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Executive Summary

Historically, the walleye *Sander vitreus* fishery in Saginaw Bay was among the largest in the Great Lakes, second to only that in Lake Erie. The walleye fishery collapsed in the mid 1940s, however, due to a series of year class failures. The failures were principally the result of spawning habitat degradation brought about by a series of human activities. The opportunity for recovery began in the 1970s with improving water quality. Walleye fingerling stocking was stepped up by the Michigan Department of Natural Resources (MDNR) in the early 1980s and a sport fishery soon developed. However, the walleye fishery plateaued by the mid 1990s, well short of historic yields. The bay remained heavily dominated by small prey fish species and there was insufficient predation to maintain ecological balance. There was some evidence of walleye natural reproduction but a lack of knowledge about modern day sources of recruitment, and the obstacles to expanding recruitment prevented the formulation of additional management strategies.

The MDNR began a series of research projects designed to obtain answers about the status of the walleye population, including recruitment sources. This research suggested an additional gauge for measuring progress towards walleye recovery based on growth rate. Walleye grow extremely fast in Saginaw Bay because of the abundance of prey resources, and an overall low abundance of walleye and other predators. New recovery objectives were defined as a walleye population sufficiently abundant that the growth of age-3 walleyes declines to 110% of the state average rate (currently 128%). The growth rate objective is superior to an objective based on historic yields, due to fundamental differences between the modern sport fishery and the historic commercial fishery. Current recovery goals are:

- Predator/prey balance
- Walleye population at carrying capacity
- Self-sustaining natural reproduction

Research conducted by the MDNR also led to the conclusion that modern day sources of walleye included natural reproduction from the bay's rivers (particularly tributaries of the Saginaw River), stocking, and immigration from sources outside Saginaw Bay. Natural reproduction on offshore reefs within Saginaw Bay was no longer a significant source of recruitment. The inner bay reefs (which were most important) were degraded by sedimentation. Reproduction in rivers was limited by dams that blocked nearly 2/3 of the watershed's river reaches. Further limitations to natural recruitment are believed to include predation by alewives *Alosa pseudoharengus* on newly hatched walleye fry. Research findings also documented the effectiveness of stocking small fingerlings as a management tool.

Armed with this information, a series of management strategies and options were devised and compiled in this report. The strategies and options listed are designed to specifically address the obstacles limiting natural reproduction.

- Fish Passage–Six different rivers were identified as candidates for either removal of dams or the construction of ladders. The purpose is to restore access to spawning for migrating walleyes.
- Reef Reclamation–If reclamation of reefs could succeed in providing suitable substrate for spawning, then this practice could reclaim some of this historic source of recruitment. Reef reclamation, however, is problematic due to the abundance of predacious alewives in the open water, and a low remaining abundance of reef spawning strains of walleyes within the bay. The approach here is included as an experimental option.
- Increased stocking–Stocking more fingerling walleye is offered as a means to make progress towards increasing predation rates and increasing abundance. Increased stocking alone is not expected to directly contribute to more natural reproduction but can indirectly facilitate natural recruitment via increased predation of alewives.
- Sediment control–Because much of the degradation to spawning habitat was a result of sedimentation and because sediment loads remain excessive in the Saginaw River system, relief is needed to help preserve remaining habitat and to protect any new habitat developed. Partnerships needed to be developed with land management and water quality agencies to ensure that fisheries needs are included for the Saginaw Bay watershed.

Additional strategies are examined in the report but were rejected as not directly addressing the known limiting factors. Research needs are also identified.

This plan advocates an adaptive management approach to recovery, where research and evaluation are used along the way to gauge progress, with strategies adjusted as necessary. However, implementation will have to come on a large enough scale to produce measurable changes. Implementation can take several forms and not all options need to be pursued simultaneously. The more varied the approach, however, the greater the likelihood for success. While some walleye recovery progress has been made, further and complete recovery will not occur without additional management intervention. The magnitude of Saginaw Bay's fishery and the economic activity generated by its fisheries justify further investment by the MDNR, other agencies, and stakeholder groups.

Introduction

Historically, Saginaw Bay supported the largest commercial walleye fishery in Lake Huron and was second in the Great Lakes to only Lake Erie (Hile 1954; Baldwin and Saalfeld 1962). The earliest commercial fisheries dated to the 1830s, and walleye were specifically noted in catch records as early as 1858 (Schneider 1977). The fishery was supported by reproduction in the watershed's rivers and on offshore reefs (Schneider and Leach 1977). River-based reproduction was lost first, due to a progression of habitat degradation. Rivers were clogged with the products and waste from the logging industry. As watershed usage gave way to agriculture, sedimentation increased further degrading the river spawning substrate. By the turn of the 20th Century, numerous dams were constructed impeding the migration of spawning walleyes. As the Saginaw River system became industrialized, water was further polluted. During this time, reef-based reproduction sustained the bay's walleye fishery. Eventually it too succumbed to habitat loss fueled by sedimentation and reef degradation (Schneider and Leach 1977; Fielder 2002).

The fishery peaked in 1942 at 930,000 kg of harvest before it collapsed in 1944 (Baldwin and Saalfeld 1962; Keller et al. 1987). Several localized walleye fisheries of Saginaw Bay collapsed around the turn of the century due to over harvest (Schneider 1977) but the overall open water fishery sustained an average yield of 458,000 kg from 1885 through 1950. Fluctuations in the fishery during this time probably represented repeated periods of over fishing and recovery. Because the fishery was sustained for such a long period, however, the collapse in 1944 is not attributed to the commercial fishery. Instead, the collapse is attributed to a series of year class failures resulting from habitat loss and degradation (Schneider 1977; Schneider and Leach 1977), although intensive exploitation by the fishery no doubt hastened the demise of the population and left it vulnerable to the effects of recruitment failures. Shortly after the collapse of the fishery in the 1940s, the bay was invaded by alewives. Alewives, along with the nonnative rainbow smelt *Osmerus mordax*, were thought to have suppressed any possible natural recovery by preying on newly hatched walleye fry (Schneider and Leach 1977).

