DEVELOPMENT OF A FISHERIES MANAGEMENT PLAN FOR LAC SEUL, NORTHWESTERN ONTARIO

by

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A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree,
Master of Natural Resources Management

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ABSTRACT

Recent fish harvest levels in Lac Seul (50°20'N, 90° 30'W) appear to be in excess of the lakes morphoedaphic index (MEI) determined potential yield. The lake also experiences marked annual water level fluctuations due to its function as a hydro-electric power reservoir. Although several authors note stable fish communities within the lake, in spite of annual water level fluctuations, this author suggests that these fluctuations may incur physical loss of spawning and nursery habitat of certain species within the Lac Seul fish community. The existence of overharvest conditions and spawning/nursery habitat loss would seriously impede the ability of Lac Seul fish stocks to contribute economic benefits to the local and regional economies of northwestern Ontario.

Historically, commercial fish harvests are within existing quota limits (42,935 kg whitefish, 9,092 kg walleye). However, sportfish harvests exhibit marked overharvests, with respect to potential yield, in particular basins--notably those basins in nearest proximity to developments. Walleye stocks for the lake as a whole are within MEI determined potential yield levels, although 8 of Lac Seul's 23 basins experience overharvest. Northern pike sportfish harvest exceeds the lake's potential yield by 28,633 kg. The majority of northern pike sportfish harvest is caught by non-resident anglers. The levels of domestic harvest by natives

of Lac Seul Indian Reserve 28 is estimated at 18,795 kg fish per year, 6,202 kg of which are walleye.

Sportfish angler catch (based on number of fish caught per angler-day) is very high - 5.07 kg fish/angler day. Future harvest targets, aiming at an angler satisfaction level of 2 kg fish/angler-day, necessitate the implementation of management strategies to reduce harvest levels without limiting angling opportunities.

Management strategies are suggested for Lac Seul basins requiring maintenance or rehabilitative management. Strategies are grouped as follows: strategies requiring immediate implementation, monitoring strategies designed to establish a trend-through-time data base, and lag or contingency strategies--the implementation of which will be contingent upon the relative success or failure of preceding management strategies. These strategies include: the implementation of a Crown Land Access Permit intended to transform non-resident, non-contributor anglers into contributors; reduced sportfish harvest limits on northern pike for non-resident anglers on Lac Seul only; basin restrictive management to divert non-resident northern pike angling effort to water bodies in proximity to Lac Seul capable of sustaining additional pressure.

Finally, the Lac Seul fisheries management strategies are priorized, and fish stocks allocated to the user-groups of the fish resource: domestic fishery, resident sport fishery, non-resident contributor anglers, and the commercial fishery. For the purpose of allocation, the Lac Seul fish community is comprised of: walleye, whitefish and northern pike.

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Finally, I wish to dedicate this practicum to the memory of my mother, Mrs. Nancy Biggs-McGovern (1918 - 1982) -- who always encouraged my endeavours and who served as a fine example of hard work and perseverance.

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INTRODUCTION

1.1 Preamble

In 1974 a federal-provincial task force was commissioned to develop new management strategies for Ontario fisheries. The task force was initiated as a result of concern over the deteriorating status of fish stocks within Ontario (Loftus et al., 1978). The Strategic Planning for Ontario Fisheries (SPOF) program resulted from the work of this task force.

As the SPOF program developed it became quite clear that the traditional approach to fisheries management--development oriented, exploitative, open access--would not be appropriate in the 1980's. Rather, a new approach to fisheries management, characterized generally by maintenance of fish stocks in northern Ontario waters and rehabilitation in the south, was deemed essential (Loftus et al, 1978).

Further to the mandate, goals and objectives stated by the SPOF federal-provincial task force, the Ontario Ministry of Natural Resources (OMNR) has initiated several SPOF working groups designed to improve fisheries management, including the development of guidelines for fisheries management plans. The management plans are currently being developed and are to be implemented at the OMNR District level. Fisheries management plans will be developed both individually for large water bodies within the Districts, and as

District fisheries management plans, to assess fisheries resources within District watersheds. Examples of individual, large water body fisheries management plans presently being developed for lakes within northwestern Ontario include the Rainy Lake Fisheries Management Plan and the Lake of the Woods Fisheries Management Plan.

Under the terms of reference provided in Strategic Planning for Ontario Fisheries: Guidelines for District Fisheries Management Plans (SPOF, 1981), and through OMNR Sioux Lookout District Office, a Fisheries Management Plan was proposed for Lac Seul. This practicum represents the results of the Lac Seul Fisheries Management Plan undertaken by the author, under private contract to Sioux Lookout OMNR and in conjunction with the Natural Resources Institute, University of Manitoba.

1.2 Study Area

Lac Seul (50°20'N, 92° 30'W) is located within northwestern Ontario's West Patricia Planning Area (Figure 1.1). The lake is a highly complex, crescent shaped reservoir approximately 150 km long, with a surface area of 1,437 km^2 (Figure 1.2). It is the second largest inland lake wholly contained within the province of Ontario (Hanna and Michalski, 1982). The complexity of basin shape is reflected by the

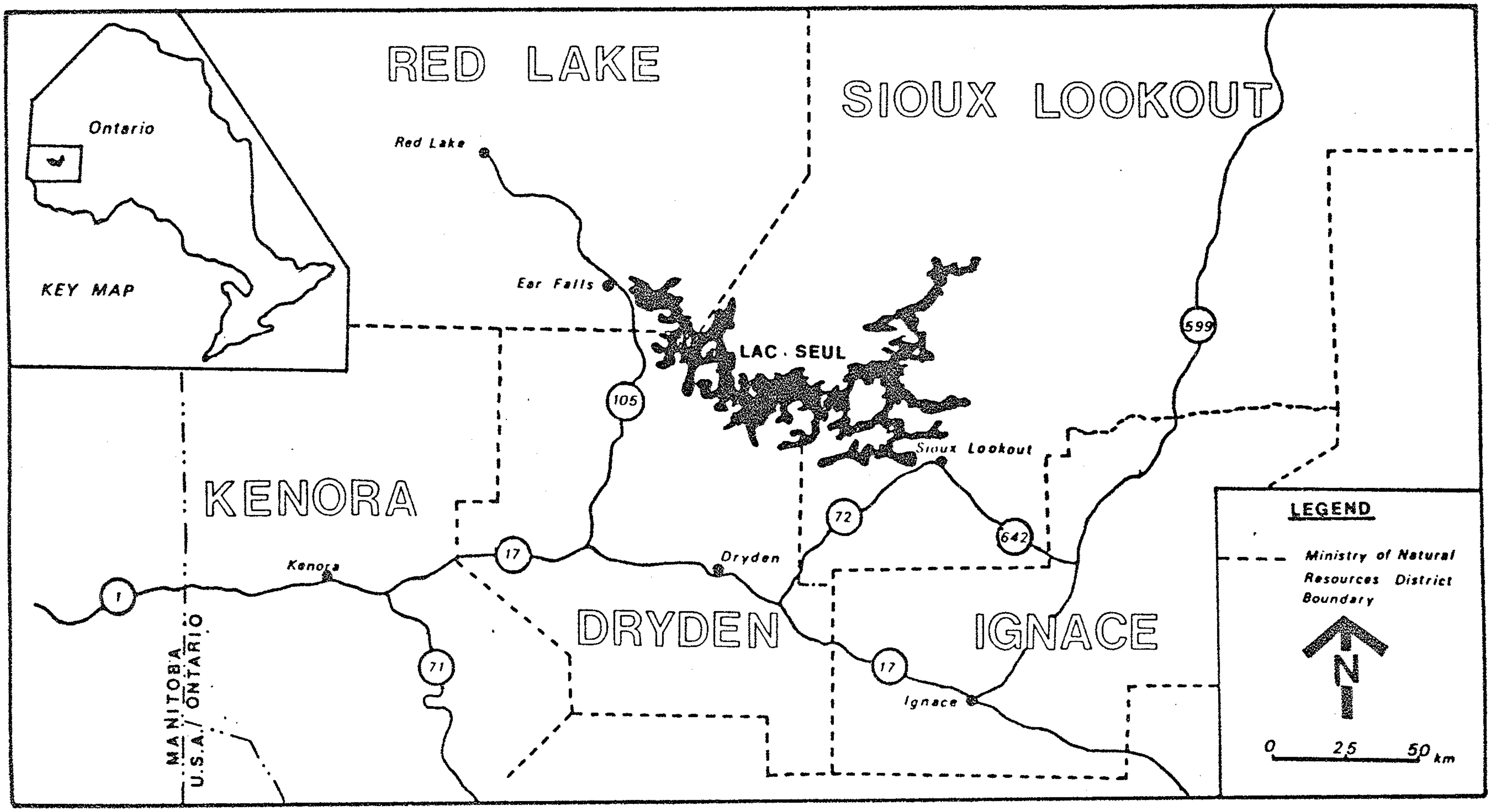

Figure 1.1: General location of Lac Seul in northwestern Ontario.

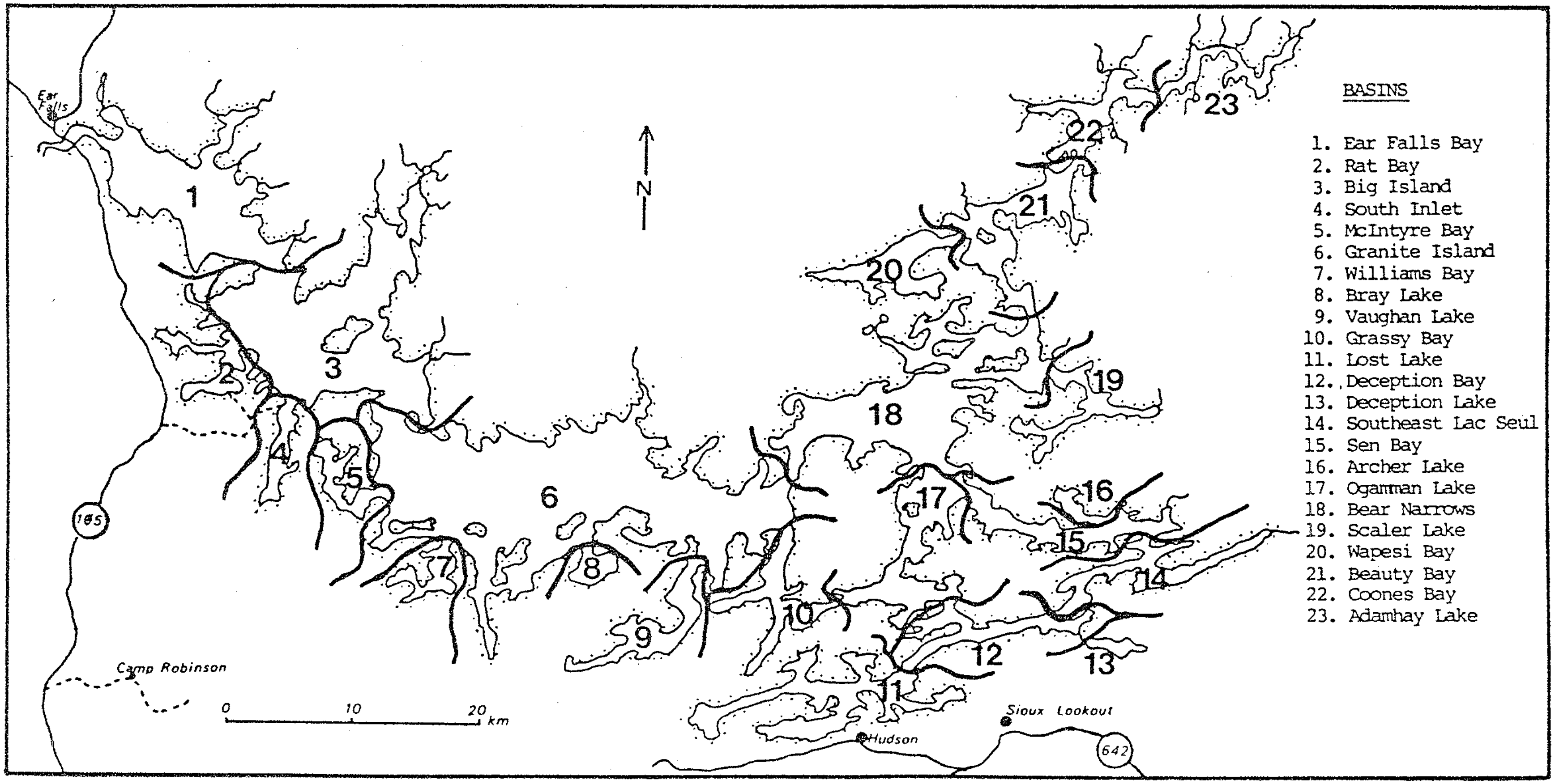

Figure 1.2: Lac Seul, Basins

high shoreline development factor[1] (35.6) of Lac Seul. The lake consists of 23 basins (Figure 1.2). Maximum depth is 47.24 m. Mean depth for the lake as a whole is 7.1 m varying from 2.8 m (mean depth - basin 23) to 14.6 m (mean depth - basin 6). Secchi disc transparency throughout the lake varies from 0.7 to 2.9 m (Table 1.1).

The Lac Seul basin lies mostly within the English River Subprovince (Superior Province) of the Precambrian Shield, characterized by felsic igneous and granitic rocks. Volcanic meta-sedimentary rocks exist in the northern belt of the subprovince, whereas the southern belt is represented by more complex formations containing numerous granitoid intrusions interspersed with gneissic material. These rocks are highly resistant to erosion (Hough et al., 1981).

Deposits associated with the latest substage of Pleistocene glaciation (i.e., the Valders substage) and post-glacial lacustrine events dominate present surficial geologic patterns. Present day Lac Seul was covered by glacial

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[1] Shoreline development factor refers to the ratio of the length of shoreline (L) to the length of the circumference of a circle of area equal to that of the lake.

$$DL = \frac{L}{2\sqrt{Ao}}$$

It reflects the potential for greater development of littoral communities in proportion to the volume of the lake (Wetzel, 1975).

Lake Agassiz from ca. 11,000 - 9,500 before present. The major contributions of Lake Agassiz to the existing surface features of the study area include the deposition of "Patrician" red till and thick deposits of lacustrine silts and clays. Varved clay of variable thickness represent the most widely distributed lake sediments (Hough et al., 1981).

The morphoedaphic index (Ryder et al., 1974) of 8.18[2] categorizes Lac Seul as mesotrophic (Table 1.1). However, Hough et al., (1981) reported that low chlorophyll a concentrations reflect an oligotrophic--mesotrophic system. It is important to acknowledge that a wide range of trophic regimes exist among the 23 basins contained within Lac Seul.

Development in proximity to the lake includes four towns (Sioux Lookout, Hudson, Perrault Falls and Ear Falls), 14 commercial fishing lodges, 10 outpost camps and 28 remote cottages. Estimates currently available (1978) suggest a population base of approximately 7,150 people (Hough et al., 1981).

A hydroelectric dam was constructed on Lac Seul's western outlet at Ear Falls in 1929-30. However, water

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[2] MEI figures calculated from Hough et al., (1981) data. TDS values were corrected for conductivity as per SPOF Working Group 12 (1982). MEI values were adjusted accordingly.

TABLE 1.1

Physical and chemical characteristics of Lac Seul[1]

Physical		Chemical		
Area (km^2)		Total Alkalinity (mg/l $CaCO_3$)		36.2
Lake	1437	Total Dissolved Solids (ppm)		43
Watershed	26470	Dissolved Oxygen (midsummer hypolimnion ppm)		7.0-8.0
Depth (m)		Morphoedaphic Index (metric units)		8.18
Mean	7.10	Sulphate Ion (mg/l)		3.35
Maximum	47.24	Total Phosphorus (ug/l)	e	16.4
Volume ($10^9 m^3$)	15.0[a]		b	20.4
Shoreline (km)	4786	Chlorides (mg/l)		1
Shoreline Dev.Factor	35.6	Nitrogen (ug/l)		
Transparency (m)	0.7-2.9 (variable)	Ammonia		30
		Nitrite-Nitrate	e	11.8
			b	20.4
		Total Kjeldahl	e	390
			b	368

[1] Data source, Hough et al., 1981

[a] OMNR, 1969 lake survey

[e] Euphotic zone sample

[b] above bottom sample

levels were not increased to full storage capacity of the reservoir until 1935. Lac Seul water levels are controlled by the Lake of the Woods Control Board (Water Resources Branch, Canada Department of Environment). The Board attempts to meet a level of 355 m.a.s.l. by the opening day of walleye *(Stizostedion vitreum)* season, although this level is not attained in some years (Hough et al., 1981). In the past, water level regulation has been the subject of much concern with regard to Federal-Provincial water management mandates, native peoples' considerations, deleterious effects on fish spawning habitats and the interests of tourist outfitter organizations.

Commercial fishing operations on Lac Seul began as early as 1910. Records of the commercial harvest have been maintained from 1924 to the present. The fishery has encountered marked fluctuations in harvest and species composition since 1924 due to changes in a variety of factors affecting the productivity of the lake's fish stocks, i.e.:

1. Flooding (1935-46 and post-impoundment water level fluctuations;
2. Root River diversion from Lake St. Joseph (1957);
3. Establishment of tourist lodges (1946);
4. Closure due to mercury contamination (1971-72) and subsequent limitation of commercial licenses; and,
5. Change from cotton to nylon gill nets, quota adjustments and gill net mesh size changes (Hough et al., 1981).

Currently, there are four commercial fishing licenses allocated for Lac Seul. Commercially important fish species include walleye[3], lake whitefish *(Coregonus clupeaformis)*, tullibee *(Coregonus artedii)*, white sucker *(Catostomus commersoni)* and burbot *(Lota lota)*. Northern pike *(Esox lucius)* were harvested prior to 1971. Incidental catches of lake trout *(Salvelinus namaycush)*[4], sauger *(Stizostedion canadense)*, yellow perch *(Perca flavescens)*, rock bass *(Ambloplites rupestris)* and muskellunge *(Esox masquinongy)* also occur.

Recreational fishing became important on Lac Seul in 1946 with the establishment of the first two tourist lodge operations on the lake. The main attraction to Lac Seul in the early years of lodge operation was trophy northern pike. This resource has declined in importance since the early 1960's. Based on number of fish harvested annually and catch per unit effort data, walleye are currently of primary importance to the sport fishery (Hough et al., 1981). However, in terms of biomass (kg of fish), both walleye and northern pike currently are harvested at a similar level (Hough et al., 1981).

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[3] Harvest permitted by quota in two blocks.

[4] Rarely caught.

1.3 Problem Statement

The Lac Seul fishery resource contributes significantly to both local and regional economies of northwestern Ontario. However, the ability of the fishery to sustain these economic contributions has been put into question as recent harvest levels have been in excess of the MEI determined potential production. Hough et al., (1981) report the loss of fishing opportunities within particular basins of Lac Seul. Loss of environmental quality, in particular the effects of water level fluctuations on fish spawning and nursery habitats (Crooks, 1972; Hanna and Michalski, 1982), has been identified as an area of concern. Conflicts also exist among users of the Lac Seul watershed environment and the fishery resources of the lake (Hough et al., 1981). Consequently, the commercial, recreational, and domestic[5] fisheries appear to be competing for a limited supply of valuable fish stocks. Management strategies are required for Lac Seul that will distribute harvest pressures among the user groups safely within the limits of the lake's potential yield. These allocational strategies are

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[5] Domestic fishery, in the context of this report, refers to the component of fish communities harvested annually by native peoples of Lac Seul Indian Reserve 28, for subsistence and/or traditional needs.

necessary to ensure a continuing supply of fish of a predictable quantity and quality.

1.4 Objectives

The factors responsible for and contributing to the previously identified problems and issues relevant to Lac Seul are not fully understood. Resolutions to these problems are essential, both in the immediate and long term, in order to satisfy the SPOF mandate to maintain fishery resources within northwestern Ontario waters. The primary objective of this study is to develop management directives and to prepare optimum fisheries management tactics upon which allocation decisions can be made. It is therefore necessary to evaluate the factors considered responsible for the decline of Lac Seul fish populations and the loss of fishing opportunities.

In addition, the study will quantify the production potential of the Lac Seul fisheries and derive supply balance estimates between the fisheries production potential and existing harvest levels. This will be accomplished by:

- estimating biological production potential using Ryder's (1982) morphoedaphic index (MEI) and species composition of the fish community;
- quantifying historic and present commercial fish harvests;
- quantifying historic and present recreational fish harvest;
- identifying shortages and surpluses between potential production and current total harvest.

In order to reconcile the existence of a shortage or surplus between the production potential of Lac Seul and current harvest patterns, it is essential to establish sound management directives on which to base fishery allocation decisions. Within this study, the allocation decisions developed for Lac Seul incorporate an application of the management directives criteria stated in SPOF (1981). The final component of this study consists of the allocation of Lac Seul fishery resources.

1.5 Limitations

In the case of Lac Seul, trend through time data for both sport fishing and commercial fishing harvests are limited. Creel survey data utilizing different data gathering techniques and focusing on specific basins limit meaningful harvest comparison. The comparative value of commercial harvest estimates over time is limited due to changes in the availability of commercial licenses and species harvested prior to and after closure of the fishery in 1971-72, changes in mesh size and structure (e.g. cotton to nylon nets) during the 1960's, and impoundment effects.

Habitat data (i.e., information on spawning habitats) are somewhat limited due to the vastness and shoreline irregularity of Lac Seul and consequent difficulties in navigation during spring (walleye and northern pike) and fall (whitefish) spawning periods.

At present, there is no determinate calculation applied to the indirect benefits and costs attributable to the commercial and recreational fisheries (Hough et al., 1981), limiting thorough economic analysis of the Lac Seul fishery. Data do exist regarding direct benefits and costs (see Hough et al., 1981). However, more complete information is necessary to ascertain the measurement of net economic yield for the purpose of valuation of sport and commercial fisheries. The data requirements are outlined in section 2.3.

CHAPTER II

LITERATURE REVIEW

The following review examines the concept of morphoedaphic index (MEI) as a fish yield estimator, the impacts of water level fluctuations on fish species found within Lac Seul and economic perspectives as they pertain to commercial and sport fisheries. A thorough account of biological concepts (such as maximum sustainable yield) and the Strategic Planning for Ontario Fisheries (SPOF) program is provided in Wepruk (1981) and does not bear repeating here.

Appendix 2.1 provides an extensive annotated bibliography on the effects of water level fluctuations on whitefish, walleye and northern pike -- the major fish community type present within Lac Seul. Discussion within this chapter is restricted to northern pike, as this species appears to have been most seriously impacted since impoundment of Lac Seul.

