An Evaluation of Stocking Strategies in Wisconsin with an Analysis of Projected Stocking Needs

by

The Bureau of Fisheries Management and Habitat Protection
101 S. Webster Street
P.O. Box 7921
Madison, Wisconsin 53707-7921

for

The Joint Legislative Audit Committee
State Capitol
Madison, Wisconsin 53703

April 1999

WISCONSIN
DEPT. OF NATURAL RESOURCES

NOTES

Contents

Report Summary

In 1997, the Wisconsin Legislative Audit Bureau published a report on the Department of Natural Resources' (DNR) fish propagation and stocking programs, entitled *An Evaluation – Fish Stocking – Department of Natural Resources – Report 97-9*, which recommended the DNR evaluate several aspects of its stocking program. This report specifically addresses the long-range stocking goals for the DNR and projected long-term propagation needs using the best available scientific information. This plan promotes the most effective use of stocking in the overall management of Wisconsin's fisheries using a goal-oriented, species- and water-specific approach that minimizes impacts to existing self-sustained populations.

Species-specific stocking guidelines were reviewed and, where needed, revised to reflect current scientific knowledge. Recommended changes include: a shift from domestic to wild trout for the inland trout program; reduced emphasis on the maintenance stocking of bass; an increase in restorative sturgeon stocking; an increased emphasis on evaluation of muskellunge stocking practices; northern pike stocking based on suitable habitat and published survival rates resulting in increased opportunities for stocking; opportunities for increased walleye stocking; and, no major changes to the Great Lakes trout and salmon stocking program. Overall recommendations include protection of existing naturally reproducing populations, more evaluation and use of appropriate genetic strains, long-term quota development, elimination of per-water maximums for planning purposes to better identify potentials for contract or cooperator involvement; and the formation of a stocking team that keeps stocking and propagation on the cutting-edge of fisheries management.

Based on the best available information, annual stocking of over 11 million fish (primarily fingerlings) is needed to sustain and enhance the sport fishery in Wisconsin (Table 1). This projected level of stocking was arrived at independent of current hatchery production capacity.

Table 1. Summary of Projected Wisconsin Stocking Goals

Fish Species (size)	Statewide Annual Stocking Goal
Walleye (2″- 4″ fingerlings)	6.5 million
Muskellunge (7″+ fingerlings)	140,000
Northern Pike (3″-7″ fingerlings)	150,000
Black bass (2″ fingerlings)	210,000
Lake Sturgeon(3″+ fingerlings)	75,000
Inland Trout	1.5 million
Great Lakes Trout and Salmon	2.5 million
Grand Total	11.1 million

I. INTRODUCTION

Advances in propagation techniques, a greater understanding of the need for ecosystem management and genetic conservation, and recent renovations to the hatchery system have all led to recent revisions of management strategies for many of Wisconsin's popular fisheries. As such, management goals, and associated stocking guidelines, have been under review for many of the major fisheries in the state. The recent legislative audit of the department's propagation program specifically prompted a consolidated review and description of our stocking practices.

Updated stocking guidelines are intended to 1) provide the hatchery system with better information for production planning, 2) ensure the most efficient use of hatchery products needed for management purposes, and 3) ensure the most prudent management of Wisconsin's exploited stocks and associated communities and ecosystems. This planning effort was initiated to evaluate and update, where needed, our stocking practices and to develop a statewide plan for the uses of, and demands for, stocked fish.

Clearly, stocking can not be considered in a vacuum. Central to this effort was a review and revision, where necessary, of the overall *management goals* for the various fisheries of the state. The ultimate success of any stocking strategy should be judged based on its contribution to achieving those management goals. Species-specific stocking strategies can then more efficiently address where, how many, what size, and what types (e.g., strain) of fish are needed to meet overall program goals. This report suggests how many fish <u>should</u> be raised to meet the overall management goals of the program, not how many <u>could</u> be raised.

The major fish species stocked by the Department of Natural Resources are addressed in this report: Inland trout (domestic and wild strains), Great Lakes trout and salmon, black bass, lake sturgeon, muskellunge, northern pike, and walleye. Existing *species management committees*, which included internal and external partners, reviewed, revised and updated management goals and developed stocking strategies to ensure that the management goals are met. The groups compiled available stocking evaluations statewide, examined current scientific literature, and reviewed other available information to produce up-to-date stocking strategies. Stocking procedures for each species include suitable waters, sizes and numbers to stock, strain management, and projected changes in statewide production. This report presents the "desired state" for our stocking program and should be viewed as a working document that is open to continuous improvement and update. The recommendations contained herein should be implemented as opportunities arise.

MANAGEMENT GOALS

The various species-specific committees independently developed management goals for the major fisheries of the state. Many similarities existed among the species-specific goals. What follows is a consolidated list of fisheries management goals for the state that incorporates most of the goals from the species-specific groups:

I. Protect, restore and enhance fisheries habitat on Wisconsin waters

II. Protect, restore and enhance Wisconsin's self-sustained fisheries, fish assemblages and aquatic communities

III. Provide a variety of quality fishing opportunities (e.g., trophy, action, harvest) within a flexible management system

IV. Ensure that resource managers have the necessary information on the status of Wisconsin's fisheries and aquatic ecosystems

V. Provide technical assistance and educational opportunities to Wisconsin's citizens and anglers, promote the value of Wisconsin's fisheries and ensure angling opportunities for future generations

STOCKING STRATEGIES

Stocking is generally used as part of an integrated approach in the management of a waterbody which also considers habitat restoration or improvement, harvest regulations, public access, and public education and involvement. As part of a management plan, stocking would be used to accomplish specific, stated objectives for the waterbody through one of the following strategies:

Introduction.- This strategy includes instances where a species is introduced into a newly created water or to expand the range of a species. Ideally, the introduction results in the establishment of a self-sustained fishery with minimal impacts on existing fisheries.

Rehabilitation.- An interim measure to re-establish formerly self-sustained populations that have been extirpated or severely reduced by catastrophic natural or intentional sources of mortality (e.g., winterkill, disease, chemical spill, mechanical removal, drainage of fowages, dam failures, chemical reclamation).

Research or Evaluation. – Experimental stocking done in conjunction with a research or evaluation project intended to determine the cost-effectiveness of stocking practices or other management actions.

Remediation (maintenance). – Stocking to maintain an existing fishery that has been reduced due to external impacts (e.g., loss of spawning habitat, invasion of exotic species, long-term changes in species composition) that cannot be readily corrected. This strategy would also include instances where restoration of predator/prey imbalance is sought.

Recreation (maintenance).– Stocking to create or maintain a recreational fishing opportunity that did not previously exist and is not self-sustaining. This type of fishery will usually have some effect on existing fisheries and is typically dependent upon stocking for continued existence.

All of these stocking strategies are currently used on Wisconsin waters. Priority is usually given to rehabilitation stockings that promise to establish self-sustained fisheries, or to research or evaluation stockings that promise to improve the cost-effectiveness of stocking practices. Recreation stockings are generally a relatively costly management activity but are often needed to sustain popular fisheries in many waters. Remediation stockings are used only as a last resort after attempts to correct underlying problems have failed and the maintenance of a stocked fishery is desired.

We currently discourage introductions of species except in newly created waters such as reservoirs or constructed ponds.

STOCKING GUIDELINES

Specific stocking guidelines for each species were developed to provide guidance for staff in making biologically sound stocking recommendations for a particular water and to allow for equitable and cost-effective allocation of limited hatchery production In the first set of guidelines, based on the best available biological information, stocking must:

1) Address the management goal(s) for the species of interest;

2) Minimize negative impacts on existing self-sustained fisheries, including safeguards to protect the integrity of native and naturalized stocks and consider interactions and potential impacts on other species; and

3) Be biologically sound (i.e., likely result in fishable populations) based on the best available scientific knowledge.

The second set of guidelines, based primarily on inevitable limitations in production from the hatchery system, consider allocation rules for limited production. Stocking requests should:

1) Be cost effective, as measured by cost per recruit to the populations or cost per fish returned to the creel;

2) Ensure equitable distribution of limited hatchery production; and

3) Utilize contracting or cooperative agreements with private aquaculture and volunteer groups, where cost-effective.

The primary purpose for the first set of guidelines is to assist fisheries biologists in developing long-term management objectives for specific waters. The second set of guidelines will allow the Department hatchery system to equitably and cost-effectively allocate production for maximum benefit, as measured by return to the angler creel. The difference, if any, between long-term stocking recommendations and Department hatchery allocation represents opportunities for contract development or cooperative agreements with private businesses or volunteer groups, or for the state to consider investments in the Department hatchery system.

In this report, we present recommendations based primarily on the best available scientific information. This allows comparison of statewide need with existing facility capacity, as described in an earlier report to the legislature (DNR 1998). However, a blend of biological and production-allocation criteria have historically been used in Department stocking guidelines. In instances where scientific information is equivocal, historic practices are retained in the current recommendations. Thus, true demand for stocked fish is difficult to accurately assess because past stocking requests have been tempered by production-allocation criteria through this historic blend of guidelines.

STOCK INTEGRITY AND NATURAL REPRODUCTION

A central goal for all management of Wisconsin fisheries should be to ensure the protection of existing self-sustained populations. Native and naturalized populations that are self-sustained through natural reproduction clearly provide the best fishing opportunities in the state (Figures 1 and 2), are the most cost-effective to manage and, if impacted or lost, can not be easily replaced. Stocking should, first and foremost, be considered an important restoration tool used to reestablish naturally reproducing populations.

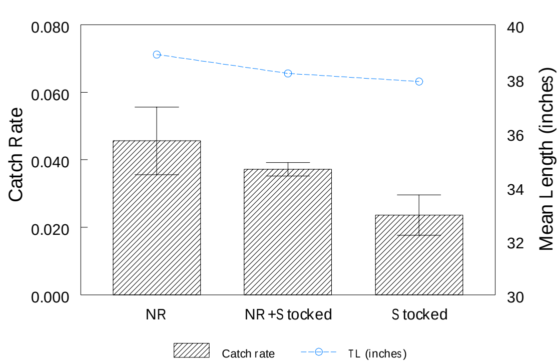

Figure 1. Muskellunge catch rate and mean length by reproductive category. (NR = natural reproduction)

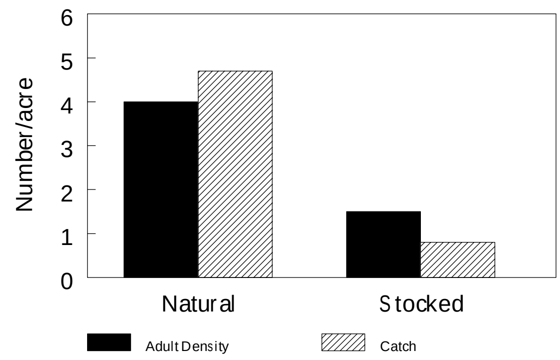

Figure 2. Comparison of density and catch information on natural versus stocked walleye fisheries, 1990-1995.

Recently, considerable work has been done on the differentiation, fitness, and performance of individual populations within a species (Philipp et al. 1983; Gharrett et al. 1988; Beachum et al. 1989; Krueger et al. 1989; Philipp 1991). The “stock concept” (i.e., managing individual breeding populations) has been bolstered over the last decade with improved technology (ability to discern stocks; see Ryman and Utter 1987) and documentation of the superior performance of “locally adapted” populations (see, e.g., Philipp and Claussen 1995). Indiscriminate transfer and mixing of stocks negatively affects the genetic resources of a species by reducing genetic diversity among populations and by decreasing the genetic fitness of locally adapted populations through outbreeding depression (i.e., when genetically different populations interbreed to produce inferior offspring).

In an experiment conducted by Illinois researchers, bass from Florida, Illinois, Wisconsin, and Texas were stocked together in lakes in all four locations. In each location the survival, growth, and reproduction of the local fish were best; nature had already produced the best adapted fish for the local conditions. However, the few surviving transplants interbred with the locals and eventually all the bass in the lakes were hybrids with inferior performance relative to the local stock (*see* Jennings 1996 for an overview). A similar experiment was conducted at a smaller scale by transplanting bass from two different watersheds in Illinois. In this study, similar results were found: local stocks had better performance (growth and survival) and fitness (reproduction). These studies suggest that indiscriminate stocking of bass in waters with naturally reproducing populations will likely result in more harm than good.

We recommend a conservative approach that reasonably assumes that these results are applicable to other freshwater fish species, pursuant to Goal II, above. Fields et al. (1997) also recommends this approach. As such, we recommend that no stocking take place in waters with self-sustained fisheries of the species in question unless the stocked fish originate from that population.

Fields et al. (1997) developed a series of recommendations for the sources of stocked fish based on the reproductive status of the population in the receiving water (Table 2).

STOCKING PLANS AND QUOTA REQUESTS

In developing new requests for fish from the hatchery system, fisheries biologists should evaluate the overall management goals, the specific objectives for the basin and the waterbody, determine a desired state for the fishery, select a long-term stocking strategy for the species of interest, and select stocking practices that will achieve the desired state. Generally, a 10-year stocking plan should be developed to fully evaluate whether the desired state has been reached. Recommended stocking guidelines for each of the stocking strategies, developed by teams of biologists and species-specific experts from throughout the state, are presented below to guide fisheries biologists. Evaluations of other stocking practices are also encouraged and should be supported by a research or evaluation project to ensure the most efficient use of hatchery and fiscal resources.

II. SPECIES-SPECIFIC STOCKING GUIDELINES

The stocking guidelines presented in this report address the major fish species stocked by the Department of Natural Resources: Great Lakes trout and salmon, inland trout (domestic and wild strains), black bass, lake sturgeon, muskellunge, northern pike, and walleye. This portion of the report is divided into two sections: 1) cold water species and 2) warm water species which will facilitate comparisons with DNR cold water and warm water hatchery capacity.

Within each management goal, each committee described:

1) The stocking strategy (e.g., rehabilitation, remediation, recreation, etc.), if any, recommended to achieve the goal;
2) Waters appropriate for the application of that stocking strategy;
3) The recommended stocking guidelines

Table 2. Stocking decisions for conservation on native stocks (modified from Fields et al. 1997. "NR" means natural reproduction; "Basin stock" means the brood stock originates from within the major basin.

Stock Origin	Reproductive Status	Recommended source of broodstock
Native to waterbody	Self sustained through NR	Fish should not be stocked
	Some NR; not self sustained	From that waterbody
	Dependent on stocking	Basin stock
	Extirpated (rehabilitation)	Basin stock
Introduced to waterbody; native to basin	Self sustained through NR	Fish should not be stocked
	Some NR; not self sustained	From that waterbody
	Dependent on stocking or new introduction	Basin stock
Introduced to waterbody; not native to basin	Self sustained through NR	Fish should not be stocked
	Some NR; not self-sustained	From that waterbody
	Dependent on stocking or new introduction	Any source

associated with the respective stocking strategy, including:

a) The size of fish;
b) Rates of stocking;
c) Frequency (e.g., annual, biannual, etc.) of stocking; and
d) Duration (e.g., 5 consecutive years; biannually for 10 years) of stocking;

4) Criteria recommended to evaluate the effectiveness of the strategy – including the cost-effectiveness of the strategy.

