Review of Proposed Changes in Water Level Regulation for Rainy and Namakan Lakes: Their Consequent Ecological Effects on Fisheries and Related Aquatic Resources

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EXECUTIVE SUMMARY

This review provides an independent assessment of the International Steering Committee's recommendation that water level management practices in Rainy and Namakan Lakes be altered to allow restoration and rehabilitation of historical ecosystem properties in these systems. Fisheries are a key component of those concerns and the primary focus of this evaluation.

Two primary sets of information were evaluated: long-term monitoring results on fisheries and fish populations of Rainy Lake and the Namakan Lakes and short-term, site-specific studies within these lake systems. Commercial fishing records and standard fisheries assessment data sets were collected by the Minnesota Department of Natural Resources and the Ontario Ministry of Natural Resources. These long-term data sets served as the basis for a series of statistical analyses intended to evaluate the relationship between water level fluctuations and fisheries yields or the catches made in test netting programs conducted by the two agencies. A shorter-term group of comparative studies and surveys were sponsored through the US National Park Service. Those offered evidence of water level effects on components of the biota other than fisheries.

Fish populations in Rainy Lake and the Namakan Reservoir system have generally declined since the dams were built and the fisheries developed. Water level regulation and fishery exploitation act in concert to exacerbate the inherent variability in fish populations, leading to uncertainty about the relative importance of causes of decline in those populations. Remedial actions required to rehabilitate the currently depressed fish populations should include water level regulatory practices that seek to simulate those representative of previous, natural conditions known to sustain fish populations plus efforts to reduce and constrain exploitation pressure. Accordingly, we endorse the proposed changes in rule curves as recommended by the International Steering Committee in its 1993 report.

This document presents the consensus of two, independent assessments. Those were conducted by James F. Kitchell of Madison, Wisconsin, USA, and by Gordon D. Koshinsky of Saskatoon, Saskatchewan, Canada. Each developed an interim report based on individual reviews. That developed by Kitchell was revised, expanded and modified in collaboration with Koshinsky; it is presented as this joint report. The original interim report by Koshinsky has been modified and expanded; it is included as an Appendix .

Our major findings and conclusions are:

1. **Further analysis of the existing data sets will not offer significant improvement in understanding of effects of water regulation on fisheries.** The long-term data derived from general monitoring efforts and were not designed to directly evaluate the effect of water level fluctuations on fish spawning success.

2. **Overexploitation has played a major role in the decline of fish stocks.** Records of commercial catches are confounded by changes in effort and gear. Those for recreational catches are intermittent and incomplete. Nevertheless, these fish populations exhibit well-known symptoms of overexploitation. Newly implemented fishery regulations are an appropriate step

toward diminishing exploitation effects and increase the likelihood that fisheries yields will begin to improve.

3. **Water level regulation has contributed to the decline of fish stocks.** Drawdown of water levels during the winter produces low water levels during the spring. In addition, the dams sustain high water levels during summer and early autumn. These practices have reduced the likelihood of successful spawning and recruitment by several important fish species. Rule curves designed to more closely simulate the previous, natural hydrologic regime in water levels are likely to improve the chances for rehabilitation of desirable fish stocks.

4. **Fisheries managers should develop and implement a more aggressive program to evaluate the importance of invasion by the exotic smelt (Osmerus mordax).** In many ecologically similar lakes, smelt have had adverse effects on walleye, yellow perch, whitefish and cisco populations.

5. **Management actions such as those embodied in new rule curves and more restrictive fishery regulations require follow-up studies.** These actions offer an excellent chance for learning through the management process. Careful and effective documentation of the consequent results is more than an opportunity, it is also an obligation. Key areas for future work are:

a. Repeat and expand previous surveys of macrophytes and benthic invertebrates,
b. Evaluate changes in and associated with fish spawning habitats,
c. Sustain or expand fisheries assessment efforts, and
d. Evaluate the role of exotics (e.g., rainbow smelt).

A central theme of this report is that variability in fish populations and uncertainty about the causes of variability are fundamental realities. Variable recruitment is an inherent property of the life history of the fish species that dominate these fisheries. Rehabilitation of high-value, sustainable fisheries is a laudable goal, but must be viewed as a continuing process rather than as an equilibrium condition or end point.

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1. INTRODUCTION

The basis for this review derives from analyses of contentious opinions about proposed changes in water level regulation practices and their consequent effects on fisheries and related aquatic resources in Rainy Lake and the Namakan Reservoir system. Waters of both lake systems are shared by the US (Minnesota) and Canada (Ontario); hence, the International Joint Commission (IJC) has responsibility for establishing regulatory policy. Water levels are regulated by two dam systems: one dam on Rainy Lake located on the Rainy River at International Falls/Fort Frances and two on the Namakan Reservoir system located at Kettle Falls and at Squirrel Falls. The Rainy Lake dam was constructed in 1909. It serves as a source of hydroelectric power to the Boise Cascade Corporation's paper pulp industrial facilities at Fort Frances, Ontario, and International Falls, Minnesota. The Namakan Reservoir system is a flowage, which includes Namakan Lake, Sand Point Lake, Little Vermilion Lake, Crane Lake and Kabetogama Lake. The Namakan Reservoir dams were constructed in 1914 and are operated to augment water levels in Rainy Lake. Water levels in both systems are to be regulated within seasonally changing maximum and minimum limits (rule curves) set by the IJC. The history of policy development is presented in greater detail elsewhere (International Steering Committee 1993).

Briefly restated, there is disagreement over ecological and economic effects that might result as a consequence of changes in current operating practices for the two dam systems. At present, Rainy Lake water levels are regulated to provide less annual variability than under natural conditions, while the Namakan system is regulated to yield greater annual change than under natural conditions. Rule curves adopted in 1970 require that maximum annual water level changes in Rainy Lake should not exceed 3.5 ft. (and have averaged 3.6 ft. since 1970), while those on Namakan should not exceed 10 ft. (and have averaged 8.9 ft. in the recent past). Historically, both systems experienced substantial, natural annual fluctuations in water levels. Annual water level range on Rainy Lake is currently 2.6 ft. less than pre-dam fluctuations while that on the Namakan system is about 3.0 ft. greater than that estimated under natural conditions (International Steering Committee 1993).

The current water level control practices produce two other major differences from the natural conditions:

1. Winter drawdown delays spring filling and peak spring water levels by about one month, and
2. Water levels are high throughout summer and early autumn which is unlike the gradual summer reduction that occurred before regulation developed.

Although water level controls have been the focus of controversy in the past, motivation for the current debate traces to development of the Voyageurs National Park (Minnesota) in 1975, which includes part of Rainy Lake and much of the Namakan system. The US National Park system has a general goal of restoring natural processes within park territories (Kallemeyn and Cole 1990). The artificially sustained and greater fluctuation of water levels in the Namakan system are an issue of particular concern for those interested in ecological restoration, for riparian property owners, and for those with vested interests in the local tourist-based economies. While similar ecological and economic issues arise for Rainy Lake, there is an additional concern about the likelihood of flooding and its consequent damage. In both cases, the delayed rise in spring water levels is thought to diminish spawning success by those species that are the focus of major fisheries: walleye (Stizostedion vitreum) and northern pike (Esox lucius). Similar concerns exist for yellow perch (Perca flavescens) and the fall spawning species, lake whitefish (Coregonus clupeaformis) and the lake herring or cisco (Coregonus artedii).

Hydrologic models (Flug 1986, Tinker 1993) were used to evaluate the consequences of alternative rule curves, and a public review process conducted during 1991-93 identified those most likely to accomplish ecological goals at lessened economic risk (International Steering Committee 1993). In addition, a suite of ecological studies have been conducted with the goal of evaluating the importance of water level fluctuations and the role they may play in regulating distribution and abundance of a number of natural and cultural resources. Among the components considered are effects on archeological resources, nesting waterfowl (e.g., loons, grebes and wetland species), piscivorous birds and mammals (e.g., osprey and otters), aquatic mammals (e.g., muskrats and beavers), aquatic macrophytes, benthic invertebrates, general limnological characteristics, fishes and fisheries (Kallemeyn and Cole 1990).

Over the past decade, the studies mentioned above plus a diversity of public hearings and information-gathering initiatives have culminated in the recommendation that the IJC act to alter the current rule curves for Rainy Lake and the Namakan system. These actions would accomplish two general goals:

1. Annual hydrographs that more closely approximate the natural cycle.
2. Reduced amplitude of water level fluctuation in the Namakan system.

Due to the substantial economic impact associated with lost hydroelectric generating capacity, these recommendations and the credibility of their scientific underpinnings have been challenged (Acres International Ltd. 1993, Boise Cascade Corporation 1994; Gray and Kovats 1993; Parkhurst et al. 1993; Tinker 1993). In addition, certain public and private interest groups are deeply concerned about--or not in agreement with--specific components of the recommendations. While many respondents endorsed the proposed rule curves and the goals of ecosystem rehabilitation, some are concerned about the prospect of increased flooding or impediments to navigation and recreational boating.

Effects on fisheries are a cornerstone of the debate. Fisheries yields in these lakes have generally declined since record keeping began [Chevalier 1977; Minnesota Department of Natural Resources (MDNR) and Ontario Ministry of Natural Resources (OMNR) 1992; Eibler 1995a, 1995b, 1995c]. The arguments about cause and effect revolve around disagreement over the relative importance of:

1. Water level regulation as it may have contributed to reduced spawning success and/or changes in habitat for juvenile fish, versus
2. Overexploitation of adult stocks and its consequent effects.

Much of the debate centers on the adequacy and analysis of long-term data sets collected through reports from commercial fisheries and monitoring programs conducted by management agencies (MDNR and OMNR). More recently, a series of shorter-term, comparative studies were commissioned by the U.S. National Park Service and conducted to specifically evaluate water level effects on macrophytes (Meeker and Wilcox 1988), on benthic invertebrates (Kraft 1988), and on the spawning success and survival of both walleye and northern pike (Kallemeyn 1987a, 1987b). This report offers views of the evidence at hand, the debate over analysis and interpretation of data, and the likely consequences of implementing the proposed changes in rule curves for water level control. In addition, suggestions are offered for improving the understanding of interactions that regulate current and future dynamics in these ecosystems.

2. LITERATURE REVIEW

Two bodies of literature were evaluated in preparing this review. Section 6.0 includes published accounts, research reports, committee reports and correspondence directly addressing the history and proposed changes in water level regulations for Rainy Lake and the Namakan system. Those particularly important to the evidence and arguments are appropriately cited in the text. In addition, the report presented as an Appendix offers a detailed and annotated evaluation of each of these materials.

Section 7.0 includes sources that address similar issues in other systems and provides key ecological principles or important perspectives on fisheries issues that are pertinent to the management questions posed for Rainy Lake and the Namakan system. Those, too, are cited in the text as appropriate to specific issues.

3. EVALUATION

Each component of this section is presented in four parts. First, we pose the key question(s) derived from review of the Plan of Study (International Rainy Lake Board of Control 1995). Next, we provide our opinion as a direct and specific answer to each key question. Third, we offer an elaboration of the background and rationale for our views on each issue based on the pertinent literature sources. Fourth, we offer a summary of our conclusions derived from that overview. The key concept employed in this assessment is that of fishery recruitment, which we define as the relative success of survival to an age and size that enters the fisheries.

Background and Rationale

Each of the important fish species (walleye, northern pike, yellow perch, whitefish, cisco, smallmouth bass and black crappie) in these lake systems are known to exhibit highly variable recruitment success. In other words, there is substantial uncertainty embedded in the biology of these species and their life histories. Accordingly, one should expect that concepts such as population stability and equilibrium yields are applicable in only the most general sense. For example, walleye populations are known to be highly variable and their recruitment success tied to weather conditions (Koonce et al. 1977). Highly variable recruitment occurs in lakes where water levels fluctuate only modestly and where there is no fishery exploitation (Kelso and Ward 1977). Exploitation tends to alter the age structure and sex ratio of the spawning population. It also increases the magnitude of recruitment variability (Hilborn and Walters 1992, Forney 1980, Kitchell 1992) because it reduces both the abundance of spawners and the variability in spawning times. These have the net effect of diminishing the chances that successful recruitment will occur (Carpenter et al. 1994, Johnson and Carpenter 1994).

As a more specific example, the sequence of conditions leading to good walleye recruitment includes the following: an adequate population of spawners, access to suitable spawning sites, an early and slowly progressing spring, adequate prey resources, and warm summers. By early autumn, this combination of conditions usually produces abundant numbers of large young-of-the-year fish which form a strong year class that persists as such for many years and is reflected in increased fishery yields (Hatch et al. 1987, Madenjian and Carpenter 1993). In Rainy Lake and the Namakan system, warm summers and the greater attendant growth rates are known to be an important component of year class success (Eibler 1995c, Pereira et al. 1995). Low water and a late spring coupled with cool summers are known to be associated with poorest survival and recruitment (Cohen et al. 1991, Colby 1993).

In this case, management controls two components of this sequence:

1. Exploitation rates that generally determine the age structure and abundance of mature adults; and
2. Water level regulation that controls access to suitable spawning sites and their quality as habitat.

The remainder of the sequence is not controlled by management activities because it is tied to the weather. In other words, the unpredictability of weather has a large role in the uncertainty of recruitment success and the subsequent dynamics of fish populations.

Summary

The generalities developed above for walleye apply to each of the species important to the Rainy Lake and Namakan system fisheries. While the fish populations are likely to increase in response to remedial management actions, a specific, accurate forecast of when and how much is simply not possible. The magnitude and timing of that result will depend on the weather in any given year and management cannot control the weather. Reducing exploitation effects and increasing access to spawning sites will increase the likelihood of rehabilitation by enhancing the chances for fish populations to increase when the appropriate weather conditions occur.

An appropriate management model will include uncertainty. We recognize that accurate and precise forecasts of effects are unlikely and ill-advised (Larkin 1978, Hanson et al. 1991, Hilborn and Walters 1992, Hilborn et al. 1995). The traditional equilibrium assumptions employed in models of sustainable fishery yields actually increase the prospect that overexploitation will occur and that fish populations will decline (Larkin 1977, Carpenter et al. 1994). Management actions should be viewed in a context that recognizes uncertainty; i.e., that a desired outcome occurs at some probability, not as a guaranteed result (Paulos 1988, Lee 1993).

3.1 Data Assessment

Key Question

Are the data, their analysis, and the consequent conclusions an appropriate basis for decision-making?

The long-term data have a significant shortcoming: they were not collected with the primary goal of testing the question of water level impacts on spawning success in fish populations. However, these data are of value because they are similar to those collected in many fisheries assessment programs. In this case as in others, the monitoring data are used as an indicator of fish population status. Bias in the data sets (i.e., they do not provide accurate and precise measures of fish population densities) and the debate about methods and results of statistical analyses nevertheless do not obscure the dominant pattern in the data: namely, that fish populations have generally declined since the dams were built and the fisheries initiated.

Background and Rationale

The earliest discussion of water level effects on fish populations trace to the key reports by Sharp (1941), Johnson (1957, 1967) and Bonde et al. (1965). Their studies offered the observational basis for the argument that the dams created artificial water level fluctuations which could be associated with the decline in fisheries yields through adverse effects on spawning habitat for northern pike and walleye in Rainy Lake and the Namakan reservoir system.

The cause(s) of adverse effects were assumed to be similar in that low water levels in early spring prevented access to preferred spawning sites. Northern pike typically spawn at or just after ice break-up. They seek shallow embayments or flood plains where the previous year's emergent marsh vegetation is flooded. Under conditions of normal water level change, such areas develop as the water level drops during summer and early autumn. The currently-practiced rule curves hold water at high levels until autumn. The potential spawning marshes are, therefore, less extensive than in pre-dam years. The lakes are drawn down throughout the winter period. As spring begins, northern pike spawning habitat is minimized by both the limited development of marsh vegetation and, due to the low water levels, reduced access to spawning sites that have that vegetation.

Walleye also spawn in early spring but in different habitats. They seek areas of rock rubble and coarse gravel on shoals or in rivers where their eggs can settle into the protected interstices and crevices. In lakes, these areas are wave-washed and cleaned of sediment and organic matter during the typical late summer drop in water levels. In the regulated systems, sustained high water prevents that cleaning and, therefore, diminishes the habitat quality. As in the case of northern pike, delayed rise of spring water levels reduces access to key spawning areas.

In an attempt to relate the effects of water level regulation to fish population dynamics, multiple regression methods were used in several analyses of commercial fishery records and water levels in Rainy Lake (Johnson 1967). For example, Chevalier (1977) found that walleye catches followed water level fluctuations with a lag time of about five years. High water years produced better spawning and recruitment conditions. Those were reflected in higher catch rates five years later. Low water years produced the opposite effect. A subsequent analysis (Osborn et al. 1981) did not support that result. We note, however, that the Osborn et al. (1981) analysis was focused on the catch records from Minnesota waters which represent a lesser subset (about 25%) of the total estimated catch.

The current controversy in evaluating the impact of water level fluctuations and exploitation effects on fisheries relates to the alternative data interpretations. Those are presented in a report by Cohen et al. (1991) plus its subsequent publications (Cohen and Radomski 1993, Cohen et al. 1993), and in a series of re-analyses of those data by the Cadmus group (Parkhurst et al. 1993). The statistical procedures of spectral analysis--a form of time-series techniques--was used by both groups as the primary basis for evaluation of fish population responses to water level fluctuation. This approach deduces the pattern of deviations from a central trend in a long-term data set and seeks to find evidence of periodicity or cycles in those patterns.

An extensive data set served as the basis for the contesting perspectives of Cohen et al. (1991) and Parkhurst et al. (1993). Their disagreement is focused on the statistical methods employed and the assertion that uncertainty has not been resolved (Parkhurst et al. 1993). In our view, the primary reasons for disagreement relate to both the shortcomings of the basic data set when used for these purposes and the conceptual framework (i.e., basic assumptions) adopted in pursuing the analyses.

Changes in the habitat occured because the dams raised average water levels in both systems. In addition, they altered both the amplitude and seasonality of water level fluctuations. These effects interact with inter-annual variability in early spring water levels. Thus, the local adaptations of reproductive strategies to water level changes (e.g., timing and site selection) and access to the ancestral spawning grounds were modified in ways of unknown importance. Those will remain unknown because their initial effects occurred before fishery monitoring programs began. Subsequent changes in water regulation have probably exacerbated that effect; i.e., mean water levels have increased and the timing and variability have been changed. In combination, these manipulations of habitat are likely to have negatively affected both the timing and the productivity of reproductive effort by the two species that spawn in early spring--walleye and northern pike. Yellow perch spawn somewhat later, but would have been similarly affected. Effects on the fall-spawning whitefish and cisco stocks would also derive from increased amplitude in water level changes as some proportion of their eggs are deposited in shallow areas that would be exposed to desiccation or freezing during winter drawdowns. Populations in the Namakan system would have been most affected. The nest-building smallmouth bass (Micropteus dolomieu) and black crappie (Pomoxis nigromaculatus) would be least influenced as their spawning times occur in late spring and tend to correspond with development of higher water levels in most years.

As indicated by the Parkhurst et al. (1993) report and subsequent communications (Colby 1993, IJC 1995), the analyses by Cohen et al. (1991) used the annual maximum change in water levels as the basic independent variable for their analyses. In other words, they assumed that the difference between highest water levels, which occur in summer, and lowest water levels, which occur in late winter, could be used as a surrogate or correlate of water level effects on the fish populations. Their basic hypothesis was that the magnitude of annual fluctuation would correlate with changes in fish populations expressed as fish abundance in catch records and the test netting programs conducted by fisheries agencies. The monitoring programs offered evidence of relative abundance for both juvenile and adult fishes. The central problem here is obvious; there are no direct measures of water levels, fish behaviors or egg laying and subsequent early survivorship taken at the time or place of primary concern--in early spring and on the spawning grounds. As noted below, the monitoring data were not collected with the goal of a rigorous test of spawning success or early life history survivorship. Searching for periodicity that correlates with maximum water level fluctuations is an indirect test of the key question.

Interpretation of the long-term fisheries monitoring data must be conducted with some caution because fish populations change in response to exploitation. This is generally termed the "non-stationarity of variables" problem (Walters 1986). Analytical models and inferences built around them must allow for the fact that compensatory responses develop as a fish population is subjected to the selective effects of fisheries based on gill nets and angling (Hatch et al. 1987). Typically, the larger and older members of the population are removed first. In northern pike and walleye, females are generally larger than males of the same age (Scott and Crossman 1973). Population fecundity declines exponentially as a result and the variance of spawning times is decreased because larger individuals tend to spawn first. In other words, the effect of exploitation will be to reduce the relative abundance of larger, older adults in the population. In addition, the effect of exceptionally low water levels in early spring will be to selectively reduce the spawning success of larger, older adults which have the highest reproductive potential. As exploitation rates continue to increase, intra-specific competition and density-dependent constraints on growth rate are reduced. Surviving individuals grow more rapidly and may mature at a younger age (Colby 1993). This also tends to reduce population fecundity because younger individuals are now more vulnerable to exploitation. The range in spawning times and spawning sites is further reduced.

Thus, the typical response to exploitation is a reduction in the range of ages and sizes of mature individuals. This translates into a reduction in the duration of spawning activity. That makes the populations more subject to vagaries in the weather and, in the case of these lakes, to the effects that delayed rise of water levels is likely to have on reproductive success for the spring-spawning species (walleye, northern pike and yellow perch). In some years, water levels and weather would both be conducive to reproduction and growth yielding strong recruitment success. In other years, one or the other might not be conducive and recruitment success would be more modest or, in the extreme case, fail. Those expectations are confirmed by the results of Kallemeyn (1987a, b). In other words, exploitation effects and water level regulation interact in ways that would reduce overall reproductive potential by decreasing the likelihood of success in years of exceptionally low water. This would also increase the variability and decrease the likelihood of recruitment success for juveniles by producing a delay in average hatching date and its consequent effect--a shorter growing season and lessened probability of survival through the remainder of the first year of life.

Another caveat for interpretation of the basic data derives from the use of long-term records based on catch per unit of effort (CPUE) from test netting or from the commercial and recreational fisheries. Over the time of records in Rainy Lake, gill nets have changed from braided twine to nylon. The latter are much more effective: under similar fish densities, they catch more fish per unit of effort. Thus, the observed decline in CPUE from commercial nets should be viewed as under-representing the actual decline in fish abundance. Similarly, the advent of better boats, motors, electronic fish finders and their analogues have made the angler much more efficient. Again, declines in angling CPUE actually under-represent the likely declines in fish abundance.

In many records of commercial fisheries, the reported CPUE is found to be biased by two general problems:

1. Commercial fishers have many incentives to misrepresent their actual catch, and
2. Market forces tend to influence the amount and efficiency of fishing effort.

We do not and cannot know the extent to which these biases are components of the data set. We do know that the problem is widely observed in other fisheries (Walters 1986, Hilborn and Walters 1992, Hilborn et al. 1995).

We emphasize that these data collecting efforts were not designed to evaluate the effect of water level fluctuation on reproductive success. If that were the primary question at the onset, the experimental design and subsequent field studies would be very different. The study would focus directly on estimating the timing, location and relative success of spawning behavior during the early spring period. That was the focus of work (albeit brief) by Kallemeyn (1987a, b). Instead, the monitoring data were collected with the goal of providing a general indication of the status of fish populations. They are not--and should not be taken as--direct measures of the fish population densities. The assessment data used in these analyses are indirect indicators. They include some combination of bias due to changes in gear, weather-related (unpredictable) recruitment success, the effects of water level manipulation on spawning habitat and early life history, the effects of exploitation on the populations of spawners, and the usual dose of uncertainty due to measurement error. The results derive from multiple causality and an unknown degree of additive or synergistic interactions among the key variables. This problem is not unique to this data set; these constraints are common components of uncertainty in evaluating fisheries data (Hilborn et al. 1995).

Each of the issues developed in the preceding paragraphs of this section relates to the problems embedded in the existing data sets and, therefore, to the analyst's ability to employ those data sets in an evaluation of cause and effect. The underpinning of analyses conducted by Cohen et al. (1991) and the alternatives posed by the Cadmus report (Boise Cascade Corp. 1993) derive from the basic assumption that the number of offspring produced is directly related to the number of adults that spawned. This stock-recruit assumption is the conceptual template of their work. As made apparent in their reports, the data sets in hand are also confounded by other variables and limited, of course, by the extent of the monitoring efforts.

Summary

None of the issues described above can be readily overcome by retrospective or alternative analytical approaches. We do not have accurate and precise measures of fish population densities in these lakes. Instead, we should interpret the existing evidence from a coarse-grained perspective. That means that we should rely most heavily on the large-scale, obvious trends, on the integrated indicators of population response (e.g., growth rates and age structure), on other indicators of potential fisheries yield (e.g., the Morpho-Edaphic Index, MEI, or patterns of change in total fisheries yields and assessment of juvenile abundances, etc.), on the discreet results of studies focused on the water level-spawning interactions, and on the generality that derives from considering similar issues in other systems. In other words, we must interpret the existing information through a cumulative "weight of evidence" approach.

3.2 Impact of Present Mode of Water Level Regulation

Key Questions

What impact do the present rule curves and the proposed mode have on the fishery compared to natural conditions?

The present rule curves risk reducing the likelihood of successful spawning because water levels can be very low during early spring when northern pike, walleye and yellow perch spawn. This condition reduces access to suitable spawning habitat. The present rule curves also create conditions that diminish the quality of that habitat by maintaining high water levels during summer and early autumn. In combination, these reduce the likelihood and increase the variability of recruitment success for individual year classes and their subsequent fisheries yields. The proposed rule curves would initiate water level rise approximately one month earlier than the current practice and would more closely approximate the seasonal water level changes under natural conditions. In addition, the proposed rule curves would require a gradual late summer-early autumn drawdown. The ecological result would encourage development of vegetation that improves spawning habitat for northern pike and yellow perch, cleanse the spawning shoal areas used by walleye, and provide better habitat for larval and juvenile fishes subsequent to hatching. Fall-spawning cisco and whitefish might also benefit from lower autumn water levels as their eggs would be deposited at greater depths and would be less subject to ice or desiccation damage during winter drawdown. The proposed late summer drawdown also more closely represents the natural hydrologic record.

What further changes to the fisheries can be expected under the present mode?

The fisheries will probably continue to produce low yields and to exhibit the effects of highly variable recruitment. Under the previous average or increasing levels of exploitation, populations of northern pike, walleye and yellow perch will probably continue to decline. Early summer and nest spawning species (black crappie and smallmouth bass) will probably not be strongly affected by the present mode or by that proposed.

Is the present fishery dominated by other factors, such as overfishing?

Virtually all of the evidence at hand indicates that overexploitation has been a major contributor to the decline of fish populations in these lakes. However, we cannot separate that effect from those due to changes in the hydrologic regime. Recent actions by management agencies have decreased the effects of commercial fisheries and a series of newly-enacted regulations will reduce the harvest by recreational anglers.

Background and Rationale

Much of the original concern about fisheries and other aquatic resources trace to the assertion that, under regulation, water levels advanced too slowly in spring to provide spawning access by northern pike to flooded vegetation and to provide spawning access by walleye to gravel and cobble shoals. In addition, water levels remained too high and constant in summer and autumn to rejuvenate walleye spawning shoals and revegetate pike spawning beds, and fell too low in winter to safeguard coregonid eggs and important food organisms. Evidence of those effects were seen by inference in many decades of general decline in catch records for commercial and recreational fisheries.

Indicators of fish abundance have two common, general features--virtually all (black crappie is an exception) have declined since the beginning of record keeping and all are highly variable. As noted in Section 3.1, there are reasons to suppose that the abundance indicators are conservative--the actual declines in fish stocks have probably been even greater than represented by Catch per Unit Effort (CPUE) data.

The present mode of water level regulation has been in effect for more than eight decades; i.e, for more than 20 generations of walleye and northern pike. There do not appear to have been any compensatory changes in life history strategies that would indicate accommodation to the water level regulation practices or to the increasing level of fishery exploitation (Colby and Nepszy 1981). Attempts to build spawning reefs that would provide alternative spawning sites have proven unsuccessful (Radomski 1990, Radomski 1991). This result confirms the assertion that compensatory spawning behaviors have not developed.

Data from fisheries surveys in Rainy Lake indicate that catch rates continue to remain below estimates of potential long-term yields expected under moderate and sustained levels of exploitation. The current yields from Rainy Lake are consistently 40-45 % below those estimated by the Morpo-Edaphic Index, MEI (Chevalier 1977). Further, the yield rates are below those of comparable lake ecosystems elsewhere in Minnesota (Eibler 1995c). These are interpreted as indicators of adverse effect due to the current water level management program. Re-establishing the historic water level fluctuations would, by implication, improve the current yields. That may be true if it is accompanied by efforts to control or diminish the effects of overexploitation.

