CPUE data. Six surveys with identical numbers of gill net sets were completed as part of a stocking evaluation on a lake. The surveys were divided into two groups of three surveys each. The first group's surveys were timed to catch the first fully recruited stocked year class and the second group's surveys were timed to catch the first fully recruited natural year class. The number of walleye caught of the correct age (first fully recruited) were summed by individual nets for the first two groups. The result was two net series; one containing the number of walleye of the stocked age class caught by net, and the other containing the number of the naturally reproduced fish caught by net. These two series could then be treated as two samples, making it possible to use any of the statistical testing procedures described in Appendix A. Statistical tests can also be used to evaluate changes in stocking strategies (frequency, rate, or size) using this strategy.

Example B. Using a year class strength model (YCSM) to interpret gill net catch information for comparisons with a stocking history. Assessments were conducted at least every three years, but no effort was made to consistently catch the first fully recruited stocked year class, as in example A. The experimental gill nets used in Minnesota lake surveys are most efficient at catching medium sized walleye, generally ages 2-4. Therefore, the year classes represented by ages outside the range of maximum catchability will be under represented in the gill net catch. This can lead to a misinterpretation of the catch at age data. The following year class strength model (YCSM) used by Parsons et al. (1994) removes the effect of age on catchability and produces output which is a unitless index of year class strength.

$$Y_{ij} = \mu + \alpha_i * Age(I) + \beta_j * YearClass(j) + \epsilon_{ij},$$

In this model, Y_{ij} is the log of gill net CPUE (number of fish age I from year class j caught divided by number of nets, plus 1 to allow log of zero values), Age(I) and Year Class(j) are vectors of dummy variables for the main effects in the model, μ, α_i, β_j are constants, and ϵ_{ij}, is the error term. Only ages one through six should be used to remove potential aging errors for older walleye (Campbell and Babaluk 1979). The relative strength of year classes as indicated by the YCSM can be compared to your stocking history to infer the effectiveness of your stocking strategy.

Example C. Using a year class strength model (YCSM) from another lake when one is not available for the lake being evaluated. The primary disadvantage of the YCSM is that it requires several surveys separated by relatively few years. Such data is generally unavailable for most Minnesota lakes. However, the age effect from the YCSM run on another lake with similar growth and exploitation rates can be used to adjust net catches from a single survey. A single assessment was conducted on a lake, and the catch included stocked and unstocked year classes (Table 11). The 1994 lake survey showed nearly equal catch of the 1991 and 1993 year classes. The year class CPUE data appeared to show that fry and fingerling stocking (1993 and 1991 YC, respectively) had been equally effective. However, the 1993 year class was sampled at age 1, below the range of maximum catchability, while the 1991 year class was sampled at age 3, near maximum catchability. The YCSM indicated through the adjusted CPUE that the 1993 year class was clearly stronger. The 1988 year class, sampled at age 6 (above the range of maximum catchability), appears to be the second strongest year class. As a result of this analysis, fry stocking and natural reproduction were shown to be more effective than fingerling stocking. Models appropriate for lakes with growth ranging from slow to fast and exploitation ranging from high to low are available on a Lotus spreadsheet from the Lake and Stream Survey Coordinator.

Comparing Angler Catch Per Unit Effort

Angler CPUE from creel surveys can also be used to evaluate stocking success. This approach works best in lakes where natural reproduction has already been evaluated. Creel survey CPUE data can be compared with quartile ranges for a Lake Class group in a way similar to the gill net CPUE example. Median and quartile values from Table 12 should be used to compare creel survey data with data collected in other lakes in a Lake Class group. The median summer walleye harvest rate on walleye lakes in Minnesota's statewide creel survey database was 0.05 fish/angler-h (Cook, personal communication 1995). Median harvest rates appeared to vary among Lake Class groups, with higher medians in the northeastern Minnesota groups. Lower walleye harvest rates in groups 4-8 were probably the result of fewer anglers on those lakes targeting walleye. When targeted harvest rates were examined, there appeared to be little difference in median values between northeastern Minnesota and other Minnesota Lake Class groups.

Additional factors to consider in use of angler catch data to evaluate walleye stocking success include fishing quality factors, angler preference factors, and timing of the angler surveys. Creel surveys should be conducted when stocked year classes are fully recruited to the fishery. When funding permits, creel surveys should be done for two consecutive years. Lake surveys or fish population assessments should be conducted in the same year as the creel survey. If a lake management plan contains an objective stating an angler CPUE, a creel survey should be done as part of the evaluation.

Fall electrofishing

Electrofishing has been proven an effective method of capturing young walleye (Serns 1982, 1983). However, the technique was rarely used in Minnesota prior to 1990. This technique has the obvious advantage of identifying the strength of a year class at an early stage. For example, if natural reproduction or fry stockings failed several years in a row, a change to an alternative management regime could be made without waiting two to four years for fish to recruit to the gill net. Conversely, a fingerling stocking could be reduced or eliminated when fall electrofishing indicated significant natural reproduction.

Insufficient data is available to develop meaningful median electrofishing catch rates by Lake Class. Additionally, the relationship between electrofishing CPUE of fingerling walleye and recruitment to the adult stage is unclear. There is evidence that yearling catch is related to fingerling catch of the previous year. Six lakes of the Cannon River chain in southern Minnesota have been annually electrofished since 1987. In these lakes, zero counts at the fingerling stage have invariably been followed by zero counts at the yearling stage. Significant numbers of yearlings have, with one exception, been preceded by significant numbers of fingerlings. Data from Minnesota's large lake sampling program provide further evidence that electrofishing CPUE of walleye fingerlings can be an indicator of future adult abundance. Fall electrofishing effort has increased sharply in recent years and, as more cohorts monitored by electrofishing are followed through to lake and creel surveys, these relationships will become better understood.

Other Evaluation Methods

The most commonly utilized stocking evaluation procedures have been to correlate age distribution of walleye captured in gill net surveys with stocking history or to extrapolate angler CPUE with age structure of the catch. There are other fish collection methods in use that may provide alternatives to standard surveys to increase sample size and augment stocking evaluation.

Quarter-inch-mesh trap nets have been used to evaluate walleye reproduction in lakes where shoreline seining and fall electrofishing are impossible or ineffective. Assessments should be done when young-of-year walleye are present in near-shore areas, and should be conducted in stocked and unstocked years. Statistical methods outlined in Appendix A can be used to compare CPUE for stocked and unstocked years.

The Large Lake Sampling Guide (Minnesota Department of Natural Resources 1985) describes the use of bottom trawls to assess natural reproduction in large, natural walleye lakes. There has been enough use of this capture gear in Minnesota to suggest that there is not a strong correlation between trawling CPUE for YOY and subsequent walleye year class strength. There does appear to be a positive correlation between young-of-year walleye growth and year-class strength (Tom Heinrich, MN DNR, personal communication 1995). Such information may provide valuable insight into the relationship of body size or condition and over-winter survival. There may be some opportunity to expand the use of trawls to evaluate the initial stocking success, growth, and over-winter survival of walleye fry stocked in suitable medium and large lakes.