5) Projected demand for fish from the hatchery system for the next 10 years.

COLDWATER SPECIES

GREAT LAKES TROUT AND SALMON STOCKING GUIDELINES

The Great Lakes trout and salmon stocking program can be traced back over a hundred years to the initial introductions of rainbow trout. The program has been greatly expanded in the past three decades, and now supports a vital and economically important fishery known throughout the world. Stocked trout and salmon are the backbone of a sport fishery that provides over 3,000,000 hours of relaxation and gainful entertainment to anglers each year. The program is reviewed below in three sections, an overview, a summary of the major management goals and strategies, and a discussion of the cost-effectiveness of the program.

Wisconsin's Great Lakes trout and salmon program involves the stocking of six species of fish – lake trout, brook trout, rainbow trout, brown trout, chinook salmon, and coho salmon – in Lake Michigan, Lake Superior, and tributaries. The splake, a cross between lake and brook trout, is also stocked in both lakes. This program provides sport-fishing opportunities, regulates the abundance and ecological impacts of alewives in Lake Michigan, and promotes restoration of naturally-reproducing populations of lake trout and rainbow trout.

This complex program, which involves the annual stocking of nearly 5 million fish, has been developed over a period of three decades. The program is operated in cooperation with agencies in Minnesota, Ontario, Michigan, Illinois, and Indiana, and in cooperation with sport fishers who provide funding through the purchase of fishing licenses and Great Lakes Trout and Salmon stamps.

The salmon and trout stocking program is part of a larger inter-jurisdictional fisheries management program on the Great Lakes, a program that involves sea lamprey control (funded by the Great Lakes Fishery Commission), a lake trout restoration program (funded primarily by the USFWS but supported by state agencies, including the Department), regulation of sport fisheries for other species, including yellow perch, smallmouth bass, walleye, sturgeon, and northern pike, and regulation of commercial fisheries on both lakes. Because state management programs, including the salmon and trout stocking program, affect other jurisdictions, the Department is a signatory to "A Joint Strategic Plan for the Management of Great Lakes Fisheries". That agreement among all state fisheries management agencies, two tribal management organizations and several Canadian and U.S. federal agencies provides a basis for joint management of all shared fisheries resources in the Great Lakes.

Current Stocking Practices. - The Department's stocking program is summarized in the table below. The primary goal of the program is to provide sport-fishing opportunities through a put-grow-and-take stocking program, but other goals are also served. On Lake Michigan the stocking of salmon and trout by four states and the USFWS has dramatically affected the ecosystem of Lake Michigan by reducing the abundance of the alewife, a non-indigenous species that had proliferated and become a major ecological and aesthetic pest by the mid 1960's. On Lake Superior the stocking of rainbow trout is intended to not only provide sport fishing opportunities, but also to enhance naturally reproducing populations in the Brule River and elsewhere.

The salmon and trout stocking plan for 1999-2000 (excluding lake trout stocked by the U.S. Fish and Wildlife Service), is summarized in Table 3.

Table 3. Proposed Great Lakes trout and salmon stocking for 1999-2000.

Species	Lake	Number stocked
Brook trout	Superior	0
	Michigan	160,080 — 109,700 fall fingerlings and 50,380 yearlings, all from domestic brood stock.
Brown trout	Superior	100,000 — all yearlings, half Seeforellen strain from feral Lake Michigan brood stock and half from a feral Soda Lake brood stock
	Michigan	1,232,940 — 682,200 fall fingerlings and 242,550 yearlings from domestic brood stock, and 308,190 Seeforellen strain yearlings from feral Lake Michigan brood stock.
Rainbow trout	Superior	100,000 — all yearlings from naturally-reproducing feral Brule River brood stock
	Michigan	500,300 — 169,900 Chambers Creek strain yearlings, 160,500 Ganaraska strain yearlings, and 169,900 Skamania strain yearlings, all from feral Lake Michigan brood stock
Lake trout	Superior	89,400 — all domestic yearlings
	Michigan	0
Splake	Superior	120,000 — all yearlings from domestic brood stock
	Michigan	40,000 — all yearlings from domestic brood stock
Chinook salmon	Superior	400,000 — all spring fingerlings from feral Lake Michigan brood stock
	Michigan	1,467,000 — all spring fingerlings from feral Lake Michigan strain brood stock
Coho salmon	Superior	0
	Michigan	498,000 — 100,000 fall fingerlings and 398,000 yearlings, all from feral Lake Michigan brood stock

The Great Lakes fisheries management program benefits from extensive public involvement. For example, over 150 individuals participated in the development of the Lake Michigan Integrated Fisheries Plan, 1995-2001. During 1998, a lake-wide review of stocking levels for Lake Michigan involved a public stocking conference held in Benton Harbor, Michigan and three open public meetings in Green Bay, Cleveland, and Milwaukee. Lake-wide conferences of that type have also been held to involve the public in management decisions related to coho salmon and yellow perch. Also, because a significant portion of the cost of obtaining, rearing, and stocking salmon and trout is covered by receipts from the sale of Great Lakes Trout and Salmon Stamps, a biennial report of those expenditures is prepared and circulated widely for public comment.

This report is limited to fisheries management goals directly served by the Department's stocking program. More complete reviews of the fisheries management programs on Lake Superior and Lake Michigan are provided in the Lake Superior Fisheries Management Plan, 1988-1998 and the Lake Michigan Integrated Fisheries Management Plan, 1995-2001. This discussion of stocking strategies does not include the stocking of lake trout in Lake Michigan or Lake Superior by the US Fish and Wildlife Service for the purpose of restoring naturally reproducing populations. Those programs are overseen by all the management jurisdictions on the lakes and supported by appropriate state and tribal harvest regulations. The Department does not stock lake trout in the Great Lakes except for limited stocking in the Western end of Lake Superior to enhance the sport fishery.

Specific Great Lakes Trout and Salmon Goals and Strategies. - The fisheries management goals for the Great Lakes, including the salmon and trout stocking objectives, are described in the Lake Superior Fisheries Management Plan, 1988-1998 and the Lake Michigan Integrated Fisheries Management Plan, 1995-2001. Because the purpose of this review is to assist in the evaluation of the Department's hatchery system, we are listing here only the goals and strategies that have direct implications for how fish are obtained, reared, and stocked.

Goal — Provide sport fishing opportunities in Lake Michigan, Lake Superior, and tributaries.

Strategy: Stock a diverse mix of salmon and trout.

The table above summarizes stocking plans for the fall of 1999 and the spring of 2000. It illustrates a diverse mix of species, and reflects the expressed interests of the angling public. The major elements of this program varies little from year to year, reflecting a stable stocking strategy that has evolved over three decades.

Strategy: Select appropriate strains to provide quality and variety in fishing opportunities.

The Department continues to explore and develop the use of alternative strains of salmon and trout. The current mix of three rainbow trout strains used in Lake Michigan, for example, provides stream angling opportunities through most of the year, while also supporting the open lake rainbow trout fishery. Department biologists are currently looking into using other rainbow trout strains to provide near shore fishing opportunities in Lake Michigan. The use of Seeforellen brown trout has improved the quality of the brown trout fishery. Chinook salmon returning to one of the three spawning facilities on Lake Michigan, the Strawberry Creek weir, serve as our primary source for stocking. We do not know the genetic basis, if any, for distinguishing those chinook salmon from others, but, because those fish have performed better than chinook salmon taken at other facilities, it is important to continue to work with that strain.

Strategy: Match stocking to available forage.

Fish can be stocked in numbers that exceed the carrying capacity of the receiving ecosystem. This was illus trated in Lake Michigan in the 1980's when the alewife forage base declined under the pressure of intensive salmon and trout stocking. This resulted in declines in chinook salmon growth rates, increased prevalence of a stress-mediated disease, bacterial kidney disease, and widespread die-off of adult chinook salmon. In 1998 concerns about a possible repeat of those events led to a lake-wide review of the issue, involving management agencies in Michigan, Illinois, and Indiana, as well as Wisconsin, and also extensive public consultation.

Strategy: Distribute stocking to serve sport fishing needs.

Salmon and trout are stocked widely in the Great Lakes to serve angler needs. On Lake Michigan, the distribution of fish is guided by a computer model that takes into consideration the distribution of harvest, the distribution of facilities such as launch ramps, and the number of miles of tributary streams available to migrating salmon and trout.

Goal — Rehabilitate naturally-reproducing anadromous rainbow trout runs in the Brule River, a tributary to Lake Superior.

Strategy: Stock offspring of naturally reproducing rainbow trout.

On the Brule River past attempts to rehabilitate the naturally-reproducing population by stocking the offspring of stocked fish have not been successful. Currently a program of capturing adult rainbow trout that themselves were the products of natural reproduction in the Brule River, and stocking their offspring back into the Brule River, is being pursued and evaluated.

Strategy: Evaluate alternative ages for stocking.

The Brule River rehabilitation program has involved the stocking of rainbow trout at different ages. For 1999-2000, yearling rainbow trout will be stocked, and the success of those plants will be compared with the success of plants of younger ages.

Goal — Minimize disease in wild fish populations.

Strategy: Limit importation of new salmon and trout strains into the Great Lakes drainage basin.

Because of the high risk of importing virulent diseases, Wisconsin along with other Great Lakes states subscribes to the Great Lakes Fish Disease Control Policy and Model Program, developed by the interagency Great Lakes Fish Health Committee of the Great Lakes Fishery Commission. This program includes stringent limitations on the importation of fish from outside the Great Lakes basin.

Strategy: Cull sick fish at the weir.

In order to limit the spread of infectious diseases, especially bacterial kidney disease, adult salmon and trout are examined and fish that have clinical signs of disease are not used for propagation.

Goal — Maintain genetic diversity within individual species.

Strategy: Use feral brood stocks to the extent possible.

Feral brood stocks are fish that swim wild in the lakes. They are collected in fall or spring when they return to tributaries to reproduce, and are mated to produce the next generation of fish for stocking. They are distinguished from domestic brood stocks, which are adult fish held in hatcheries for propagation purposes. Feral brood stocks are a superior source for propagation. Because they have survived in the open lakes, they are known to possess desirable genetic properties. Also, because huge numbers of fish are included in the feral brood stocks, they allow the maintenance of desirable broad genetic diversity.

Strategy: Maximize the numbers of breeding pairs used in propagation.

The preservation of genetic diversity within individual species is vital to the long-term health of the stocking program. Therefore, protocols are followed that assure the use of the largest numbers of breeding pairs that is feasible.

Strategy: Use breeding pairs from throughout a run.

Because the timing of spawning runs is, in part, genetically programmed, the preservation of genetic diversity also requires the use of parent fish from all parts of a spawning run.

Goal — Evaluate propagation strategies

Strategy: Compare returns from different breeding, rearing, and stocking strategies.

To continually improve rearing and stocking practices, special studies are conducted to evaluate stocking strategies. For example, the stocking of fall-fingerling coho salmon has been compared with the stocking of yearlings, the stocking of rainbow trout reared to different ages is being studied on the Brule River, and the importance of age-at-spawning is being studied in chinook salmon.

Cost-effectiveness of the Great Lakes Stocking Program. - The salmon and trout stocking program has had a large impact on the economies of the Great Lakes States. According to the American Sportfishing Association (ASA), in 1996 all sport fishing on all five of the Great Lakes generated expenditures of $1.9 billion, economic output of $5.4 billion, and earnings of $1.4 billion, while supporting 60,298 jobs. These figures include sport fisheries not supported by stocking (for example the large walleye fishery in Lake Erie), but stocked salmon and trout are responsible for a significant share of this economic activity. Wisconsin residents benefit greatly. The same ASA survey suggested Great Lakes fishing in Wisconsin accounted for $100 million in direct expenditures, $200 million economic output, and supported 3,214 jobs.

This represents a substantial return in economic activity for a Department program that costs less than $2.5 million annually, and that is not only entirely supported by anglers, but is largely supported by the direct beneficiaries, the trout and salmon anglers. Approximately $1.2 million is provided annually by anglers through the purchase of Great Lakes Salmon and Trout Stamps and 2-day Great Lakes Licenses (Keim 1998).

The total cost of Wisconsin's Great Lakes fishery management program is approximately $2.5 million, but that includes costs of assessing the salmon and trout fishery, costs of managing a large commercial fishery, and costs related to management of yellow perch, smallmouth bass, walleye, and other species not considered part of the trout and salmon program. The actual cost of obtaining, propagating, rearing, and stocking salmon and trout for the Great Lakes is approximately $1.7 million per year.

Cochrane and others (1992), analyzed salmonid stocking costs for Wisconsin waters of Lake Michigan. They found that chinook salmon fingerlings were the least expensive of all species at $0.35 per captured fish, and brook trout yearlings the most expensive at $12.67 per captured fish.

There are at least three cost/benefit ratios that can be computed to measure the value and effectiveness of this program. One measure of the relationship between costs and benefits is suggested above; it is the ratio of the cost of the program ($1.7 million) to the amount of direct economic activity generated ($200 million dollars in economic output). Another cost/benefit ratio is the amount spent on stocking divided by the number of fish harvested. In 1997, approximately 490,000 salmon and trout were captured by anglers, at a cost per fish of a little over $3.47. This figure is somewhat ambiguous, however, because some of the harvest is attributable to naturally-reproduced fish. Also, stocked fish swim throughout each lake, so some fish stocked by Wisconsin are captured in other states and some of the fish captured in Wisconsin waters were stocked elsewhere. Finally, the overall cost of the program, divided by the amount of Great Lakes fishing each year in Wisconsin waters (approximately 3,000,000 hours) yields a cost of about $0.57 per hour. The relative cost-effectiveness of stocking different life stages of the Great Lakes trout and salmon species is still poorly understood. In the future, we need to more directly measure costs and benefits and experiment with stocking different life stages in order to improve overall cost-effectiveness of the program.

Recommended Stocking Guidelines.- No changes are recommended at this time, except that stocking of chinook salmon will be reduced by 15% to accommodate a lake-wide goal of reducing chinook salmon density. This reduction was agreed to by all the states around Lake Michigan in order to reduce the likelihood of a recurrence of bacterial kidney disease, which severely reduced chinook salmon in the 1980's. The Lake Michigan Fisheries Team and the Lake Superior Geographic Management Unit will review and develop requests for stocking and ensure compliance with interstate agreements and negotiate with the Propagation Coordinator to balance other requests for cold water fish species.

Projected Demand for Great Lakes Trout and Salmon.- We do not anticipate changes to the numbers listed in the above table over the foreseeable future. The chinook quota above does not reflect a 15% reduction that we expect to implement. This 15% reduction will be revisited annually.