Improvements to water quality in the bay, largely brought about by the passage of the Clean Water Act of the early 1970s, provided the foundation for a walleye recovery. Walleye fingerlings were stocked by the Michigan Department of Natural Resources (MDNR) in the early 1980s and a sport fishery soon emerged (Keller et al. 1987; Mrozinski et al. 1991). Over time, the walleye population and its fishery grew but, with stocking at its maximum capacity and habitat and recruitment limitations still in place, the fishery eventually plateaued by the mid 1990s, well short of full recovery (Fielder et al. 2000). The modern day walleye population in the bay is supported by recruitment from both stocking and natural reproduction, and supplemented by immigration (Fielder et al. 2000; Fielder 2002). Natural reproduction is limited to unimpounded portions of certain rivers and reef-based reproduction is still lacking (Fielder 2002). Despite the three sources of walleye to the bay (limited river-based natural reproduction, stocking, and immigration), the bay's walleye population and fishery still subsisted short of the full potential of the habitat and prey base. The bay's ecosystem also continued to suffer from the effects of an over abundant (under utilized) prey base.

This plan seeks to provide a conceptual framework to further the recovery of the walleye population and fishery in Saginaw Bay, and assumes a fundamental understanding by the reader of the issues necessitating walleye recovery. The reader is encouraged to consult the published works summarized above for proper context of this plan.

Background

The Fisheries Division of the MDNR has long been committed to restoration of degraded Great Lakes fisheries, including the recovery of walleye in Saginaw Bay. Recovery in Saginaw Bay is an issue of larger importance than simply the restoration of a walleye fishery. For decades Saginaw Bay has experienced an imbalance of predator and prey, with too few predators to fully control the abundant prey fishes (Keller et al. 1987; Haas and Schaeffer 1992). The consequence of this imbalance is that zooplankton resources are over grazed and dominated by unfavorably small organisms. Furthermore, growth of some middle trophic species like yellow perch have been slow and even stunted (Keller et al. 1987; Haas and Schaeffer 1992; Fielder et al. 2000). Survival and growth of juveniles of some sport and commercial species also suffer from a shortage of larger invertebrate prey. Walleye recovery in Saginaw Bay has significant ramifications not only for the fishery but also for the ecological balance of a large part of the Michigan waters of Lake Huron.

The MDNR's goal for walleye recovery in Saginaw Bay has been to reestablish walleye as the dominant predator. The walleye population should be self-sustaining and capable of supporting a fishery of historical proportions (Keller et al. 1987). The historical commercial fishery for walleye in Saginaw Bay sustained a long-term, precollapse average yield of 0.45 million kg. Similarly, the Fish Community Objectives for Lake Huron established by the Great Lakes Fishery Commission, Lake Huron Committee, calls for walleye to fill the role of dominant coolwater predator, with populations in Lake Huron capable of sustaining an annual surplus of 0.7 million kg (DesJardine et al. 1995).

Fielder (2002) questioned the appropriateness of using commercial fishery yield as a recovery target for a population now exploited solely by a sport fishery. A sport fishery may not be able to achieve and sustain an exploitation rate as high as that of a commercial fishery. Fielder (2002) addressed the issue of measuring progress to recovery and recommended using growth as the primary target or objective. Because growth of most fish populations is density dependent (at least at higher densities), growth rate can be used as an indicator of abundance (Colby et al. 1994). One advantage of a growth rate based recovery target is that it would reflect the available habitat and prey base. As carrying capacity of the ecosystem may change over time, the objective remains appropriate, even though management action may be necessary to maintain it.

In Saginaw Bay, walleyes grow extremely fast, a reflection of their low abundance relative to the capacity of the habitat and prey base (Figure 1) and by comparison to other notable walleye populations of similar latitude (Figure 2). In Lake Erie, growth of walleyes followed a predictable downward trend as walleye abundance recovered during the 1970s (Muth and Wolfert 1986). Managing for a decline in growth rate might seem counter intuitive, however, for a fish population existing below carrying capacity of the habitat and prey base, a declining growth rate is an indication of increasing abundance or density. Growth objectives are usually established with some reference growth rate such as state average rates (Schneider et al. 2000) and are expressed as a certain length by a specific age. The premise of a growth objective is that a balance between numbers and size is the ultimate intent. Large or trophy size members of the population can still be achieved via fishery escapement and longevity (controlled exploitation rate).

Fielder (2002) addressed a series of unknowns that prevented formulation of a strategy for furthering, and ultimately completing, the task of walleye recovery in Saginaw Bay. The MDNR Fisheries Division's, Lake Huron Basin Team and Management Team, along with other walleye experts from the Division, met during 2001 and 2002 to fully review all past and existing study findings relevant to the walleye population and corresponding ecosystem of Saginaw Bay. The Fisheries Division came to several important conclusions based on those meetings.

- The walleye population of Saginaw Bay is not fully recovered or is at least not functioning at the full capacity of the adult habitat and prey base.
- The current situation (walleye population existing below carrying capacity; heavily dependent on stocking; and an ecologically unbalanced bay ecosystem) is unacceptable and further management initiatives are required to reach full recovery.
- Recovery should not be defined by fishery yield alone, but also by density-dependent growth rate (density increasing such that growth rate declines): specifically mean length of age-3 walleye declining to a level of 110% of the state average.

The above assessments, adopted by the Fisheries Division, MDNR were predicated on certain widely acknowledged limitations and concepts, many of which are documented in previous research. They are:

- Walleye abundance in Saginaw Bay is recruitment limited.
- Limitations to reproduction are primarily habitat driven.
- Limitations to recruitment likely include predation on walleye fry by alewives and possibly smelt.
- The walleye population of Saginaw Bay at its present level is insufficient to bring about the desired ecosystem balance between predator and prey densities.
- The existing walleye population is a mix of locally produced river-spawned recruits, recruits from fingerling stocking, and seasonal adult immigration from the Lake St. Clair/Lake Erie corridor.
- Historical reef spawning habitat is degraded and no longer a significant source of walleye recruitment in the bay.
- The existing walleye fishery in the bay is primarily dependent on walleye stocking.
- Walleye natural reproduction is not expanding under current conditions.

- The walleye fishery and population has plateaued short of full recovery.
- The Saginaw Bay walleye fishery benefits from immigrants, but even with immigration, objectives have not been achieved and there is no realistic way to affect or encourage more immigration.
- The current level of exploitation is not a limiting factor to further walleye recovery and harvest regulation changes are not presently needed.

The MDNR's Fisheries Division further directed that this plan be developed to explore management options and provide a prescription of management initiatives to increase density of walleye sufficient to reach recovery goals. It is understood that the long-term goal is to achieve the increase in density and sustain the population via natural reproduction. It is acknowledged, however, that stocking can be a vehicle in the interim to: (1) increase density of walleyes, (2) support and expand the fishery until natural reproduction can be increased, and (3) be a vector for the introduction of new strains if desired.