Specialized sampling assessments such as spring trap netting are becoming an increasingly popular approach to supplement information gained from standard surveys and increase sample size in assessing age structure, total annual mortality, or fish movements among lakes. Trap nets or other trapping structures are set when fish are actively moving during the spring spawning period. Fish captured by this method tend to be older, sexually mature fish that may not be well represented in standard surveys. Due to the difficulty in aging older walleye, dorsal spines should be removed for sectioning and aging. Such innovative sampling is encouraged to provide greater insight into the long-term contribution of stocking.

Collection of heads from harvested fish has proven to be a very cost-effective means to increase sample size for age analyses and substantiate the contribution of stocked and naturally reproduced fish in the creel. Parsons et al. (1991) reported a seven-fold increase in walleye sample size over that obtained through creel surveys conducted on Lakes Ida, Mary, and Miltona, by enlisting assistance from resort owners to save the heads of walleye captured by resort patrons. Resort owners froze severed heads of harvested walleye cleaned at their facilities and provided them to fisheries research staff for evaluation. Age of harvested fish was determined from opercular annuli. Total length was determined by a head-length equation. Since a portion of stocked fish were marked or implanted with coded-wire tags, the head collection process was valuable in determining the contribution of stocked fish to the angler. As with spring trap netting, head collection samples provided a greater representation of larger, older fish than was observed during creel surveys (Parsons et al. 1991).

Identification of Stocked Fish

Meaningful evaluation of stocking carries the supposition that the investigator can differentiate stocked fish from wild fish in the population. Contribution of stocked fish, where there is natural reproduction or in open systems where fish can move through connecting streams and basins, can be difficult to evaluate. In order to differentiate stocked and wild fish, it may be necessary to tag or mark stocked fish. Extensive bibliographies and discussions of various marking techniques are provided by Everhart and Youngs (1981), Younk and Cook (1991), Wydoski and Emery

(1983), Nielsen (1992), and Parker, et al. (1990).

Few marking techniques are readily adaptable for use in evaluating walleye fry stockings. Batch marking techniques such as pigment marking or oxytetracycline hydrochloride immersion have had mixed results. Variability in results can be attributed to handling or treatment mortality, increased vulnerability to predation of pigment marked fish, starvation and variability in chemical uptake based on degree of ossification, and inconsistency in persistence of the mark. Younk and Cook (1991) were encouraged by initial fluorescent chemical marking trials and suggest further evaluation in marking walleye fry to better assess long term mark retention. Peterson and Carline (1996) found that tetracycline marking had no effect on post-stocking walleye fry mortality, while Hoopes and Burman (1992) reported 100% mark retention for tetracycline-marked fry.

Electrophoresis may hold promise in differentiating stocked walleye fry from wild populations, assuming stocked fry originate from a genetically discrete population and the genetic fingerprint of the receiving population is distinguishable from the stocked fish. Large scale application is limited by lack of genetic background information, extensive laboratory analyses, and past stocking practices that resulted in commingling of strains.

Fin clipping is the most common and simplest technique used in evaluating initial and short-term survival and contribution of walleye fingerling stockings. Limitations of this marking technique include possible regeneration of fin rays, limited marking combinations, undesired changes in behavior or survival that could bias investigation results, and difficulties in marking small fish. External tags are another popular technique for marking juvenile and adult walleye, particularly in those stocking evaluations in which success is measured by relative contribution to the angler's creel and mark visibility is critical.

In studies where mark visibility is not critical or marked fish can be identified by non-visual means, coded-wire tags offer some distinct advantages over other forms of physical marking because no body parts are removed, the tag does not protrude from the body, tag retention is improved, fish experience less stress than with other tagging methods, smaller fish can be tagged, multiple stockings can be differentiated, and the technique is fairly quick. The Section of Fisheries currently has two coded-wire tagging units. Parsons et al. (1994) successfully utilized coded-wire tags to determine the contribution of high-density walleye fingerling stockings in three west-central Minnesota lakes where natural recruitment was occurring. Metal detectors were used to identify tagged fish.

Other Variables to Consider in Evaluating Stocking

Evaluation of stocking success can be hindered by a multitude of variables with the potential to bias investigation results. Investigators should consider potential external influences when designing and analyzing stocking programs.

Fish migration and dispersal may bias stocking evaluations. If evaluation is occurring within a basin that has a flowage connection to other basins, there is some probability of fish movement into or out of the study basin. Stocking evaluations can be further confounded if connected basins are not stocked in the same year, natural reproduction occurs in connected basins, or there is disparity in habitat or fish community character among basins. Young fish may move into or out of a particular basin to avoid predators. Dependent on downstream flow velocity, newly hatched fry may be flushed from receiving waters and transported to downstream basins.

Dispersal of stocked walleye fingerlings does not appear to be immediate nor consistent among lakes. Parsons et al. (1994) observed that stocked fingerling walleye demonstrated a tendency to remain near release sites on Lakes Mary, Miltona, and Ida and did not fully disperse until their third growing season. This study suggests that rate of dispersal may be variable based on lake size and morphometry. Larger walleye fingerlings appear to disperse from the stocking site sooner than small walleye fingerlings (Parsons and Pereira, in preparation). High capture rates of age-3 and younger fish from sampling near stocking sites could mislead investigators in assessing initial stocking successes or failures.

Review of the stocking history of a particular lake may provide some valuable insight into predicting stocking success. Deviations from planned stockings, lack of stocking blanks from which to evaluate natural reproduction, stocking of multiple age classes of fingerlings, and variance in stocking procedures or chronology may explain inconsistencies in stocking effectiveness. Documentation of size and number stocked, condition of stocked fish, origin of eggs, fingerling distribution from a single or multiple rearing ponds, distribution methodology and distance traveled, water temperature at stocking, location, zooplankton counts, other game fish stocking, etc. may be lacking when assessing stocking successes. Investigators are cautioned that such documentation may also be inaccurate or misleading. For example, walleye harvested from drainable ponds (frylings) in the 1950s and 1960s were often identified as fingerlings. Additionally, the standard to differentiate young-of-year fingerlings from age-1+ and older fingerlings was based on length rather than actual age determination. Historical records should be well researched if stocking decisions or predictions are based on a history of past stocking.

Maintaining a well documented stocking history will be very beneficial in assessing future stocking success. Physical condition, size, handling-induced stresses and general fish health at time of stocking can greatly influence initial and short-term survival of stocked walleye, and may explain significant variation in success among stocking trials. Laarman (1980) estimated that initial stocking mortality attributable to handling and transportation can range from 2-16%. Schreiner (1985) estimated 20% of stocked fingerlings may suffer immediate and short-term mortality induced by harvest and transportation stress. Fingerlings which are in poor physical condition, diseased, or heavily parasitized, may not survive their first winter. Small-sized fingerlings may have lower survival rates than medium- or large-size fingerlings. If fingerling stockings are being evaluated, it would be beneficial to record lengths, evaluate physical condition, and crib subsamples of stocked fish to assess initial or short-term mortality. Investigators should be aware that holding fingerlings for more than 48 hours may amplify distribution stress and increase mortality (Parsons et al. 1994).

Zooplankton abundance and community composition can be highly variable among lakes at the same time and temperature. Scarcity of prey items or preferred prey may greatly influence stocked fry survival. Further evaluation of the influence of water temperature and forage availability may be warranted in fry stocking investigations.