Conversely, the MEI estimates for the Namakan system appear to under-represent its observed yields of walleye and an alternative, temperature-based model is used to indicate its performance relative to expected (Eibler 1995a). Nevertheless, the long-term trend of population indicators in the Namakan lakes is generally negative.

As indicated by the Fisheries Atlas (MDNR and OMNR 1992), angler catch rates have generally declined over the past decade while angling effort has increased, which reinforces the importance of recent measures designed to reduce overall exploitation pressure. Northern pike populations show continuing evidence of recruitment failure over the course of the past decade.

Average age and average size are increasing while abundance and catch rates are decreasing. In other words, young fish are not entering the fishable or monitored stock. This is a cause of growing concern among fisheries managers responsible for the Rainy Lake and Namakan systems.

Walleyes in Rainy Lake produced a very strong year class in 1991. That year class is entering the fishery now. It will soon be large enough to be protected by the new “protected slot” regulations (a "protected slot" of 17-25 inches; i.e., walleye in that size range cannot be kept and only one over 25” can be kept), which will reduce harvest of spawners, and should provide up to six years of enhanced reproductive potential. As cautioned above, there is only a general basis for forecasting improvements in recruitment as a consequence of spawning by members of this large year class. That outcome is uncertain, but the presence of a substantial population of spawners increases the probability. It does not, however, guarantee it.

Black crappie populations continue to generally increase and, as is common elsewhere, to be highly variable. Yellow perch and smallmouth bass populations continue to vary at or near their average since the 1950's when a standardized assessment program was initiated (Eibler 1995a, 1995b, 1995c).

Summary

The current fish populations appear to be varying around a long-term and generally much lower abundance than those suggested by previous indicators. The Fisheries Atlas reflects the opinion of fish managers: fish stocks have reached a new and depressed average level in these lakes. A series of recruitment failures cause the future of northern pike stocks to be of substantial concern. If the proposed rule curve changes were implemented promptly and in conjunction with more restrictive fishery regulations, they might help effect two important improvements:

1. A greater prospect for successful recruitment by northern pike and,
2. Increased potential for large, successful year classes derived from the large 1991 year class of walleye in Rainy Lake. Members of that year class which are now approaching maturity will be afforded greater protection from overexploitation.

3.3 Impact of Rule Curve Changes

Key Questions

Would the proposed changes be effective in enhancing the social and economic benefits of the fisheries?

Social and economic benefits should increase in proportion to the increases in fish populations. The increase in benefits will probably not be linear and direct, but the rehabilitation of fish stocks will foster additional growth in the tourist industries and in angling effort by local residents. Estimating these benefits is among the most significant challenges for researchers and for those who must make management recommendations. The traditional tools of economic assessment depend heavily on equilibrium assumptions. In the case of sport fisheries, those assumptions are both wrong and dangerous (Carpenter et al. 1994, Hilborn et al. 1995). Great unknowns exist in our ability to forecast the response of anglers to changing fish populations.

Are all the proposed changes required to achieve fisheries benefits?

Both the earlier spring flood-up and the gradual summer drawdown seem to be steps in the right direction. The relative importance of each is difficult to assess. Reducing the amplitude of annual water level change in the Namakan system should also serve to mitigate the negative effects in those lakes.

Are there alternative changes to the rule curves that would forther enhance the economic and social values of the fisheries resource?

Any changes that create seasonal water level fluctuations analogous to those of the natural conditions will increase the likelihood of improvements in fish populations. As stated above, the combination of new, more restrictive fishery regulations and the proposed changes in rule curves offer the greatest prospects for enhancement of fisheries resources. Fish populations in the lakes of the Namakan system should experience the greatest relative benefits.

Background and Rationale

The Minnesota-Ontario Boundary Waters Fisheries Atlas (MDNR and OMNR 1992) provides estimates of the economic and social benefits derived from fisheries in these waters. Stated in terms of 1990 Canadian dollar equivalents, the Rainy Lake fisheries generate approximately $6.7 million in gross annual revenues. Of that, 20 % occurs in Ontario and 80 % in Minnesota. By contrast, the 1989 commercial fisheries in Ontario waters generated $109,000 dollars while the 1990 commercial fisheries in Minnesota generated only $20,000. The recreational fisheries provided 250 full or part-time jobs in Minnesota and 58 in Ontario. The commercial fisheries supported eight jobs in Ontario and one in Minnesota. Clearly, the recreational fishery has both the greatest social and economic value. As detailed below, both MDNR and OMNR have aggressively pursued programs that would reduce or close commercial fisheries.

During the 1980-90 period, angling activity increased by about 20 % in these lakes. Similar rates of increase are expected into the next century.

Angling on the Namakan system lakes was estimated to produce $5.0 million during 1989. Employment by the fishery totaled 140 full or part-time jobs. The commercial fisheries are modest (four jobs, less than $35,000 in revenues). The vast majority of these socio-economic benefits derive to Minnesota-based tourist facilities. Growth of fishery-focused activities will likely parallel that of visitation to Voyageurs National Park which is estimated to increase at 2-4 % per year over the next decade.

Important unknowns exist in our ability to forecast the response of anglers to changing fish populations (Holland and Ditton 1992). We do know that increased catch rates are quickly communicated and that the angling public responds rapidly to news of an improved fishery

(Johnson and Carpenter 1994). We also know that this response is non-linear. For example, doubling the fishable stock may result in a modest increase in angling effort (and its consequent socioeconomic benefits) plus an increased catch rate per angler or it may result in a several-fold increase in angling effort and substantial increase in socioeconomic benefits but no apparent change in catch rate per angler. Any of the intermediates is possible and contingent on other variables. A single, highly-visible magazine article can bring about a 10-fold increase in angling effort on one lake for a year and that can be followed by an equally large reduction in the following year (Carpenter et al. 1994).

Important elements of this complex equation include the effects of weather on fishing effort, the ratio of resident vs tourist-based anglers, and the status of fishing in other, nearby lakes. We do know that the rapid and substantial responses of anglers can increase exploitation rates in excess of those justified by the increased fish populations (Kitchell 1992, Johnson and Carpenter 1994). Unless angler catch is closely regulated, the consequence of increased effort is an increase in the probability of overexploitation and the negative ecological and economic effects to be seen in subsequent years.

Summary

Clearly, the recreational fishery offers substantial current socio-economic benefits and potential for continued growth. Total benefits from the fisheries were recently estimated at $11.7 million (Canadian) per year and more than 450 people secured part or full-time employment as a result.

The goal of the management agencies is to increase recreational fisheries yields by 20%. Their recent, aggressive attempts to diminish the effects of overexploitation give evidence of commitment to that end. A comparable increase in benefits should arise. Even greater benefits might arise if changes in the rule curves allow additional rehabilitation of fish stocks. The current levels of employment and economic activity substantially exceed the estimated costs of lost hydropower (approx. $350,000 per year) to be incurred by Boise Cascade as a consequence of implementing the proposed rule curves.

Further improvement in fisheries benefits will require additional rehabilitation of the exploited stocks. The combination of aggressive pursuit of effective fishery regulations and prompt implementation of the proposed rule curves offers the strongest prospects for improving the socio-economic benefits derived from these fisheries.

3.4. Impact of Changes in Fishery Regulations

Key Question

To what extent can changes in exploitation patterns contribute to recovery of the fish populations?

Increased controls on exploitation pressure are essential to recovery of the fish populations. Without those, any improvements owing to changes in the rule curve will be masked or overwhelmed by increased exploitation.

Background and Rationale

The Minnesota-Ontario Boundary Waters Fisheries Atlas provides a detailed review of changes in fishery regulations for the Rainy and Namakan systems (MDNR and OMNR 1992). The Atlas also summarizes the extent of current exploitation levels by lake and region, and offers a rationale for target harvest levels which are, on average, about 20% below those of current exploitation rates. Rainy Lake, in particular, is experiencing exploitation levels substantially above harvest goals for the primary species--walleye and northern pike.

Virtually all recent changes in regulatory policy have been directed toward reducing exploitation. Among the most significant are the fact that the Minnesota legislature authorized a buy-out of all commercial fishing ventures targeting on Rainy Lake walleye. That program was initiated in 1983 and completed by 1985. Ontario has engaged in a similar practice which had reduced commercial take of walleye by 86% by 1986. Licenses issued to Namakan commercial fishers (2 US, 1 Canadian) have been modest, primarily in support of whitefish as the target, and are now also reduced to very low levels.

Ontario has been particularly aggressive in establishing fish refuges. Fishing is prohibited until well after opening day in a number of areas where spring spawning aggregations occur. Similarly, Minnesota has sought to protect its walleye stocks by a combination of extended closures for spawning areas (Black Bay), construction of spawning reefs, and a walleye fingerling stocking program. The spawning reefs appear to offer marginal improvements while the stocked fingerlings give evidence of some survival and enhancement of adult stocks as made evident by their representation (12% of adult fish captured) in the Rat Root River spawning runs (Eibler 1995c).

In general, stocking programs are of mixed success (Forney 1980, Johnson and Carpenter 1994). Although they can supplement stocks when exceptionally poor year classes occur, effective natural reproduction is required to sustain populations in these large lakes. Stocking programs may have more to do with public relations than with walleye population ecology.

Angling is and will continue to be a growing component of exploitation. A plethora of changes in sport fishery regulations have taken place in Rainy Lake and the Namakan lakes. The most recent regulations were proposed in 1991 (Radomski et al. 1991), enacted in 1994, and are designed to enhance survival of the walleye spawning stock. Similarly, reduced bag limits and increased minimum size limits for northern pike are intended to protect the mature adults.

In addition to new fishery regulations promoted by the management agencies, local fishing clubs encourage further development of a "no kill" or catch-and-release fishing ethic among anglers through public education campaigns and a reward system. Based on recent results of interviews conducted by creel census clerks, both the new fishery regulations and the catch-release campaign appear to be successful (Eibler 1995a).

Although these conservation efforts are to be applauded, the continuing issue of open access fisheries must be acknowledged in planning for future regulatory changes. Growth in the number of anglers is likely as a consequence of simple demographic trends, and will certainly increase in response to any success accomplished in rehabilitating these fisheries. The news of improved fishing spreads quickly and the angling public responds promptly (Kitchell 1992, Carpenter and Johnson 1994). Management agencies should anticipate that result and plan for a more aggressive and adaptive regulatory policy that can adjust to increased angling effort.

Summary

The main conclusion brought forward through these examples is that the resource management agencies (MDNR and OMNR) and the organized angling interests are successfully exhibiting a commitment for increased protection of walleye and northern pike populations. In all cases, the goal is directed toward rehabilitation of the spawning stocks. Success in these efforts can be increased by changes in water level regulation practices designed to offer increased likelihood of access to favorable spawning habitat. The two competing arguments about cause and effect--overexploitation versus water level regulation--represent an artificial dichotomy. The current and previous rule curves differ from the natural condition. It is logical to conclude that the resulting changes in habitat have had a negative effect on fish populations. Overexploitation has also played a significant role in causing declines of the fish populations. **The management agencies have implemented remedial actions designed to reduce exploitation levels. A comparable effort from those responsible for water level regulation seems an appropriate complement.**

3.5 Unresolved Issues

Key Questions

What additional questions are pertinent to reaching a decision on the proposed rule curve change?

Yields of walleye in the Namakan system continue to be above those forecast by the MEI. This result is not commensurate with the expectation that fisheries yields decline in proportion to the magnitude and timing of water level changes. On the other hand, northern pike populations continue to decline in both the Namakan and Rainy Lake systems. The critical unknown here is the degree to which spawning behavior responds adaptively to existing water levels each spring. The two species may differ in that regard as they have different behaviors and preferences in selection of spawning sites.

Some of the evidence from Kabetogama Lake is enigmatic. It experiences the greatest relative change in littoral habitat (up to 25% exposure under the present rule curves) and appears to have greater primary productivity. The basic limnological characteristics suggest that its drainage basin provides a different and higher annual nutrient input. Interactions linking the drawdown effects and the resulting higher trophic status are not clear (Walters and Collie 1988). Nevertheless, the historic trends and current status of its fish populations offer evidence of the same basic problems--negative effects due to water level regulation and their interactions with overexploitation.

In both lake systems, First Nation subsistence fishing continues and will likely persist or grow somewhat. Future management efforts must seek to fully include First Nation representatives in the policy process. If experiences in other Great Lakes states (e.g., Wisconsin and Michigan) serve as a basis for expectation, both Minnesota and Ontario need to prepare for an important and potentially difficult set of resource allocation decisions in dealing with the First Nation interests on these lakes (Hanson et al. 1991).

Does water level fluctuation have negative effects on fish populations through its effect on juvenile fish habitat or prey populations?

The macrophyte community and benthic invertebrate surveys commissioned by the National Park Service derived from the concern that water level changes were having adverse, indirect effects on fish habitat and/or their prey resources. The key question relates to the role of aquatic macrophytes as a source of refuge from piscivory and as a foraging site for juvenile fishes. This topic has an extensive and rich history in experimental aquatic ecology. A seminal study by Crowder and Cooper (1982) demonstrated that intermediate macrophyte density and high diversity of growth forms maximized growth for juvenile fishes by providing conditions that minimized risk of predation while maximizing the availability of invertebrate prey associated with the macrophytes. An extensive review by Werner and Gilliam (1984) demonstrated the critical interactions of habitat complexity and body size in the feeding, growth and survivorship of juvenile fishes. The work of Meeker and Wilcox (1989) and its subsequent reports (Wilcox and Meeker 1991, 1992) was directed toward those issues for macrophyte communities in Rainy Lake and the Namakan system. Their main result is consistent with the expectation of lower-than-optimal habitat diversity associated with the more modest water level change in Rainy Lake and the enhanced water level change in the Namakan lakes produce. Both systems had lower species and habitat diversity than the unregulated Lac La Croix.

Sharp (1941) offered the initial observation that water level fluctuations in Kabetogama Lake caused “stranding of forage fish” and “destruction of bottom fauna” and, as a consequence, reduced the available food for walleye. The more recent Kraft (1988) study also found extensive stranding of benthic invertebrates in the Namakan lakes and, by inference, argued that these represented prey resources lost from the food web that supports fishes.

The studies of both macrophyte and benthic invertebrate communities were criticized by Gray and Kovatz (1993) on the basis of methodological procedures and on the basis of insufficient replication. While we agree that an expanded survey and greater replication would be desirable, we do not feel that the Gray and Kovatz (1993) critique is sufficient reason to disregard these results. The results of Kraft (1988) and Meeker and Wilcox (1989) are commensurate with work done in a variety of other systems and with the simple, logical expectation that non-natural water level fluctuations will have effects on benthic animals and plants. Up to 25% of the sediment surface of Kabetogama Lake is exposed during winter drawdowns. Reduction in the magnitude and changes in the timing of those drawdowns would be an obviously effective and restorative measure if they were to more closely approximate the natural hydrologic cycle.

We do believe that the studies of benthic communities suffer from two shortcomings and that future work should address those issues. In particular, we encourage that:

1. There needs to be direct and quantitative evidence of linkage between the benthic invertebrates lost during drawdown and their contribution to the diets of fishes, and
2. The role of macrophyte beds needs to be elaborated. We suggest quantitative evidence of the both the extent of development of these communities and of their role in the life history of fishes.

What are the significant data gaps and the degree of uncertainty that gaps have on conclusions reached?

Much of the rationale for the proposed rule curves resides in the assumption that re-establishing more natural conditions will improve the fish populations. That is built on the assumption that spawning success is compromised under the current conditions. Although some data exist to support that contention, a more extensive and directly targeted study would help reveal the mechanisms that produce better year classes when spring water levels are higher. Variable survival in the early life stages and its associated uncertainty in forecasting fisheries yields is embedded the life history of these species. It is expressed in virtually every lake they occupy. A more extensive data set would help create a better record of the natural variability and, therefore, a more realistic expectation by both the managers and the angling public. If the proposed rule curves are adopted, many years of observation should follow before the next remedial action is considered. The duration of that monitoring program must exceed at least two generation times for the key species if changes are to be interpreted against inherent variability.

Cohen et al. (1991) encouraged that extreme high water levels be allowed periodically. The flood risks associated with that prospect need to be assessed. As stated above, this management protocol would be more complex and require an even greater commitment to monitoring. While there is merit in the argument that extreme water levels are a component of the ecological history in these lakes, the proposed changes in rule curves do not remove the effects of natural fluctuations. In fact, the substantial snowpack and late spring thaw of 1996 have produced near record water levels in Rainy Lake. That type of variability will continue under the proposed rule curves. The primary effects of the proposed rule curves would be seen in earlier flooding of spawning habitat and in the changes in marsh vegetation, spawning shoals, and submerged macrophytes that might derive from a late summer drawdown. While we agree that high-amplitude events at some low frequency might be a valuable management approach, we do not encourage that practice at this time. The change in rule curves and the change in fishery regulations will interact in ways that can best be discerned by several years of monitoring and process studies. Adding planned high water events to that would confound the picture to an even greater extent. For the present, we do not encourage that practice.

The divergent views of Parkhurst et al. (1993) are rightly based on criticism of the assumptions made by Cohen et al. (1991) in analyzing the long-term fisheries data. Parkhurst et al. (1993) concluded that changes in water level regulation policies will not improve the fisheries. As portrayed in the previous pages, we believe that adopting the rule curves suggested by the International Steering Committee is an appropriate step toward rehabilitation and restoration of these fish populations. Parkhurst et al. (1993) also assumed that an equilibrium condition can be established and maintained through optimum sustainable yield management practices for the fisheries. We do not agree with that assumption. Our view derives from the frequency of failures in optimum or maximum sustainable yield management practices (Larkin 1972, Walters 1986, Hilborn et al. 1995). The history of those failures includes a very large proportion of the world's exploited fish stocks. Those histories inevitably trace to conceptual and analytical models that do not account for inherent variability, the uncertainty it requires, and the need for conservative exploitation policies. In other words, the assumptions of an equilibrium model have proved to be wrong and to have contributed to overexploitation in many cases. We see no reason to believe them to be less dangerous is this case.

Background and Rationale

Several exotic species have become established in these lakes. Two of those, black crappie and smallmouth bass, now serve as major contributors to the recreational fisheries. A new exotic, the rainbow smelt (Osmerus mordax) appeared recently and is now established. Managers seem less alarmed by the prospects of negative effects due to smelt than might be imagined. Based on experiences in other lakes, smelt invasions can have devastating effects on local stocks of cisco, whitefish, perch and walleye. They are thought to do so through competition for prey and through predation on larval or juvenile fishes (Evans and Loftus 1987). Although adult walleyes may exhibit greater growth rates as smelt are added to the forage base, walleye recruitment has declined dramatically in some lakes in concert with the rise of the invading smelt population. The low visibility of these tannin-stained waters and the modest development of thermal stratification may restrict the negative interactions with smelt. This invasion requires careful monitoring as it represents yet another perturbation.

Understanding the cause of change in fish stocks must now include the effects and interactions of three newly-manipulated variables: fishery regulations, the new rule curves, and the invasion of yet another and potentially important exotic fish species. The inherent variability of recruitment processes coupled with changes in these three driving variables creates even greater uncertainty for effective evaluation of causal processes. An expanded sampling program that assessed abundance of young-of-the-year walleye and northern pike during early autumn might form the basis for forecasting potential fishery yields several years into the future. This approach has been successfully employed in some lakes (e.g., Forney (1980) and in the current policies employed by Wisconsin DNR in calculating safe harvest levels for the 250+ lakes involved in Treaty Rights regulations (Hanson et al. 1991)). A sound, annual assessment can serve as a means for adjusting regulatory policies as well as creating a better public understanding of the nature of inherent variability in recruitment success for these species.

Summary

Calling for return to the natural condition is a logical response to declining resources. Those who raise that prospect must also acknowledge that commercial and recreational fisheries were not a part of the natural condition. Like unnatural water level changes, exploitation is a perturbation. Although these fish populations evolved in a variable environment, their compensatory capacity is not well documented. Management actions designed to rehabilitate these fish stocks must accept the complexities of multiple causality.

In a rigorous and strictly experimental approach to these issues, resolution would be accomplished by one of two direct manipulations:

1. Close the fisheries, or
2. Remove the dams.

Responses of the fish populations would allow a direct evaluation of the importance of each. Neither of these actions is likely. Neither may be necessary.

4. RECOMMENDATIONS FOR FUTURE STUDIES

In our view, the complex nature of current and future responses to management actions requires that the management agencies engage in four important activities. Stated as recommendations for future studies, these are:

1. If the suggested rule curve changes are implemented, we strongly encourage that the management agencies (National Park Service, Minnesota Department of Natural Resources and Ontario Ministry of Natural Resources) accept the obligation to **conduct further studies on macrophytes, benthic invertebrates and spawning success of walleye and northern pike**. In particular, we encourage follow-up studies that will expand on those conducted on macrophytes (Meeker and Wilcox 1989) and on spawning success of northern pike and walleye (Kallemeyn 1987a, 1987b). These are the cornerstones of the argument for changes in the rule curves. They are taken as the parsimonious explanation for changes in fish populations. If altered by changes in the rule curves, they will be the proximate indicators of habitat restoration. Evaluating those changes is essential. Previous work has been criticized for lack of replication, lack of synchrony in time (years/seasons), and proximity in space (basins/stations). Careful and complete follow-up studies are necessary. These should also be expanded to include process studies such as those implicit in the argument about linkages between macrophytes, invertebrates and fishes. A sustained, community-monitoring program would provide the essential basis for understanding inter-annual variability. If the rule curves are changed, it will be because the Park Service, MDNR and OMNR made the case on ecological grounds. **These agencies must accept the responsibility for follow-up studies** that can offer unequivocal tests of those assertions. As noted below (#4), the effects of an invading, exotic species (smelt) can confound evidence derived from traditional fisheries data.

2. We encourage a study that will **identify spawning grounds and evaluate changes in their extent and conditions**. The main argument about loss of spawning habitat is open to direct test and can be evaluated within a relatively short time before and after the new rule curves are enacted. Many of the reports we reviewed referred to spawning aggregations of walleye and northern pike in tributaries or near river mouths. The sites of these spawning areas must be documentad and their significance must be evaluated as part of an overall assessment of spawning habitats in these systems.

3. **Establish and sustain a standardized, coordinated fisheries monitoring program**. Better yet, the assessment program should be expanded to include a greater emphasis on

measures of relative abundance for age 0+ fishes in late summer or early autumn. Further, the agencies must document fishery harvests and should make a greater effort to develop and coordinate lake-wide efforts in estimating recruitment success. These programs provide the basis for long-term reference and comparison. They may also serve as the basis for adjusting fishery regulations and better communication with the angling public.

4. The agencies need to **evaluate the ecological consequences of invasion by the exotic r ainbow smelt** and its effects on native fish species. This program should include documentation of smelt population changes in the Rainy and Namakan systems and an evaluation of the effect of smelt invasions in analogous lakes elsewhere. The confounding effects of smelt may compromise all of the gains accomplished through changes in the rule curves and more restrictive fishery regulations.

Our recommendations represent an obligation that must be accepted if greater understanding is to be gained from management manipulations and rehabilitative actions. As oft-stated above, fish population responses to new rule curves may include a strong component of uncertainty. Interpreting those at the level of fisheries yields is even more problematic. In addition, there are possible confounding effects due to smelt invasion and the unknowns associated with climate change in this region and possible contaminant effects (e.g., bioaccumulation of mercury).

Changes in the rule curves should bring about relatively rapid responses of macrophyte communities, the benthic invertebrate assemblage, and the conditions on spawning grounds. Those will be less subject to the inter-annual vagaries expressed in fish population dynamics and fisheries harvest data. They should be taken as the direct evidence of habitat changes evoked by changes in water level regulations. If those do not change as expected, then it should be clear that additional and more stringent controls on exploitation pressure are a next, logical step in seeking to restore and rehabilitate these ecosystems.

5. CONCLUSIONS

The biological components of these ecosystems evolved in a naturally variable environment. Uncertainty and its consequent variability are natural components of these systems. Scientific evidence can improve our understanding of inherent uncertainty but it cannot remove it. Understanding can help create a more realistic basis for expectation. That expectation must accept natural variability and expect some continuing level of uncertainty. In the recent past, these fish populations have been subjected to the additional challenges of manipulations in the historic hydrograph, species-selective and size-selective mortalities due to exploitation, and the addition of exotic species. Those will continue to be factors in the future of the fisheries practiced in these lakes.

An extensive review of the history of natural resource management conducted by some of our most widely-experienced scientists concluded that uncertainty must be an accepted reality in developing management strategies (Hilborn et al. 1995). The presence of uncertainty is not an appropriate basis for delaying management actions if they are designed around the best available knowledge and intended to improve the ecological conditions that can help rehabilitate fishery resources. Instead, those management actions should be viewed as a means for learning more about these systems and their response capabilities. Taking those actions also carries with it the obligation to assure that the results are well documented. In essence, this approach advocates a philosophy of "learning by doing". These are the tenets of adaptive management (Walters 1986, Lee 1993).

As described in the previous sections, there are a number of caveats and shortcomings associated with the present long-term data base and the analyses based on those data. Similarly, the comparative and process-focused studies conducted to date suffer from insufficient replication in space and time. Nevertheless, their results and interpretation are useful and generally appropriate--regulation of water levels creates ecological conditions that differ from those of unregulated lakes and, in this case, has generally adverse effects on populations of fishes, benthic invertebrates and macrophytes.

Overexploitation also played a major role in the decline of fish populations in Rainy Lake and the Namakan lakes, but is not likely to have been the sole cause. Moreover, the management agencies and the angling public are currently joined in taking rehabilitative measures.

Thus, the weight of evidence derived from these studies and the understanding developed from analogous problems elsewhere leads to a single conclusion: modification of the rule curves as recommended by the International Steering Committee (1993) is an important and appropriate mitigative measure. That is supported by the most fundamental logic; namely, that water level fluctuations more closely resembling the natural hydrograph are most likely to effect rehabilitation goals. These are a corollary of the "Precautionary Principle" now adopted by the UNFAO and practiced by a majority of the world's federal fisheries agencies. This Principle can be stated as: "Management actions should proceed in ways that reduce existing damage to fish stocks, minimize the prospects of future, adverse effects and encourage sustainable resource use."

In considering both the specific evidence available and the conceptual arguments advanced above, we offer the following set of conclusions and recommendations:

1. **Effects of water level regulation on the fisheries will not be better discerned through additional analysis and interpretation of the existing data sets**. The long-term data were derived from a general monitoring effort. That program was not specifically designed to evaluate the central question of water level effects on spawning success. Much of the continuing effect on recruitment may have been underway before any data were collected. At best, the long-term data sets offer a coarse-grained view of trends in fish populations. The short-term studies of mechanisms that regulate early life history success in fish populations offer only modest replication and statistical power. But, their collective result is commensurate with the logical expectation that low water levels at the time of spawning will have negative and cumulative effects on important fisheries such as those for walleye and northern pike. These results also confirm the expectations of other, long-term and larger-scale studies, but do not offer a basis for empirical forecasting of management actions.

2. **Overexploitation has played a major role in the decline of the fish populations**. All evidence available confirms the chronic effects of overexploitation by a combination of commercial fisheries and, more recently, by the growing recreational fisheries. Newly-implemented fishery regulations are an appropriate step toward diminishing those effects and increase the likelihood that fisheries yields will begin to improve.

3. **Water level regulation has contributed to the decline of the fish populations.** Rule curves designed to more closely simulate the previous, natural variation in water levels (International Steering Commitee 1993) are likely to improve the chances for rehabilitation of desirable fish stocks. More ecologically-appropriate rule curves and reduced exploitation must be viewed as increasing the prospects of a desired effect but cannot assure that. Weather plays a large and uncontrolled role in reproductive success of these fish populations. Improving the spawning and nursery habitats plus greater protection for the larger, reproductive adult fishes will increase the likelihood of successful year classes and improved fisheries yields, but cannot guarantee the outcome with accuracy or precision.

4. **Fisheries managers should develop and implement a more aggressive program to evaluate the importance of invasion by the exotic smelt (<u>Osmerus mordax</u>)**. In many ecologically similar lakes, smelt have had adverse effects on walleye, yellow perch, whitefish and cisco populations.

5. **Management actions such as those embodied in new rule curves and more restrictive fishery regulations should be viewed as experiments** that offer an excellent chance for learning through the management process. Careful and effective documentation of the consequent results is both an opportunity and an obligation.