In summary, the recovery goals are:

- To increase abundance of walleyes in Saginaw Bay to the carrying capacity of the adult habitat.
- To achieve a balance in predator/prey ratios in Saginaw Bay with walleye functioning as the principle predator.
- For the above walleye population to be self sustaining.

The measurable recovery objectives are:

- A density of walleyes such that walleyes grow no faster than 110% of the state mean length at age-3.
- A population of walleye capable of sustaining an annual harvestable surplus of 0.45 million kg (1 million pounds).
- Above objectives to be achieved without dependence on stocking (stocking cessation or decrease to occur when three year classes within five years, meet or exceed a ratio of 50:50 wild to hatchery fish; see stocking section to follow).

The fundamental premise of this recovery plan is that further recovery of the Saginaw Bay walleye population will result in desirable outcomes benefiting both users and the overall ecosystem. Specific advantages to a fully recovered walleye population in Saginaw Bay (population existing at carrying capacity of the bay's adult habitat and prey base) are;

- Reduction of over abundant prey (especially nonnative planktivores) to: (1) reduce over-grazing of zooplankton resources, (2) reduce interspecific competition between prey species and yellow perch, (3) conversion of biomass into desirable species, and (4) encourage more walleye natural recruitment.
- Ecosystem more resistant to the invasion of exotic species.
- Provide foundation for possible restoration of other native species.
- Provide for better walleye fishing.

Possible disadvantages might include:

- Increased predation on main basin prey resources (competition between walleye and other sport species).
- Possible lower survival rate of near-shore salmonine juveniles in Lake Huron due to walleye predation.

Analysis of potential impacts by emigrants on main basin prey resources from a recovered Saginaw Bay walleye population are believed to be negligible compared to other main basin predators based on consumption estimates (D. G. Fielder, MDNR, unpublished data). If lower survival of newly stocked salmonines is a consequence of walleye recovery, management action may be necessary such as increasing salmonine stocking rates, and other measures to improve survival such as use of stocking windows (time periods of abundant near-shore prey which buffer predation). In general, these tradeoffs are deemed manageable and acceptable in return for achieving walleye recovery.

Unfortunately, enough obstacles exist to successful natural reproduction and recruitment of Saginaw Bay walleyes that no single course of action will lead to complete recovery. In the open water of the bay, obstacles include degradation of reef spawning habitat, low abundance of reef spawning brood stock, and predation by nonnative planktivores. In the rivers, dams and other barriers impede migration of spawning walleyes and may also interfere with the successful transport of fry back to the bay or to downstream nursery areas. Downstream nursery habitat may also be lacking or limiting in some rivers.

The following is an examination of options that address various factors thought limiting to walleye natural reproduction/recruitment and collectively constitute the recommended recovery strategy.

Management Options for Recovery

Fish Passage/Dam Removal

The Saginaw Bay watershed is fragmented by nearly 300 dams or spillways (Figure 3). Of the watershed's rivers, 72% of river reaches are inaccessible to fish migrating from the bay because of dams and spillways (M. MacKay, MDNR, personal communication). Leonardi and Gruhn (2001) aptly described the negative environmental and ecological consequences of a watershed fragmented by dams. Improving fish passage at existing dams, either by ladders or by dam removal, is the single surest means to increase natural reproduction. River spawning walleyes are the only proven source of natural recruitment in the bay. The principle source is river spawning in reaches below the first impoundments in the Saginaw River system (chiefly the Tittabawassee and Flint Rivers) (Fielder et al. 2000; Fielder 2002). The annual amount of recruitment from natural reproduction in rivers, however, is inadequate to meet recovery goals and is no longer expanding (Fielder 2002). Establishment of fish passage and/or removal of unnecessary dams, while no small undertaking, can pay great dividends in terms of enhancing walleye reproduction. Enhancement of fish passage can also benefit lake sturgeon, white bass, and a variety of other species.

Dam removal is the preferred option for maximizing benefits of natural reproduction. Dam removal eliminates the problem of safe and effective downstream transport of walleye fry and adults that may otherwise be retained above dams or killed in hydroelectric turbines. Removal of dams also facilitates recovery of higher gradient river reaches, which are often necessary for successful natural reproduction. When dam removal is deemed impossible or undesirable, passage of migrating walleyes would be an alternative, providing suitable spawning habitat exists above the impoundment and good survival during downstream passage of adults and juveniles could be expected.

Numerous fish passage and ladder designs exist. Designs must be customized to solve individual problems at each site. Fishway design strategies should be coordinated with the U. S. Fish and Wildlife Service to minimize upstream access for sea lampreys while facilitating passage of other fish species. Each fishway installation will require evaluation to determine the levels of benefit and any necessary refinements.

Management Option:

Embark on a program of fish passage facilitation in the Saginaw Bay watershed with emphasis on the following rivers:

- Shiawassee River
- Cass River
- Pine River
- Chippewa River
- Tittabawassee River
- Flint River

The first priority should be the downstream most barrier. Subsequent priorities for restoration of access to spawning grounds should then proceed to the next upstream barrier in each of the primary rivers of the watershed. Means for establishing fish passage and/or achieving dam removal will have to be formulated. Dam removal should be opportunity driven, capitalizing on the willingness of dam owners to participate in retirement and removal of dams.

Research Needs:

A. Design and implement a study of riverine habitat in the Saginaw Bay watershed, with the objective of identifying river reaches most beneficial for passage and/or dam removal. Employ a Geographic Information System and Habitat Suitability Index approach (verified by field surveys of extant conditions when necessary). Use this information to prioritize fish passage and/or dam removal initiatives and utilize findings from the existing Tittabawassee River dams survey.
B. Design and implement a study of walleye fry production, downstream transport, and survival, related to the availability of downstream nursery habitat in Saginaw Bay tributaries. Identify and analyze factors affecting and limiting river-based natural reproduction.

Reef Reclamation

The recovery needs of reef-spawning stocks are more problematic than those for river-spawning stocks. Maintenance or enhancement of brood stock alone will likely do nothing to achieve natural reproduction in the face of degraded habitat. Stocking reef-spawning strains of walleye in Saginaw Bay may help ensure the presence of that strain of walleyes, when and if conditions and habitat become available. The re-introduction of reef-spawning strains of walleye may also provide for an opportunity to achieve some reproduction from remaining outer bay reefs at least in some years (which are otherwise thought to occur in water too cold in most years for walleye spawning). Genetic selection for certain reef spawning behavior traits may lead to a strain of walleye better suited to outer bay spawning. Such traits might include later spawning dates that would coincide with slower warming of the outer bay.