Appendix A

Statistical Analysis of Gill Net Catches

Example 1. Moyle and Lound. Moyle and Lound (1960) described two methods of statistically comparing net catches. The first, a parametric method, was used to compare mean gill net catch means from the same lake for two sampling years. They concluded that walleye gill net catch, in numbers per individual net set, usually has a negative binomial distribution. They then used the equation $y_i = \log(x_i + (k/2))$ to transform the data x_i to a variable y_i, having approximately a normal distribution. The variables in the above equation are defined as follows: x_i = original catch numbers; k = (sample mean^2 / (sample variance - sample mean)). They then used a two sample *t* test to test for differences between means of normally distributed populations. To further illustrate this approach, the example from their paper follows:

Year A...

Number/set	Transformed number/set
1	0.30103
2	0.47712
4	0.69897
6	0.84510
9	1.00000
10	1.04139
11	1.07918
14	1.17609
16	1.23045
27	1.44716

Year B..

Number/set	Transformed number/set
0	-0.31084
0	-0.31084
1	0.17284
1	0.17284
6	0.81217
6	0.81217
12	1.09652
14	1.16103

Statistics..

	Year A	Year B
Number of nets	10	8
Mean CPUE	10	5
Sample Variance	60	30.57
Sample Standard Deviation	7.75	5.53
k	2	0.977654

A two sample *t* test yields a two tailed *P* = 0.0706. Since *P* is low, we reject the null hypothesis that the means of the samples are the same and the samples are drawn from equal populations. In this case, we can say that sample means this different would be expected to come from equal populations only 7 times out of 100. It is quite easy for investigators to build a computer spread sheet or use *Statistix* software to transform the data and perform the *t* test. *Statistix* software could also be used to test the transformed data sets for normal distribution with a Wilk-Shapiro Rankit Plot. If the Rankit Plots were non-linear, a non-normal distribution would be suspected and a non-parametric test would be called for.

Example 2. Moyle and Lound. The second method Moyle and Lound (1960) described was a non-parametric test that tests for differences between medians, rather than means, of two series of net catches. The two samples could be from the same lake and two different years, or from different lakes. Catch was recorded by net for the two samples. The two samples were combined and a common median was determined. The items in the two original samples were then arranged in a 2 by 2 table as described below. The example from their paper follows:

Sample 1 was a series of 7 net catches from a lake survey. Sample 2 was from a survey with 9 net sets. Numbers of walleye taken in the individual net sets of sample one were 0, 0, 1, 2, 3, 3, and 4. Numbers of walleye taken by set in sample two were 2, 4, 4, 5, 6, 6, 8, 9, and 11. Combining the two samples produced a common median of 4. A 2 by 2 table was then arranged as follows:

	Number of items in sample series	
	Below or equal to common median	Above common median
Sample Series 1	7	0
Sample Series 2	3	6

They then used a Chi-square test to determine how probable it was that the two samples were drawn from an equal parent population. Results of the Chi-square test are shown below:

CASE		VARIABLE BELOW	ABOVE	
1	OBSERVED	7	0	7
	EXPECTED	4.38	2.63	
	CELL CHI-SQ	1.57	2.63	
2	OBSERVED	3	6	9
	EXPECTED	5.63	3.38	
	CELL CHI-SQ	1.23	2.04	
		10	6	16

OVERALL CHI-SQUARE 7.47
P-VALUE 0.0063
DEGREES OF FREEDOM 1
CAUTION: 3 cells have expected values less than 5.0
CASES INCLUDED 4 MISSING CASES 0

Since there were three cases where the expected value was less than 5, the Chi-square test could not be used. Instead, they used Fisher's exact probability test to calculate a *P* = .01. Thus, they concluded that the probability that these two samples came from the same population was about 1 in 100.

Moyle and Lound did not have the tools for statistical testing that are now available to fisheries managers. Computers and commercial software programs have made it a simple task to run statistical tests on samples. *Statistix* version 4.1 is the standardized statistics software for DNR fisheries managers. It is very easy to use with a minimum amount of training as can be seen from the examples that follow.

Example 3. Using "Statistix" to enter data and perform median test on Moyle and Lound's data set. To illustrate how easy it is to test gill net CPUE using *Statistix*, we can use Moyle and Lound's data set from the above example. Data are entered into the program under the data management menu option. Once entered, data can be run through a variety of tests. In this example, data are entered under two variables we chose to call YEAR1 and YEAR2. *Statistix* uses M's for missing data. In our example, 7 sets were run one year and 9 sets the other. Note that both of the following tests (examples 3 and 4) are of the non-parametric type. The data set and two tests, as they appear in *Statistix,* are shown below.

STATISTIX 4.1 MOYLE, 05/25/95, 2:25

VIEW DATA

CASE	YEAR1	YEAR2
1	0	2
2	0	4
3	1	4
4	2	5
5	3	6
6	3	6
7	4	8
8	M	9
9	M	11

To test if the medians of the two samples are equal we can use the median test.

STATISTIX 4.1 MOYLE, 05/25/95, 2:26
MEDIAN TEST FOR YEAR1 - YEAR2

	YEAR1	YEAR2	TOTAL
ABOVE MEDIAN	0	6	6
BELOW MEDIAN	6	1	7
TOTAL	6	7	13
TIES WITH MEDIAN	1	2	3

MEDIAN VALUE 4

CHI-SQUARE 9.55 DF 1 P-VALUE 0.002

MAX. DIFF. ALLOWED BETWEEN A TIE 0.00001

CASES INCLUDED 16 MISSING CASES 2

The small *P* means that the probability that the medians of the two groups are equal is very low. Thus, we conclude that the medians are different. We could say that the probability of these two samples being drawn from an equal parent population is only 2 in 1000.

Example 4. "Statistix" rank sum test. To test if the two samples have the same distributions we can use the rank sum test. It is shown below as it appears in *Statistix* output.

STATISTIX 4.1 MOYLE, 05/25/95, 2:27

RANK SUM TWO-SAMPLE (MANN-WHITNEY) TEST FOR YEAR1 VS YEAR2

VARIABLE	RANK SUM	SAMPLE SIZE	U STAT	MEAN RANK
YEAR1	32.5	7	4.500	4.6
YEAR2	103.50	9	58.500	11.5
TOTAL	136.00	16		

EXACT PROBABILITY OF A RESULT AS OR MORE EXTREME THAN THE OBSERVED RANKS (ONE TAILED P-VALUE) 0.0010

NORMAL APPROXIMATION WITH CONTINUITY CORRECTION 2.805
TWO TAILED P-VALUE FOR NORMAL APPROXIMATION 0.0050

TOTAL NUMBER OF VALUES THAT WERE TIED 11
MAXIMUM DIFFERENCES ALLOWED BETWEEN TIES 0.00001

CASES INCLUDED 16 MISSING CASES 2

Again we see that the *P* value is very low, indicating that the probability that these samples are different is high. In general, *P* values of 0.2 to 0.1 would indicate that the samples are different. A *P* value of 0.01 would indicate that the samples are very different.