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APPENDIX:

Synopsis and Evaluation of Historical Studies and Analyses

Prepared by

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A. INTRODUCTION

1. This Appendix constitutes a review and assessment of the "on-site" literature, focusing on the implications of hydrological regulation with respect to the "fisheries and related aquatic resources" of Rainy Lake and Namakan Reservoir. The "related aquatic resources" are taken to include the aquatic vegetation along with the biota living in or on the substrate or in the water column. Aquatic resources in this context have been taken to exclude mammals, birds, reptiles, and amphibian fauna, except insofar as such fauna may have implications for "fisheries and related aquatic resources".

2. This evaluation is based entirely on information already in existence, without any basic new data being developed. As a step toward utilizing the available information, this Appendix provides synopses, in chronological order, of 37 reports and publications which were examined in detail. These items were selected for examination on account of their treatment of man-induced impacts on the "fisheries and related aquatic resources" of Rainy Lake and Namakan Reservoir. The primary criterion for selecting an item for examination was the pertinence of the item to hydrological regulation, but key items dealing with fishery exploitation were also deemed to 'qualify' for attention. Many of the items in fact have a mixed perspective.

3. A review and evaluation was prepared and is provided for each of the 37 literature items which were examined. Also undertaken was a critique of several pertinent items of historical correspondence.

4. A summary of the trends and conclusions in the historical studies and analyses was developed and is presented.

B. SYNOPSIS OF DOCUMENTS WHICH WERE EXAMINED

The possible impact of hydrological modification of Rainy Lake and Namakan Reservoir on the fisheries and related aquatic resources has been the subject of directed attention and analysis for more than fifty years. The written record of this effort includes a large body of documents and correspondence. Another body of literature exists with respect to the effects of exploitation and ensuing management initiatives regarding the fisheries per se (cf. their habitats).

The two influences (fishery exploitation and habitat alteration) are often treated concurrently in individual documents. The most pertinent of these items (according to present knowledge) are extracted herewith (this section) for their contributions in furthering this debate.

Also given in these synopses (below) are hypotheses and insights pertaining to the structure and functioning of these ecosystems in general, and of such "fishery-related" ecosystem components as aquatic vegetation, water quality and benthos. It is only in an ecosystemic context that the Rainy and Namakan aquatic habitats and fisheries will ultimately be understood sufficiently to permit confident and effective management and rehabilitation.

Following these synopses (this Section, below), the various items are evaluated (Section C, following) in terms of data content, technical analysis, scientific advancement, and credibility of conclusions. These evaluations, of course, reflect the perspective of the reviewer and to that extent can legitimately be interpreted as subjective.

1. Sharp, R.W. 1941. Report of the investigation of biological conditions of Lakes Kabetogama, Namakan and Crane as influenced by fluctuating water levels. Minn. Dept. Natur. Res., Invest. Report 30. 17 pp + appendices.

- Estimated that on the date of the survey (1 April 1941) one-quarter of the bottom of Kabetogama Lake (the lake "most seriously affected") was exposed (bays were "dry, except for narrow drainage channels running through them").

- Observed that by 28 April the water level in Kabetogama Lake had risen by about 4 feet, "but these bays were still largely dry."

- Noted that falling of the water through the winter months "allows the ice to settle and rest upon the lake bottom in a zone varying with the bottom contours."

- Observed that, although the fluctuation on Crane Lake is less severe than on Kabetogama (the natural dike at King Williams Narrows holding Crane Lake about 4 feet higher), the winter drop is still "sufficiently great to remove all the water from the shallow bays."

- A considerable area of lake bottom (in bays) was still exposed when Namakan Lake was visited on 26 April, by which time the water had already risen 4 feet.

- Concluded that suitable "pickerel" (= northern pike) spawning areas "along the lake shores and in the shallow bays over their entire area were completely inaccessible to these fish during the spawning season of 1941."

- Postulated that northern pike might be "going up the tributary streams and finding suitable spawning areas in marshes above the level of the lakes."

- Concluded that spawning conditions for walleye "appeared to be entirely suitable for this species…. Any stream of sufficient size to attract spawning walleye was accessible to these fish."

- Postulated that available food for walleye might be reduced somewhat "by the destruction of bottom fauna, particularly crayfish", perhaps exacerbated by stranding mortality of forage fish (reported by area residents). A listing of benthic invertebrate groups is provided, in descending order of observed mortality due to winter drawdown, derived primarily from Kabetogama Lake. Crayfish, mayfly nymphs and snails headed the list. "It was not uncommon to find from 4 to 6 dead crayfish per square yard over portions of exposed muddy bottoms. No doubt the numbers of smaller, less easily observed organisms killed far exceed those of the larger forms listed. This mortality results primarily from the complete drying and freezing of the lake bottom on a large portion of the shoal areas; secondarily from the settling of the ice upon the deeper shoal areas as the water recedes during the winter."

- Presented numerical catch ratios for species captured by test nets in 1936 and 1937: the first (known) quantitative fishery assessment data for these lakes.

- Calculated growth rates for both walleye and northern pike in both Namakan and Kabetogama Lakes to be well below average for Minnesota waters.

- Documented a preponderance of small walleyes in the angling catch. Attributed this to "some condition other than fluctuating waters."

- Considered it "probable" that the eggs of whitefish and "tullibees" (or ciscoes) "suffer considerably……as the water drops through the winter and exposes the gravel bars to freezing and ice action."

- Cited the field notes of J.B. Moyle (Kabetogama Lake, September 1935) pertaining to clear impacts of water level fluctuations on aquatic vegetation.

- Noted that "Before the construction of the Kettle Falls Dam the shallow, muddy bays of Kabetogama supported extensive stands of wild rice. This has now disappeared."

2. Bonde, T.J.H., C.A. Elsey and B. Caldwell, 1961. A preliminary investigation of Rainy Lake, 1959. Minn. Dept. Conserv., Invest. Report 234. 43 pp.

- This study was undertaken in 1959 by Minnesota and Ontario.

- A total of 1439 walleyes were tagged "in the East Arm of the lake. Recoveries of 152 (10.6%) of the tagged fish were made by anglers and commercial fishermen by October 2, 1959. Of the tagged fish 80% had travelled 15 miles or less but some crossed natural barriers and were recaptured in areas influenced by other spawning runs. No migrational pattern could be seen and the movement is described as random."

- "Experimental gillnets showed large numbers of small walleyes present in the four study areas which were set up." No statistically significant difference was found in the number of walleye (or most other species) taken per net in each of these areas.

- "Creel census indicated that angling success has remained close to 0.5 walleye per man-hour since 1956 with little variation between years. The 1959 figures show angling as being slightly better on the Ontario side of Rainy Lake.

- "Walleyes taken in all phases of the 1959 investigation were small with fish under 16 inches predominating. …it seems likely that this……is related to the intensity of both sport and commercial fishing."

- It is suggested that trap netting (for walleyes) "would have been more successful had trapping begun about mid-April. Many of the bays where spawning occurs are shallow and 'past records' indicate that in areas such as Black Bay walleyes move upstream from the bays two weeks before the ice is off the main body of Rainy Lake."

3. Bonde, T.J.H. and C.A. Elsey, 1964. A fisheries survey of Namakan Lake, 1962 - 1963. Minn. Dept. Conserv., Invest. Report 282. 27 pp.

- This report is based on:

- Work done in July 1962 by Minnesota and Ontario.
- Additional netting done in 1963.

- "As far as can be determined, both sport and commercial walleye fishing was originally quite good, reaching success and production peaks in the early 1930s. Declining success in the 1940s, however, prompted the closing of commercial walleye fishing in Minnesota waters. The one Ontario commercial fisherman on the lake is permitted to harvest any species and averages annually about 6,000 lb of walleye. No estimate of the magnitude of the sport catch is available. As reports of poor fishing have been infrequent in recent years, it is assumed that success has been rather good."

- "Results of the July, 1962 and 1963 test nettings……(indicate) an excellent walleye population which is numerically two to six times the Minnesota state-wide gillnet median. …growth……(and) size distributions show a youthful population with the greater percentage of walleyes being in age groups of four years and younger, older age groups are also fairly well represented and there is no evidence of missing year classes. Other species……are maintaining themselves adequately."

- Concluded that the Namakan Lake walleye population "has maintained itself at a relatively high level under present management."

4. Bonde, T.J.H., C.A. Elsey and B. Caldwell. 1965. A second Rainy Lake report, 1957-1963. Minn. Dept. Conserv. with Ontario Lands/Forests, Invest. Report 284. i + 42 pp + map.

- Reported a stable commercial fishery harvest from Rainy Lake from 1941 through 1962 of just under one pound per acre of walleye per year. Angling was thought to harvest a comparable amount.

- Despite constant commercial fishery catch volumes, catch per unit of effort dropped by more than a factor of 2 (1950 through 1963), equally evident throughout the lake. Angling success declined in parallel, albeit most severely in the northwest third of the lake (1.2 walleye per angler-hour in 1956; 0.2 walleye per angler-hour in 1961 and 1962). "Important as total catch figures are, they often do not reflect walleye abundance. …it is apparent that since 1950, the commercial fisherman has been fishing harder and harder to get nearly the same poundage of fish."

- Test netting confirmed the reduction in walleye abundance.

- Demonstrated (from tagging) at least three "rather distinct walleye sub-populations" in Rainy Lake.

- Concluded that a succession of poor year classes had reduced walleye abundance in the lake.

- Demonstrated a positive growth response by walleye to the reduction in standing stock.

- Recommended that priority attention be devoted to "prevent the sporadic failures of certain walleye year classes."

5. Scidmore, W.J. and F.H. Johnson. 1965. A comparison of the abundance of walleyes in the commercial catch in Rainy Lake, Minnesota-Ontario, with lake elevations during the walleye spawning period in the years contributing to the catch. Minn. Dept. Conserv., Staff Report. 4 pp.

- Reported a decline, commencing most notably in 1957 or 1958, in walleye fishing success, both sport and commercial, in all parts of Rainy Lake. This decline was general, despite evidence of more or less discrete walleye stocks in different areas of the lake.

- Reported that walleye spawning in Rainy Lake, exclusive of the rivers, occurs on clean gravel beaches which are within the zone of summer wave action. "As the water rises in the spring, the extent to which these beaches are inundated determines whether the spawning fish have satisfactory areas for egg deposition or are forced to use less favourable bottom types where the chance of egg survival is poor."

- Compared walleye catch-per-unit-effort in the commercial fishery (using 3-year moving averages, over the period 1948 through 1963) with mean water elevations during the walleye spawning period (assumed to be the 15 days following ice-out) in the years contributing to those catches (i.e. 4, 5, and 6 years earlier).

- Determined a correlation coefficient between the two variables of r=0.81 (95% CI 0.50-0.90).

- Concluded that the water level prevailing at time of spawning is a key determining factor in walleye year-class abundance.

- Deduced (from field observation of walleye egg deposition) that optimum water elevations for walleye spawning in Rainy Lake lie between the (then) IJC-prescribed levels of 1106.8 feet for May 1-15 and 1108.1 feet for the summer average, albeit with 1106.8 feet being about the lowest level tolerable.

- Observed that May 1-15 water levels were exceptionally low in 1952 and 1953, years which would have contributed particulary to the exceptionally poor walleye fishing in 1957 and 1958.

- Suggested that:

  • Rainy Lake elevations during the period of walleye spawning be held at no less than 1106.8 feet.

  • Artificial spawning beds for walleye, oriented perpendicular to shore, might provide a measure of insurance against periodic loss of natural habitat.

6. Johnson, F.H., R.D. Thomasson and B. Caldwell. 1966. Status of the Rainy Lake walleye fishery, 1965. Minn. Dept. Conserv., Invest. Report 292. 13 pp + tables.

- Reported a lake-wide decrease in the Rainy Lake walleye population between 1959 and 1963, referable to "three consecutive years (1958, 1959, 1960) of low spring water levels and poor reproduction, accompanied by considerable competition between the sport and commercial fisheries for the available stock."

- Proposed that the "lake-wide" nature of the walleye population decline ("irrespective of variations in fishing intensity and the presence of three sub-populations") indicated that reduced quality of fishing was "a symptom rather that the basic cause of stock depletion."

- Added another year (of walleye commercial fishery catch-per-unit-effort or CPUE data) to the relationship between 3-year moving-average CPUE and average spring water levels 4, 5, and 6 years earlier as derived previously (Scidmore and Johnson 1965). The excellent fit (described earlier) was extended.

- Observed "some increase" in the 1995 walleye population compared to 1993 "due to recruitment of the abundant 1961 year class" when spring (1-15 May) water levels in Rainy Lake were once again favourably high.

- Presented evidence of relatively unfavourable forage (food availability) conditions for walleye young-of-the-year in Rainy Lake, and postulated this as a potentially important factor in survival.

- Cited the recent general decline in Rainy Lake walleye populations as indicative of the population being reliant for its maintenance on fry hatched within the lake proper, since "Spawning areas in the tributaries are unaffected by low water levels." Noted the elimination of perceptible current in one (presumably major) tributary caused by backup from rising water (at this time of year) in Rainy Lake.

- Recommended that in future "every effort be made to assure adequate spring water levels so that the best spawning shoals available can be used by the walleyes."

7. Johnson, F.H. 1966a. Report on the results of shoreline seining and test netting in Kabetogama in 1966 with special emphasis on the status of the walleye population. Minn. Dept. Conserv., Staff Report. 6 pp.

- Reported a good seining catch of young-of-the-year (Y0Y) walleye (in early August) for 1966.

- Found weak representation by walleye from the 1958, 1959 and 1962 year-classes in test-net catches. Fish from the 1961 and 1963 year-classes were notably well represented.

- Made no attempt to relate the data specifically to any particular influence(s).

8. Johnson, F.H. 1966b. Report on the results of shoreline seining and test netting in Namakan Lake during 1966 with special emphasis on the status of the walleye. Minn. Dept. Conserv., Staff Report. 7 pp.

- Attributed a low seining catch of young-of-the-year (in August) to poor seining conditions (much less favourable than in Kabetogama).

- Demonstrated considerable fluctuation in walleye year-class strength between 1956 and 1963, through analysis of test gillnet catches:

• The 1963 year-class was fairly abundant.

• The 1962 year-class appeared notably weak.

- Stated that "The obvious environmental condition that could affect reproduction in both lakes and that varies from year to year is the spring water level. …the weak year-class of 1962 was produced in a year when spring water levels in Namakan were 5 to 6 feet below the summer high." Referred to observations of walleye spawning by T. Bonde to the effect that the availability of good gravel spawning beaches was reduced in 1962 because of the low water.

-Noted a general similarity between the catch curves for Kabetogama and Namakan Lakes, and concluded that "factors that affect walleye reproduction and survival operate in the same way for both lakes in most years."

9. Johnson, F.H. 1967. Status of the Rainy Lake walleye fishery, 1966. Minn. Dept. Conserv., Invest. Report 295. 10 pp + figures.

- Noted that following the report on the 1965 walleye fishery (Johnson et al. 1966):

  • Agreement was achieved on a revised program of operation for the Rainy Lake dam to improve lake stages for (during) walleye spawning.

  • Construction was completed of an artificial reef (in Black Bay) "to provide some suitable (walleye) spawning substrate when water levels are uncontrollably low".

- Observed continued dominance of the 1961 year-class of walleye (now age 5) in the 1966 commercial fishery.

- Observed a 17% reduction in walleye catch per test net from 1965 to 1966, and deduced a 72% mortality of the dominant 1961 year-class (attributed to fishing) over the same one-year period. Catch per unit effort of walleye in the commercial fishery in 1966 was only 62% of the catch rate for 1965.

- Found that only 10% of the commercial walleye catch in 1966 was age 6 or older, compared to 37% in 1965.

- Observed increased growth rate (accompanying reduced stock size), so that "the bulk of the walleyes are now harvested a year or two before they reach maturity."

- Noted that egg deposition and production of young-of-the-year walleye in Rainy Lake in 1966 was fair, but definitely lower than expected given the "excellent water levels at the spawning time." Reproduction was better (same year) in Kabetogama Lake (Johnson 1966a) and in other Minnesota walleye lakes generally.

- Expanded the previous (Scidmore and Johnson 1965) simple correlation of walleye catch per unit effort and average spring water levels 4, 5, and 6 years earlier, to also encompass abundance of spawning stock in a multiple correlation analysis for two regions of Rainy Lake. Found very high (R=0.96 and 0.97) multiple correlation coefficients.

- Concluded that the Rainy Lake walleye spawning stock had been "reduced to a critical level at which the abundance of reproduction is affected."

- Recommended reduced walleye harvest, along with maintenance of adequate spring water levels, "for restoration of the fishery."

10. Chevalier, J.R. 1977. Changes in walleye (*Stizostedion vitreum vitreum)* population in Rainy Lake and factors in abundance 1924-75. J. Fish. Res. Board Can. 34:1696-1702.

- Extended the time frame of earlier presentations and analyses for Rainy Lake walleye (Bonde et al. 1965, Johnson 1967, etc.), and re-worked the longer data set.

- Documented a productive but notably declining commercial walleye harvest, from 150,000 kg annually in the 1920s to 19,000 kg annually in the early 1970s. The annual commercial catch of northern pike declined from about 100,000 kg to about 50,000 kg in the same period.

- Determined the following changes in the Rainy Lake walleye population:

  - Catch per unit effort in the commercial fishery dropped 58% ($P<0.01$) from 1948 to 1969.

  - Growth rate, as indicated by mean total length of age 4 fish, increased by 11% ($P<0.01$, $r=0.98$) from 1959 to 1965.

  - Mean age of fish in the commercial catch decreased ($P<0.05$):

    - from 5.33 to 3.63 years from 1957 to 1967 in the North Arm.
    - from 6.53 to 4.37 years from 1955 to 1967 in the East Arm

- Referred to other earlier studies (e.g. Caldwell 1964, Johnson et al. 1966) documenting lake-shoal spawning of walleye in Rainy Lake, primarily "on beaches with gravel, rubble, or shingle rocks in waters less than 0.3 metres deep."

- Through regression analysis using 1948-1969 CPUE data for the commercial fishery, but without smoothing the catch data over 3-year running averages (in contrast to Johnson et al. 1966 and earlier studies) found:

  - That spring water levels 4,5 and 6 years earlier accounted for 50% of the variation in the commercial CPUE ($r=0.71$, $P<0.01$).

  - That brood stock abundance accounted for 44% of the variation in walleye abundance 5 years later.
  - (By multiple linear regression) that spring water levels and brood stock abundance together accounted for 65% of the variation in the commercial walleye CPUE.

- Concluded that:

  - "Spring water levels in Rainy Lake undoubtedly affect walleye year-class strength through spawning success on lake shoals."

  - "Brood stock abundance probably regulates future population size through the number of eggs laid and the subsequent recruitment to the population."

  - "Exploitation of the walleye population in Rainy Lake acts to depress the number of spawners. This depressing effect may have intensified in the recent past because of the observed greater exploitation of younger age-groups and the subsequent loss of older age-groups."

- "It is not possible to conclude which of the two variables, spring water levels or brood stock abundance, has played the major causative role in the decline of the Rainy Lake walleye population."

- Suggested that management might opt for an experimental approach by maintaining the present exploitation rate in conjunction with optimized spring water levels. "Then, if the optimized spring water levels do not increase the population...one will have a better understanding of the role of exploitation."

11. Osborn, T.C., D.H. Schupp and D. Ernst. 1978. Walleye and northern pike spawning area examination on portions of Crane, Kabetogama, and Sand Point Lakes, spring 1978. Minn. Dept. Natur. Res., Staff Report. 26 pp.

- Reported on a field reconnaissance of the availability and use of walleye and northern pike spawning areas in relation to water levels, with particular attention to levels prevailing at the time of the examination: May 9 (water level 1113.5 feet) and May 10 (water level 1113.8 feet).

- In general, concluded that "A water level of 1113.5 feet on Namakan Reservoir in early May will ensure continued reproduction of walleye. Substantially higher water levels (1117.0 +) are needed to maximize northern pike reproduction. Although walleye spawning would likely not be affected at levels as low as 1110.0, northern pike reproduction would probably not be successful."

- More specifically, observed/concluded:

  - For Kabetogama Lake, "ample walleye spawning habitat is available within the range of the present rule curve (1110-1118), but would be maximized at higher levels. For northern pike, spawning habitat would be maximized at levels of 1117 or higher. Although some spawning substrate was available at the level encountered during this investigation, it appears to be minimal for successful reproduction." Noted the presence of extensive marsh areas (potential northern pike spawning habitat) adjacent to this lake. Reports of northern pike spawning into June prompted the suggestion of an emerging adaptation by this species to defer spawning until water levels are favourable.

  - For Crane Lake, "conditions for walleye spawning were good at any water level between 1110 and 1118. Conversely... northern pike spawning areas are limited throughout the annual range of water levels."

  - For Sand Point Lake, though not as "ideal" as Crane Lake, many suitable areas for walleye spawning between 1110 and 1118 do exist. "Northern pike spawning areas are limited."

12. Osborn, T.C. and D. Ernst. 1979. Walleye and northern pike spawning area examination on portions of Namakan and Rainy Lakes, spring 1979. Minn. Dept. Natur. Res., Int. Progress Report. 27 pp.

- Reported on a field reconnaissance of the availability and use of walleye and northern pike spawning areas in relation to water levels, with particular attention to levels prevailing at the time of the examination (Namakan 20 May 1979, 1116.9 feet; Rainy 21 May 1979, 1107.6 feet). Both lakes were higher than the maximum rule curves for those dates: Namakan by about 1.4 feet; Rainy by about 0.4 feet. The reconnaissance was confined to the U.S. portion of the lakes.

- In Namakan Lake, most of the clean rubble areas examined had walleye eggs. "Sufficient walleye substrate would be available" between lake levels 1113.9 to 1116.9 feet. "Bays with extensive areas of flooded vegetation are not common", and "spring flooding of these bays occurs generally after 'normal' spawning time" (for northern pike). "Thus it would seem that northern pike would not have sufficient spawning substrate to reproduce" sufficient to maintain the population.

- In Rainy Lake, clean rubble areas did harbour walleye eggs, but such areas were uncommon, "and many of these would be either unavailable or more limited at water levels one foot lower (1106.6)." It was noted that walleye spawning in 1979 was abnormally late, "and walleye generally would not encounter levels in the 1106.6 to 1107.6 foot range in early May." No actual evaluation of northern pike spawning habitat or egg deposition was conducted in Rainy Lake, although "several large areas have potential" with "vast areas of flooded vegetation. Whether these areas are available (to pike) in more 'normal' years was not determined."

13. Osborn, T.C., D.B. Ernst and D.H. Schupp. 1981. The effects of water levels and other factors on walleye and northern pike reproduction and abundance in Rainy and Namakan Reservoirs. Minn. Dept. Natur. Res., Invest. Report 374. i + 32 pp + appendix.

- Identified management strategies adopted by Minnesota following the studies of Johnson (several), Bonde et al. (1965) and Chevalier (1977) in an effort to restore the walleye population:

  - resumption of fry stocking,
  - increase of minimum mesh size from 4.00-inch to 5.25 -inch for any new commercial fishing licences,
  - closure of Black Bay (Rainy Lake) to sport fishing •until spawning fish had dispersed,
  - installation of artificial spawning reefs in Black Bay,
  - advocacy of higher spring water levels.

- Mesh size adjustments in the Ontario portion of the Rainy Lake commercial fishery over the intervening period precluded a straight-forward extension of the earlier time series comparisons of walleye catch per unit effort and water levels at time of spawning in the appropriate preceding years. Extracting and extending the data set for only the Minnesota component of the fishery (about 20%):

- yielded a continuing positive relationship (r=0.12) between spring water level and CPUE 5 years later for the years 1949-1969, but the relationship was no longer statistically significant (P>0.05), and

- the correlation did not improve (r=0.11, P>0.05) with the addition of data for 1970-1980.

- Noted that mean water levels in Rainy Lake at the most probable time of walleye spawning (from ice-out until 2 weeks later) were about the same in the 12 years prior to and in the 12 years following the rule changes in 1969. Levels became much less variable (more consistent from year-to-year) in the period 1969-1980 (range of 2.4 feet) than in the period 1957-1968 (range of 4.1 feet). Under the 1957 rule, the mean (spring) water level exceeded 1106.8 feet in 6 of 12 years, but did so in only 4 of 12 years after 1969. (Johnson et al. 1966 suggested that a mean spring water level in excess of 1106.8 feet was probably necessary to inundate sufficient suitable substrate to ensure adequate walleye spawning.)

- Reported a 216% increase (r=0.84; P<0.01) in CPUE of walleye in the Minnesota component of the Rainy Lake commercial fishery between 1964 and 1980. Test netting confirmed that this recovery was general in the lake, but with a steeper slope (0.49 cf. 0.45; P<0.05) in the commercially fished area.

- Observed a reversal in the previously escalating trend in walleye growth rate in Rainy Lake reported earlier by others for the period 1959 to 1965. "A significant (P<0.05) decrease in growth was observed...between 1963 and 1980", indicating density dependence. The mean age of walleye also increased (in test nets), from 2.6 in 1963 to 4.2 in 1980 (r=0.91, P<0.01).

- Spring water levels for Namakan Reservoir tended to be lower (0.7 feet) and more variable (F=1.73, P<0.05) under the 1969 rule than under the previous (1957) rule. Year-to-year variations in spring water levels were significantly greater (entire period) in Namakan than in Rainy Lake.

- Observed (1978 and 1979) that all lakes (comprising the Namakan Reservoir) "likely have sufficient high quality walleye spawning substrate at water levels within those specified by the (1969) rule curve and probably at water levels above and below the allowable range."

- On the other hand, "There are few potential northern pike spawning areas and their availability to spawning fish is affected by water levels. Only Kabetogama Lake has ample shallow vegetated flowage conducive to northern pike spawning. Areas on the other lakes are typically small and restricted to the heads of bays and inlets."

- "A positive relationship between spring water levels and subsequent abundance of either northern pike or walleye in any of the four reservoir lakes is not indicated by the evidence. Northern pike abundances as determined by periodic test netting CPUE appeared to vary over time independent of spring water levels 2 to 4 years prior…. Walleye indices of abundance were not correlated with mean spring water levels 2,3 and 4 years prior to netting."

- The "lack of correlation between abundance and spring water levels……does not preclude a beneficial influence of high water levels on walleye spawning. The population may have recovered more rapidly if higher water levels had been attained consistently."

- While this analysis revealed no significant relations between absolute (average) spring water levels and year-class strength of walleye and northern pike in these waters, a significant relation was found between the average rise in water levels during the spawning period and the subsequent abundance of 4-year-old northern pike in two of the lakes (Kabetogama and Sand Point), albeit this relationship pertained in no other combination of situations (for pike ages or for lakes).

- "The combination of more efficient (nylon) commercial fishing gear and increased harvests by sport fishing could have been important factors in the (until 1970) decline." This evidence "is circumstantial"; however "The arguments for over-exploitation as a cause of the decline appear to be at least as strong as those for spring water levels."
- Cited an observed disposition for northern pike in Kabetogama Lake in 1978 to spawn later than expected, i.e. perhaps deferring spawning until such time as flooding of vegetation does occur.

- Cautioned that efforts to increase northern pike populations in these lakes may be counterproductive if they are successful at the (possible) expense of walleyes, since walleyes are by far the more preferred species.

14. Cole, G.F. 1982. Restoring natural conditions in a boreal forest park. Pp 411-420 in Trans. 47th N. Amer. Wildl. and Natur. Res. Conference.

- The park referenced in the title is Voyageurs National (VN) Park.

- The main focus of the paper is on terrestrial ecology and impacts, and on aquatic wildlife. Fish are mentioned more incidentally, and only through citing the observations and findings of other investigators.

- The introduction of a comprehensive outlook on the assessment of man-induced impacts in this area (of Voyageurs National Park) is a significant departure from previous narrowly-focused studies. The treatment, as befits a pioneering effort, is however incomplete.

- Water level ranges and fluctuations are described in terms which are conducive to the formulation of hypotheses regarding possible linkages to "fisheries and related aquatic resources".

- Observed that "extensive beds of wild rice were replaced by other aquatic vegetation in the lakes with 9-foot fluctuations, but still occur in Rainy Lake."

- Suggested that "The present adverse effects of regulating lake levels on various aquatic species can be reduced, without serious conflicts with other presently authorized uses of water, by approximating the magnitude and timing of natural fluctuations in most years and reducing the extreme fluctuations from occasional natural floods or droughts."

15. Flug, M. 1986a. Analysis of lake levels at Voyageurs National Park. U.S. Nat. Park Serv., Water Resources Report 86-5. 52 pp.

- Characterized the various, often conflicting interests pertinent to hydrological regulation in this area:

  • Lake shore interest groups, primarily concerned about lake levels (but sometimes in conflicting ways).

  • Downstream interests, primarily concerned about discharges.

  • National Park Service (U.S.A.), most interested in restoring "natural conditions."