The morphoedaphic index literature is examined here, as this method has been the subject of much controversy since its inception as a fisheries management tool. Further, the MEI is used throughout Ontario (by OMNR fisheries management personnel) as the primary criterion for determining potential fish supply within watersheds. An elucidation of the MEI concept, in terms of its utility, precision and justifiability as a fish yield predictor, would be useful to fisheries managers involved with long-term fisheries management schemes.

2.1 The Morphoedaphic Index

The morphoedaphic index (MEI) is an empirically derived formula that was first described as a convenient method of rapidly calculating potential fish yield for unexploited north-temperate lakes (Ryder, 1965).

Ryder (1965) originally coupled two limnological variables to determine the MEI. Total dissolved solids (TDS) was chosen to represent an average edaphic[6] condition for any watershed as it reflects, to a certain degree, geological characteristics of the watershed as modified by climatic effects such as rainfall (Henderson et al., 1973). It is suspected that TDS is generally proportional to one of its component ions (limiting or indicative of biological production) such as phosphorus, nitrogen or carbon (Henderson et al., 1973). Mean depth ($\bar{Z}$) was chosen to represent a morphometric variable of the lake basin. Thus in its basic form the MEI is expressed as an edaphic factor, representing nutrient value, divided by a morphometric factor:

$$\text{MEI} = \frac{N}{\bar{Z}} \text{ or more commonly } = \frac{\text{TDS (mg/l)}}{\bar{Z}\text{ (m)}}$$

where N = nutrient value

and $\bar{Z}$ = mean depth

(Ryder, 1982).

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[6] Edaphic factors: environmental conditions that are determined by the physical, chemical and biological characteristics of the soil.

Numerous researchers (e.g. Oglesby, 1977; Dillon and Rigler, 1974; 1975) have used surrogate values for TDS as nutrient variables. However, mean depth ($\bar{z}$) is most commonly used to represent the morphometric variable.

2.1.1 *Fundamental Concept*

The fundamental concept in all morphoedaphic expressions is that energy and matter placed in an aquatic system from external sources are channelled, cascaded, dissipated or retained in the system because of that system's morphology. These two inputs, regulated and constrained by the basin shape, produce both a yield of fishes and other biotic outputs such as production of plants and invertebrates. Fish yield is considered to be a substantial, predictable proportion of total internal production in intensive fisheries (Ryder, 1982).

After recognizing the morphoedaphic relationship ($MEI = \frac{TDS}{\bar{z}}$), Ryder (1965) found a significant positive correlation between the MEI and fish yields from 23 intensively fished lakes in Canada and the United States (Schlesinger and Regier, 1982). Consequently, the simplified metric formulation of the MEI-based potential fish yield, as expressed for north-temperate lakes is:

$$\hat{Y} \sim 0.966 \quad X$$

where $\hat{Y}$ = annual yield to a fishery and is
analagous to the maximum sustainable
yield of a fish community

and X = MEI (Ryder et al., 1974).

This formula has since been refined and individual MEI-based yield functions have been determined for various watersheds and physiographic units within north-temperate latitudes (SPOF, 1982).

The MEI was originally developed to meet three major objectives:

- to determine empirical relationships of fish yield with abiotic factors,
- to provide fisheries managers with an easily applied technique for first approximation of annual fish yield, and
- to provide a fundamental conceptual base for the global synthesis of production processes in aquatic systems.

(Ryder, 1982).

2.1.2 *Advantages and Disadvantages*

Timeliness is perhaps the most oft-quoted advantage regarding the use of MEI as a fish yield estimator, since a "quick-and-dirty" solution to a fisheries management problem is often more important than the level of precision attained in its solution. The proper application of the MEI provides a rapid, first approximation to fisheries yield problems. Precision in the result may be improved later with feedback data from existing fisheries (Ryder, 1982). Of foremost importance in this regard is the derivation of yield estimates for large lakes and reservoirs prior to the implementation of any management scheme. Once first approximations have been derived for the total fish community the ichthyomass can be apportioned to the various fisheries by a number of management methods (e.g. quota, gear regulations, size/season limits, etc.) of an appropriate time frame (Ryder, 1976).

One other advantage of the MEI is its simplicity of use. Mean depth data is readily measureable within lake systems through sounding techniques and contour maps. Total dissolved solids data is readily obtainable via conductivity conversions or gravimetric analysis, and requires little sampling intensity compared to other productivity determinants.

Simplicity, however, has also been indicated as a disadvantage with respect to MEI determination. Many authors have criticized that the MEI oversimplifies and understates the inherent ecological complexities (Ryder, 1982). Adams and Olver (1977) have identified geological conditions (within lacustrine and outwash deposits) that can result in overestimates of both TDS and conductivity readings, and subsequently affect MEI-determined yield estimates. Hough et al., (1981) and Crooks (1972) have compared MEI-yield and harvest data with length-weight-age data and both concluded that MEI may be underestimating the productive potential of Lac Seul. This discrepancy is likely due to the wide variability of MEI at the 95 per cent confidence level. Estimates of MEI at this level vary by a factor of three between upper and lower limits (SPOF, 1982). Although these problems are of minor consequence in unexploited fisheries they can present significant long-term management problems within exploited fisheries involving a number of user groups. Underestimates of the MEI-determined potential yield can lead to sub-optimal allocation and waste of valuable fish stocks.

2.1.3 *Substitutes and Surrogates*

> *The greatest contribution of the morphoedaphic index has been its demonstration that empirical prediction of fish yield was possible. This has led to the development of several indices based on phytoplankton standing crop, macrobenthos standing crop and total phosphorus concentration ... which appear to be superior in their generality, predictive power, and the insights they give into the nature of the biological process operating.*
>
> (Hanson and Leggett, 1982)

Dillon and Rigler (1974; 1975) developed a significant predictive relationship between spring [TP] and mean summer phytoplankton standing crop, based on conditions where phosphorus is the limiting ion within the aquatic system. Following this, Oglesby (1977) has related an index of mean phytoplankton standing crop to annual fish yield. Oglesby (1977) however measured Chl. <u>a</u> as his initial edaphic variable (surrogate to TDS). Ryan (1980) has evaluated the above techniques, as well as several other TDS surrogates, for lakes within Ontario's West Patricia region (e.g. Lac Seul). Ryan (1980) determined that the use of phytoplankton standing crop is of limited use in this region due to the variability of Chl. a phytoplankton biomass in north-temperate lakes. Further, collection of Chl. a data requires intensive field work and is not very practical in a lake-dense area such as West Patricia. Ryan (1980) advocates the use of [TP] as a better indicator of productivity due to its ease of measurement and direct control over phytoplankton standing crop.

Recently, employment of spring [TP] as a fish yield predictor, appears to be approaching the "state of the art" in terms of its utility as a fisheries management tool. Hanson and Leggett (1982) employed an extensive analysis using two data sets, to evaluate the precision of several popular edaphic variables (e.g. TDS, TP, mean depth, macrobenthos biomass) in predicting fish yield. Univariate and multivariate predictors (i.e. edaphic variables used in combination) were compared for both data sets. For the first data set the best univariate predictors were macrobenthos biomass/mean depth and macrobenthos biomass.

The best multivariate predictor for the first data set included macrobenthos biomass, TDS, mean depth and lake area. Their results indicated [TP] to be the best univariate predictor for data set 2. The best multivariate predictor included a combination of [TP] with mean depth as independent variables (Hanson and Leggett, 1982).

2.1.4 *Conclusions*

The MEI has been both praised and criticized, both as a methodology and a concept. Ironically, both criticism and acclamation have been directed at the perceived inherent simplicity of the index. Properly applied, the MEI provides a rapid first approximation to fish yield problems and is a reasonable compromise between unmanageable complexity and ecological oversimplification (Ryder, 1982). While the MEI is expected to be a major tool for yield estimation in northwestern Ontario, the use of other descriptors of lake productivity should allow for an evaluation of the precision or applicability of the MEI (Ryan, 1980). Total phosphorus is perhaps the best candidate currently available for this purpose due to its key role in production dynamics, relative ease of measurement and strong predictive power (Hanson and Leggett, 1982). To conclude, the following two-step process is suggested for the acquisition of reliable, long-term fish yield data for specific lakes:

1. The calculation of a timely, rough empirical fish yield prediction (e.g. using MEI), followed by,
2. The lengthy development of a more accurate prediction of maximum sustainable yield (e.g. using [TP]).

(Matuszek, 1978).

2.2 Water Level Fluctuation Effects on Fish Productivity

2.2.1 *Response of a natural lake to impoundment*

The classic long-term response of a natural lake system to impoundment was first detailed by Ellis (1941). Ellis (1941) pointed out inherent factors of reservoirs or dam operations that reduce or limit biological productivity, and consequently, fish populations in impounded waters. Among the characteristics iterated by Ellis (1941) were:

- stagnation of large masses of water,
- removal of food materials within the aquatic system via drawoff,
- limitation of productivity within the littoral zone,
- extensive water level fluctuation and,
- continued and often heavy siltation of the lake bottom.

Ellis (1941) described temporal changes within reservoirs as following a number of classical stages. Initially following impoundment, biological productivity and natural fish food rapidly increases due to inundation of soils and subsequent leaching of minerals from those soils. After initial inundation fish productivity "booms" at an accelerating rate and remains high for a 5-10 year period. Ellis (1941) noted that after the boom period, fish productivity begins to decline with amazing suddenness for the following reasons:

1. The supply of raw materials from freshly inundated soils has been largely leached out,
2. Most organic matter left in the basin has been removed by bacteria, used in fish food production, or expelled in draw-off water,
3. The lake bottom begins to silt in, establishing new conditions at the sediment-water interface and,
4. Large numbers of fish, developed during the accelerated production stage are now consuming food sources at a more rapid rate than the declining food supply will support. This condition has a particular marked effect on top predators (e.g. northern pike, walleye).

Fish populations eventually reach a "stable" level approximately 20-35 years post-impoundment. The final level is usually disappointingly low compared to pre-impoundment levels. This classic post-impoundment response of fish populations has been documented for Lac Seul, which was impounded in 1935 (Crooks, 1972).

Despite the eventual stabilization of impounded waters, detrimental effects may linger as a result of continued water level fluctuations. These detrimental effects include:

- decreased water quality,
- increased sedimentation affecting spawning success and confusing migration of potential spawners to spawning beds (June, 1970; Hassler, 1970).
- negative economic impacts as a result of increased *Triaenophorus crassus* cyst counts in commercial species such as lake whitefish (McLaren, 1978; Bodaly et al., 1980).
- winter drawdowns necessary to meet hydro demands result in low spring water levels, sometimes preventing walleye and northern pike access to spawning grounds, and causing de-watering of lake whitefish eggs (Gaboury and Patalas, 1982).

Crooks (1972) and Hanna and Michalski (1982) both concur that the Lac Seul fish community currently exhibits stable post-impoundment population levels. However, marked annual water level fluctuations (mean annual fluctuation = 2.26 m) continue to affect component species of the Lac Seul fish community during spawning and nursery periods (Hough et al., 1981).

The remainder of this literature review will concentrate on these water level fluctuation impacts as they pertain to northern pike. Prior to the discussion of these impacts, it is useful to indicate those conditions necessary for quality northern pike spawning and nursery habitat.

2.2.2 *Northern Pike - spawning and nursery habitat requirements*

According to Scott and Crossman (1973), northern pike spawn after ice-melt, between April and mid-May, in water temperatures ranging from 4.4°C to 11°C. Preferred habitat within lake systems appears to be embayment areas, sheltered from wind and wave action, amongst submerged vegetation inundated by high spring water levels (Machniak, 1975).

Johnson (1957) noted that high spring water levels during spawning and a small, gradual decline in water levels during egg incubation (nursery periods) represent good conditions for the production of a strong northern pike year-class. Franklin and Smith (1963) add that stability of both water level and temperature are critical factors for the survival of northern pike year classes within spawning and nursery areas. Most authors contend that survival during these early critical stages depends upon the presence of inundated submerged vegetation within protected embayments, minimal wind and wave action, a silt-free water system and stable temperature and water level conditions. Changes in water temperature are not necessarily critical, provided they are gradual (Hassler, 1970).

2.2.3 *Water level fluctuation impacts on Northern Pike -- the case of Lac Seul*

Crooks (1972) and Hanna and Michalski (1982) examined relationships between water level fluctuations and fish productivity for Lac Seul. However, in neither case were water level fluctuations examined from the viewpoint of habitat loss or degradation due to water level fluctuation induced sedimentation.

On December 24, 1982, this author discussed potential water level fluctuation effects on northern pike spawning habitats with Dr. Bruno Boucek (Professor of Remote Sensing, Sir Sandford Fleming College, Lindsay, Ontario). Dr. Boucek recommended that a time-series of air-photos be examined for Lac Seul to determine the extent to which water level fluctuations had increased the rate of infilling of Lac Seul embayments. This exercise would provide a preliminary indication of northern pike spawning habitat loss or degradation.

Hassler (1970) observed that strong year-classes of northern pike (in Lakes Oahe and Sharpe, South Dakota) were associated with stable to rising water levels and temperature, flooded vegetation and calm weather during the spawning season. Benson (1980) pointed out that the absence of such flooded vegetation and habitat conditions, due to the establishment of unfavourable shore substrate, can result in poor reproductive success and a relative scarcity of adult northern pike within a population. June (1970) associated atresia (resorption of eggs) and interrupted spawning activity with fluctuations in water temperature and level. Further, Hassler (1970) has reported that erosion and silt deposition represent serious mortality factors in the development of pike embryos. Silt deposition and turbidity tongues have been observed in Lac Seul during spring seiching and turnover periods. If silt depositions are accompanied by abrupt temperature or water level changes, complete mortalities of an entire year-class can occur (Machniak, 1975).

2.2.4 *Conclusion*

The preceeding discussion suggests that an assessment of the impacts of annual water level fluctuation on northern pike spawning and nursery habitat would provide a realistic determination of the contribution of these habitats to the recruitment of northern pike stocks. Data generated from the assessment could then be utilized to refine/adjust potential yield estimates for northern pike as determined by the MEI.

2.3 Economic Perspectives

Economic efficiency is essential for establishing allocational criteria among conflicting resource uses, based on comparative evaluation of individual activities (Wepruk, 1981). The incremental values are important in making decisions relative to resource allocations (Knetsch and Davis, 1966). In order to integrate recreational and commercial fisheries valuation it is necessary to relate both to common denominators (Copes and Knetsch, 1981). Net economic yield is the only measure that will permit accurate comparisons of the benefits and costs of fishery development programs, of fish with other services from multi-purpose projects (e.g. hydro projects) and of commercial versus sport fishing (Crutchfield, 1962)

The purpose of this section is to review methods and information requirements necessary to ascertain the measurement of net economic yield for the purpose of valuation of sport and commercial fisheries. The review is intended to provide fisheries managers with rudimentary economic considerations that will become increasingly important for the reconciliation of demand conflicts among those who derive benefits from fishery products or fishing opportunities.

2.3.1 *Commercial Fisheries*

Bioeconomic models for the operation of commercial fisheries have been well developed (see Crutchfield and Zellner, 1962; Wepruk, 1981; Gordon, 1954). The majority of these models develop criteria for economic efficiency based on a consideration of the fundamental relationships between sustainable yield and levels of fishing effort under a variety of management modes. All of the models attempt to reconcile externalities inherent in the common property nature of the fishery resource. This section presents a collation of information requirements and management modes necessary for efficient operation of a commercial fishery.

Copes and Knetsch (1981) review and compare a variety of management modes (e.g. free access/free market, public management, consumers' monopsony, producers' monopoly, resource owners' monopoly) that occur in commercial fisheries in terms of their effect on the generation of three categories of net social benefits. Net benefits constitute a difference between total utility enjoyed by consumers and real costs of production (Copes and Knetsch, 1981).

The three categories of net social benefits are:

1. Consumer's surplus (CS):
   i.e. what fish are worth to consumers over and above what they have to pay (CS = willingness to pay - cost of commodity).

2. Producers surplus (PS):
   a form of economic rent to the commercial enterprise (PS = revenue - [opportunity cost and operating cost])

3. Resource Rent (RR):
   in a common property/free access resource, resource rent measures the surplus revenue that could be appropriated by the owner of a fishery resource who is exploiting the resource to his best pecuniary advantage.

(Copes & Knetsch, 1981).

The authors favour a mode of public access management that attempts to maximize the sum total of net benefits to society via the combined total of consumer surplus, producer surplus and resource rent that may be derived from utilization of a fishery (Copes and Knetsch, 1981).

The system of public access management requires fishing effort limitation to a level of catch production capable of achieving maximum net benefits. In order to determine this optimum level of fishing effort, three sets of data are required:

1. Estimates of the demand function for fish
2. Pattern of private costs for fishing fleet, and
3. Bioeconomic information to estimate the relationship between effort and yield (i.e. a eumetric fishing curve as described in Crutchfield and Zellner, 1962).

Data requirements for short-run regional analysis of a commercial fishery's performance are outlined more specifically in Meuller and Wang (1981). These include information on the following:

1. Price changes,
2. Net income in the harvesting sector,
3. Employment in the harvesting sector,
4. Labour income in the harvesting sector,
5. Net income in the processing sector,
6. Employment in the processing sector,
7. Labour income in the processing sector,
8. Regional income,
9. Consumer surplus,
10. Management and enforcement costs, and
11. Trade flows - regional import/export.

Following the acquisition of the above data the next step is to specify the assumed behavioural relationships that exist among the various categories of data and empirically estimate these relationships (Meuller and Wang, 1981).

The efficient acquisition of the above data inherently requires control systems on the fishery that will progress away from common property externalities and toward a "best use" principle aimed at satisfying biological, economic and social objectives. The conclusions of the Sinclair (1979) Report for British Columbia salmon fisheries suggest that license limitation alone is an inadequate tool to achieve the economic optimum of best use. Sinclair (1979) stressed that extant fisheries must also be under effort control. To correct the problems of the B.C. fishery, Sinclair (1979) recommended limited entry, control of over-capitalization by an increase in fishing vessel license fees and the implementation of a royalty on landings. The desireability of implementing a royalty on landed-value as a means of capturing resource rent is discussed fully in Cauvin (1979).

Mitchell (1981) discusses the advantages of the royalty or landing charge considered by Sinclair (1979) as a regulation means which would (1) act as a governor of the rate of growth of the fishing fleet and would decrease incentive for overcapitalization, and; (2) act as a means of increasing government revenues by recovering resource rent, thereby providing payment to the owners of the resource--the people of Canada. However, equity considerations are inherent in the collection of royalties. Should royalties be captured by or shared with government or distributed more widely by allowing more fishermen into the fishery (Mitchell, 1981)? These decisions are crucial at the regional level, particularly when unemployment is a primary governmental concern.

The establishment of property rights (e.g. enterprise quotas) within the fishery, has been forwarded as a powerful solution to the common property problems of fisheries exploitation. Such a system would permit fishermen to make rational decisions of how best to make their quotas in the same way a farmer determines the best combination of labour and capital to exploit his land (Mitchell, 1981). The biological, social, economic and philosophical implications of establishing property rights within the fishery are discussed in Wysocki (1981). The advantages of establishing property rights from a management standpoint are as follows:

1. They are a means of assuring catch remains within biologically acceptable levels,
2. They provide operational flexibility to fishermen since they determine the best way to catch their quota -in this 'milieu' overcapitalization will be rationalized,
3. Rights can be marketable, and
4. They are a means of collecting management fees.

(Mitchell, 1981).

Thus, an individual vessel and enterprise quota system accompanied by a free market for these quotas, once established can be a strong self-regulatory mechanism for fisheries exploitation (Mitchell, 1980).

It is encouraging to note that the Ontario Ministry of Natural Resources (OMNR) is attempting to adopt principles outlined by Mitchell (1981) to Ontario's commercial fisheries. Initiatives aimed at modernizing Ontario's commercial fishing industry are in progress involving both government (OMNR) and industry (through the Ontario Council for Commercial Fisheries--see OMNR - OCCF, 1982). The property rights system for fisheries exploitation has already been successfully implemented in the Bay of Fundy herring fishery. There, the system proved that "individual vessel quotas can be administratively feasible, acceptable and popular with fishermen, achieve greater efficiency in production and bring about a more equitable distribution of incomes and returns" (Mitchell, 1981).

2.3.2 *Recreational Fishing*

The critical product to be measured in a recreational fishery is the value of the fishing opportunity (Anon., in press; Copes and Knetsch, 1981; Crutchfield, 1962). As with the commercial fishery, the net benefit of a sport fishery is expressed by what individuals are willing to pay (in addition to what they already pay) for the experience.

rather than to go without it (McConnell and Norton, 1976). Willingness to pay is equivalent to the consumer surplus area under a demand curve. However, due to the non-market nature of most sport fisheries, the derivation of this area poses problems. An essential requisite, regardless of valuation method utilized, is a means of translating net benefits from fishing to net value of fish in order to make stock allocations among competing users (McConnell and Norton, 1976).

2.3.2.1 Information Requirements for Demand Analysis

If any economic model is to be of practical use, it must be capable of capturing the economic effects of changes in the quality of sport-fishing (Anon., in press). McConnell and Norton (1976) and Meuller and Wang (1981) list the following as quality determinants for individuals partaking in the sportfishing experience:

- success ratio (e.g. CUE), stock size,
- user--congestion,
- availability and selection of time,
- availability and selection of income, and
- availability of alternative fisheries.

Each of these quality determinants is capable of affecting the position and slope of the sport fishery demand curve (Meuller and Wang, 1981). Consequently these determinants constitute the desired information sought from the methods of recreational fishery valuation.

In addition to the acquisition of demand data, a careful delineation of the region for analysis and import/export money flows is necessary to achieve sound evaluation of regional income effects (Crutchfield, 1962). Trade flow data includes 'downstream' impacts of sport fishing (i.e. food and lodging consumed or contributions to the regional economy). Data of this nature is the domain of input-output analysis (Meuller and Wang, 1981). Besides identifying regional trade flows, this data also indicates substitution effects and available alternatives to the sport fishery. It is important to note that input-output analysis constitutes a separate dataset from that used to determine sportfishery demand (Al Barber, pers.comm.). To include this type of data in sport fishery demand analysis would be to invite double counting errors. Nevertheless, the acquisition of input-output data is crucial in making allocation decisions.

2.3.2.2 Valuation methods for demand analysis

Several methods have been developed for generating data or the relationship between willingness to pay and the quantity of angling. McConnell and Norton (1976) and Knetsch and Davis (1966) advocate the direct interview (or contingency valuation) approach combined with the imputation of a demand curve from travel cost data as a reasonable means for obtaining meaningful estimates of net economic benefits.