In each of the examples above, we have rejected the null hypotheses (the null hypotheses that means or medians are the same) because there was a low probability (P value) that the two samples tested were drawn from the same or similar parent populations. However, in cases where we fail to reject the null hypotheses, we cannot infer that the means or medians are the same unless we can show that the statistical test used had an acceptable level of power to detect differences. Peterman (1990) describes the importance and implications of reporting statistical power when we fail to reject the null hypotheses. Readers are encouraged to read Peterman's paper before drawing conclusions from statistical tests that fail to reject the null hypotheses.

Appendix B

Stocking Decision Key *- When stocking strategies are listed, use the strategy at the end of the key to determine what size, rate, and frequency are recommended. Evaluate the recommended strategy before moving on to the next decision couplet.*

1. The lake has a good yellow perch forage base (> 8.0 fish/gill net) 5
1. The lake does not have a good yellow perch forage base 2

2. The lake is in Lake Class groups 1-3 and supports a low diversity fish community dominated by northern pike or white sucker 5
2. The lake is not as described above 3

3. The lake has a high black bullhead population 5
3. The lake does not have a high black bullhead population 4

4. The lake has a good alternate forage base 5
4. The lake does not have any alternate forage base ....STOP

5. The lake is known to have good natural walleye reproduction................................STOP
5. The status of walleye reproduction in the lake is unknown 6
5. The lake is known to have little or no natural reproduction 8

6. There is a high demand for stocking in the lake 7
6. There is little or no demand for stocking in the lake ....Strategy 8.................5

7. Based on your experience, fry stocking might be successful...........Strategy 2D or 2E........5
7. Based on your experience, fry stocking would probably not be successful ....Strategy 5D or 5E........5

8. The lake is known to winterkill occasionally ....Strategy 1A or 1B
8. The lake rarely or never winterkills 9

9. The management goal is a bonus or trophy walleye fishery, where walleye is not the primary species ....Strategy 1C or 1D..........10
9. Walleye is the primary species, and the goal is a productive walleye fishery 13

10. Strategies 1C or 1D were not successful ....Strategy 4C or 4E..........11
10. Strategies 1C or 1D were successful 25

11. Strategies 4C or 4E were not successful ....Strategy 7E..........12
11. Strategies 4C or 4E were successful 25

12. Strategy 7E was not successful ....STOP
12. Strategy 7E was successful 25

13. A walleye stocking strategy is currently being evaluated on the lake ....Complete evaluation, then restart key..1
13. No walleye stocking evaluation is being done at present ....Strategy 2C or 2D........14

14. Strategies 2C or 2D were not successful ....Strategy 3C or 3E or 5C.............15
14. Strategies 2C or 2D were successful ....17 or 25

15. Strategies 3C, 3E, or 5C were not successful ....Strategy 6B or 7E.............16
15. Strategies 3C, 3E, or 5C were successful ....21 or 25

16. Strategies 6B or 7E were not successful ....STOP
16. Strategies 6B or 7E were successful 25

17. Walleye in the lake do not exhibit good survival, fast growth, and high mortality 18
17. Walleye in the lake exhibit good survival, fast growth, and high mortality
....Strategy 2A or 2B...........20
18. Walleye in the lake exhibit good survival, but growth is slow and forage is reduced
....Strategy 1C or 1D...........19
18. Walleye in the lake not as described above 14

19. Strategies 1C or 1D were not successful 14
19. Strategies 1C or 1D were successful 25

20. Strategies 2A or 2B were not successful 14
20. Strategies 2A or 2B were successful 25

21. Walleye in the lake do not exhibit good survival, fast growth, and high mortality 22
21. Walleye in the lake exhibit good survival, fast growth, and high mortality
...............................Strategy 3A, 3B, 5A, or 5B...........23

22. Walleye in the lake exhibit good survival, but growth is slow and forage is reduced
....Strategy 2E, 4C, or 4E...........24
22. Walleye in the lake not as described above 15

23. Strategies 3A, 3B, 5A, or 5B were not successful ....Strategy 3C, 3E, or 5C.......15
23. Strategies 3A, 3B, 5A, or 5B were successful 25

24. Strategies 2E, 4C, or 4E were not successful ....Strategy 3C, 3E, or 5C.......15
24. Strategies 2E, 4C, or 4E were successful 25

25. Continue stocking using the successful strategy. Re-evaluate stocking success, and the need for continued stocking, at each lake management plan revision. You may want to try stocking at a lower rate.

Strategy list:

Size and rate	Frequency
1 = fry, 250-500/LA*	A = annual
2 = fry, 500-1,000/LA	B = 2 of 3 years
3 = fry, 2,000-3,000/LA	C = 1 of 2 years
4 = fgl, < 0.5 lb/LA	D = 2 of 4 years (consecutive blanks)
5 = fgl, 0.5-1.0 lb/LA	E = 1 of 3 years
6 = fgl, 1.5 lb/LA	
7 = fgl, 3.0 lb/LA	
8 = no stocking, monitor reproduction	

* LA denotes littoral acreage

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Table 1. Geometric mean CPUE of walleye (gill nets) in relation to CPUE of northern pike and yellow perch (gill nets). Values in bold face are significantly lower (P ≤ 0.05) than 2.73 (mean walleye gill net CPUE for all surveys).

Northern Pike per gill net	Yellow Perch / gill net: None	< 2.0	2.0-7.9	8.0-31.9	≥ 32.0
None	5.86	4.69	4.92	5.51	4.79
< 3.0	1.88	**2.05**	**2.23**	3.48	4.30
3.0-5.9	**1.51**	**1.76**	**2.10**	3.16	4.27
6.0-8.9	**1.34**	**1.63**	2.53	2.89	3.31
≥ 9.0	**1.30**	**1.55**	**2.04**	2.69	3.00

Table 2. Geometric mean CPUE of walleye (gill nets) in relation to CPUE of black crappie (gill and trap nets) and yellow perch (gill nets), Lake Classes 20-43. Values in bold face are significantly lower (P ≤ 0.05) than 2.73 (mean walleye gill net CPUE for all surveys).

Black Crappie per gill net	Yellow perch / gill net: None	< 2.0	2.0-7.9	8.0-31.9	≥ 32.0
None	2.87	2.64	2.72	3.54	4.65
< 1.0	**1.40**	**1.70**	2.65	4.08	4.51
1.0-4.9	**1.60**	**1.96**	**2.09**	2.87	3.65
≥ 5.0	**1.63**	**1.44**	**1.82**	**2.30**	2.45
Black Crappie per trap net					
None	3.11	2.25	2.62	4.14	4.58
< 1.0	**1.30**	**2.06**	2.78	3.71	4.34
1.0-4.9	**1.39**	**1.66**	**1.87**	2.84	4.06
≥ 5.0	**1.94**	**1.70**	**2.18**	**1.93**	2.29

Table 3. Geometric mean CPUE of walleye (gill nets) in relation to CPUE of northern pike and black crappie (gill nets), Lake Classes 20-43. Values in bold face are significantly lower (P ≤ 0.05) than 2.73 (mean walleye gill net CPUE for all surveys).