INLAND TROUT STOCKING GUIDELINES

The inland trout stocking program consists of stocking brook trout, brown trout, rainbow trout, lake trout, and splake. This program serves a number of purposes such as providing immediate fisheries, improving existing fisheries, and restoring fisheries in waters with improved habitat. The program has a long history and is well supported by the angling public. Waters stocked, species stocked, and numbers stocked are currently based on the local manager's request using stocking guidelines in the Fish Management Handbook, results of surveys, results of historical stocking practices, and public input.

Over the past decade, inland stocking requests for brook, brown, and rainbow trout have remained fairly stable, with total numbers ranging from 1.4 to 1.7 million. Requests were reduced by 25% in 1995-97 because of budget shortfalls. In 1994 we began experimenting with stocking trout derived from wild parents in order to improve the survival of stocked fish and create better long-term fisheries. The results of this program have been encouraging and we continue to receive requests for additional wild trout. Increased production of wild fish has been limited by hatchery space limitations, fish health concerns, and the need for a comprehensive review of trout stocking guidelines. Meeting the future demand for wild fish will be a major challenge to our current hatchery system.

Stock Integrity. – Recent concerns have arisen about the effects of our past stocking practices on the genetic integrity of our native stocks. The Illinois Natural History Survey was contracted to do a genetic analysis of brook trout and brown trout. The results of the brook trout report suggest genetic management zones for conservation of genetic diversity of brook trout (Fields and Philipp 1998). We therefore recommend that transfers of wild brook trout take place from within the same watershed, where possible, or, at a minimum, take place within the basins delineated on Figure 3.

Genetic analysis of brown trout proved difficult and is generally recognized to be of less importance than brook trout because brown trout were introduced from Europe in the late 19th century. However, stocked wild brown trout have survived better than domestic brown trout in paired stockings. Local strains of brown trout have also faired better than non-local strains in northeast Wisconsin. Because of the importance of broodstock, and different rearing techniques, it is critical to maintain a high level of quality control during the rearing of wild trout.

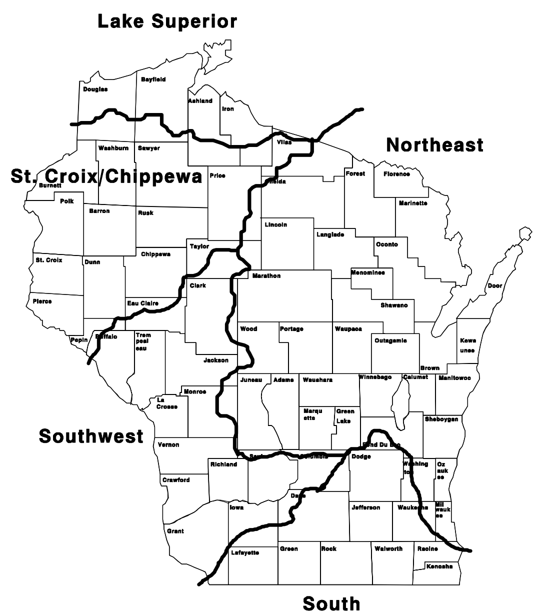

Figure 3. Recommended genetic management zones for wild brook trout in Wisconsin.

Specific Management Goals for the Inland Trout Fishery

I. Protect, restore, and enhance habitat and water quality

II. Emphasize wild, naturally-reproducing trout populations

III. Provide diverse angling opportunities

IV. Use the best scientific management possible, based on population and habitat monitoring and utilizing the principles of ecosystem management

V. Have the support of an informed, educated, and involved public

Cost effectiveness of inland trout stocking.- The most recent cost information we have for trout propagation is from WLAB (1997). Costs vary be type and size of trout, but are not available for wild trout or for spring fingerlings, which make up a large part of the wild trout needs. Costs include only operational costs and not capital costs such as buildings and maintenance. Costs for wild trout have been estimated to be at least twice as much as domestic trout because they can only be raised at half the density. Additional costs of wild trout are for collecting and transporting brood stock, doing fish health assessments, and buying automatic feeders. Some costs may be less, such as those related to manual feeding and maintaining a captive brood stock.

Cost effectiveness needs to be considered in terms of the type of fishery desired. In a pure put-and-take fishery, such as the urban trout ponds, legal trout are necessary to provide an immediate consumptive fishery. Historical information shows that the fish should be legal size and stocked as close as possible to the open season to maximize returns. In this type of fishery, return to the creel can be used as a direct measure of effectiveness. A recent study by Loomis and Fix (1998) in Colorado showed that if all the costs are included for put-and-take fisheries, the costs outweigh the benefits.

In put-grow-and-take fisheries, longer-term survival becomes more important than immediate return to the creel. In these fisheries, survival to a certain size or age may be a better measure of effectiveness. If survival is high, smaller fish that are cheaper to raise can be stocked in these waters. On a pure cost basis, using the 1997 cost figures, fingerlings would be more cost effective than yearlings if over-winter survival is greater than 24% for brook trout, 45% for brown and 39% for rainbow trout. This assumes that growth is similar in the hatchery and the wild, and that yearling size fish are the management goal. Although no comprehensive summary of trout survival rates is available in Wisconsin, rates over 35% would be considered high, which suggests that stocking yearlings will be more cost-effective.

Recent unpublished DNR surveys show that wild fish survive better than domestic fish in high-quality class 2 streams (streams that show good survival and carry over of adult trout, may have some natural reproduction, but not enough to utilize the habitat). Even though wild fish may be more expensive to rear than domestic fish their improved survival may make up for it. Also, wild fish may survive better at smaller sizes, so that cheaper spring fingerlings can be used. If captive brood stocks were not necessary for wild fish this would also reduce their total cost. If stocking wild fish creates self-sustaining fisheries, the long-term costs are much reduced. More studies on costs and measures of effectiveness need to be done for wild fish. Some benefits of wild fish to anglers, such as appearance, fighting ability, species preferences, and wildness are very difficult to quantify.

Recommended Stocking Guidelines. - The following stocking objectives (in priority order) are used to address goals II, III, and V:

1. Restoration or rehabilitation. Restoration applies when a water is returned to the ecological state present before degradation. Wild fish transfers are recommended over stocking hatchery fish and native brook trout should be given priority over exotic species where possible. Rehabilitation applies to an altered ecosystem that cannot be restored but can be managed in its altered state. Both restoration and rehabilitation should have a time limit of three years of stocking unless exceptions are documented. Generally, trout populations should be self-sustaining within the 3-year time period.

2. Experimental management evaluations. These are active projects with approved experimental designs that are being assessed by research or management. They may have specific requests for type of fish or strain, and should have a time

limit to the evaluation and stocking request.

3. Special management with demonstrated results. These are special cases that have demonstrated exceptional or unique results as measured by creel surveys, angler use surveys, exceptional growth or carry-over, or a unique fishery for that area such as lake trout in Big Green Lake, or the urban fishing program in the southeast.

4. Put, grow, and take. Put-grow-and-take fish realize significant growth before harvest. These waters are class II streams and lakes/spring ponds capable of overwintering fish on the basis of habitat. Fish stocked in this priority should be spring or fall fingerlings, unless justified in writing. Lakes or streams could be higher priority in this category based on management goals and past results; individual waters differ greatly so it is difficult to generalize.

5. Put and take. Put-and-take fish are harvested soon after stocking and have limited survival (<10% by number) the first year because of harvest or poor habitat. They will be yearlings or legal-size fish. Lakes are higher priority than streams because they generally have better return and higher use. Put-and-take waters that are regionally important or provide exceptional returns can be priority 3 if results are documented.

Projected Demand for Inland Trout – The Trout Team sent out mock quota requests to all fish managers with the above guidelines but without artificial constraints on the number requested and that wild trout be used in better class 2 streams where survival is expected to be high. Demand for the urban fishing program was assumed to be stable. The results are shown in Table 4.

In summary we are proposing to replace about 55% of the current quotas for domestic brown trout and brook trout with increased numbers of wild trout. The numbers increased because of the projected use of more spring fingerlings. There are no wild rainbows because Wisconsin does not have any wild rainbow populations in streams that are large enough to use as a brood stock and most rainbows are used in put-and-take fisheries. The shift from domestic trout to wild trout (Figure 4) should result in improved fishing opportunities in the better class 2 streams where wild fish should survive better and result in more naturally-reproducing fisheries. Domestics will continue to be used in put-and-take fisheries in class 3 streams and lakes.

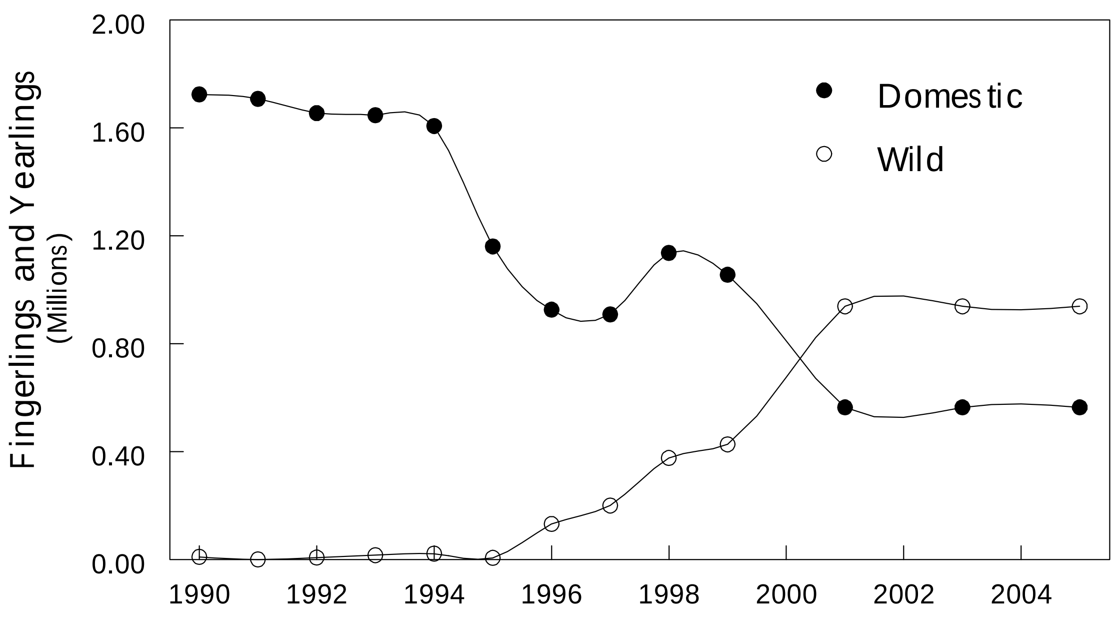

Figure 4. Recent and projected demand for inland brook, brown and rainbow trout, 1990-2005.

Table 4. Comparison of current (1999) and projected (2000) needs for inland trout stocking by species and size.

Species	Current Quotas	Projected Need
Brook trout (domestic)		
Spring fingerlings	1,000	
Fall fingerlings	48,250	15,700
Yearlings	156,125	78,400
Total	205,375	94,100
Brook trout (wild)		
Spring fingerlings	53,550	106,550
Fall fingerlings	13,950	70,050
Yearlings	27,700	91,750
Total	95,200	268,350
Brown trout (domestic)		
Spring fingerlings	70,000	
Fall fingerlings	233,690	91,300
Yearlings	260,550	161,900
Total	564,240	253,200
Brown trout (wild)		
Spring fingerlings	144,550	272,030
Fall fingerlings	177,800	391,810
Yearlings	9,280	6,700
Total	331,630	670,540
Rainbow trout (domestic)		
Spring fingerlings	20,200	19,200
Fall fingerlings	28,650	48,750
Yearlings	237,250	148,750
Total	286,100	216,700
Lake trout (unspecified)		
Fall fingerlings	20,000	20,000
Yearlings	25,000	25,000
Total	45,000	45,000
Lake trout (Trout Lake)		
Spring fingerlings	100,000	
Fall fingerlings		100,000
Total	100,000	100,000
Splake(Yearlings)	4,000	4,000
Grand Total	1,482,545	1,651,890

WARM WATER SPECIES

LARGEMOUTH AND SMALLMOUTH BASS STOCKING GUIDELINES

By the turn of the 20th century, serious habitat loss and declining water quality prompted concerns for Wisconsin's fisheries. In 1903, a hatchery was established at Minoqua to produce bass for stocking. Klingbiel (1981), described the history of stocking in Wisconsin's bass management program from 1900 to 1980: Bass stocking increased steadily until about 1940, when there were 8 state-operated bass hatcheries stocking between 1.5 and 2.5 million fry and fingerling bass each year. Maintenance stocking was widespread throughout the state and was popular with anglers. During the 1950s, results from numerous research projects showed that maintenance stocking contributed little and that natural reproduction in most waters was adequate to reach carrying capacity. As a result, stocking of bass was drastically reduced and bass production in state facilities was virtually eliminated. Almost all stocked bass then came from federal hatcheries. By the late 1960s and early 1970s, many lake reclamation projects were carried out and state facilities were again geared-up to produce bass for chemically reclaimed waters. Production during this period (about 1960 to 1980) averaged about 850,000 fry and fingerling bass annually, with almost half originating from federal hatcheries. Most bass were stocked in chemically reclaimed waters, waters experiencing winter-kills, or waters subject to some infrequent mortality events.

Stocking of bass fry or small fingerlings in waters with established populations is generally regarded as ineffective or unnecessary (Newburg 1975). However, bass have been the major beneficiary in about 65% of the more than 400 chemically treated waters prior to 1981. Many of these waters have developed outstanding, self-sustained fisheries. Stocking small bass in waters devoid of fish or where they have been significantly reduced is often an effective management practice to restore or develop a fishery.

Stocking is currently a minor component of the bass management program in Wisconsin. During the 1980s and 1990s an average of about 500,000 fry and fingerlings were stocked annually (374,629 to 622,416), with about 3,400 yearling and adult stock transfers each year. Most stocking is used to re-establish severely depressed (intentionally or naturally) populations. Stocking generally occurs on lakes that have had a winter-kill or have been rehabilitated using chemical fish toxicants.

Summary of Current Stocking Practices. - The majority of black bass fingerlings requested for management purposes are largemouth bass fingerlings for Northern Region waters (50% of waters; see Table 5). Most waters stocked in the Northern Region are winter-kill lakes, while most waters stocked in the West Central Region (32% of waters overall and 48% of all fingerlings) are for maintenance of existing populations. Most smallmouth bass are stocked in the Southeast Region for maintenance of existing populations.

Most largemouth bass from the DNR propagation system originate as brood stock from the Mississippi River and the young are hatched and raised at the Northfield rearing station in the WCR. Most smallmouth bass fingerlings originate from the state of Illinois hatchery program, although some are hatched and raised at the Oehmke hatchery. See Appendix Table 1 for specific stocking rates and frequencies currently used.