Contingency valuation -

The contingency valuation method simply involves asking a sample of anglers how much they would be willing to pay. It is the only method available for obtaining information on how much anglers would have to be compensated to forego the opportunity to fish (Anon., in press). Therefore, the survey is a direct measure of the value respondents receive from the fishing opportunity.

Problems inherent in willingness to pay questionnaires include response reliability, bias in answers dealing with matters of opinion and the exclusion of quality determinants affecting value. These shortcomings can be overcome to an extent by carefully worded questions (to eliminate the 'ask a hypothetical question, get a hypothetical answer' syndrome McConnell and Norton, 1976) and by including additional questions asking anglers their willingness to pay for fishing of different qualities (Anon., in press).

Travel Cost Method -

The travel cost approach (McConnell and Duff, 1976) is used to estimate a per capita demand function and compute consumer surplus. The method generates price-quantity data by utilizing existing quantities for an angler and treating the anglers' travel costs as a proxy for the price of going fishing (Anon., in press). The basic assumption is that anglers would react to an access fee for the fishery in the same manner as they would to an identical increase in their travel costs. The exact steps for applying this approach are provided in Anon.(in press).

In utilizing the travel cost approach problems can arise when demand is rationed or congestion occurs to the extent that the consumer's perception of spatial availability and demand affects the likelihood of travel. Under such conditions, the travel cost approach can lead to underestimates of resource value (McConnell and Duff, 1976).

However, by using the contingent valuation method in combination with travel cost data gathering, the results of both approaches could be compared to check for consistency and reliability (Anon., in press). Interviews may be the best way of resolving the ambiguities in the travel cost method concerning multiple destination cases and for finding the appropriate valuation for converting distance into dollars (Knetsch and Davis, 1966).

2.3.2.3 Externalities and Costs

> *The most important issue facing all of Canada's recreational fisheries is that of reconciling the continually increasing demand for sport fishing with the fixed supply of angling opportunities provided for by the resource.*
>
> *Should agencies continue to permit free entry to the fishery (or entry at a relatively nominal cost) in which case the likely result would be overcrowding, falling success rates and, in general, a deterioration in the quality of the sport fishery? Or, should there be measures to restrict the number of fishermen and thereby preserve the quality of sportfishing?*
>
> (Anon., in press.)

Copes and Knetsch (1981) identify two categories of social costs in a sport fishery that are exclusive of private costs. These are:

1. Public Management Costs - incurred by public authorities in providing access to recreation sites and maintaining environmental conditions and facilities, and

2. External Diseconomies - e.g. congestion resulting from the "cost" that each additional participant imposes on the fishermen already committed to the fishery.

Figure 2.1 represents the model developed by Copes and Knetsch (1981) describing the relationship of private and social benefits and costs in a recreational fishery. An itemized description of the model in Figure 2.1 follows:

1. AB - represents the demand curve and measures marginal value of the sport fishery assuming no further entry.

2. CED- the area within this triangle represents the "cost" of congestion externality as each additional fisherman affects an increasing number of fishermen already committed to the fishery.

3. If free access is maintained, total social cost becomes the area CEBO. Therefore social benefits are represented only by the area of ABO that exceeds CEBO.

4. At participation level OG, the social cost of providing access for additional fishermen exceeds the net benefits per person-day. Therefore, any fishing beyond this level represents "overfishing" or a "socially detrimental use of the resource."

Copes and Knetsch, 1981.

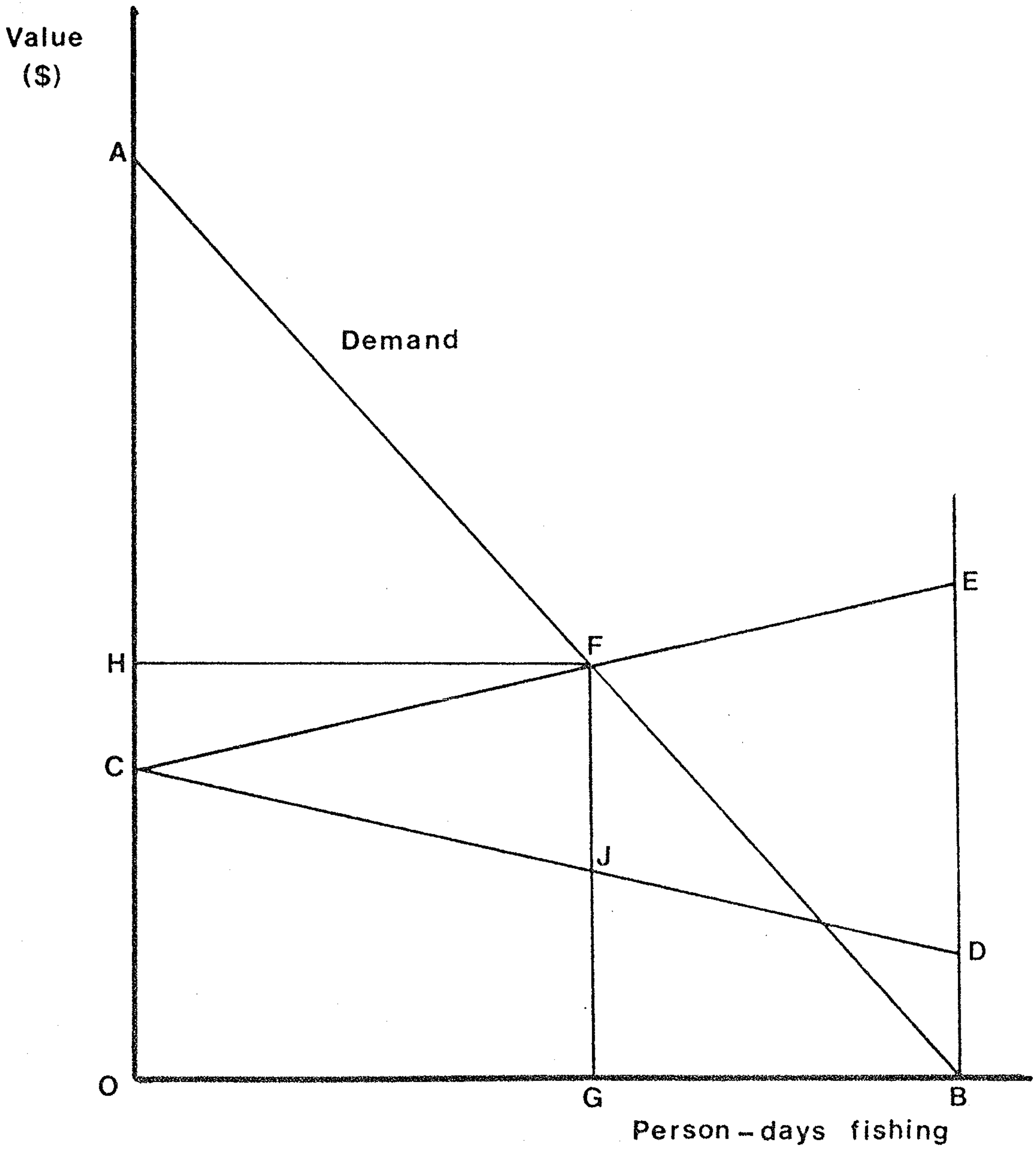


Figure 2.1: Relationship of private and social benefits and costs in a recreational fishery with public resource ownership. (Copes and Knetsch, 1981).

Therefore, the optimum participation level is OG as it generates the largest possible aggregate net social benefit -- AFC (Copes and Knetsch, 1980).

Optimum participation could be achieved if an access fee of FG per person-day of angling were charged. Potential participants in the range GB would then not join in as the fee of FG would exceed their willingness to pay for further use of the fishery (Copes and Knetsch, 1981).

This model could prove to have interesting applications to the non-resident, non-contributor user groups of the northwestern Ontario sport fishery. Currently, these groups camp on Crown Land free of charge and their only access fee is the nominal charge of a fishing license. The introduction of OMNR's proposed Crown Land Access Permit combined with increased user fees and species-specific licensing could provide useful vehicles for controlling congestion externalities and maintaining a quality fishery.

Costs remain to be considered in the model developed by Copes and Knetsch (1981). For example, if the costs attached to enforcement and collection of access fees were to exceed area FEB (Figure 2.1), then it would be socially preferable to allow free access to continue. Further, at the prestated level of maximum net social benefit (OG) with an associated access fee of FG, the public authority then collects revenues equivalent to the area HFGO, offset by public expenses of CJGO. The remainder (HFJC) after outlays is the sum collected by the public authority to assure optimal use (Copes and Knetsch, 1981). This amount -- HFJC -- is in the nature of a resource rent, collected by the public authority representing society as resource manager and owner. As the resource is owned by all of society and not just those using it for fishing, the fees might also accrue to the public treasury thereby avoiding the inefficiencies inherent in earmarked funding (Copes and Knetsch, 1981).

2.3.2.4 Pricing as an alternative to proxy valuation

Cauvin (1980) and others (e.g. Crutchfield, 1962) firmly believe that recreational fishing opportunities are grossly underpriced and that it will become increasingly necessary to adopt a pricing system to value recreational resources. Cauvin (1980) argues that the provision of free goods produces bad market signals (e.g. signals of infinite demand) whereas a pricing system assures that equitable allocation decisions might be made and that government management programs will stand scrutiny:

> *...without prices the fisheries manager is deprived of the tools required to measure adequately the desires of society and thus the economic value of fisheries resources as an underlying requirement for making investment and allocation decisions ... distorted 'demand' signals place pressure on government to expand the supply of resources to satisfy the requirements of the beneficiaries...*
>
> Cauvin, 1980

The importance of pricing is two-fold. Firstly, it provides price control on demand and informs sport fishermen of the costs of providing recreational benefits; revenue is generated; demand is under control; and the price-quantity information to measure demand signals is available. Secondly, by pricing of recreational resources at their economic cost, the sport fisherman is expressing his evaluations of the benefits he receives on the basis of willingness to pay (Cauvin, 1980). This provides signals of whether recreational benefits should be expanded or contracted; information for governments to assess their expenditures in supply of the resource and therefore allows governments to make more efficient allocation of resources (Cauvin, 1980).

2.3.3 *Conclusions*

In order to make rational allocation decisions within a fishery, economic information is required that is capable of assessing comparative value of all component user groups. The comparative unit of value desired for allocation among user groups is maximum net economic yield.

The establishment of property rights within the commercial fishery has proved effective, in the Bay of Fundy herring fishery, as a self-regulatory means of achieving efficiency in production and consumption and equity. The Report of the Committee on Modernizing Ontario's Commercial Fisheries (OMNR-OCCF, 1982) proposes to adopt property rights initiatives as a means of assuring sustainable harvests and controlling overcapitalization and various externalities inherent in a fishery resource. This process is also capable of providing the economic information necessary for valuation of the commercial fishery.

The combined use of travel cost and contingency valuation methods for recreational fisheries appears to offer a reasonable means for obtaining meaningful estimates of net economic yield. In conjunction with these valuation methods, it is necessary to identify the presence, and magnitude of any externalities affecting the quality of the sport fishery. Depending upon the severity of the externalities, a system of pricing may be necessary in order to control demand and/or to permit the public authority to assess the sport fishery value for allocative purposes.

While a number of the valuation methods discussed contain certain problems, the acquisition of such data will, at least, provide for informed judgment and thereby contribute to allocational and policy decisions.

CHAPTER III

METHODS

Principally the fisheries management plan was developed using fisheries data filed at OMNR, Sioux Lookout District Office, consultant reports and relevant published and unpublished manuscripts.

Specific methods relating to previously discussed objectives are as follows:

- estimating production potential of Lac Seul ichthyomass using Ryder's (1965) morphoedaphic index (MEI).

The MEI was determined for each of Lac Seul's basins using the formula:

$$\text{MEI} = \frac{\text{Total dissolved solids (TDS) in mg/l}}{\text{Mean depth } (\bar{Z}) \text{ in m}}$$

TDS and $\bar{Z}$ data were obtained from OMNR lake survey files. MEI was then used to calculate potential yield, utilizing the yield function derived for the Winnipeg-Nelson river physiographic watershed unit (SPOF, 1982):

$$\hat{Y} = 1.38\ (\text{MEI})^{.45}$$

where $\hat{Y}$ = potential yield

Assuming a fish community type of whitefish, walleye and northern pike, fish yield was partitioned as follows:

Fish Community Species	Percent of Potential Yield (%)
Lake Whitefish	22
Northern Pike	15
Walleye	26

(Northwestern Region partitioning criteria, Neville Ward, pers.comm.)

- quantify historic and present commercial and recreational fish harvest.

Commercial and recreational fish harvest data were obtained from OMNR Sioux Lookout District files. Present and historic harvest data for the commercial fishery were examined and compared with existing quota levels for species on quota (walleye, whitefish). Current quota levels represent target levels for future commercial fish demand (OMNR, 1982). For commercial species not on quota (e.g. sucker, burbot, tullibee), future allocation targets comprise average annual harvest over the 1976-1981 period, as per OMNR (1982) targets.

Recreational fish harvest levels were determined using creel survey data (Crooks, 1972; Hough et al., 1981; Marshall, 1982). Allocation targets to the year 2000 are based on projected demand as per OMNR (1982). OMNR (1982) data suggest that angling demand by resident sport fisherman will be maintained at present levels to the year 2000; whereas non-resident angler demand is expected to increase at an annual rate of 1.25 per cent to the year 2000.

- Identify shortages and surpluses between potential production and current total harvest.

Estimates of biological production potential were compared with present commercial and recreational fish harvest levels to determine supply-balance ratios (i.e. the extent of over/under harvest) for each basin. Present supply-balance ratios were then compared with a fishery demand scenario to the year 2000 based on SPOF (1982) targets and allocational criteria.

Management strategies were developed employing mitigative measures to basins, or components of the Lac Seul fishery, exhibiting discrepancies between short-term/long-term targets and supply/demand inadequacies. Management strategies were priorized, based on subjective evaluation, under the following categories:

1. Strategies requiring immediate implementation,
2. Monitoring strategies,
3. Lag or contingency strategies.

Further priorization of strategies employing benefit-cost analyses or cost-effectiveness techniques will be necessary once budget allocation has been finalized for the implementation of the management plan.

The final section of the Plan allocates the Lac Seul fish stocks based on the following allocational ranking system established by SPOF (1978):

Priority ranking	Allocate to:
1	All residents (maintenance and/or rehabilitation of the resource).
2	Native people with Treaty fishing rights for subsistence and/or traditional needs.
3	Resident sport fishermen.
4	Business enterprises--priority between commercial fishing or sportfishing industries to be decided on the basis of optimum benefits to residents of Ontario.

(modified from Wepruk, 1981).

For the purpose of fishery allocation for Lac Seul, priority 4 is broken down such that non-resident contributor sport fishermen have priority over the commercial fishery. The benefits to the local and regional economy of northwestern Ontario, from the lodge based fishing industry (catering almost wholly to non-resident sport fishermen), far exceeds those derived from the commercial fishery of Lac Seul (Hough et al., 1981). It is this premise that establishes priority of non-resident contributors over the commercial fishery.

Finally, a spring aerial reconnaissance survey was conducted to examine sediment sources and turbidity tongues which may have impacts on northern pike spawning and nursery habitats. In conjunction with the aerial survey, air photos spanning the period 1958-1978 were examined (at National Air Photo Library, Ottawa) to determine the extent of infilling of embayment areas, representing potential northern pike spawning/nursery habitat. This data was compared with water-level fluctuation literature to serve as a preliminary indicator of the status of northern pike spawning and nursery habitats.

CHAPTER IV

RESOURCE INVENTORY AND ANALYSIS OF LAC SEUL

4.1 User Groups and the Resource

4.1.1 *Users*

Potential local users of the Lac Seul fishery resource consist of approximately 7,300 people (based on 1978 determinations), within the study area delineated by Hough, et al., (1981). Approximately 31% of the population base live along Highway 105 from Camp Robinson to Ear Falls, 63% within Sioux Lookout-Hudson area and 7% on the Lac Seul Indian Reserve (Figure 1.2).

User groups for the Lac Seul fishery include: recreational anglers (including locals, Ontario residents, non-resident contributors and non-resident non-contributors), commercial fishermen, tourist operators and their guests, and native peoples.

4.1.1.1 Anglers

Anglers are primarily non-residents. In 1979, angler origin was 20% local, 4% non-local Ontario residents, 1% non-resident Canadians (i.e. citizens of Canada residing outside of Ontario) and 74% American (Hough, et al., 1981).

An estimated 186,657 angler hours effort were exerted from June to August 1979, with 40% of this effort exerted in June. Eighty-two percent of all angling occasions were through Sioux Lookout-Hudson access points; these basins represent 46% of Lac Seul's total area.

In 1979, species sought by anglers were exclusively walleye and northern pike. Approximately equal weights of both species were taken although twice as many walleye were caught.

4.1.1.2 Commercial Fishermen

The earliest systematic commercial fishing of Lac Seul began in 1910 (Weilandt, 1982). Records of commercial harvests are available from 1924 to the present in Sioux Lookout District files (J. McDonald, pers.comm.). The fishery has undergone a marked fluctuation in harvest and species composition since 1924 (Table 4.1).

Flooding in 1935 caused by installation of a dam at Ear Falls, was followed by a 78% average increase in harvest (295,000 kg/year) over the period 1940 to 1949. This compared with an average harvest of 166,000 kg/yr during the period 1924-1939. During the period 1950-1961, harvests levelled off averaging 200,100 kg/yr; these harvests were slightly higher than pre-flood catches. This increase has been attributed to the increased productive surface area of Lac Seul (Hough, et al., 1981).

Harvests averaged 180,400 kg/yr during the period 1962-1970. Coarse fish (i.e. burbot, suckers, chubs, etc.) accounted for 31% of this harvest, in comparison with 5% for

Table 4.1: History of commercial harvests on Lac Seul, 1924-1979.

Time Period	Influencing Factors	% of Total Harvest (Bracketed values in kilograms)			Average Total Catch (kg/yr)
		Sportfish	Coregonids	Coarse Fish	
1924-1939	Pre-flooding	60 (100,700)[a]	38 (63,300)	2 (2,600)	166,600
1940-1949	Post-flooding "boom"	70 (207,900)	27 (78,500)	3 (9,400)	295,800
1950-1961	Nylon gill nets used; increasing sportfish harvest. Greater water level fluctuations.	57 (114,600)	38 (75,500)	5 (10,000)	200,100
1962-1970	Coarse fish harvest increases	41 (73,300)	28 (50,500)	31 (56,600)	180,400
1971-1972	Lake closed due to mercury levels	0	0	0	0
1973-1980	Quota management & licence reduction	9 (7,100)	52 (42,900)	39 (32,500)	82,500

[a] Bracketed number is weight of catch, in kg/year.

Source: Hough et al., 1981.

the 1950-1961 period.

From 1928-1970, harvests were not based on scientific information. Annual harvest was governed primarily by the abundance of fish and market conditions.

In 1970, thirteen commercial fishing licences were held for Lac Seul. Three of these licences were held by treaty Indians from the Lac Seul Reserve. In that same year, the discovery of elevated mercury levels in walleye and northern pike led to the closure of the commercial fishing seasons in 1971 and 1972. Following this, one licence was issued in 1973. Quota restrictions based on historic maximum sustained yield estimates were put into effect. The harvest was restricted to whitefish, tullibee and coarse fish showing acceptable levels of mercury. Northern pike was eliminated as a commercial species and walleye was allowed only as an incidental catch, with size limit restrictions imposed (38 - 48 cm, J. McDonald, pers. comm.).

Since the re-opening of the fishery in 1973, harvests have averaged 82,500 kg/yr. The walleye catch has been reduced to 9% of the total harvest. Coarse fish constitute 39% of the harvest (Weilandt, 1982).

At present, Lac Seul is commercially fished under four gill net licences held by three fishermen. Each licence is assigned to a fishing block (Figure 4.1) with a quota assigned for whitefish on all four blocks and an incidental catch quota

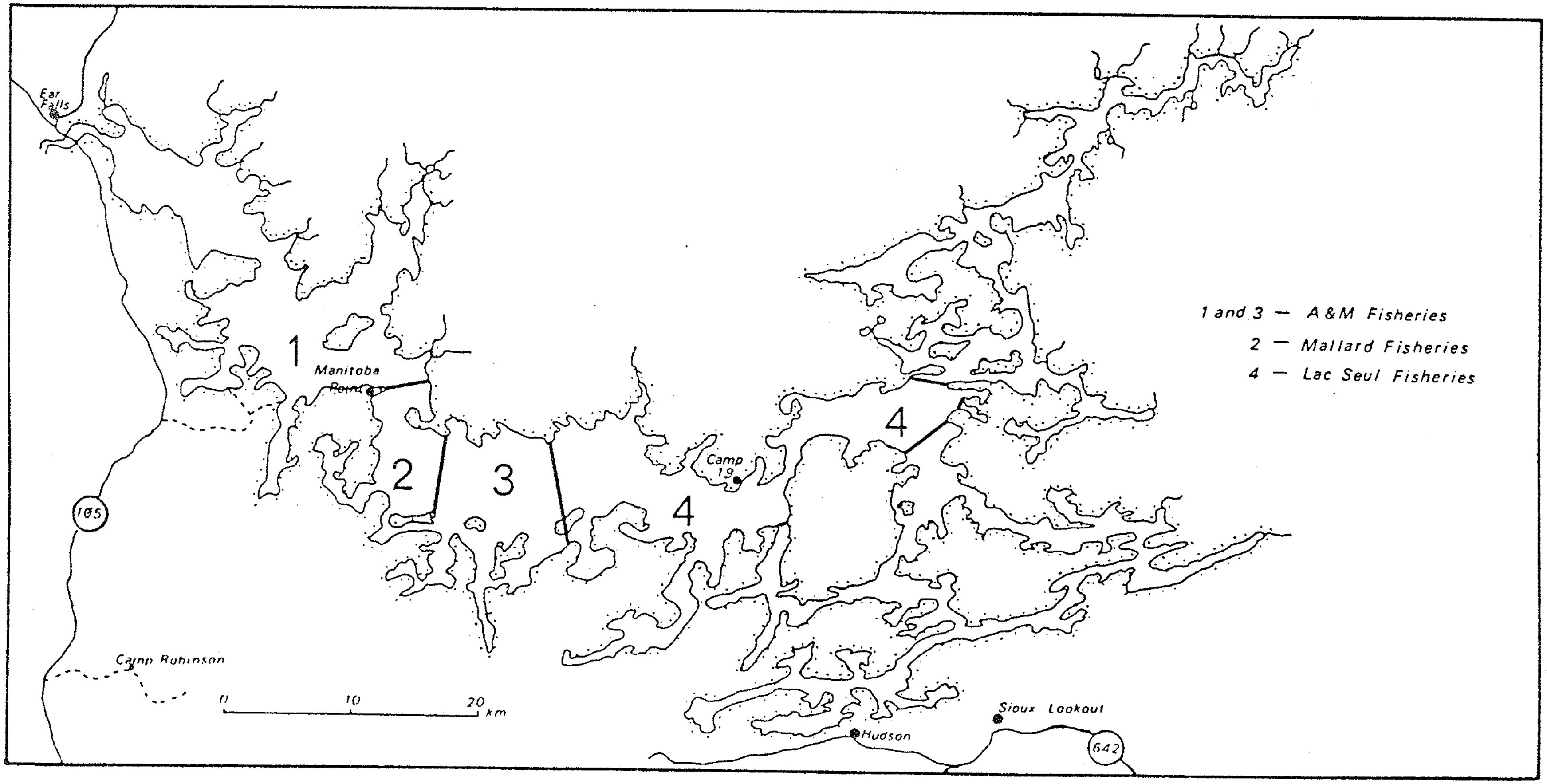


Figure 4.1: Commercial fishing blocks, Lac Seul.