Northern Pike per gill net	Black Crappie / gill net: None	< 1.0	1.0-4.9	≥ 5.0
None	7.12	4.53	4.52	3.52
< 3.0	3.69	3.43	2.78	**2.28**
3.0-5.9	3.56	3.27	2.38	**1.97**
6.0-8.9	2.73	2.89	2.29	**1.71**
≥ 9.0	2.61	2.41	**2.17**	**1.55**

Table 4. Geometric mean CPUE of walleye (gill nets) in relation to CPUE of black bullhead and yellow perch (gill nets), Lake Classes 20-43. Values in bold face are significantly higher ($P \leq 0.05$) than 2.73 (mean walleye gill net CPUE for all surveys).

Black Bullhead	Yellow Perch / gill net				
per gill net	None	< 2.0	2.0-7.9	8.0-31.9	≥ 32.0
None	1.39	1.24	1.65	2.63	**3.35**
< 1.0	1.21	1.67	2.00	**3.57**	**4.04**
1.0-9.9	1.66	1.90	2.85	**3.70**	**4.25**
≥ 10.0	**3.67**	**3.41**	3.30	3.17	**4.01**

Table 5. Geometric mean CPUE of walleye (gill nets) in relation to CPUE of black bullhead (gill nets) and black crappie (trap nets), Lake Classes 20-43. Values in bold face are significantly lower ($P \leq 0.05$) than 2.73 (mean walleye gill net CPUE for all surveys).

Black Bullhead	Black Crappie / trap net			
per gill net	None	< 1.0	1.0-4.9	≥ 5.0
None	2.54	2.50	**1.44**	**1.83**
< 1.0	3.90	2.91	**2.15**	**1.42**
1.0-9.9	3.76	3.65	3.02	**1.93**
≥ 10.0	4.97	3.78	3.49	2.32

Table 6. Number of walleye stocking successes and failures by Lake Class and Lake Class group for Minnesota lakes as reported by Minnesota DNR Section of Fisheries staff. Determination of success or failure was based on attainment of management goals, assessment data, creel survey data, fish community effects, and natural reproduction data.

Lake Class	Lake Class group	Failures	Successes	Percent successful
1	1	5	0	0.0
2	1	3	1	25.0
3	1	3	7	70.0
4	2	1	1	50.0
5	1	4	16	80.0
6	2	6	4	40.0
7	1	7	4	36.4
8	2	1	5	83.3
9	2	0	1	100.0
10	2	5	4	44.4
11	2	3	6	66.7
12	3	13	14	51.9
13	2	2	6	75.0
14	2	1	1	50.0
15	3	7	3	30.0
16	3	5	2	28.6
17	3	4	3	42.9
18	3	0	2	100.0
19	3	1	3	75.0
20	5	1	2	66.7
21	6	0	1	100.0
22	4	17	27	61.4
23	4	13	18	58.1
24	7	15	58	79.5
25	4	20	25	55.6
26	4	0	0	0.0
27	4	9	45	83.3
28	5	7	8	53.3
29	5	8	16	66.7
30	6	3	4	57.1
31	5	21	28	57.1
32	5	3	7	70.0
33	6	2	4	66.7
34	7	8	32	80.0
35	7	4	10	71.4
36	6	1	2	66.7
37	6	1	2	66.7
38	7	2	9	81.8
39	8	6	23	79.3
40	8	2	4	66.7
41	8	6	37	86.0
42	8	1	12	92.3
43	8	4	50	92.6

Table 7. Lake Classes included in various Lake Class groups, the range of Lake-Class mean values for limnological variables in the groups (Schupp 1992, revised), and number of walleye stocking successes and failures by Lake Class group, for Minnesota lakes, as reported by Minnesota DNR Section of Fisheries staff. Determination of success or failure was based on attainment of management goals, assessment data, creel survey data, fish community effects, or natural reproduction data.

	Limnological variables					
Lake Class group	Surface area (acres)	Maximum depth (ft)	Percent littoral area	Total alkalinity (ppm)	Secchi Disk (ft)	SDF[1]
1	263-29,504	45-139	22-46	12-38	8-18	1.9-7.3
2	18-279	16-61	28-97	8-63	7-17	1.4-3.1
3	20-1,242	6-17	97-100	12-61	4-10	1.3-2.5
4	289-109,308	51-102	30-48	112-149	6-15	1.4-2.8
5	78-256	32-55	37-63	25-148	9-13	1.4-2.1
6	37-70	13-39	60-99	23-147	5-11	1.4-1.5
7	240-429	26-45	52-86	100-193	4-8	1.4-2.6
8	48-2,321	9-16	98-100	99-185	2-6	1.4-2.6

Reported Stocking Success

Lake Class	Lake Classes included	Reported stocking success		
		failures	successes	percent successful
1	1, 2, 3, 5, 7	22	28	56.0
2	4, 6, 8, 9, 10, 11, 13, 14	19	28	59.6
3	12, 15, 16, 17, 18, 19	30	27	47.4
4	22, 23, 25, 26, 27	59	115	66.1
5	20, 28, 29, 31, 32	40	61	60.4
6	21, 30, 33, 36, 37	7	13	65.0
7	24, 34, 35, 38	29	109	79.0
8	39, 40, 41, 42, 43	19	127	87.0
All groups	All classes	225	508	69.3

[1] SDF is the ratio between the length of shoreline of the lake and the circumference of a circle of the same area.

Table 8. Chi-square *p*-values testing the hypothesis of independence between stocking success and the environmental and management variables[2] and the species abundance variables[3]. Variables with underlined p-values were found to be significant (*P*<0.05) in a single-variable logistic regression of the variable on the dependant variable for stocking success. The sign of the regression coefficient is in parentheses - a plus indicates increased stocking success with higher levels of the variable, a negative indicates an inverse relationship. ND indicates that some expected cell values were too low for valid Chi-square analysis.

	Lake Class Group								
Variable	1	2	3	4	5	6	7	8	All
GROUP									**0.00** (+)
SURFCAT	**0.04** (-)	**0.02** (-)	0.64	ND	0.28	ND	ND	0.0	0.04
LPCENT	0.21	0.24	ND	0.41	0.60	ND	ND	0.70 (+)	**0.01**
SIZE2	0.24	0.16	0.09	**0.01** (+)	0.48	ND	ND	ND	**0.00** (+)
FREQ2	ND	ND	ND	**0.04** (-)	0.90	ND	ND	0.09	**0.00** (-)
FRYLA	ND	ND	ND	ND	ND	ND	ND	ND	0.54
FRYSA	ND	0.44	ND	ND	ND	ND	ND	ND	0.32
FING	ND	ND	ND	ND	ND	ND	ND	ND	0.33
NOP	0.25	0.08	0.57	0.46	0.07	ND	**0.04** (-)	0.63	**0.02** (-)
CRP	0.17	ND	ND	0.09	0.48	ND	0.08	0.13	**0.01** (+)
CAP	ND	ND	ND	0.97	ND	ND	0.75	0.42	0.04
BLB	ND	ND	ND	0.39	0.64	ND	0.30	0.37	0.01
TLC	ND	ND	ND	0.30	ND	ND	ND	ND	**0.03** (-)
WTS	0.21	0.06	0.66	0.48	0.78	ND	0.62	0.73	0.83
BAS	0.32	ND	ND	0.46	0.37	ND	0.67	ND	0.62
YEP	0.27	0.10	0.87	0.32	**0.01** (+)	ND	0.06	0.61	**0.03** (+)

1 Logistic regression models yield values of ln(p/(1-p)), where p = probability of successful stocking, and p/(1-p) = odds that stocking will be successful. Negative values for coefficients indicate that odds of success are reduced as the value of that variable increases.