- Reviewed the history of lake levels and their regulation within the Park. Presented mean monthly lake elevations under the various rule curve regimes which have been in effect, and compared these with the computed (U.S. Army Corps of Engineers) natural (unregulated) lake levels over the period.

- Stressed that "naturally occurring lake levels and discharges (i.e., river flows) are quite variable with time in an uncontrolled system as compared to a highly regulated system. This difference has strong implications on the conservation of...wildlife...in an unimpaired state for future generations."

- Recognized that natural hydrological conditions, per se, are unlikely ever to be restored in their entirely.

- Developed an optimizing simulation model in order to permit evaluation of alternate (hypothetical) modifications to the rules of hydrological operation, within a multi-lake (watershed) context.

16. Monson, P.H. 1986. An analysis of the effects of fluctuating water levels on littoral zone macrophytes in the Namakan Reservoir/Rainy Lake system. U.S. Dept. Int. Final Contract Report. iv + 95 pp.

- Provides a good description of the generalized dynamics of aquatic macrophyte establishment and perpetuation in the littoral zone of lakes, i.e. in that zone where light penetrates deeply enough to permit growth of green plants on the bottom. "In Kabetogama, Namakan and Sand Point Lakes, the magnitude of the annual fluctuations is more than enough to involve the entire littoral zone. In Rainy Lake with its lesser annual fluctuations, the extent of the littoral zone affected would be less but still substantial." Made reference to average annual water level fluctuations of 3.6 feet in Rainy Lake and 9.3 feet in the Namakan Reservoir lakes.

- Set out to examine the effects of fluctuating water levels by comparing the maximum above-substrate standing crop and species diversity of littoral-zone macrophytes at selected sites in each of the four large VN Park lakes in 1982 and 1983.

- Employed a quadrat sampling system deployed at a total of eleven stations during two summers.

- Found some evidence of higher macrophyte productivity (as indicated by standing crop) in Kabetogama than in the other lakes, but not in terms of species diversity.

- Interpreted a paucity of standing crop in the floating-leaf macrophyte community (all lakes) as possibly indicative of the effects of water level fluctuations, perhaps exacerbated by winter desiccation.

- Observed a significant ($P < 0.05$; $r \pm 0.66$) correlation between mean depth of water and mean number of species at the sites. This correlation pertained to both emergent and submerged (negative and positive correlations respectively) macrophyte communities. It was tentatively attributed to the annual increase in water depth favouring species which can grow totally submerged, and disfavouring species which survive only if upper parts of the plant are emergent.

- Found little in the data "to suggest that the aquatic macrophytes in these four lakes are responding differentially to the annual water level fluctuations." In other words, while some relatively subtle effects of water level fluctuation per se (on species composition) seemed evident, no indication was found of differential effects (on species composition) related to the magnitude of those fluctuations.

- Observed considerable apparent difference in the overall data between the two (consecutive) years of the study. "This suggests the possibility of significant difference in the year-to-year details of the water-level fluctuations, especially in the early part of the growing season."

- Noted that alterations in amplitude and timing of water levels could be expected to affect turbidity, to which aquatic macrophytes are very sensitive, especially in early growth stages.

17. Kallemeyn, L.W. 1987a. Correlations of regulated lake levels and climatic factors with abundance of young-of-the year walleye and yellow perch in four lakes in Voyageurs National Park. N. Amer. J. Fish. Management. 7:513-521.

- Noted that previous studies about the effects of regulated lake levels on the fish communities in these lakes have produced contradictory results. "Chevalier (1977) reported a positive relationship between spring water levels in Rainy Lake and walleye year-class strength as determined from commercial gill-net catches of walleye from both the Minnesota and Ontario portions of Rainy Lake from 1948 to 1969. Osborn et al. (1981), however, found no significant correlations when they compared spring water levels with both commercial gill-net catches of walleye from the Minnesota portion of the lake from 1948 to 1980 and experimental gill-net catches of walleye. They also found no significant correlations between spring water levels and experimental gill-net catches of walleye in Kabetogama, Namakan, and Sand Point lakes."

- In this (Kallemeyn) study:

- "Significant positive correlations were found between lake level and walleye year-class strength in three of the four lakes sampled."
- "The correlation between lake level and yellow perch year-class strength, while generally positive, was significant in only one lake."
- "Significant positive correlations were also found between thermal conditions during the 30-day period following ice-out and year-class strengths of walleye and yellow perch; the strongest year classes of both species were produced in years with higher, more stable temperatures."

- The paper presents several intriguing new insights and hypotheses (see Review and Evaluation, item C17 below). Several avenues for potentially profitable research are made apparent.

- Concludes by recommending that:
  - The Namakan Reservoir lakes should be regulated so that levels average at least 339.9 metres no later than May 1 to provide better spawning conditions for walleye.
  - Rainy Lake should be regulated so that the level reaches at least 337.4 metres no later than May 1.
  - Further lake level increases during May beyond these targets (all lakes) would be beneficial.
  - Summer drawdowns, of the order of 0.6 metres, would allow rejuvenation of spawning areas at lower elevations, and would be beneficial in the long term.

18. <u>Kallemeyn, L.W. 1987b.</u> Effects of regulated lake levels on northern pike spawning habitat and reproductive success in Namakan Reservoir, Voyageurs National Park. U.S. Dept. Int., Research/Resources Management Report MWR-8. 15 pp.

- Noted that "Under the present water management program, all wetland or apparent northern pike spawning areas in Namakan Reservoir are routinely de-watered by late March or early April. This may be limiting the recruitment of northern pike...since this species is a spring spawner that prefers to spawn on a mat of short vegetation comprised of grasses and sedges (several references are given). A weak or poor year class is usually produced when the availability of flooded vegetation is limited by low spring water levels" (several references are given).

- Topographic maps of two tributary deltas and the results of vegetative cover type surveys were combined to quantify the amount of northern pike spawning habitat between 1112 and 1117 feet in the Kabetogama Lake portion of Namakan Reservoir.

- Found that over three summers of sampling young-of-the-year northern pike, abundance was consistently highest (for all three sampling methods) in the year (1985) of highest spring water levels (>1116 feet within three weeks of ice-out), and was consistently lowest (for all three methods) in the year (1983) of lowest spring water levels (1114 feet at three weeks after ice-out).

- Concluded that "Since over 90% of the emergent vegetation occurs above 1115 feet msl, a 5- to 6-foot rise in the lake level must occur to flood and provide access to the preferred substrate for egg deposition."

- Recommended that the existing water management regime for Namakan Reservoir be altered in order to provide higher lake levels earlier in the spring, with a target of 1117 feet no later than May 15.

- Proposed that consideration be given to drawing down the level of the Reservoir two or three feet between June 1 and September 1 in an effort to expand the area covered by emergent vegetation at lower elevations, and thereby reduce the amount of rise required to flood northern pike spawning habit (subsequently).

19. <u>Kepner, R. and R. Stottlemyer. 1988.</u> Physical and chemical factors affecting primary production in the Voyageurs National Park lake system. Grt. Lks. Area Resource Studies Unit. Tech. Report 29. 80 pp + appendices.

- This report sets out to:

- establish a baseline for nutrient chemistry, algal biomass, and primary productivity,
- validate and quantify lake trophic states,

- explore mechanisms by which water level modification may influence lake productivity.

- Fundamental morphometric differences among these lakes are listed. For example, among the three largest reservoir lakes a 3-metre reduction in water level from full capacity:

- "decreases the volumes of Namakan, Sand Point and Kabetogama Lakes by approximately 20, 23 and 34% respectively, while
- exposing 17, 24 and 25 % of their respective bottom areas."

- These lakes are not characterized by strong or persistent summer thermal stratification, except perhaps in the very deepest waters.

- Sampling was done from May 1985 through October 1986.

- Kabetogama in general is the "most different" among this group of lakes, in terms of, inter alia, highest pH, alkalinity, conductivity, chlorophyll concentration and primary production (rate of carbon assimilation). Other studies are cited to the effect that Kabetogama Lake supposedly has:

- "more than twice the overall summertime average zooplankton density of Sand Point and Rainy, and three times that of Namakan Lake", and
- nearly three times the average density of benthic invertebrates found in the other three lakes.

- In August, when differences were greatest, the chlorophyll concentration in Kabetogama Lake was more than five times higher than in Rainy Lake and primary production was more than six times higher.

- On a "trophic state" scale of 0 - 100 (derived from summer chlorophyll concentrations), Kabetogama averaged 53, Namakan 41, Rainy 44, and Sand Point 46.

- Linkages are suggested whereby lake levels (and changes therein) can influence productivity in these lakes, generally in conjunction with morphology:

- proportion of lake volume removed through drawdown
- proportion of bottom area exposed through drawdown
- concentration/dilution of nutrient availability
- mortality of vegetation and mineralization of the material in the drawdown zone.

- Presents a preliminary and quite primitive modular mass balance analysis for total phosphorus in Kabetogama Lake as an example of how dilution/concentration effects due to volume variation might be examined. Despite the lack of total phosphorous data from the study itself, and the approximate nature of the various input parameters and the general lack of calibration notwithstanding, the method does show promise. Kabetogama was selected because it is (apparently) both most productive and most influenced (morphologically) by drawdown. In keeping with intuition the model analysis suggests that phosphorus availability in Kabetogama Lake would be diminished and "the phytoplankton biomass and accompanying primary production would be reduced, though not extremely, under 'natural' fluctuation conditions." More specifically, according to the exercise and its derivatives:

- Simulated peak seasonal total phosphorus concentration would be reduced 1.5 % by a return to 'natural' hydrological conditions.

- Average chlorophyll standing crop would decline by 15%.

- Clarity of the water would increase by 25%.

20. Kraft, K.J. 1988. Effect of increased winter drawdown on benthic invertebrates in Namakan Reservoir, Voyageurs National Park. U.S. Dept. Int. NPS Research/Resources Management Report MWR-12. 76 pp.

- Samples collected at 1-metre depth intervals (1 - 5 metres) at stations in Reservoir lakes (Kabetogama, Namakan and Sand Point) were compared with samples collected in Rainy Lake.

- During the 3 years of sampling (August 1983 to June 1986) winter drawdowns averaged 1.1 metres in Rainy Lake and 2.5 metres in the Reservoir. "…all depths sampled in Rainy Lake were not de-watered while the one- and two-metre sampling depths in the Namakan Reservoir lakes were de-watered each winter." This statement is acknowledged to not take account of ice cover, which effectively increased the extent and duration of de-watering. Thus "the one-metre sampling sites in Rainy Lake may have also been de-watered at times."

- "The average density of invertebrates showed a pattern similar to that of (primary) productivity and water chemistry, being lower and roughly equal in Rainy, Namakan and Sand Point Lakes, but 2.7 times greater……in Kabetogama Lake."

- The study demonstrated a number of specific effects of increased winter drawdown in Namakan Reservoir lakes, viz:

- "Relatively large numbers of animals became stranded and died each year."

- "At least one group, the isopod genus Asellus, appeared to have been completely eliminated from the Namakan Reservoir lakes."

- "Other groups (including mayfly nymphs, snails, alderflies) suffered reductions in density."

- "Chironomid density may have increased."

- "Diversity was lowered in the Namakan Reservoir lakes, particularly in the drawdown zone."

- "Total invertebrate density in Namakan Reservoir lakes appeared to be more variable in the drawdown zone and to often be reduced in spring and early summer."

- "Density at the Reservoir locations was significantly higher in June and August 1985, the year during the study with the least drawdown."

- No insights are developed or hypothesized regarding possible relationships between water regulation and benthic invertebrates in Rainy Lake. This was effectively precluded because the study design utilized Rainy Lake as its control.

- Intriguing and useful behavioural foundations are suggested for some of the observed impacts in Namakan Reservoir, e.g.:

- The well-know proclivity of freshwater isopods (e.g. Asellus) to remain hidden (under rocks, etc.) and to avoid water deeper than about one metre "may prevent them from moving in response to changing water levels."

- The nymphs of the mayfly Hexagenia construct U-shaped burrows in the sediment "and may become trapped in their burrows when water levels fall" (and/or when the sediment surface film freezes).

21. Kallemeyn L.W., M.H. Reiser, D.W. Smith and J.M. Thurber. 1988. Effects of regulated lake levels on the aquatic ecosystem of Voyageurs National Park. Pp 133 - 146 in D. Wilcox, ed. Interdisciplinary approaches to freshwater wetlands research.

- This is the first attempt recorded in the open literature to rigorously examine the impacts of present (as per 1970 rule curves) hydrological regulation on a range of aquatic ecosystem components in VN Park.

- The present water regulation regime is characterized as one that:

- Utilizes "larger-than-natural fluctuations in lake levels on Namakan Reservoir……to maintain less-than-natural fluctuations on Rainy Lake." (The average annual water-level fluctuation is about 2.7 metres in Namakan Reservoir and about 1.1 metres in Rainy Lake.) "The fluctuation of Namakan Reservoir is about 0.9 m greater than the estimated natural or pre-dam fluctuation while (that of) Rainy Lake is about 0.8 m less (Flug 1986)."

- Displays different timing of the fluctuations than was the natural condition. "Regulated lake levels usually peak in late June or early July rather than late May or early June as they did prior to dam construction, remain stable throughout the summer rather than gradually declining, and on the Namakan Reservoir lakes decline 1.8 m over the winter rather than 0.6 m."

- Reviewed the history of concern about the effects of regulated lake levels, which led to "a research program to assess the impacts of the regulated lake levels on the park's aquatic ecosystem and to develop possible alternatives to the present water management program……initiated in 1983 by the National Park Service", and which encompassed five primary elements.

- This paper presents study results about three of these elements: fish community, shore-and-marsh-nesting birds, and beaver/muskrat.

- Presentation of results pertaining to fish is confined to a re-visitation of the data and conclusions pertaining to northern pike, given previously in Kallemeyn 1987b.

- Reiterated that "When water levels reached the emergent vegetation within three weeks of ice-out, which is when northern pike spawning typically occurs in these lakes, reproductive success was higher. Flooding of the spawning habitat within three weeks of ice-out only occurred, however, because water levels exceeded the maximum levels called for under the current water management program."

- Concluded that "All the species investigated were found to be adversely affected by the present water management programs, and in particular by the greater-than-natural water level fluctuations that occur on the Namakan Reservoir lakes."

- Proposed an alternative system of water management, to restore more natural conditions, specifically to provide:

  - higher water levels earlier in the spring,
  - stable water levels during June,
  - summer drawdowns of 0.6 and 0.9 m for Rainy Lake and Namakan Reservoir respectively, and
  - a reduction in the winter drawdown on Namakan Reservoir from 1.8 m to 0.8 m.

22. <u>Meeker, J.E. and D.A. Wilcox. 1989.</u> A comparison of aquatic macrophyte communities in regulated and non-regulated lakes, Voyageurs National Park and Boundary Waters Canoe Area, Minnesota. U.S. Dept. Int., NPS, Research/Resources Management Report MWR - 16. 39 pp.

- "The effects of water-level regulation on aquatic macrophyte communities, individual plant species, and potential faunal habitat were investigated……in two regulated lakes (Namakan, Rainy) and an unregulated lake (Lac La Croix) in northern Minnesota". The study took place in 1987, a "low-water year."

- The study was conducted "by estimating the cover of each plant species in randomly placed quadrats along transects that followed depth contours (approximately parallel to shore) in the lakes. These contours were selected to represent different plant habitats, as defined by the timing and duration of flooding and de-watering in (nearby, similar) unregulated Lac La Croix."

- Four transects were established at each study site (two per lake) relative to mean annual high water (<u>not</u> relative to the water levels specific to 1987) as follows:

0.0m: "Shoreline"
0.5 m: "Amphibious"
1.25 m: "Submersed"
1.75 m: "Deep water"

- The plant communities in Lac La Croix "resembled those expected at depths that experienced permanent inundation or springtime flooding combined with summer or winter drawdown. Altered hydrology in Rainy and Namakan lakes not only resulted in a difference in species that dominated each transect, it created differences in the structural nature of the vegetation. The 1.75 m transect of Rainy Lake is never disturbed by de-watering, and the stable environment allows a few erect aquatics to dominate, resulting in a lack of both taxonomic and structural diversity. The 1.25 m transect of Namakan Lake is annually exposed to the disturbance effects of desiccation and ice action. Mat formers and low rosettes are favored by these conditions, again resulting in a lack of structural diversity."

- The three lakes studied "generally contained the same plant species; it was the abundance of individual species at each depth that differed. However, several dominant taxa in Lac La Croix were rare or absent in the regulated lakes."

- The conclusions of Kallemeyn (1987a, 1987b) on the role and dynamics of aquatic vegetation in these lakes with respect to spawning of northern pike and yellow perch were accepted. However, it was noted that these lakes harbour at least 48 species of fish, most or all of them ecologically inter-related, and many of them variously dependent on the aquatic flora during one or more life history stages. Some of these relationships are explored, in the context of hydrological regime.

- Concluded that "The integrity and viability of these lake systems increases with increased diversity, and the amount of disturbance determines diversity". Most probably (consistent with the literature) "the highest diversity is maintained at intermediate scales of disturbance...The natural hydrologic regime at Lac La Croix represents intermediate disturbance. There is too little disturbance from water-level fluctuations in Rainy Lake, and a stable macrophyte community with little diversity has developed at depths that never undergo drawdown. There is too much disturbance from water-level fluctuations in Namakan Lake; only those species that are very well adapted to the pervasive physical disruptions or that can invade and mature quickly have survived at depths that undergo long winter drawdowns. Both Rainy and Namakan lakes could benefit from a return to more natural hydrologic regimes."

- Recommended that "Namakan Reservoir should be regulated to reach its maximum water level at the beginning of June. Summer drawdowns should occur at both Rainy Lake and Namakan Reservoir so that near-minimums are reached before ice forms……the amplitude of the drawdowns should be increased at Rainy Lake and decreased at Namakan Reservoir to approximate natural drawdowns of 1.8 - 1.9 m, and there should be variability between years."

- "As shown for Lac La Croix, these hydrologic conditions should, over time, result in more diverse macrophyte communities throughout the littoral zone of the regulated lakes and more diverse habitats for aquatic fauna."

23. Kallemyen, L.W. and G.F. Cole. 1990. Alternatives for reducing the impacts of regulated lake levels on the aquatic ecosystem of Voyageurs National Park, Minnesota. U.S. Dept. Int. NPS Report. 99 pp.

- This report, including its eleven appendices, was the primary documented input to the deliberations and conclusions of the International Steering Committee which examined and recommended with respect to Rainy Lake and Namakan Reservoir water levels (1993).

- With respect to the present evaluation of "fisheries and related aquatic resources", the pertinent material has already been identified by reference to six of the appendices in separately published form, viz:

1) Hydrology: Flug 1986a (item 15).
2) Primary production: Kepner and Stottlemyer 1988 (item 19).
3) Walleye and yellow perch: Kallemeyn 1987a (item 17).
4) Northern pike: Kallemeyn 1987b (item 18).
10) Aquatic vegetation: Monson 1986 (item 16); also Meeker and Wilcox 1989 (item 22).
11) Benthos: Kraft 1988 (item 20).

- Enlarges upon the insight expressed by Kallemeyn et al. (1988) that water level fluctuations in aquatic ecosystems confer certain benefits. "From a natural perspective, high and low runoff years are an integral component of the hydrologic system...such variability often provides an intermediate level of disturbance that results in higher levels of biological diversity".

- The following conclusions are enunciated:

  • "The studies revealed that the species and biological communities in Voyageurs were adversely affected by the present water management program. They were especially impacted by the greater than natural water level fluctuations that occur on the Namakan Reservoir lakes. The plants and animals have been unable to adjust to the changes in the magnitude and timing of lake level fluctuations since the dams were constructed, and in particular to the water management program that has been used since 1971.

  • "Negative impacts on Voyageurs' aquatic ecosystem occurred throughout the year with those that occurred in a particular season frequently the result of a combination of water level conditions that occurred in previous seasons. For example, high stable summer and early fall water levels contribute to spring spawning problems by causing potential vegetative and wave washed gravel spawning substrates to develop at relatively high elevations. This in combination with a large winter drawdown makes their flooding the following spring difficult, particularly in low runoff years. Thus, while poor spawning conditions are usually blamed on the low spring water levels, they are actually the culmination of a series of water management actions that occurred throughout the year. Similar interactions were observed for the other organisms that were studied in the park.

  • "Most of these biological problems could be overcome by implementation of a water management program that more closely approximates the magnitude and timing of natural fluctuations in lake levels with which these species evolved. Obviously, complete restoration of natural conditions in the park is not possible due to the presence of the dams and the need to meet the requirements of other water users. Development of an alternative water regulatory program that is more ecologically sound is possible, however, given our understanding of the relationships between water levels and various biological factors."

- "Results from the research studies and the scientific literature were used to develop and evaluate thirteen alternative regulatory systems using the hydrological model (which was developed as part of the overall study). These results indicate the adverse effects from the present water management program can be reduced by implementing a program that more closely approximates the magnitude and timing of natural fluctuations in lake levels. Implementation of such a program can be accomplished without seriously conflicting with other authorized water uses."

- In the process of evaluation, the various resource attributes (including aquatic vegetation, benthic invertebrates, and fish spawning) were assigned ranking factors from 1 (low) to 5 (high) in respect to each of the alternative regulatory regimes for each of Rainy Lake and Namakan Reservoir, based on conditions predicted by the simulation model. These ranking factors were set out in an Impact Analysis Matrix, which provided the framework for arriving at the actual recommendation.

- Although not the most ideal 'biological alternative', Alternative T8 was identified to best meet the needs of all water users. A major perceived shortcoming was the failure of alternative T8 (and for that matter all of the other alternatives) to "allow for the year-to-year variation that is inherent in nature."

- The recommended alternative and the projected benefits for "fisheries and related aquatic resources" will not be reviewed here. This recommendation and its predicted benefits were modified and further developed by the International Steering Committee for its recommended alternative (see item 30 below).

24. Kallemeyn, L.W. 1990a. Impact of sport fishing on walleye in Kabetogama Lake, Voyageurs National Park. Pp 23-39 in G. Carson and M. Soukup, eds. Vol. 6, Proc. 4th Conf. on Research in National Parks and Equivalent Reserves.

- This study was pursued through aerial and creel surveys and a mark-recapture program from 1983 to 1985.

- "Approximately 35 angler hours per hectare were expended in the fishery each year, resulting in an annual harvest of approximately 45,000 walleye and a yield of 2 kg/hectare. Between 55 and 60% of the fishing pressure was concentrated between the opening of fishing season in mid-May and the end of June."

- "Angler harvest of walleye consisted primarily of two- to five-year-old fish. The first-year exploitation rate of tagged walleye was 23%."

- Referred to a previous study by Ernst and Osborn (1980) which showed that:

  • Fishing pressure in Kabetogama Lake was 44 and 58 angler hours per hectare in 1977 and 1978 respectively.

  • Walleye comprised 53% and 68% of all fishes caught in Kabetogama Lake in those two years.

  • These (1977) and 1978) walleye catches represented yields of 3.8 and 7.5 kg/hectare.

- Calculated the Kabetogama walleye population, age 3 and older, to be 169,000 fish or 16.2 fish per hectare. Total annual mortality was estimated to be 57% (34% natural; 23% fishing).

- "Seasonal catch rates of walleye by anglers ranged from 0.10 to 0.14 fish per hour."

- Age-classes two to five inclusive comprised 77% of the Kabetogama angling catch in 1983, 89% in 1984, and 81% in 1985.

Over the period 1977/1978 to 1983/1985:

- Fishing pressure declined in Kabetogama Lake by about 30%.

- Number of walleye harvested declined by more than half.

- Mean age of walleye in the catch declined from 4.9 (1977) to 3.9 (1985), due mainly to a 5-fold increase in the proportion of age-2 fish.

- Growth rate of walleye in Kabetogama Lake appeared to have increased somewhat after 1966, but the data are meagre.

- Concluded that "Although the present walleye population appears to have compensated for harvests and yield to date, over-exploitation could occur if fishing pressure increases or if regulated lake levels or some other influence lower reproductive success for several consecutive years." The yield per hectare is at a level to cause some concern.

- Noted that, since the walleye is a principal predator, changes to its population "may also affect the other members of the aquatic community."

25. Wilcox, D.A. and J.E. Meeker. 1991. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minnesota. Can. J. Bot. 69: 1542 - 1551.

- This peer-reviewed publication focuses on the floristic aspects of the U.S. National Park Service Report MWR - 16 by Meeker and Wilcox (1989) pertaining to Rainy Lake, Namakan Reservoir, and Lac La Croix (control).

- Reiterates that:

- "The macrophyte communities at all sampled depths of the regulated (Rainy and Namakan) lakes differed from those in the unregulated lake (Lac La Croix).

- "The unregulated lake supported structurally diverse plant communities at all depths.

- "In the lake with reduced fluctuations (Rainy) only four taxa were present along transects that were never de-watered; all were erect aquatics that extended through the entire water column.

- "In the lake with increased fluctuations (Namakan), rosette and mat-forming species dominated transects where drawdown occurred in early winter and disturbance resulted from ice formation in the sediments.

- "The natural hydrologic regime at the unregulated lake (Lac La Croix) resulted in intermediate disturbance and high diversity.

- "There was either too little (Rainy) or too much (Namakan) disturbance from water-level fluctuations in the regulated lakes, both resulting in reduced structural diversity."

- With respect to northern wild rice specifically, it "was conspicuously absent from the sampling in both Namakan Lake and Lac La Croix. In Lac La Croix, however, viable stands……were observed in wetlands adjacent to those sampled, and the species seems to be locally abundant elsewhere in the lake." Literature is cited to the effect that northern wild rice:

- "does not grow well in areas with wide water-level fluctuations,
- "is intolerant of both low water levels and flooding. Low water levels cause seeds to desiccate, and rising water levels force too much energy to be directed into shoot elongation.
- "is nearly absent from Namakan Lake, being restricted to a few plants near river mouths."

26. Cohen, Y., P. Radomski and R. Moen. 1991. The fish communities of Rainy Lake and the Namakan Reservoir. (Available from Minn. Dept. Natur. Res.) 155 pp.

Note: This report is sometimes cited (e.g. by Parkhurst et al. 1993) as Cohen et al. 1993.

- Assessed all available data to develop a comprehensive characterization of the fish communities in these two lakes over time.

- Endorsed the mean water level recommendations of Kallemeyn and Cole (1990) to the extent that specific water levels may be determinants of fish populations.

- Anticipated that periodic fluctuations in the range of water levels might be more important than specific mean water levels in regard to regulating fish populations.

- Introduced the concept of YMXR (maximum yearly range of water levels), and more particularly year-to-year fluctuations in YMXR, to the analysis of Rainy/Namakan fish populations. This index was calculated by subtracting the minimum water level from its maximum for every given year.

- Through the rather esoteric statistical process of spectral analysis, concluded that:

- Fish species populations (as evidenced by commercial catch) fluctuated with YMXR.
- YMXR fluctuations exhibited periodicity, with a dominant period of about 5 years.

- The scope of frequencies and amplitudes of YMXR fluctuations differed between the two lakes.

- Frequencies of fluctuations in fish populations also differed between the two lakes.

- From a management point of view, observed that "if maintaining a healthy fishery is a major goal, then (there is a need to) accept some level of periodic flooding. This can be done by allowing higher-than-normal water levels……followed by lower-than-normal water levels, within a single year. These should be repeated at about 5-year intervals."

- Anticipated that such a regimen would:

  - enhance the diversity of aquatic vegetation

  - clean shoals and other shallow spawning grounds.

- Recognized that such a policy would entail substantial economic and social costs.

- Observed or concluded further that:

  - Cycles of large ranges in YMXR have been a natural feature of the system(s).

  - Links between young-of-the-year and adult fish populations were generally non-linear (these lakes), indicating that augmentation of spawning substrate by constructing additional (artificial) shoals in the lakes was unlikely to be effective.

  - YMXR affects survival from age 0 right up to age of recruitment into the fishery, indicating that stocking is unlikely to enhance the fisheries.

  - Short-term fluctuations in year-class dominance are normal.

  - Unpredictability, paradoxically, is an indication of a healthy ecosystem/fishery.

27. <u>Wilcox, D.A. and J.E. Meeker. 1992.</u> Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota. Wetlands 12: 192 - 203.

- This peer-reviewed publication focuses on the faunistic implications of the U.S. National Park Science Report MWR - 16 by Meeker and Wilcox (1989).

- "Results of previous faunal studies (by other investigators) in the regulated lakes were used as a basis for assessing the effects of vegetation changes on faunal communities."

- Found and proposed as follows:

- "The unregulated lake (Lac La Croix) with mean annual water-level fluctuations of 1.6 m supported structurally diverse plant communities and varied faunal habitat at all depths studied."

