LAKE MICHIGAN: AN ECOSYSTEM APPROACH FOR REMEDIATION OF CRITICAL POLLUTANTS AND MANAGEMENT OF FISH COMMUNITIES

Report of a Round Table Sponsored in 1990 by the Great Lakes Fishery Commission, the Science Advisory Board of the International Joint Commission, and the Lake Michigan Federation

Great Lakes Fishery Commission

SPECIAL PUBLICATION 91-2

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(Report of a Round Table Sponsored in 1990 by the Great Lakes Fishery Commission, the Science Advisory Board of the International Joint Commission, and the Lake Michigan Federation)

by

Randy L. Eshenroder
Great Lakes Fishery Commission
1451 Green Road
Ann Arbor, MI 48105

John H. Hartig
International Joint Commission
Great Lakes Regional Office
P. O. Box 32869
Detroit, MI 48232

John E. Gannon
U.S. Fish and Wildlife Service
National Fisheries Research Center--Great Lakes
1451 Green Road
Ann Arbor, MI 48105

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Great Lakes Fishery Commission
1451 Green Road
Ann Arbor, MI 48105-2898

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ABSTRACT: A round table attended by 31 persons from private and public organizations concerned with environmental and fishery management programs on Lake Michigan was held in 1990. The purpose of the round table was to assess the potential for formally coordinating the Lakewide Management Plan (LAMP) and Fishery Management Plan (FMP) for Lake Michigan. Called for in the 1987 Protocol to the Great bakes Water Quality Agreement (GLWQA), LAMPS are a vehicle for reducing loadings of critical pollutants, especially toxic substances, to restore beneficial uses. FMPs define objectives for the structure of the fish community in each Great Lake, and are developed by fishery management agencies under the aegis of the Great Lakes Fishery Commission (GLFC). Although not formally linked, both planning processes have socioeconomic and ecological connections because beneficial uses defined in the GLWQA involve human or wildlife consumption of fish, fish health, and fish habitat. In addition to developing recommendations for coordinating the existing LAMP and FMP processes, the round table produced recommendations that would require either expansion of the purview of both processes or arrangements with other vehicles. These extended recommendations reflect the language of the GLWQA that calls for a comprehensive and systematic ecosystem approach. Recommendations were divided into three categories depending on whether they require unilateral, bilateral, or multilateral arrangements for implementation. All recommendations are directed at the International Joint Commission and the GLFC because they are viewed as having mandates to formally communicate with the implementing agencies. The round table recommendations are summarized at the conclusion of the report,

INTRODUCTION

Since the signing of the 1972 Great Lakes Water Quality Agreement (GLWQA) between Canada and the United States, billions of dollars have been committed to an environmental cleanup of the Great Lakes ecosystem (Johnson 1980). Early programs focussed on nutrient abatement, but with the adoption of the revised GLWQA of 1978 as amended by the 1987 Protocol, emphasis has shifted to remediation of toxic substances. Concurrent with these environmental initiatives, fishery managers have attempted to:

1) remediate losses in the native fish community by more effective fishery regulation,

2) suppress sea lamprey (Petromyzon marinus), a parasitic fish that invaded the Great Lakes from the Atlantic Ocean, and

3) stock native and imported fishes (Pearce et al. 1980; Smith and Tibbles 1980).

Recently, water quality managers reporting through the International Joint Commission (IJC) and fishery managers, working under the aegis of the Great Lakes Fishery Commission (GLFC), have engaged in major planning efforts that are only weakly collaborative. One of these efforts is the Lakewide Management Plan (LAMP), focussing on reductions of critical pollutants but dealing initially with toxic substances (Appendix A, Fuller). The second effort is Fish Community Objectives, a type of Fishery Management Plan (FMP) [1] defining a desirable state of each lake's fish community. These efforts have obvious socioeconomic and ecological connections and more collaboration seems intuitively advantageous. For example, LAMPs are concerned with restoration of beneficial uses that, in connection with toxic substances, involve either human or wildlife consumption of fish, fish health, or fish habitat. Clearly, LAMPs and FMPs have significant overlap, and an evaluation of the potential for improved coordination is warranted.

Opportunities for improved coordination between LAMP and FMP initiatives are most evident on Lake Michigan. The Lake Michigan LAMP is in a formative stage and attractive recommendations have potential to influence the process from the start. In contrast, LAMPs for Lakes Superior, Huron, and Erie are not scheduled to commence for several years and offer no immediate opportunity. Further, a toxic substances management plan has already been developed for Lake Ontario prior to the establishment of the LAMP concept. This plan that is similar to a LAMP has progressed too far to offer ground-floor opportunities for fishery involvement through the GLFC. Within the GLFC, development of FMPs is viewed as an ongoing process. Most efforts, including those for Lake Michigan, are in a draft stage, especially those sections dealing with environmental elements. Therefore, the

1 The process of developing objectives for the fish community in each Great Lake has the characteristics of fishery management planning, but the process is usually not described in this way. The Fishery Management Plan (FMP) acronym is used here to better illustrate the parallelisms between LAMPs and FMPS.

prospects for coordinated planning between water quality and fishery managers are brightest on Lake Michigan where LAMP and FMP schedules most closely coincide.

Even on a single Great lake, an evaluation of the potential for coordinating LAMP and FMP processes is complex, although institutional parallels between the IJC and GLFC are evident. Under the 1987 Protocol, the Parties to the GLWQA, (Environment Canada and the U.S. Environmental Protection Agency (USEPA)) have responsibilities to produce and implement LAMPs. The IJC has a review function. Because Lake Michigan is entirely within the United States, the USEPA has the lead responsibility for its LAMP. The requirement for FMPs by lake is a recommendation in the Joint Strategic Plan for Management of Great Lakes Fisheries (GLFC 1980), an agreement signed in 1980 by the directors of Great Lakes fishery agencies. This recommendation is implemented through each lake's Lake Committee, which contains policy-level fish managers from each jurisdiction. On Lake Michigan, these jurisdictions are the Chippewa-Ottawa Treaty Fishery Management Authority and the states of Illinois, Indiana, Michigan, and Wisconsin. The GLFC has a review responsibility for the FMPs produced by its Lake Committees. Therefore, both Commissions have a review function, but production and implementation of Plans are a responsibility of the associated water quality or fish management agencies.

To facilitate an assessment of the potential for formally coordinating the LAMP and FMP efforts on bake Michigan, a round table meeting was held on 5-7 September 1990 at the Yahara Center in Madison, Wisconsin. A steering committee had previously been formed with sponsorship from the GLFC, the Science Advisory Board of the IJC, and the Lake Michigan Federation. Because the GLFC and IJC endorse the ecosystem approach concept, the steering committee attempted to obtain a diverse group of principals for the round table with significant representation from resource users, public advocacy groups, researchers, and agency representatives (all water quality and fishery management agencies on Lake Michigan). Appendix B lists the 31 persons who participated. The theme of the round table was merging LAMPs and FMPs. Briefing material was circulated in advance of the round table so that all participants were familiar with the goals of the workshop and had a general understanding of LAMPs and FMPs. This publication reports the results of the round table.

APPROACH

The format for the round table was fairly conventional. It consisted of an introductory statement of purpose followed by a series of presented papers intended to provide a more comprehensive explication of the problem than was sought with the advance briefing material. These papers, in the form of extended abstracts, are provided in Appendix A of this report. After hearing the presented papers and engaging in open discussion, the participants were divided into three groups that were charged with developing recommendations for merging LAMP and FMP initiatives on Lake Michigan.

Because of insights and issues raised in the presented papers and open discussion, the scope of the recommendations from the break-out groups was widened beyond merging of LAMP and FMP initiatives. Opportunities for an effective expansion of both processes were also sought. This was in keeping with the concept of an ecosystem approach (accounting for interrelations between land, air, water, and all living things, including humans) and the language of the GLWQA that specifically calls for a comprehensive and systematic ecosystem approach. The steering committee sought ideas not only on how the two processes could be more complementary and reinforcing within their mandates, but also wanted recommendations for implementing a true ecosystem approach even if new arrangements for implementation would be required.

The round table ended with another general session where the break-out groups presented their findings and a synthesis was attempted. The findings of the break-out groups were not considered to be conclusive, however, but were seen as a universe of ideas from which the steering committee could formulate a final set of recommendations. These recommendations would be directed especially to the IJC and the GLFC, who are viewed as mandated to formally communicate with other affected principals such as the USEPA and fishery managers. However, other round table participants and readers of this report may also be important stakeholders concerned with the restoration of beneficial uses to bake Michigan. Their support and involvement are sought and appreciated.

In keeping with the goals of the round table, the recommendations and supporting arguments that follow are organized into three major sections. The first section identifies unilateral initiatives that could be incorporated into LAMP and FMP processes within existing mandates. These unilateral areas are specific to each planning process and do not require coordinated implementation. The second section deals with bilateral initiatives that are within the existing mandates, but require coordinated action between LAMPs and FMPs for implementation. The third and last section targets multilateral initiatives that are outside existing mandates for LAMPs and FMPs. These initiatives require new arrangements for implementation.

UNILATERAL INITIATIVES

LAMPs and FMPs were created in recognition that vehicles were needed by governments to address persistent environmental problems. Neither LAMPs nor FMPs were created with the other process in mind. Also, neither process was designed as a comprehensive framework for resolution of environmental problems. Because of these limitations, each process needs to use its full mandate to address issues that might otherwise be ignored, and each process needs to be collaborative in ways not originally foreseen. The unilateral initiatives in this section identify areas where the LAMP and FMP processes can, within their mandates, be more supportive of a comprehensive and systematic ecosystem approach, a goal of the GLWQA.

Health of Wildlife

Participants at the round table strongly concurred that impairments to wildlife from consumption of contaminated Lake Michigan fish were overlooked in the FMP. Fishery managers on Lake Michigan have naturally been most concerned with persistent toxic substances as they affect fish health and human consumption advisories, but contaminated Lake Michigan fish may also affect the health of fish-eating birds (Harris et al. 1985; Evans 1988; Gilbertson 1988), reptiles (Gilbertson 1989), and mammals (Gilbertson 1989). In keeping with the concept of an ecosystem approach, the Lake Michigan FMP should acknowledge the detrimental effects that consumption of Lake Michigan fish has on wildlife. Further, this FMP should explicitly support reductions in toxic substances necessary to restore the beneficial uses (identified in the 1978 GLWQA) associated with wildlife consumption advisories or with bird or animal deformities or reproductive problems. These reductions should eventually be identified in the Lake Michigan LAMP.

<u>Recommendation 1</u> The Lake Michigan FMP should incorporate objectives for reductions in toxic substances that will eliminate bird or animal deformities and reproductive problems in fish-eating birds, reptiles, and mammals.