The reclamation of reefs in inner Saginaw Bay is an option that directly addresses the lack of suitable inner bay spawning habitat. Reef reclamation, however, distinguishes between reclamation and construction of artificial reefs. In reef reclamation, habitat work can include sediment removal as well as substrate placement. Placement of substrate would be limited to natural material (gravel/cobble) that is consistent with the original reef substrate. Artificial reefs too can use natural material but often have included unnatural material such as construction debris. While this plan distinguishes between the two practices and is limited to reclamation, there is some value in understanding the past uses of “artificial reefs”.

Construction of artificial reefs in freshwater dates back to the 1930s (Stone 1985). Construction of artificial reefs has since become very popular with anglers who consider them as tangible actions for their license dollars and club investments, although biologists have not always shared their enthusiasm (Radonski et al. 1985; Grossman et al. 1997).

There is some precedent for artificial reef construction in the Great Lakes and inland waters of Michigan. Some reefs were only intended to serve as fish attractants and not necessarily to benefit reproduction (Binkowski 1985; Kelch and Reutter 1995). Evaluation of many artificial reefs has often been limited to this first criteria (Binkowski 1985; Kevern et al. 1985; Rutecki et al. 1985; Kelch and Reutter 1995).

A 610 m reef built in Brevoort Lake, Michigan stimulated walleye reproduction. Walleyes were documented to spawn on the reef the first spring after construction in 1984. Egg deposition and age-0 walleye production increased in subsequent years (Bassett 1987, 1988; Colby et al. 1994).

The artificial reef constructed in the Tawas Bay portion of Saginaw Bay was intended to benefit lake trout and walleye reproduction (Foster and Kennedy 1995) and lake trout have been documented to spawn there. However, walleye usage of the reef was never fully evaluated. Sampling by Fielder (2002) did not detect evidence of a significant spawning population on the reef. Its location, however, is in the outer-bay region of Saginaw Bay and may not be indicative of how an inner bay reclaimed reef might perform.

A primary consideration is whether enough habitat could be reclaimed to make a measurable contribution to the population. For example, there are about 300 reefs in western Lake Erie (Herdendorf 1985). Of those, the thirteen most notable reefs collectively offered 137 ha of preferred spawning area (< 5m depth) (Herdendorf 1985). While the replication of the original inner bay reef habitat in Saginaw Bay may be impossible, it may be achievable to create enough to add an element of diversity to the sources of recruitment. Such diversity in recruitment would add resiliency to walleye population and help restore the normative condition as described by Coutant (1997). The efficacy of such efforts, however, may be moot in the absence of reef spawning strains of fish, the continued presence of larval predators like alewives, or if sedimentation is an on-going problem.

Because restoration of reef-based reproduction is more problematic than enhancements to other recruitment sources, this option may form a lower overall priority in the implementation phase of the plan or be pursued only after other options are exhausted. In addition, reef reclamation is offered here only as an experimental approach with a stepwise method to first explore feasibility and then pursue the option on an experimental basis.

Management Option:

Evaluate feasibility for reclamation and efficacy for natural reproduction on reclaimed reefs in Saginaw Bay. Investigate the potential for reclaiming a reef as an experimental project in the inner portion of Saginaw Bay. Evaluate its usage by spawning walleye using the methods of Fielder (2002). Depending on its success, consider additional reef reclamation projects in other locations in the inner bay.

Research Needs:

A. Conduct a comprehensive study of the condition and usage of the existing Tawas artificial reef.
B. Conduct a feasibility study for the reclamation of an inner bay reef.
C. If feasible, reclaim a reef and supplement (if necessary) with substrate placement and evaluate spawning use by walleyes and subsequent fry production.

Alewife Control

Alewives and their predatory effects on newly hatched walleye have been postulated to be among the factors limiting walleye recovery (Schneider 1977; Schneider and Leach 1977; Keller et al. 1987). Walters and Kitchell (2001) described such a phenomenon, proposing that for some predator populations, high predation rates by adults favors survival of juveniles. This cultivation/depensation hypothesis is based on a depensatory relationship between juvenile survival and high abundance of adults of the same species, which is a departure from more traditionally held compensatory mechanisms of a stock/recruitment relationship. Under this hypothesis, a “trophic triangle” between adults, juveniles, and forage fish exists where predation by adults cultivate a fish community assemblage that favors survival of their own juveniles. At insufficient densities of predatory adults, forage fish gain the upper hand creating a competitive and predatory juvenile bottleneck. Walters and Kitchell (2001) believe that such cultivation effects are common to dominant predators in freshwater fish communities and urge the consideration that successful recruitment may require higher adult densities than would otherwise be necessitated for brood (spawning) purposes alone.

Colby et al. (1994) noted that walleye recovery in Bay of Quinte, Lake Ontario, and western Lake Erie both appeared to be partly dependent on a critical threshold of adult abundance. This may well have been the depensatory/cultivation hypothesis at work. Walters and Kitchell (2001) also note other examples of this relationship at work in walleye populations.

Consequently, control of alewives in Saginaw Bay might be considered among the suite of recovery options employed. Alewives, however, have supplanted many of the native prey species of Lake Huron and their importance in sustaining other fisheries is well rooted. Pacific salmon introductions of the 1960s were successful in controlling this exotic species, but alewives remain abundant and Lake Huron's offshore salmonine predators now depend on them as sufficient prey for most sport species. Thus, complete elimination of alewives from Lake Huron is neither possible nor desirable. Reduction of current levels of alewives locally in Saginaw Bay, however, may be a possibility.

Given a large enough predator population in the bay, alewife abundance could be reduced (Vandermeer and Maruca 1998). This, coupled with natural fluctuations in alewife abundance, may provide periodic years with conditions that would allow for improved recruitment of walleyes. A higher density of larval walleyes resulting from higher brood stock abundance may allow more escapement of walleye fry. Likely, this is the mechanism by which yellow perch recruitment is still possible in the face of the same alewife population.

Walleye Stocking

Walleye stocking in Saginaw Bay was originally intended to reestablish the species' presence and to provide for natural reproduction. These goals have been realized. The magnitude of that natural reproduction, however, has not met the goals of reaching the biological capacity of the adult habitat, providing for a fishery that is commensurate with historic yields, or leading to a population of sufficient proportion to achieve the desired balanced ecosystem. Walleye stocking has continued and has evolved into a put-grow-and-take sport fishery supplement.