Source: Hough et al., 1981.

for walleye on blocks 3 and 4. No quotas are set for tullibee or coarse fish such as sucker or burbot. Fishing operations usually run from mid-June to mid-August.

Commercial fishing licences for Lac Seul are as follows:

Commercial Licence	Type
SL 4459	Gill
SL 4333	Gill
SL 4566	Gill
SL 4567	Gill
SL 4552	Trap

Lac Seul Fisheries is based in Hudson where a packing and cold storage facility is operated. A fishing camp at Camp 19 on Wesley Bay is used as a base.

Mallard Fisheries, based in Hudson, maintains a fish camp near Manitoba point (north of William Bay); fish is shipped from this camp to Hudson and has recently been shipped to Ear Falls for truck pick-up.

A and M Fisheries operates out of Dryden; fish are trucked to this location from Lac Seul.

There is no local market for the commercial fishermen's catch. Fish are marketed in Thunder Bay, Fort Francis or Kenora. Walleye are exported to the United States.

Based on O.M.N.R. records of fishermen's receipts, the gross value of these sales outside of the local area was $103,000 in 1979. Indirect spinoff benefits cannot be estimated for Lac Seul (Hough et al., 1981).

4.1.1.3 Tourist Operators

Lodge operations on Lac Seul began in 1946 with the opening of two lodges. In 1948, two more were operating; five more lodges opened in the early 1950's; two more lodges opened in the 1960's; one in 1964 and one in 1969.

During the 1950's and early 1960's Lac Seul was known for its trophy northern pike fishing. Walleye and northern pike now represent, equally, the mainstay of tourist operations on Lac Seul.

Fourteen licenced commercial lodges now operate on Lac Seul. All are located on the western or central portions of Lac Seul. Ten outpost camps are located on the more remote sections of the lake (Figure 4.2). Four of these outposts are operated by Lac Seul lodges; five are operated by lodges in the Sioux Lookout area, and one by a lodge in the Dryden area.

In 1979, two of the lodges did not operate as tourist lodges and one was closed. Of the remaining 11 lodges, one offered American Plan only, four offered housekeeping only, while the remaining six offered both. Campsites were available at six of the lodges.

The tourist lodges provided approximately 25,568 guest days during 1979; 99% of the guest-days represented U.S. visitors. Seventy-three percent of all anglers on Lac Seul

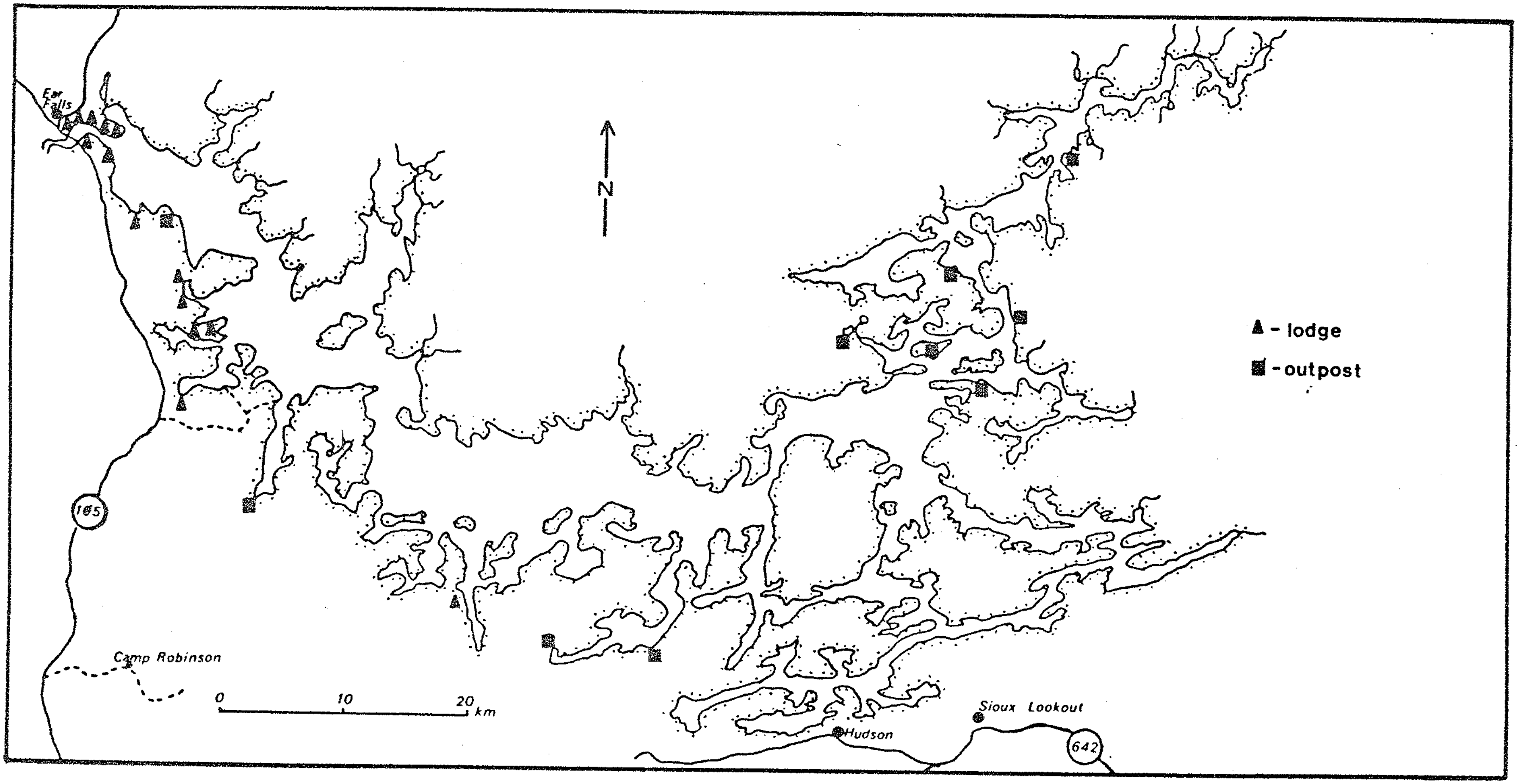


Figure 4.2: Tourist lodges and outpost camps, Lac Seul

After: Hough et al., (1981)

stayed at lodges in 1979. Ninety-two percent of lodge guests were found to be anglers and eight percent were hunters. All lodge operations began in May with, on average, closing occurring in October (Hough et al., 1981). Hough et al., (1981) reported that 8 of the 11 tourist operators made investments of $2,500. or more towards upgrading of buildings and equipment within the five seasons prior to and including 1979. Total capital investments reported were approximately $290,000. The estimated capital market value of all lodge operations (1979) was $1,746,000. (Weilandt, 1982).

Gross revenue for all lodges was estimated at $595,000. for 1978. There was an average increase of 7.9% in gross revenue during 1979. This provided a capital productivity (gross revenue divided by market value) of 37%; this figure is comparable to the capital productivity for the whole of the Kenora District (Weilandt, 1982).

4.1.1.4 Native People

Lac Seul Reserve 28 is the only reserve located on Lac Seul. It has an area of 26,832 hectares. In 1978, the population of the band was 1,237; 460 actually lived on the reserve. The remainder live in Hudson, Sioux Lookout, Ear Falls, Kenora and Savant Lake (Hough, et al., 1981).

Use of the fishery resource by native people for their own use is unknown. In the commercial fishery, three licences were held by treaty Indians prior to the 1971 closure. Since reopening, all four licences have been held by non-Natives (J. McDonald, pers.comm.)

4.1.2 *The Resource*

4.1.2.1 Climate

The Lac Seul area experiences a continental climate moderated by the influences of Hudson Bay, Lake Superior and Lake Winnipeg.

Average daily temperature in January is -18.8°C and 18.3°C in July. Mean annual temperature variation is 37.1°C. Mean daily temperature throughout the year is 1.25°C with a mean annual frost free period of 108 days (Weilandt, 1982).

Mean annual precipitation is 704.5 mm; 37.4% of this occurs during the summer months. The ground is usually covered with snow from November to April. Mean annual snowfall is 215.1 cm with the greatest amount falling in November (19.2%). Northwestern Ontario is subject to periods of drought which can lead to uncharacteristically low water levels.

Hours of daylight range from approximately 16.5 hours to 8 hours in June and December, respectively (Weilandt, 1982).

4.1.2.2 Physiography

The major physiographic characteristics of the Lac Seul region have been outlined in Chapter I (Introduction) of this report.

Climatic and geological characteristics within the Lac Seul region are factors limiting fish production in this area, compared to most other areas of Ontario. The short growing season and the long duration of ice and snow cover limit primary productivity, and ultimately fish productivity. Although granite bedrock is characteristically low in nutrients, the ancient lake bed history and clay deposits of the area would compensate somewhat for the low nutrient composition of the bedrock within the watershed.

The Lac Seul watershed drains an area of 26,470 km^2 of the Winnipeg-English River system. Since 1957, the Root River diversion bringing water from Lake St. Joseph on the Albany River watershed, has increased the drainage area of Lac Seul by 12,238 km^2 (Weilandt, 1982).

In 1980, the discharge of the English River at Ear Falls was 232 m^3/sec while the inflow at Sioux Lookout averaged 69 m^3/sec (Environment Canada, 1981). In comparison, the Root River discharges 84 m^3/sec into Lac Seul during peak flow periods (John McDonald, pers.comm.).

4.1.2.3 Hydrology and Limnology

Lac Seul undergoes a marked annual fluctuation in water levels due to its use as a water storage reservoir for hydro-electric facilities downstream. Water levels have averaged 356.0 m above sea level during the 20-year period from 1958 to 1978. Water level fluctuations for this period are presented in Table 4.2.

From 1958 to 1978, the annual water level fluctuation was 2.26 m. Annual fluctuations prior to impoundment averaged 0.97 m. After impoundment, but prior to the operation of the Manitou hydro station (i.e. from 1935 to 1957), fluctuations averaged 1.34 m (Hough et al., 1981).

On a yearly basis, minimum levels are reached in April after a continuous water drawdown during the winter. Spring runoff recharges the reservoir by early June. Peak levels are attained in September (Environment Canada, 1981).

Water quality was evaluated in 1979; a brief discussion of the results is now given. Water clarity was limited; Secchi disc readings ranged from 0.7 m to 2.9 m, average 1.6 m. Presence of temperature stratification was variable, due to the differing nature of the basins. However, temperature stratification was present in deeper basins such as McKenzie Bay, McIntyre Bay, Eagle Island, Wapesi Bay and Sen Bay. More detailed data on temperature stratification is available in Hough, et al., (1981).

Table 4.2: Water level fluctuations, Lac Seul 1957-1978.

Year	Elevation (m)		Fluctuation (m)
	Maximum	Minimum	
1957/58	356.58	354.88	1.70
1958/59	357.24	355.18	2.06
1959/60	356.68	354.95	1.73
1960/61	356.13	354.29	1.84
1961/62	357.10	354.58	2.52
1962/63	357.07	355.29	1.78
1963/64	357.26	354.57	2.69
1964/65	357.30	355.01	2.29
1965/66	356.94	354.60	2.34
1966/67	356.87	354.10	2.77
1967/68	357.31	354.49	2.82
1968/69	357.35	354.65	2.70
1969/70	357.24	354.70	2.54
1970/71	357.30	355.17	2.13
1971/72	357.33	354.90	2.43
1972/73	356.75	354.46	2.29
1973/74	357.49	355.04	2.45
1974/75	356.70	354.82	1.88
1975/76	356.51	354.64	1.87
1976/77	356.20	353.60	2.60
1977/78	356.87	354.80	2.07
			2.26[a]

[a] Mean difference

Source: Hough, et al., 1981.

4.1.2.4 Potential Yield

Because of the complex nature of Lac Seul, data on area, mean depth, TDS, morphoedaphic index (M.E.I.) and potential yield is presented for each basin (Table 4.3). The TDS values for all 23 basins were derived from 7 sampling sites, some of which were remote from the basins to which they were applied (Hough et al., 1981).

Hough et al., (1981) partitioned species yield into 30% walleye, 10% northern pike, 30% coregonids and 30% coarse fish. For basins 2, 4, 9, 16, 20, 21, 22 and 23, species yields were partitioned into 40% walleye, 10% northern pike and 50% coarse fish. Hough et al., (1981) argue that these shallow water basins lack suitable mid-summer cool water habitat, required by coregonids. The partitioning rationale adopted by Hough et al., (1981) is used in this text only to illustrate comparisons of past harvests with potential species yields (see Table 4.13). However, in determining actual allocation of the Lac Seul fish species to existing user groups, a more current partitioning rationale (prescribed for northwestern region) will be utilized. This partitioning of species yields assumes a whitefish/walleye/northern pike fish community type with allowable sustainable yields assigned as follows:

Species	Partitioned Species Yield (% of MSY)
Whitefish	22
Walleye	26
Northern Pike	15
Total	63

(Neville Ward, Regional Fisheries Biologist, Kenora--
pers.comm.)

Table 4.3: Potential Yield and partitioned species yield, Lac Seul.[a]

Basin	Surface Area (ha)	Mean Depth (m)	TDS (mg/l)	MEI	Total Potential Yield (kg/ha)	MSY (kg/yr)	Partitioned Yield (Kg/yr)[b]		
							Walleye	Northern Pike	Whitefish
1	12,000	9.7	51.94	5.35	2.91	34,907	9,076	5,236	7,680
2	1,549	5.3	53.61	10.11	3.86	5,982	1,555	897	1,316
3	20,667	8.7	53.61	6.16	3.09	64,004	16,641	9,601	14,081
4	2,248	4.7	53.61	11.41	4.08	9,161	2,382	1,374	2,015
5	2,176	6.4	57.94	8.12	3.50	7,621	1,981	1,143	1,677
6	40,610	14.6	47.82	3.28	2.34	94,984	24,696	14,248	20,896
7	2,176	4.1	47.82	11.66	4.11	8,954	2,328	1,343	1,970
8	1,124	13.7	47.82	3.49	2.40	2,703	703	405	595
9	3,302	5.6	74.79	13.36	4.37	14,436	3,753	2,165	3,176
10	3,118	6.4	47.82	7.47	3.37	10,522	2,736	1,578	2,315
11	7,832	8.5	42.82	5.04	2.83	22,181	5,767	3,327	4,880
12	2,031	6.3	42.82	6.80	3.24	6,573	1,709	986	1,446
13	435	8.4	42.82	5.10	2.84	1,238	322	186	272
14	2,336	6.4	42.82	6.69	3.21	7,505	1,951	1,126	1,651
15	4,452	8.2	43.29	5.28	2.89	12,872	3,347	1,931	2,832
16	570	5.3	43.29	8.17	3.51	2,001	520	300	440
17	4,711	4.7	45.15	9.60	3.77	17,777	4,622	2,667	3,911
18	16,752	14.2	45.15	3.18	2.30	38,645	10,048	5,797	8,502
19	1,595	3.5	45.15	12.90	4.30	6,854	1,785	1,030	1,510
20	3,546	6.8	46.62	6.86	3.25	11,520	2,995	1,728	2,534
21	4,659	5.5	46.62	8.48	3.57	16,636	4,325	2,495	3,660
22	2,683	3.6	46.62	12.95	4.31	11,568	3,008	1,735	2,545
23	3,152	2.8	46.62	16.65	4.82	15,200	3,952	2,280	3,344
	143,726					423,855	110,002	63,578	93,248

[a] TDS, MEI and subsequent yield determinations, as per SPOF Working Group #12, March, 1982.

[b] Partitioning assumes a fish community type as follows: Walleye 26%, Northern Pike 15%, Whitefish 22%, as per Northwestern Region partitioning criteria (Neville Ward, pers.comm.)

Oxygen concentrations were not found to be a limiting factor in any area of the lake tested in 1979. Marked oxygen depletion with depth or area was not evident. All readings were either near saturation or at complete saturation at all depths.

The minimum oxygen concentration recorded was 5.8 mg/l in Wapesi Bay at a depth of 16 meters. Total dissolved solids (TDS) varied between basins but were generally between 41 and 51 mg/l (Table 4.3).

Fish species recorded for Lac Seul are shown in Table 4.4.

4.1.2.5 Rivers and Streams

The importance of the numerous inflows into Lac Seul has not been determined. Some actual and potential spawning areas were located by Crooks (1972) but these locations represent an incomplete list. These sites were generally walleye spawning sites with northern pike and whitefish spawning areas more dispersed and difficult to locate. Known and potential spawning areas are shown in Figure 4.3.

Other lakes are accessible to fish from Lac Seul; the contribution of these lakes to fisheries habitat for Lac Seul populations has not been determined. Tagging projects by Milko (1960 and 1961) showed some movement of walleye into Wenasaga Lake and one northern pike into Broad Lake. This study also showed that a number of northern pike are swept over the dam at Ear Falls (Milko, 1960; 1961).

Table 4.4: Fish species present in Lac Seul

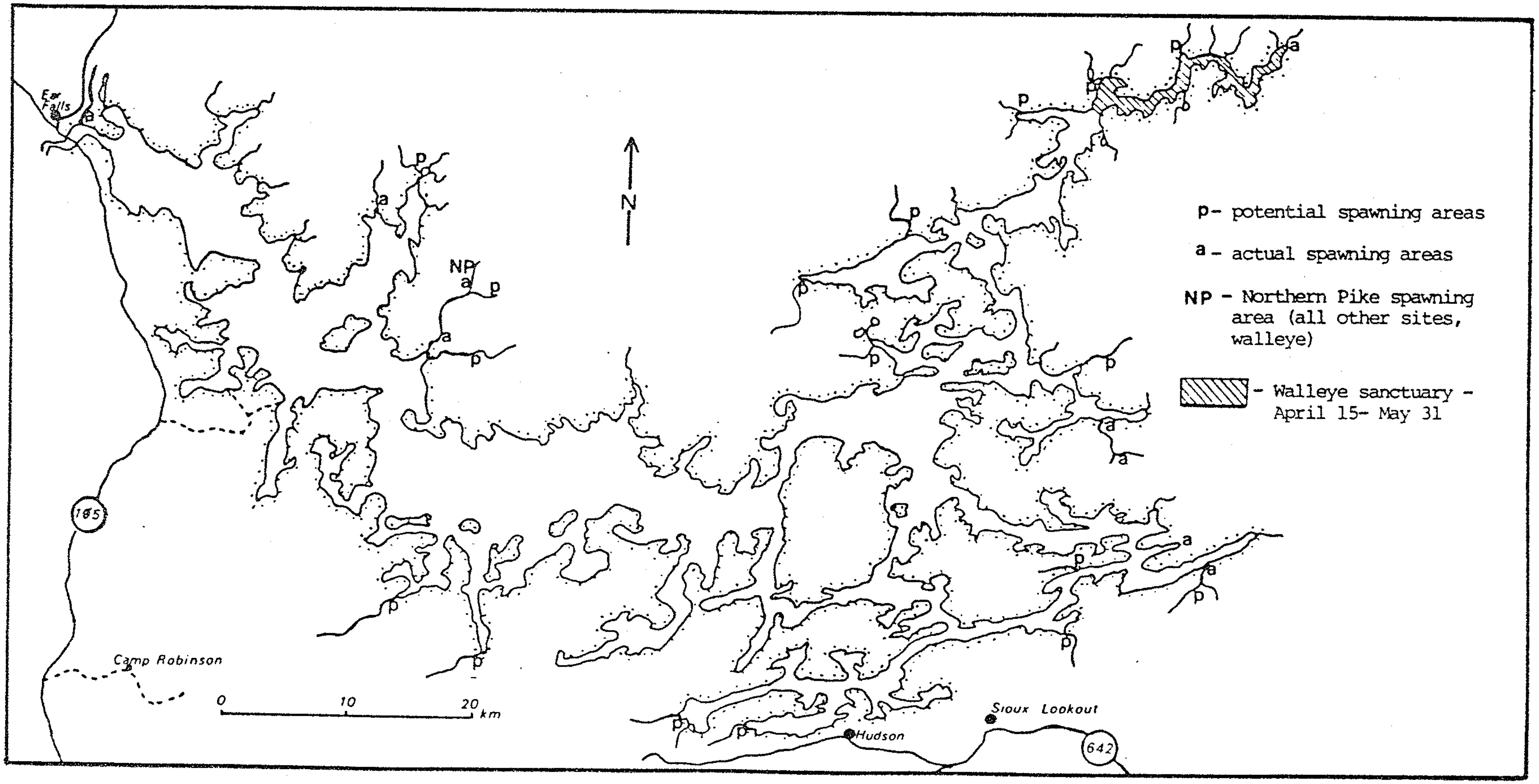
Common name[a]	Scientific Name
Lake Whitefish	*Coregonus clupeaformis*
Lake Herring	*Coregonus artedii*
Ciscoes	*Coregonus spp.*
Lake Trout	*Salvelinus namaycush*[b]
Northern Pike	*Esox lucius*
Muskellunge	*Esox masquinongy*[c]
Yellow Perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*
Sauger	*Stizostedion canadense*
Golden Shiner	*Notemigonus crysoleuras*
Emerald Shiner	*Notropis atherinoides*
Common Shiner	*Notropis cornutus*
Spottail Shiner	*Notropis hudsonius*
Mimic Shiner	*Notropis volucellus*
Least Darter	*Etheostoma microperca*
Johnny Darter	*Etheostoma nigrum*
River Darter	*Percina shumardi*
Iowa Darter	*Etheostoma exile*
Logperch	*Percina caprodes*
Longnose Dace	*Rhinichthys cataractae*
Lake Chub	*Couesius plumbeus*
Fathead Minnow	*Pimephales promelas*
Whitehead Sucker	*Catostomus commersoni*
Redhorse	*Moxostoma sp.*
Burbot	*Lota lota*
Brook Stickleback	*Culaea inconstans*
Nine-spine Stickleback	*Pungitius pungitius*
Trout-perch	*Percopsis omiscomaycus*
Rock Bass	*Ambloplites rupestris*
Mottled Sculpin	*Cottus bairdi*

[a] Nomenclature follows W.B. Scott and E.J. Crossman, 1973 Freshwater Fishes of Canada. Bulletin 184, Fisheries Research Board of Canada, Ottawa.