Specific Management Goals and Objectives. – The Bass Committee has developed the following specific management goals and objectives:

I. Protect, restore and enhance fisheries habitat on Wisconsin waters.

A. Locate, document and protect existing functional littoral and riparian habitat.
B. Insure that fishery concerns are incorporated into habitat alteration decisions.
C. Review and develop educational material on the value of aquatic habitats.
D. Ensure that effective, cost-efficient habitat protection, restoration and enhancement procedures are documented and used consistently throughout the state.
E. Improve enforcement of existing habitat protection regulations.

II. Protect and maintain Wisconsin's self-sustained fisheries, fish assemblages and aquatic communities.

A. Maintain and enhance existing self-sustained bass populations.
B. Rehabilitate formerly self-sustained bass populations.
C. Maintain the genetic integrity of self-sustained bass populations.
D. Review available information on the impacts and interactions of bass with other species.

III. Provide a variety of quality fishing opportunities (e.g., trophy, action, harvest) within a flexible management system.

A. Provide fisheries biologists with more flexibility to manage for a variety of bass fishing opportunities through a specified set of management options with established criteria.
B. Increase opportunities to catch "big" bass.
C. Endorse the concept of increasing the Department's flexibility in establishing conditions for the issuance of fishing tournament permits.
D. Endorse the development of a waters classification system for fisheries management.

IV. Ensure that sound, up-to-date technical information is available for Wisconsin's fisheries.

A. Develop cooperative efforts with external partners to obtain information on fisheries.

Table 5. Quota requests for largemouth and smallmouth bass fingerlings, 1997 to present.

Species, Region and Stocking Strategy	Year					
	1997		1998		1999	
Largemouth bass	Waters	Fingerlings	Waters	Fingerlings	Waters	Fingerlings
NER	7	32,435	9	35,210	6	18,550
NOR	45	170,010	37	130,750	23	119,575
SCR	8	2,850	1	450	0	0
SER	6	50,355	6	51,305	1	50,000
WCR	17	56,700	16	92,800	14	100,820
Total	83	312,350	69	310,515	44	288,945
Reason for stocking						
1. Rehabilitation	32%	43%	24%	36%	14%	33%
2. Introductions	1%	0.1%	1%	0.1%	2%	1%
3. Evaluations	40%	24%	35%	30%	34%	18%
4. Maintenance	27%	32%	40%	34%	50%	48%
Smallmouth bass						
NER	0	0	0	0	0	0
NOR	1	9,000	0	0	0	0
SCR	0	0	0	0	1	3,100
SER	6	1,800	8	53,125	1	50,000
WCR	0	0	0	0	0	0
Total	7	10,800	8	53,125	2	53,100
Reason for stocking						
1. Rehabilitation	86%	83%	88%	6%	50%	6%
2. Introductions	0%	0%	0%	0%	0%	0%
3. Evaluations	14%	16%	0%	0%	0%	0%
4. Maintenance	0%	0%	12%	94%	50%	94%

B. Develop a statewide strategy to ensure sufficient data are available for bass fisheries.

V. Communicate with Wisconsin anglers and promote the recreational value of Wisconsin's fisheries.

A. Increase awareness of the importance of bass to aquatic systems.
B. Increase awareness of the importance of quality bass fisheries to Wisconsin's economy.
C. Educate anglers on the differences between largemouth and smallmouth bass.

Costs and cost-effectiveness of bass stocking. - The cost to produce and stock black bass fingerlings is about $0.07 per fingerling (WDNR unpublished data); production costs vary from year to year. Due to the unique life history of black bass, stocking of fry is not recommended. Male bass guard their nests and, after the fry hatch, continue to guard fry schools until they break up (generally by about July). When bass are needed for rehabilitation stocking, either fingerlings or adult transfers are suitable choices. While we do not currently have specific estimates for survival of stocked bass and subsequent cost-effectiveness, we know that many bass populations have been successfully reestablished through stocking in reclaimed lakes throughout the state. Reestablishment of a self-sustaining population is an extremely cost-effective practice because it results in a population that is not dependent upon further stocking. Subsequent recruits to the fishery are free and, when cost-averaged, the initial stocking becomes more and more cost-effective through time as benefits continue to accrue from a relatively small one-time investment.

Currently, we have very little flexibility in our propagation program to produce the numerous strains of bass needed to protect the genetic integrity of native bass stocks. Any attempt to increase the stocking of bass without compromising their genetic integrity will be considerably more expensive than the current $0.07 / fingerling, which will affect the cost-effectiveness.

Recommended Stocking Guidelines. - The following stocking strategies, summarized in Appendix Table B, are recommended in order to achieve the black bass management goals for Wisconsin (listed in priority order).

1. Rehabilitation: Waters – Winter-kill lakes should not be stocked with bass if serious mortality occurs more frequently than 2 times in 10 years unless a plan to minimize the risk of future winter-kills is developed and implemented.

Size of Fish – Either large fingerlings (2"+) or adult transfers.
Source of fish – Same waterbody, if possible, (fingerlings), otherwise basin stock.
Stocking rate – Large fingerlings - up to 25/acre. Adults - up to 5/acre. If production is unable to meet all quota requests, a maximum of 25,000/water will be stocked.
Frequency – Three consecutive years.
Evaluation - If natural reproduction is not reestablished after 6 years from the onset of stocking, discontinue stocking until action is taken to identify and correct the reason(s) for the poor natural recruitment.

2. Evaluation: Very little need exists to conduct evaluations of bass stocking; we do not recommend development of projects or requests for evaluation quotas.

3. Remediation or Recreation: We do not recommend development or maintenance of bass fisheries dependent upon stocking due to the expense, the ubiquitous nature of bass, and availability of populations throughout the state. Other management activities should be pursued to enhance natural reproduction.

Projected Demand for Black Bass. - The committee recommends, based upon current scientific evidence (much of which was presented in the Introduction), that maintenance stocking of bass not be used where the potential exists to impact the genetic integrity of self-sustained bass populations. Further, we do not recommend increased investment in bass propagation unless strain management can be done in a cost-effective manner. This shift in management philosophy is anticipated to reduce the current demand by about 33% for largemouth bass and 94% for smallmouth bass. The annual demand

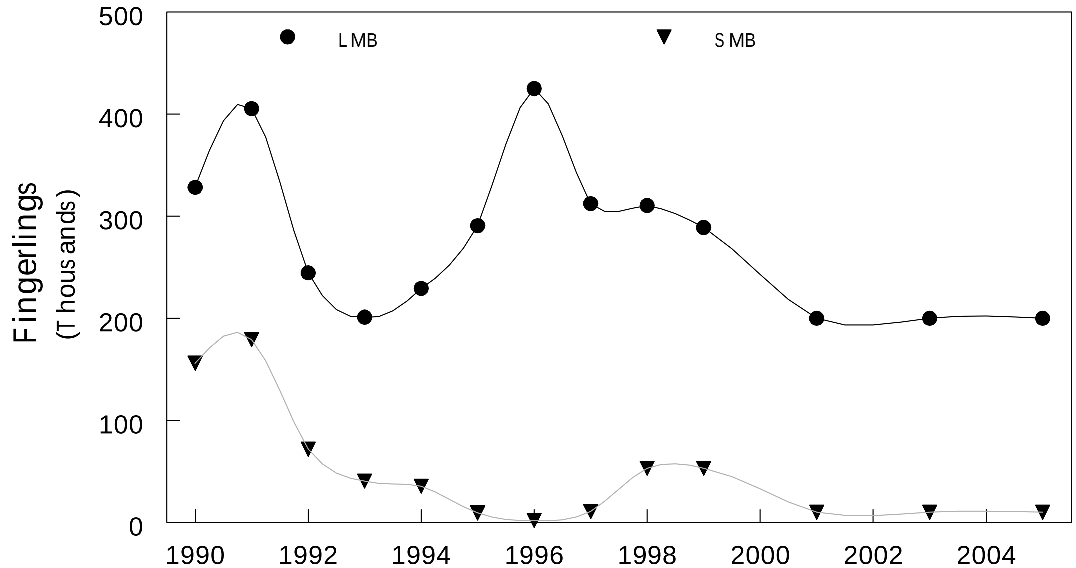

Figure 5. Recent and projected demand for largemouth and smallmouth bass fingerlings, 1990-2005.

for largemouth bass over the next 5 years is expected to be 150,000 to 200,000 fingerlings. (Figure 5). The committee did recommend adding the option of stocking adult bass in order to rehabilitate self-sustained populations, but these stockings would result from field transfers and will not impact the hatchery system.

LAKE STURGEON STOCKING GUIDELINES

Lake sturgeon propagation began only recently (late 70's) in Wisconsin and was pioneered by the hatchery staff at the Wild Rose Hatchery and fisheries management personnel in Oshkosh, with assistance from Sturgeon for Tomorrow and the University of Wisconsin Center for Great Lakes Studies. The propagation of lake sturgeon from the Winnebago system in the form of eggs, fry, and fingerlings has contributed to lake sturgeon management and restoration programs throughout the Great Lakes states. Eggs, fry, and fingerlings have also been instrumental in bioenergetics, virology and cell culture, aquaculture, development and chemical registration projects.

Sturgeon stocking in Wisconsin waters is a relatively recent activity. Lake sturgeon were stocked in the Menominee River and the waters of Lake Superior in the early 80's. Since that time, there have been additional stockings in the Wisconsin, Flambeau, Namekagon, and Chippewa rivers. More recently, they have been stocked in the Wolf River above Keshena as part of an attempt to bring sturgeon back to their historic presence on the Menominee Reservation. *Appendix Table 1* describes the current stocking guidelines for lake sturgeon. These stockings have all been conducted for restoration purposes under the following assumptions: 1) The lake or stream is considered to be part of the original range; 2) No sturgeon exist there now or reproduction is absent or drastically reduced; and 3) There is a reasonable possibility of developing a self-sustaining population through natural reproduction.

Specific Management Goals for Lake Sturgeon. **-** Wisconsin fisheries biologists manage lake sturgeon to:

I. Preserve and enhance existing naturally reproducing populations.

II. Re-establish populations in waters within their original range.

III. Develop harvestable surpluses through natural reproduction.

IV. Provide sport angling opportunities to harvest the surpluses.

V. Cooperate with other states in their efforts to re-establish lake sturgeon populations in appropriate waters.

Cost-Effectiveness of Lake Sturgeon Stocking

In 1998, approximately 64,000 lake sturgeon were propagated at the Wild Rose Hatchery. Propagation costs (e.g, obtaining and spawning wild stock, egg incubation and hatching, rearing and feeding), stocking costs, and administrative overhead totaled $26,500 ($15,000 donated by Sturgeon for Tomorrow, a private conservation organization). Rearing costs per thousand fish were estimated at $414 or $0.41 per fish. This estimate represents the propagation, rearing, and stocking of fish into the Menominee, Wisconsin, Flambeau, and St. Louis rivers, and propagation and rearing only from the Wolf River.

Because of the recent interest in sturgeon stocking and the lack of information on its effectiveness, biologists are incorporating stocking evaluation methodologies into their sturgeon work. For example, we currently have a cooperative project with the states of Michigan and Minnesota on stocking sturgeon obtained from the Sturgeon River in Michigan (a Lake Superior source) into the St. Louis River. All the sturgeon that are stocked in the project area receive a double micro tag. We anticipate expanding this micro-tagging statewide as we begin to evaluate our sturgeon stocking program. We also have ongoing a small study to look at tagging procedures and tag retention for fingerling sturgeon at the Wild Rose hatchery. We will be tagging the fish and holding them at the hatchery to provide some insight on the effectiveness of the tagging procedures.

***Recommended Stocking Guidelines.* -** Lake sturgeon are currently stocked for rehabilitation purposes only. Fry and fingerlings used in these restoration projects (i.e., stocking and transfers) must be obtained from waters within the same basin. Inter-basin stocking and transfer are no longer acceptable practices.

Stocking procedures, rates and frequencies. - Stocking procedures include scatter planting fry or fingerlings, after acclimation, over fine sand, course gravel, or boulders. Planting in and around vegetation is discouraged. The biological characteristics of lake sturgeon (slow growing, late maturing), dictate that stocking occur for at least 25 years (time needed for females to reach sexual maturity). Considering the extended duration of stocking required, the following rates are recommended (see also Appendix Table 2): Fry stocking, in most cases, has been reduced in favor of fingerling and yearling stocking (large 3-6" fingerlings at 80/mile or 0.5/acre; Yearling >6" at 40/mile or 0.25/acre) or in the case of adult transfers, the genetic literature suggest 200 fish as the minimum number for a viable population.

Projected Demand for Lake Sturgeon. - In the 90's, lake sturgeon quotas ranged from 20,000-50,000 a year. Quota demands will likely increase over the next few years as additional restoration opportunities arise and interest in improving fish passage at dams increases. The projected demand will range from 55,000-90,000 sturgeon (Figure 6). The sturgeon propagation program at Wild Rose is currently funded in large part (~$10,000) by Sturgeon for Tomorrow, a private conservation organization.

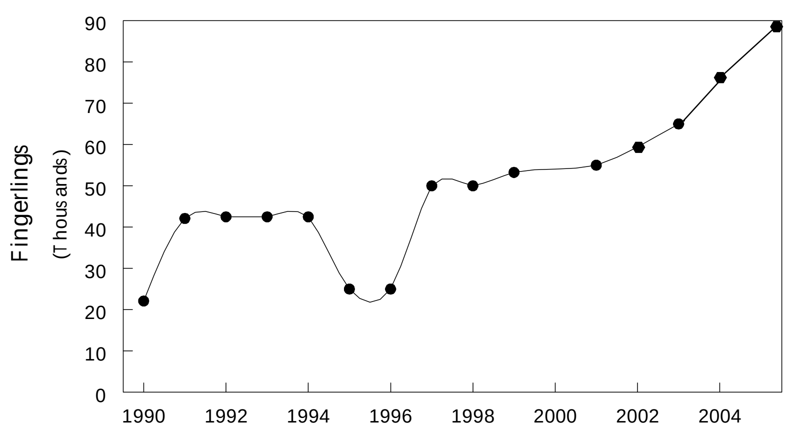

Figure 6. Recent and projected demand for lake sturgeon fingerlings, 1990-2005

MUSKELLUNGE STOCKING GUIDELINES

Little was known about the abundance of muskellunge in Wisconsin at the beginning of the 20th century; at this time, native muskellunge were apparently confined to lakes and streams at the headwaters of the Chippewa, Flambeau, Black and Wisconsin Rivers. About 20 counties were believed to contain muskellunge. The artificial propagation of muskellunge in Wisconsin was initiated in 1899 at Woodruff. For over 25 years, little effort was directed toward rearing muskellunge beyond the sac fry stage. Up until about 1941, 18 seasonal hatcheries in northern Wisconsin produced from several thousand to 28 million fry annually. Nearly all muskellunge were stocked shortly after hatching from eggs incubated in jars. The rearing of muskellunge to fingerling size in ponds was attempted sporadically from 1926 to 1938 with little success.