Walleye stocking with spring fingerlings is effective in Saginaw Bay despite its supplementary nature (Fielder 2002). This is because the natural reproduction is insufficient to meet the carrying capacity of the bay for walleye. Thus, walleye stocking in recent years has functioned more as a maintenance stocking program rather than a supplemental stocking program as defined by Laarman (1978).

Stocking provides a powerful tool to managers for increasing the abundance of walleyes and for possibly reintroducing reef spawning walleye in Saginaw Bay. With the possible exception of this "threshold" phenomenon previously described, further or increased stocking will likely not directly serve to increase natural reproduction. Stocking has been, however, essential to supporting the sport fishery to date. Without stocking, the sport fishery would be only 20% of its present size (Fielder 2002).

The recovery goals for abundance and ecosystem balance might be artificially achieved through increased stocking. The principle advantage is that a walleye population at or near recovered levels would help to answer fundamental questions necessary to evaluate management goals. They are:

- Will ecosystem balance be affected by higher densities and how much benefit can then be expected for other species?
- Is there a threshold phenomenon (depensatory relationship between adult predation and juvenile production) that will stimulate more natural recruitment?
- Can a sport fishery of a walleye population at carrying capacity in Saginaw Bay match historic yields?

- What are the implications for main basin prey resources and the exportation of walleye to other areas of Lake Huron?

Other advantages of increased stocking include:

- Progress towards a balanced ecosystem via increased predation rates on planktivores resulting from a higher density of adult walleye.
- By shifting to reef-spawning strains of walleye for stocking, the potential for reef-based reproduction is preserved, will supplement any reef reclamation initiatives, and reduce potential breeding between hatchery fish and existing river-based natural reproduction.
- Expansion and improvement of the sport fishery.
- Stocking is a management option more fully under the purview of the MDNR compared to some habitat based initiatives such a dam removal and sediment control.
- Increased abundance of brood to be in place to take advantage of improved habitat.

Disadvantages to increased stocking include:

- The possibility of jeopardizing wild genetic genotypes with the further introduction of hatchery-selected genetic characteristics.
- The cost of investing in such a large rearing and stocking effort.
- The difficulty of weaning the public from large-scale stocking programs if and when natural recruitment increases.
- In the absence of habitat improvements, increased stocking may have to be maintained perpetually to sustain the fishery.

Fielder (2002) modeled an expanded Saginaw Bay walleye fishery at historical proportions and estimated the number of walleye fingerlings necessary for stocking if that fishery were achieved principally by hatchery sources. The exercise evaluated the number of walleye fingerlings necessary to simulate a recovered fishery and estimated the value at 5.8 million walleye fingerlings per year for a minimum of 13 years. Presently, walleye stocking in Saginaw Bay has averaged 0.75 million fingerlings. While stocking increases on this maximum scale may be impossible, some intermediate level of increase may provide for measurable benefits.

The monetary costs of increased walleye stocking investments may provide good fiscal returns. Past estimates have placed rearing and stocking costs at about US $44,000 per million spring fingerlings stocked in Michigan (O'Neil 1998). To stock the entire 5.8 million fingerlings per year would cost about $255,000. Such an investment may more than double the walleye harvest. Economic activity (angler expenditures) generated by Saginaw Bay's fishery is already estimated at $21,000,000 per year (Rakoczy 1992; U. S. Department of Interior 2003; Rakoczy and Svoboda 1994; G. P. Rakoczy, MDNR, personal communication) and accounts for 58% of the total sport fishing effort on the Michigan waters of Lake Huron in most years (Fielder et al. 2000). An annual stocking of nearly six million spring fingerlings in Saginaw Bay would still only amount to about 20/ha compared to the normal stocking density in Michigan of 62-247/ha (O'Neil 1998).

Implementation of increased stocking would require additional rearing ponds for producing fingerlings from hatchery fry. Land acquisition and construction for new rearing ponds in the Saginaw Bay watershed or possibly at a centralized hatchery like the proposed MDNR, Fisheries Division Coolwater Culture Facility would be an additional one-time capital investment. There may be low-cost lease or partnership alternatives that could be brokered in the Saginaw Bay watershed with stakeholder groups. A centralized facility would allow greater and more efficient control over production and allocation and could benefit other statewide needs. Short of constructing the entire new

Coolwater Culture Facility (cost estimated at $2 Million), an alternative exists with construction of enough ponds to meet the Saginaw Bay needs on the existing Wolf Lake State Fish Hatchery property.

Management Option:

Increase walleye stocking in Saginaw Bay to the extent possible. A total of 2.5 million fingerlings (an increase of 1.8 million) is recommended as an obtainable target (short of the maximum predicted by modeling). Shift from stocking river spawning strains of walleye to reef spawning strains of walleye (at least partially if not wholly). Arrange for the importation of eggs from reef spawning strains in Lake Erie. Stocking should continue until growth of age-3 walleyes approaches the recovery criteria of 110% of the state average rate and the ratio of locally produced wild walleye to hatchery fish remains under 50:50. If natural recruitment produces three year classes within five years that meet or exceed the 50:50 ratio of locally produced wild walleye to hatchery fish, then stocking reductions or alternate year scheduling should be introduced to evaluate the potential of natural reproduction in the absence of stocking regardless of growth rate.

Research Needs:

A. Continue to annually monitor growth rate, recruitment, abundance, and age structure through the existing Saginaw Bay Fish Population Survey. Continue to estimate survival, exploitation, and movement from the annual tagging operation. Continue to evaluate contribution of hatchery fish through marking with oxytetracycline. Continue to annually estimate harvest, fishing pressure, and collect biological data from the sport catch in the bay's open water, ice, and Saginaw River system fisheries. This will facilitate recovery efforts on all fronts.
B. Conduct or sponsor a detailed analysis of the historic walleye stocking in Michigan to determine if remnant reef spawning strains (especially from Saginaw Bay) were introduced into any inland lake. Conduct an analysis of genetic types between Saginaw Bay and any candidate reef spawning inland population. Contrast with Lake Erie reef spawners. Either source may constitute a suitable source of reef spawning brood for reintroduction back into Saginaw Bay

Watershed-wide Sediment Abatement and Riparian Improvement

Land use activities in the Saginaw Bay watershed and management of the riparian zones play a significant role in delivering sediment to the basin. Increasing impervious surfaces on the landscape can increase runoff events and result in erosion both on the landscape and within stream channels. Wind erosion also delivers significant amounts of sediment to channels that flow into the bay. The Saginaw Bay Watershed Initiative Network (WIN) is a cooperative network established to develop and promote sustainable stewardship of the bay's watershed. Included is an emphasis on land use practices and sediment control.