[b] Taken, rarely, by native fishermen.

[c] One specimen recorded in trap net survey (Milko, '60-'61).

Source: Crooks, 1972; O.M.N.R. Lake Survey data, 1969; Milko, 1960-61.



4.3: Known and potential spawning areas, Lac Seul.

Source: Weilandt, 1982.

4.1.2.6 Trend-through-time Information

Weilandt (1982) presented a comparison of the biology and harvest statistics of individual species for 1970 and 1979 surveys. The general findings are summarized in Tables 4.5 and 4.6. (More detailed information can be found in the Hough et al., [1981] original document).

Commercial harvest data indicates an increase in mean age of both walleye and whitefish from 1970 to 1979. The data also implies a greater variety of age-classes within the 1979 whitefish harvest and reduced mortality from 1970 - 1979. Overall, the data indicate a more stable commercial fish base was present in 1979, in comparison to 1970.

As outlined above, a number of changes were implicit in the 1970 to 1979 harvest data. These changes can be attributed to any or all of a number of factors; the contribution of each factor is unknown. Possible contributing factors are those listed in Table 4.1.

Table 4.5: A comparison of 1970 and 1979 survey harvest statistics, for commercially caught fish.

Species	Mean Age		Mean Total Length (cm)		Dominant Age Class		% Catch of Dominant Age		Mortality	
	1970	1979	1970	1979	1970	1979	1970	1979	1970	1979
Walleye	6.8	7.7	34.8	50.3	7+	7+	32.2	33.6	0.78	0.55
Whitefish	7.0	7.1	47.5	47.0	7+	7+	43.7	29.9	0.59	0.50
Tullibee	-	7.9	40.9	39.6	-	6+ 7+	-	19.2 19.2	-	0.48

Source: Weilandt, 1982

Table 4.6: A comparison of 1970 and 1979 creel survey sport-harvest statistics.

Species	Mean Age		Mean Total Length (cm)		Dominant Age Class		% Catch of Dominant Age		Mortality	
	1970	1979	1970	1979	1970	1979	1970	1979	1970	1979
Walleye	6.2	5.0	43.0	42.0	5+ 6+	4+	26.0 26.0	30.0	0.41	0.49
Northern Pike	4.3	7.6 to 11.9	64.0	63.2 to 71.4	4+	7+	-	-	0.71	0.27 - 0.53

Source: Weilandt, 1982.

A comparison of 1970 and 1979 sport harvest data (Table 4.6) indicate that fishing pressure on walleye had increased over the 1970-79 period. In general, younger walleye were being taken in 1979. Conversely the mean age increase in northern pike from 1970 to 1979 suggests a decrease in sport harvest pressure. However, data presented in later sections of this report indicate a condition of over-harvest in the 1979 northern pike sport fishery (see Table 4.13). One must view Weilandt's (1982) mean age comparisons with caution; Crook's (1972) data is not basin specific, whereas Hough et al. (1981) only utilized data from 5 of Lac Seul's 23 basins. These types of variation make comparison difficult. Weilandt (1982) proposes that the elimination of the commercial fishery for northern pike and angler selection of larger fish may partly explain the apparent contradiction of mean age increase in the presence of over-harvest (see Table 4.6).

4.2 Resource Use and Projections

4.2.1 *Use*

4.2.1.1 Commercial Fisheries

Table 4.7 presents information on the number and type of commercial fishing licences issued and their respective harvests for the years 1960 to 1981, inclusive. Quotas

Table 4.7: Summary of information of commercial fish licenses, equipment, reported harvest (in kg) and dollar value for Lac Seul, 1960-1981.

	No. of Licenses		Amount of Licences			
Year	Gill	Impounding Gear	Yards	Number of Traps	Total Reported (kg)	Total Value of Harvest $b
1960	11	2	42,000	4	192,923	-
1961	11	2	42,000	4	247,749	-
1962	11	2	42,000	4	233,786	-
1963	11	2	42,000	4	260,607	-
1964	11	2	42,000	4	213,461	-
1965	11	2	42,000	4	180,939	-
1966	11	2	42,000	4	170,752	-
1967	11	2	42,000	4	155,883	-
1968	11	2	42,000	4	150,820	-
1969	11	2	42,000	4	148,824	-
1970	11	2	42,000	4	108,933	-
1971	a	-	-	-	-	-
1972	a	-	-	-	-	-
1973	1	0	2,000	-	5,461	-
1974	3	0	10,000	-	68,849	-
1975	3	0	10,000	-	82,079	-
1976	3	0	10,000	-	66,186	-
1977	3	0	12,000	-	130,549	-
1978	4	0	12,000	-	125,442	-
1979	4	0	12,000	-	105,142	109,105
1980	4	0	12,000	-	98,584	113,319
1981	4	0	12,000	-	100,608	108,294

a - Season closed - mercury restrictions
b - Data not available for 1960-1978, inclusive

Source: Weilandt, 1982.

were put into effect in 1973, resulting in marked changes in both total harvest and species composition. Commercial harvest amounts, by species for the years 1960 to 1981, and relative dollar values by species for the year 1979 to 1981, are presented in Tables 4.8 and 4.9 respectively. (Dollar value estimates are not available for the years previous to 1979). Estimates are based on specific assumptions of market value, i.e. $1.50/lb ($3.30/kg) for walleye, $0.55/lb. ($1.25/kg) for whitefish, $0.30/lb ($0.66/kg) for tullibee and $0.15/lb ($0.33/kg) for sucker and burbot. The Freight Equalization Assistance Program paid fishermen $0.09/lb ($0.19/kg) for sucker, burbot and tullibee in 1981, resulting in total grant payments of $7,933 (Weilandt, 1982).

The type and value of investment in the commercial fish industry in Lac Seul is given in Table 4.10.

4.2.1.2 Anglers

A summary of information collected through creel census projects conducted on Lac Seul, is presented in Table 4.11. Such projects usually restricted their areas of survey to specific sections of Lac Seul. The most comprehensive of the creel census projects was conducted in 1979 (Hough et al., 1981). Results of this census are presented in Table 4.12.

Table 4.8: Annual summary of reported commercial fish harvest, by species, for Lac Seul, 1960-1981. Data given in kg.

Year	Northern Pike	Burbot	Lake Trout	Tullibee	Yellow Perch	Sucker	Whitefish	Walleye	Other	Totals
1960	62,022	15,394	79	15,069	15	31,728	37,779	34,837	0	196,923
1961	63,863	20,493	24	23,395	0	32,755	61,904	40,056	0	242,748
1962	47,110	21,505	0	12,255	0	32,783	72,168	47,966	0	233,787
1963	53,620	37,439	0	11,910	0	48,228	53,965	55,456	0	260,618
1964	49,732	34,318	0	11,385	24	41,228	32,171	43,878	0	212,712
1965	43,679	8,938	30	10,351	9	8,209	28,429	42,859	38,435	180,900
1966	25,638	25,529	0	10,315	31	39,232	24,747	44,440	820	170,752
1967	21,221	21,189	0	13,779	34	32,655	29,809	37,196	0	155,883
1968	22,447	14,918	0	10,422	173	25,889	37,015	39,955	0	150,815
1969	16,235	22,908	0	16,781	3	24,034	45,191	23,654	19	148,825
1970	15,954	13,441	0	8,291	0	17,196	25,781	28,360	5	109,028
1971[a]	-	-	-	-	-	-	-	-	-	-
1972[a]	-	-	-	-	-	-	-	-	-	-
1973[b]	0	0	0	0	0	1,553	445	3,464	0	5,462
1974	1,419	4,384	0	418	0	26,620	20,247	15,760	0	68,848
1975	1,019	19,211	0	4,404	0	6,449	43,785	6,229	983	82,080
1976	0	7,141	0	3,753	0	6,735	46,188	2,316	54	66,187
1977	27	37,975	0	14,826	27	24,300	49,029	4,371	0	130,555
1978	57	33,436	0	9,950	0	25,790	49,994	6,215	0	125,442
1979	0	23,005	0	6,624	0	15,113	51,275	9,125	0	105,142
1980	57	7,136	0	5,501	0	18,499	57,990	9,401	0	98,534
1981	0	23,318	0	10,620	0	6,129	51,779	8,762	0	100,608

[a] Fishery closed - mercury restrictions

[b] Quotas established in 1973

Source: Hough et al., 1981.

Table 4.9: Value[a] in dollars; of reported commercial harvest, by species, for Lac Seul, 1979-1981.

Year	Northern Pike	Burbot	Tullibee	Sucker	Whitefish	Yellow Pickerel	Total
1979	0	7,592	4,371	4,987	62,042	30,113	109,105
1980	38	2,355	3,630	6,105	70,168	31,023	113,319
1981	0	7,694	7,009	2,023	62,653	28,915	108,294

[a] Values are approximations.

Source: Weilandt, 1982.

Table 4.10: Status of 1981 commercial fish investment, Lac Seul.

Number of Licencees	Number of Man-months Fisheries-Related Employment	Number of Craft[a]	Amount of Gear[a]	Shore Type[a]	Capital Type	Investment Value	Total Investment
4	9.5	5 ($68,000)	12,000 yds. ($6,000)	Packing plant & Fish Camp ($100,000)	0	0	$174,000

[a] Value given in brackets.

Source: Weilandt, 1982.

Table 4.11: Summary of creel census information for Lac Seul, including estimates of angler use, harvest, and catch per unit effort (C.U.E.)

Year	Area Censused	Estimated Number of Anglers	Estimated Angler Pressure (Hrs.)	Success and Harvest			
				Northern Pike		Yellow Pickerel	
				CUE	Harvest	CUE	Harvest[c]
1970	Basins 1-3	-	-	0.60	-	0.19	-
1979[a]	All Basins	-	186,657 (33,935)[b]	0.27	50,118	0.52	97,735
1981	Basin 23	7	54.0	0	0	0.96	52
	Basin 15 & 16	1,587	17,513	0.09	670	0.35	3,163

[a] Refer to Table 4.12 for more detailed information on this creel census.

[b] Estimate of angler days.

[c] Harvest in numbers.

Source: Weilandt, 1982.

Table 4.12: Summary of 1979 creel census information for Lac Seul, by basin.

	Angler Pressure		Success and Harvest			
			Walleye		Northern Pike	
Basin	Hours	Days	C.U.E. (kg/man hr.)	Harvest[a]	C.U.E. (kg/man hr.)	Harvest[a]
1	34,270	7,450	0.27	9,253	0.33	11,309
2	7,410	1,950	0.09	667	0.30	2,223
3	43,364	6,377	0.34	14,744	0.38	16,478
4	2,211	273	0.32	708	0.18	398
5	1,853	195	0.11	204	0.29	537
6	5,476	702	0.89	4,873	0.24	1,314
7	4,058	527	0.49	1,988	0.39	1,583
8	1,720	215	0.50	860	0.26	447
9	11,489	1,853	1.39	15,969	0.20	2,298
10	4,502	804	0.73	3,287	0.36	1,621
11	15,797	3,361	0.33	5,213	0.16	2,528
12	18,614	3,447	0.47	8,748	0.22	4,095
13	634	144	0.88	558	0.14	89
14	2,596	618	0.79	2,051	0.10	260
15	600	158	1.22	732	0.09	54
16	232	29	0.64	148	0.26	60
17	11,118	2,269	0.78	8,672	0.16	1,779
18	15,358	2,844	0.87	13,361	0.15	2,304
19	619	129	2.10	1,337	0.05	31
20	1,842	302	1.33	2,450	0.20	368
21	1,699	144	0.76	1,291	0.18	306
22	-	-	-	-	-	-
23	1,195	144	0.52	621	0.03	36
Total	186,657	33,935		97,735	0.27	50,118

[a] Harvest in numbers

Source: Hough, et al., 1981.

Sport and commercial harvest estimates for yellow pickerel, northern pike, coregonids and coarse fish, for 1979, are presented in Table 4.13. For comparison, estimates of potential yield for each species are also given in Table 4.13 and 4.14[6]. Based on these figures, it appears a surplus of all commercially available species exists, with only 58% of the whitefish yield and 27% of coarse fish yield in Lac Seul being utilized. However, actual harvests are taken primarily in basins 3, 6 and 18, an area representing only 54% of Lac Seul's total area (Table 4.13). Therefore, based on an evaluation of demand versus supply within these 3 basins Hough et al., (1981) suggest that 98% of coregonid yield is presently being utilized.

Hough et al., (1981) assumed that no contributions to coregonid production were available from shallow, warm water basins. This assumption is relaxed in the northwestern region partitioning rationale which assumes a positive contribution to coregonid production within these basins. Big Trout Lake (Sioux Lookout District) represents a fitting example of a shallow water lake with significant coregonid production. In light of all the above factors, a 98% coregonid exploitation rate appears somewhat inflated. However, MNR personnel in Sioux Lookout believe that the whitefish harvest within the licensed areas is now at an optimal level (J. McDonald, personal communication).

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[6] Table 4.13 presents potential yield and harvest data from Hough et al. (1981).

Table 4.14 presents potential yield based on northwestern region partitioning criteria and Hough et al. (1981) harvest data.

Table 4.13: Maximum sustainable yields and 1979 sport and commercial harvest data for yellow pickerel, northern pike, coregonids (lake whitefish and tullibee), and coarse fish in 23 basins in Lac Seul.[1] All values in kg.

	Walleye				Northern Pike			Total Gamefish			Coregonids			Coarse Fish		
		Harvest														
Basin	MSY	Sport	Commercial	MSY Remaining	MSY	Sport Harvest	MSY Remaining	MSY	Harvest	Remaining	MSY	Commercial Harvest	MSY Remaining	MSY	Commercial Harvest	MSY Remaining
1	10,442	4,349	-	6,093	3,481	15,154	-11,673	13,023	19,503	- 5,580	10,442	-	10,442	10,442	-	10,442
2	2,416	487	-	1,929	604	3,579	- 2,975	3,020	4,066	- 1,046	-	-	-	3,021	-	3,021
3	19,158	12,680	-	6,478	6,386	32,957	-26,571	25,544	45,637	-20,093	19,158	24,463	- 5,305	19,158	6,897	12,261
4	3,696	941	-	2,755	924	529	395	4,620	1,470	3,150	-	-	-	4,620	-	4,620
5	2,298	102		2,196	766	930	- 164	3,064	1,032	2,032	2,298	-	2,298	2,298	-	2,298
6	28,021	6,823	4,116	17,082	9,340	3,680	5,660	37,361	14,619	22,742	28,021	21,706	6,315	28,021	21,000	7,021
7	2,716	2,485	-	231	905	3,672	- 2,767	3,621	6,157	- 2,536	2,716		2,716	2,716	-	2,716
8	799	1,307	-	- 508	266	1,252	- 986	1,065	2,559	- 1,494	799	-	799	799	-	799
9	5,878	14,213	-	- 8,335	1,469	5,147	- 3,678	7,347	19,360	-12,013	-	-	-	7,347	-	7,347
10	3,162	3,648	-	- 486	1,054	3,160	- 2,106	4,216	6,808	- 2,592	3,162	-	3,162	3,162	-	3,162
11	6,626	3,753	-	2,873	2,209	5,358	- 3,149	8,835	9,111	- 276	6,626	-	6,626	6,626	-	6,626
12	1,974	6,474	-	- 4,500	658	6,388	- 5,730	2,632	12,862	-10,230	1,974	-	1,974	1,974	-	1,974
13	369	429	-	- 60	123	172	- 49	492	601	- 109	369	-	369	369	-	369
14	2,243	923	-	- 1,320	748	444	304	2,991	1,367	1,624	2,243	-	2,243	2,243	-	2,243
15	3,847	747	-	3,100	1,282	62	1,220	5,129	809	4,320	3,847	-	3,847	3,847	-	3,847
16	807	123	-	684	202	130	72	1,009	253	756	-	-	-	1,009	-	1,009
17	5,399	6,764	-	- 1,365	1,800	3,220	- 1,420	7,199	9,984	- 2,785	5,399	-	5,399	5,399	-	5,399
18	11,408	11,491	4,618	- 4,701	3,803	5,068	- 1,265	15,211	21,177	- 5,966	11,408	11,336	72	11,408	10,727	681
19	2,788	1,645	-	1,143	697	28	699	3,485	1,673	1,812	-	-	-	3,485	-	3,485
20	4,596	2,352	-	2,244	1,149	670	479	5,745	3,022	2,723	-	-	-	5,745	-	5,745
21	6,672	1,278	-	5,394	1,668	557	1,110	8,340	1,835	6,505	-	-	-	8,340	-	8,340
22	4,668	-	-	4,668	1,167	-	1,167	5,835	-	5,835	-	-	-	5,835	-	5,835
23	6,228	236	-	5,992	1,557	54	1,503	7,785	290	6,854	-	-	-	7,785	-	7,785
Total	136,211	83,250	8,734	44,227	42,258	92,211	-49,954	178,469	184,195	- 6,637	98,462	57,505	40,957	145,649	38,624	107,025

Source: Hough, et al., 1981.

[1] This table is submitted for comparative purposes only—to compare the Hough et al., (1981) supply-balance scenario with that shown in Table 4.4 which utilizes revised MEI calculations and fish community partitioning criteria established for Northwestern Region.

Table 4.14: MSY and 1979 sport and commercial harvest data for walleye, northern pike and lake whitefish, Lac Seul, using Northwestern Region partitioning rationale (Neville Ward, pers.comm.). All values in kg.

	Walleye				Northern Pike			Whitefish		
Basin	MSY	Sport	Commercial	MSY Remaining	MSY	Harvest	MSY Remaining	MSY	Harvest	MSY Remaining
1	9,076	4,349	-	4,727	5,236	15,154	- 9,918	7,680	n/a by basin	n/a by basin
2	1,555	487	-	1,068	897	3,579	- 2,682	1,316		
3	16,441	12,680	-	3,761	9,601	32,957	-23,356	14,081	-	-
4	2,382	941	-	1,441	1,374	529	845	2,015	-	-
5	1,981	102	-	1,879	1,143	930	213	1,677	-	-
6	24,696	6,823	4,507	13,336	14,248	3,680	10,568	20,896	-	-
7	2,328	2,485	-	- 157	1,343	3,672	- 2,329	1,970	-	-
8	703	1,307	-	- 604	405	1,252	- 847	595	-	-
9	3,753	14,213	-	-10,460	2,165	5,147	- 2,982	3,176	-	-
10	2,736	3,648	-	- 912	1,578	3,160	- 1,582	2,315	-	-
11	5,767	3,753	-	2,014	3,327	5,358	- 2,031	4,880	-	-
12	1,709	6,474	-	- 4,765	986	6,388	- 5,402	1,446	-	-
13	322	429	-	- 107	186	172	14	272	-	-
14	1,951	923	-	1,028	1,126	444	682	1,651	-	-
15	3,347	747	-	2,600	1,931	62	1,869	2,832	-	-
16	520	123	-	397	300	130	170	440	-	-
17	4,622	6,764	-	- 2,142	2,667	3,220	- 553	3,911	-	-
18	10,048	11,491	4,618	- 6,061	5,797	5,068	729	8,502	-	-
19	1,785	1,645	-	140	1,030	28	1,002	1,510	-	-
20	2,995	2,352	-	643	1,728	670	1,058	2,534	-	-
21	4,325	1,278	-	3,047	2,495	557	1,938	3,660	-	-
22	3,008	-	-	3,008	1,735	-	-	2,545	-	-
23	3,952	236	-	3,716	2,280	54	2,226	3,344	-	-
Total	110,002	83,250	9,125	17,627	63,578	92,211	-28,633	93,248	51,275	42,112

Although there is a surplus of coarse fish in all basins, an increase in harvest for these species is not being actively sought due to their low market value. Coarse fish are generally caught incidentally to whitefish; any increase in pressure on coarse fish will therefore result in greater whitefish harvests.

A comparison of walleye harvest estimates with predicted yields for this species, indicates a condition of surplus (Table 4.13 and 4.14). Unequal distribution of angler pressure, however, created overharvest situations in basins closest to the Sioux Lookout access area while surpluses existed in other more remote basins (Table 4.13 and 4.14).

Northern pike were generally overexploited in Lac Seul, although Basin 6, and the more remote basins at the northeast end of the Lake, had a surplus production in 1979 (Table 4.13).

Northern pike harvests are approximately two times larger than estimates of potential yield, while walleye harvests are approximately 2/3 of the maximum sustainable yield. Harvests for both species are concentrated in certain basins. Greatest harvest pressures are exerted in Vaughan Lake (Basin 9) and other basins closest to the Ear Falls and Sioux Lookout access areas.

Creel census data from Sen Bay (Basins 15 and 16--Marshall, 1981) suggest that pressure and harvest estimates for 1979 were, in fact, under-estimates. This may be a result of under representation of certain access points in the 1979 sampling schedule. In 1981, harvests of walleye and northern pike in Basins 15 and 16 were 4864 kg and 3306 kg greater than the 1979 estimates of 870 kg and 192 kg, respectively. Therefore, overharvests of both species were occurring in Basins 15 and 16 in 1981. (This in addition to those overharvests shown in Table 4.13). It was assumed that the majority of the 1981 harvest, estimated through the creel census in Sen Bay, actually took place in Sen Bay, (Basins 15 and 16). Although it is known that some of the pressure was actually exerted outside Basins 15 and 16, in all likelihood this excess fishing pressure would have occurred in Basins 17 and 18, which, as other data show (Table 4.13) are also overexploited.