Fish Habitat

Physical habitat loss and degradation in the Great Lakes are serious problems requiring much more attention (Smith 1987; Herdendorf et al. 1981). Draft Fish Community Objectives for Lake Michigan contain only a brief statement on the importance of protecting habitat. Draft statements for fish community goals for Lakes Erie and Ontario are similarly brief regarding habitat. The only published fish community goals to date are for Lake Superior (Busiahn 1990). The no-net-loss philosophy for existing habitat (similar to policy statements issued by the United States and Canadian governments) is embraced in that document. The draft international habitat policy document prepared under the auspices of the GLFC's Habitat Advisory Board (HAB) in 1990 recommends going one step further than the no-net-loss philosophy by advocating a ten percent gain in habitat.

The drafters of fish community goals are concerned about habitat, but lack meaningful information on quantitative, species-specific, habitat requirements that can be readily obtained and incorporated into their statements. Also lacking is basic information on an aquatic habitat classification system that can be used as a framework for a habitat inventory. HAB sponsored a workshop on the classification and inventory of Great bakes aquatic habitat (Busch and Sly, unpubl. data) to address this problem. Inventories have been compiled about the locations of many important fish spawning habitats in Lake Michigan (Goodyear et al. 1982). However, the current status (quantity and quality) of these habitats has not been addressed except for a few historically important spawning shoals for lake trout (<u>Salvelinus namaycush</u>). Moreover, inventories of spawning and nursery habitat in wetlands, river mouths, and tributaries used by anadromous fish species have not been conducted in a comprehensive fashion. Loss of fish habitat has been identified as one of the 14 use impairments for the Areas of Concern (Hartig et al. 1990). The strategy recommended in the Areas of Concern may be applicable to lakewide fish community goals:

> It is essential that the jurisdictions identify species-specific fish andwildlife goals for each Remedial Action Plan. Once this is done, one can quantify the amount of physical, chemical, and biological habitat required to meet such goals and compare it against present habitat conditions.

Habitat protection and rehabilitation along shorelines, in wetlands, in bake Michigan's ten Areas of Concern, and in tributaries (as far upstream as accessible to anadromous fishes) require attention for achievement of the Fish Community Objectives for bake Michigan. Such considerations should include the fate of old hydropower dams as impediments to anadromous fishes. Moreover, the role of habitat as part of a strategy to accommodate naturalization of purposefully introduced exotic species, such as coho salmon (<u>Oncorhynchus kisutch</u>), and native fish species in tributary streams requires review in the context of achieving Fish Community Objectives.

Recommendation 2 A workshop of state fishery managers and selected fisheries and habitat experts should be organized and conducted to compare and contrast state fish habitat protection and rehabilitation policies and to explore the possibility of developing common policies for the entire Lake Michigan basin. This workshop should be sponsored by the GLFC's Habitat Advisory Board in cooperation with the Lake Michigan Committee.

Ecological Processes and Policy Implications

Research reported by both Carpenter and Harris (Appendix A) at the round table clearly indicated that concentrations of persistent toxic substances in the biota of Lake Michigan are measurably influenced by internal processes. Toxic substances are cycled between sediments and benthos. Levels in fish are determined by diet and growth rate, and these variables are influenced by fish stocking policies. In Green Ray, Wisconsin, conventional pollutants such as phosphorus and eroded sediments affect zooplankton grazing rates, production of benthos and marsh insects, and food chain efficiency. Conventional pollutants can thereby affect fish and wildlife diets and associated concentrations of toxic substances in fish flesh. In addition, remediation of toxic substances may not restore beneficial uses unless conventional pollutants that are also suppressing fish and wildlife populations are reduced.

Internal processes that are influenced by both fishery management policies and loadings of conventional pollutants suggest that the LAMP process will need to employ a broad ecological approach in setting targets for loading reductions of toxic substances. Although such an approach increases the complexity of the undertaking, the provision in the GLWQA for a comprehensive and systematic ecosystem approach implies that a wider problem definition is desirable. A narrow ecological approach may be logistically attractive, but cannot be advocated because it risks not attaining the LAMP goals, restoration of beneficial uses.

Implementation of a broader ecological approach for the bake Michigan LAMP can be facilitated through linkages with other collaborative initiatives. Collaboration will also be useful in identifying critical information gaps. Initiatives that have the potential to contribute substantially to the LAMP process are:

1) the results and continuing research associated with the food web workshops (Kitchell et al. 1988; Hartig et al. 1990),

2) the new sustainability of intensively managed populations in lake ecosystems project being undertaken in collaboration with the bake Michigan Committee, and

3) the Great Lakes-St. Lawrence ecosystem model being considered by the IJC's Council of Great Lakes Research Managers.

A number of holistic and integrative research efforts with great potential for technical contribution to the LAMP process are underway and should be used to provide a broad-based, ecological approach.

<u>Recommendation 3</u> A comprehensive problem definition for the Lake Michigan Lakewide Management Plan should be established from a broad ecological perspective that accounts for the role of processes such as internal cycling and fish predation on the prospects for achieving ecosystem objectives through reductions in loadings of toxic substances.

BILATERAL INITIATIVES

Virtually all round table participants recognized that LAMPS and FMPs would benefit by merging as much as possible (Appendix A, Gannon; Kernen). Merging would be consistent with the spirit of the GLWQA which calls for a comprehensive and systematic ecosystem approach. Fishery managers are very concerned about contamination of Lake Michigan fish and its impact on salmonid reproduction (Cairns et al. 1984; Mac et al. 1985; Giesy et al. 1986), on United States Food and Drug Administration action levels for commercially caught species (Hesselberg et al. 1990), and on consumption advisories for sport-caught fish (Clark et al. 1987; DeVault et al. 1985). Wholesomeness of fish as human food has been one of the most perplexing and persistent environmental problems faced by fishery managers. Yet, fishery managers have had little recourse to influence a resolution mainly because policy-making decisions are vested with others (departments of human health or environmental management). This divesting has apparently even inhibited coordinated action under the GLFC. This may be because complex jurisdictional responsibilities make prospects for success appear dim. one successful concerted action outside the GLFC occurred in 1985 when the states of Illinois, Indiana, Michigan, and Wisconsin established uniform consumption advisories for sport-caught fish from Lake Michigan (IJC

1985). However, the social value of this uniform advisory was diminished by the 1989 release of an alternative, more severe advisory from the National Wildlife Federation.

Against this backdrop of vital interest but limited opportunity, the LAMP process of reducing loadings of critical pollutants (initially toxic substances) to restore beneficial uses provides fishery managers with an institutional framework for focussed involvement. This involvement would be particularly important in the establishment of objectives for load reductions. Equally important, LAMPS will eventually employ a mass balance approach (Appendix A, Bier-man) to establish targets for load reductions that may invite a reappraisal of existing consumption advisories for sport-caught and action levels for commercially caught fish. Fishery managers would be very interested in recommended load reductions, associated impacts, and any reappraisal of consumption advisories. More generally, LAMP activities will likely become an important focus for academic, institutional, and public involvement in issues surrounding chemical contamination of Lake Michigan's biota, and fishery managers will want to be closely involved. Clearly, a strong rationale for merging LAMPs and FMPs exists and these processes should be complementary and reinforcing. The questions to be addressed, then, are:

1) What elements can be merged?

2) How can merging be done within existing references?

Institutional Merging

Merging LAMPs and FMPs will be challenging because each process has its own clientele (either water quality or fishery managers). Merging must be efficient as well as effective because of limited resources, including time available from managers. Functionally, the LAMP framework, unlike the FMP process, is designed to be broadly collaborative with provisions for a working committee, a lakewide advisory council, and public meetings and workshops. In contrast, the FMP process is less collaborative. Internal reviews are sought only after a draft plan is produced by fishery managers, and public review is optional.

To promote merging, each plan should explicitly acknowledge the other's goals. For example, because natural reproduction of lake trout may be impaired by PCBs in Lake Michigan (Mac et al. 1985), the LAMP should both acknowledge the FMP goal for natural reproduction of lake trout and identify and support the monitoring program that will be implemented to confirm its achievement. Concomitantly, the FMP should acknowledge the LAMP's goal for reduction of PCB loadings and elimination of PCB exposure so that the goal for natural reproduction of lake trout can be achieved. The FMP should also identify and support the monitoring program that will be implemented to confirm its achievement.

Linking the LAMP and FMP processes will necessitate an arrangement between the LAMP Working Committee and the Lake Michigan Committee. Targets for load reductions and identification of the associated indicators and monitoring programs will be developed most efficiently within the LAMP and transported to the FMP. Initially, the LAMP needs fish management input that can be accomplished by making the Lake Committee chairperson a member of the LAMP Working Committee and by making the chairperson of the LAMP Working Committee a corresponding (receives all correspondence and invited to meetings) member of the Lake Michigan Committee. However, because of the complexity of the problem being addressed, Committee appointment without substantial technical support is unlikely to provide effective linkage. With good technical support, an appointee from the Lake Michigan Committee could be well briefed for meetings, obtain more detailed input from other fishery managers, and keep other interested parties appraised of progress. In short, technical support would greatly facilitate input from fishery managers and expedite the LAMP review process as called for in the GLWQA. Therefore, in addition to establishing a Lake Committee appointment to the LAMP Working Committee, the support of a technical expert is necessary for effective participation. A technical expert position could be established by secondment on a one-year trial basis with funding shared between the Commissions and the USEPA.

Other linkages between LAMPs and FMPs may be beneficial. Increased visibility of these initiatives and more opportunities for stakeholder input were also seen as desirable by round table participants. Yet, because the LAMP process is so new, it is difficult to identify exactly how best to effect other linkages. An evaluation of linkages by the Commissions after the end of the first year of a Working Committee appointment is recommended. opportunities for more effective arrangements will become evident after the LAMP process for Lake Michigan begins to take shape. Also, at the end of the first year the technical expert should, as part of a completion report, provide insights on ways to make the linkage process more complementary and reinforcing.

Recommendation 4 The LAMP and FMP should each acknowledge the goals of the other as well as identify and support monitoring programs for achievement of goals.

Recommendation 5 Both Commissions and the USEPA should jointly support the establishment of a technical expert position on a one-year trial basis to provide support for effective fishery collaboration in the LAMP. Also, the chairperson of the Lake Michigan Committee should be appointed to the LAMP Working Committee and the chairperson of the LAMP Working Committee should be appointed as a corresponding member of the Lake Michigan Committee.

Ecosystem Objectives

The first GLWQA (1972) emphasized restoration of water quality based on water chemistry. However, when the Agreement was revised in 1978, an ecosystem approach to restoration and maintenance of Great bakes water quality was adopted. As a joint activity of the GLFC and the Science Advisory Hoard of the IJC, the concept of ecosystem objectives was developed (Ryder and Edwards 1985). Subsequently, the 1987 Protocol calls for the development of lake ecosystem objectives for each Great Lake and designates the first objectives for bake Superior:

> The Lake should be maintained as a balanced and stable oligotrophic ecosystem with lake trout as the top aquatic predator of a cold-water community and the Pontoporeia hoyi as a key organism in the food chain.