A decline in muskellunge populations was observed concurrent with the growth of sport fishing activity following World War II. Although the exploitation of muskellunge populations by anglers was not documented, it was generally believed that the annual harvest exceeded recruitment to populations through natural reproduction. From 1940 to 1970, improvements in the propagation program helped contribute to the recovery and maintenance of fishable muskellunge populations. Systematic procedures for pond rearing of fingerlings were developed in the 1940's and the two major muskellunge hatcheries went into full production by about 1950. The shift to raising larger fingerlings (8 to 15 inches) occurred in 1954, when 2 to 6 inch fingerlings were cropped off and remaining fish were reared to a larger size and stocked by October.

By about 1970, about 30% of the muskellunge waters were stocked annually with large fingerlings. Refinements in stocking procedures resulted in targeted plantings in critical problem waters. These specialized stocking situations included waters faced with heavy depletion by angling, excessive competition with northern pike, loss of spawning areas, natural catastrophes, and stocking waters that had been reclaimed with toxicants. When actual catch from a given lake is known, a fingerling stocking of twice the annual harvest was recommended. Otherwise, a standard rate of 2 fingerlings per acre was used. A certain amount of stocking at this rate was conducted to assure adequate spawning stock in prime waters and to remediate for the loss of spawning habitat. By 1970, the species inhabited about 33 counties in all geographic areas except the extreme southwest. This expanded range was primarily a result of stocking.

Current stocking practices.- Since 1970, an average of 128,747 large fingerlings have been stocked annually. In the last 4 years, since the renovation of the two major muskellunge hatcheries, an average of about 72,000 muskellunge have been stocked annually. Recent renovations, particularly the new plastic-lined rearing ponds, have resulted in a "learning curve" for hatchery managers. During 1998, the department stocked 90,177 muskellunge. The hatchery at Woodruff had an excellent year after 5 years of trial and error. Managers at the hatchery in Spooner don't anticipate long-term problems and expect improved production once they fine-tune their fry stocking rates in rearing ponds.

Requests for muskellunge from 1995 to 1999 have averaged about 141,000 annually, while requests from 1983 to 1993 averaged about 157,000. At present, approximately 216 waters (27% of Wisconsin's 804 muskellunge waters) are regularly stocked with muskellunge to maintain the fishery.

Current stocking practices are listed in Appendix 1. Existing stocking practices under the Remediation and Recreation strategies, by far the most common strategies, are presented in Table 6, along with the number of waters within each stocking strategy.

Specific Muskellunge Management Goals and Objectives.-

I. Protect and enhance Wisconsin's self-sustained muskellunge populations.

A. Identify and protect existing spawning and nursery habitat.

B. Protect the genetic integrity of self-sustained muskellunge populations.

II. Manage Muskellunge for a variety of unique fishing opportunities

A. Trophy fisheries – Increase catch of 50″+ fish.
B. Action fisheries – Maintain catch of 1 muskellunge/25 hour of angling.
C. Improve existing Class B and C waters.
D. Terminate management in waters not suited for muskellunge, where management activities have not resulted in fishable populations, and where supported due to impacts to other desirable species.

III. Increase available information for muskellunge fisheries and educational efforts to inform anglers about the status and management of muskellunge fisheries.

A. Monitoring – Establish long-term trends waters; conduct regular angler surveys.
B. Evaluation – Develop an index of natural reproduction; define and develop criteria to identify "self-sustained" populations; conduct a comprehensive stocking evaluation.
C. Education - Continue to focus on the value of catch and release; provide technical assistance to cooperators on hooking and handling mortality and interactions with other species.

IV. Minimize User conflicts.

A. Provide unique, aesthetic fishing experiences.

Costs and Cost-effectiveness of muskellunge stocking. - The cost to produce and stock muskellunge increases considerably with size, from about $1.36/1000 fry (WLAB 1997) to about $5.20/spring yearling (Margenau 1992) (Table 7); production costs can also vary considerably from year to year (Margenau 1992). Cost-effectiveness is measured as the cost per stocked fish that is recruited to the fishery (i.e., of catchable size). Cost-effectiveness could also be measured as the cost per fish caught or harvested by anglers. The cost-effectiveness of stocking various sizes of muskellunge varies considerably among waters and years due to variability in survival and variability in production costs.

In general, stocking fewer large fish has been shown to be more cost-effective than stocking many small fish. For example, with muskellunge fry stocking, the costs are relatively low but the survival of fry is highly variable and the likelihood of any muskellunge surviving at all in any given year is very low (Hanson et al. 1986).

Table 6. Number of waters under the current muskellunge stocking practices for fall fingerlings under Remediation and Recreation strategies (priority 3 and 4 maintenance). Note: 22 waters are currently affected by the 2,500/water maximum; 10 are currently stocked at < 1 per acre (listed below) and 12 are currently stocked between 1 and 2 per acre. Note: 12 waters under Rehabilitation (priority 1 introductions; 3 waters) and Research (priority 2 evaluations; 9 waters) strategies are not included.

	Nominal stocking rate (number/acre)							
Frequency	0.1	0.2	0.3	0.4	0.5	1	2	Total
Annual	1	4	1	1	5	32	10	54
Alternate	0	2	1	0	4	80	75	162
Total	1[1]	6[2]	2[3]	1[4]	9[5]	112	85	216

[1] Petenwell Flowage, [2] St. Louis River, Turtle-Flambeau Flowage, Lake Koshkonong, Chippewa Flowage, Castle Rock Flowage, [3] Lake Wisconsin, [4] Lake Wissota, [5] Shawano Lake, Holcombe Flowage.

Given a survival rate of 0.004% to fall (Hanson et al. 1986) and a survival rate of 4.2% from the first fall to the next fall (at 18 months of age; Margenau 1996), 588,235 fry would need to be stocked to result in 1 surviving muskellunge, at a cost of about $800.00 per muskellunge. Cost effectiveness of fall-stocked fingerlings to 18 months of age averages about $70.75 per surviving muskellunge. Cost per spring-stocked yearling muskellunge surviving to 18 months of age averages about $27.42 per muskellunge.

These estimates are based on averages: because survival and production costs vary considerably from year to year, the cost-effectiveness should be evaluated over several years on an individual water in order to get an accurate estimate. Also, WDNR Fisheries Biologists routinely use professional judgment when they determine what size of fish is most appropriate for stocking on specific waters. Their primary concern is to maximize survival of stocked fish, which obviously improves cost-effectiveness. For this reason, the department often uses fry stocking in winterkill or reclaimed lakes that are free of predators, and stocks larger sizes in waters having well established fish communities with a variety of natural predators. The reason stocking is even economical at all rests in the fact that the cost per survivor can be very inexpensive in certain years when survival of stocked fish is excellent and production costs are low, so it is cost-effective over a longer time period. A further benefit of stocking larger fish rather than smaller fish is that the variability in survival for larger fish is lower from year to year (i.e., more likely to have at least some survival; e.g., Hanson et al. 1986), providing a more consistent return on investments in stocked fish. The less time the fish is at-large when it is small and vulnerable to a whole host of sources of mortality, the higher its chances of survival and eventual contribution to the fishery.

Recommended Stocking Guidelines. - To fully attain the above objectives that relate to stocking (I.B., II.B, C., and D), we recommend obtaining better information on the efficacy of our stocking practices (goal III.B.). One of the key goals of the 1979 management plan (WDNR 1979) was to evaluate our stocking practices (stocking rates and frequencies), yet we have very little additional information available at this time. Therefore, the recommended stocking strategies and practices, listed in priority order and summarized in Appendix B, are as follows:

1. Rehabilitation: Waters – Winter-kill lakes should not be stocked if serious mortality occurs more frequently than once in 15 years unless a plan to minimize the risk of future winter-kills is developed and approved.

   Size of Fish – Either fry or small fingerlings (4"-6") the first year, followed by large fingerlings (> 7") or adult transfers in subsequent years.
   Source of fish – Same waterbody, if possible, otherwise basin stock .
   Stocking rate – Fry – 500/acre; small fingerlings up to 5/acre; Large fingerlings up to 2/acre. If production is unable to meet all quota requests, a maximum of 100,000 fry, 5,000 small fingerlings or 2,500 large fingerlings will be stocked per water.

Table 7. Estimated cost-effectiveness for stocking different sizes of muskellunge.

Muskellunge size	Production cost per fish	Survival rate to 18 months of age	Number stocked/ survivor	Cost per survivor to 18 months
Fry	$1.36/1000	0.00017%	588,235	$800.00
Fall fingerlings	$2.83	4%	25	$70.75
Spring yearings	$5.21	19%	5	$27.42

Frequency – Fry or small fingerlings the first year, then large fingerlings for 4 years.
Evaluation - If natural reproduction is not reestablished after 10 years from the onset of stocking, discontinue stocking until action is taken to identify and correct the reason(s) for the poor natural recruitment.

2. Research: Stocking sizes and frequencies as needed to realistically meet the objectives of the evaluation project.

3. Remediation or Recreation: Waters - Based on evidence provided by Fields et al. (1997), we recommend that no stocking occur in waters with adequate natural reproduction, in order to minimize the potential negative impact of stocked fish on naturally reproducing populations in the receiving or connected waters.

Size of Fish – Either small fingerlings (4"-6") or large fingerlings (> 7"), depending upon abundance of existing predators.
Source of fish – Basin stock.
Stocking rate – Small fingerlings up to 5/acre; large fingerlings up to 2/acre. If production is unable to meet all quota requests, a maximum of 5,000 small fingerlings or 2,500 large fingerlings will be stocked per water.
Frequency – Small fingerlings or large fingerlings annually or in alternate years.
Evaluation - If the fishery objective is not met after 10 years, discontinue stocking until action is taken to identify the reason(s) for poor survival.

No dramatic changes are recommended in the current recreational stocking practices because no compelling scientific evidence for change exists. However, this does not mean that inefficiencies do not exist or that improvements are not needed, just that we lack adequate information at this time. In order to obtain the information needed to sufficiently evaluate our stocking practices, we recommend establishment of a management framework to allow a comprehensive evaluation of our stocking practices. We propose to assign each of the 220 stocked muskellunge waters to a specific stocking practice for 10 years (Table 8). During this period, we will assess these fisheries through existing survey efforts. This will allow us to evaluate the effectiveness of various rates (number of muskellunge per acre) and frequencies (annual, alternate years, etc.) for fall fingerling stockings in a variety of waters.

Table 8. Hypothetical muskellunge stocking framework for fall fingerlings under Remediation and Recreation strategies (maintenance - priorities 3 and 4). Note: 12 waters under the Rehabilitation strategy (priority 1 introductions; 3 waters) and Research strategy (priority 2 evaluations; 9 waters) are not included.

Stocking	Treatments – (Nominal stocking rate; number/acre)				
Frequency	0	0.5	1	2	Total
Cease	30 (0)	-	-	-	30 (0)
Annual	-	30 (4)	30 (32)	30 (10)	90 (54)
Alternate	-	-	30 (80)	30 (75)	60 (162)
Every fourth year	-	-	-	30 (0)	30 (0)
Total	30 (0)	30 (19[1])	60 (112[2])	90 (85)	210 (216)

[1] Ten of these waters are currently affected by the per-water-maximum: Petenwell Flowage, St. Louis River, Turtle-Flambeau Flowage, Lake Koshkonong, Chippewa Flowage, Castle Rock Flowage, Lake Wisconsin, Lake Wissota, Shawano Lake, Holcombe Flowage. [2] Twelve of these waters are affected by the per-water-maximum.

We will be working with regional Fisheries Biologists over the next year to refine the details of this framework, assign waters to categories, and phase this plan in by 2000. Therefore, we anticipate reviewing these stocking practices after 2005, with potential recommendations for changes after 2010. This approach will 1) allow long term, consistent application of experimental treatments, 2) provide a long-term production target for the hatchery system, 3) aid the hatchery system in development of basin-specific stocks, and 4) greatly reduce annual workload related to quota requests. Also, we recommend this framework remain somewhat flexible so managers can respond to interim changes in the population with changes in management strategies. Serious concerns can be reviewed and addressed annually prior to the spawning period.

Projected Demand for Muskellunge.- The current demand for muskellunge has averaged 138,000 fingerlings annually since the renovation of the two major warm water facilities. Because we do not anticipate recommending major changes in our stocking practices over the next 10 years, no significant changes are anticipated in the demand for muskellunge fingerlings from the hatchery system (Figure 7). However, we have observed a trend toward lower requests in recent years. Discussions with Regional Fisheries Biologists over the last year have confirmed that several biologists have been requesting fewer fish because higher size limits, and increased voluntary release of legal-sized fish by anglers has reduced mortality and resulted in higher densities of adult muskellunge. Also, higher quality (larger) fingerlings from the hatcheries have higher survival and have reduced the numbers needed to improve fishing. Therefore, demand for muskellunge fingerlings may decline somewhat regardless of changes in stocking policies.

NORTHERN PIKE STOCKING GUIDELINES

Fishing regulations for northern pike (*Esox lucius*) have been in existence since the early 1900’s. The early laws enacted by the Legislature were most likely based on the theory that fewer fish caught now will result in more available for future fishing. Size limits began in 1909 (12” minimum), bag limits in 1917 (15 daily), and closed seasons in 1935 (Jan 1st to May 15th or March 1st to May 15th). Frequent changes in the regulations in the early years were often based on economic and social considerations. There was little concern for habitat.

In the 1940’s, a period of liberalized fishing regulations began for most species in the state; in 1953 the statewide minimum length limit for pike was eliminated.

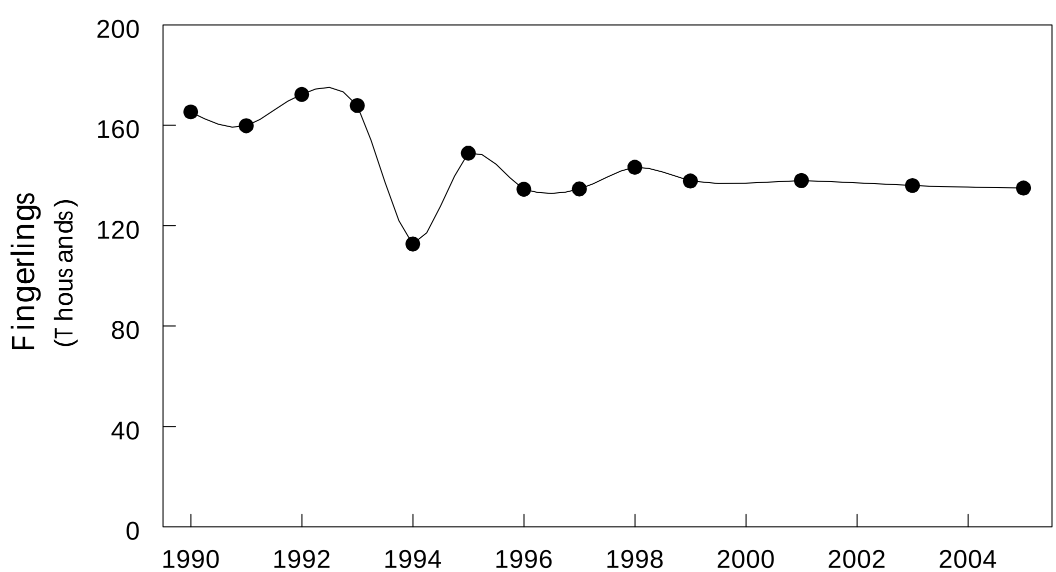

Figure 7. Recent and projected demand for muskellunge fingerlings, 1990-2005

Prevailing ideas of the time assumed high rates of total mortality, mostly due to natural causes rather than fishing. The first experimental size limits began in the mid 1950's. Evaluations of the regulations began to show that benefits size limits will vary, depending upon exploitation rates, growth rates and structure of the fish community (Kempinger and Carline, 1978). It was found unreasonable to assume that a single length limit could produce desirable results over a wide range of lake types and fishing pressure.