- "Mean annual fluctuations on one regulated lake (Rainy) were reduced to 1.1 m, and dense beds of four erect aquatic macrophytes dominated the 1.75 -m depth that was never de-watered. We suggest that this lack of plant diversity and structural complexity resulted in diminished habitat for invertebrates, reduced availability of invertebrates as food for water birds and fish, reduced winter food supplies for muskrats, and reduced feeding efficiency for adult northern pike, yellow perch, and muskellunge."

- "Mean annual fluctuations in the other regulated lake (Namakan) were increased to 2.7 m, and rosette and mat-forming species dominated the 1.25-m depth that was affected by winter drawdowns. We suggest that the lack of larger canopy plants resulted in poor habitat for invertebrates, reduced availability of invertebrates as food for water birds and fish, and poor nursery and adult feeding habitat for many species of fish."

- "In addition, the timing and extent of winter drawdowns (Rainy and Namakan) reduced access to macrophytes as food for muskrats and as spawning habitat for northern pike and yellow perch."

\- Suggested that dense plant structure (as at 1.75 m in Rainy Lake) may unnaturally inhibit foraging. Sparse plant structure (as at 1.25 m in Namakan Lake) may unnaturally promote predation. Intermediate macrophyte density (as per all transects in Lac La Croix) may be the best habitat both in terms of foraging and growth of predators and stability between forage fish species and their invertebrate prey. Failure of attempts to introduce muskellunge to Namakan Reservoir (despite their occurrence in Rainy Lake) may be related to factors similar to those that inhibit effective spawning of northern pike.

\- Concluded that:

- "The adverse effects (of water-level regulation) in Rainy Lake are in deeper waters and can be compensated for by habitat available in shallower water. Those species that require the use of wetland or aquatic macrophyte communities during one or more life history stages can find suitable habitat."

- "In Namakan Reservoir, conditions are more limiting. The deeper waters do provide some structurally diverse habitat to compensate for the poor habitat present at intermediate depths. However, those fish species that spawn in near-shore vegetated areas in the spring are severely limited by the current regulation scheme that delays water-level peaks and does not allow access to the near-shore or shoreline vegetation during the spawning season."

28. Kallemeyn, L.W. 1992. An attempt to rehabilitate the aquatic ecosystem of the reservoirs of Voyageurs National Park. The George Wright Forum 9: 39-44.

- Provided a convenient synopsis of the history of water-level regulation in VN Park, and of concerns pertaining thereto. "Because of those concerns, in 1983 the U.S. National Park Service started a research program to assess the impacts of the regulated lake levels on the park's aquatic ecosystem and develop possible alternatives to the present water management program."

- Outlined the framework and scope of the USNPS research program, which included:

  - development of a hydrological model that could be used to assess the effects of alternative regulatory programs;

  - analysis of the impacts of the present operating system on (a number of aquatic ecosystem components, including):

    * littoral vegetation

    * benthic organisms

    * the fish community, particularly walleye and pike.

- Noted that additional studies were commissioned on primary production in the large lakes, and on other related topics.

- Summarized observations to the effect that:

  - "The species and biological communities that were investigated were generally found to be adversely affected by the present water management programs, particularly the greater-than-natural fluctuations in water levels on Namakan Reservoir."

  - "Impacts on Voyageur's aquatic ecosystem occurred throughout the year. Those in a particular season frequently were the result of a combination of water level conditions in previous seasons."

- Recognized that there are other legitimate users. "But even with these limitations it should still be feasible to develop more ecologically sound water regulations given our understanding of the relationships between hydrologic conditions and the various biological factors."

- Described the process which was adopted to develop and evaluate alternative regulatory programs. Noted that the evaluation procedure "is now being used by a steering committee consisting of U.S. and Canadian representatives from private industry, the public, and government."

- Foresaw that any new regulatory program would require compromise, "particularly in regard to integrating some of the annual and long-term variation that is an integral component of an unregulated hydrologic system."

29. Wepruk, R.L, W.R. Darby, D.T. McLeod and B.W. Jackson. 1992. An analysis of fish stock data from Rainy Lake, Ontario, with management recommendations. Ont. Min. Nat. Res. Ft. Frances Dist. Report Ser. 41. 196 pp.

- All available/pertinent information pertaining to fish population status, harvest, and yield potential for Rainy Lake (Canadian sector) is presented and analyzed from the perspective of fishery management.

- Preferred management measures are derived and put forward in the context of sustainable development.

- Material (for Rainy Lake) is presented according to the three traditional management areas or regions:

- North Arm
- Redgut Bay
- South Arm (shared with U.S.A.)

- A clear synopsis of historical fish sampling in Rainy Lake is provided. Important milestones include:

- Records of reported commercial harvest available since 1924.
- Effort data incorporated in 1948.
- Sampling for attributes of harvested fish in the commercial catch initiated in 1957.
- Roving creel surveys began in 1956 as part of a preliminary investigation of the lake.
- Limited creel surveys in the Ontario portion of the lake: 1958 to 1962, 1964 and 1966.
- Stratified random creel survey in Redgut Bay in 1967.
- Stratified random creel survey in the North Arm in 1969.
- Intensive lake-wide creel survey in 1968 - 1972.
- Creel surveys alternating between the North Arm and Redgut Bay in 1971 to 1974, and in 1978 and 1979.
- Annual creel surveys, 1982 to 1986.
- Experimental test netting (index netting) commenced in 1959; continued on various schedules up to the present.
- Index net configurations were modified three times since 1959; standardized in 1970.
- Trap netting has been conducted in various locations on various schedules since 1957.

- A good history of the fishing effort and fish catch in Rainy Lake by the various participating exploitation groups is given.

- An extensive treatment of the condition of the fish communities in each of the three regions of Rainy Lake is provided. Highlights are noted in the "findings and recommendations" summary later in the present synopsis (see following).

- A concise history of fishery management on Rainy Lake is presented. Items include:

  - "Regulations were first directed to the commercial fishing industry……thought to be the largest component of the annual walleye catch in the early 1960s…. The industry was regulated through fishing gear legislation. Minimum mesh size was increased from 102 mm (4 inch) to 108 mm (4.25 inch) in 1970. In addition, until 1989 only walleye greater than 38 cm (15 inches) could be sold as a commercial product."

  - "The first lake-wide estimate of angling harvest was in 1970 when it was acknowledged that angling harvest was an important factor. …changes to fishing regulations and other management efforts followed. In 1988 the District Fisheries Management Plan was completed which provided a focused plan with strategies and tactics to start rehabilitating Rainy Lake."

  - "North Arm walleye commercial quotas were introduced in 1971……(and) applied in 1978 to fishing areas of the South Arm. Total walleye quota allocation to the commercial fishery in 1981 was 20,866 kg (46,000 lb), or 97% of the annual allowable yield of the basins fished. The five-year average annual harvest between 1976 and 1980 was 13,689 kg (30,116 lb)…. In 1983……walleye quotas were established to reflect the need for stock rehabilitation……(and) commercial fishermen were encouraged to retire from the industry through the 'willing-seller/willing-buyer' program started in 1986…. Before 1986, commercial fishing was responsible for roughly 28% of the total annual walleye harvest on the lake. By 1992 this had been reduced to less than 9%……(and) the intent is to reduce the commercial quotas on Rainy Lake to zero."

  - Anglers have been the largest group of fish resource users on Rainy Lake for about 35 years. "There were few management changes to the Rainy Lake angling fishery until the minimum size limit of 38 cm (15 inches) was put in place from 1947 to 1954. Creel census surveys……in 1983 and 1984……demonstrated that sport fish harvest, particularly of walleye, could not be sustained at those levels, and certainly did not allow for fish stock rehabilitation. Beginning in 1985, the Daily Angling Validation Tag (DAVT) program was introduced. …U.S.-based non-resident anglers fishing Ontario waters……were required to purchase a $3.50 daily tag." (This program was not immediately effective in reducing American participation, with a continuing upward sales trend through 1990.)…. "Maximum size limits for angling walleye and northern pike became regulation in 1990. …Only one walleye greater than 50 cm (19.5 inches) could be retained in the daily catch and possession limit. For northern pike, only one fish greater than 70 cm (27.5 inches) could be kept."

- The fish community of Rainy Lake is currently "described as unstable, particularly in the North Arm and Redgut Bay, where historic top predators like walleye and northern pike are being displaced by black crappie and smallmouth bass."

- The findings and recommendations of this examination are summarized as follows:

- "Since the 1920's the natural fish community of Rainy Lake has undergone considerable change because of: heavy exploitation pressure, the introduction of new species; and other environmental factors.

- "In the early 1960s, the walleye population of the North Arm declined rapidly, and since then the population has been depressed and unstable. Recruitment is sporadic and the age distribution of walleye has shifted to young ages with a reduced mean age. There is a shortage of prime breeding adults (over eight years of age). Growth is rapid and fish mature early. Other changes in the North Arm fish community have been a decrease in the abundance of whitefish and cisco over time, and an increase in centrarchids (black crappie, smallmouth bass and pumpkinseed).

- "The walleye population in Redgut Bay has recently started to show similar evidence of over-exploitation, namely: an age frequency distribution skewed to young age classes, low mean age, increased growth, early maturation, a shortage of large prime breeders, and unstable recruitment.

- "The South Arm walleye and fish community are in better shape, but the walleye population there appears to be at an early phase of the same pattern, showing exploitation stress.

- "To achieve rehabilitation of the North Arm walleye population it is recommended that the annual harvest of walleye be reduced to zero. This could be achieved by one of the following options: walleye season closure; a daily and possession limit of zero; or a high minimum size limit…. It is also recommended that the walleye brood stock be supplemented with adult transfers.

- "To rehabilitate the Redgut Bay and South Arm walleye populations it is proposed that the annual harvest of walleye from those basins be reduced to 2,000 and 11,200 kg respectively (4,400 and 24,600 lbs), from the most recent estimates of 4795 and 20,153 kg (10,549 and 44,337 lbs). It is recommended that the daily and possession limit for walleye on these basins be reduced to two, assuming that the contribution to harvest by U.S.-based non-resident anglers is addressed by other measures. In addition, it is considered necessary to regulate the size of fish taken so that the survival of young fish is improved, that they are given at least one opportunity to spawn before being subject to harvest, and that the survival of large prime breeders is also improved. Several regulatory options for doing this are provided. Biologically, the preferred option is a 45 cm (17.7 inches) minimum size limit in combination with the existing maximum size limit of one over 50 cm (19.5 inches) and the proposed daily and possession limit of 2.

- Other species recommendations are also made. For example, for smallmouth bass, a maximum size limit of one fish over 35 cm (13.8 inches) in the daily and possession limit is recommended. It is also recommended that quotas be established for the commercial fishing of cisco on the lake.

- "Strong measures are considered necessary to rehabilitate the sport fishery of Rainy Lake because past management actions have essentially been too little, too late."

30. <u>International Steering Committee. 1993.</u> Rainy Lake and Namakan Reservoir Water Level: Final Report and Recommendations. Report to International Joint Commission. viii + 83 pp + appendices.

- This report is the focus of the present exercise. It represents the culmination of a long and arduous effort to:

  - Bring together all the known information pertinent to the matter.

  - Deploy that information in a logical and coherent manner.

  - Evaluate alternative modes of hydrological management, including those now in effect.

  - Have input from all legitimate interests.

  - Reach a compromise conclusion.

- The International Steering Committee itself was "a voluntary, nine-member group of private citizens, government officials from Canada and the United States, and a Boise Cascade representative." The Steering Committee first met in June of 1991.

- "The Steering Committee sought a balance" among the following users or features representing legitimate concerns:

  - navigation
  - fish and wildlife
  - hydropower generation
  - flooding
  - shoreline property
  - archaeological features
  - aquatic vegetation

- public beaches
- native people's interests
- water quality
- water intake lines
- tourism
- up- and downstream impacts.

- The Steering Committee undertook as an initial step to evaluate the existing water level management system as defined by the existing rule curves. The elements of those evaluations in respect to "fisheries and related aquatic resources" have been abstracted earlier via the various lead-up documents, many of which originated or culminated as Appendices to the Steering Committee report. These elements are summarized briefly here as follows, now incorporating the benefit of the consensus overview of the Committee; literature citations are omitted since they have all been cited previously:

- "At present the annual fluctuation of Namakan Reservoir is larger than natural, and on Rainy Lake it is less than natural. Both reservoirs have high water levels throughout the growing season. This unnatural pattern has adversely affected the aquatic ecosystem. Indeed there is a noticeable shortage of marshes and wetlands in bays and shallows of Namakan, Sand Point, Crane and Little Vermilion lakes, and where marshes exist on shallow Lake Kabetogama, they exhibit poor species diversity."

- "On Rainy Lake and Namakan Reservoir, emergent wetland plants and near-shore aquatic plants occur at relatively high elevations because high stable lake levels are maintained throughout the growing season. As a result of the large winter drawdown on Namakan Reservoir, these plants are exposed to dry, freezing conditions. On Rainy Lake, the plant communities, although not exposed to the severe winter conditions, are affected by the stable growing season levels and the lack of year-to-year variation in water levels. The latter factor also affects plants in Namakan Reservoir. This stability prevents aquatic vegetation from growing at a range of elevations."

- "Water level management under the existing rule curves ……reduces fish spawning success……by negatively altering aquatic plant communities and spawning shoals. …Fish eggs are dried due to unnatural large drawdowns, and in some cases, eggs are retained or absorbed in female fish because of a lack of suitable spawning habitat. Lake bottom organisms, which are food for young fish, are stranded and killed by excessive winter drawdowns on Namakan Reservoir…. The altered aquatic plant communities, created by the unnatural seasonal water level changes of the existing rule curves, reduce habitat for fish and wildlife. This creates less habitat for invertebrates, reduces abundance of invertebrates as food……, reduces the potentially available spawning habitat for northern pike, and limits the nursery habitat and adult feeding habitat for many species of fish."

- "Fisheries managers have documented declines of fish stocks in the area…. The declines of greatest concern are with walleye and cisco in Rainy Lake and northern pike in the Namakan Reservoir…. On Rainy Lake, the primary factor causing decline is overharvest for walleye, and perhaps for cisco, but water levels are an important secondary factor. On a population basis, overharvest affects how long adult fish live, while water levels affect how many young fish enter the fishery. On Namakan Reservoir there is a documented recruitment problem with northern pike and water levels are the major cause of the problem."

- "The existing rule curves have a detrimental effect on walleye reproduction…. The low water levels occurring in late April and early May prevent walleye from accessing some of the good rock rubble spawning sites on shorelines, river mouths and shoals. Also, the stable water levels in summer and early fall hinder the cleaning of walleye spawning beds. The preferred spawning habitat for walleye is rock rubble 4 inches to 12 inches in diameter with clean spaces between the rock, free of silt and algae. In spring, walleye eggs incubate in these spaces, receiving oxygen from currents or wave action, while being protected from predators. Wave action and desiccation are the primary mechanisms by which shoals are cleaned and thereby improved for egg-hatching success. High, stable summer water levels contribute to poor spring spawning conditions by cleaning rock at levels higher than those submerged in spring, and by not allowing for the drying out and killing of algae by a summer drawdown. This, in combination with low spring levels makes submersion of preferred rock rubble at spawning time less likely."

- "Northern pike reproduction has also been negatively affected by the existing rule curves…. The best spawning habitat for northern pike is submerged cattails, sedges and grasses in flooded wetlands or marshes. Pike lay their sticky eggs on the matted vegetation on the bottom, or their eggs adhere to standing vegetation in the water. Where this habitat exists on Namakan Reservoir, it is primarily at elevations above 1117.0 feet (340.5 m) -- levels at which it became established during the growing season. However, lake levels during late April or May, the period when pike are trying to spawn, are at 1110.0 to 1114.0 feet (338.3 to 339.6 m). This is at least 3.0 feet (0.9 m) below their best spawning habitat. As a result, in some years no substantial reproduction of pike occurs on Namakan Reservoir."

- "Although there is no documented reproduction problem for northern pike on Rainy Lake, there would likely be reproductive benefits if spawning pike could better access the best spawning habitat."

- "Whitefish and cisco can be affected by the winter drawdown of the existing curves. These species spawn from October through December, and their eggs incubate on the bottom until spring when they hatch. Many spawn on the shallow rock rubble of shorelines, river mouths and shoals. An overwinter drawdown greater than three feet (0.9 m) causes significant mortality of these eggs…. Winter drawdown on Namakan Lake is from 6 to 10 feet (1.8 to 3.1 m); on Rainy it is from 2 to 3.5 feet (0.6 to 1.1 m)."

- "On Rainy Lake, there has been a documented decline of cisco on all basins since the 1950s and 60s, and for whitefish on the North Arm and Redgut Bay. The reasons for these declines are not clear, but in addition to the lake level effects, they may include excessive harvest by the commercial fishing industry and the introduction of exotic species such as black crappie, bass and bullheads."

- "Beyond seasonal effects, there are long-term effects of the existing rule curves which negatively impact fish and wildlife. Existing water level management significantly affects the health of the fishery by altering cycles in annual water level fluctuations...a period of modest annual fluctuations followed by a single large fluctuation may allow aquatic vegetation to be rejuvenated, and fish and wildlife in turn, to flourish…. A lake's water level fluctuations are an index of change to the lake itself -- shoals are exposed and inundated, nutrients are recycled, and the diversity and abundance of aquatic plants are affected. Shoals and emergent plants provide spawning habitat for walleye and northern pike."

- "The existing water level regulations adversely impact benthic (bottom-dwelling) organisms as well, such as invertebrates. Winter drawdown on Namakan Reservoir can de-water up to 25 percent of the reservoir bottom and cause a massive layer of ice to be in contact with the substrate for periods exceeding 100 days. These conditions, which typically extend to levels 6.5 to 10 feet (2 to 3 m) below summer elevation of the reservoir, have reduced both the density and number of invertebrate species in this drawdown zone…. Stranding and subsequent mortality appear to be a major contributing factor in the observed reduction…. Adverse effects of the existing rule curves on invertebrates in Namakan Reservoir are most obvious in the drawdown zone. Alderfly and mayfly densities were low in this zone compared to what would be expected naturally. Instead, this zone was dominated by midge larvae, insects that can quickly colonize recently inundated areas."

- In pursuing the more proactive part of its mandate, the Steering Committee first agreed upon a set of guidelines within which alternative modes of hydrological management would be evaluated, including recognition of public aversion to flooding and an undertaking to develop proposals only within the range of existing IJC maximums and minimums.

- The Steering Committee then identified/constructed a series of "single purpose" rule curves, each to maximize benefits to one of the various users or features acknowledged as representing legitimate concerns.

- The Steering Committee next searched for similarities in the single-purpose rule curves in order to develop a consensus that would represent improved hydrologic management over the annual cycle for a majority of users/features without incorporating aspects that would be seriously detrimental to any of them.

- Once a "consensus hydrologic management regime" (proposed set of rule curves) had been developed, the Steering Committee evaluated these proposed rule curves, in a qualitative manner, in respect to each of the various users or features representing legitimate concerns. Except for indications of minor disbenefits to hydropower generation and no or uncertain change with respect to some concerns, the Steering Committee interpreted positive effects for most users/features including aquatic vegetation, fish (including downstream) and benthic invertebrates.

- The Steering Committee's two primary recommendations, stemming from this analysis and evaluation, are stated as follows:

  - "**The IJC should make modest changes in the existing rule curves**...to help alleviate the existing navigation and environmental problems. These modifications include an earlier rise in spring water levels, stable or declining June water levels, a slight summer drawdown, and a reduction in the amount of overwinter drawdown on Namakan Reservoir.

  - "To offset the potential for the proposed rule curve modifications to increase the frequency of spring flood events, **the IJC should enforce the provision of its 1970 Supplemental Order requiring the dam operators to anticipate inflows and maximize the discharge capabilities of the dams to prevent emergency water levels.** The Steering Committee believes that diligent use of the existing network of upstream lake level gauges and currently available hydrologic models can make this IJC mandate a reality and improve the accuracy and reliability of reservoir level control."

31. Kallemeyn, L.W., Y. Cohen and P. Radomski. 1993. Rehabilitating the aquatic ecosystem of Rainy Lake and Namakan Reservoir by restoration of a more natural hydrologic regime. Pp 432-448 in Hesse, L.W., C.B. Stalnaker, N.G. Benson and J.R. Zuboy, eds. Biological Report 19, Proc. Symposium on restoration planning for the rivers of the Mississippi River ecosystem. U.S. Dept. Int., Nat. Biol. Surv. Washington, D.C.

- A comprehensive and concise retrospect of the data inputs used and the conclusions developed by the Rainy Lake and Namakan Reservoir Water Level International Steering Committee.

- Reiterated the conclusion that "The controlled water levels adversely affect key elements of the aquatic ecosystem: littoral vegetation, benthic organisms, fish, aquatic birds and fur bearers. Specific water levels, particularly spawning season levels, and annual fluctuations of water levels influence fish densities and spawning success. Simulation models indicate that phytoplankton biomass and primary production may also be affected by the regulatory program…. Regulations that emulate natural fluctuations in water levels, including annual and long-term variability, may overcome the adverse biological effects of the present program."

32. Parkhurst, B.R., W. Warren-Hicks, T. Etchison and J. Butcher (The Cadmus Group). 1993. Evaluation of the effects of water level fluctuations and other environmental factors on walleye and northern pike populations in Rainy Lake and Namakan Reservoir. Report to White Paper Division, Boise Cascade Corp. vi + 90 pp.

- This report was provided for/to Boise Cascade Corporation and Boise Cascade Canada Ltd. in rebuttal to the report of the International Steering Committee, and more specifically in rebuttal to two of the Steering Committee's primary source documents. The report is annexed as Exhibit 202 to/in Boise's comprehensive statement of response directed to the IJC.

- This report represents a formidable undertaking, involving among other things the deployment of considerable biological and statistical expertise and computer power.

- The work entailed two aspects:

  • "a search, compilation and evaluation of literature on the effects of water level fluctuations and other environmental factors on walleye and northern pike populations in Rainy Lake and Namakan Reservoir and other lakes; and

  • "an independent analysis of the data used by Cohen et al. (1993:sic)." (Note: the Cohen et al. report is more commonly referenced to the year 1991. The document itself bears no date. It was published in two parts in the open literature in 1993.)

- Statistical analyses commenced with correlation and spectral analyses. "Based on the results of these analyses, we developed multiple regression models relating various environmental parameters, including water levels, brood stock abundance, temperature, abundances of other species, and other parameters to the abundance of adult and YOY walleye and northern pike in Rainy Lake and Namakan Reservoir."

- Considerable divergence is identified among the conclusions of previous investigators regarding water level conditions that are most conducive to successful spawning of walleye and northern pike.

- Commercial catch data were used as an index of adult population levels. Seining data were used as an index of the abundance of young-of-the-year (YOY).

- Explanatory models were developed for adult and YOY walleye and northern pike "as time series regression models involving lagged values of both dependent and independent variables." The following data pre-selection steps were undertaken:

  • Before beginning the model selection process, both spectral and correlation analyses "to support the choice of proper lagged values of the variables to be included in the models."

- Partial autocorrelations "to determine which (if any) other lagged values of commercial catch were to be included in the model as predictors."

- Cross-correlation analysis "To identify potential independent predictors of fish populations."

- "The information obtained in the correlation analyses was used to build multiple regression models which evaluate the effects of multiple explanatory variables simultaneously. Our strategy in the evaluation of important predictive variables for Rainy and Namakan fish populations was to investigate a number of regression models, from simple to complex. For models involving lagged variables, if the errors are uncorrelated, then it is well known that the estimators of the regression coefficients are consistent and standard multiple regression techniques can be applied. For the stepwise multiple regression procedure, we checked at each step to insure that the errors were uncorrelated."

- "Based on our models, we calculated the predicted values of commercial catch and YOY under the current operating rules and under the proposed changes to the rule curves for both lakes."

- A compilation and assessment of past studies on relationships between water level fluctuations and fish populations in Rainy Lake and Namakan Reservoir is given. A summary table of statistical analyses which have been undertaken in the past (since Scidmore and Johnson's report of 1965) is provided. It is a very helpful birds-eye view of statistical approaches which have been addressed to this problem over time, and their results.
- The reports and conclusions of Kallemeyn and Cole (1990) and Cohen et al. (1991) are evaluated in some detail, the former matter-of-factly; the latter with mainly negative overtones. This criticism involves complex statistical argument.

- The writers present the results of their own statistical analysis. Their main aggregate conclusions:

- "Water levels are not important factors in explaining numbers of YOY and adult walleye and northern pike in these lakes. The predictive models we developed indicate that the changes to the rule curves recommended by the...Steering Committee are not likely to produce measurable benefits to YOY or adult walleye and northern pike populations in these lakes…. The impacts of the recommended changes in rule curves are small, not necessarily beneficial, and have high uncertainties."

- "The fisheries in these lakes have all the classical characteristics of over-fishing which is indicated by decreased catch rates, increased growth rates, and increased harvest of young fish. The best approach for improving these fisheries would be to reduce harvests."

33. Gray, B.T. and Z.E. Kovats (Golder Associates and/or Environmental Management Associates). 1993. Review and analysis of studies on the effects of water level fluctuations on wildlife populations on Rainy Lake and Namakan Reservoir. Report to White Paper Division, Boise Cascade Corp. ii + 49 pp.

- This report was provided for/to Boise Cascade Corporation and Boise Cascade Canada Ltd. in rebuttal to the report of the International Steering Committee. The report is annexed as Exhibit 302 to/in Boise's comprehensive statement of response directed to the IJC.

- The authors evidently did not have direct access to Monson's (1986) report. They cite the low-key reiteration by Kallemeyn and Cole (1990) of Monson's contention that inadequate sampling effort and inconsistency in the magnitude and timing of annual water level fluctuations may have prevented him (Monson) from demonstrating a difference between the aquatic vegetation in Rainy Lake and that of Namakan Reservoir.

- The authors interpreted that Meeker and Wilcox (1988, etc.) took over where Monson left off, and that their results indicated that "shoreline vegetation was similar in all three lakes, but that significant differences were evident in plant assemblages from the deeper water zones". They criticized Meeker and Wilson's experimental design on four counts:

- Did not sample deeper than 1.75 m.
- Did not replicate adequately.
- Did not measure alternative factors that affect aquatic plant communities.
- Did not collect data from more than one year.

- With respect to their critique of Kraft's benthic invertebrate work and conclusions, the authors acknowledge that absence of pre-impact data need not preclude assessment if appropriate controls are used. Their quarrel is with Kraft's implicit use of Rainy Lake as a 'natural condition' when in fact it too is a regulated water body. Their implicit suggestion is that dampening of water level fluctuations by the hydrologic control regime in Rainy Lake may have enhanced benthic invertebrate populations in that situation, so that the lesser populations observed in Namakan Reservoir relative to Rainy Lake are suspect. They do however acknowledge the overall weight of evidence that "one may expect some degree of improvement of environmental conditions for invertebrates in Namakan Reservoir if more natural water level fluctuations were established, especially at the 2 meter depth where the greatest impacts were demonstrated." By their assessment of the situation, "inasmuch as the winter drawdown in Rainy Lake will not change under the proposed rule curve, the invertebrate populations in this lake should not change." Kraft (1988) made no prediction on this one way or the other.

- On the basis of their interpretation (among others) that "the aquatic vegetation results were equivocal", these reviewers formulated the general conclusion that "taken as a whole, no scientifically convincing case has been made that a change in the present rule curves for Rainy Lake and Namakan Reservoir, as proposed by the International Steering Committee, will noticeably increase numbers and distribution of the plant and animal species studied."

34. <u>Cohen, Y. and P. Radomski. 1993.</u> Water level regulations and fisheries in Rainy Lake and the Namakan Reservoir. Can. J. Fish. Aquat. Sci. 50: 1934-1945.

- This is an updated and refined presentation of the water levels/fish populations component of the earlier more comprehensive report (Cohen et al. 1991).

- The paper follows up on the basic premise (Cohen et al. ibid.) that "The difference between the yearly maximum and minimum water levels (YMXR) is an index of lake dynamics: shoals are exposed and inundated, nutrients are oxidized and reduced, and the diversity and density of the aquatic plant community are affected." These processes are favourable to fish.

- The statistical treatments termed "spectral analysis" are novel and complex and are difficult to assess with respect to derivation and methodological appropriateness and credibility. Since the paper did pass peer review (for publication in the open literature), as have other papers using this same technique previously, these treatments are assumed to be methodologically in order, and attention is focused on the overall conclusions as they are verbally presented.

- These conclusions include:

- "The 5-year moving variance of YMXR fluctuates regularly with periods of about 11.2 years" (which happens to coincide with the periodicity of sunspot cycles). "This reflects the effects of within-year consecutive periods of storms and dry spells."