2 SURFCAT (surface area) = 1 (0-150 acres), 2 (151-500 acres), 3 (501-2,000 acres), 4 (2,001-10,000 acres), or 5 (> 10,000 acres). LPCENT (percent littoral) = 1 (0-25), 2 (26-50), 3 (51-75), or 4 (76-100). SIZE@ = 1 (fry), 2 (fry and fingerlings), or 3 (fingerlings). FREQ2 (stocking frequency) = 1 (triennial), 2 (biennial), 3 (two of three years), 4 (three of four years), or 5 (annual). FRYLA (fry stocking rate by littoral acre) = 1 (<1,000/LA), 2 (1,000/LA), 3 (1,000-2,000/LA), or 4 (>2,000/LA). FRYSA (fry stocking rate by surface acre) = 1 (<1,000/SA), 2 (1,000/SA), or 3 (>1,000/SA). FING (fingerling stocking rate) = 1 (<0.5 lb/LA), 2 (0.5-1.0 lb/LA), 3 (1.0-2.0 lb/LA), 4 (2.0-3.0 lb/LA), or 5 (>3.0 lb/LA).

3 Species abundance variable values(YEP, NOP, CRP, CAP, BLB, TLC, WTS, and BAS) ranged from 1 (CPUE in first quartile range for Lake Class group) to 4 (CPUE in fourth quartile range).

Table 9. Number of walleye stocking successes and failures by Lake Class group and size walleye stocked (fry or fingerling), in Minnesota lakes, as reported by Minnesota DNR Section of Fisheries staff. Determination of success or failure was based on attainment of management goals, assessment data, creel survey data, fish community effects, and natural reproduction data.

	Fry stocking			Fingerling stocking		
Lake Class group	Failures	Successes	Percent successful	Failures	Successes	Percent successful
1	12	12	50.0	8	16	76.7
2	14	15	51.7	5	13	72.2
3	24	16	40.0	6	11	64.7
4	21	17	44.7	37	94	71.8
5	8	10	55.6	32	48	60.0
6	3	6	66.7	3	6	66.7
7	17	28	62.2	11	76	87.4
8	14	85	85.9	4	35	89.7
All groups	113	189	62.6	106	299	73.8

Table 10. Number of walleye stocking successes and failures by Lake Class group and fingerling or fry stocking rate in Minnesota lakes, as reported by Minnesota DNR Section of Fisheries staff. Determination of success or failure was based on attainment of management goals, assessment data, creel survey data, fish community effects, and natural reproduction data. LA = littoral acres, SA = surface acres.

	Lake Class Group								
Stocking rate	1	2	3	4	5	6	7	8	All
Fingerling									
0.5-1.0 lb/LA									
successes	13	10	7	71	39	4	57	26	227
failures	5	4	4	25	17	3	7	3	68
percent success	72.2	71.4	63.6	74.0	69.6	57.1	89.1	89.7	76.9
< 0.5 lb/LA									
successes	3	1	3	1	0	ND	4	2	14
failures	3	1	1	0	1		0	0	6
percent success	50.0	50.0	75.0	100.0	0.0		100.0	100.0	70.0
> 1.0 lb/LA									
successes	1	ND	ND	23	10	2	19	4	59
failures	0			9	14	0	6	1	30
percent success	100.0			71.9	41.7	100.0	76.0	80.0	66.3
> 2.0 lb/LA									
successes	ND	ND	ND	3	1	1	4	1	10
failures				3	3	0	0	0	6
percent success				50.0	25.0	100.0	100.0	100.0	62.5
Fry									
1,000/LA									
successes	1	1	3	8	5	3	18	31	70
failures	0	0	1	9	3	0	10	2	25
percent success	100.0	100.0	75.0	47.1	62.5	100.0	64.3	93.9	73.7
> 1,000/LA									
successes	4	3	2	4	1	1	3	8	26
failures	0	0	3	7	0	0	1	1	12
percent success	100.0	100.0	40.0	36.4	100.0	100.0	75.0	88.9	68.4
> 2,000/LA									
successes	2	2	0	2	ND	1	ND	4	11
failures	0	0	1	1		0		1	3
percent success	100.0	100.0	0.0	66.7		100.0		80.0	78.6
1,000/SA									
successes	6	3	2	1	0	0	1	0	13
failures	2	6	1	1	2	1	1	1	15
percent success	75.0	33.3	66.7	50.0	0.0	0.0	50.0	0.0	46.4
> 1,000/SA									
successes	0	5	8	1	2	ND	ND	0	16
failures	3	7	20	1	1			3	35
percent success	0.0	41.7	28.6	50.0	66.7			0.0	31.4

Table 11. Use of the age effect from the year class strength model for a lake with fast growth and moderate exploitation to adjust the gill net CPUE from a 1994 survey.

Age	Year	Stock	Catch	Actual CPUE	Adjusted CPUE
1	93	Fry	61	4.07	13.9
2	92	Fing	23	1.53	0.75
3	91	Fing	58	3.87	2.17
4	90	None	6	0.40	0.39
5	89	Fry	1	0.07	1.44
6	88	None	26	1.73	5.64

Table 12. Median, first quartile, and third quartile values, by Lake Class group and for all groups, for fishing pressure (angler-h/acre), walleye harvest rate (fish/angler-h), targeted walleye harvest rate (fish/angler-h), and walleye yield (lb/acre), from summer creel surveys conducted on Minnesota lakes supporting walleye fisheries. N = number of lakes. Data from multiple creel surveys on single lakes were averaged.

	Lake Class Groups								
Variables	1	2	3	4	5	6	7	8	All
Fishing pressure									
median	6.6	11.3	10.5	20.0	38.3	157.8	49.7	22.0	23.2
first quartile	3.4	3.4	5.7	13.2	20.8	ND	32.6	13.4	12.8
third quartile	13.1	14.6	25.2	28.9	44.2	ND	70.6	49.2	40.9
N	16	6	3	61	11	2	34	14	148
Harvest rate									
median	0.15	0.16	0.03	0.09	0.02	<0.01	0.01	0.04	0.05
first quartile	0.06	0.06	0.02	0.02	<0.01	ND	<0.01	<0.01	0.01
third quartile	0.17	0.20	0.13	0.16	0.06	ND	0.03	0.06	0.13
N	16	6	3	60	10	2	33	14	145
Targeted harvest rate									
median	0.19	0.12	0.04	0.20	0.15	ND	0.11	0.09	0.16
first quartile	0.15	ND	ND	0.14	0.07	ND	0.02	0.04	0.08
third quartile	0.25	ND	ND	0.26	0.19	ND	0.19	0.18	0.23
N	11	2	2	23	5	0	7	4	55
Yield									
median	0.94	1.16	1.63	1.57	0.92	0.19	0.38	1.00	1.03
first quartile	0.37	0.03	0.21	0.77	0.27	ND	0.09	0.25	0.27
third quartile	1.51	2.39	2.29	3.20	2.85	ND	1.42	2.94	2.59
N	16	6	3	61	10	2	34	14	147