Current Stocking Practices and Priorities.- Current stocking practices are summarized in Appendix Table 1. The current stocking guidelines are presented in detail below:

Rehabilitation stocking and evaluation projects requiring northern pike stocking. Rehabilitation projects should stock fry (1,000/acre, maximum of 200,000 per water), followed by fingerling in the fall if investigation show poor fry survival. Fingerling may be stocked again the next year, if desired. Small fingerlings (3.5-5.5 inches long) may be stocked at a rate of no more than 5 per acre (maximum of 5,000 per water) and large fingerlings (>7 inches long) at a rate of no more than 2 per acre (maximum of 5,000 per water). Stocking adults (field transfer) to reproduce is also acceptable. Winter-kill lakes that have serious mortality no more frequently than 2 times in 10 years may be stocked. Winter-kill waters should only be stocked once after a mortality, but a second year's stocking is permitted if the first survives poorly. For evaluation projects stocking sizes and frequency shall be as required to realistically meet the objectives of the evaluation project.

Initial Introductions. Fry should be stocked, followed by fingerling later in the year if fry survival is poor. Fingerling stocking may continue for the following 2 years. Small fingerlings (3.5-5.5 inches long) may be stocked at a rate of no more than 5 per acre (maximum of 5,000 per water) and large fingerlings (>7 inches long) at a rate of no more than 2 per acre (maximum of 5,000 per water).

Maintenance. Stocking where evaluations have shown success in establishing a viable fishery. Maintenance stocking may only be done in waters having a history of poor natural reproduction of northern pike. Growth rate of northern pike must be satisfactory in such waters. Catchable size fish may be stocked for maintenance purposes, but only if fish become available as a byproduct of another operation through field transfer. All maintenance stocking should be for put-grow-and-take management not for put-and-take. Small fingerlings (3.5-5.5 inches long) may be stocked at a rate of no more than 5 per acre (maximum of 5,000 per water) and large fingerlings (>7 inches long) at a rate of no more than 2 per acre (maximum of 5,000 per water).

Panfish Control. No stocking will be done specifically for panfish control unless special regulations are imposed to reduce northern pike harvest.

Specific Management Goals and Objectives.- The overall goal of northern pike management in Wisconsin is to link the diversity of lakes and their pike populations to pike anglers' diverse attitudes and preferences. In the past management actions primarily supported consumptive interests among anglers. Today we recognize that angler preferences and motivations for northern pike fishing are diverse. One management approach cannot meet all anglers' expectations. To account for different demands liberal harvest regulations may be maintained on many fisheries, elsewhere, regulations other than traditional bag limits must be used to improve or maintain size-structures for larger fish.

Likewise, lakes and their pike populations are ubiquitous and diverse. Northern pike populations are found in 2,874 waters, with 795, 1,697 and 382 occurrences in water <20 acres, 20-300 acres and >300 acres, respectively. Growth rates, size-structures, and abundance of northern pike populations vary widely from lake to lake. The average standing stock and biomass reported in selected Wisconsin waters is 7.3 fish/acre and 9.2 lbs/acre, respectively. However, density and biomass estimates ranged from 0.7 to 49 fish/acre and from <1 to 59 lbs/acre, respectively. Characteristics of each lake (biological, chemical, and physical) determine each pike population's, growth rate, size-structure and abundance. Wisconsin has a diverse spectrum of lakes that cannot be managed similarly, but require different management strategies.

At one end of the spectrum are what anglers often refer to as "hammerhandle" lakes. These small, marshy lakes are loaded with aquatic plants and spawning habitat for northern pike, and are renowned for producing a lot of slow-growing, small northern pike. The pike are of an unacceptable size to many anglers. Panfish and bass are common, however larger, soft-rayed forage fish necessary for good pike growth are absent. Competition between pike for available prey is severe, growth is limited, and most deaths in the population are the result of natural causes rather than fishing. Many eutrophic lakes of Northern Wisconsin have these characteristics. Past research and evaluations of fishing regulations and stocking have shown that these actions will do little to "improve" the characteristics of northern pike in these waters. Here the fisheries management objective is to manage populations for "consumptive" angling opportunities (i.e., to provide opportunities for anglers who value retaining a meal of fish), though the average size of pike caught will be smaller.

At the other end of the spectrum are waters that are renowned for producing 10-25 lb. northern pike. These lakes are larger, cooler, deeper, and well oxygenated. Because of their depth, and steeper shorelines, these lakes often have fewer marshy areas and less aquatic plants for northern pike spawning. Here pike are less abundant, however they have the ability to grow to over 20 pounds. Their growth is good because larger, soft-ray forage fish (cisco, white sucker, redhorse) and yellow perch are generally abundant. Because of good growth and less competition, fewer deaths in the population are the result of natural causes. These lakes can produce large pike, however angling pressure is considered the most important factor in determining whether northern pike do well in these fisheries. That's because angler exploitation is a significant component of mortality among pike populations of low or moderate density. Here the management objective is to manage for quality- or trophy-sized pike, though catch rates will be lower, and size limits are often quite restrictive.

Unlike muskellunge, northern pike traditionally have not been afforded significant protection. Managing pike in Wisconsin is changing; fisheries biologists utilizing this natural diversity to manage for quality northern pike, not just on any water, but on those that are best-suited for growing large northern pike.

Biologists have witnessed a decline in the abundance and size-structure of northern pike populations through many Southern Wisconsin waters. These declines are due to: 1) losses in spawning habitat through wetland drainage, dredging, shoreline development and eutrophication; and 2) increased exploitation from angling.

In southern Wisconsin habitat loss is often typified by high phosphorus, turbid water, dominance of algae, absent macrophytes, and dominance of benthivorus (carp and bullhead) and planktivorus (crappie) fish. The alternative and preferred conditions are typified by seasonal windows of clear water where algae are heavily grazed, dominance of macrophytes, and a dominance of fish species closely associated with macrophytes (eg. bluegill, pumpkinseed, northern pike, and bass). Restoration efforts often call for biomanipulation, water-level management, and reduced phosphorus loads in attempt to shift from the turbid condition to a clear-water condition. Here the management objective is to rehabilitate/restore habitat and water quality through biomanipulation and other management actions (aeration; long-term water level management; drawdowns; landuse and nutrient controls; wetland protection/restoration; northern pike rearing marsh construction, boating restrictions, barrier islands, and temporary breakwaters to restore aquatic plants). Bio-manipulation and rehabilitation involves some of the following actions: protecting piscivores like pike from harvest; northern pike stocking; chemical reclamation; stock suppression of carp using rotenone, and rough fish removal through fishing contracts.

Cost Effectiveness of Stocking Strategies for Northern Pike. - Fry survival is extremely variable and influenced by a host of factors (climate, water levels, forage, temperature, amount of refuge from predators, etc.). Fry stockings following chemical rehabilitation and winter-kill have provided excellent survival of stocked fry and established dense pike populations. A strategy of stocking fry in these “open environments” (few predators and abundant food resources) has been shown to be the most cost-effective approach. Where resident fish communities exist, we lack quantitative comparisons between fry and fingerling pike cost-effectiveness. The estimated proportion of pike surviving to the fall YOY stage is dependent upon the size of pike stocked; larger fish have significantly higher survival. Several general assumptions can be used to compare the cost-effectiveness of rearing and stocking pike at different sizes. Data taken from WLAB (1997) can be used to approximate cost-effectiveness of stocking different sizes of fingerlings. Using size-dependent survivorship described above, the cost-effectiveness of small fingerlings (4″) and large fingerlings (8″) to fall YOY stage is estimated to be $2.11/pike and $3.50/pike, respectively. Given the variability in the assumptions and factors which influence survival of stocked fingerling pike, the difference between these two estimates is minimal. Since the differences are minimal, other factors should be used to determine stocking size. Size structure, density, and growth of the resident piscivore fish community should be considered when considering stocking size for fingerling pike. If the potential for predation among the resident fish community is high (as evidenced by high CPE’s of piscivores and slow growth) large fingerling should be stocked in the fall, under lower and favorable water temperatures.

Recommended Stocking Guidelines (listed in order of priority)

1. Rehabilitation: Rehabilitation projects that involve complete chemical treatment should stock fry (1,000/ acre of habitat). Fingerling may be stocked the next year, if desired. The following equation should be used to determine fingerling stocking rates: Total number of fingerlings to be stocked= total habitat acres X desired density of fall YOY (use 10/acre of habitat; Klingbiel 1986) / (estimated proportion of fish surviving to fall YOY which is size dependent: 0.09 for pike 3.5″-5.5″ in length; 0.20 for pike 5.6″-8.5″ in length; and 0.40 for pike 8.6″-12″ in length). These size-dependent survival estimates are taken from several studies of esocids (Hanson et al. 1986, Serns and Andrews 1986, Wahl and Stein 1989, Szendrey and Wahl 1996). Winterkill lakes that have serious mortalities no more frequently than 2 times in 10 years may be stocked. Winterkill waters should only be stocked once after a mortality, but a second year’s stocking is permitted if the first survives poorly. For evaluation projects stocking sizes and frequency shall be as required to realistically meet the objectives of the evaluation project. Stocking adults (field transfer) to reproduce is also acceptable.

Note: Acres of habitat are defined by estimates of total area that supported (remediation) or would support (biomanipulation and rehabitation) emergent, floating-leaf, and submergent aquatic plants.

2. Biomanipulation: This is a management tool that involves increasing the biomass of predators to alter the food web and, ultimately, improve habitat or water quality. Biomanipulation stocking typically involves additional actions like increasing length limits for pike; protecting stocked fish from harvest, or supressing the numbers of benthivorus or planktivorus fish. Biomanipulation projects must set and objective for desired endpoint for total acres covered by aquatic plants. Fingerlings are the recommended size for stocking. The following equation should be used to determine fingerling stocking rates: Total number of fingerlings to be stocked= total habitat acres X desired density of fall YOY (use 10/acre of habitat) / (estimated proportion of fish surviving to fall YOY which is size dependent: 0.09 for pike 3.5″-5.5″ in length; 0.20 for pike 5.6″-8.5″ in length; and 0.40 for pike 8.6″-12″ in length). Secondarily, biologists can chose to use fry instead of fingerling stocking: stock fry at a rate of 1,000/ acre of habitat.

3. Remediation: **S**tocking that seeks to remediate loss of northern pike habitat to provide a fishery, and where a decline in the northern pike population is evident. The population decline should be reasonably shown to be the result of habitat loss rather then over-exploitation. Stocking under this category is recommended to be in conjunction with other management actions (size-limits, land use and

nutrient controls; wetland protection/restoration; northern pike spawning/rearing marsh construction). All remediation stocking should be for put-grow-and-take management not for put-and-take: total number of fingerlings to be stocked= total habitat acres X desired density of fall YOY (use 10/acre of habitat) / (estimated proportion of fish surviving to fall YOY which is size dependent: 0.09 for pike 3.5″-5.5″ in length; 0.20 for pike 5.6″-8.5″ in length; and 0.40 for pike 8.6″-12″ in length) X (the proportion of spawning habitat lost or the historic proportion of stocked fish contributing to the fishery). Catchable size fish may be stocked for maintenance purposes, but only if fish become available as a byproduct of another operation through field transfer.

4. Recreational Pike Fisheries: Stockings in this category are where pike is managed to provide angling opportunities for an additional species. All stocking should be for put-grow-and-take management not for put-and-take. Fingerling stockings are recommended. For recreational pike populations, a density range of 1-3 YOY pike/habitat acre is recommended. The total number of fingerlings to be stocked= total habitat acres X desired density of fall YOY (use 1-3/acre of habitat) / (estimated proportion of fish surviving to fall YOY which is size dependent: 0.09 for pike 3.5"-5.5" in length; 0.20 for pike 5.6"-8.5" in length; and 0.40 for pike 8.6"-12" in length). Careful considerations should be taken when stocking northern pike to provide an additional fishery. Growth rates of existing piscivores and the density of larger soft-rayed forage need to be carefully considered. Stocking of northern pike has a potential for negative consequences due to inter-specific competition and predation impacts on other species. Major changes in existing fish assemblages can occur when piscivorous fishes are introduced into new locations. Several years of stocking 'winter rescue" northern pike had negative effects on the fish community of Horseshoe Lake Minnesota. The artificially induced increase in northern pike population was followed by a sharp declines in the yellow perch, largemouth bass, and walleye populations. The Horseshoe Lake bluegill population eventually exploded and their growth rates became "stunted", providing a very marginal fishery. Nineteen years later the Horseshoe Lake fish community has not yet recovered .