The MDNR can partner with agencies such as WIN, the Natural Resource Conservation Service, or municipal land use planners to provide a foundation for watershed restoration plans, and a linkage between erosion and sediment control and benefits to the fishery. Sediment and erosion control is a long-term priority for achieving sustainability within the bay. Both stream spawning habitat and reef habitat will improve with incremental improvements in the riparian and on the land. Furthermore, improvement of reef spawning habitat will be fruitless without first reducing the sediment that is delivered to the bay.

Research Need:

A. Watersheds within the basin need to be systematically assessed for their contributions of sediment to the bay. Once this information is gained, prioritization and targeting of management actions can occur to capitalize on the areas of greatest contribution.

Harvest Regulations

Harvest regulations such as season closures, length limits, and creel limits form one of the few tools that the Michigan DNR has direct control over. Increased harvest regulations are a popular management strategy with much of the angling public. This idea is born out of the popular belief that walleye in Saginaw Bay are brood stock limited and that recruitment is proportional to brood stock. As has been determined previously, the principal factors limiting further walleye recovery in Saginaw Bay are suitable spawning habitat, particularly in rivers, and the predacious effects of alewives. Presently, suitable riverine spawning habitat below dams is saturated with spawning walleye. The walleye population stopped expanding in the mid 1990s for this reason. In addition, exploitation rates of walleye in Saginaw Bay routinely average less than 10% (Fielder et al. 2000), a level considered easily sustainable for most walleye populations (Colby et al. 1979). Consequently, this recovery plan discourages further harvest regulations at this time. This recovery plan recommends maintaining current harvest regulations in Saginaw Bay and its tributaries, and periodically reevaluating those regulations in the future. As gains are achieved via the other strategies, new or different harvest regulations may become appropriate.

Research Need:

A. While current exploitation levels are deemed acceptable, unnecessary mortality of walleye should be understood so as to be minimized. The degree to which walleye are incidentally caught and killed in commercial trap nets in Saginaw Bay is unknown. Walleye by-catch may die under some circumstances. An investigation is needed to quantify walleye by-catch and possible subsequent mortality to describe the scale and scope of the mortality rate.

Implementation

Fielder (2002) argued for recovery of walleye in Saginaw Bay to proceed on an adaptive management basis. Adaptive management is a management approach to natural resources that acknowledges the inherent uncertainty of natural systems, e.g. fish populations and their ecosystems. Rather than proceeding only with management strategies that are assured a precise outcome, the uncertainty is embraced as a learning process by applying an investigational management style (Walters 1987). In his treatise on the concept of adaptive management, Walters (1987) argued that management initiatives need to constitute bold moves to affect measurable change. In adaptive management, managers and researchers partner to form the basis of the “management by evaluation” approach. The management initiatives in Saginaw Bay will have to be of sufficient scale and magnitude to produce quantifiable results. In Saginaw Bay, these initiatives, when properly evaluated, can serve as a means to move walleye recovery forward, based on the most effective strategies that evolve in the face of an ever-changing ecosystem. Equally important will be commitment and resolve by agency partners and stakeholder groups to see the walleye population in Saginaw Bay recovered to self-sustaining status, and at a density that fully utilizes the available adult habitat and prey base.

Subsequent to this strategy, it is expected that a series of implementation plans will follow. These plans will seek to implement elements of this strategy and will include operational essentials to achieve the recovery options. Support of these plans by the MDNR, Fisheries Division should reflect their commitment to the recovery objectives within the resources of the Fisheries Division. Implementation will also take the form of partnerships with other agencies and stakeholders.

Time to implement will depend on the level of priority given the various recovery options by agency partners, the public at large, and the resources made available to it. Undoubtedly, even with a high priority, these options will transpire in a time span of years or even decades. By using the adaptive management approach and by pursuing the suite of recommended options concurrently, however, some level of benefits can be realized relatively soon.

Summary of Recovery Strategy and Options

While several management options have been detailed in this plan, the interrelationship of the options should be noted (Figure 4). The principle approach being advocated is one that directly addresses the limiting factors functioning as obstacles to natural reproduction and recruitment. These stated options seek to either mitigate or rectify those obstacles. Increased stocking plays a compound role. Stocking is a means with which to reintroduce reef-spawning strains of walleyes, an initiative that may be necessary to achieve utilization of experimental reclaimed reefs, if constructed. Increased stocking also can serve as a means to reduce the negative effects of alewife and walleye fry interactions through increased predation on alewives. Consequently, stocking can indirectly serve to enhance or support the principal recovery strategy of habitat and environmental manipulations. Increased stocking can also provide for fishery benefits while habitat and environmental improvements are materializing.

Conclusion

Unlike Lake Erie, the walleye population in Saginaw Bay will not recover without significant intervention. Saginaw Bay has suffered degraded and lost spawning habitat as well as an increased abundance of alewives, factors that did not plague Lake Erie's walleye recovery to the same extent. Keller et al. (1987) predicted correctly that the fishery would plateau in the mid 1990s without expanding recruitment. It is unlikely that a single course of action will lead to the final recovery of walleye in Saginaw Bay. However, with a concerted effort on several fronts of management, the walleye population can be brought to the capacity of the adult habitat, approximating or even exceeding historical proportions, and maximize the contribution of natural reproduction.