The 1987 Protocol further describes ecosystem health indicators for lake objectives in an annex on surveillance and monitoring. These indicators for Lake Superior are:

> than 0.38 kg/ha: stable, self-producing stocks; free from toxic substances at concentrations that adversely affect the trout themselves or the quality of the harvested products.
>
> Pontoporeia w--abundance to be maintained throughout the entire lake at present levels of **220-320/m^2** (depths less than 100 meters) and 30-160/m' (depths greater than 100 meters).

Unfortunately, the ecosystem objectives for Lake Superior were not included in the development of Fish Community Objectives by the Lake Superior Committee (Busiahn 1990). Nor has a monitoring plan been implemented to discern whether or not the ecosystem objectives for Lake

Superior are being met. Concurrently, however, ecosystem objectives are being developed for the Lake Ontario Toxics Management Plan (now a LAMP) well after the plan began. This effort was recommended by the Parties to the GLWQA (Environment Canada and USEPA) and is being coordinated by their Ecosystem Objectives Workgroup. Because ecosystem objectives are required by the GLWQA and are integral to a comprehensive and systematic ecosystem approach, the Lake Michigan LAMP and FMP should identify common ecosystem objectives from the beginning. These objectives may be broader than LAMP and FMP goals, which may identify toxic substance load reductions or fish yields, but ecosystem objectives and plan goals should be complementary.

Recommendation 6 Development of ecosystem objectives for Lake Michigan should be jointly sponsored by the Ecosystem Objectives Workgroup and the Lake Michigan Committee to ensure the development of scientifically defensible ecosystem objectives that are compatible with LAMP and FMP goals. Development of ecosystem objectives should include agreement on quantitative indicators of ecosystem quality and a monitoring plan to obtain the necessary status and trend information.

Independent Review of LAMPs and FMPs

Technical peer review of LAMPs and FMPs is needed to ensure that plans are adequate and being implemented, data and information gaps are being filled, effectiveness of regulatory/resource management authorities and enforcement programs is being periodically assessed, and both plans are complementary and reinforcing. The GLWQA states that the IJC will perform independent peer reviews of LAMPs at four stages:

1) identification of the problem,

2) determination of the schedule for load reductions,

3) selection of remedial measures, and

4) confirmation that beneficial uses are not impaired by critical pollutants.

An internal review of FMPs is also being performed within the committee structure of the GLFC. Each committee is reviewing those elements of FMPs relevant to its terms of reference. Although water quality and fishery management experts will likely be reciprocally involved in the review of LAMPs and FMPs, these reviews are not geared to assess the effectiveness of linkages between these processes. To help ensure that LAMPs and FMPs are complementary and reinforcing, cross representation of water quality and fishery interests should occur within both peer-review processes.

Recommendation 7 The IJC and GLFC should ensure that cross representation exists in the peer-review process for LAMPs and FMPs. This process should assess opportunities for effective linkages between these plans, ensure that each acknowledges the other's goals and objectives, and evaluate the effectiveness of monitoring programs to achieve common goals.

Public Participation

Public participation in governmental planning initiatives like LAMPs and FMPs is the inevitable result of the democratization of modem society. The United States and Canada have recognized the value and importance of public involvement by stating in the GLWQA that the federal governments, in cooperation with state and provincial governments, shall ensure that the public is consulted in all actions undertaken by LAMPs. The Canadian and U.S. governments have agreed to set up a lakewide advisory council (made up of senior representatives from public and private organizations) for each LAMP and to convene public meetings and workshops at appropriate stages of LAMP development and implementation.

True public participation in governmental initiatives for environmental protection and resource management involves all sectors of society who affect, use, or wish to make use of a resource. One benefit of effective public participation in the LAMP and FMP processes is sociopolitical support for full implementation. Experiences with Remedial Action Plans have shown that broad community support must be sustained through all stages for full implementation. Further, strong public involvement is needed to maintain political support (funding).

Recommendation 8 The IJC and GLFC should periodically review and evaluate public participation in LAMPs and FMPs, and encourage specific research on how to undertake and sustain effective public participation. This research includes an understanding of the role of public perceptions and expectations.

Fish Consumption Advisories

Initiation of the LAMP process will heighten the need for a standard, credible basis to establish fish consumption advisories for each of the Great bakes. Within the LAMPs, remediation of toxic substances will be predicated on a mass balance approach that requires specific targets for load reductions (Appendix A, Bier-man). Such targets will likely be derived, at least in part, from achievement of levels that result in fish safe for human consumption as established by the advisories. Therefore, the advisories are very important to the LAMP process, and controversy over the existing advisory for bake Michigan (the National Wildlife Federation advisory) needs to be resolved so that progress in implementing the LAMP is not impeded.

A standard basis for establishing fish consumption advisories has been a goal of the 1986 Great Lakes Toxic Substances Control Agreement. Despite this demand by the governors of the Great lakes states, uniform advisories for the basin do not appear to be close to reality. Although substantial efforts to recommend uniform advisories were made under the Great lakes Toxic Substances Control Agreement by the Great Lakes Fish Advisory Task Force that has representation from the Province of Ontario, the goal remains elusive. The impediment appears to be jurisdictional inflexibility. However, even if the jurisdictions did produce a standard methodology, it may not possess scientific credibility because of perceptions (perhaps unfair) of self-interest.

Recognizing that uniform, well-accepted advisories continue to be sorely needed and that results from existing state and provincial task forces producing them are likely to be problematical, a new approach is sought. Based on discussions at the round table, it is recommended that the IJC and GLFC sponsor an impartial determination, employing highly respected scientific bodies, to formulate a uniform methodology for establishing fish consumption advisories. The Royal Society of Canada and the National Research Council of the United States, who jointly undertook the well-respected review of the 1978 GLWQA (National Research Council/Royal Society 1985), are recommended for this study. Such a determination could provide an acceptable methodology for a mass balance approach and alleviate the impasse affecting the goals of the Great Lakes Toxic Substances Control Agreement. To be successful, a scientific assessment would carefully consider the efforts of the Council of Great lakes Governors and of the Great lakes states and the Province of Ontario, who have authority to establish advisories. Although the results of an outside assessment cannot be imposed on the jurisdictions, an assessment is clearly needed for such a pervasive issue, and the Commissions, as independent bodies, would be ideal sponsors.

Recommendation 9 An impartial determination of a uniform methodology for establishing fish consumption advisories should be jointly sponsored by the IJC and GLFC.

Coordinated Reporting

Separate reporting mechanisms are being established to measure progress in implementing LAMPs and FMPs and in achieving their goals. Periodic State of the Lake Reports will be the primary measure of LAMP and FMP progress. Based on experience with Remedial Action Plans, annual or biennial progress reports have proven effective in manifesting progress, sustaining momentum, celebrating milestones, and building a record of success. Each of these objectives is equally important in sustaining long-term initiatives like LAME's and FMPs.

There was a clear consensus at the round table for joint reporting mechanisms for LAMPS and FMPs. Joint reporting was viewed as a way of promoting coordination between the initiatives and in fostering public support. Joint reporting would also be consistent with the ecosystem approach sanctioned by the IJC and GLFC.

Recommendation 10 The IJC and GLFC should explore joint evaluation mechanisms (State of the bake Reports, workshops, or conferences) every two to five years in order to evaluate trends, assess progress toward management goals, account for interrelationships between management programs, address research needs, and provide opportunity for redirection.

MULTILATERAL INITIATIVES

The LAMP and FMP processes are major efforts directed at a more ecosystemic approach to remediation of critical pollutants and multispecies fish management. Previously, critical pollutants were addressed individually, lakewide, or in the aggregate at specific sites (Remedial Action Plans). Fishery management was undertaken on a species-by-species basis. Notwithstanding the remarkable step forward implicit in these initiatives, neither effort (jointly or individually) is capable of achieving a comprehensive and systematic ecosystem approach as called for in the GLWQA (Appendix A, Donahue et al.). The steering committee believes that the previously identified recommendations, if implemented, will promote an ecosystem approach. However, it also recognizes that expectations for resolution of all major environmental problems that affect a Great Lake within a single framework is unrealistic. Simply stated, if the task becomes too large, the prospects for accomplishment become less because of logistical complications. Recognizing that the LAMP and FMP frameworks are already ambitious, that new mandates to provide for inclusion of new responsibilities were undesirable, but that other pervasive issues requiring new arrangements need to be addressed, the workshop participants made recommendations on watershed habitat protection and information dissemination that are outside the scope of LAMPs and FMPs.

Watershed Habitat Protection

In the true sense of ecosystem integrity (Edwards and Regier 1990), habitat goals and objectives should focus broadly on the entire Lake Michigan ecosystem, not fish communities exclusively. Achievement of fish community objectives will be problematical if wetlands and connected terrestrial habitat are further depreciated or left unrestored. As water quality (especially eutrophication effects) has improved in Lake Michigan, cultural development along beaches, embayments, tributary mouths, and harbors has escalated. This development raises concerns about the protection of these habitats for wildlife. Moreover, there are concerns about quality and accessibility of Lake Michigan shoreline for aesthetic appreciation and enjoyment, and for the protection of threatened and endangered plants.

Wildlife in the Lake Michigan basin needs and deserves particular attention. Wildlife does not have the multi-state, interagency framework for basinwide management and research as fish do. As noted by Harris (1988):

> . . . bird and mammal populations have had far less consideration on the Great Lakes than other vertebrate forms (fish) or even invertebrates. Birds, in particular, cross over national, state, and provincial governmental jurisdictions; they are a shared resource of the Great Lakes system, as are fish.

Linkage between toxic substance cause and effect (reproductive impairment and abnormal growth and development) is greater for fish-eating birds and mammals than for any other group or organisms in the Great Lakes (Gilbertson 1989). As exposure to toxic substances is reduced through various remediation programs, questions remain on the adequacy of habitat to restore wildlife populations.

Initiatives are underway at federal, state, and local levels of government to inventory, identify, and protect environmentally critical habitats and unique natural areas. The National Oceanic and Atmospheric Administration has a critical habitats inventory program, and the USEPA and United States Fish and Wildlife Service (USFWS) have wetlands inventory programs. The U.S. Coast Guard has begun to map environmentally sensitive areas that may require special protection during and following a pollution (spill) incident. The USFWS also conducts programs on threatened and endangered species and their habitats. The Great Lakes states and Province of Ontario conduct land-use inventories and natural heritage programs. Private organizations like the Nature Conservancy and local groups such as the Little Traverse Nature Conservancy in northwestern lower Michigan have been effective in protecting shorelands and other habitats through land trusts, conservation agreements, and other mechanisms. Also, a basinwide program, "Great Lakes Legacy," to conserve aquatic natural areas (including wetlands) was announced recently by the Center for the Great Lakes in cooperation with the Nature Conservancies in the U.S. and Canada. Nonetheless, there is little communication from one program to another and a lack of knowledge about whether these programs are adequate to protect the integrity of the Lake Michigan ecosystem.