***Projected Demand for Northern Pike.* –** Due to the uncertain timing of major rehabilitation

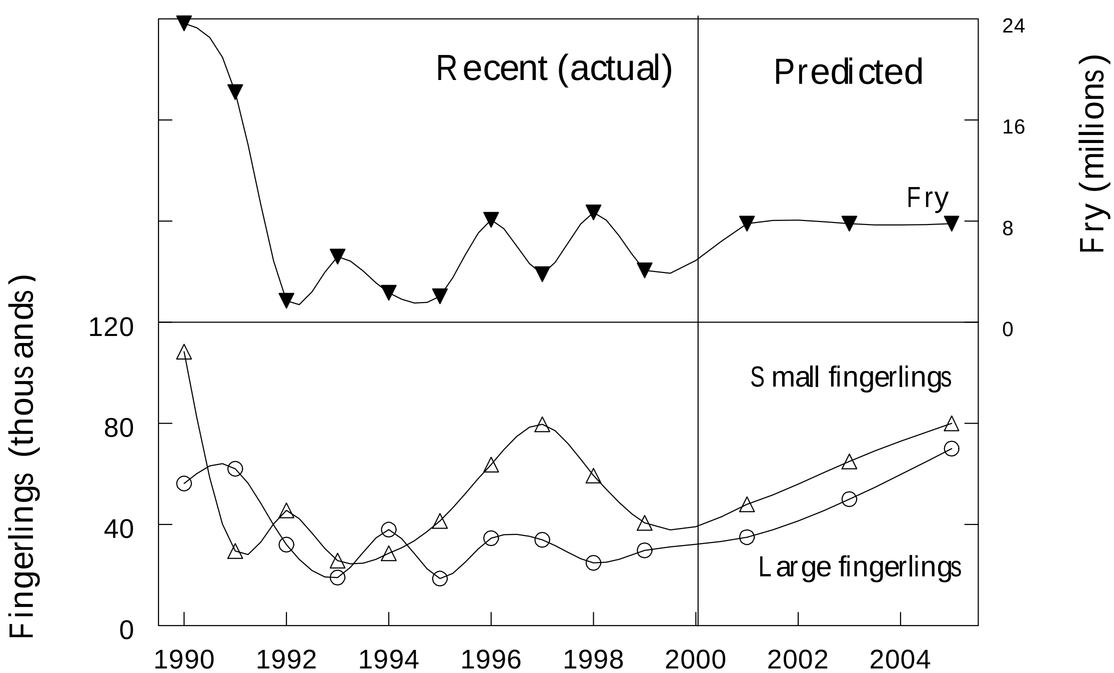

Figure 8. Recent and projected demand for northern pike fry and fingerlings (small and large), 1990-2005

projects, quota requests for northern pike vary considerably from year to year, especially for fry. Projected demand for fry is approximately 8 million per year. Priority and policy changes now place greater biological emphasis on size dependent survival of stocked pike, quantification (actual or projected) of northern pike habitat, biomanipulation, and remediation projects. Because projections are largely based on historic quota requests, development of a field staff "mock" quota exercise will be required to further refine the estimates of projected stocking demand for northern pike. The per-water-maximums are no longer recommended, but the rates are now tailored for individual waters based on surface acres of suitable habitat. Increases in demand are anticipated. The average projected demand for northern pike fry is 7.8 million; small fingerlings is 80,000; and large fingerlings is 70,000 (Figure 8). These estimates are based on projected increases in stocking rates for rehabilitation, remediation and biomanipulation projects, many of which use fry stocking. However, if poor fry survival is evident, fingerling demand could be greater. For example, assuming a fall YOY objective of 10 pike/acre of habitat for a remediation project with 50% spawning habitat loss and 30% of the lake as suitable pike habitat, the stocking rate for small fingerlings would be about 16.7 small fingerling/acre. With the same assumptions, large fingerling stocking demand would be 3.75 large fingerling/acre. This represents a substantial increase in stocking rates for small and large fingerlings. Many biomanipulation projects take place in shallow lakes. Here, assuming 65% of the lake area is pike habitat, with no natural reproduction and a fall YOY objective of 10 pike/acre of habitat, the stocking rate for small fingerlings would be 72/ lake acre, which would also be a substantial increase in the stocking rate.

WALLEYE STOCKING GUIDELINES

The fisheries management program has a long history of propagating and stocking walleye throughout the state. This program began in the late 1870's, with the first walleye propagated from the Lake Winnebago system. Until the early 1900's, all walleye stocked in the state were from the Winnebago system. Propagation efforts moved north and expanded to cover the entire state during the early 1900's. By the year 1910, there had been 77,904,996 walleye stocked in Wisconsin. Walleye were probably originally found in the large river systems and large drainage lakes throughout Wisconsin. Most walleye populations found in small drainage and seepage lakes were probably the result of the walleye stocking program. Some of these waters have established self-sustained walleye populations, others are maintained through continued stocking, and others contain remnant populations that are not likely to improve. Because of the long history of walleye stocking, we do not fully understand the effects of our stocking program on native walleye stocks. However, considerable regional genetic diversity still exists despite our past stocking practices.

Large numbers of fish were stocked throughout the state, with little or no evaluation of success. In the late 1950's and early 1960's, the efficacy of stocking practices were scientifically examined. Evaluations of the size at fish stocked, survival of stocked fish, and development of management goals and objectives resulted in changing emphasis from stocking all waters with fry to developing individual lake recommendations. These recommendations included the size, number and frequency of walleye stocking. Improvements at both major walleye hatcheries, increased concern about detrimental effects of walleye stocking on other species and on genetically distinct walleye stocks, as well as a need to examine the cost-effectiveness of various stocking practices, led to the recent review of walleye stocking practices.

Walleye stocking success is highly variable and is difficult to predict. There are variations in stocking success, just as there are year-to-year fluctuations in natural reproduction of walleye. Available stocking evaluations suggest that only about 50% of new stockings are effective in creating walleye populations (reviewed in Kampa and Jennings, 1999). Maintenance and enhancement efforts generally have even lower success rates; walleye stocking to maintain populations has a lower success rate. About 85 % of fry stockings result in no measurable year class (WDNR unpublished data). Waters supported entirely by stocking have much lower walleye densities, and anglers catch walleye at a substantially lower rate than from waters supported by natural reproduction (see Figure 2, page 3).

We have identified genetically distinct walleye populations throughout the state. Based on this information, distinct stocks are delineated in Figure 9. Although we are able to determine genetic differences among stocks, it is unclear whether differences in growth, fecundity, or survival have occurred. If genetically distinct walleye populations exhibit performance differences (which we suspect they do), mixing of these stocks could result in outbreeding depression and lower fitness of the population. Genetic fitness could directly affect cost-effectiveness of the propagation program. Evaluations of stock-specific performance and fitness differences among waters are underway in Wisconsin and should help to better assess benefits and risks of alternative stocking strategies.

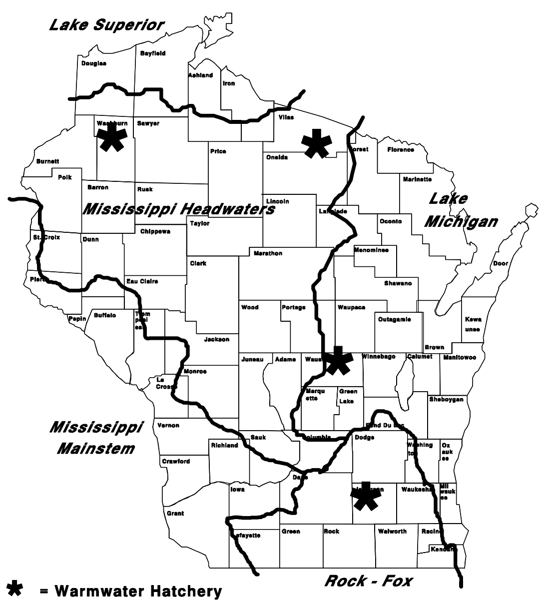

Figure 9. Major Wisconsin basins recommended as walleye brood sources.

The implications of genetically distinct stocks, along with recent research showing some negative impacts of stocking on naturally reproduced walleye year classes (Li et al. 1996), suggest that lakes with adequate natural reproduction should not be stocked. Although there have been no field evaluations on the genetics effects of stocking walleye, we could be causing more harm than good. Recent research in Minnesota suggests that stocked walleye suppress adjacent year classes, resulting in no net benefit to the fishery. Most of the scientific evidence on stocking is relatively new in comparison to our stocking program. In the future, more emphasis needs to be placed on the rigorous evaluation of the cost-effectiveness of stocking.

Walleyes are a top predator, and can have a significant impact on the structure of fish communities. While there have been few experiments on the impact of walleye stocking on fish communities, there is some anecdotal evidence that suggests negative interactions between bass and walleye. For example, after the initiation of walleye stocking, Escanaba Lake converted from a smallmouth bass-dominated fishery to a walleye dominated fishery. Conversely, the presence of bass is suspected to reduce the chances of successful walleye stocking. When walleye stocking is successful, the fish community structure is likely to change. There will likely be a change in the other predators. The net influence may be viewed as positive or negative, depending on the management objective for the specific water. Of course, the reverse is also true; other species can impact walleye populations and can seriously hinder walleye stocking efforts.

Specific Walleye Management Goals.-

I. Protect, develop, maintain, and restore critical habitats for natural walleye stocks.

II. Provide a variety of opportunities for the catch and harvest of walleye.

III. Ensure that adequate information on the status and trends of walleye populations is available.

IV. Maintain the genetic integrity of naturally reproducing walleye populations.

V. Provide educational opportunities to develop appreciation of Wisconsin's fishery resources.

Costs and cost-effectiveness of walleye stocking practices. – The cost to produce and stock walleye increases considerably with size: $0.56 / 1,000 fry; small fingerling at $0.04/fish; large fingerling at $0.18/fish; and extended growth fingerlings at $4.47/ fish (WLAB 1997)(Table 9). Production costs can vary considerably from year to year for the fingerling sizes that require additional forage fishes to be provided. Cost-effectiveness is measured as the cost per stocked fish that is recruited to the fishery (i.e., of catchable size). Cost-effectiveness could also be measured as the cost per fish caught or harvested by anglers. The cost-effectiveness of stocking various sizes of walleye varies considerably among waters and years due to variability in survival and variability in production costs.

For walleye, stocking fewer large fish has not been shown unequivocally to be more effective than stocking many small fish (Kerr et al. 1996). However, some circumstances may require the stocking of larger fish to improve survive if predation by other fish on walleye fingerlings is a major limiting factor. With walleye fry stocking, the costs are relatively low but the survival of fry is highly variable and the likelihood of any walleye surviving at all in any given lake is also very low (Kampa and Jennings 1999). Given a survival rate of 0.015% for fry to fall (S. Hewett, unpublished data, 1998) 41,667 fry would need to be stocked to result in 1 surviving walleye to the creel, at a cost of about $ 23.33 per walleye. Cost effectiveness of summer-stocked fingerlings to fall averages $7.44 per surviving walleye. Cost per large fingerlings and extended growth walleye to the creel averaged higher than the small fingerlings (Kampa and Jennings 1999). We estimated 33% survival from age 0 fall to age 1 fall; and 49% survival from age 1 to age 3 (recruitment into the fishery) for fry and small fingerlings.

Tailoring our stocking efforts for water-specific conditions improves the cost-effectiveness of walleye stocking. On average, small fingerlings tend to be the most cost-effective size for stocking. However, many stocked waters have shown limited survival of small fingerlings in the summer. Up to 30 % of stocked waters in some areas may show no contribution to the fishery from stocking small fingerlings (Rick Cornelius, personal communication). Whether predation by other fishes or warm water temperatures are the cause, larger fingerlings or extended growth fish may be the more appropriate option in such waters. There is evidence that larger walleye survive better and return more fish to creel in certain situations. However, because it costs significantly more to raise larger fish, very selective use of these fish is warranted. Similarly, evidence from southern Wisconsin lakes indicates that stocking walleye fry is often successful in lakes with low water clarity. Even in clearer lakes in northern Wisconsin, fry stockings have been successful for rehabilitating winter-kill lakes. It can be very cost-effective to stock fry in certain situations, such as in lakes with turbid waters or in winter-kill lakes that lack predators. Water specific stocking plans and subsequent evaluations are, therefore, the

Table 9. Estimated cost-effectiveness for stocking different sizes of walleye.

Walleye size	Production cost per fish	Survival rate to 3 years of age	Number stocked/ survivor	Cost per survivor to age 3
Fry	$0.56/1000	0.0024%	41,667	$23.33
Small fingerlings	$0.06	0.81%	124	$7.44
Large fingerlings	$0.18	1.62%	62	$11.16
Extended growth fingerlings	$0.65	5.7%	18	$11.70

most efficient means of maximizing cost-effectiveness.

Traditionally, nearly all walleye were hatched at either the Spooner or Woodruff hatchery systems. Before the renovations at these hatcheries, most walleye were raised off-site in leased ponds. Travel costs have been reduced because most walleye are now raised on hatchery grounds. However, costs to stock walleye in the southern part of the state have been high due to transportation costs from the northern hatcheries. With recent changes in the propagation system, walleye for the southern part of the state are now being hatched and raised at Lake Mills, lowering distribution costs, which should improve cost-effectiveness.

Recommended Stocking Guidelines (listed in priority order).- In general, we recommend flexibility in the size of walleye available for stocking to assure that the most cost-effective stocking techniques are used and so that we can use the latest information on stocking practices to ensure that success is not limited by stocking practices. Recommended stocking practices for walleye, summarized in Appendix A, are as follows:

1. Rehabilitation; Remediation: Waters - Winter-kill lakes should not be stocked if serious mortalities occur more frequently than twice in 10 years. Walleye are not recommended for lakes with more frequent winter-kills because walleye are sensitive to low oxygen concentrations and development of a fishable population is unlikely.

Size of fish - Fry should be stocked the first year. If investigation shows poor survival of stocked fry, 2"+ fingerlings should be stocked in subsequent years.
Source of fish - Same waterbody, if pos sible, otherwise basin stock.
Stocking rate - There is some concern that current stocking densities might not be adequate to develop a self-sustaining walleye population. Therefore, we recommend higher stocking rates, as follows: 1,800/acre (fry) or 100/acre (2"+ fingerlings).
Frequency - Annually for 5 years.
Evaluation criteria - Rehabilitation efforts should be evaluated within 10 years prior to further stocking. An evaluation of fingerling stocking should be done. Initial evaluations should consist of fall electrofishing subsequent to stocking or during years when stocking does not occur, to evaluate natural reproduction. Further, a survey should be done to assess survival of stocked fish to reproductive age. This survey should be completed after sufficient time has passed to allow multiple year classes to mature and be present. If adequate survival is not found, rehabilitation stocking can continue for 2 more years, after the spring survey. After this initial rehabilitation period is completed, an assessment of natural reproduction should be made. If no natural reproduction is found, and the decision is made to continue management as a stocked water, the water will be moved to the Recreation category.. Stocking should be discontinued if significant natural reproduction is found and if the management strategy for the water is changed from a rehabilitation to a natural reproduction water.

2. Research/Evaluation: Stocking practices should vary depending upon the objectives of the project. An existing or approved funded evaluation project is required.

3. Recreation (Maintenance): Waters – Existing waters with maintenance stocking. New maintenance quotas will be established only after investigation shows growth is satisfactory and there is little or no natural reproduction for at least 3 years. For walleye to be introduced into new waters, an Environmental Impact Assessment (EIA) will need to be prepared. If the EIA indicates no impact on existing species, then new introductions can be made.

Size of fish – Fingerlings (2"+) or fry.
Source of fish - Basin stock for drainage lakes and rivers; Basin stock for land locked lakes, if available.
Stocking rate – Up to 1800 fry/acre; up to 100 - 2" fingerlings/acre
Frequency – Annual for fry; alternate years for fingerlings. Fingerlings may be

stocked annually for 4 years in new introductions.

Evaluation - Existing maintenance stocking programs should be evaluated every 5-7 years and discontinued if not successful in developing a fishery after 4 years of stocking fingerlings. Initial introductions should be evaluated at the start of year 5 prior to further stocking. This evaluation should include an assessment of impacts to other species. If adequate survival is found, stocking may continue for 2 more years. At that time, alternate year stocking should commence to allow for evaluation of natural reproduction. If no natural reproduction is found, stocking should follow the above strategy.

Production shortfalls - If there are shortfalls in production, cuts will be made from the bottom up. Regions should develop their own priority system for Recreation Stocking waters.