Comparison of 1970 creel census data (Crooks 1972) with 1979 creel data show a shift in preferred species. In 1970, northern pike and walleye accounted for 67% and 33%, respectively, of the harvest in numbers. In 1979, northern pike and walleye each accounted for 50% of the harvest by numbers in Basins 1 to 3 (corresponding to Crooks 1970 study area). For the entirety of Lac Seul, northern pike and walleye accounted for 21% and 79%, respectively, of the harvest by numbers. Although weight data are not available for 1970, for comparison with 1979 data, numbers data indicate that walleye had replaced northern pike as the dominant fish species harvested in 1979.

4.2.2 *Projections*

Estimates of future demand for the fisheries resource must take a number of factors into consideration. First, commercial fishery harvests are regulated by quotas, which regulate the use of fish resources based on the estimated maximum sustainable yield. Any increase in the commercial quotas would be based on more accurate estimates of the maximum sustainable yield. Commercial fishermen have generally expressed the view that they are satisfied with the present quotas. No increase in the commercial quotas are foreseen (John McDonald, pers.comm.).

With respect to the sport fishery, angler satisfaction and quality of fishing, local population changes, and increased access are the most apparent factors affecting future harvests.

Lodge guests accounted for 74% of angling pressure on Lac Seul (Hough et al., 1981). Lodges reported repeat visitation as accounting for approximately two-thirds of occupancy (Hough et al., 1981). Angler satisfaction with the fishing experience may influence future angling pressure; in 1979, 26% of all lodge-based anglers were not satisfied with their fishing experiences and only 40% were moderately satisfied (Hough et al., draft report, 1980). Assuming that present overharvests continue, a decline in average size and C.U.E., with an associated decline in angler satisfaction, could be expected. A reduction in demand could follow as non-residents are attracted to other areas.

However, the lodge industry also has the capacity to increase harvest pressures utilizing present facilities. Lodge and outpost occupancy rates for 1979 averaged 31% and 30%, respectively. Peak occupancy was 48%, attained in June. If the economic climate were to change, an increase in pressure and greater overharvests could result.

Resident anglers comprised 20% of all anglers in 1979 (Hough et al., 1981). Population trend data comparing northwestern region angler-day estimates from 1970 (Cox and Straight, 1970) to 1980 angler-day estimates (OMNR, 1982) suggest that angling demand by resident sport fishermen will be maintained at present levels until the year 2000 (OMNR, 1982). However, non-resident angler trends indicate an expected annual increase of 1.25 percent to the year 2000. Assuming this trend continues, projected demand for sportfish by non-residents will be 41,408 angler days.

Harvest and demand data for natives of Lac Seul Indian Reserve 28 currently do not exist. However, mean fish consumption data exists for Lake of the Woods and recent reserve population trend data exists for Lac Seul Indian Reserve 28. These data are utilized in Chapter V to determine the present and future demands of the domestic fishery on Lac Seul fish resources.

4.3 Present Fisheries Management Strategies

Fisheries management for Lac Seul is the responsibility of the Dryden, Red Lake and Sioux Lookout Districts of the Ministry of Natural Resources. The area of jurisdiction for each district is shown in Figure 1.1. Historical information (i.e., prior to 1978) pertinent to the fisheries resource of Lac Seul, is available at the Sioux Lookout District Office. Information gathered from 1978 to the present is on file in the respective district offices.

4.3.1 *Enforcement and Public Relations*

Enforcement patrols are carried out from Ear Falls and Sioux Lookout by boat, during the open water period. These patrols are primarily enforcement checks on angler licences, catch limits and gill nets. Public relations activities are also part of the enforcement patrols.

Winter patrols are also undertaken in order to check ice fishermen. These patrols are performed on Lost Lake (Basin 11) and Adamhay Lake (Basin 23), since it was accessed by the Vermillion River road in 1981.

Public relations activities are undertaken by enforcement staff during regular patrols. When required, dealings with commercial fishermen, lodge operators, cottagers, and the one houseboat operator are on an individual basis. Staff of the Red Lake District also attend the annual meeting of the Ear Falls Outfitters Association.

4.3.2 *Habitat Management*

In general, the goal of the three districts having jurisdiction over Lac Seul is to maintain present habitat quality and quantity in both the aquatic system and that portion of the surrounding terrestrial system having influence on fish habitat.

Little alteration or degradation of fish habitat has occurred, outside of the effects of the initial flooding of Lac Seul and the continuing water level fluctuations. This situation is largely due to the relatively undisturbed nature characterizing much of the shoreline and surrounding area. As a result, no projects to improve existing habitat conditions are presently performed or planned for the future.

The maintenance of fish habitat in Lac Seul is the goal of two policies adhered to by all districts involved. First, no further shoreline development is allowed in order to protect shore spawning areas and prevent increased erosion. Secondly, timber reserves of 120 m around the perimeter of Lac Seul and 30 m on all inflowing streams have been designated. The restriction on cutting in these areas eliminates the siltation, nutrient enrichment, loss of cover and temperature elevation problems associated with aquatic habitats in proximity to cut areas.

Currently, there is not a habitat inventory program for Lac Seul. Previous projects have included a lake survey in 1969, identification of some actual and potential spawning sites (Crooks 1972), and water quality samples by Hough et al., (1981) in 1979. The information gained from these projects forms the basis for present habitat management strategies.

At present, approximately 30 man-days per year are expended on habitat management activities, including the review of timber harvest programs and the development of the Root River Sanctuary (see Section 4.3.3.3) (Weilandt, 1982).

4.3.3 *Population Management*

Present population management strategies aim to maintain both the present quantity and quality of angler success and commercial harvests at present levels.

The number and extent of population assessment programs has been limited. No regularly scheduled creel census projects are undertaken. The most recent netting study was in 1970 (Crooks, 1972) and the most recent and comprehensive creel survey was conducted in 1979 (Hough et al., 1981). The 1979 creel survey provided data on angler harvest, species composition and biology of the angled species. Information on commercial fishery harvests is obtained through commercial fish returns.

In 1981, a creel survey, covering Sen Bay (Basins 15 and 16) was conducted (Marshall, 1981). A repetition of this creel survey is planned for 1983 or 1984 to serve as an index of use in this area of Lac Seul. In addition, a tagging project in Basin 23 was conducted in 1983 to determine the migration patterns and mortality of walleye spawning in the Root River.

Potential harvests for each fish species are determined from partitioning of the M.E.I. derived potential yield. Information on the extent of human and other impacts on fish populations is derived through comparison of data gathered in previous investigations (i.e., C.U.E. and statistics on average length, weight and age).

Supplemental stocking or introduction of new fish species are not considered necessary or desirable; the fish community now present in Lac Seul represents a balanced fish community. Also, the self-sustaining capabilities of the fish populations appear sufficient to meet current harvest demands.

Although estimates for potential harvest are available, there are no long-term, standardized monitoring programs in place to provide trend-through-time data on angling harvests. As discussed in Section 4.2.1, 1979 creel census harvest estimates may be unreliable, and/or harvest pressures may have increased significantly in the interim.

Harvest control measures currently in effect include daily catch and possession limits, season restrictions, the designation of a sanctuary, access limitations, commercial quotas, mesh restrictions and enforcement efforts.

4.3.3.1 Catch Limits

Daily catch and possession limits are as given for divisions 20 and 22 in the Ministry of Natural Resources publication "Summary of Fishing Regulations, 1982." The daily catch and possession limits are six per angler for both walleye and northern pike.

4.3.3.2 Seasons

There is no closed season for northern pike; the open season for walleye commences the third Saturday in May and continues to the second week of April in the following year.

4.3.3.3 Sanctuary

A section of the lake and the Root River between latitudes 50°49' and 50°39' was designated as a sanctuary for the 1982 season. Fishing is prohibited between March 15 and June 21, inclusive. This area has become well known for its high walleye catches, in both winter and summer.

4.3.3.4 Access

Access to Lac Seul is limited through Ontario's Ministry of Natural Resources policy which prohibits permanent roads from within 610 m (2000 ft.) of the shoreline. Generally, there are no restrictions on the use of forest roads by the public.

4.3.3.5 Enforcement

Enforcement efforts attempt to prevent gross overharvest and helps to distribute catch fairly. These efforts include the monitoring of commercial harvests for incidental catches, checking licenses, catch limits, etc.

4.3.3.6 Regulation of the Sport Fish Industry and Commercial Fishery

According to commercial harvest regulations, minimum gill net mesh size is 5 inches (12.7 cm). This regulation was modified in 1982 for one Lac Seul commercial operation to allow the use of 4½ inch (11.5 cm) mesh to harvest walleye only (John McDonald, pers.comm.).

Present quotas for walleye and whitefish are to remain as follows:

Fishing Block	Quota (kg/yr)	
	Whitefish	Walleye
1	18,144	0
2	6,818	0
3	4,546	4,546
4	22,727	4,546

(for locations, see Fig. 4.1)

Quotas are not set for tullibee, sucker or burbot.

Efforts are being made to reach a cooperative agreement with the one operator renting houseboats on Lac Seul. The objective of the agreement would be to re-distribute fishing effort to basins showing a surplus of fish. Harvest from houseboat anglers was not recorded in the 1979 creel survey; hence, those basins shown to be over-utilized by the

1979 survey may actually have experienced greater harvests due to houseboat anglers. Re-distribution of this unknown but additional harvest, could prove beneficial.

The Ontario Ministry of Natural Resources (Northwestern Region) is collecting boat cache information on northwestern Ontario lakes in an attempt to monitor and control fishing pressure resulting from boat cache users. An inventory of chached boats commenced in 1983 (Neville Ward, pers.comm.).

In general, controls on commercial harvest have been very effective. Commercial fishermen appear satisfied with mesh-size restrictions and quota sizes. Most commercial operators are able to harvest their quota within a few weeks in June and/or July; this aids the monitoring of the fishery, and ensures that harvest data will be available at an early date.

It is probably that the 5 inch (12.7 cm) gill net mesh size restriction is contributing to year-class stability through the maintenance of a varied age class structure. This stability may to some extent, compensate for a possible increase in egg mortality during winter drawdown.

Angling regulations for walleye have generally proved effective in previous years and should provide a margin of protection for the near future. The Root River sanctuary will protect a known spawning population of walleye allowing dispersal prior to exposure to angling pressure.

Current regulations have been ineffective in limiting northern pike harvests to the level of the estimated potential yield. Information collected in the 1981 Sen Bay creel census indicate that the situation has deteriorated.

If harvests continue at present levels, northern pike populations would eventually decline. In fact, a decline in fish size and hence angling quality, has been evident since the early 1960's. Angling opportunities for northern pike, an important component of the non-resident harvest, may suffer further decline. This would likely result in an economic impact on the local tourist industry catering to non-residents.

4.3.4 *Conclusions*

Fisheries management strategies have achieved a harmonious co-existence of sport and commercial fisheries. A stable supply of fish for the commercial fishery has been achieved through management strategies currently in place. To date, fisheries management has also proved effective in providing angler opportunities. However, more effort is needed towards the development of strategies to maintain or improve the sports fishery on Lac Seul.

4.4 Issues and Problems

4.4.1 *Issues*

Past and present issues pertinent to the Lac Seul fisheries resource, are presented here in order to provide an insight into the changing concerns of the public. Many of these issues, although currently resolved, are still potential influences on fisheries management programs for Lac Seul. Issues are discussed under three major headings: loss of fish and fishing opportunities, loss of environmental quality and conflicts among users of the environment and the fishery resources.

4.4.1.1 Loss of Fish and Fishing Opportunities

a. The livelihood of lodge operators and commercial fishermen depends upon a continuing supply of fish of a predictable quantity and quality. Lodge operators in particular are concerned that overharvests are occurring on certain parts of Lac Seul, notably Vaughan Lake (Basin 9) and the Wenasaga River area. However, to date they have been able to move to areas of excellent fishing in other basins.

   Fish populations in these areas are subject to heavy demands by lodge guests and local anglers (Weilandt, 1982).

   The most serious concern expressed by Hough et al. (1981), was the excessive harvest of northern pike in 1979. Harvest estimate for this species exceeded the estimated potential yield of 42,258 kg by 49,954 kg (Table 4.13). Hough et al. (1981), however, assigned northern pike a potential yield value of 10% of total sustainable yield. The partitioned value for northern pike has since been adjusted within a whitefish/walleye/northern pike fish community type, assigning a value to pike of 15% of the total sustainable yield (Neville Ward, pers.comm.). Under this new partitioning rationale, the degree of overharvest of northern pike in Lac Seul appears less severe both by basin and for the lake as a whole (i.e. revised overharvest levels for pike estimate a 28,633 kg overharvest, Table 4.14, compared with the Hough et al. (1981) estimate of 49,954 kg).

Potential yield and harvest estimates for walleye indicated overharvest in some basins (8, 9, 10, 12, 13, 17 and 18) during 1979 (Hough et al., 1981; Table 4.13). Hough et al. (1981) utilized a 30 - 40 per cent[7] partitioning of total sustainable yield for walleye.

For comparison, Table 4.14, illustrates revised maximum sustainable yield (MSY) determinations, 1979 harvest data and supply balance estimates based on northwestern region determinations for walleye/ whitefish/northern pike communities. This partitioning rationale will be followed here in the allocation of Lac Seul fisheries.

b. Involvement of the native community in commercial fishing is another area of concern. Some members of the Lac Seul Indian Band have indicated an interest in commercial fishing (Hough et al., 1981). Walleye have been expressed as the preferred species (J. McDonald, pers. comm.).

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[7] -30% partitioning for walleyes for basins in which walleye, northern and whitefish cohabit.

-40% partitioning in basins lacking cool, deep mid-summer habitat suitable for whitefish.

The Ministry of Natural Resources has not issued an additional commercial licence since present harvests are considered optimal and walleye is not a target species for the commercial fishery. It should be noted, however, that the Band was issued a commercial licence to fish whitefish, pike and walleye in 1975. This licence was later changed to "whitefish only" as increased angling pressure became evident. The Band, through the Department of Indian Affairs and Northern Development (DIAND), had first priority to obtain another licence but did not feel the fishery was economical as they traditionally harvested walleye (John McDonald, pers.comm.). In conclusion, the Band has been provided with commercial fishing oppertunities but feel they require a top predator quota to make those opportunities economically viable.

4.4.1.2 Loss of Environmental Quality

The issues relating to environmental quality have included water level fluctuations, diversion of water from Lake St. Joseph, mercury contamination, and preservation of spawning habitat.

a. The issue of water level fluctuations has historically brought the most vocal protests from tourist outfitters. This issue was at its height during the 1960's when the annual water level changes, inundating or exposing spawning beds, were held as the primary factor in the decline in fish populations. Consequently, the Ear Falls Outfitters Association prepared a "Brief Concerning Water Levels of Lac Seul" (1967). This culminated in a study by Crooks (1972) who noted that the long term decline of fish populations was due to natural processes, related to decreased fertility of the water, rather than overharvest or annual water level changes.

b. Water level fluctuations, commercial harvests and diversion of the Lake St. Joseph inflow via the Root River have been iterated as factors contributing to the decline of both the fishery and the average size of northern pike in the early 1960's. Commercial harvests illustrated a gradually declining trend coincident with the period following the Root River diversion. Ministry of Natural Resources staff at that time were doubtful that increased flushing rates resulting from the diversion were sufficient to affect the average size of pike. Rather, they proposed that intensive angling pressure may have been the greatest contributing factor in the average size reduction of pike (letter from W.G. Cleavely to L. Ringham, February 22, 1965 - in Weilandt, 1982).

c. In 1970, elevated mercury levels were discovered in northern pike and walleye from Lac Seul. Subsequently, commercial fishing operations were closed and cautions were placed on the consumption of angler caught fish during 1971 and 1972. Commercial fishing operations are currently restricted to harvesting only species that are free of elevated mercury levels; incidental catches of predator species are controlled by legislation which designates permissible mercury levels consumption guidelines (Weilandt, 1982). Consumption guidelines, available to anglers, are outlined in the "Guide to Eating Ontario Sport Fish" (OMOE, 1979).

At the time of closure of commercial harvests in 1971 and 1972, fish with mercury concentrations exceeding 0.5 ppm were not permissible for sale in Canada or the United States. Presently, fish with mercury levels up to 1.0 ppm can be marketed in the United States and some European countries. OMOE (1979) report the following values as representative of levels in northern pike and walleye.

	Mercury Concentration (ppm)		
	0.5-1.0	1.0-1.5	1.5
Walleye (cm)	35 - 55	55 - 65	N/A
Northern Pike (cm)	45 - 55	55 - 65	65

d. Habitat quality concerns are presently expressed by lodge operators. Their concerns relate primarily to the maintenance and enhancement of spawning areas to ensure a continuing supply of fish (Hough et al., 1981).

4.4.1.3 Conflicts Among Users of the Environment and the Fishery Resource

a. The most publicized conflict concerns the use of Lac Seul as a reservoir. Hydro-electric stations downstream necessitate the previously cited water level fluctuations. In addition to the possible effects of water level fluctuations on fish populations, the fluctuations have created difficulties with dock access during the spring, i.e., prior to the recharging of normal water levels in the reservoir.

b. Another conflict between commercial and sport fishermen concerned the decline in size of northern pike caught by anglers. Tourist operators noted that commercial fishermen were taking many large pike. Large pike are also the main attraction for many non-resident anglers (meeting of Ear Falls Chamber of Commerce, August 21, 1978; meeting of L. Ringham, B. Bousfield, H. Yoachum, J.E. Barnes, February 15, 1965). It was suggested at this time, that commercial fishermen be compensated for not taking pike.

Spatial conflicts between the commercial fishermen and tourist operators were largely resolved upon the reopening of the commercial fishery in 1973.

Commercial fish licensing following 1973 was effective in separating anglers and commercial fishermen with respect to species sought and respective fishing grounds. Commercial fishing currently take place in basins where angling pressure is light.

Tourist operators expressed the view that commercial walleye harvests ought to be strictly incidental, with no commercial quota. Commercial fishermen contend that, in dealing with an overharvest situation, it would be more equitable if both groups were so restricted (Hough et al., 1981).

c. Lodge operators have voiced concern over the overharvest potential of the one houseboat enterprise operating on Lac Seul. Lodge operators feel that houseboats should be regulated as tightly as outpost camp operations (Hough et al., 1981).

d. Lodge operators are also concerned with the expanding network of forest access roads in the vicinity of Lac Seul. Operators are primarily concerned with the possible loss of remote angling experience and additional contributions to overharvests. In an attempt to resolve this issue, the Ministry of Natural Resources encourages public input prior to road construction, and has adopted interim policies, expressed in land use guidelines[8] cited in OMNR (1981). These polices are designed to control potential land use activities which conflict with remote tourism.

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[8] Ontario Ministry of Natural Resources, 1979. Operating Guidelines for Locating Forest Access Roads and Managing Forest Reserves.

> In general, the major issues of concern to lodge operators relate to the maintenance of quality and quantity of their clients' angling opportunities. Most of these issues have been resolved by the Ministry of Natural Resources to the satisfaction of lodge operators. Sioux Lookout District MNR encourages the discussion of issues of concern by holding annual meetings with local tourist operators (John McDonald, pers. comm.)

4.4.2 *Problems*

4.4.2.1 Inadequate Scientific or Technical Knowledge

It is difficult, if not impossible, to compare the biological data and harvest data available for Lac Seul. The few studies that have been completed lack consistency in both methods and types of data collected. For example, Crooks' (1972) creel census examined only the west (Ear Falls) end access points while both west and east (Sioux Lookout-Hudson) access points were covered in 1979 (Hough et al., 1981). Also, weights of fish were not collected by Crooks (1972) further prohibiting any comparison with 1979 harvest estimation and average weight data.

Several changes have occurred on the Lac Seul reservoir since impoundment in 1935 (Table 4.15). The documentation of the effects of these changes on factors controlling fish community composition, productivity and harvests and habitat, is sparse. The influence of these changes on present and future fish productivity is speculative.

Table 4.15: Changes in factors affecting productivity and biology of fish populations in Lac Seul.

Year	Change in conditions
1935	Flooding of reservoir
1940's	Increase in productivity, due to nutrient release.
1935-1957	Average annual fluctuation of 1.34 m.
1957-1978	Average annual fluctuation of 2.26 m.
1957	Root River diversion from Lake St. Joseph begins.
1960's	Increase in sport fishing. Change from cotton to nylon gill nets (1½ times more effective).
1963-1970	Root River made up 22% of annual discharge from Lac Seul.
1971-1974	Root River made up 28.6% of annual discharge from Lac Seul.
1975-1978	Root River made up 35.5% of annual discharge from Lac Seul.
1971 and 1972	Closure of commercial fishery.
1973	Commercial quotas restricted to annual productivity estimates and restricted to whitefish and coarse fish with small quota on walleye.
1975	Minimum gill net mesh size increased from 4½" to 5".
1982	Gill net mesh size reduced from 5" to 4½" for D. McMillan for harvesting walleye only.

As a result, there is essentially no baseline data with which to compare biological information on a trend-through-time basis. The most recent and comprehensive data available is contained within the study undertaken by Hough et al., (1981). For future comparisons, this study would represent the best baseline data source currently available.

a. Water Level Fluctuations

Several authors (Benson, 1973, 1980; Machniak, 1975; June, 1970) have noted that water level fluctuations incur a detrimental impact on spawning and nursery habitat of various fish species. The majority of those impacts are related to winter drawdown. The eggs of fall spawning species, such as whitefish, are subject to increased mortality due to atmospheric exposure during winter drawdown. If low spring water levels ensue following winter drawdown, spring spawning esocid populations may be affected either by atresia[9] (June, 1970) or loss of shallow weed bed spawning habitat.

Crooks' (1972) study identified the classic long term change in biological productivity following impoundment of Lac Seul in 1935. However, the specific effects of annual water level variation upon fish populations within the lake remain unanswered. Hough et al., (1981) noted that such fluctuations were indeed detrimental to Lac Seul fish production. Their opinion was based on a correlation between increased annual water level fluctuations (commencing in 1958) and decreasing commercial harvests (post-1963). Consequently, the actual sustainable yield for commercially harvested coregonids may in fact be lower than that suggested by the currently accepted yields based on partitioning of the M.E.I.

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[9] Resorption of eggs.

b. Diversion of Water from Lake St. Joseph

Flow from Lake St. Joseph has increased by increments since inception of the diversion in 1958 (Table 4.15). Although water coming into Lac Seul from this source is lower in total dissolved solids, this factor is considered to have a minimal effect on fish growth and productivity (letter from W.G. Cleavely to L. Ringham, February 22, 1965, in Weilandt, 1982). In fact, however, no data currently exists concerning the nutrient regimes operating in Lac Seul with respect to the relationships between the lake and incoming tributaries. Regardless, this condition must be accepted as is, since the Ministry of Natural Resources has no jurisdiction over the diversion flow from Lake St. Joseph.

c. Population Evaluation

Data is needed on populations, distribution and movements of the fish species inhabiting Lac Seul. Further, consistent and comparable fish harvest monitoring methods must be implemented in order to refine estimates of the fish resource base within each basin. These types of data are necessary to confidently identify the degree of overharvest evident in some of Lac Seul's basins and to efficiently allocate the fisheries resource base by basin.