<u>Recommendation 11</u> The adequacy of inventories, programs, and plans for protecting critical habitat and unique natural areas in the Lake Michigan watershed should be reviewed by a coalition of public advocacy organizations such as the Lake Michigan Federation, the Sierra Club, and the National Wildlife Federation.

<u>Recommendation 12</u> The states of Illinois, Indiana, Michigan, and Wisconsin should jointly develop a watershed habitat protection and rehabilitation strategy for wildlife in the Lake Michigan basin. Similarly, the USFWS and the states bordering Lake Michigan should develop a planning framework for management and protection of wildlife. The habitat strategy and wildlife management plan should be reviewed by the Commissions for compatibility with the LAMP and FMP for Lake Michigan.

Information clearinghouse

Interdisciplinary issues, such as merging water quality and fisheries issues on Lake Michigan, require that many kinds of documents and publications need to be reviewed and referenced. Because of this need, round table participants recommended that an information clearinghouse be established to support themerging of LAMPs and FMPs.

The concept of a Great bakes information clearinghouse has been widely endorsed but difficult to implement. The IJC Great bakes Regional Office has repeatedly been requested to provide this function, but it has never had the human and financial resources or the facilities to operate such a clearinghouse. Other agencies and institutions, although endorsing the concept, are reluctant to commit limited resources to a clearinghouse function. Previous attempts to establish a clearinghouse have stalled and disappeared. For example, Michigan Sea Grant initiated the Great lakes Information Network in the late 1970s, but could not sustain long-term funding. Similarly, a clearinghouse specific to Lake Michigan was begun several years ago by the Illinois Natural History Survey, but it also became defunct because of lack of support.

Operation of an information clearinghouse is a large undertaking, especially if hard copies are the principal medium in the archive. However, computers are increasingly used for developing databases, and for providing a communication link between sources of information and potential users. For example, the Great Lakes Commission (GLC) has been operating a Great bakes Information Clearinghouse and Great Lakes Information Network for several years. The Clearinghouse provides information as a public service, but the Network is a group of users (mostly professional communicators) who have agreed to share information through the Clearinghouse. The GIC provides this service at minimal cost with a small staff. Although it may be possible to find an agency or library in the Lake Michigan basin to house a LAMP and FMP information clearinghouse, it is more feasible for such information to be compiled into a database managed by the GIC. Such a database has the potential to be expanded to include information from all of the Great bakes.

Annotated bibliographies of documents, including unpublished reports used to prepare LAMPs and FMRs, and the plans themselves could be supplied to the Great Lakes Information Clearinghouse of the GLC. Committees working on these initiatives would be responsible for preparing the associated bibliographies using computer software designed for organizing bibliographic references. The bibliography would include sources where the references can be obtained and updates would be supplied as necessary.

To ensure that the Clearinghouse remains a focal point for information, the availability of this service needs to be publicized among those involved in the LAMP and FMP processes. Those wishing to join the Network would contact the GLC. Agencies and individuals with fishery and water quality responsibilities and interests would be encouraged to participate *in* the Network to forge communication contacts among the broader Great Lakes informational and scientific community. The GLFC, IJC, and the Parties to the GLWQA may need to supply funds or technical assistance to the GLC to assure sustainability of the system.

Recommendation 13 The IJC, the GLFC, and the Parties to the GLWQA should work with the Great Lakes Commission to develop the ways and means of using the Great Lakes Information Clearinghouse and the Great Lakes Information Network to provide access to sources of information used in LAMPs and FMPS.

SUMMARY OF RECOMMENDATIONS

The concept of employing a comprehensive and systematic ecosystem approach to eliminate use impairments identified for Lake Michigan is intuitively appealing and was widely supported at the round table. Implementing the concept will require improved linkages between environmental and fishery managers because the fish themselves and human and wildlife consumers of fish are beneficiaries of proposed remediation efforts. Despite this broad appeal and the obvious linkages, achieving an ecosystem approach will be challenging,, because the institutional arrangement is complex and institutions tend to resist change as a natural consequence of convention. Nonetheless, institutions do evolve, albeit on an incremental and prolonged basis (Hartman and Donahue 1990). Jointly, the International Joint Commission (IJC) and the Great Lakes Fishery Commission (GLFC) have the potential to catalyze an ecosystem approach on a single lake (Lake Michigan) where the problem is tractable and vehicles for implementation (the Lakewide Management Plan and Fishery Management Plan) are fortuitously converging.

The recommendations summarized below do not require major reallocations of resources, and although the focus is Lake Michigan, the needs are similar on the other lakes. Partial applications to the other lakes should emerge soon from a Lake Michigan focus, because the relevant organizations are well connected within each Commission. A commitment to attempt implementation of these recommendations through the IJC and GLFC is practicable and has considerable relevance to the other lakes. Accordingly, the Commissions are strongly urged to jointly consider these recommendations, summarized below, as one means of fostering an ecosystem approach for the Great Lakes.

Unilateral Initiatives

Recommendation 1 The Lake Michigan Fishery Management Plan (FMP) should incorporate objectives for reductions in toxic substances that will eliminate bird or animal deformities and reproductive problems in fish-eating birds, reptiles, and mammals.

Recommendation 2 A workshop of state fishery managers and selected fisheries and habitat experts should be organized and conducted to compare and contrast state fish habitat protection and rehabilitation policies and to explore the possibility of developing common policies for the entire Lake Michigan basin. This workshop should be sponsored by the Great Lakes Fishery Commission's (GLFC) Habitat Advisory Board (HAB) in cooperation with the Lake Michigan Committee.

Recommendation 3 A comprehensive problem definition for the Lake Michigan Lakewide Management Plan (LAMP) should be established from a broad ecological perspective that accounts for the role of processes such as internal cycling and fish predation on the prospects for achieving ecosystem objectives through reductions in loadings of toxic substances.

Bilateral Initiatives

Recommendation 4 The LAMP and FMP should each acknowledge the goals of the other as well as identify and support the monitoring programs for achievement of goals.

Recommendation 5 Both Commissions and the U.S. Environmental Protection Agency (USEPA) should jointly support the establishment of a technical expert position on a one-year trial basis to provide support for effective fishery collaboration in the LAMP. Also, the chairperson of the Lake Michigan Committee should be appointed to the LAMP Working Committee and the chairperson of the LAMP Working Committee should be appointed as a corresponding member of the Lake Michigan Committee.

Recommendation 6 Development of ecosystem objectives for Lake Michigan should be jointly sponsored by the Ecosystem Objectives Workgroup and the Lake Michigan Committee to ensure the development of scientifically defensible ecosystem objectives that are compatible with LAMP and FMP goals. Development of ecosystem objectives should include agreement on quantitative indicators of ecosystem quality and a monitoring plan to obtain the necessary status and trend information.

Recommendation 7 The International Joint Commission (IJC) and GLFC should ensure that cross representation exists in the peer-review process for LAMPs and FMPs. This process should assess opportunities for effective linkages between these plans, ensure that each acknowledges the other's goals and objectives, and evaluate the effectiveness of monitoring programs to achieve common goals.

Recommendation 8 The IJC and GLFC should periodically review and evaluate public participation in LAMPS and FMPs, and encourage specific research on how to undertake and sustain effective public participation. This research includes an understanding of the role of public perceptions and expectations.

Recommendation 9 An impartial determination of a uniform methodology for establishing fish consumption advisories should be jointly sponsored by the IJC and GLFC.

Recommendation 10 The IJC and GLFC should explore joint evaluation mechanisms (State of the lake Reports, workshops, or conferences) every two to five years in order to evaluate trends, assess progress toward management goals, account for interrelationships between management programs, address research needs, and provide opportunity for redirection.

Multilateral Initiatives

Recommendation 11 The adequacy of inventories, programs, and plans for protecting critical habitat and unique natural areas in the Lake Michigan watershed should be reviewed by a coalition of public advocacy organizations such as the Lake Michigan Federation, the Sierra Club, and the National Wildlife Federation.

Recommendation 12 The states of Illinois, Indiana, Michigan, and Wisconsin should jointly develop a watershed habitat protection and rehabilitation strategy for wildlife in the Lake Michigan basin. Similarly, the United States Fish and Wildlife Service (USFWS) and the states bordering Lake Michigan should develop a planning framework for management and protection of wildlife. The habitat strategy and wildlife management plan should be reviewed by the Commissions for compatibility with the LAMP and FMP for Lake Michigan.

Recommendation 13 The IJC, the GLFC, and the Parties to the Great Lakes Water Quality Agreement should work with the Great Lakes Commission to develop the ways and means of using the Great Lakes Information Clearinghouse and the Great Lakes Information Network to provide access to sources of information used in LAMPs and FMPs.

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APPENDIX A

ECOSYSTEMIC APPROACHES FOR PLANNING AND REMEDIATION

John E. Gannon
United States Fish and Wildlife Service
National Fisheries Research Center--Great Lakes
1451 Green Road
Ann Arbor, MI 48105

Water quality and fishery management evolved as scientifically and institutionally separate programs in the Great Lakes and elsewhere in the world. With increasing awareness of the complexity and interconnectedness of issues, there is also increased recognition that to achieve common goals of improved environmental quality and ecosystem integrity, better communication and cooperation between water quality and fishery management programs are needed. The challenge is how to improve such communication and cooperation between water quality and fishery disciplines and institutions that essentially have been separate for so long.

There have been several attempts in the Great Lakes to meld water quality and fishery interests to provide a more ecosystemic perspective. Little progress has been made, however, in the sense of program operations. Most recently, both groups of managers have undertaken separate planning efforts with common overall objectives, namely the Lakewide Management Plans (LAMPs) under the auspices of the International Joint Commission (IJC) and Fish Community Objectives through the Great Lakes Fishery Commission (GLFC).

Current Status of Lakewide Management Plans

The concept of Lakewide Management Plans first evolved from the 1986 report of the Niagara River Toxics Committee. Since the Niagara River was identified in this report as the major source of toxic contamination to Lake Ontario, a plan for tackling toxic substances in Lake Ontario was deemed necessary. Subsequently, the need for LAMPs on each of the Great Lakes was included in the 1987 revisions to the Great Lakes Water Quality Agreement. The first plan to resemble a LAMP (Lake Ontario Toxics Management Plan) was completed in 1989. Understandably, since it was an outgrowth of a water quality study on the Niagara River, it did not involve much input from fisheries scientists or managers. As the first LAMP to be completed, it could be the model for LAMP development on the other lakes. On the other hand, an opportunity may be available to develop the next scheduled

LAMP (for Lake Michigan) with actual collaboration between water quality and fishery interests.