4. Additional recommendations: A) Sauger should not be stocked into waters with naturally reproducing walleye populations. "Saugeye" (walleye x sauger hybrids) should not be stocked into any Wisconsin waters. B) Develop methods and procedures to ensure that all stocked walleye are marked to allow for reliable evaluation of our stocking practices.

Projected Demand for Walleye.- The number of walleye requested by managers has increased steadily since 1990 (Figure 10). Here, we focus on fingerlings because this is the most common size used for stocking; the number of fry produced is typically only limited by demand, except in southern Wisconsin, where a consistent egg source has not yet been identified. During the 1990's, quotas have ranged from about 2,000,000 to 5,400,000 fingerlings. Two of the major recommendations of this report are 1) to eliminate the per-water-maximums for walleye, and 2) to increase the stocking rates for all sizes of walleye. We have 2 years of experience under these new guidelines that suggest that the demand for walleye will increase. The projected number of fingerlings needed for management purposes is 5,600,000. We anticipate that the quota requests will level off now that the new guidelines are in place. Another notable change relates to year-to-year fluctuations in demand. Prior to the new guidelines, quota requests from one year to the next varied by about 2 million fingerlings. After 2 years under the new guidelines, annual fluctuations appear to be much less. Demand for large (4"+) fingerlings is projected to further increase as we increase our efforts to evaluate the use of these fish for management purposes. We anticipate that the demand for large fingerlings will exceed 1 million by 2005.

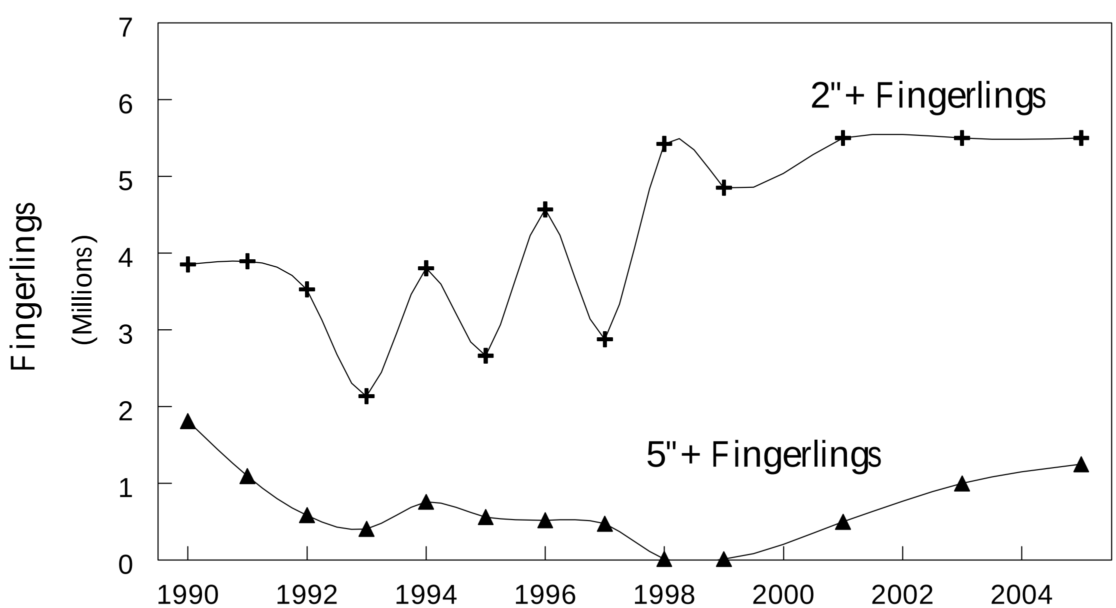

Figure 10. Recent and projected demand for walleye fingerlings, 1990-2005.

III. SUMMARY AND RECOMMENDATIONS

Risks associated with projections.- The projections contained in this report are based on a combination of past stocking practices and best professional judgment. Historically, the demand for hatchery fish has been based partially on public expectations and perceptions and, to some degree, on available supply. Projections based on historic supply are constrained by past hatchery practices which, while untested, could be modified considerably to meet demand. This is the first contemporary attempt by DNR to estimate demand for hatchery fish, so there is some uncertainty associated with these projections. However, the approach taken in this report is viewed as a logical first step from which future refinements can be made.

MANAGEMENT RECOMMENDATIONS

Several recommendations were common across many of the species reviewed in this report. The most important ones are highlighted below.

Protection of existing natural reproduction. - This is a universal theme throughout this report. Populations sustained through natural reproduction provide the best fishing, and are therefore worthy of vigorous protection. Any actions we can take to reduce the risk of impacting naturally reproducing populations should be pursued, whether through the hatchery system, habitat protection, or harvest regulation.

Strain Development.- The department should fully evaluate the development and use of genetic strains. Broader use of this approach would ensure that the most appropriate stock or strain is used to most efficiently manage Wisconsin's fishery resources. Therefore, as a first step, basin-specific stocks should be used for most stocking in the state. This may initially result in some difficulties in the hatchery system, in terms of timing and location of appropriate feral stocks and keeping stocks separate in the hatchery system. However, it is believed that this approach will, in the long term, result in stocking a product that is better suited to the receiving waters and, ultimately, better fishing. In the future, requests for different strains will need to be evaluated through the quota system in order to accurately assess demand.

Define "Self-sustained". - Many of the recommendations in this use the term "self-sustained" to characterize fisheries supported by natural reproduction. We need to ensure that population characteristics indicative of self-sustained populations are identified and well defined.

Long-term quotas.- We recommend the establishment, where feasible, of stocking plans with long-term quota requests for individual waters. For the major stocked species, the demand for stocked fish is relatively constant from year to year. Development of a 5- or 10-year stocking plan for stocked waters will reduce annual planning workload and will provide the hatchery system, private fish hatcheries, and cooperators with a long-term demand. In cases where special needs arise, the system should be flexible enough to address these short-term demands from the hatcheries. Stocking plans for individual waters should clearly identify the desired outcome of the stocking regime and an evaluation of the success of the plan. Attainment of that outcome should be evaluated before renewal of another long-term commitment for fish from the hatcheries or private providers.

Per-Water-Maximums.- In general, the per-water-maximum numbers for stocking are eliminated in deference to the best biological recommendation, regardless of limitations in production. However, due to the high variability in hatchery production from year to year, there will be inevitable shortfalls. We recommend addressing this problem by prioritizing stocking strategies statewide and, within those categories, requiring cuts in the waters that are stocked rather than spreading out fewer fish in all waters where fish were requested. This approach assumes that the likelihood for success is higher for a few waters that get adequate numbers of fish rather than for a few fish in a greater number of waters, assuming the quota requests are biologically-based.

Shortfalls in WDNR Hatchery Capacity- The requested number of fish of any one species could likely be met by the hatchery system, but it would adversely affect the availability of other species from the hatcheries. For example, walleye and muskellunge are the primary species competing for space in the warm water hatcheries while Great lakes and inland salmonids compete for space in the cold water facilities. Demand for many of these species is currently not being met.

Examination of the need for stocked fish, coupled with instances where we are unable to meet that need through the state hatchery system suggests that there may be room for increased involvement from private fish hatcheries throughout the state, as suggested by WDNR (1997). Development of longer-term quotas would make it easier for private industry to plan for and provide fish for stocking. Development of more cooperative agreements would benefit both the state and private fish hatcheries.

Stocking Team.- A team of Department biologists and hatchery personnel should be formed to periodically evaluate the stocking program. This forum would provide an outlet for 1) presentations on in-state stocking evaluations; 2) review of current scientific literature related to stocking, propagation, and related issues; 3) increased communication between biologists and hatchery personnel; and 4) development of work planning guidance for future stocking evaluation projects. In short, the purpose of this team would be to maintain the state-of-the-art in our stocking program through a continuous improvement process.

IV. LITERATURE CITED

Beacham, T., C.B. Murray, and R.E. Withler. 1989. Age, morphology, and biochemical genetic variation of Yukon River chinook salmon. Transactions of the American Fisheries Society 118:46-63.

Fields, R.D., M.D.G. Desjardins, J.M. Hudson, T.W. Kassler, J.B. Ludden, J. V. Tranquilli, C.A. Toline, and D.P. Philipp. 1997. Genetic analyses of fish species in the upper midwest. Aquatic Ecology Technical Report 97/5. Illinois Natural History Survey. Champaign.

Gharrett, A.J., C. Smoot, and A.J. McGregor. 1988. Genetic relationships of even-year northwest Alaska pink salmon. Transactions of the American Fisheries Society 117:536-545.

Hanson, D.A., M.D. Staggs. S.L. Serns, L.D. Johnson, and L.M. Andrews. 1986. Survival of stocked muskellunge eggs, fry and fingerling in Wisconsin Lakes. Pages 216-228 in G.E. Hall, Editor. Managing muskies. American Fisheries Society Special Publication 15, Bethesda.

Jennings, Martin. 1996. Genes make all the difference. Wisconsin Natural Resources, February.

Kampa, J.M. and M.J. Jennings. 1998. A review of walleye stocking evaluations and factors influencing stocking success. WDNR, Research Report.

Keim, S. 1998. Expenditures of Great Lakes Salmon and Trout Stamp Revenues; Fiscal Years 1996-1999. WDNR, Bureau of Fisheries Management and Habitat Protection. Administrative Report 42.

Kerr, S.J. and six other authors. 1996. Walleye stocking as a management tool. Ontario Ministry of Natural Resources. Petersborough, Ontario.

Klingbiel, J. 1981. The status of bass management - an informational report to the natural resources board. WDNR, Bureau of Fish Management, Administrative Report 12.

Klingbiel, J. 1986. Population Data for Fisheries Management, Fish Management Reference Book. WDNR, Bureau of Fisheries Management. Madison.

Krueger, C.C., E.J. Marsden, H.L. Kincaid, B. May. 1989. Genetic differentiation among lake trout strains stocked into Lake Ontario. Transactions of the American Fisheries Society 118:317-330.

Li, J., Y. Cohen, D.H. Schupp and I.R. Adelman. 1996. Effects of walleye stocking on year-class strength. North American Journal of Fisheries Management 16:840-850.

Loomis, J. and P. Fix. 1998. Testing the importance of fish stocking as a determinant of the demand for fishing licenses and fishing effort in Colorado. Human Dimensions of Wildlife 3(3):46-61.

Margenau, T.L. 1992. Survival and cost-effectiveness of stocked fall fingerling and spring yearling muskellunge in WI. North American Journal of Fisheries Management 12:484-493.

Newburg, H. J. 1975. Review of selected literature on largemouth bass life history, ecology, and management. Minnesota Department of Natural Resources, Investigational Report 335.

Oehmcke, A.A. 1969. Muskellunge management in Wisconsin. WDNR Division of Fish, Game and Enforcement. Bureau of Fish Management Report 19.

Philipp, D.P. 1991. Genetic implications of introducing Florida largemouth bass *Micropterus salmoides floridanus*. Canadian Journal of Fisheries and Aquatic Science 48:58-65.

Philipp, D.P. 1991. Survival and growth of northern, Florida, and reciprocal F1 hybrid largemouth bass in central Illinois. Transactions of the American Fisheries Society 120:58-64.

Philipp, D.P., W.F. Childers and G.S. Whitt. 1981. Management implications for different genetic stocks of largemouth bass (*Micropterus salmoides*) in the United States. Canadian Journal of Fisheries and Aquatic Science 38:1715-1723.

Philipp, D.P. and J.E. Claussen. 1995. Fitness and performance differences between two stocks of largemouth bass from different river drainages within Illinois. American Fisheries Society Symposium 15:236-243.

Ryman, N. and F. Utter. 1987. Population genetics and fishery management. University of Washington Press, Seattle.

Serns, S.L. and L.M. Andrews. 1986. Comparative survival and growth of three sizes of muskellunge fingerlings stocked in four northern Wisconsin lakes. Pages 229-237 in G.E. Hall, Editor. Managing muskies. American Fisheries Society Special Publication 15, Bethesda.

Szendrey, T.A., and D.H. Wahl. 1996. Size specific survival and growth of stocked muskellunge: effects of predation and prey availability. North American Journal of Fisheries Management 16:395-402.

Wahl, D.H., and R.A. Stein. 1989. Comparative vulnerablility of three esocids to largemouth bass (Micropterus salmoides) predation. Canadian Journal of Fisheries and Aquatic Sciences 46:2095-2103.

WDNR (Wisconsin Department of Natural Resources). 1998. Production capacities of the Wisconsin Department of Natural Resources' Fish Propagation Facilities. WDNR, Bureau of Fisheries Management and Habitat Protection, Madison.

WDNR (Wisconsin Department of Natural Resources). 1997. The role of private fish hatcheries in Wisconsin: in search of a clear direction. WDNR, Bureau of Fisheries Management and Habitat Protection, Madison.

WDNR (Wisconsin Department of Natural Resources). 1979. Fish and wildlife comprehensive plan. Part I - Management strategies 1979-1985. WDNR, Madison.

WLAB (Wisconsin Legislative Audit Bureau). 1997. An evaluation - Fish stocking activities – Department of Natural Resources. Report 97-9.

V. APPENDICES

Appendix Table 1. Previous stocking guidelines for the sizes of warm water fish available from the hatchery system. Data are stocking rates per acre (maximum number per water).

Size	Muskellunge	Walleye	Northern pike	Black bass	Lake sturgeon
Fry	500/acre (100,000)	1000/acre (500,000)	1000/acre (200,000)	100/acre (100,000)	200/acre (250,000)
Small fingerling	4.0-6.0″ 5/acre (5,000)	1.75-2.25″ 50/acre (100,000)	3.5-5.5″ 5/acre (5,000)	1.5-2.0″ 50/acre (50,000)	1.0-3.0″ 50/acre (50,000)
Large fingerling	>7.0″ 2/acre (2,500)	2.5-3.25″ 25/acre (50,000)	>7.0″ 2/acre (2,500)	2.25-2.75″ 25/acre (25,000)	>3.0″ 5/acre (5,000)
Extended growth	-------	>5.0″ 10/acre (10,000)	-------	>4.5″ 10/acre (10,000)	-------
Adults					50 minimum

Appendix Table 2. Revised stocking guidelines and recommended sizes of fish needed from the hatchery system. Data are stocking rates per acre (maximum number per water, if production is limited).

Size	Muskellunge	Walleye	Northern pike	Black bass	Lake sturgeon
Fry	500/acre (100,000)	1800/acre	1000/habitat acre	-------	-------
Small fingerling	4.0-6.0″ 5/acre (5,000)	>1.0″ 100/acre	3.5-5.5″ 5/habitat acre	-------	>3.0″ 80/mile or 0.5/acre
Large fingerling	>7.0″ up to 2/acre (2,500)	>4.0″ 20/acre	>5.5″ 2/habitat acre	2.0+″ 25/acre	>6.0″ 40/mile or 0.25/acre
Adults				5/acre	200 minimum