As previously stated, overharvest of northern pike was evident in 1979. However, the 1979 harvest data also indicated exploitation over a broad size range, revealing strong representation by older age classes (Hough et al., 1981). Data from Marshall (1981) indicated overharvests in basins 15 and 16, coupled with an increase in average weight and decrease in catch per unit effort (C.U.E.) over 1979 data. Hough et al., (1981) noted that 1979 angling pressures were actually less than the combined commercial and angling harvests experienced prior to 1970. Further, decreased growth rates were observed by Crooks (1972) between 1960-61 and 1968-70 and by Hough et al., (1981) between 1970 and 1978. In combination, these data patterns suggest that either the northern pike populations are being underexploited (thereby implying that the partitioned potential species yield assigned to northern pike is extremely conservative), or that habitat quality has been reduced, owing to increased water level fluctuations. This dilemma reinforces the necessity to establish population and habitat assessment data.

Information is required concerning the distribution patterns of Lac Seul walleye and pike. Specifically, data is required that will identify distinct sportfish populations within the lake. The acquisition of such data would allow for more accurate determinations of relative harvest potential within basins, and could necessitate reallocation between basins to better suit fisheries management purposes. Tagging studies would be useful to determine the extent to which overharvest in one population basin may be compensated for by migration from underutilized basins. Spatial and temporal sportfish migration data would also provide an indication of the utility of sanctuaries, such as Root River.

Data concerning the location of spawning beds is sparse. Crooks (1972) identified a few walleye spawning sites, however, the present condition of these areas, and their potential contribution to recruitment is unknown. Present manpower and equipment availability, coupled with the inaccessibility to potential spawning sites on Lac Seul during the spring thaw, make the acquisition of this data a formidable task.

Generally, habitat and population assessment data is needed, concerning sportfish and coregonid species inhabiting Lac Seul. Present harvest controls and management efforts are insufficient in the prevention of increased fishing pressure and provision of additional fish resources. A data base beyond that provided by the M.E.I. is necessary to more efficiently manage the Lac Seul fishery.

4.4.2.2 Lack of Public Awareness

With respect to the issues previously iterated, lack of public awareness does not appear to be a major problem. Regulations have eliminated major conflicts between commercial fishermen and anglers, timber companies and lodge operators. Past investigations on water level fluctuations, mercury contamination and the Root River diversion have incorporated adequate public information components.

Once a scientific data base is established with respect to populations, habitat and harvest data, it will be necessary to inform the public of conditions and effects of exploitation on Lac Seul and the initiatives necessary to effectively manage the fishery. However, any future public information component regarding the fishery resources of Lac Seul will only meet with success if the management decisions affecting the interest groups are supported by a sound scientific and technical data base.

a. Ineffective Institutions

The Ministry of Natural Resources has no control over water level fluctuations in Lac Seul. Control and monitoring of water levels is the sole responsibility of the Lake of the Woods Control Board (Hough et al., 1981). Although minimum water

> levels, or maximum fluctuation ranges, are not in effect, the Board attempts to reach a level of 355 m a.s.l. by the opening of fishing season (ca. May 15, annually) to allow safe navigation to and from most lodges (Hough et al., 1981). This target cannot always be met. Therefore, OMNR fisheries management programs must operate within this constraint regardless of potential effects on fish population stability.

4.5 Projected Yield Based on Present Management Practices

Harvest available to commercial fishermen is expected to remain constant for whitefish and coarse fish species. Projected yield for walleye will depend upon commercial and, more notably, sport harvests. It is assumed that commercial walleye harvest will comprise components of the walleye stocks not utilized by the sport fishery. This level of harvest is expected to continue as per 1981 levels. Projected annual yields available to the commercial fishery are:

Lake Whitefish:	52,935 kg	(quota)
Walleye:	9,092 kg	(quota)
Coarse Fish:	46,679 kg	(avg. harvest 1976-1981)

The supply of northern pike available for sport fish harvest is expected to decline at a constant rate (Weilandt, 1982). Based on the supply balance between sustainable yield and annual angling harvest, it is not unreasonable to expect a 50% or greater reduction in the availability of northern pike by the year 2000. This would result in a reduction of annual allowable harvest from 42,248 kg to 21,129 kg. In order to retain constant angling quality to the year 2000, this reduction in northern pike allowable harvest would necessitate a drop in angler day effort from 7,126 (1979 estimates) to 3,563 angler days ((projected year 2000 (Weilandt, 1982)).

Since current walleye harvests are at a level below the sustainable yield, the walleye supply is expected to remain constant for Lac Seul as a whole to the year 2000. Variation in this supply balance is expected to occur for some basins. Using the 1979 effort estimate for walleye of 26,808 angler-days (Hough et al., 1981) effort to the year 2000 is expected to increase by 30% (i.e., to 34,800 angler-days). However, factors such as non-resident angling pressure, shifts in species-specific effort towards walleye as northern pike C.U.E.'s decline, harvest levels by native people and an improvement in the current economic climate are as yet poorly accounted for. An increase in any or all of these factors could easily contribute to future walleye overharvests under the existing supply balance relationships. Another potentially significant component of the walleye harvest, winter angling pressure, remains unquantified. Considering the lack of these data in the harvest component of walleye, it is perhaps reasonable to assume that the 1979 walleye harvest estimates are conservative.

CHAPTER V

MANAGEMENT DIRECTIVES

5.1 Introduction

This section presents optimum fisheries management strategies aimed towards the efficient allocation of the Lac Seul fishery resources. The primary objective of the fisheries management strategies for Lac Seul reflects the goals of the SPOF programme, that is;

> *to protect, rehabilitate, enhance and maintain Ontario's fish communities and their environment to provide an optimum contribution of fish, fishing opportunities and associated benefits to society.*
>
> (SPOF, 1981)

The objectives, targets and management tactics specific to the allocation of Lac Seul fish resources will be discussed under each SPOF sub-goal, specifically:

- Fish Communities
- Water Quality and Fish Habitat
- Contributions to Society
- Public Awareness and Scientific Knowledge

(SPOF, 1981)

The objectives and targets stated for each SPOF sub-goal will be followed by a brief discussion of management strategies suggested to achieve objectives and targets.

5.2 Fish Communities

> SPOF Sub-goal: to secure a desirable fish community based on a foundation of stable self-sustaining stocks.

The physical and biological characteristics of Lac Seul have been described in Chapter I. The lake consists of 23 morphometrically distinct basins, inhabited by walleye, northern pike and whitefish. Discrete subpopulations of these three species are as yet unidentified for Lac Seul. Deep, cool water habitat is limited in a number of Lac Seul basins. However, temperature and oxygen (Hough et al., 1981) profiles indicate that conditions are sufficiently within the tolerance limits of all three community species (Scott and Crossman, 1973) throughout the basins of Lac Seul. Therefore, for the purpose of allocation, Lac Seul is assumed to consist of 23 distinct basins, each containing a fish community structure of walleye (26% potential yield), whitefish (22%) and northern pike (15%) (Neville Ward, pers. comm.).

The allocational objectives and targets for the Lac Seul fish community will be discussed from the points of view of the three main use components of the fishery: sport fishery, commercial fishery and domestic fishery.[1]

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[1] Domestic fishery refers to the component of fish communities harvested annually by native peoples of Lac Seul Indian Reserve 28 for personal consumption.

5.2.1 *Sport Fish*

5.2.1.1 Objective and Target

> *To meet the angler demand for sport fish at the year 2000 based on an angler satisfaction level of two kilograms per angler-day or the lake's capability to produce sport fish, whichever is least.*
>
> (OMNR, 1982)

Questionnaires and interviews provided recreational user-day data (Hough et al., 1981) and an estimate of angler demand of 35,700 angler days for Lac Seul during the period May 19 - October 31, 1979. Ontario residents account for 3,800 angler-days (20% local, 4% non-local Ontario residents) and non-residents for 31,900 angler-days (74% American, 1% non-resident Canadians).

Trend data stated in Section 4.2.2 suggest that angling demand by resident sport fishermen will be maintained at present levels until the year 2000. However, non-residents demand is expected to increase by 1.25 percent per year to the year 2000. Assuming this trend continues, projected demand for sport fish by non-residents is 41,408 angler-days -- representing a 30% increase in demand from 1979 to 2000. Table 5.1 illustrates the determination of the sport-fish target by user group, given an angler satisfaction level of two kilograms per angler-day. Projected sport-fish demand by species is determined in Appendix 5.1.

Table 5.1: Sportfish targets to the year 2000 for Lac Seul.

User Group	Angler Demand 1979[a] (angler-days)	Projected Demand 2000[b] (angler-days)	Harvest Target[c] (kg)	Projected Harvest Based on 1979 Harvest Levels[d] (kg)
Ontario Resident	3,800	3,800	7,600	18,677
Non-Resident	31,900	41,408	82,816	203,515
Total	35,700	45,208	90,416	222,192

[a] Table 9.10, Hough, et al., (1981).

[b] Demand projection based on NW region growth criteria.

[c] Harvest target based on angler satisfaction level of 2 kg per angler-day.

[d] Hypothetical harvest based on 1979 harvest levels of 5 kg. per angler-day.

In 1979, a total of 175,461 kg of sportfish (walleye, northern pike) was harvested during 35,700 angler-days throughout the creel survey period (Hough et al., 1981). This represents 5 kg of sportfish per angler-day. The capability of Lac Seul to produce sportfish, as determined by the MEI is estimated at 173,580 kg. Compared, these figures indicate that during 1979, the Lac Seul sport fishery was being overharvested.

The extent and percentage of overharvest, by basin, for walleye and northern pike is illustrated in Table 5.2. Commercial walleye harvest values are included for the applicable basins. These data suggest that 12 of Lac Seul's 23 basins--most notably basins 8, 9 and 12 with greater than 100% overharvest - were overharvested during 1979. Overharvests of northern pike are most evident in basins 1, 2, 3, 7, 8, 9, 10 and 12 (Figure 5.1). These data strongly suggest that immediate strategies designed to ensure the maintenance of northern pike populations within Lac Seul are necessary.

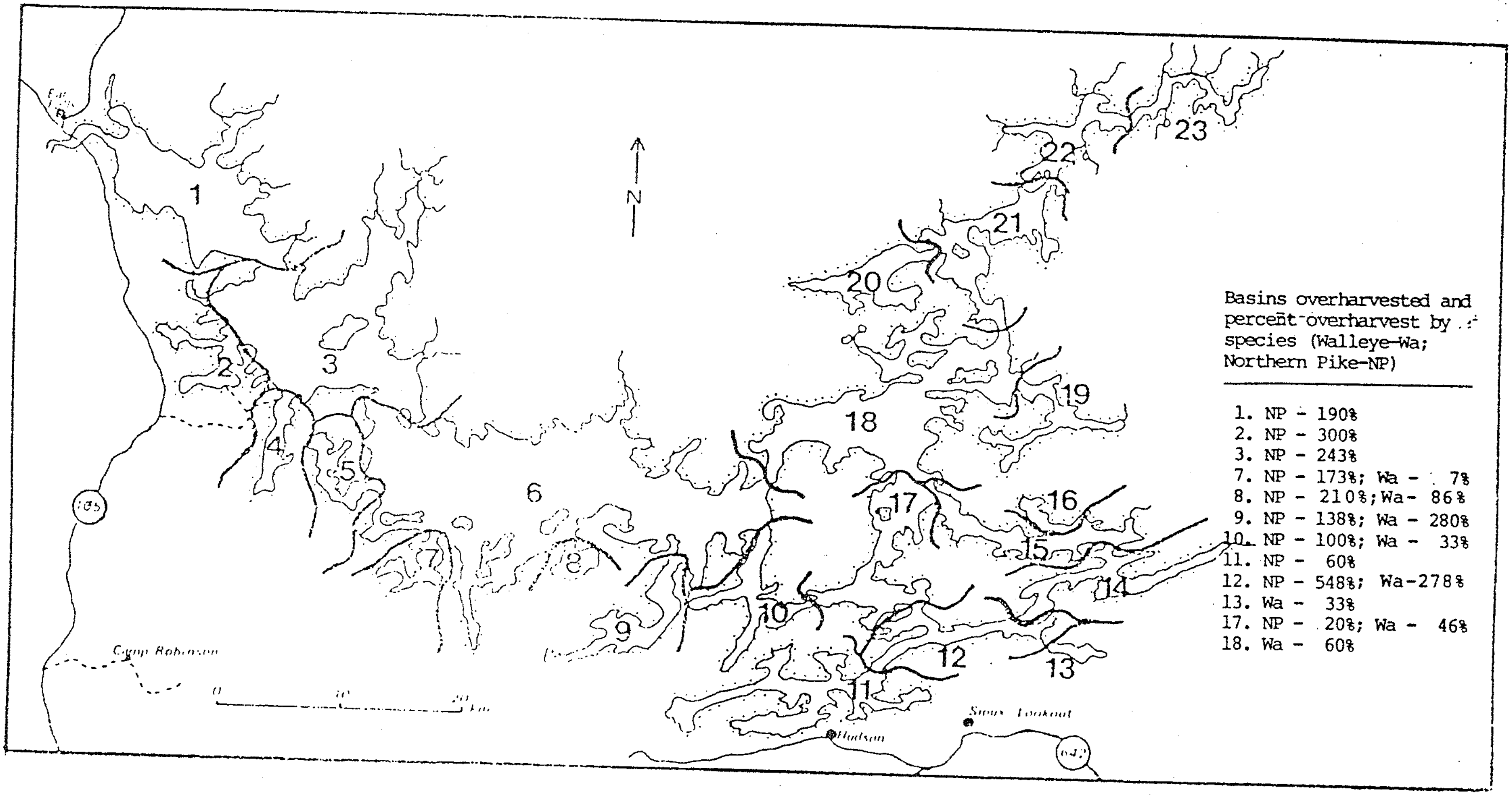
Sportfish demand and harvest targets for the year 2000 are compared with 1979 figures and the lake's capability to produce sport fish in Table 5.3. The data in this table illustrates the challenge to the fishery manager of realizing the SPOF sportfish targets for Lac Seul to the year 2000. As the sportfish demand of 35,700 angler-days

Table 5.2: Maximum sustainable yield and 1979 sport and harvest data, using N.W. Region partitioning criteria, for walleye and northern pike in the 23 basins of Lac Seul.

	Walleye					Northern Pike				Total Game Fish			
Basin	MSY[a]	Sport[b]	Commercial[b]	MSY Remaining	Percent(%) Over-harvest	MSY	Harvest[b]	MSY Remaining	Percent(%) Over-harvest	MSY	Harvest[b]	MSY Remaining	Percent(%) Over-harvest
1	9,076	4,349	-	4,227	-	5,236	15,154	- 9,918	190	14,312	19,503	- 5,191	36
2	1,555	487	-	1,068	-	897	3,579	- 2,682	300	2,452	4,066	- 1,614	66
3	16,441	12,680	-	3,761	-	9,601	32,957	-23,356	243	26,042	45,637	-19,595	75
4	2,381	941	-	1,441	-	1,374	529	845	-	3,756	1,470	2,286	-
5	1,981	102	-	1,879	-	1,143	930	213	-	3,124	1,032	2,092	-
6	24,696	6,823	4,507	13,366	-	14,248	3,680	10,568	-	38,944	15,010	23,934	-
7	2,328	2,485	-	- 157	7	1,343	3,672	- 2,329	173	3,671	6,157	- 2,486	68
8	703	1,307	-	604	86	405	1,252	- 847	210	1,108	2,559	- 1,451	130
9	3,753	14,213	-	-10,460	280	2,165	5,147	- 2,982	138	5,918	19,360	-13,442	227
10	2,736	3,648	-	912	33	1,578	3,160	- 1,582	100	4,314	6,808	- 2,494	58
11	5,767	3,753	-	2,014	-	3,327	5,358	- 2,031	60	9,094	9,111	- 17	1
12	1,709	6,474	-	- 4,765	278	986	6,388	- 5,402	548	2,695	12,862	-10,167	377
13	322	429	-	- 107	33	186	172	14	-	508	601	- 93	18
14	1,951	923	-	1,028	-	1,126	444	682	-	3,077	1,367	1,710	-
15	3,347	747	-	2,600	-	1,931	62	1,869	-	5,278	809	7,469	-
16	520	123	-	397	-	300	130	170	-	820	253	567	-
17	4,622	6,764	-	- 2,142	46	2,667	3,220	- 553	20	7,289	9,984	- 2,695	37
18	10,048	11,491	4,618	- 6,061	60	5,797	5,068	719	-	15,845	21,177	- 5,332	34
19	1,785	1,645	-	140	-	1,030	28	1,002	-	2,815	1,673	1,142	-
20	2,995	2,352	-	643	-	1,728	670	1,058	-	4,723	3,022	1,701	-
21	4,325	1,278	-	3,047	-	2,495	557	1,938	-	6,820	1,835	4,985	-
22	3,008	-	-	3,008	-	1,735	-	1,735	-	4,743	-	4,743	-
23	3,952	236	-	3,716	-	2,280	54	2,226	-	6,232	290	5,942	-
Total	110,002	83,250	9,125	17,617		63,578	92,211	-28,633		173,580	184,586	-11,006	

[a] Maximum Sustainable Yield - sportfish - based on N.W. Region partitioning criteria.

[b] Sport, commercial and other harvest estimates from Hough, et al., 1981.



Basins overharvested and percent overharvest by species (Walleye-Wa; Northern Pike-NP)

1. NP - 190%
2. NP - 300%
3. NP - 243%
7. NP - 173%; Wa - 7%
8. NP - 210%; Wa- 86%
9. NP - 138%; Wa - 280%
10. NP - 100%; Wa - 33%
11. NP - 60%
12. NP - 548%; Wa-278%
13. Wa - 33%
17. NP - 20%; Wa - 46%
18. Wa - 60%

Figure 5.1: Overharvested Basins, Lac Seul.

Table 5.3: Comparison of year 2000 sportfish targets with Lac Seul sportfish production capability and 1979 demand and harvest figures.

User Group	Capability[a]	Year 1979 Sportfish Demand		Year 2000 Sportfish Demand		MSY Minus Anticipated Harvest (Year 2000)
		Angler Days[b]	Estimated Harvest (kg)	Angler Days	Anticipated Harvest (kg)	
Ontario Resident	-	3,800	Wa 17,316 Np 3,043	3,800	7,600	-
Non-Resident	-	31,900	Wa 42,682 Np 45,699	41,408	82,816	-
Total	173,580	35,700	108,740[c]	45,208 x 2 kg=	90,416[d]	83,164

[a] Capability (in kg/yr) represents total potential yield, assuming yield partitioned on the basis of 15% for northern pike and 26% for walleye (Neville Ward, pers.comm.). Data from Table 4.3.

[b] From Table 9.10, Hough, et al., 1981.

[c] From Table 6.15, Hough, et al., 1981, based on number of fish kept.

[d] Sportfish harvest target for the year 2000, based on angler satisfaction level of 2 kg per angler-day.

increases by 30% to 45,208 angler-days during the period leading up to the year 2000, harvest levels must be controlled such that the current yield of 5 kg per angler-day (Hough et al., 1981) is reduced to the angler satisfaction level of 2 kg per angler day (OMNR, 1982). The following management strategies are suggested in order to achieve the sportfish targets.

5.2.1.2 Management Strategies - Sportfish

Northern pike are currently being overharvested in several basins of Lac Seul. In order to meet projected angler demand for the year 2000 it is apparent that harvest levels for pike must be brought within the biological limits of the population.

As non-resident anglers comprise up to 88% of all anglers on Lac Seul (Hough et al., 1981), control of this user group, with respect to the harvesting of northern pike, could effectively reduce harvest pressure on this species.

Tactic:

1. Decrease present possession limit for northern pike of 6, to a possession limit of 3 for non-resident anglers utilizing Lac Seul. New limit of 3 northern pike will further be restricted to include only 1 northern pike at trophy size.

2. Encourage a redirection of non-resident northern pike angling effort to waters in the vicinity of Lac Seul capable of sustaining additional angling pressure for northern pike, i.e., restrictive zoning of overharvested Lac Seul basins (e.g., resident-only angling, basin-specific).

Walleye are similarly being overharvested in a number of basins. Additional harvest pressures on this species could be anticipated as a result of shifts in species-specific angler effort as the supply of northern pike declines. Both walleye and northern pike stocks are experiencing the majority of overharvest pressure in basins of closest proximity to Ear Falls, Hudson and Sioux Lookout. Redirection of angler-effort to less exploited basins would present formidable management and enforcement difficulties. Rather, the following strategies are suggested:

Tactic:

3. Initiate an "Assessment Study" on Basin 9 - Vaughan Lake, for a 3-year period. This study would necessitate a 3-year closure of the Vaughan Lake fishery. Chemical and physical data would be collected to verify the production potential of this basin. Index netting would be undertaken to establish growth rate data, condition factors and population stress indicators. Spawning and nursery habitat availability/utilization would be investigated for walleye and northern pike. Sedimentation studies would be initiated to determine rate of succession (infilling) of potential northern pike spawning habitat.

   Once acquired, such data would provide a solid foundation upon which to base rehabilitation strategies for similarly stressed basins within Lac Seul.

4. Conduct a "roving" creel survey[2] on basins 1, 2 and 3 (through Red Lake District, OMNR) and basin 12 -- Deception Bay (through Sioux Lookout District, OMNR) to verify/determine levels of angler harvest and pressure and to examine these parameters by angler origin. Compare creel

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[2] As per Malvestuto et al., 1978.

survey parameters to those calculated for all basins in 1979. Continue creel survey monitoring every third year thereafter to develop trend data. Utilize creel survey data to evaluate the impact of a reduced northern pike catch limit for non-resident anglers.

5. Promote a greater utilization of fish species (e.g. perch, whitefish) other than prime sportfish (walleye, northern pike) within basins capable of incurring increased harvest levels.