Current Status of Fish Community Objectives

The development of Fish Community Objectives has been given to the Lake Committees under the aegis of the GLFC. The Fish Community Objectives for Lake Superior were published in spring 1990. Fish Community Objectives for the other lakes are still in draft. Preservation and restoration of habitat, including water quality, is the focus that makes Fish Community Objectives relevant to the goals of the LAMP process. Again, *there* appears to be an opportunity to nurture stronger collaboration between water quality and fishery interests in the development of fish community goals for Lake Michigan.

The Challenge

An excellent record of international cooperation exists on the Great Lakes. In reality, however, in spite of the best intentions, documents such as LAMPs and Fish Community Objectives often have had difficulty in making the giant step from planning to implementation. The timing seems ideal to develop water quality and fishery collaboration in these complementary activities. The challenge is to define the scope (narrowly focused on toxic substances or broadly focused on toxic substances as well as other ecosystem stresses), and to identify the scientific issues and institutional - arrangement protocols necessary fordeveloping truly useful planning documents, including implementation strategies.

THE SCOPE OF LAKEWIDE MANAGEMENT PLANS

Kent B. Fuller
Great Lakes National Program Office
United States Environmental Protection Agency
230 S. Dearborn
Chicago, IL 60604

The 1987 revisions to the Great Lakes Water Quality Agreement added several planning and management provisions. For nearshore problem areas, Remedial Action Plans will be developed. On a larger scale, Lakewide Management Plans (LAMPs) for critical pollutants are also to be developed.

Remedial Action Plans and LAMPs must include parallel action tracks to address implementation of existing programs. Key program actions and responsible parties must be identified and scheduled to stimulate implementation and create accountability. They must also identify additional Programs and pollution reductions needed to attain beneficial uses. Key monitoring and modeling steps must be identified that will determine further reductions in ambient concentrations and total loadings needed to restore beneficial uses. Also, key program actions must then be identified that will attain the needed reductions in loadings and ambient concentrations.

With respect to the relationship between LAMPs and fishery plans, LAMPs must fully consider relationships between critical pollutants and fisheries, critical pollutants and wetlands, and critical pollutants and other plans. But LAMPs are not fisheries plans, wetland plans, or other plans. Those responsible for development of LAMPs and those responsible for fisheries or other plans need to agree to go beyond standard content and develop joint plans. This could lead to a true joint plan for the Great Lakes basin ecosystem.

Representatives of the United States and Canada agreed upon a framework for LAMPs that expands upon the language of the Agreement, and have adopted LAMP review criteria. Roth the framework and the criteria are built upon the following language from the Agreement:

Lakewide Management Plans for Critical Pollutants

> The Parties, in consultation with State and Provincial Governments, shall develop and implement Lakewide Management Plans for open lake waters, except for Lake Michigan where the Government of the United States of America shall have that responsibility. Such Plans shall be

designed to reduce loadings of Critical Pollutants in order to restore beneficial uses. Lakewide Management Plans shall not allow increases in pollutant loadings in areas where Specific Objectives are not exceeded.

Lakewide Management Plans shall be submitted to the Commission for review and comment at four stages:

When a definition of the problem has been completed under sub-paragraphs 6(a)(i), (ii) (iii);

When the schedule of load reductions is determined under sub-paragraph 6(a)(iv);

When remedial measures are selected under sub-paragraphs 6(a)(v), (vi) and (vii): and

When monitoring indicates that the contribution of the Critical Pollutants to impairment of identified beneficial uses has been eliminated under sub-paragraphs 6(a)(viii) and (ix).

Such Plans shall include:

A definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combination with another substance, including their contribution to the impairment of beneficial uses;

An evaluation of information available on concentrations, sources and pathways of the Critical Pollutants in the Great Lakes system, including all information on loadings of the Critical Pollutants from all sources, and an estimation of total loadings by modeling or other identified methods;

Steps to be taken pursuant to Article VI of this Agreement to develop the information necessary to determine the schedule of load reductions of Critical Pollutants that would result in meeting Agreement objectives, including steps to develop the necessary standard approaches and agreed procedures;

A determination of load reductions of Critical Pollutants necessary to meet Agreement Objectives;

- An evaluation of remedial measures presently in place, and alternative additional measures that could be applied to decrease loadings of Critical Pollutants;

- Identification of the additional remedial measures that are needed to achieve the reduction of loadings and to eliminate the contribution to impairment of beneficial uses from Critical Pollutants, including an implementation schedule:

- Identification of the persons or agencies responsible for implementation of the remedial measures in question;

- A process for evaluating remedial measure implementation and effectiveness;

- A description of surveillance and monitoring to track the effectiveness of the remedial measures and the eventual elimination of the contribution to impairments of beneficial uses from the Critical Pollutants:

A process for recognizing the absence of a Critical Pollutant in open lake waters.

In addition to the specific language of the Agreement, several points should be emphasized. LAMPs must build upon the successes of earlier programs, but have a new focus. They must reflect a new paradigm that will:

1) have an ecosystem approach that fully considers the health of both humans and the living resources of the Great Lakes basin,

2) identify demonstrable environmental results in terms of beneficial uses, ecosystem objectives, and clear action steps,

3) define success up front and provide a basis for celebrating accomplishments,

4) identify and address intermediate issues that relate to airborne deposition, land runoff, and sediment,

5) address chronic effects of long-term exposure, total loadings of pollutants, and risk-based priorities,

6) provide for stakeholder acceptance to ensure a broad base of implementation, and

7) address pollution prevention and sustainable development.

Fig. 1 illustrates where LAMPs fit into the overall pollution control picture. The perspective is the long-term process of reducing the load of pollutants entering the environment and reducing the concentration of pollutants in the environment. LAMP Track 1 is the reduction that can be attained through full implementation of existing control programs that limit discharges using national effluent concentration rules. Track 2 is the further reduction in loads based on monitoring and modeling of the lakes in cases where bioaccumulation in Great Lakes species requires protection beyond nationwide limits. The last increment of reduction is further progress toward the goal of eliminating pollution, contained in the Clean Water Act and the Great lakes Water Quality Agreement. It is in this last category of reduction where pollution prevention becomes the primary means of implementation. Using Fig. 1 for perspective, it is easy to see the importance of accelerating existing programs in Track 1 while developing the basis for Track 2.

Fig. 2 depicts a Great lakes Water Quality Framework. The Great Lakes Water Quality Agreement provides a management process that calls for setting chemical and biological objectives, development of action plans (LAMPs) for critical pollutants and Remedial Action Plans for geographic Areas of Concern, and verification of results.

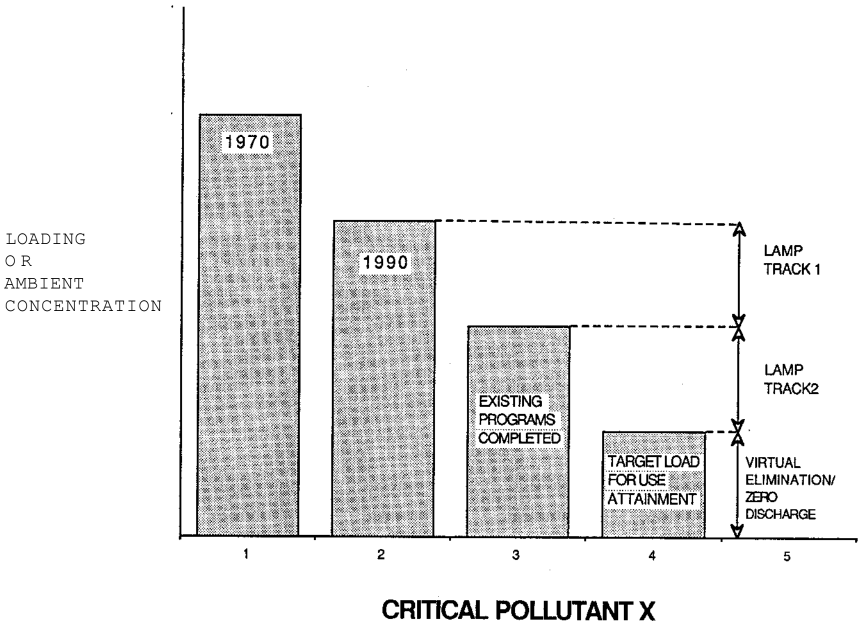

Fig. 1. Process for reducing pollutant loadings using existing national effluent concentration rules (Track 1), new rules based on bioaccumulation (Track 2), and virtual elimination.

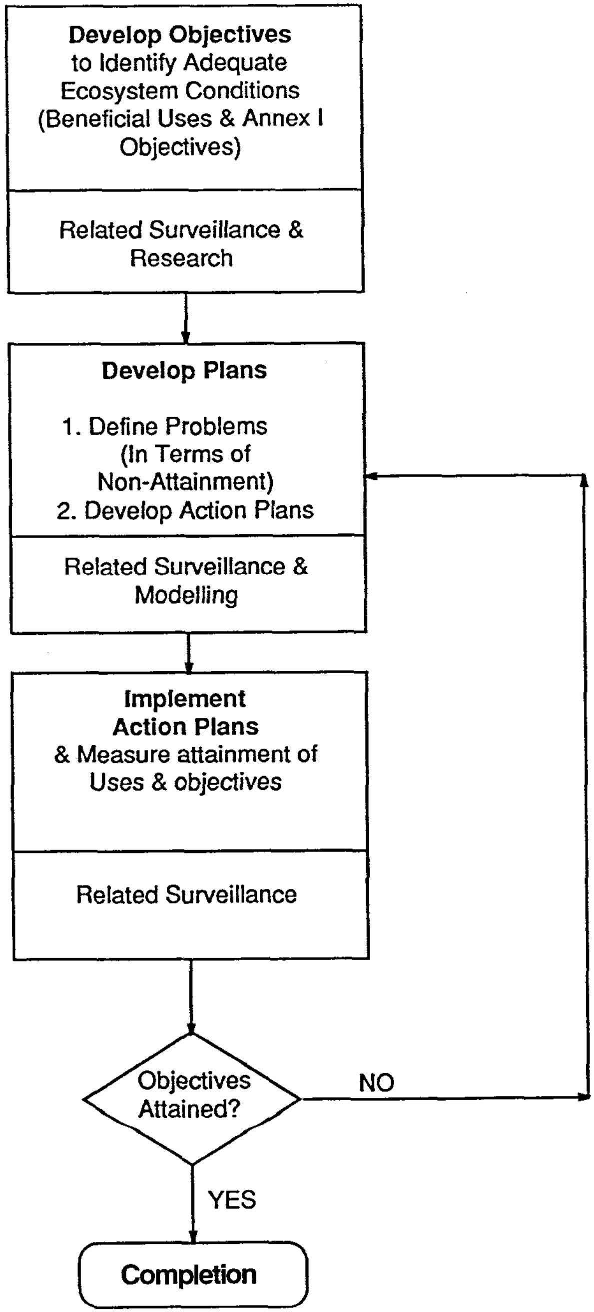

Fig. 2. The Great Lakes Water Quality Agreement Framework.