- "Water level regulation (Rainy and Namakan Lakes, cf. unregulated Lac La Croix) resulted in changes in both amplitudes and frequencies of YMXR compared with natural fluctuations."

- Fluctuations in YMXR are linked to fluctuations in fish populations.

- Reiterated the earlier (Cohen et al. 1991) admonition that "in regulating water levels, one must be concerned with frequencies and amplitudes of water level fluctuations (i.e., in their dynamics). It is not enough to address problems of annual mean water levels only. This reemphasises the connection between ecosystem dynamics and fish population dynamics."

- Observed that "fish populations in lakes such as Rainy and Namakan may fluctuate regardless of management efforts and that these fluctuations do not necessarily indicate over-fishing, but rather may be natural phenomena." As a corollary, maintained that "in managing fish populations, it is not the population mean that needs to be considered as an index of the state of the fisheries. Rather, management should strive to maintain a certain amount of fluctuation in fish populations, with appropriate amplitudes."

35. Pereira, D.L., C.S. Anderson, P.J. Radomoski, T. Sak and A. Stevens. 1995. Potential to index climate with growth and recruitment of temperate fish. Can. Spec. Publ. Fish Aquat. Sci. 121: 709 - 717.

- This paper borrows data from three walleye fisheries, one of which is Rainy Lake, for analysis of climate change effects.

- The authors calculated indices of yearly recruitment and growth by application of linear models to routinely collected data on fish age structure and scale growth.

- Found that walleye growth indices were associated with several measures of extreme air temperatures ("key events") and that first-year growth was most sensitive. More specifically, for Rainy Lake, found that:

- Recruitment was significantly correlated with both high and low mean July temperatures.

- Growth of young-of-the-year fish was faster in years of high cumulative degree-days above a base of 20 degrees celsius, and slower in years with low mean annual temperatures.

- "El Niño key events had a significant relationship with young-of-the-year walleye growth in Rainy Lake." Postulated that this effect might somehow be mediated via a lengthened growing season.

- Little or no coherent synchrony was observed between the walleye responses among the different lakes examined.

36. Eibler, J. 1995a. Large lake sampling program, Rainy Lake 1994. Minn. Dept. Natur. Res., Div. Fish and Wildl. Completion Report. 117 pp.

- This document is the latest available in a continuing series of reports on a standardized sampling program which was initiated for Rainy and Kabetogama Lakes and less comprehensively for Namakan and Sand Point Lakes by the Minnesota Department of Natural Resources in 1983. A parallel program of angler creel surveys has also been conducted and reported.

- These documents provide an ongoing update of all available/pertinent information and analysis pertaining to fish population status and harvest for Rainy Lake and Namakan Reservoir lakes (U.S. sector) from the perspective of fishery management.

- Observations and conclusions from this particular (Rainy Lake 1994) document include:

- Continuing evidence of a very strong 1991 walleye year class, "the second-highest year-class strength rating on record; second only to that of 1979."

- A disconcerting relative scarcity of other year-classes, especially larger/older fish.

- "Abundance of northern pike in Rainy Lake reached its lowest recorded level in 1994…. The simultaneous increase in proportional stock density suggests a recruitment problem in the fishery. This is supported by the absence of a strong year-class in the fishery."

- Densities of rainbow smelt have not (yet?) approximated densities achieved in other lakes where smelt have gained access.

37. Eibler, J. 1995b. Large lake sampling program, Lake Kabetogama 1994. Minn. Dept. Natur. Res., Div. Fish and Wildl. Completion Report. 25 pp + figures + tables + appendices.

- This is another in the ongoing series of reports by Minnesota DNR on the status and exploitation of fish populations in the Rainy/Namakan system.

- The history of fishery problems and proposed solutions in Kabetogama Lake is reviewed:

  - "Resort and property owners expressed concern over the quality of fishing in 1966. A special investigation determined the problem was due to the scarcity of a walleye year-class and high populations of prey species, particularly young-of-the-year yellow perch (Johnson 1966a). Subsequent seine and gillnet catches showed this to be a temporary situation. Similar complaints in the 1970s and 1980s led to a comprehensive review of past management of the lake (Osborn et al. 1981)."

  - Osborn et al. (ibid) "found no consistent correlation between spring water levels and the subsequent abundance of 2, 3, and 4-year-old walleye and northern pike. Kallemeyn (1987a) however, found a significant positive correlation between YOY walleye abundance and the mean lake level for 15 and 30 day periods after ice out…. Kallemeyn and Cole (1990) showed that existing water level operations……also have adverse effects on a variety of aquatic organisms other than fish."

  - "Cohen et al. (1991) accepted these findings but added that fluctuations in maximum annual range were in synchrony with fish abundance and therefore, approximately once every five years, the annual range in water levels should be maximized to benefit the fishery."

- Observations and conclusions presented include:

  - "Abundance of the Lake Kabetogama walleye stock appears to be relatively low." The walleye gillnet CPUE over three consecutive years is the lowest recorded since 1966. "Neither the 1992 or 1993 year-classes appear to be strong in number. Both of these year-classes hatched during cool summers and subsequently their growth was poor."

- "The 1994 walleye year-class may be the next cohort to exhibit above average abundance in Lake Kabetogama. Although the catch per haul of YOY walleye was low, growth through the summer was good."

- "In spite of low walleye abundance no increases in walleye growth rates are apparent……dating back to 1984. A more thorough analysis of growth is needed."

- "Northern pike abundance in 1994 dropped from that recorded in 1993 as the strong 1989 and 1990 year-classes faded in importance to the fishery… …the 1989 and 1990 cohorts both hatched during springs in which water levels were high allowing access to reproductive habitat located at relatively high elevations… …the 1987 and 1988 cohorts hatched during low-water springs and scored low" on the index of year-class strength.

C. REVIEW AND EVALUATION OF DOCUMENTS WHICH WERE EXAMINED

- For more complete citations of the documents treated in this Section, see Section B (earlier). For full citations, see Sections E and F.

C1. Sharp, R.W. 1941. Report of the investigation of biological conditions of Lakes Kabetogama, Namakan and Crane as influenced by fluctuating water levels.

- Except for some gillnet catch ratios and growth index comparisons, all the biological material presented is of a qualitative nature only.

- The gillnet catch ratios suggest a preponderance of ciscoes (58%) in Kabetogama Lake, followed by walleye (17%). Northern pike contributed 6%. Whitefish replaced ciscoes as the biggest contribution to catch (29%) in Namakan Lake; walleye contributed 10% and northern pike 4%. Catch per set was more than twice as high in Kabetogama than in Namakan. However, it is impossible to be completely confident about the interpretation of even these meagre data. It must also be noted that even at the early date of this sampling (1936 and 1937) these lakes had already been under altered water regimes for more than 20 years, representing about five generations for the fish species of greatest interest and concern.

- Despite the paucity of actual data, the report is a treasure trove of useful information and insights. The observations of benthic invertebrate mortality due to winter drawdown in Namakan Reservoir, specifically Kabetogama Lake, are one example.

C2. Bonde, T.J.H., C.A. Elsey and B. Caldwell. 1961. A preliminary investigation of Rainy Lake, 1959.

- This is the first systematic examination and rigorous treatment of fish behaviour and fishery population dynamics (emphasis on walleye) for Rainy Lake. It is an important bench mark.

- There are no significant prior data for meaningful comparison. A geographically uniform, stable and productive fishery is indicated, albeit with smaller-sized fish than would ordinarily have been anticipated. Some possible response to fishing pressure is suggested. The absence of strong indicators that the fisheries are impacted is important.

- The observation regarding walleyes moving upstream to spawn is of interest. There is no consideration of habitat factors, such as water levels, as determinants of fish populations.

C3. Bonde, T.J.H. and C.A. Elsey. 1964. A fisheries survey of Namakan Lake, 1962 - 1963.

- This is the first systematic examination and rigorous treatment of fishery population dynamics for Namakan Lake (Reservoir). It is an important bench mark.

- Prior data for meaningful comparison are sparse. The Namakan walleye population was judged to have "maintained itself at a relatively high level……and no change in either regulations or management is recommended." Again, the favourable assessment of the status of the fishery at this juncture is noteworthy.

- There is no consideration or treatment of habitat factors.

C4. Bonde T.J.H., C.A. Elsey and B. Caldwell. 1965. A second Rainy Lake report, 1957 - 1963.

- This is one of the first products of the first long-term study of Rainy Lake, initiated in 1957 "with Ontario's decision to eliminate walleye stocking." (Minnesota joined the study in 1959.)

- Consistent with the fish-management-based trigger for the work, this report is focused on the fishery per se rather than on habitat factors such as water levels.

- The demonstration of sub-populations of walleyes in Rainy Lake is a useful contribution.

- Also useful is the early clear demonstration of walleye depletion in Rainy Lake during this period. This was contrary to more preliminary reports (cited) that "no evidence of overfishing or depletion existed."

C5. <u>Scidmore, W.J. and F.H. Johnson. 1965.</u> A comparison of the abundance of walleyes in the commercial catch in Rainy Lake, Minnesota - Ontario, with lake elevations during the walleye spawning period in the years contributing to the catch.

- As is the case with any correlation study, correlation per se is not proof of cause (low early-May lake water levels) and effect (poor walleye reproductive success) in this particular case. It is, however, an indication, within a range of confidence, that cause-and-effect cannot be discounted.

- The amalgamation of commercial fishery CPUE data into 3-year moving averages is a useful visual tool, but is a questionable procedure for rigorous correlation analysis. The correlations, however, seem sufficiently robust to have prevailed even without this treatment.

C6. <u>Johnson, F.H., R.D. Thomasson and B. Caldwell. 1966.</u> Status of the Rainy Lake walleye fishery, 1965.

- The proposition that reproduction of walleye in tributary systems (to Rainy Lake) must be inconsequential because of (their) observed decline in the population despite the tributary systems being "unaffected" by low water levels artificially induced in the lake is not convincing. Presumably low lake levels, even if artificially induced, are generally indicative of reduced-water-availability conditions, which would also be expected to affect tributary systems in the same geographical area. Examination of precipitation data would provide a measure of clarification on this matter. The observed loss of water current in tributaries, attendant upon rising water levels in the lakes, may be a more significant consideration in that it might eliminate a mechanism of attraction for fish seeking spawning sites.

C7. <u>Johnson, F.H. 1966a.</u> Report on the results of shoreline seining and test netting in Kabetogama in 1966 with special emphasis on the status of the walleye population.

- This is merely a data report, with no significant attempt at analysis.

- However, the general synchrony between weak walleye year classes in Kabetogama Lake (1958, 1959, 1962) and years of low spring water levels (as indexed to Rainy Lake: 1958, 1959, 1960), and the abundance of the 1961 walleye year-class in both lakes, lend credence to the hypothesis (expounded elsewhere) of cause-and-effect.

C8. <u>Johnson, F.H. 1966b.</u> Report on the results of shoreline seining and test netting in Namakan Lake during 1966 with special emphasis on the status of the walleye.

- Confirmation of a weak walleye year class in Namakan Lake for 1962 (paralleling Kabetogama), coupled with good walleye reproduction (both lakes) in 1963, lends further credence to the existence of a common environmental determinant.

- Although consistent with the data, spring water level is not necessarily (as stated) the only "obvious environmental condition that could affect reproduction in both lakes and that varies from year to year."

C9. Johnson, F.H. 1967. Status of the Rainy Lake walleye fishery, 1966.

- Provides a useful synopsis of the evolving nature of walleye management strategies for Rainy Lake.

- The first written indication of erosion of confidence (in this series of reports) in the hypothesis that spring lake levels alone are adequate to account for walleye reproductive success. Excellent spring water levels in 1966 were not reflected in superior reproduction.

- The expansion of the ongoing analysis of Rainy Lake walleye year-class strength to encompass abundance of spawning stock in addition to spring water levels is an important milestone in the comprehension of factors affecting these fish populations.

C10. Chevalier, J.R. 1977. Changes in walleye (Stizostedion vitreum vitreum) population in Rainy Lake and factors in abundance, 1924-75.

- Use of standard linear models as per this paper is deemed by some (e.g. Cohen et al. 1991) to be more or less inappropriate for the type of data at hand. Such models:

- Do not allow for population fluctuations.
- Are difficult to apply to time-series data, due to the existence of auto- and cross-correlations, particularly when time lags are involved.
- Cannot accommodate "the rich behaviour of population changes observed in nature" (Cohen et al. 1991).

- Whatever the validity of some of the specific treatments, this paper makes a useful contribution by drawing concerted attention to the probable joint roles of water regime and fish harvest as determinants of fish populations in these lakes.

C11. Osborn, T.C., D.H. Schupp and D.Ernst. 1978. Walleye and northern pike spawning area examination on portions of Crane, Kabetogama, and Sand Point Lakes, spring 1978.

- Makes an erroneous interpretation of the present (1970) upper (maximum prescribed) rule curve elevation for mid May. (Refers to 1118 feet potentially available during the spawning period. Assuming the normal end of the spawning period for northern pike and walleye in these lakes to be about mid May, the maximum rule curve elevation is 1115 feet. 1118 feet is not prescribed until mid June.)

- No criteria are given regarding how fish eggs found were identified to species. Since this is not even mentioned, a high level of confidence about it must have prevailed in the minds of the investigators.

- Although many useful observations are made, visual appraisal of possible spawning sites, even when confirmed by the observation of a few eggs, is not necessarily indicative of egg survival or reproductive success.

- The cited observations of deferred northern pike spawning are of interest. However the explanation may not be so much one of adaptation (as is proposed), but may be due simply to a lack of earlier spawning opportunity. The progressive elimination of larger (older) fish from the population may also have been a factor; older fish often tend to spawn earlier.

- There is no way of quantifying, from a qualitative examination such as this, any relationship between egg deposition and the "requirement" for egg deposition to meet the actual needs for maintaining the population.

C12. Osborne, T.C. and D. Ernst. 1979. Walleye and northern pike spawning area examination on portions of Namakan and Rainy Lakes, spring 1979.

- Many useful observations are made/provided.

- Some of the same shortcomings are evident as for Crane, Kabetogama, and Sand Point Lakes (item C11 above).

- Water levels in the year of the survey (1979) were described as uncharacteristically high. This is not notably evident from the hydrographs (Acres Exhibit 102, in Baxendale 1994), except in comparison to the ensuing year (1980).

C13. Osborn, T.C., D.B. Ernst and D.H. Schupp. 1981. The effects of water levels and other factors on walleye and northern pike reproduction and abundance in Rainy and Namakan Reservoirs.

- The addition of more years of data to Johnson's time series, and the (purported) demonstration of breakdown in Johnson's (e.g. 1967) positive correlation between walleye year-class strength and years when Rainy Lake water levels were high enough to cover the spawning shoals, is an important new development.

- However, the disqualification of about 80% (Ontario component) of the Rainy Lake commercial CPUE data on account of a methodological change in the Ontario fishery seriously erodes the power of the analysis.

- Furthermore, Larry Kallemeyn has pointed out (personal communication) that some of the ice-out dates and water elevations used in this report are not correct, and that "the authors never attempted to go back and reanalyse their data with corrections." This is probably not consequential although (for example) the ice-out dates given for Rainy Lake

(Table 1 of the document) differ by a high of 10 days (too soon) and by an average of 1 day (too soon) compared to the attributed source (International Falls Daily Journal). Ice-out dates as thus recorded may already be somewhat subjective ("the earliest date the length of the lake could be navigated"), and the introduction of an additional element of data error into this the most dynamic period of annual water-level changes in these lakes is unfortunate.

- It may be worthwhile to determine the effective magnitude of this data problem, and to reassess the conclusions at least qualitatively in this light.

- The inability to confirm any relation between average spring water levels and year-class strength notwithstanding, the demonstration of a significant relation between the change (rise) in water level during the spawning period and subsequent abundance of fish (albeit for only one of three age classes examined, of only one of the two species, in only two of the four lakes) does open a new avenue for contemplation.

C14. Cole, G.F. 1982. Restoring natural conditions in a boreal forest park.

- This pioneering introduction of a comprehensive outlook to describing the situation and developing proposals for improvement is an important milestone in the treatment of this matter.

- The work is too sketchy and the treatment too 'basic' to contribute significantly of itself to addressing the specifics of problems regarding fisheries and related aquatic resources in Voyageurs National Park. However, the beginnings of a framework for such an effort are made apparent.

- The author sees value in restoring a more natural hydrological regime, but gives more weight to the stability aspects of the natural system than to the ecological benefits of natural variation, particularly in the context of extreme highs and lows.

C15. Flug, M. 1986a. Analysis of lake levels at Voyageurs National Park.

- While this document presents no specific data or impact assessments for fisheries or for any resources, it does make a very useful contribution by introducing the concept (and the reality) of an optimizing simulation model into this arena.

- This model provided an important tool for examining whether specific/proposed changes to the hydrological operating rules (pertaining in Voyageurs National Park) would change hydrological conditions for the benefit of aquatic resources (or for other beneficial uses) in the system.

- The model which was developed is somewhat 'coarse', i.e. it routes mean monthly inflows through the system and cannot accommodate daily operational parameters in real time nor provide daily outputs.

C16. Monson, P.H. 1986. An analysis of the effects of fluctuating water levels on littoral zone macrophytes in the Namakan Reservoir/Rainy Lake system.

- The literature pertaining to tolerance of particular macrophytes to water level fluctuations is poorly developed and inconsistent, and provides a relatively weak background for this kind of work.

- It was not possible to deploy a statistically adequate range of fully representative stations. As the author concedes, "In a system of lakes as large and variable as that involved in this study, the designation of a 'typical' suite of littoral zone macrophytes is problematical, at best."

- Although reasonably useful baselines were established, the title of the document is more reflective of aspiration and intent than of actual achievement, at least in reference to a comparative context (among the lakes, with different amounts of water-level fluctuation).

- A suggestion in the data of an overall difference in macrophyte communities from one year to the next could not be followed up in respect to a possible reflection of different water regimes in the two years.

- The paucity of wild rice in these lakes at present, compared with anecdotal records from the past, is enigmatic. A useful synopsis of wild rice biology as it relates to habitat requirements is presented, and numerous (albeit not very convincing) hypotheses can be advanced on why the regulated water regimes in these lakes might have been (and might still be) detrimental. "The reality of 'the wild rice problem' is therefore the need for further research."

- The identification of turbidity as a probable correlate with water level manipulation is important because of the effects of turbidity on macrophytes as well as on other organisms including fish (e.g. walleye). This subject merits further attention.

C17. Kallemeyn, L.W. 1987a. Correlations of regulated lake levels and climatic factors with abundance of young-of-the-year walleye and yellow perch in four lakes in Voyageurs National Park.

- This is the first known examination of factors besides water levels and exploitation as possible determinants of walleye (and yellow perch) populations in these lakes.

- Although shoreline seining may be considered a weak method of fish sampling in terms of reproducibility, it has the strong advantage of being a direct methodology that avoids requirements (as per earlier studies) for back-calculation and other indirect simulations based upon older fish to provide estimates of young-of-the-year abundances. This may be the basis for the different conclusions compared to those of Osborn et al. (1981). As the author also notes, however, abundance in the first summer of life may not be consistently reflected in ensuing effective year-class strength.

- The positive associations observed between year-class strength of walleye (and yellow perch) and thermal conditions (air and water) are certainly suggestive of an influence not previously analyzed for these waters. However, the fact that the most consistent and strongest correlations were with air temperatures (higher and more stable being preferred) rather than with water temperatures suggests that the thermal influence may be mediated quite indirectly. The fact that water temperatures were actually measured on only one lake (Kabetogama) is a weakness in the design.

- A plausible environmental mediator between air temperature and year-class strength would be water levels and flows. It is of interest that the most consistent and strongest correlations observed (this study) for walleye year-class strength continued to be hydrologically-based (specifically, for this study, based on lake levels in the short period after ice-out).

- What is not explored (this paper) is the relationship (if any) between ambient temperatures and lake levels, perhaps in turn mediated through precipitation or perhaps through timing of spring runoff (which would in turn be masked or modified by the regime of lake regulation). This seems potentially fertile ground for further study.

- The observed similarity in fluctuations of walleye young-of-the-year CPUE in all the lakes except Namakan is of interest, especially for the ensuing proposition that this "may result from use of the Namakan River for spawning...which would reduce the dependence of fish on lake levels for satisfactory spawning habitat." The use (or not) of out-of-lake reproductive habitat by the economically important fish species in these lakes certainly merits further study.

- Introduction of the concept of an alternative (or complementary) strategy to lower the effective elevation of spring spawning sites through summer drawdowns is an important contribution.

C18. Kallemeyn, L.W. 1987b. Effects of regulated lake levels on northern pike spawning habitat and reproductive success in Namakan Reservoir, Voyageurs National Park.

- The observation that under the present water management regime northern pike spawning requirements (in Namakan Reservoir) are accommodated only in years when the maximum levels permitted are inadvertently exceeded is of fundamental importance. Although this does occur periodically, the author argues that such "management by default" cannot be a reliable means of providing the necessary spawning habitat for northern pike on a long-term basis.

- Extension to northern pike of the concept enunciated for walleye, that summer drawdown might be used as an alternative (or, even better, as an effective complement) to higher water levels in spring, this through rejuvenation of spawning sites at lower elevations, is an important contribution. With respect to northern pike this strategy would be expected to operate by lowering the elevation of appropriate aquatic vegetation, whereas with respect to walleye it would be expected to operate by removing organic matter from spawning shoals.

C19. Kepner, R. and R. Stottlemyer. 1988. Physical and chemical factors affecting primary production in the Voyageurs National Park lake system.

- The authors note that changes to natural systems are difficult to predict quantitatively even with respect to very onerous environmental insults such as toxic pollutants. Lake drawdown, especially at the scale represented by Rainy/Namakan, is deemed a relatively "subtle" form of environmental insult. For such it is acknowledged that evaluation, in terms of projecting impacts on such system functions as nutrient dynamics and primary production, will inevitably be weak and subjective.

- The nutrient generally acknowledged to be most critical in such lakes, i.e. phosphorus in its various forms, was not measured due to procedural problems or shortcomings.

- The total phosphorus mass balance model presented, while replete with shortcomings, does suggest that prediction of impacts on photosynthetic productivity by way of water regulation changes in these lakes might be within the realm of possibility, albeit requiring a great deal more information.

- While some (slight) reduction in phytoplankton biomass and primary production is predicted under a 'more natural' hydrological regime, and while "ramifications upward through the food web" would be anticipated, no attempt was made nor do techniques yet exist to actually model or quantify the magnitude of such predicted lower-trophic-level changes on upper-trophic-level fish (such as walleye and northern pike). It thus remains problematical whether this approach could be functionally worthwhile or cost-effective.

- The authors' arguments for a return, to the extent possible, to more natural hydrological conditions is reasonably based on expectations for:

- Reduced bottom areas exposed by drawdown and accompanying sediment-water interactions.

- Reduced die-off of littoral macrophytes and their accompanying nutrient inputs.

- Reduced nutrient concentration effects due to volume changes.

- Reduced alteration of the aquatic habitat in general.

- The authors make the useful observation that hydrological operating rules should not be 'cast in stone', but should be constantly open to improvement based on new knowledge and experience.

C20. Kraft, K.J. 1988. Effect of increased winter drawdown on benthic invertebrates in Namakan Reservoir, Voyageurs National Park.

- Provides a concise synopsis of the most pertinent literature on this subject.

- Internal consistencies within the observations are sufficiently good to inculcate considerable confidence in the representativeness of the data set. This is a common concern when attempting to extrapolate to an overall lake from what are invariably (in such studies) a relatively few, discontinuous, 'accident-prone' highly-labour-intensive grab samples taken (particularly in this case) from a dynamically fluctuating environment.

- The study would have been much strengthened had it utilized something other than Rainy Lake as the effective control. Impact of water regulation on invertebrates in Rainy Lake itself is a matter of considerable interest in the present context and it is frustrating, not to mention methodologically compromising, for it to be used as the base of reference for Namakan in this regard. The study would also have been improved had it accounted for 'hydroperiod' by incorporating a fixed point from which the period of inundation could be estimated. (Refer to the work of Meeker and Wilcox on aquatic macrophytes, items 22 and 33 of this document).

- The study does derive convincing demonstrations of effects, within the benthic invertebrate community, of winter drawdown. There is no concerted treatment of any of the other aspects of hydrological regulation, such as variation in amplitudes or in ranges of water-level change. There is no attempt to interpret the findings in any broader context, such as implications for fish. For example, one wonders if or to what extent increased productivity of chironomids might compensate reductions or losses in some other groups.

- Incomplete examination of some of the groups, particularly the chironomids (by the time of the report) may have left some potential insights undisclosed.

- The author gives no consideration to the possibility that some or many of the observed impacts on the benthic invertebrates might have been mediated through the macrophyte communities, rather than by physical factors acting directly on the invertebrates themselves.

- Dynamics of mortality and/or migration of invertebrates as an element of stranding in conjunction with the combined forces of de-watering and freezing is treated as a confounding factor, rather than as a key operating phenomenon to the extent that is probably warranted. This is an important area for further (and difficult) study.

- Hypotheses or predictions regarding the future, either under continuation of the present regime or some alternative, are not developed beyond the generalization that "A reduction in drawdown in Namakan Reservoir should result in an amelioration of the drawdown effects observed in this study, and any increase will undoubtedly cause further changes."

C21. Kallemeyn, L.W., M.H. Reiser, D.W. Smith and J.M. Thurber. 1988. Effects of regulated lake levels on the aquatic ecosystem of Voyageurs National Park.

- The 'thumbnail' characterization of the present (as per 1970) mode of regulation is stated in terms which are 'ecosystematically meaningful', and as such provides a useful building block for this and subsequent examinations.

- From the perspective of "fish and related aquatic resources", this presentation is confined to material (for northern pike) already presented earlier. However, the simultaneous attention to other biotic elements (birds and mammals) of the aquatic ecosystem introduces an important new dimension.

- The authors note/repeat that water levels within three weeks after ice-out already reach or exceed levels important for northern pike spawning in over half the years. The observation merits reiteration, however, that "In all instances where this occurred, lake levels were above the upper level of the rule curve."

- The consistently negative impacts of the current water management regime deduced for all species examined, encompassing three widely divergent classes of biota (fish, birds, mammals), is mutually reinforcing.

- The important point is made that water level fluctuations per se are not the problem, since "all these species evolved in an ecosystem that included fluctuating water levels." The problem (this aspect), as perceived, stems from the present unnatural timing and magnitude of those fluctuations.

C22. Meeker, J.E. and D.A. Wilcox. 1989. A comparison of aquatic macrophyte communities in regulated and non-regulated lakes, Voyageurs National Park and Boundary Waters Canoe Area, Minnesota.

- This study utilized a basic design which appears superior to the one utilized earlier (1982 and 1983) by Monson (1986). The sampling in the present case was designed to focus on depths with different/specific ecological attributes related to water regimes, with reference to a nearby similar but unregulated lake which also served as a control. This design permits attribution of differences in plant communities to water-level regulation.

- The good agreement in aquatic plant community characteristics observed between study sites within lakes enhances confidence in the validity of the extensive differences observed among lakes. "In contrast to the conclusions of Monson (1986), the regulation of water levels on Rainy and Namakan lakes does alter the plant communities there."

- The failure to sample deeper than 1.75 metres is unfortunate. Since effects/differences were observed to this depth, the interpretations without benefit of deeper samples are necessarily open-ended.

- Provides an excellent synoptic review of the role of macrophytes in aquatic ecosystems, stressing that different macrophyte communities represent different habitats for aquatic fauna. "Much of the difference depends on the species diversity, density and structural aspects of the plants within the macrophyte community."

- Provides a strikingly effective graphic presentation, "as it might be viewed by aquatic fauna", of differences in macrophyte community composition and structure pertinent to these three lakes.

- The model of an optimal macrophyte community in Lac La Croix associated with an intermediate level of hydrologic disturbance, and sub-optimal macrophyte communities in Rainy Lake (too little disturbance) and in Namakan Reservoir (too much disturbance) is very convincing. Simultaneous comparative fish and invertebrate community studies involving all three lakes would provide the ultimate "reality check".

C23. Kallemeyn, L.W. and G.F. Cole. 1990. Alternatives for reducing the impacts of regulated lake levels on the aquatic ecosystem of Voyageurs National Park Minnesota.

- This report is essentially an 'administrative step' between the primary studies which were commissioned by the U.S. National Park Service and the work of the International Steering Committee which reported in 1993.

- Since the material contained is fundamentally reviewed and evaluated in the context of other/earlier items in the present document (i.e. in this Section), a repetition will not be pursued here.