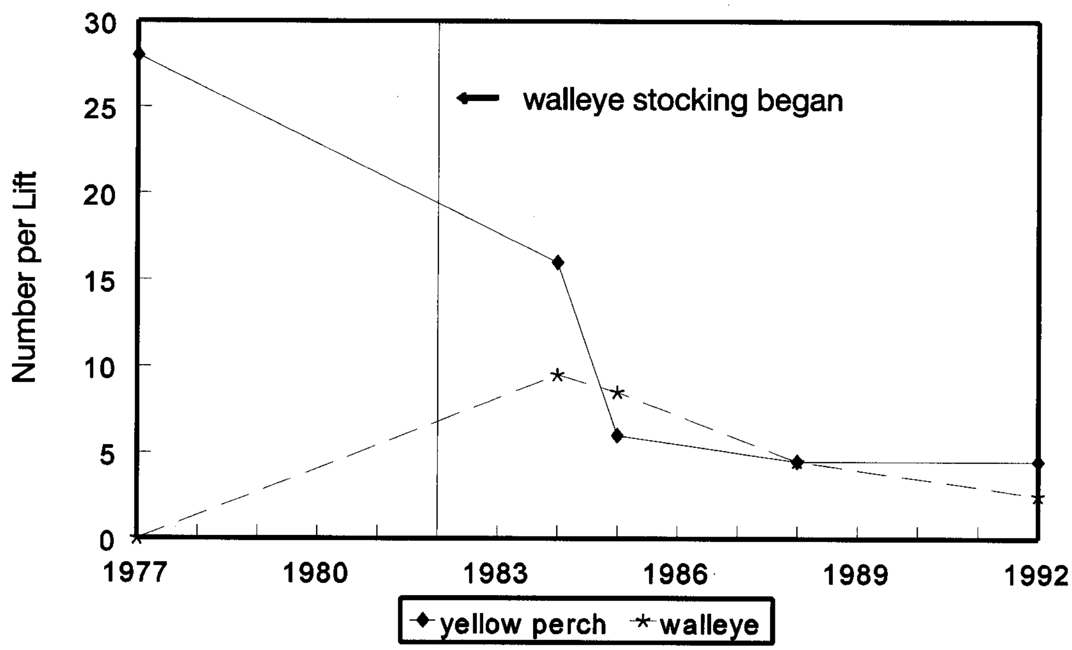

Figure 1. Catch per unit effort for yellow perch and walleye collected by gill nets in Agassa Lake, St. Louis County, Minnesota, 1977-1992.

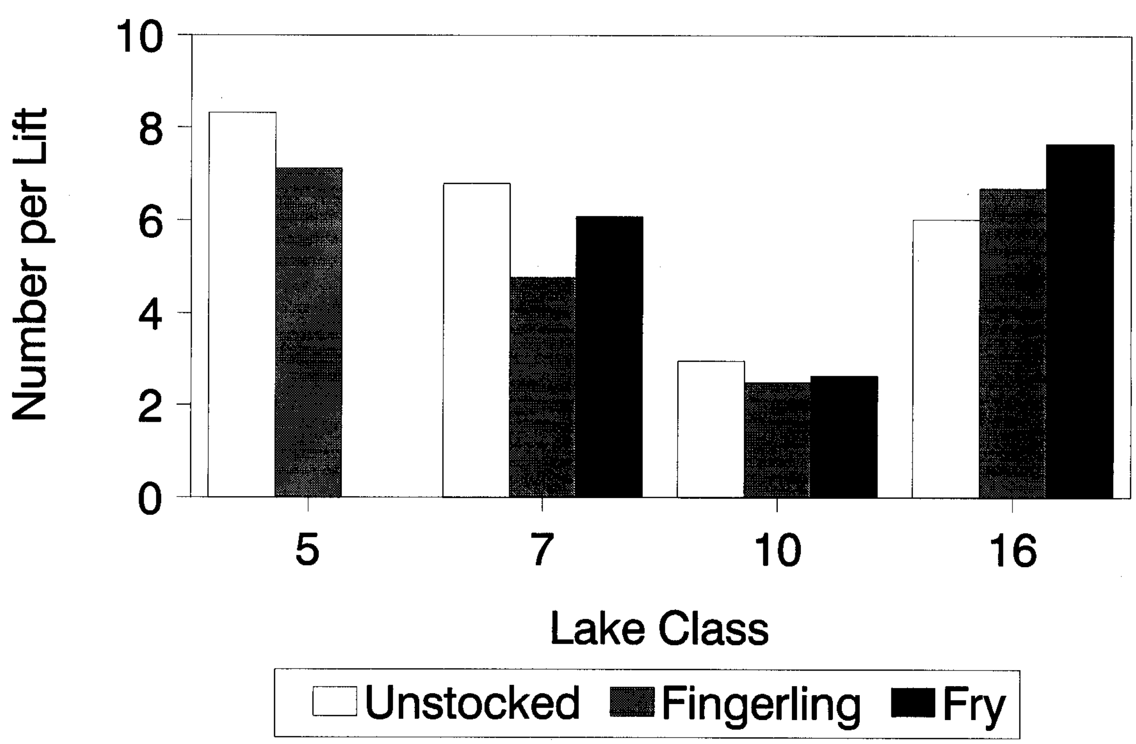

Figure 2. Mean gill net CPUE for walleye in unstocked lakes and lakes stocked with fry and fingerlings for Lake Classes 5, 7, 10, 16.