ENVIRONMENTAL OBJECTIVES FOR FISH COMMUNITY REMEDIATION

Lee T. Kernen
Wisconsin Department of Natural Resources
P. 0. box 7921
101 S. Webster, 4th Floor
Madison, WI 53707

Some might say the marriage of fisheries and water quality institutions is long overdue on the Great Lakes. The truth is actually much worse than that--they have hardly made acquaintance. Ecosystem management must include fisheries managers, and this round table can be an important catalyst to assist the development of integrated resource planning.

Why has this seminar taken until 1990 to be organized? I think it is because so many of us were trained to be specialists in a particular area. To be professionally competent today often requires intensive focus. Look at a physician who may specialize in one disease, a fisheries biologist who studies one species, a toxicologist who looks at the same fish and sees only parts per billion of a particular toxic substance. Also, the public has difficulty with complex issues. The task at hand is a tough one but our presence here is in itself a harbinger that we collectively see the need for integrated management.

Wisconsin is a good choice for this session because the Green Ray/Fox River Remedial Action Plan is a beacon of hope and progress. A few years ago when fisheries agencies in some states hadn't even heard of the Remedial Action Plan process, Wisconsin had already assigned fisheries personnel to the Green Ray project. Field personnel called me and urged me to support the project saying "We need this, it's a good thing." I'm proud of our involvement.

Organization of Great Lakes Fishery Agencies

A basinwide plan called the Strategic Great Lakes Fisheries Management Plan (SGLFMP) was developed under the Great bakes Fishery Commission (GLFC). Each lake has a committee comprised of senior biologists from state and tribal agencies. This operational committee will coordinate management and implement the strategic plan. These bake Committees are charged with developing Fish Community Objectives. Every year the Committees will report to their agency directors who sit on the Committee of the Whole. The yearly progress report is called the State of the Lake Report.

The common goal statement of the SGLFMP is:

> To secure fish communities, based on foundations of stable self-sustaining stocks, supplementedby judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for wholesome food, recreation, employment and income, and a healthy human environment.

Note that the first need for society is wholesome food. Further on, the plan continues under a heading entitled Inadequate Environmental Quality:

> The ecosystemview of fishery management espoused by the fishery agencies, and reflected by the 1978 Canada-United States Great Lakes Water Quality Agreement, places particular emphasis on water quality and various habitat features that are required for normal functioning of fishes and unrestricted consumption of fish by man. Attempts to secure such an environment may well place fishery interests in conflict with the interests of other water users. All agencies must address the threats to Great Lakes fishery resources posed by these conflicting uses.

This section intimates that fishery interests may be in conflict with other uses. This can be interpreted to mean that objectives for toxic substance-free fish may well impact on municipal and industrial users who discharge into the Great Lake basin.

Finally, the GLFC will create a Fish Habitat Advisory Committee to assist each Lake Committee in developing environmental objectives essential to meeting fishery objectives. Unresolved environmental issues may be referred to the GLFC by the Lake Committees for representation to the appropriate body. The strategic plan was written ten years ago, and in the interim, the toxic substance issue has grown in importance and fishery agencies have become more and more involved. This direction needs to continue.

In the Lake Michigan Fish Community Objectives there are still only two paragraphs on toxic substances. The primary explanation for this is that fisheries people are often totally frustrated by the toxic substance issue. Many remember areas in Lake Michigan that couldn't support any fish 20 years ago because of gross nutrient pollution. Recently, in one of these areas, the Fox River in Wisconsin, a sport fishery took approximately 25,000 walleyes (Stizostedion vitreum). This incredible revival has been stained, of course, by the discovery of microcontaminants. Lake Michigan of the 1960s, which bulged with alewives Alosa pseudoharengus), was reclaimed for sport fishermen through the use of stocked salmonids. This fishery has fostered immense public interest and concern over Great Lakes resources. But even the 80% decline in PCBs in lake trout (Salvelinus namaycush) and Pacific salmon (Oncorhynchus spp.) in the past 20 years has not been enough. The fisheries are still deemed dangerous to human health. The one predator species, lake trout, that truly belongs in Lake Michigan, that could reproduce and lend the stability that is not obtainable under an artificially maintained system of stocking, is also the species that, because of its long life and fatty flesh, concentrates more toxic substances than any other. At the moment, the goals of rehabilitating lake trout and providing safe-to-eat sport fish may be mutually exclusive.

While fishery agencies are wrestling with the above dilemma, other experts are calling for a cessation of fish stocking to protect human health by reducing the availability of the fish themselves. A cessation is totally unacceptable to fishery interests. The problem might be managed by stocking some species that concentrate fewer toxic substances, but this strategy is not a total solution. That is why Fish Community Objectives for Lake Michigan deal so briefly with toxic contaminants. We can't resolve the toxic substance issue ourselves. Fisheries must be an important part of the larger plan that looks at trade-offs with the water quality people in the pursuit of long-term goals.

Fisheries people think the attention drawn to the lakes may be the most important aspect of the past 30 years of fisheries rehabilitation. More people love and respect these waters than ever before because of the fish inhabiting them. The public doesn't identify well with a Hexagenia hatch or a one-meter improvement in a Secchi-disk value. The public is pragmatic. Their support is needed to fund programs to clean the Great Lakes for the future generations who will demand and deserve toxic substance-free fish and water. Without widespread backing the monies that drive environmental programs will dwindle and remediation could stop. The current challenge is to develop strategies without destroying the fisheries and losing public support.

COMMENTS ON INCORPORATING HUMAN AND WILDLIFE HEALTH CONCERNS INTO LAKEWIDE AND FISHERY MANAGEMENT PLANS

H. J. Harris
University of Wisconsin-Green Hay
Green Bay, WI 54302

Human and wildlife health concerns should be incorporated into lakewide and fishery management plans. The current question is how to accomplish this.

Jim Karr was close to a strategy when, at the National Symposium on Water Quality, he said that the goal should be to "improve the quality of the water resource" rather than the "water quality of the resource." That is an abbreviated way of talking about the ability to sustain a balanced biological community. In essence the focus must remain on ecosystem integrity if we are to protect wildlife and human health.

To be more specific, there are some recent research findings that illustrate the need to promote and maintain an ecosystem approach in basinwide planning and remediation of toxic substances. There are four separate examples, two deal with conventional pollutants and two deal with persistent toxic substances.

Emerging Insect and Avian populations on Two Coastal Marshes

The first example is based on data collected by McLaughlin and Harris (1990) on emerging insect and avian populations on two coastal marshes on Green Hay. Importantly, both marshes are located in lower Green Hay where Secchi-disk depths average 0.5 m.

One marsh is diked, the other is not. Nesting bird population densities in these two marshes were estimated over a seven year period. The diked marsh had a greater species diversity and approximately twice as many nesting birds as did the undiked marsh. The second part of this long-term study was an evaluation of nesting habitat and food resources.

Emerging insect populations were estimated in four habitat types in both marshes. Three water quality characteristics were also evaluated (light extinction, Secchi-disk depths, and populations of submergent aquatic vegetation).

Emerging insect biomass in the diked marsh was approximately twice as much as the undiked marsh. No dragonflies or damselflies (Odonata), particularly important food items for some of the marsh-nesting birds, were found in the undiked marsh. Further, the peak period of emergence for the insects coincided with the nesting period of the birds in the diked marsh, but occurred at a far later date in the undiked marsh. bight extinction coefficients in the diked marsh were always less than 1 (around .7), while extinction coefficients in the undiked marsh were always greater than 1 and ranged as high as 2.5. Inverse differences were found in Secchi-disk depth readings. Aquatic submergent plants were abundant in the diked marsh, but virtually absent in the undiked marsh.

This information, in conjunction with other studies, indicates that high algae production in the bay along with heavy sediment loads creates excessively turbid waters. Seiches cause inundation of the undiked marsh with turbid bay water, which reduces available light for submerged aquatic vegetation. Reduced vegetation, in turn, affects the availability of habitat for aquatic insects. Ultimately, the lowered insect production is reflected in a lower abundance and diversity of birds. The end result is degradation of wildlife populations due to inadequate control of conventional pollutants such as phosphorus and eroded soil.

Ammonia

The second example is of particular interest because it deals with a nonpersistent toxic substance, ammonia. The information was generated primarily from a study conducted by Ankley et al. (1990), at the Duluth Laboratory of the United States Environmental Protection Agency (USEPA). This research was part of a larger study designed to characterize the nature of the toxicity of the sediments from the lower Fox River and Green Ray.

The Ankley et al. study revealed that the apparent acute toxicity of sediment pore water from the area of concern was due primarily to ammonia. These investigators identified high algae production and subsequent decomposition as a source of ammonia. The benthos community is degraded by acute toxicity, and thus available food (macro-benthos) for waterfowl and fish are affected (Rades 1990). All these problems appear to ultimately result from a conventional pollutant (phosphorus) that causes the high algal production.

Trophic Dynamics and PCBs

The third example deals with trophic dynamics and the potential impact on the fate of PCBs in Green Bay. This example arises from studies of Sager and Richman (1991) and from Debra Swackhammer (University of Minnesota, pers. commun.).

Sager and Richman have found marked differences in the efficiency at which zooplankton are cropping the phytoplankton in different portions of the bay. These differences are directly related to nutrient availability and primary productivity. Lower bay zooplanktors are inefficient in grazing the available phytoplankton. Consequently, much of the phytoplankton is not being incorporated in the pelagic food chain and is going instead to the detrital food chain. Conversely, in the upper bay (essentially Lake Michigan waters) zooplankton are very effective in processing or cropping the available phytoplankton. In addition, there are marked differences in the turnover rates of phytoplankton populations between areas. Growth rates are approximately six to seven times higher in the lower bay than in the upper bay. The significance of these differences in growth rates for the fate of a persistent toxic substance such as PCBs could be very great. Because of the increased food chain efficiency, the bioconcentration factor for PCBs may be higher in the upper bay than the lower bay. Also, Swackhammer has found that there is a selective enrichment of some of the more toxic PCB congeners by phytoplankton. She has also found that slower growing algae take up larger amounts of toxic-ants. The significance to wildlife and human health is that there appears to be a direct link between nutrients and the manner in which persistent toxic substances are processed in the ecosystem.