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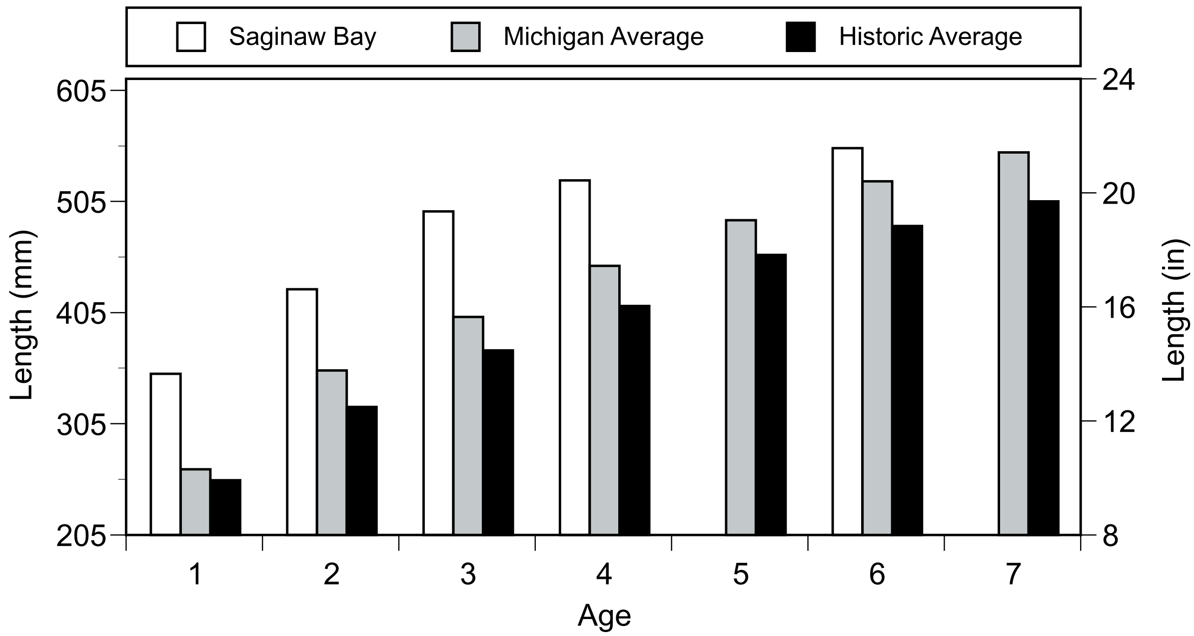

Figure 1.–Walleye growth rate (mean length at age) for Saginaw Bay walleye in September 2003, with the Michigan mean and Historic (precollapse; 1912-1940) mean for Saginaw Bay for comparison (same season or month).

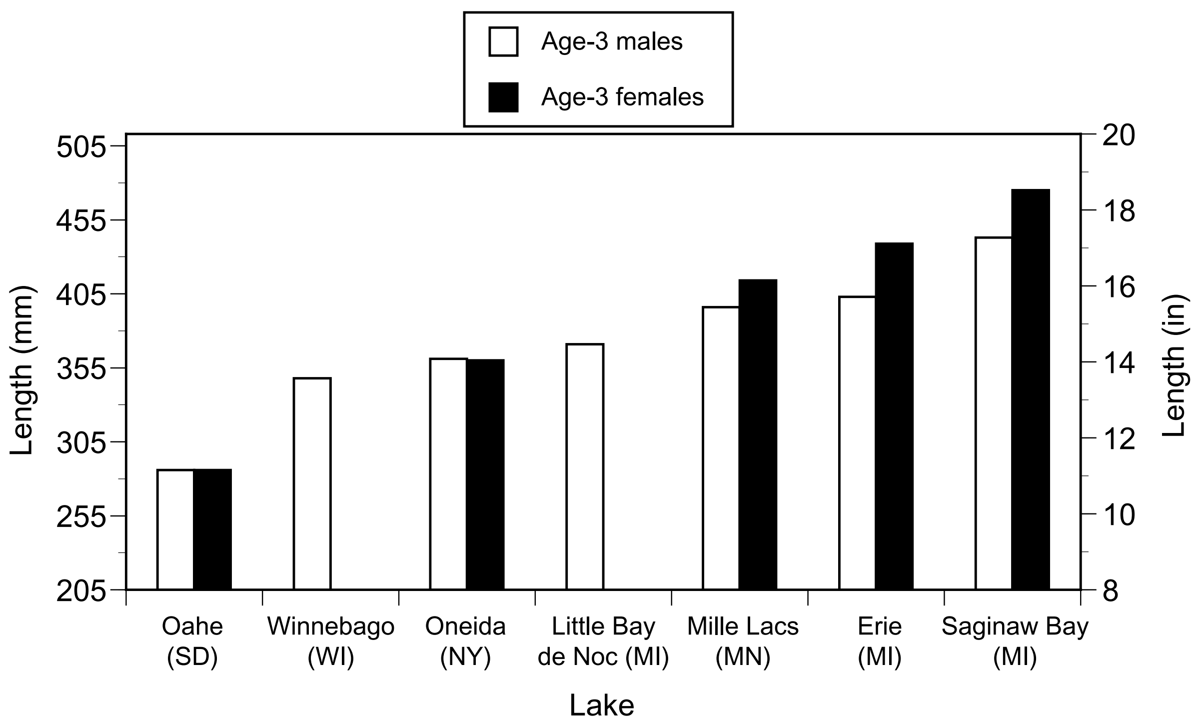

Figure 2.–Walleye mean length at age-3 (at annulus) for male and female walleyes from seven notable walleye populations of similar latitude.