- The report, of course, is a necessary and invaluable compilation, synthesis and treatment of (then) existing information, for these particular waters as well as from other relevant sources. It sets out in detail the process which was followed to develop, evaluate, and ultimately choose among a number of alternative hydrological models. As an item in what will surely be an ongoing process to seek optimal/compromise lake/reservoir operating rules, the development and presentation of a methodology incorporating ranking factors by ecosystem component for different alternatives is a particularly important contribution.

- Recognition not only of the role of water-level fluctuations, but also of inter-annual variability of water levels and fluctuations in maintaining the health of aquatic ecosystems is of interest and importance.

- The evaluation of alternatives is handicapped by some of the shortcomings of the "Flug model" for hydrological simulation which was employed. However, it is unlikely that this had significant repercussions with respect to fisheries and related aquatic resources.

- No obvious flaws or errors of interpretation are apparent in the ranking factors which are proposed and used for particular "fisheries and related aquatic resource" communities in respect to specific hydrological features.

C24. Kallemeyn, L.W. 1990a. Impact of sport fishing on walleye in Kabetogama Lake, Voyageurs National Park.

- No explanation is provided on how the number of hours expended per angler in an angler-day was determined. This datum is integral to the expression of fishing pressure as angler-hours, a derivative which is employed in the presentation.

- All of the walleye tagged (Table 1) were ascribed to spawning-run sources (page 27). Yet other sources of walleye for tagging are implied under "Methods". No definition or description of 'spawning run' is provided. The nature and contribution of 'spawning runs' (implying a stream orientation) vis-a-vis spawning aggregations (which would be a more appropriate term for spawning on shoals) is potentially significant to the evaluation of walleye spawning sites in the context of lake/reservoir/stream water levels and flows. The strong bias towards males (92%) in the 'spawning runs' does suggest a particular time phase in a stream-oriented spawning situation.

- The main value of this paper is in the rigorous baseline it provides against which walleye population and fishery parameters can be assessed in future. Paucity (although not a complete lack) of such information from the past precluded a confident analysis of the status of the Kabetogama walleye fishing as at 1985.

C25. Wilcox, D.A. and J.E. Meeker. 1991. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minnesota.

- This is an inspirational publication, reporting on a well-designed and successful study.
- The authors note that emphasis in previous studies "has usually been on characterization and prediction of communities in reservoirs with large and varied water-level fluctuations. Little information is available about macrophyte responses in lake systems where water level cycles have been closely regulated for many years and the amplitude has not been extreme. The occurrence of such systems that have no obvious expanses devoid of vegetation may lead to a misconception that natural plant communities are present."

- The paper makes clear just how deep, fundamental, and important such a misconception could be.

C26. Cohen, U. P. Radomski and R. Moen. 1991. The fish communities of Rainy Lake and the Namakan Reservoir.

- This massive report is written in an style which is at times somewhat informal and self-deprecating. This seems to be intended as a mechanism to counterbalance the sheer bulk and scope of the presentation. It is a ploy which can invoke reader interest and sympathy or, alternatively, provide gold-plated openings for easy criticism. The considerable attention devoted to detailing data and analytical shortcomings and constraints is very useful but again can facilitate either positive or negative reaction.

- The report is the first to attempt to quantify the concept, tentatively enunciated by Kallemeyn and Cole (1990), that water level fluctuations, and more particularly variability (or periodicity?) in those fluctuations, may be more important than particular water levels to accommodate fish in these waters. This brings an order-of-magnitude greater complexity to the question of optimizing the hydrological regime. It also poses an unwelcome intrusion for anyone who would have hoped that the matter would get more comprehensible and more tractable with increasing knowledge over time.

- Additionally inconvenient, this new dimension is identified and introduced through application of a statistical treatment (spectral analysis) that is at best difficult to follow and comprehend. Furthermore, the investigators deemed it appropriate to use an intuitively suspect surrogate or proxy for fish abundance, the magnitude of the annual commercial harvest, in order to best meet the statistical requirements of their key analysis. All of which requires acceptance of the supposition that the abundance of fish available for catching derives proportionately from (earlier) life history stages to the extent that such earlier life history stages are affected by water levels. As a final reason for dismay, it is immediately obvious that an ecologically satisfactory solution to address the newly elucidated requirement (or at least the newly enunciated preference) for periodically greater water level fluctuations around some mean would be very costly, or even completely impractical, in economic and social terms.

- As already noted, the report introduces some novel, unfamiliar and perhaps in some cases, questionable statistical treatments, in an effort to deal with the unusual scope and diversity of data content, as well as to advance the methodology of analysis vis-a-vis previous treatments.

- Similarly, the report introduces many new (and arbitrary ?) definitions, which may be useful and intriguing, but have not yet stood the test of time. For example "A community is (defined as) a collection of those species whose CUE summed to over 90% of the total CUE consistently."

- The report was released at least one-draft-too-soon. Minor typographical and some more serious construction errors provide more windows for easy criticism.

- Despite these problems and "unconventionalities" the report poses an hypothesis (on the value of variability) which is intuitively difficult to repudiate a priori. This hypothesis, and the process leading to it, is fundamentally consistent with such 'ecological axioms' as:

- The more we learn the less complete our spectrum of knowledge becomes.
- Ecosystems are generally most stable and most productive overall when maintained in their natural state.
- Everything in an ecosystem affects (is connected to) everything else.

- Proliferation of edges, in space or in time or both, is conducive to long-term ecosystem stability and productivity.

- The report was downplayed in some quarters because it (per se) had not (at the time) passed peer review leading to publication in a primary journal.

C27. Wilcox, D.A. and J.E. Meeker, 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota.

- A very useful publication, which extracts those findings from the more comprehensive study report which pertain to assessing the implications of the floristic changes for the animal (including fish, birds, mammals) components of the aquatic ecosystem in Rainy Lake and Namakan Reservoir.

- The authors report no actual new faunistic (e.g. fish) observations per se, but interpret the literature in an effective and convincing manner.

- They make the important point that water-level management plans for lakes/reservoirs have generally tended to focus on direct effects, e.g. on aquatic fauna, including fish. "However, indirect effects on aquatic fauna (e.g. on fish) may also result from alteration of wetland and aquatic plant communities. These effects should be considered when water management plans are developed."

- The linkage between macrophyte effects and benthic invertebrate effects as determined by hydrologic regime is convincingly presented. However, the conclusions would be stronger if the field studies had been conducted concurrently and had utilized the same stations. The invertebrate program was undertaken in 1983 - 1986 whereas macrophytes were sampled in 1987, at different site locations.

C28. Kallemeyn, L.W. 1992. An attempt to rehabilitate the aquatic ecosystem of the reservoirs of Voyageurs National Park.

- The synopsis which is provided of the framework and intent of the USNPS research program is useful. Among other things, it provides a coherent perspective on the expected utility of the work, i.e.:

- "It would allow the USNPS to present recommendations to the IJC for alternative regulatory programs if warranted."

- "It would allow testing whether alternative programs that more closely approximated natural conditions could be used without seriously conflicting with the other water uses."

- "Should the IJC authorize an alternative, results from these studies could serve as baseline information……to evaluate the impacts of the new regulations."

- This is a verbal overview only; no actual data are presented. Details are available in the primary reports.

- The introduction which is provided to the process embodied in the International Steering Committee's deliberations is valuable.

C29. Wepruk, R.L., W.R. Darby, D.T. McLeod and B.W. Jackson. 1992. An analysis of fish stock data from Rainy Lake, Ontario, with management recommendations.

- This is a valuable compendium and synthesis of the available body of fishery research by the Province of Ontario pertaining to Rainy Lake. The Ontario research in this particular geographical area has tended to be fishery-management-oriented rather than ecosystem-process-oriented as has been more the case in Minnesota. This is a reflection of mandates, and especially of the presence in this area of Minnesota (but not in Ontario) of a National Park dedicated specifically to, among other things, understanding, restoring and maintaining overall ecosystem values.

- Availability of this comprehensive document provides a convenient shortcut to the previous literature and to present initiatives. In conjunction with the Minnesota-Ontario Boundary Waters Fisheries Atlas (1992) it covers the available documentation on fish stock status, trends, and available harvest estimates. The atlas, of course, has a broader geographic focus, embracing Namakan Lake, Rainy River and Lake of the Woods in addition to Rainy Lake.

- The management proposals contained in this report, following public consultation and further reflection by an international task group, have been realized for Rainy Lake as follows (as at February 1994):

1) South Arm

- for residents of Canada, and non-residents who are exempt from the new regulations, the daily catch and possession limit for walleye has been reduced from six (6) to three (3). Legal size is now 35 to 45 cm long, and only one (1) walleye larger than 70 cm may be kept.

- to keep fish, non-resident anglers who do not meet tourism or property requirements need a seasonal South Arm Rainy Lake Border Waters Conservation Tag.

- tags must be affixed to the back of the angler's Ontario non-resident fishing license.

- tags can be purchased for $10.00 from any Issuer of Ontario Fishing Licenses.

- the following daily catch and possession limits are established for non-resident anglers fishing under the authority of a South Arm Rainy Lake Border Waters Conservation Tag:

  * zero muskellunge or sturgeon;
  * zero walleye;
  * zero sauger;
  * two bass;
  * two northern pike;
  * fifteen crappie;
  * zero lake trout

- non-resident anglers who do not meet tourism and property requirements or do not hold a conservation tag, may only fish on a catch and release basis, and no fish may be kept for a shore lunch.

2) Remainder of Rainy Lake (North Arm and Redgut Bay)

- for residents of Canada, and non-residents of Canada who are exempt from the new regulations, the daily catch and possession limit for walleye has been reduced from six (6) to three (3). Legal size is now 35 to 45 cm, and only one (1) walleye larger than 70 cm may be kept.

- non-resident anglers who do not meet tourism or property requirements, may only fish on a catch and release basis, and no fish may be kept for a shore lunch.

- Lack of good agreement among various indices of abundance (e.g. commercial, angling, and test-netting CPUE for the South Arm of Rainy Lake) is somewhat disconcerting, but clear reasons are hypothesized.

- Possible new environmental constraints to fish (especially walleye) productivity in Rainy Lake are tentatively identified, but not analyzed. Those mentioned are spawning bed degradation, new species introductions, and water-level management. With respect to the former, several rehabilitation projects have been undertaken so that "Spawning habitat is no longer considered to be a limiting factor to the rehabilitation of walleye stocks." With respect to the latter, it is asserted that this is "being addressed by management action", viz. the detailed studies recently completed along with the (then current) deliberations of the International Water Level Steering Committee.

- The virtually exclusive focus of the work here reported on fish population management provides an 'uncluttered' demonstration of exploitation impacts in their own right and is very useful and important in this context; however, the disassociation from what might be called an 'ecosystem perspective' carries its own shortcomings and disadvantages.

- These shortcomings are recognized and appreciated by the authors. They note that "In the long term it will be necessary to take an ecosystem approach to management and this will mean managing additional components of the fish community." They also recognize that information on other elements, such as aquatic vegetation, plankton and benthos "is essential in assessing the impact on the ecosystem of various perturbations such as changes in water levels."

C30. International Steering Committee. 1993. Rainy Lake and Namakan Reservoir Water Level: Final Report and Recommendations.

- The Steering Committee report is a lucid document that fully addresses the Committee's mandate within the confines of existing knowledge.

- It is not clear to what extent the Steering Committee members were charged to actually represent their parent agencies. This would ordinarily be assumed but there are indications, including a certain lack of membership stability, that perhaps not all agencies took the matter as seriously as might have been expected. Dutiful accreditation of participants is a key element in any consensus-building exercise and becomes especially crucial for buy-in at the end of the process.

- It is noted that while ecosystem-oriented interests and concerns appear to be the key motivators for change and certainly the central focus of the present debate, the proposed rule curves are considerably divergent from the 'preferred' rule curves for the 'single-purpose' accommodation of fish and wildlife.

- With both the earlier (Flug) and the new SIMUL8 hydrologic models available to it, the Steering Committee chose to rely more heavily on the latter. The SIMUL8 model is both more sensitive (resolves into much shorter time units) and also tends to project a greater risk of flood events. The Steering Committee, commendably, opted to "err on the side of caution" in this regard.

- The Steering Committee process embodied a concerted effort to inform the public and to seek and utilize public input.

- The Steering Committee report includes the expression and the analysis of public opinion and reaction, both solicited and unsolicited, as the exercise unfolded.

- The Steering Committee report conveys the impression of being less rigorous and less definitive than the NPS report (Kallemeyn and Cole 1990: item 23 herein) which provided much of the stimulus and background. It is in fact not surprising that a true consensus effort would suffer in terms of sharpness of presentation, which of itself is testimony to the comprehensiveness of the process, and in that sense at least, to the legitimacy of the result.

C31. Kallemeyn, L.W., Y. Cohen and P. Radomski. 1993. Rehabilitating the aquatic ecosystem of Rainy Lake and Namakan Reservoir by restoration of a more natural hydrologic regime.

- A valuable retrospect of the International Steering Committee background, process, and results, e.g. the use of "principled negotiation" for incorporating environmental policy into resource-use conflict resolution.

- Provides a useful shortcut to comprehending some of the methodology and rationale embodied in the earlier background documentation.

- Provides a useful synopsis of the Steering Committee conclusions, among them, with respect to fish and related aquatic resources, that:

  • A preferred water management system should allow for variability in water levels,

  • A summer drawdown, by providing spawning habitat at lower elevations, would reduce the amount of spring rise required to provide satisfactory spawning conditions and, in general,

  • The more closely that the magnitude and timing of natural fluctuations in lake levels could be restored, the greater the benefits would be to the affected species which evolved with those systems.

- Enunciates realistic insights with respect to implementation of the Steering Committee's recommendations:

  • The proposals should be considered as goals towards which to work rather than as objectives to be achieved. Continued presence of the dams and conflicting water uses pose real and legitimate constraints.

  • Proponents for the conflicting water uses believe that the preferred alternative (of the National Park Service) places too much emphasis on ecosystem integrity.

  • "Incorporating some of the annual and long-term variability in water levels that is an integral component of an unregulated system will be particulary difficult", and may require development of a better forecasting system.

C32. Parkhurst, B.R., W. Warren-Hicks, T. Etchison and J. Butcher (The Cadmus Group). 1993. Evaluation of the effects of water level fluctuations and other environmental factors on walleye and northern pike populations in Rainy Lake and Namakan Reservoir.

- Although the treatment is methodologically formidable, it is ultimately no more credible than the earlier treatments which it disparages.

- A fundamental nagging problem is with the identification and use (this critique, as well as earlier analyses) of appropriate dependent variables. Actual fish harvest (which is used) is a notoriously unreliable proxy for fish abundance. There is no compelling reason to accept the proposition (which is advanced in the critique) that commercial catches can be taken as reliable indicators of abundance in this instance on the basis that both commercial catches and test-net catches (the latter being a fairly well accepted indicator of abundance) were found to be cross-correlated in "similar patterns" with something else (i.e. with the "physical variables"). If harvest and/or test net catches are reliable (and genuinely correlated) proxies for abundance, then even better proxies pertaining to each of them (i.e. CPUEs) ought to be positively correlated with each other as well. In fact, Wepruk et al. (1992) show an <u>inverse</u> relation over a period of 30 years between commercial-fishing CPUE and index-fishing CPUE for both walleye and northern pike in <u>both</u> North and South Arms of Rainy Lake (Canadian sector). It is true that these two CPUE indices are directly correlated in Redgut Bay, but this is a rather atypical or at least a rather geographically isolated locale among these lakes.

- A different problem pertains to use of seining data as an index of young-of-the-year (YOY) abundance, specifically the amalgamation of data from different regions of these lakes without consideration or confirmation of their homogeneity.

- In both cases, the procedures adopted are understandable; commercial harvest and amalgamated seine hauls are simply the only "workable" data available which could be hoped to reflect abundance over an adequate span of years to permit the analyses here attempted. But workable data are not necessarily reliable or credible data unless shown to be so, and this shortcoming is in sharp contrast to the exquisite care which is taken by the protagonists to ensure the admissibility of data pertaining to the independent variables which are examined.

- Many of the derivations made and most of the predictions presented are counter-intuitive. For example:

- "For (Rainy Lake) walleye, if we increase ELEV15 (lake elevation 15 days after ice-out) by 0.8 feet (the change proposed by the International Steering Committee), with all other variables held constant, the predicted values of commercial catch <u>decrease</u> by a range of 2% to 4%"...(with much uncertainty).

- "For northern pike (still Rainy Lake), if we increase ELEV15 by 0.8 feet, the predicted values of commercial catch <u>decrease</u> by as much as 19% to 30%"...(with much uncertainty).

- "For YOY walleye (still Rainy Lake), if we increase ELEV15 by 0.8 feet, the predicted values of YOY catch <u>decrease</u> by a range of 50% to 100%"...(with much uncertainty).

- "For (Namakan Reservoir) walleye, if we decrease YMXR5 (maximum minus minimum yearly lake elevation with 5-year lag) by 25% (a supposed approximation of the change proposed by the International Steering Committee), the predicted values of commercial catch decrease in the range of 22% to 71%"...(with much uncertainty).

- "For northern pike (still Namakan Reservoir), if we decrease YMXR by 25%, the predicted values of the commercial catch decrease by a range of 25% to 51%"...(with much uncertainty).

- It seems clear that many of the analyses presented in this crique, and probably in the Cohen et al. (1991) paper as well, are beyond the range and capability of the existing data to accommodate. There is really not enough information, or at least not enough information specific to the purpose, to realistically permit such a heavy statistical approach.

- The most credible observation in the document, although not necessarily extending to the exclusivity implied in the ensuing conclusion, is that "The fisheries in these lakes have all the classical characteristics of over-fishing…. The best approach for improving these fisheries would be to reduce harvests".

C33. Gray, B.T. and Z.E. Kovats (Golder Associates and/or Environmental Management Associates) 1993. Review and analysis of studies on the effects of water level fluctuations on wildlife populations on Rainy Lake and Namakan Reservoir.

- This document focuses more on birds and mammals than on "fisheries and related aquatic resources".

- The tendency to endorse the work of Monson (1986), albeit apparently not read; and to repudiate the work of Meeker and Wilcox, largely because they were deemed not to have taken enough samples, seems more indicative of the focus of the reviewers than an illumination of the materials reviewed. In point of fact, it was the Monson study that demonstrated very little; generally on account of design flaws such as the reviewers attribute to Meeker and Wilcox. Pertinent is Kallemeyn and Cole's insightful summary that "Meeker and Wilcox's (1988) results indicate Monson's inability to detect differences between (sic.) the lakes may indeed have been due to inadequacies in his sampling design. They found elevation alone was not as important as elevation mitigated by the period of inundation (hydroperiod) in determining vegetational distributions. They concluded that a study would likely fail to detect differences in the plant assemblages unless it included a fixed point from which the period of inundation could be estimated. Monson did not account for hydroperiod in his study."

- Meeker and Wilcox, on the other hand, deployed a design of sufficient elegance that they were able to derive very credible conclusions with an economy of sampling effort (purported design flaws 1, 2 and 4) and without the need to invoke other hypotheses (purported design flaw 3). The reviewers go to the spin-off paper (Wilcox and Meeker 1991) from which they derive a round-about analysis to support their contention of inadequate replication. However, this question was adequately put to rest at the outset (i.e. in the primary report) wherein the researchers showed that "the two study sites at each lake were similar to each other; they seemed to adequately represent each lake. The detrended correspondence analysis (DCA) ordination showed that the transects at any given water depth in an individual lake had very similar plant communities, as witnessed by the similarities in ordination coordinates." The power of this demonstration is in fact very impressive.

- Granted, the failure of Meeker and Wilcox to sample deeper than 1.75 m does leave somewhat open-ended the possibility that positive responses by the macrophyte community at greater depths might be occurring. However, it is unlikely that this could be substantial. Monson (ibid) suggests that in view of the transmissibility of light for the lakes in question, "macrophyte growth would be limited to depths of about 3 meters or less."

- Sampling in only one year can of course be legitimately criticized. But the critism does beg the question of how many years of results would be 'adequate'. This might indeed be an area where further replication could be used to pay considerable dividends, in the event that additional macrophyte studies were contemplated.

- The conclusions of Meeker and Wilcox are paraphrased in an unconscionably weak light. To rest on the out-of-context quotation (actually taken from Kallemeyn and Cole) that Meeker and Wilcox found "shoreline vegetation (to be) similar in all three lakes, but that significant differences were evident in plant assemblages from the deeper water zones" camouflages the reality of what they <u>did</u> find/report, i.e. "The aquatic macrophyte communities of Lac La Croix, Rainy Lake, and Namakan Lake differed at all depths, and the differences were more pronounced along the deeper transects…. The differences in plant communities can be attributed to water-level regulation because the sampling was designed to focus on depths with different ecological attributes related to water regime". In fact, the "shoreline vegetation" which Meeker and Wilcox acknowledged to be similar among the lakes was for the shoreline transect (0.5 m) per se, which is where the greatest differences could not be (and were not) expected. As a result of the transect layout design, the 0.5 m transects in Rainy and Namakan "do not have minimally flooded conditions throughout the growing season in all years. In low-water years (as 1987 was), these transects are ecologically similar to those (at the same relative elevation) in Lac La Croix; the similarities in vegetation between the shoreline transects reflects this fact."

- In short, the critique by Gray and Kovats does not appear to overturn the analyses and important conclusions of Meeker and Wilcox (1988).

- With respect to benthic (macro)invertebrates, Gray and Kovats reviewed the work of Kraft (1988). They noted that Kraft attributed differences in invertebrate communities between Namakan Reservoir and Rainy Lake to different degrees of water level fluctuation. While agreeing with Kraft's main conclusion concerning impact at 2 meters in Namakan Reservoir, the reviewers suggest that "the findings of this study may be inaccurate due to (1) the absence of pre-impact data, (2) the use of control sites that are located in Rainy Lake, with a lower than natural degree of water level fluctuation, and (3) methods employed during invertebrate sample processing." Concerns (1) and (2) appear to be justified, but do not detract seriously from Kraft's main conclusion in its relative expression. Concern (3) also is valid, but probably has insignificant consequences for Kraft's relative assessment.

- Gray and Kovats' general conclusion that changing the water regime as proposed by the International Steering Committee would have little or no noticeable benefit on aquatic ecosystem components connected with the welfare of the fish communities seems a bit severe even in reference to their own treatment of the evidence. They go to the extent of seeking possible negative outcomes, proposing that "Reducing the extent of water level fluctuations in Namakan Reservoir might decrease the detritus load and thereby negatively impact the crayfish populations." This seems like an unworthy suggestion when viewed in the context of the spectacular crayfish mortalities observed and attributed to winter drawdown in Namakan Reservoir by Sharp as far back as 1941.

C34. Cohen, Y. and P. Radomski. 1993. Water level regulations and fisheries in Rainy Lake and Namakan Reservoir.

- This is a useful and more credible (by virtue of its being published) consolidation of a central thesis of an earlier more broad-ranging report (Cohen et al. 1991.)

- Brings to the fore the concept that fluctuations in the ranges of water levels are more important than water levels per se in determining the long-term stability and productivity of aquatic ecosystems.

- Uses statistical treatments that are only beginning to come into the mainstream of ecological science.

- Cannot overcome the urgent doubts which are engendered about the applicability of the data at hand to this kind of treatment. The impression is left of data being forced through a treatment mill to wring a conclusion which the data are not really equipped to inform. The conclusions could be correct, but the process remains a distraction.

C35. Pereira, D.L., C.S. Anderson, P.J. Radomski, T. Sak and A. Stevens. 1995. Potential to index climate with growth and recruitment of temperate fish.

- The apparent influence of "discordant thermal events" on walleye recruitment and growth in Rainy Lake is of interest. The lack of coherent response among different lakes suggests that the disruptive impacts of "key events" themselves may be more important than their average manifestation. Perhaps there are impacts associated with variability in climate, analogous to impacts associated with variability in, say, water levels from year to year.

- The discussion on dynamics of walleye recruitment is useful, i.e.:

  - the "common finding that walleye recruitment is positively associated with first-year growth" (several references), and

  - the finding of "significant temperature - recruitment tests" in Rainy Lake, and that

  - "Factors involved in the link may include prey size suitability, lipid content, or vulnerability to predation", while

  - "growth rates may influence (vulnerability to) mortality from cannibalism".

C36. Eibler, J. 1995a. Large lake sampling program Rainy Lake, 1994.

- This report is part of an ongoing series. The series pertains to matters of interest and concern for fisheries exploitation and management. The focus is thus analogous to that of Ontario's "Analysis of Fish Stock Data from Rainy Lake, Ontario, with Management Recommendations" (Wepruk et al. 1992; item 29 above).

- As with the Ontario report, this (Minnesota) series of documents provides a convenient shortcut to the previous literature and to present initiatives.

- In the course of implementing this sampling and reporting program, the investigators have developed a very useful series of ongoing indices or indicators regarding fish population status.

- This particular report contains important insights on the current status of the Rainy Lake (US sector) fish populations, including new data (for the most recent years) on year class strength. Ongoing instability of the populations, or at least extensive variability in their parameters, continues to be evident.

- The report offers useful suggestions for ongoing and new studies to further elucidate the dynamics of these fish populations and the factors controlling them.

C37. Eibler, J. 1995b. Large lake sampling program, Lake Kabetogama 1994.

- This is a very useful continuation of an extensive series of data reports, based on a consistent collecting and reporting protocol.

- The current (as at 1994) low ebb of the Kabetogama walleye and northern pike populations is of interest and concern.

- The far-from-spectacular within-year agreements among year-class abundance indices for walleye and northern pike should perhaps not be surprising. However, the lack of agreement for the same species (particularly evident for northern pike) between lakes is disconcerting. Very weak pike year-classes were indicated for Kabetogama Lake for

1987 and 1988 (described as low-water springs), and very strong year-classes for 1989 and 1990 (described as high-water springs). However the year-class abundance indices for Rainy Lake northern pike for these years show more or less the reverse pattern. Even more disconcerting, examination of the small-scale hydrograph records (as per Acres Exhibit 102, Baxendale 1994) suggests that the spring water level descriptors cited do not in fact apply to Kabetogama (sensu Namakan), but refer more appropriately to Rainy Lake. Perhaps the explanation is in the detail; these hydrographs cannot easily be read to small time intervals. Perhaps it is another instance of attempting to do more than the data merit. In any event, this matter warrants further attention.

REVIEW AND EVALUATION OF CORRESPONDENCE

CC38. Parmeter, D.D. 14 August 1987. Letter to Citizens' Council on Voyageurs National Park.

- This letter sets out the mandates and bases of interest of the IJC and the US National Park Service in regulating water levels in Rainy Lake and Namakan Reservoir to take account of renewable resource interests, including wild rice beds and fish spawning.

- The letter also sets out the history of interpretations (up to 1987) of the impacts of water levels on fish reproduction in these waters, i.e.

  - "Research conducted by the Minnesota DNR in the 1960s indicated a strong correlation between spring water levels and walleye spawning success in Rainy Lake."

  - Chavalier (1977) "supported the DNR findings (for walleye in Rainy Lake) and concluded that the most recent rule curve adjustments (1970) did not establish minimum spring water levels sufficient for improving spawning conditions and that only the upper levels (1106.8) were considered satisfactory for proper spawning areas."

  - "A more recent (Minnesota) DNR report (Osborn et al. 1981) is less convincing in terms of the relationship between spring water levels and walleye spawning success. There does not appear to be evidence of a similar relationship between spring water levels and walleye spawning success on the Namakan Reservoir. The most recent DNR report concludes that all lakes in the Namakan chain likely have sufficient walleye spawning areas at water levels within the existing rule curve."

Comment: The changing interpretations of the relationship between water levels and fish (especially walleye) reproduction in these waters may be indicative of a genuine evolution in that relationship, rather than of any progressive improvement in the analyses.

CC39. Holmes, R. 4 October 1993. Memorandum to R. Sando, re: Critique of the Boise Cascade Reports/Division Recommendations.

- This letter covers (forwards) reviews by Minnesota Fish and Wildlife Division staff in respect to the two critiques prepared for Boise Cascade on the aquatic ecosystem components of the International Steering Committee report.

- The letter ends by reiterating the Fish and Wildlife Division's view "that the literature and research supports the Steering Committee's recommendations; in that the existing rule curves have a detrimental effect on the fisheries resource and the recommended changes will be beneficial to the Rainy Lake and Namakan Reservoir ecosystems."

- With respect to the critique by the Cadmus Group (Parkhurst et al. 1993) specifically, the MFWD respondents were generally very critical. They:

- Did acknowledge that overharvest has been a key factor in decline of the fisheries, as proposed by Parkhurst et al.

- Severely criticized the use of commercial catch data as an index of adult walleye abundance. They cited their own analyses to indicate that commercial catch bears no useful relationship to commercial CPUE (a generally accepted indicator of abundance), and that models derived on this basis on the effects of water level management will necessarily be "spurious".