These two studies provide a plausible explanation for the apparent increase in incidence of deformities and other birth defects in cormorants from the upper bay where there is no apparent source of PCBs. Apparently, nobody has given an explanation for the source loading related to the biological response of these cormorant populations. In this case, the loss of system integrity is due to both a conventional pollutant and a persistent toxic substance. The lesson may be that our efforts cannot be concentrated on toxic substances alone if effective lakewide management plans are to be carried out.

Measurement of Ecosystem Response

The fourth example serves as evidence that it is possible to measure an ecosystem response to the reduced availability of toxic substances. The subject is Forster's terns. The results, while preliminary, involve a comparison of the reproductive performance of Forster's terns on Green Bay in 1983 (Harris et al. 1985; Kubiak et al. 1989) with their performance in 1988 (Harris, et al., unpubl. data).

Growth rates of chicks were carefully monitored in the 1988 study and chicks were collected at various ages to examine bioconcentration of toxicants. Both chemical and enzyme induction (H4IIE Rat Hepatoma Cell Assay) were conducted on 1988 egg and chick samples. No enzyme assay was conducted on the 1983 samples. Analysis of the data to date reveals that there was a 45% increase in hatchability from 1983 to 1988 with a 40% increase in number of young produced per pair. The length of the incubation period in 1988 was not extended as it was in 1983.

Approximately 75% of the TCDD-Equivalent (toxicity) is attributed to PCB congener 126. From 1983 to 1988 there was a 23% reduction in congener 126 and a concomitant 30% reduction in TCDD-Eq of the eggs. Post-1988 hatching rates and production of young have continued to increase. There are at least three reasons why these changes might have occurred:

1) There was a 30% reduction of PCB loading from the Fox River (as measured at Appleton) from 1987 to 1988 (USEPA/DNR Mass Balance Study). This result is to be expected because of low flows resulting from the 1988 drought. Early spring and summer river flows were about three times as great in 1983 as in 1988.

2) Fort Howard Corporation reduced their PCB loading from 22 kg (61 lbs.) per year in 1982 to 4.5 kg (12 lbs.) per year in 1987 (an 80% reduction).

3) The Green Bay colony may be receiving an influx of young, relatively uncontaminated birds from Lake Poygan that dilutes the toxicity effect.

It presently appears that there was a reduction in the loading of PCBs and a biological response was measured. The tern might serve as an integrator species reflecting a reduction in ecosystem toxicity. However, normal tern reproduction does not ensure no effect of toxic substances in other parts of the system. Monitoring of life table parameters of sensitive short-lived species may be necessary to assure no loss of ecosystem integrity.

Conclusions

These four separate studies relevant to wildlife and human health concerns will be useful to the development of lakewide and fishery management plans. They point to the folly of focusing all attention on toxic substances to the exclusion of other problems in the Great Lakes. This tendency is inconsistent with a true ecosystem approach and may be counterproductive to rehabilitating some Great Lakes ecosystems.

For the Green Hay ecosystem, nutrient and particulate loading remain critical stresses. These factors cannot be ignored in rehabilitative strategies for wildlife and fishery populations and other beneficial uses. According to impaired use criteria identified by the International Joint Commission (IJC), 9 out of 14 impaired uses are due to conventional pollutants rather than persistent toxic substances.

A second conclusion is that the apparent normal reproductive performance of atop predator in the system may not be sufficient and conclusive evidence that all aquatic and human health concerns are being safeguarded. Basinwide and fishery management plans need to incorporate multiple toxic assessment criteria and testing similar to those proposed by the IJC in 1987.

A third conclusion is that basinwide and fishery management plans must incorporate strategies that address the restoration and maintenance of ecosystem integrity. This will help ensure habitability by humans and wildlife alike.

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STRENGTHS AND WEAKNESSES OF A MASS BALANCE APPROACH FOR TOXIC CHEMICALS IN THE GREAT LAKES

Victor J. Bierman, Jr. [1]
Department of Civil Engineering
University of Notre Dame
Notre Dame, IN 46556

A mass balance model is simply an accounting device to ensure that differences between inputs and outputs during a particular interval of time, in a particular volume in space, are equal to the net sum of production and decay processes within the volume. In practice, there are many complex processes that influence the transport, transformation, and fate of toxic chemicals in the Great Lakes. The degree of complexity actually incorporated in any particular model depends on the objectives of the analysis, the amount of data available to run and validate the model, and on the resources and time available for a particular study.

Strengths of Mass Balance Models

The principal strengths of mass balance models are:

1) models constitute a framework for organization and synthesis of experimental data,

2) models are useful as research tools for understanding processes that lie behind the data, and

3) models provide quantitative linkages between external source inputs and system responses.

Models can be used as experimental design tools to identify data gaps and research needs. Because they are simplified abstractions of reality, models can be used to conduct controlled numerical experiments in order to test different hypotheses on underlying process mechanisms. The most notable example of the utility of mass balance models for management purposes was the use of a suite of models to develop the target phosphorus loading objectives to the Great bakes as part of the 1978 Great lakes Water Quality Agreement between the United States and Canada.

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1 Was unable to attend the round table.

A model must be scientifically credible *in order* to be useful as a management tool. To achieve scientific credibility, mass balance models require extensive sets of experimental data for development and field validation. Model validation is partly a science and partly an art. It is a science because model equations follow the law of conservation of mass and model coefficients must be consistent with results from site-specific measurements or with results from the scientific literature. Model validation is an art because it is usually impossible to find a unique set of model coefficients that produces the best fit between model output and *experimental* observations. This is because of data uncertainties and because the model equations do not represent environmental processes at their ultimate levels of physical, chemical, and biological resolution. Furthermore, the nature and relative importance of these finely resolved processes may differ among physical systems and among various spatial-temporal scales. Consequently, although mass balance model equations are generic in a functional sense, precise values for calibration coefficients must be determined on a site-specific basis.

The costs of comprehensive, site-specific mass balance modeling studies can be very high. For example, the total cost of the eutrophication modeling studies used to develop the target phosphorus loading objectives was approximately $100 million. The total cost of the ongoing Green Bay mass balance study for toxic chemicals is approximately $11 million. However, one of the least appreciated aspects of mass balance modeling is that typically, 85% to 90% of total project costs are expended on data acquisition, as opposed to actual modeling. Perspective can be gained by realizing that the total cost of wastewater treatment plant upgrades during the 1970s in the United States portion of the Great Lakes basin was approximately $12 billion.

weaknesses of Mass Balance Models

The principal weaknesses of mass balance models are conceptual oversimplification, extensive data requirements, and lack of quantitative measures of model uncertainty. Although models are deliberate simplifications of reality, errors can occur if important governing processes are not included in the model equations. This can result from inexperience or poor judgment on the part of the modeler, or from a lack of scientific understanding.

The principal conceptual weaknesses in contemporary toxic chemical mass balance models are related to sediment-water exchange processes and particle-toxics interactions. Sediments are the repository for a major portion of the historical loadings of many toxic chemicals to the Great Lakes. Current modeling results indicate that sediment feedback strongly influences lake response times to reductions in external source inputs. Sediment-water exchanges are the net result of complex processes such as settling, resuspension, particle transformations, and pore water diffusion, each of which is not completely understood. With regard to particle-toxics interactions, the fate of sorbed toxic substances as a result of particle transformations and decomposition is also not completely understood.

Another weakness that is partly conceptual and partly data related is quantification of volatilization fluxes. Current modeling results indicate that volatilization is the major loss mechanism on a whole lake scale for chemicals such as PCBs and DDT. The classic two-film theory of gas exchange across an air-water interface is completely satisfactory for controlled laboratory experiments. Whole lake mass balance models operate at completely different scales. They must also contend with spatial-temporal variability in environmental parameters that influence apparent gas- and liquid-phase transfer coefficients. Furthermore, fieldmeasurements of volatilization fluxes are virtually nonexistent.

The principal obstacle to further development of mass balance models for toxic chemicals in the Great Lakes is data limitation. The most critical data gap is for external loadings from point and nonpoint sources in the watershed and from atmospheric deposition. Serious gaps also exist for concentration distributions in the water column, sediments, and biota. For these measurements to be useful for whole lake mass balance models, they must be taken synoptically at spatial scales that differentiate between near- and off-shore zones and among epilimnion, hypolimnion, and near-bottom layers. Because response times can be on the order of years for the Great Lakes, measurements must be conducted as long-term time series.

Data limitation is not solely a function of limited resources. In contrast to conventional pollutants, sensitive, accurate, and precise analytical methods still need to be further developed for most toxic chemicals of concern in the Great Lakes. In the ongoing Green Bay mass balance study, available laboratory capacity itself placed an upper limit on the number and types of samples that could be analyzed within the overall time period of the project.

Another weakness of mass balance models is that there are no rigorous methods for quantifying model prediction uncertainty. Statistical techniques such as mean square error, regression analysis, and "Student's t-test have been used to quantify goodness-of-fit to experimental observations. First-order error and Monte Carlo analyses can be used to determine model output uncertainty as a function of uncertainty in model coefficients. Although these statistical techniques are valuable, they do not quantify predictive capability because they cannot detect conceptual errors in model formulation.

It should be recognized that a mass balance model cannot make absolute predictions, even if it is conceptually sound and has been thoroughly field validated. The state of a lake system depends on external forcing functions such as loadings, winds, water circulation, temperature, and solar radiation. These forcing functions are not computed by mass balance models, but must be specified as model input by the user. Consequently, model predictions depend on the assumptions used to specify future values for these functions. Typically, predictive simulations are conducted over ranges of forcing function values that, based on historical data, are thought to be reasonable.

Summary

Despite its many weaknesses and limitations, the use of a mass balance approach for toxic chemicals in the Great Lakes is inevitable. The only real alternative is to impose some degree of control on external source inputs and watch what happens. If the desired results are not obtained, then the controls can be modified. Such a trial-and-error approach is not rational or cost effective. At a minimum, the mass balance approach constitutes an internally consistent framework for comparing and ranking the consequences of a range of different management actions.

CRITICAL INTERNAL CYCLING PROCESSES

Stephen R. Carpenter
Center for Limnology
University of Wisconsin-Madison
680 North Park
Madison, WI 53706

Better knowledge of internal cycling mechanisms can lead to innovative management strategies for reducing toxic substance levels in exploited fish stocks. Critical uncertainties are associated with flux rates of chemicals between water and sediments and from sediments to benthic organisms, effects of diet differences and growth rate differences on relative chemical accumulation by fishes, and the capacity of stocked fishes to suppress key links in the trophic transfer of chemicals.

Restrictions on the use and disposal of chlorinated organic chemicals have decreased concentrations of certain toxic substances in the water (Swackhammer and Armstrong 1986) and some fish stocks of Lake Michigan (DeVault et al. 1985, Evans 1988; USFWS 1989). Despite these encouraging trends, some toxic substances regularly occur in fishes at concentrations that exceed United States Food and Drug Administration (USFDA) action levels and International Joint Commission (IJC) Water Quality Objectives (Michigan DNR 19139; Wisconsin DNR 1989). Health guidelines are themselves subject to research, debate, and revisions that may demand new environmental information and innovative responses by environmental managers.