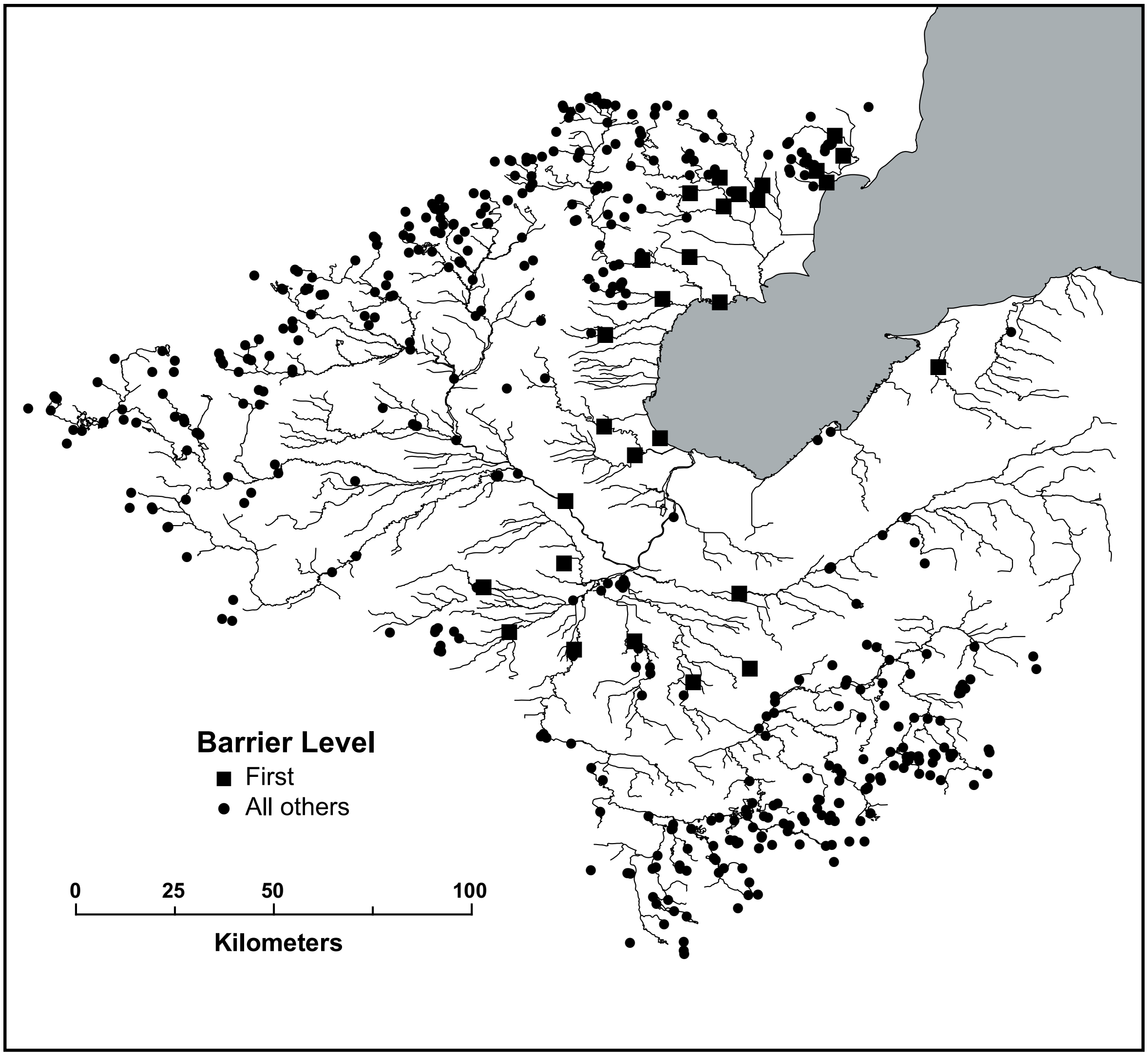

Figure 3.–Saginaw Bay watershed and locations of dams or spillway obstacles.

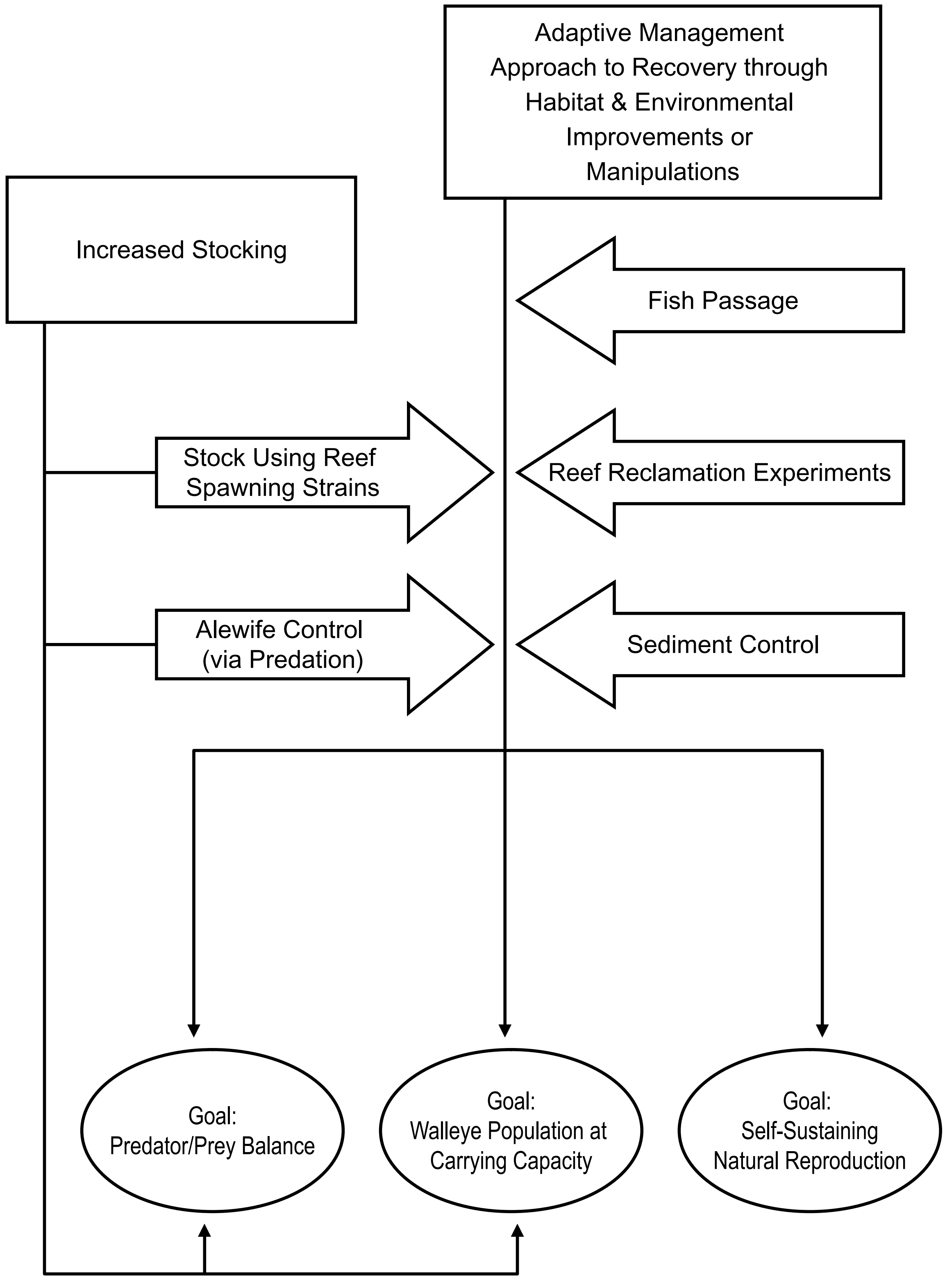

Figure 4.–Conceptual schematic of the Saginaw Bay walleye recovery prescription. Adaptive management is the process with which to achieve recovery goals (ovals). Strategies in the process appear as boxed arrows.

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