- Believed that Parkhurst et al. "used...seining data inappropriately", specifically with respect to:

  * using Rainy Lake North Arm YOY (seining) data with South Arm adult (commercial fishing) data.

  * pooling Sand Point, Namakan and Kabetogama seining data to represent Namakan reservoir.

- Were unenthusiastic about the analysis methods employed by Parkhurst et al. (even if the data used had been appropriate). Stated the opinion that any relationship (regression) observed under one set of rule curves would most likely not apply under a different regime, rendering predictive models based on linear statistics of little or no validity.

<u>Comment</u>: Criticism of the use of catch data as a proxy for abundance seems rational. (See also item C32, this document.) Criticism of the use of seining data in the manner in which they were assembled also seems justified. (But one aspect of this concern apparently involves a presentational error; see also items C32 and CC42, this document.) The criticism of statistical treatments seems partially a matter of personal preference and is difficult to assess. However, it has been noted that many of the derivations were counter-intuitive. (See item C32, this document.)

- With respect to the critique by Golder Associates/EMA (Gray and Kovats 1993) specifically, the MFWD reviewers expressed their main concern in terms of the perceived failure of the critics "to adequately review the scientific literature", limiting themselves to "reporting on research done on the lakes in question", including in respect to "aquatic plants and invertebrates." They dismiss as "illogical" Gray and Kovats' contention that no scientifically convincing case has been made that a change in rule curves will noticeably affect wildlife.

Comment: It is difficult to characterize Gray and Kovats' conclusions as "illogical"; they merely purport to be unconvinced. Their reticence, however, does not seem entirely warranted; see also item C33, this document.

CC40. Colby, P. 22 October 1993. Letter to R. Darby, concerning Cadmus Group report of 17 June 1993.

- This letter expresses the writer's opinion, in his capacity as a Research Scientist in the Ontario Ministry of Natural Resources Walleye Research Unit, in respect to the Parkhurst et al. (1993) critique prepared for Boise Cascade regarding the International Steering Committee report. This opinion focuses on the fisheries aspects, specifically walleye.

- The writer's opinions include:

- That "the new rule changes should be tried."
- That walleye carrying capacity (of Rainy Lake) was reduced (1940s, 1950s and 1960s) by water level changes, but that this effect was very gradual and was masked by the effects of overfishing.
- That the chief protagonists (Cohen et al., Parkhurst et al.) should develop and deliver "some common statistical approach acceptable to both parties."
- That at the moment, "Because of the high degree of uncertainty, large variances and wide confidence intervals, and opposing conclusions, their models presently have limited, if any, predictive value."
- That the lag time (elapsed) from an hydrological (or any) event that influenced fish reproduction until the manifestation of that reproduction via fish catches, would necessarily change over time as the fish population dynamics (growth, age at recruitment, etc.) changed in response to exploitation. Therefore, any analysis that assumed a constant lag time (as per both Cohen et al. and Parkhurst et al.) would inevitably be in error on this account.
- That some other variable, not adequately taken into account by any analysis to date, is strongly operative. "The weak coherence (Parkhurst et al.) between YMXR and walleye recruitment may be because high water levels are associated with cold, wet summers which would not favor walleye year class strength."

- That ecosystem effects of water level modifications may be considerably manifested through the effects of such modifications, in turn, on water turbidity/clarity.

- That "A more proper analysis to test the effects of water level on walleye year class might be to compare high and low water levels during warm and cold summers."

- That "the references, the Cadmus Group report, and most of the walleye literature are in agreement that temperature is the most important factor determining walleye year-class strength."
- That many of the previous results characterized by Parkhurst et al. as contradictory were not in fact comparable in the first place, for a variety of reasons including:

    * They did not cover the same time periods. Fishery practices changed in the interim.

    * The 1970 rule curve adjustment "did not establish minimum lake levels sufficient for improving spawning conditions."

    * "Most of the water level effects occurred before 1969 and the various walleye stocks in Rainy Lake collapsed in the 1960s. During and following the collapse...their recovery was more dependent on the size of the brood stock than other explanatory variables tested."

    * Since the 1970 rule curves have been in effect, "which included a period of years with lower than normal rainfall, Rainy Lake water levels have varied less than historical (natural) levels."

- The writer expressed considerable reservations about the appropriateness or at least the comparability of much of the data used in the Parkhurst et al. analysis, due to the (walleye) population not being in constant status over the period.

- Noted that the Parkhurst et al. report "does not refute that water level influences exist; only that they are difficult to demonstrate in light of other important factors."

- Brought attention to the possibility that the International Steering Committee's recommendations, if implemented, might have considerable impact on downstream (Rainy River) fish populations.

<u>Comment</u>: This is a well-reasoned and useful response. A credible chronology of dominant impacts on the Rainy Lake walleye population is proposed, i.e. that water level effects predominated and set the stage ('reduced the carrying capacity') up to or through the 1960s, with other factors "such as brood stock: progeny relationships" and "possible species interactions" dominating thereafter. The observation is advanced that high spring water levels tend to be associated with cool, wet weather; while the latter conditions may

be neutral for northern pike they are generally regarded as unfavourable for walleye. Thus a common response of the two species to spring water levels should not necessarily be expected. The observation that lag time would not remain constant in a dynamic exploited fish population is astute and important. It suggests that the more powerful and esoteric the statistical treatments, the greater the ability to generate wrong answers depending on the relevance and quality of the input variables. In view of this, however, the proposition which the reviewer advances for reconciliation or improvement of the Cohen et al. and Parkhurst et al. statistical treatments is deemed to have no practical foreseeable merit.

CC41. Gray, B. 18 November 1993. Letter to R. Baxendale, re: Minnesota Division of Fish and Wildlife's review of EMA report entitled "Review and analysis of studies on the effects of water level fluctuations on wildlife populations on Rainy Lake and Namakan Reservoir."

- This letter responds to the Minnesota FWD review of the Golder/EMA (Gray and Kovats 1993) critique of the wildlife aspects pertaining to the International Steering Committee report.

- In regard to their treatment of the "fisheries and related aquatic resources", the respondents defend their focus on data specific to the study area because that was their primary mandate and because no other precisely parallel situations exist. They note that they did in fact consult other literature.

- The respondents reiterate their overall conclusion that "no scientifically convincing case has been made that the proposed change in the rule curves will have more than negligible or minor positive impacts on the wildlife species investigated by the Park Service."

Comment - No new information or insights are presented, except that "minor impacts" and "negligible impacts' are defined.

CC42. Parkhurst, B. and W. Warren-Hicks. 3 January 1994. Memorandum to R. Baxendale, re: Response to MDNR and OMNR comments on Cadmus fish analysis.

- In attempting to describe the superiority of their (June 1993) approach compared to the earlier approaches on which the International Steering Committee relied, these critics state, "In contrast to our analyses, they did not objectively look at all possible causes of reduced fish populations and did not try to quantitatively predict the benefits of changing the rule curves, nor did they state the uncertainties in their unquantitative predictions."

Comment: While it may be true that these critics analyzed more factors concurrently than did any of the earlier studies, a superior tally in this regard is not necessarily indicative of a superior result. Statistical treatments can never be better than the understanding of the system to which they are directed, and the general state of comprehension of ecosystem function tends to preclude ultra-fine demonstrations of cause and effect. One might ask what is the biological significance of lake elevation precisely 15 days after ice-out, or of average (air) temperature exactly in the month of May? These critics are not alone in being encumbered with the need to make the best use of the data available; all the previous investigators necessarily used similar approaches. Some approaches (e.g. examining impacts of introduced species, or impacts of high/low water levels in warm/cold summers, or impacts of turbidity) may be more productive than any of those yet attempted, but at the moment are probably intractable. In short, a greater volume of ever-more-powerful treatments will not provide useful answers if those treatments exceed the limitations of the data or exceed the ecological comprehension required for treatment design and interpretation.

- The three procedural criticisms put forward by the Minnesota DNR regarding the Parkhurst et al. (1993) report are addressed by the respondents as follows:

- On use of commercial catch as a surrogate for adult fish abundance, that there has been no convincing proof of a lack of direct relationship, and in any event the catch statistics were the best (in some cases the only) effectively useable data available. Also, Cohen et al. relied heavily on the same data. "It is illogical and unfounded to say that commercial catch cannot be used as an index of abundance. Any fisherman knows that when fish are more abundant, the fishing is better."

- With respect to use of Rainy Lake North Arm YOY data as the dependent variable with South Arm independent variables, this is explained as essentially a clerical error. Actual use of South Arm seining data (as an index of YOY abundance) did not change the results.

- With respect to pooling of YOY seining data for Namakan Reservoir (three lakes), the respondents cite Cohen et al. (1991) that "The distinction among the 3 lakes of the Namakan Reservoir is for convenience. ...From the fish perspective, all of the Reservoir's lakes belong to a single body of water; there are no physical barriers among them."

<u>Comment</u>: The appropriateness of (commercial) catch as a surrogate for abundance is highly questionable, despite the arguments presented both here, and by others such as Chevalier (1977). Fishing may indeed be better when the fish are more abundant ("as any fisherman knows"), but the quality of fishing is not necessarily going to be reflected in the total amount of fish caught. There are too many possible intervening incentives, dis-incentives, effective barriers, etc., especially in a commercial operation. Bonde et al. (1965) reported that although the annual harvest remained virtually constant, CPUE for the Rainy Lake commercial catch dropped by more than a factor of 2 from 1950 through 1963. As they so lucidly put it, "Important as total catch figures are they often do not reflect walleye abundance… …it is apparent that since 1950, the commercial fisherman has been fishing harder and harder to get nearly the same poundage of fish." The unity of the walleye population among the various lake basins of Namakan Reservoir is also highly questionable, despite the lack of physical barriers to migration. The basins (especially Kabetogama Lake) are certainly quite dissimilar ecologically (see for example items 19 and 20, this document). Eibler (1994) shows little or no coherence in the annual progression of walleye year class strength for the Kabetogama and Namakan Lake basins

over the period 1978 - 1989. The existence of discrete walleye populations in different regions of adjoining Rainy Lake is also well established (Wepruk et al. 1992).

- Several statements and suggestions in the MDNR critique are isolated by the respondents for comment. Among them:

- They concurred with the suggestion that their (Parkhurst et al. 1993) report should be submitted for peer-reviewed publication.

- They concurred with the acknowledgement that overfishing was an important factor in the decline of some fish stocks in the area.

- They reiterated the opinion that "overfishing and water temperature are much more important than water levels in affecting walleye recruitment and abundance."

- They proposed that harvest regulations be used alone "for several years, to allow the population to rebuild. Then, if the fishery does not respond, the lack of response would be good evidence that other factors, perhaps including water levels, are affecting recruitment and suppressing the fish populations."

- They defended their application of the regression approach to time-series data on the basis of having rigorously "checked the model error terms for independence and distribution."

- They counter-critiqued the Cohen et al. (1991) methodology in application of spectral analysis.

Comment: It would be instructive to see the results of this material (and/or a rebuttal by Cohen et al.) submitted to a good journal for publication. It is hard to imagine why this is only talked about, not (apparently) done. The debate would seem to resolve more usefully around the (un?)appropriateness of the data (both dependent and independent variables) than around the actual methodology of treatment. The proposed timetable for 'experimental management' on this matter (harvest regulations first; water level changes later, if necessary) gives no credence to the likelihood that hydrologic manipulation eroded carrying capacity in the first place, nor to the probability that it continues to constrain the space for fish population recovery.

- A near-verbatim reiteration is provided of the original Parkhurst and Warren-Hicks critique of the Cohen et al. (1991) paper contained in their response to the International Steering Committee report (item 32, this document). This is basically a comparative exposé of statistical procedures.

Comment: It seems disingeneous to place much confidence in the relative superiority of various statistical refinements in this matter. Questions of data suitability and depth of understanding for hypothesis-setting and interpretation seem far more paramount.

- The critique of Dr. Peter Colby (item CC40, this document) is reviewed. This involves primarily expressions of agreement with views expounded. Colby's assertion that the fundamental disagreement about what the data show precludes serious consideration of these analyses for the development of rule curve decisions is however taken to task: "Since there is so much uncertainty, reliable predictions about the benefits of the rule curve changes cannot be made."

Comment: The uncertainty debate (Cohen et al. vs Parkhurst et al.) in the context here pursued is an unhelpful distraction. This distraction serves the interests of the status quo. However, it ignores the compelling early (1960s) evidence that water-level regulation per se had been instrumental in reducing the fish carrying capacity and had precipitated an initial collapse or near-collapse in these fisheries.

CC43. Sternberg, F.B. 20 January 1992. Letter to R.C. Mollin, Border Lakes Association, critiquing Cohen et al. report of 1991.

- This letter critiques the 1991 report by Cohen et al. on "The Fish Communities of Rainy Lake and the Namakan Reservoir".

- The respondent acknowledges that the paper "contains some interesting analytical procedures, (but) it is poorly written and laced with problems that severely detract from its value as an aid in making decisions on water level regulation on these lakes." Contends that the novel techniques are inadequately explained.

- Claims that the report has been rejected for publication by the Canadian Journal of Fisheries and Aquatic Sciences.

- Lists many "mistakes and inconsistencies" that, taken together, "form a serious roadblock to understanding what the authors are driving at, and in accepting their conclusions."

- Recognizes that "the authors are trying to use sophisticated analytical procedures to draw conclusions from a set of data that was not collected with long-term analysis in mind. However, at some point data becomes so weak that it (sic.) is not usable and, in fact, may be downright misleading. I felt that much of the data the authors used fell into this category." Examples are given:

- Paucity of actual seining data.
- Lack of evidence that walleyes could impact cisco populations (as proposed).
- Illogical treatment of outlier data.

Comment: The editorial style and mechanical shortcomings of the Cohen et al. paper certainly do undermine its usefulness and cloud its credibility. This is especially problematic on account of the complicated statistical techniques which are used. The document, however, was in fact published subsequently, in two papers rather than one. Applicability of the data to the treatments which are imposed upon them is certainly a legitimate concern and criticism. In fact this critic (Sternberg) does not go nearly as far as he perhaps might in enunciating this concern.

- The respondent offers evidence from the literature and from the comments of "others who have studied these lakes" to the effect that there is "little agreement as to how water levels affect fish populations":

- "It would seem logical that low spring water levels would be detrimental to walleye spawning success because gravel shoals that were washed clean by wave action in summer would not be flooded. But the largest year class in recent history was produced in 1983, when spring water levels were very low."

- The changing (at present very substantially reduced or eliminated) commercial fishery is hypothesized as a factor "that has strongly impacted walleye populations, especially in Rainy Lake." Closure of the walleye commercial fishery prior to the 1985 season on the Minnesota side of Rainy Lake was followed (in 1990) by the highest angler harvest and harvest rate "on Rainy Lake...ever recorded."

- Walleye yields in Namakan Reservoir (especially in Kabetogama Lake) are currently so high that walleye recovery "is unlikely, regardless of how water levels are regulated."

Comment: It is not readily apparent from the hydrographs (Acres Exhibit 102, Baxendale 1994) that 1983 was a particularly low-water spring. Furthermore, indices presented by Eibler (1995a,b) do not show the 1983 walleye year class to have been particularly strong in either Rainy or Kabetogama Lakes, although YOY walleye in Rainy Lake did grow rapidly that year (Pereira et al. 1995). In any event, meaningful projection of the effects of low spring water levels in any one year would require knowledge of the effects (on spawning shoals) of water levels that prevailed the year before. It is, however, of considerable interest that 1983 was a "strong intensity" El Niño year, with exceptionally high cumulative degree days (Pereira et al. ibid). There can be no doubt that exploitation is currently a factor in these fisheries, but a more fundamental consideration is the base of productivity (or carrying capacity) on which exploitation operates, and whether this has been reduced and if so whether it could be restored.

- The respondent recommends more aggressive and more refined measures to control or minimize the effects of fishing, coupled with vigorous monitoring "to determine if the recovery is for real." He advocates evaluating the effects of reducing the harvest prior to changing water level regulation in order not to confuse the interpretation of any ensuing results.

Comment: More aggressive control of fish harvest is certainly appropriate. The schedule for any efforts to improve the hydrologic regime for fisheries requires further consideration.

CC44. Sanborn, J., for Border Lakes Association, Inc. Undated (approximately September 1995). Letter to Colonel J. Wonsik, concerning proposed changes in Rainy Lake and Namakan Reservoir regulation.

- This letter refers to the critique of Richard Sternberg (item CC43, this document) on the Cohen et al. (1991) paper, plus another critique (by Professor John Tinker, a professional hydrologist) on recent modelling efforts, both of which were commissioned by the Border Lakes Association.

- The letter contends that Cohen et al. "distorted the expected result of a change in the lake level"; it also refers to "misstatements, errors, and inappropriate scientific analysis."

- The letter transmits the conclusion that "the water level in Namakan/Crane Lakes should be increased to accommodate navigation in the spring of the year. Rainy Lake...should not be changed at all."

Comment: this letter is an expression of a single-interest viewpoint which is unconnected with ecosystem concerns. It per se presents no new information or insights.

D. SUMMARY OVERVIEW OF THE HISTORICAL LITERATURE

Concern about the impacts of hydrological manipulation of Rainy Lake and Namakan Reservoir on the fisheries (and other aquatic resources) has had long standing. The Final Report of the International Joint Commission on the Rainy Lake Reference (1934) contains numerous expressions of this concern. Of the earliest known actual studies, Sharp (1941) documented winter and early spring de-watering which, although of variable severity among the lakes, was deemed to be seriously inimical to reproduction of all the economically important fish species.

A well-documented decline in the walleye fisheries extending to about 1970 led to a concerted search for cause, especially by the State of Minnesota, concentrated initially in the 1960s. The work focused on absolute water levels at particular seasons, in the regulated condition, mainly from the perspective of fish reproduction. The dynamics of exploitation were also considered. Early conclusions were that seasonal water levels were indeed a key factor in abundance of walleye and northern pike, and probably also of whitefish and ciscoes. The hypotheses (which were not rejected) were that, under regulation, water levels advanced too slowly in spring to provide spawning access by northern pike to flooded vegetation, remained too high and constant in summer and autumn to rejuvenate walleye spawning shoals and pike spawning beds, and fell too low in winter to safeguard coregonid eggs and food organisms. By the end of this period of investigation, research attention was beginning to focus more intensively on the effects of exploitation on the fish stocks. By the early 1970s, water levels and brood stock numbers were considered to be contributing near equally to the determination of abundance of walleye in Rainy Lake, the most important of these fisheries overall.

In 1982, Cole introduced a comprehensive ("ecosystemic"?) approach to describing the biological situation in the Park and to developing proposals for improvement. This was followed by a US National Park Service program of studies (initiated in 1983, and continuing on through the decade) in a concerted effort to unravel the effects of hydrologic regulation on the aquatic ecosystem(s) by way of attention to individual ecosystem components. At about the same time and in response to continuing evidence of decline in these fisheries generally, both of the fishery management agencies (Ontario Ministry of Natural Resources and Minnesota Department of Natural Resources) had developed standardized, ongoing, time-series programs to obtain and analyze data on fish population parameters and harvests. These programs, of course, had their beginnings in much earlier more ad hoc initiatives.

By 1990, Kalemeyn and Cole documented their comprehensive treatment of alternative water management regimes, based mainly on the various US NPS studies of the previous half decade. This document and one or two others, along with the interest and reaction they engendered, led to the formation of the International Steering Committee on Rainy Lake and Namakan Reservoir Water Levels. The Steering Committee published its report in autumn of 1993. The recommendations contained are the subject of the present evaluation and have elicited various rebuttals and counter-rebuttals in the interim. The present document is an attempt to trace the development of the issue and the solutions which have been proposed in the existing literature, as well as another (interim) step to assessing the matter with the ultimate aim of arriving at an independent conclusion or set of conclusions.

Of most direct interest from any review of literature regarding a particular question or debate is whether the literature is found relevant to or contains a basis for entering the debate or for selecting among the choices which are available. It is immediately apparent that not much of the existing literature derives from concerted studies specifically designed to address the question of effects on "fisheries and related aquatic resources" of alternative water regimes at Rainy Lake and Namakan Reservoir.

There are some exceptions, notably among the National Park Service series of studies, and including studies devoted to aquatic vegetation, benthic invertebrates, and fish (namely young-of-the-year walleye, yellow perch, and northern pike), as well as to some other aquatic fauna. However, even these studies were short, simple, one-time efforts generally not of a scope and magnitude commensurate with the complexity of the question or with the range of confounding factors and the inherent variability of ecological systems. Despite the paucity and within these limitations, the evidence which has been developed in this manner is near-unanimous and generally credible to the effect that the present hydrological regime has had and will continue to have negative impacts on the aquatic ecosystem (including fish) in comparison with the natural regime of water levels. Among the most convincing of the demonstrations is the one respecting aquatic macrophytes, and a strong case can be made for the key role of these flora in the biological economy of these waters. Of course, deducing a direction of impact is not the same thing as determining its quantitative effect. The studies contributing to the International Steering Committee exercise did not attempt to estimate 'how much fish productivity is actually foregone' on account of water regulation, nor would such an attempt seem generally practicable.

A much larger body of literature has been developed on another equally (but differently) indirect approach to demonstrating the consequences of past and present hydrological management on these fisheries. This encompasses numerous attempts, some of the later ones specifically expanding on those done earlier, to relate abundance estimates for walleye and/or northern pike to earlier hydrologic (and sometimes other) conditions. Such efforts are constrained at the outset from reaching definitive conclusions, since correlation studies can never 'prove' an hypothesis; the best they can do is to show that it has not been disproved. In the present case, these efforts are in double jeopardy because the fish abundance estimates were invariably more or less indirectly acquired, and never for the specific purposes of the correlations being attempted. It is entirely predictable that progressively more energetic treatment of these numbers will lead to progressively more divergent results, possibly more reflective of the treatment process than of actual relationships in the ecosystem. The current debate has now reached this impasse, and it would be futile to try to refine the analysis further without access to new and better data. The impasse already reached indicates that the data have already been pursued beyond their means to deliver, and any further statistical refinements could only be expected to produce more artifacts rather than reveal more realities. Suffice to say at this juncture that the analyses purporting to demonstrate a deterioration in fish productivity under the present hydrologic regime are at least as credible as, and probably somewhat more credible than, those arrayed in opposition. In other words, both intuition and analysis indicate that the Rainy Lake and Namakan Reservoir fisheries are less productive and are less inherently stable now than they would be if the systems were unregulated hydrologically. By extension, it can realistically be inferred that a hydrological regime which more nearly approximated the natural condition would benefit the fisheries.

It is important to recognize, of course, that water regulation has not been the only external factor impacting upon these ecosystems, including their fish components. Far from it. Fish exploitation, now almost exclusively by angling plus some utilization by First Nations, but previously including also substantial commercial fishing, has been intensive for nearly a century. The fish populations have been analyzed extensively from this perspective, for fishery management purposes. Of course the problem of lacking baselines is once again evident and paramount. Even the very first of these studies (Sharp, 1941) only commenced some decades after impacting actions (water regulation and fishing) were already underway. Although we cannot determine precisely 'where these fisheries were at the beginning', it is still possible to deduce, mainly on a comparative basis with other fisheries in reference to the recorded harvest and the characteristics of the populations, that the major fisheries in these lakes have been and remain substantially impacted by exploitation.

Whether the two impact foci (water regulation and exploitation) can be separated as to their respective influences is extremely unlikely and probably not worth attempting. The two influences function dynamically together, being integrated into the workings of the ecosystem as is characteristic of such systems. Altered water levels impact at least to some extent negatively on fish reproduction and most likely on subsequent stages in the life cycle. Fishing pressures impact on the population not only directly, but also to at least some extent through the availability and character of fish available for reproduction and most likely on other stages as well. These interactives are not as predictable as, for example the interactions among geomorphology, precipitation and evaporation in producing yield from a watershed. They cannot, in fact, be modelled realistically to provide a quantitative output.

In addition to the interactive effects of water levels and fishery exploitation, we must recognize yet a third body of "assaults" on the ecosystems here under consideration. These include climate change (generally predicted to become as strongly manifested in this region as almost anywhere, and probably already being manifested to some extent), airborne contaminants (acid precipitation, organochlorines, heavy metals, etc.: some river otters in Rainy Lake already bear body burdens of mercury deemed near-lethal), increased incidence of ultra-violet radiation, and perhaps the most aggressive current assault of all, at least potentially: that of exotic species such as rainbow smelt (recently introduced to and becoming well established in this system). These developments add another, emerging dimension to frustrate any attempts to differentiate among impacting agents as to their specific effects on these ecosystems and fish communities.

If the problem has many interconnected parts, it follows that the solution should be similarly constructed. There can be no doubt that these fisheries have been and are impacted, in some cases seriously by fishing per se. Exploitation must be brought under better control, and aggressive actions are now underway (both governments) to achieve this. But controlling exploitation alone will not permit these fisheries to achieve their full potential. Only a return to something closer to a natural hydrologic regime can legitimately be expected to provide that foundation.

The key features (aquatic ecosystem perspective) of the International Steering Committee's recommended hydrological alternative include (in their words):

- an earlier rise in spring water levels, to provide better conditions for spawning of walleye and northern pike,

- stable or declining June water levels,

- a slight summer drawdown, to improve diversity and abundance of aquatic vegetation and fish and wildlife habitat,

- a reduced winter drawdown, to improve whitefish and cisco spawning success, and to improve overwinter survival of invertebrates (etc.).

All of these objectives and anticipated fish responses are reasonable, both from the specific information at hand and also based on the wider literature. However the proposed measures very much reflect the compromise among competing interests which was the arena for their genesis. They do not go nearly as far as 'single-purpose' fisheries interests would prefer, particularly in the magnitude of summer drawdown (not enough: both lakes). They also do not effectively address a potentially important matter which has been the subject of substantial recent attention regarding these waters: the 'ecosystematic preference' for greater inter-annual variability in water regimes. Both of these matters (increased summer drawdown; occasional higher summer peaks) would be integral to the natural system but inimical to other ('non-ecosystematic') interests. It is unlikely that these measures could be pursued to an optimal degree, but any steps taken to restore natural conditions must be cognizant of these ultimate preferences and constraints.

The historical studies suffice to demonstrate that any corrective measures which may be adopted to restore or enhance these fisheries should be implemented in a manner and with an accompanying commitment to enable measurement and evaluation of the results. This applies to the more aggressive measures for fishery management now being implemented, and it applies as much or more to measures that might be taken to restore a more natural hydrologic regime. Restorative measures should ideally be initiated when a complementary monitoring and research plan is funded and in place. An overall implementation plan should precede any physical measures, and might well include some focused pre-intervention studies to further inform the interventions (i.e. the hydrologic regulation adjustments) to be undertaken, as well as to background the subsequent monitoring efforts. Preliminary consideration suggests that it would be desirable to replicate some of the earlier directed work (e.g. on macrophytes, invertebrates, and walleye/northern pike early-life-history stages), taking advantage of insights gained earlier in terms of hypothesis generation and study design, and working in a more integrated fashion, i.e. utilizing a common sequence of years, sampling dates, stations, sites, depths, etc. Some directed observations to quantify the use (and the results) of walleye and northern pike reproduction in tributary systems to these lakes would also be very useful. There is much anecdotal reference to this occurring, but no estimates of importance relative to within-lake reproductive processes. Access of spawners to tributary systems, if an important factor, may or may not have different hydrological requirements than does spawning and incubation in the shallows of the main lakes. Improved knowledge of the actual importance of young-of-the-year recruitment to subsequent year class strength for walleye and northern pike in these waters would also be very useful.

E. LISTING OF PERTINENT LITERATURE, INCLUDING DOCUMENTS WHICH WERE EXAMINED

Note: Numerals in bold brackets at left margin designate the identity and the chronological position, in Sections B and C of this Appendix, of items that were reviewed and evaluated in detail.

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F. HISTORICAL CORRESPONDENCE REVIEWED (IN CHRONOLOGICAL ORDER)

Parmeter, D.D., for Donald D. Parmeter Natural Resources Consultant. 14 August 1987. Letter to Citizens' Council on Voyageurs National Park. 3 pp + appendices.

Holmes, R., for Minnesota Department of Natural Resources. 4 October 1993. Memorandum to R. Sando, re: Critique of the Boise Cascade Reports/Division Recommendations. 2 pp + 2 enclosures. This letter is incorporated in Appendix H of the International Steering Committee report (1993).

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Sanborn, J., for Border Lakes Association, Inc. Undated (approximately September 1995). Letter to Colonel J. Wonsik, concerning proposed changes in Rainy Lake and Namakan Reservoir regulation. 2 pp + enclosures.

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