PCB concentrations in Lake Michigan's fishes dropped significantly following the ban in 1976 (Devault et al. 1985; USFWS 1989). However, concentrations have been stable since the early 1980s, and concentrations in several exploited fish stocks remain above 2 mg kg $^{-1}$ (DeVault et al. 1985; Masnado 1987; USFWS 1989). Relatively high nonpoint source inputs probably contribute to high PCB concentrations in the biota. The atmosphere is a major source of PCBs to the ecosystem, and atmospheric concentrations did not decline during the 1980s (Manchester-Neesvig and Andren 1989).

Recycling of PCBs within the ecosystem appears to be relatively efficient in Lake Michigan, and tends to stabilize concentrations in the biota (Fig. 1). Recycling from sediment may significantly influence PCB flux into the foodweb. Diet and growth rate are among the major factors that determine PCB concentrations in fishes (Thomann 1989). The kinds and numbers of salmonids stocked determine the structure of the food web and manipulate growth rates and diets of fishes. Consequently, stocking policy can influence the PCB concentrations in harvested fish.

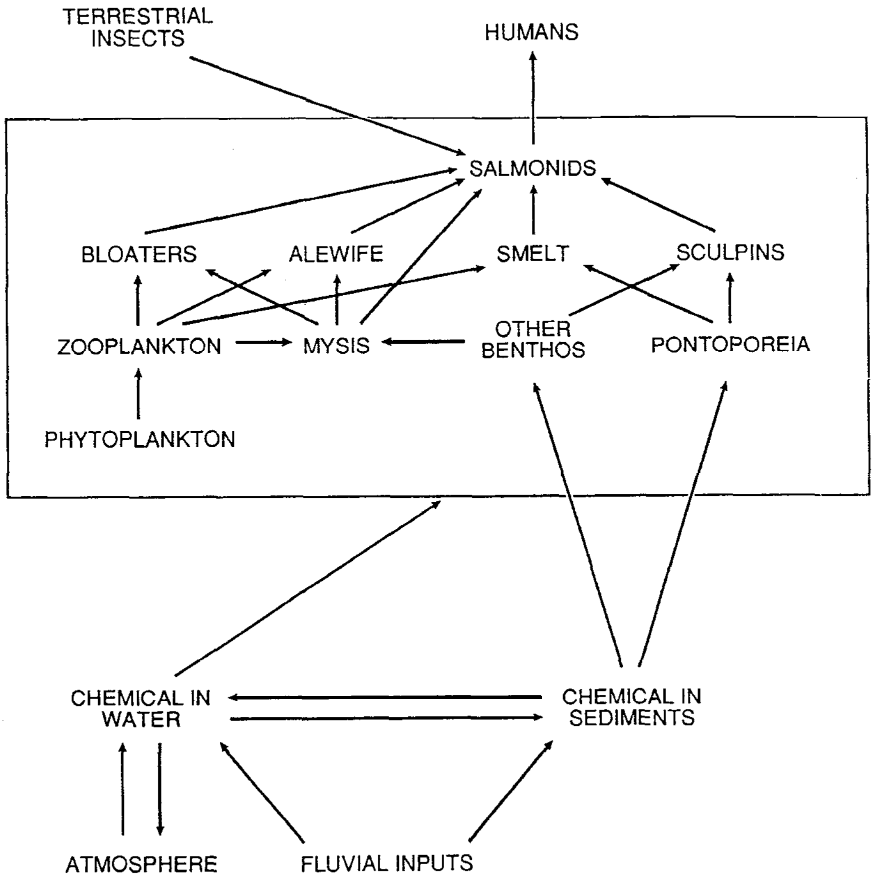

Fig. 1. Simplified chemical toxic substance cycle in Lake Michigan. The box contains key components of the food web.

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LAKEWIDE MANAGEMENT PLANS: CURRENT STATUS AND FUTURE PROSPECTS

Michael J. Donahue
Great Lakes Commission
Argus II Bldg., 400 S. Fourth St.
Ann Arbor, MI 48103-4816

Paul R. Muldoon
Canadian Inst. for Environmental
Law and Policy
517 College St., Suite 400
Toronto, Ontario, CANADA M6S 4A2

Orie L. Loucks
Holcombe Research Institute
Butler University
46th & Sunset
Indianapolis, IN 46208

The Great Lakes Water Quality Agreement (1987 Protocol) calls for the development of Lakewide Management Plans (LAMPs) "to reduce loadings of critical pollutants in order to restore beneficial uses." By doing so, the United States and Canada commit themselves to a major new undertaking to address pervasive and persistent toxic pollutants in the open waters of the lakes. As a complement to the Remedial Action Plan process established some years earlier, the LAMP process offers a new strategy to attain a long-standing goal: "To restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem."

Annex 2 of the Agreement presents a conceptual framework for the LAMP process and delineates, in broad terms, LAMP content and review and reporting requirements. However, the role of LAMPs in terms of the Remedial Action Plan process and other Agreement activities is left for conjecture, and little guidance is offered in a number of managerial, technical, and institutional areas. In brief, the substance and breadth of the LAMP "niche" are not well defined in the overall context of Great lakes water quality management, nor are the institutional arrangements for LAMP design, development, and implementation.

A study team was assembled at the request of the International Joint Commission's Science Advisory Board to;

1) assess recent activities supporting LAMP development,

2) consider implications of these plans as they relate to Great Lakes Water Quality Agreement provisions, and

3) offer recommendations concerning future LAMP initiatives and a potential role for the Science Advisory Board.

The origin and objectives of the LAMP process were explored by the study team, and six initiatives predating Annex 2 language in the 1987 Protocol to the Agreement were assessed to determine their potential contributions to the continuing refinement of that process. These initiatives included:

1) the Phosphorus Reduction Plans of the mid-1980s under the terms of the Great Lakes Water Quality Agreement,

2) the Niagara River Toxics Management Plan adopted by a four-agency Niagara River Toxics Committee in 1987,

3) the Lake Ontario Toxics Management Plan adopted by the same agencies in 1989,

4) the Upper Great Lakes Connecting Channels Study completed in 1987,

5) the Lake Michigan Toxic Pollutant Control/Reduction Strategy developed in 1986, and

6) the Green Bay Mass Balance Project initiated in 1987.

Each of the six initiatives was examined on the basis of various general principles and LAMP components specified in Annex 2 that call for:

1) incorporation of an ecosystem approach,

2) a public participation component,

3) identification of ecological threats and information gaps,

4) a determination of load reductions and remedial measures, and

5) institutional responsibilities and assessment of effectiveness.

On the basis of this assessment and a thorough review of the relationship of LAMPs to other Agreement activities, a series of findings and recommendations were developed. Among others, they include:

1) None of the six initiatives predating Annex 2 fulfill LAMP requirements in their entirety. However, all offer important lessons with applicability to future LAMP initiatives.

2) The Canada-United States Framework for Lakewide Management Plans for Critical Pollutants overcomes many weaknesses of earlier initiatives. However, they should be developed further to better define the relationship of LAMPs to Remedial Action Plans and other Agreement activities, provide greater specificity concerning institutional roles and responsibilities, and specify criteria and procedures for LAMP evaluation.

3) The LAMP process is best viewed as a comprehensive, systematic planning framework where many activities are pursued, including but not limited to, control of critical pollutants.

4) Considerable opportunities exist for successful LAMP implementation, including building upon experiences from current initiatives, incorporating the work of Remedial Action Plans, and taking advantage of lakewide constituency building. Obstacles to be overcome include the challenge of justifying load reductions, integrating the LAMP process within the current regulatory structure, ensuring adequate funding and resources, and developing criteria for LAMP evaluation.

5) An array of research needs must be addressed to adequately support the LAMP process. These include, among others, documenting the consequences of uncertainty in source strengths of priority substances, exploring regulatory instruments, determining the cost effectiveness of alternate control strategies, and examining alternate institutional arrangements for LAMP implementation.

The study team concluded that a role for the Science Advisory Hoard exists throughout the LAMP design, development, and implementation process. This role should include identification of research needs and existing gaps, establishment of benchmarks and a LAMP evaluation procedure, provision for liaison services to the broader research community, building support end confidence among the public, exploring alternate institutional arrangements for LAMP implementation, and ensuring exchange of scientific information between LAMP working committees and Remedial Action Plan teams. Specific initiatives to support this role include a workshop to fully review the lessons to be learned from the six non-Annex 2 initiatives, undertaking a biennial evaluation of the LAMP process, and establishing subcommittees to offer scientific advice during LAMP implementation.

APPENDIX B

LAKE MICHIGAN: AN ECOSYSTEM APPROACH
FOR REMEDIATION OF CRITICAL POLLUTANTS
AND MANAGEMENT OF FISH COMMUNITIES

Steering Committee [1]

Anders Andren[1]
University of Wisconsin-Madison

Steve Carpenter
University of Wisconsin-Madison

Fred Copes
University of Wisconsin-Stevens: Point

Glenda Daniel
Lake Michigan Federation

Randy Eshenroder
Great Lakes Fishery Commission

John E. Gannon
National Fisheries Research Center--Great Lakes

John Hartig[1]
International Joint Commission

Richard Hess'
Illinois Department of Conservation

Joseph F. Koonce
Case Western Reserve University

Attendees

Tim Bartish
International Joint Commission

David Borgeson
Michigan Department of Natural Resources

Barry Boyer
State University of New York-Buffalo

James Butterbrodt
Great Lakes Sport Fishing Council

Bill Davis
Citizens for a Better Environment

Michael Donahue
Great Lakes Commission

Jane Elder
Sierra Club

Kent Fuller
U.S. Environmental Protection Agency

James Giattana
U.S. Environmental Protection Agency

Kathy Glassner
Center for the Great Lakes

Michael J. Hansen
Wisconsin Department of Natural Resources

---

[1] Could not attend.

H. J. (Dud) Harris
University of Wisconsin-
Green Bay

Dennis Hickey
Wisconsin Commercial Fishing
Association

Bob Kavetsky
U.S. Fish and Wildlife Service

Lee Kernen
Wisconsin Department of Natural
Resources

Timothy J. Kubiak
U.S. Fish and Wildlife Service

Charles Ledin
Wisconsin Department of Natural
Resources

Richard Powers
Michigan Department of Natural
Resources

Dick Reuss
Great Lakes Sport Fishing
Council

Jon G. Stanley
U.S. Fish and Wildlife Service

Richard Stoffle
University of Michigan

Dan Thomas
Great Lakes Sport Fishing
Council

Tom Trudeau
Illinois Department of
Conservation

Mark Van Putten
National Wildlife Federation

Philip Weller
Great Lakes United

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