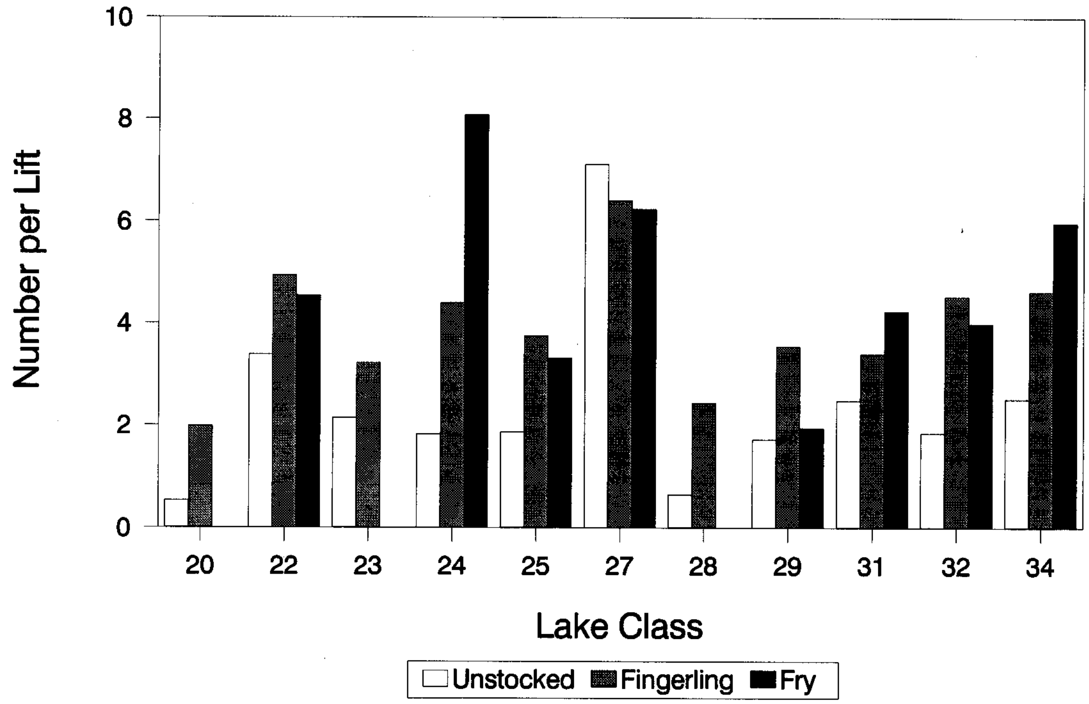

Figure 3. Mean gill net CPUE for walleye in unstocked lakes and lakes stocked with fry and fingerlings for Lake Classes 20 to 34.

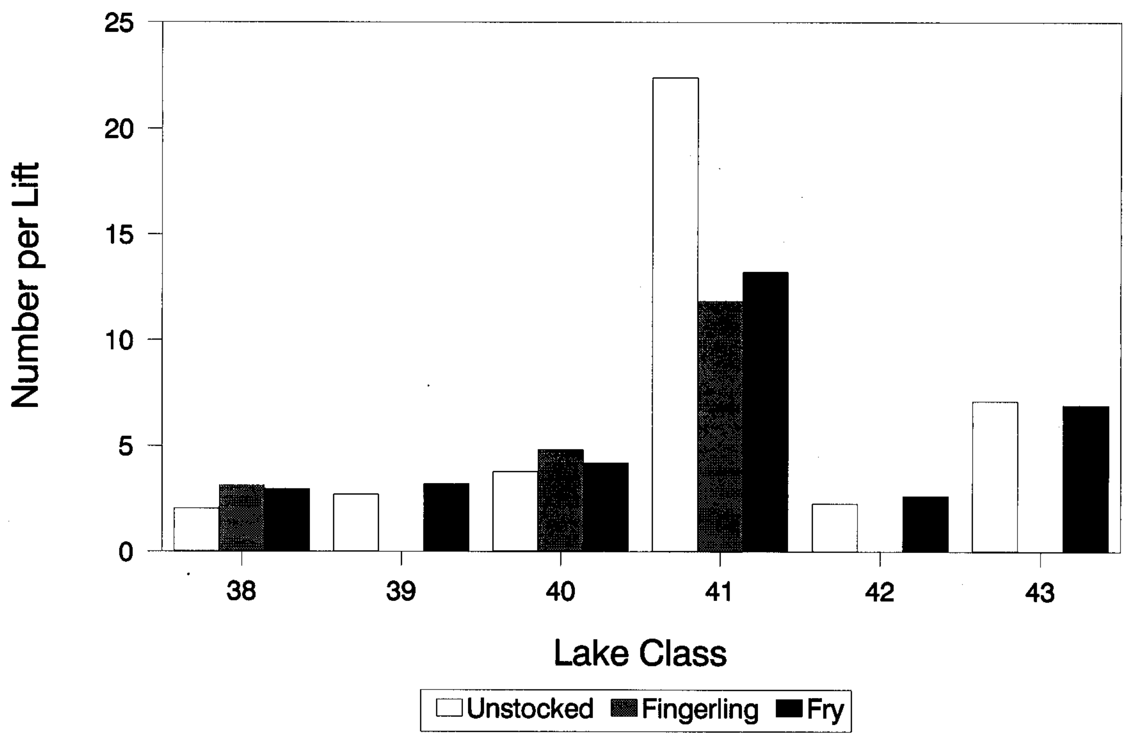

Figure 4. Mean gill net CPUE for walleye in unstocked lakes and lakes stocked with fry and fingerlings for Lake Classes 38 to 43.

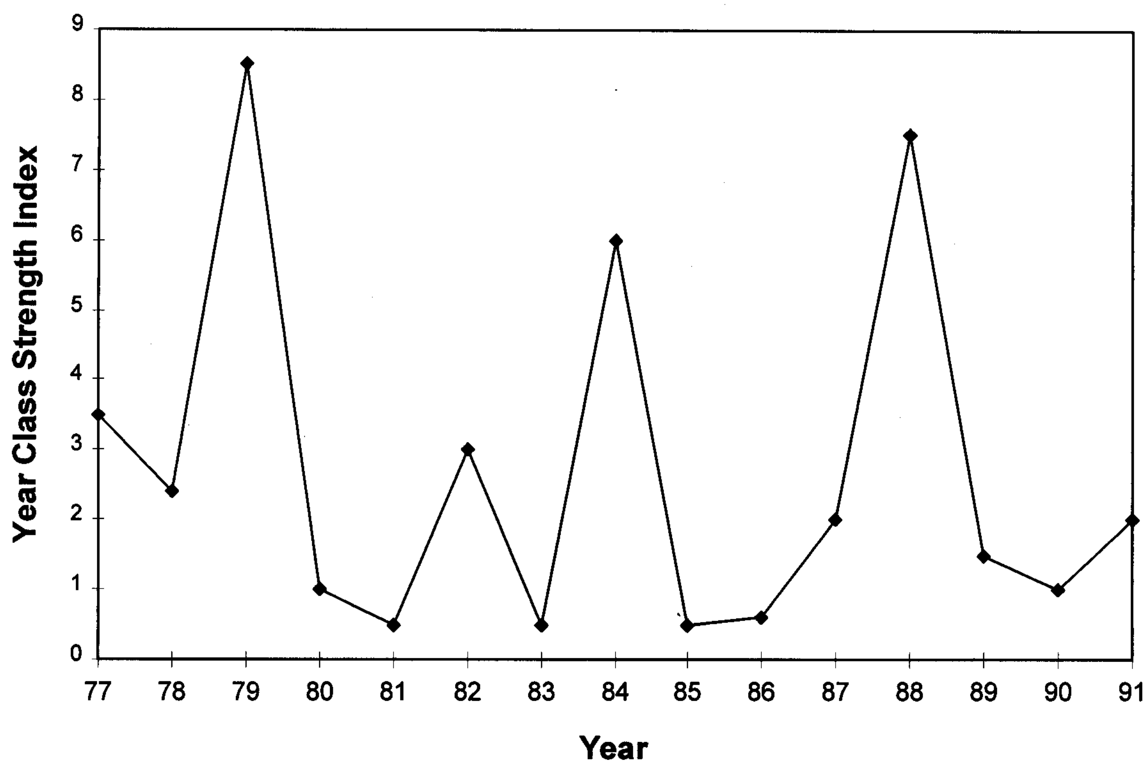

Figure 5. Index of year class strength of walleye in Mille Lacs Lake, estimated from gill net CPUE at ages 2-5 (Pereira et al. 1993).