The Adamhay Lake (basin 23) winter walleye fishery appears to be a very significant, though as yet unquantified, component of the walleye harvest within this basin (John McDonald, pers. comm.). Adamhay Lake is considered a very important walleye spawning area due to the large number of inflowing tributaries; the area retains sanctuary status for spawning walleye from March 15 to June 21, inclusive. Bodaly (1980) has suggested that spawning walleye tend to move back towards spawning areas as early as the fall prior to spring spawning. If such is the case for Lac Seul, then it is likely that a significant portion of potential walleye spawners are being removed by the Adamhay Lake winter fishery. Continued removal of potential spawning walleye by a winter fishery could severely limit the utility of applying sanctuary status to this important basin of Lac Seul. The following management strategies are suggested for the Adamhay Lake area:

Tactic:

6. Continue walleye spawning sanctuary status (March 15 - June 21) each year.

7. Initiate a walleye tagging program to provide temporal and spatial information on walleye movements and inter-basin migration.

8. Initiate an extensive winter creel survey of Adamhay Lake. Data collected should include angling pressure and harvest, average weight determination, catch per unit effort and condition of walleye at time of catch (i.e. with or without spawn/ milt).[3] If harvests are found to be excessive--especially with respect to potential spawners--it may be necessary to extend sanctuary status to include protection of the winter fishery.

5.2.2 *Commercial Fish*

5.2.2.1 Objective and Target

> *To maintain the current level of commercial fish production within the commercial fishing blocks of Lac Seul. The target for Lac Seul commercial fisheries will be the sum of existing quotas and average harvest (1976 - 1981, inclusive) for species not on quota.*
>
> (OMNR, 1982)

Average commercial harvest levels (1976-1981 inclusive) are compared with existing quotas for commercially fished species in Table 5.4. These data indicate that

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[3] The author has been informed that this management tactic is currently being undertaken, Jan. 6 - March 15, 1983, 7-days per week (J. McDonald, pers.comm.).

Table 5.4: Comparison of average commercial harvest levels (1976-1981) with commercial harvest quotas, Lac Seul. All values in kg.

	Walleye		Whitefish		Other[a]		Total Commercial Harvest
Year	Harvest	Quota	Harvest	Quota	Harvest	Quota	
1976	2,316	9,092	46,188	52,955	17,863	0	66,187
1977	4,317	9,092	49,029	52,955	77,155	0	130,555
1978	6,215	9,092	49,994	52,955	69,223	0	125,442
1979	9,125	9,092	51,275	52,955	44,742	0	105,142
1980	9,401	9,092	57,990	52,955	31,193	0	98,584
1981	8,762	9,092	51,779	52,955	40,067	0	100,445
Average	6,698	9,092	50,543	52,955	46,679	0	104,393

[a] Species included ling, sucker, tullibee, yellow perch, northern pike (incidental), chubs.

Data source: Table 4.8, this report.

quota controls have been reasonably effective in regulating the commercial fishery. Hence, walleye and whitefish quotas should be maintained as they currently exist within respective commercial fishing blocks; an annual commercial harvest level of 46,680 kg is suggested for species not on quota.[4]

5.2.2.2 Management Strategies - Commercial Fish

As indicated in Figure 5.1, walleye overharvest is apparent in basin 18. A portion of commercial fishing Block 4 is contained within this basin. Although there is no data to suggest that walleye overharvest in this basin is attributable to commercial fishing, the following management strategies are suggested as a means of avoiding potential conflicts with the sport fishery:

Tactic:

9. Encourage a redirection of demand to basins, or parts of basins capable of sustaining additional fishing pressure with particular attention to basins where conflicts are anticipated with the sport fishery.
10. Continue to promote a greater utilization of coarse fish species such as sucker, tullibee and burbot.

The following are intended as general management strategies aimed at achieving commercial fish targets to the year 2000:

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[4] Species not on quota include: tullibee, burbot, perch, suckers, chubs, etc.

Tactic:

11. Monitor commercial fish operations on a continual basis for signs of overharvest and adjust quotas accordingly.

12. Apply scientific knowledge, as it becomes available, to refine the MEI determined potential yield of the commercial fishing blocks, such that accurate productivity determinations and quotas will ensure a sustained yield.

13. Encourage full utilization of fish stocks allocated toward the commercial fishery.

5.2.3 *Domestic Fishery*

SPOF Guidelines do not provide specific management directives for the domestic fishery component. Therefore, suggested objectives, targets and management strategies appropriate to the allocation of the fish community component utilized by native peoples inhabiting Lac Seul Indian Reserve 28 will be outlined.

The current population (1982) of natives living on Lac Seul Indian Reserve 28 is 537 residents (Marg Eady, Band Membership Clerk, DIAND, Sioux Lookout, personal communication, February 11, 1983). Off-reserve residents, living in Hudson, Sioux Lookout, Ear Falls, Savant Lake and Kenora, approximates 734 residents (OMNR, 1981). This data compared with 1982 estimates suggests a growth rate of 3.5 percent per year for Lac Seul Indian Reserve 28 on-reserve residents. Projecting this growth rate to the year 2000 indicates that on-reserve residents of the Lac Seul Band will be approximately 1000 residents.

Domestic consumption by natives on Lake of the Woods was estimated at 35 kg of fish per year (Hough et al., 1982). The Lake of the Woods study further suggested that 33% of the domestic harvest was comprised of walleye.

Applying these values to Lac Seul Indian Reserve 28, the domestic component of harvest in 1982 would be 18,795 kg of fish, of which 6,202 kg are walleye. Projected harvest to the year 2000 (based on the above population estimates and a consumption level of 35 kg fish per year), will be 35,000 kg of fish, 11,550 kg of which will be walleye.

In order to refine the species composition of the domestic fishery, it has been suggested that index netting experiments be initiated to determine the percent fish biomass (by species) of the domestic fishery (Neville Ward, pers.comm., February 4, 1983).

5.2.3.1 Objective and Target

> To maintain a domestic consumption level of 35 kg/fish per year for members of Lac Seul Indian Reserve 28. The target for the year 2000 will be 43,750 kg/fish per year, 11,375 kg of which are walleye.

5.2.3.2 Management Strategies - Domestic Fishery

Tactic:

14. Conduct a survey on Lac Seul Indian Reserve 28 to determine consumption levels of all fish and the top predator component. Obtain census data from DIAND, Sioux Lookout Office, regarding the number of on-reserve inhabitants. Conduct index netting experiments to indicate percent fish biomass, by species, for the domestic harvest. Use data to refine demand and harvest estimations. Repeat survey at 5-year intervals to establish population growth rates, emigration rates and capacity of the reserve to support band members.

5.3 Water Quality and Fish Habitat

SPOF Sub-goal: to secure an environment which will sustain unimpaired fish communities and those ecosystem components on which they depend.

This sub-goal presupposes the sub-goal for Fish Communities as desireable fish communities may require the maintenance of both water and habitat quality.

5.3.1 *Water Quality*

In general, water quality does not appear to be a problem with regard to Lac Seul. Navigational hazards exist (e.g. sunken timber debris) and are further aggravated by fluctuating water levels. However, this issue is beyond the jurisdictional control of the OMNR. Data presented in Section 4.1.2.3 indicates that fish in Lac Seul are fit for human consumption, though users are advised to follow

Ministry of Environment (OMOE, 1979) guidelines as they pertain to the consumption of walleye and northern pike. All other water quality criteria measured by MOE indicate that the water quality of Lac Seul is adequate to secure an environment which will sustain unimpaired fish communities and related ecosystem components.

5.3.1.1 Objective and Target

Maintain water quality at present standards to the year 2000.

5.3.1.2 Management Strategies - Water Quality

The responsibility of maintaining water quality is shared cooperatively between OMOE (through Water Resources Act and Environmental Protection Act) and OMNR (through the Fisheries Act) (Neville Ward, pers. comm.)

Fisheries management strategies pertaining to water quality will be contingent upon the acquisition of water quality data as it becomes available either through MOE or MNR monitoring programs.

Tactic:

15. Acquire water quality data every 5 years and incorporate this data into on-going fisheries management schemes.

5.3.2 *Fish Habitat*

5.3.2.1 Objective and Target

To maintain the present quantity and quality of fish habitat for the fish communities of Lac Seul to the year 2000.

5.3.2.2 Management Strategies - Fish Habitat

Section 2.2.3 of the Literature Review discusses the specific impacts of water level fluctuations on northern pike habitat. The observations of several authors (Section 2.2.3) would suggest that an assessment of northern pike spawning and nursery habitat would provide a realistic determination of the contributions of these habitats to the recruitment of northern pike stocks. Data generated from the assessment could then be utilized to refine potential yield estimates for northern pike as determined by the MEI.

Tactic:

16. Initiate an assessment to evaluate potential spawning and nursery habitat for northern pike. Examine succession rates of embayments using aerial photos from 1954 to present. Conduct spring on-site surveys to determine presence/absence of spawning northern pike. Use Landsat imagery or infrared photos to examine water thermal changes at time of spawning. Apply collected data to productivity determinations for northern pike.

The following general management strategies relate to the protection of fish habitat for the remaining fish species comprising the Lac Seul fish community.

Tactic:

17. Continue shoreline development regulations to prevent erosion and protect shore spawning habitats.

18. Continue modified management area designation of shorelines to protect potential spawning areas and littoral habitats that are of importance for fish productivity.

19. Examine proposed road construction and bridge crossing plans (e.g. MacKenzie Bay Road) which may affect Lac Seul and inflowing tributaries with the aim of regulating access to vulnerable fish resources and protecting potential spawning and nursery habitats from upstream erosion.

5.4 Contributions to Society

SPOF Sub-goal: to provide an optimum contribution of fish, fishing opportunities and associated benefits to meet society's needs for: wholesome food, recreation, employment and income and a healthy human environment.

5.4.1 *Objective and Target*

To increase the contributions to the local economy of the Lac Seul area and to the regional economy of northwestern Ontario, coincident with the anticipated increase in angler-days through to the year 2000.

5.4.2 *Management Strategies - Contributions to Society*

In order to ensure a continual contribution to local and regional economies through fishery based tourism, it is essential that quality sport fishing opportunities are made available through the achievement of fish community targets. The increased demand projected for non-resident sport fishermen is expected to make significant contributions to local and regional economies. However, for such economic contributions to be realized, mechanisms are required to transform current non-resident non-contributors into future contributors to the sport fishery based economy.

In 1984, the OMNR proposes to institute regulations that will require non-resident sport fishermen to be identified with a "base of operations." Those non-resident anglers not staying at an established tourist lodge or Provincial Park will be required to purchase a Crown Land Resource Access Permit (John McDonald, pers.comm.). The fee for such a permit is proposed to approximate the Provincial Park daily camping fee. Changes in current licensing structure for non-resident anglers have also been proposed, whereby the present seasonal non-resident angling permit may be changed to a three-week angling permit of which a maximum of two such permits are available per non-resident angler per year (John McDonald, pers.comm.).

It is anticipated that these management strategies, proposed by OMNR, will generate increased revenues to the province and will encourage an increased utilization of the Lac Seul area tourist lodges.

Tactic:

20. Institute a mandatory Crown Land Resource Access Permit program aimed at non-resident sport fishermen not identified with an established tourist lodge or Ontario Provincial Park.

21. Evaluate current non-resident seasonal angling permit as provincial policies affecting the sport fishery change.

5.5 Public Awareness and Scientific Knowledge

SPOF Sub-goal: to contribute to society's understanding of fish ecosystems and their interdependence with man.

5.5.1 *Public Awareness*

5.5.1.1. Objective

To inform the public of the management planning activities proposed for Lac Seul.

5.5.1.2 Management Strategies - Public Awareness

Tactic:

22. Hold public information and participation meetings upon the release of the Lac Seul Fisheries Management Plan - Final Draft and at each 5-year review and update of the plan.

5.5.2 *Scientific Knowledge*

5.5.2.1 Objective

To promote the expansion of the fisheries data base to enable managers to make better decisions and to assess progress and impacts of management programs.

5.5.2.2 Management Strategies - Scientific Knowledge

Tactic:

23. Apply and integrate data collected in proposed assessment studies for Lac Seul (Section 5.2.1.2 and 5.3.2.2) to areas of the lake exhibiting similar conditions.

24. Utilize assessment study data from Lake of the Woods Assessment Unit and other units such as Lake Nipigon or Lake Nipissing.

CHAPTER VI

ALLOCATION AND SUMMARY

6.1 Introduction

This section presents the priorization of management tactics developed in Chapter V and a discussion of potential yield based on priorized management tactics, leading to the efficient allocation of Lac Seul fish stocks to the various user groups.

To facilitate the priorization of management tactics, tactics discussed in Chapter V are listed and grouped (Appendix 6.1) to illustrate those tactics which are new, those implying a continuation of management tactics currently in place, tactics requiring further consideration and tactics deemed not feasible at present.

New management strategies are priorized by subjective evaluation, rather than the cost-effectiveness approach suggested in The Guidelines for District Fisheries Management Plans (SPOF, 1981). The subjective evaluation method for priorization reflects the author's opinion regarding those strategies which will incur the least relative costs upon implementation. The priorization of new management strategies may be reassessed using cost-effectiveness analysis once annual budgets for Lac Seul have been allocated.

Potential yield based on new management tactics is discussed for each basin in Section 6.3. Management emphasis required to achieve future targets is indicated for each basin.

The final section indicates the allocation of the Lac Seul fish stocks based on the following allocational ranking system established by SPOF (1978):

Priority Ranking	Allocate to
1	All residents (maintenance and/or rehabilitation of the resource)
2	Native people with Treaty fishing rights for subsistance and/or traditional needs
3	Resident sport fishermen
4	Business enterprises - priority between commercial fish or sport fishing industries to be decided on the basis of optimum benefits to the residents of Ontario.

(modified from Wepruk,1981)

For the purpose of fishery allocation for Lac Seul, priority 4, is broken down such that non-resident contributor sport fishermen have priority over the commercial fishery. The benefits to the local and regional economy of northwestern Ontario, from the lodge based fishing industry (catering almost wholly to non-resident sport fishermen), far exceeds those derived from the commercial fishery at Lac Seul (Hough et al., 1981). It is this premise that establishes priority of non-resident contributors over the commercial fishery. However, a thorough valuation of benefits between these groups remains to be completed. It is suggested that the economic analysis techniques discussed in Section 2.3 be undertaken to provide a more thorough account of these values.

Once this is done, allocational priorities listed under rank 4 may be established with greater confidence and accountability.

6.2 Priorization of New Management Tactics

The priorization of new management tactics will proceed by sub-dividing tactics with respect to their expected time of implementation.

The Lac Seul Fisheries Management Planning program is considered to continue for a 20-year period. This period can be sub-divided into four 5-year time frames. Five-year revisions of the operational management plan are proposed at the end of each time frame (SPOF, 1981). These revisions will evaluate the relative success or failure of management tactics in achieving planned objectives. In order to facilitate the evaluation of management tactics during future revisions, new management tactics are priorized by time frame, within the following categories:

1. Tactics requiring immediate implementation--i.e. those tactics that are implemented in time frame one. Some of these tactics will require monitoring within later time frames.

2. Monitoring Tactics--i.e. tactics intended to commence during some year within time frame one, with monitoring at, e.g., 5-year intervals in subsequent time frames (e.g., creel surveys).

   It is intended that these tactics will generate a trend-through-time data base.

3. Lag/Contingency Tactics--i.e. tactics intended to come on stream during the second or later time frames within the planning period. The implementation of these tactics will be contingent upon the relative success/failure of preceding tactics to achieve objectives, temporal structure of budgeting, etc.

The following represents new management strategies priorized within the above categories.

6.2.1 *Immediate Implementation Strategies--Time Frame 1.*

Priority 1 - Tactic 20:[1] Evaluate the proposed Crown Land Access Permit.

The Crown Land Access Permit is scheduled for implementation early in time frame one and will continue throughout the duration of the management planning period, on an experimental basis. It will be necessary to review the utility of the Crown Land Access Permit at each 5-year operational revision. Revisions should examine the effects of the tactic implementation on non-resident angler demand, and the success of the tactic as a means of generating revenue from sport fishing--in particular the generation of revenues from the current non-resident, non-contributor angler group.

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[1] Tactics are stated here in abbreviated form; for further detail, see Chapter V.

Priority 2 - Tactic 1: Decrease non-resident northern pike angling limit from 6 to 3, allowing for one trophy size northern pike; this restriction to apply to Lac Seul only.

Tactic one is intended to be implemented early in time frame one, on an experimental basis, at least until the first revision. At that time, the tactic should be assessed with respect to its effects on northern pike populations and non-resident angler demand.

Priority 3 - Tactic 24: Utilize assessment studies from other Assessment Units that will aid in fish stock improvements.

Priority 4 - Tactic 14: Survey Lac Seul Indian Reserve 28 to determine annual quantity of fish consumption; Index net to determine percent biomass by fish species of domestic harvest.

Tactic 14 is intended to produce an accurate value of the requirements of the domestic fishery.

6.2.2 *Monitoring Strategies*

Priority 1 - Tactic 4: Conduct roving creel surveys on basins 1, 2, 3 and 12.

Tactic 4 is intended for implementation within time frame one (e.g. year 2) with subsequent monitoring every fifth year thereafter. This will allow for the acquisition of a trend-through-time data base.

Priority 2 - Tactic 12: Apply scientific knowledge as it becomes available to refine the MEI determined potential yield of the commercial fishery, such that accurate productivity determinations and quotas will ensure a sustained yield.

Priority 3 - Tactic 3: Continue the monitoring tactics currently in place (see Appendix 6.1, B), in particular the Adamhay winter creel survey and tagging program, to provide a solid trend-through-time data base.

The degree to which immediate implementation and monitoring tactics can proceed in concert will depend upon cost-effectiveness determinations made by district fisheries managers for the Lac Seul fishery.

6.2.3 *Lag/Contingency Strategies*

Priority 1 - Tactic 2: Redirect non-resident northern pike angling effort away from Lac Seul - restrictive zoning

The implementation of Tactic 2 will occur during time frame 2 contingent upon the relative success/failure of proposed immediate implementation strategies aimed at reducing northern pike overharvests. This tactic is designed to mitigate against gross overharvests of northern pike in specific basins.

Priority 2 - Tactic 3: Initiate assessment study of Vaughan Lake - basin 9 - to examine factors relating to overharvest.

It will be necessary to implement Tactic 3, within time frame 2, should immediate action strategies and scientific knowledge (e.g. relating to MEI and production potential) fail to indicate factors responsible for the gross overharvests in this basin. An assessment study of this nature would require substantial funding. Therefore, it is considered here as a lag strategy in order that managers are provided with sufficient time to weigh the data collected in the interim and be prepared to justify expenditures should such an assessment be necessary. Tactic 3 is intended for implementation at some year within time frame 2, contingent upon the deliberations of the first five-year revision.

<u>Priority 3</u> - Tactic 23: Apply and integrate Vaughan Lake assessment study data to similar basins within Lac Seul.

Tactic 23 is intended to come on stream during time frame 2 or 3, contingent upon the completion of the Vaughan Lake assessment study.

<u>Priority 4</u> - Tactic 9: Where conflicts occur between the commercial fishery and other user-groups, redirect commercial fishing demands to basins capable of sustaining additional pressure.

The implementation of Tactic 9 is intended for basins where top predators (e.g. walleye) are harvested by both commercial and sport fisheries (e.g. basin 18). This tactic should be considered in time frames 2, 3 and 4.

Redirection of commercial walleye harvest may also be necessary contingent upon changes in domestic fishing rights.

6.2.4 *Management Strategies Requiring Further Consideration*

6.2.4.1 Establishment of a Lac Seul Fisheries Assessment Unit

To date Lac Seul has not been assigned Fisheries Assessment Unit status. However, many arguments have been forwarded regarding the establishment of an Assessment Unit for Lac Seul. For example, Hanna and Michalski (1982) state:

> *...it is apparent that trends in the yield of Lac Seul's fishery correspond to the water level changes that have occurred. To answer definitively, what the optimum (water) regulation pattern should be, regular biological analysis for each of the lake basins would be required. Water resource managers will need to collect this type of data in the future if credible responses are to be made and optimum regulation patterns are to be formulated...*

Further, much of the data required to adequately assess the effects of water level fluctuations on spawning and nursery habitats for the fish community of Lac Seul could be feasibly collected only through the large scale undertakings of an assessment unit. Although Lac Seul is not presently a candidate assessment unit, this option should be left open for future consideration.

6.2.4.2 Assessment of Embayment Areas (Potential Northern Pike Spawning Grounds) Using LANDSAT Imagery

This technique was proposed (Section 5.3.2.2) as a least-cost method for detecting rapidly changing thermal regimes within embayments during northern pike spawning periods. Hassler (1970) has suggested that northern pike egg mortalities would be complete if increased siltation and water level changes were combined with abrupt temperature changes during the early stages of egg development.

LANDSAT data is currently not available within the required frequency (apparently the satellite passes over northwestern Ontario every 18 days, Neville Ward, pers.comm., February 4, 1983) to properly detect these thermal effects.

At present, it is considered more crucial to acquire fundamental data regarding location of northern pike spawning areas, siltation effects and spring water levels within spawning zones. Once the fundamental data base is established, further data, regarding water thermal regimes during the northern pike spawning period, may be collected using infra-red photo-techniques or LANDSAT imagery (should data frequency improve, for this type of application, in the future).

6.3 Projected Yield Based on New Management Strategies

Quantitative projections of yield, by basin, are not possible at this time since predicting the quantitative effects of new management strategies on fish production is purely speculative. Rather, this section will indicate management emphasis (i.e. maintenance or rehabilitation) for each basin depending on the current state of harvest of the respective basin. Maintenance or rehabilitative management emphasis will be conducted through the aforementioned priorized management tactics. The progress of the management tactics toward the achievement of management emphasis for each basin will be assessed at each 5-year revision throughout the planning period.

Table 6.1 presents potential yield, by basin, and management emphasis. Basins exhibiting current (1979) overharvest will require rehabilitative management emphasis aimed at bringing harvest levels within that basin's maximum sustainable yield (MSY). Management emphasis on basins with no apparent overharvest will involve maintenance of harvest levels within the potential (MSY) yield (SPOF, 1981).

Through the implementation of priorized management strategies, with consideration of the management emphasis and production potential of each basin, the projected yield for Lac Seul fish stocks will be as follows:

6.3.1 *Commercial Fishery*

Projected yield will remain as per present quota levels for commercially harvested species, i.e.:

Species	Harvest (kg)	
Whitefish	52,935	quota
Walleye	9,092	quota
Coarse	46,679	average 1976-1981

The walleye harvest will be distributed evenly between the two commercial blocks (3 and 4) retaining walleye quotas. Rehabilitative emphasis may become necessary in block 4 (basin 18) should future conflicts arise between this commercial fishery and other users (domestic, sport, see Table 6.1).

6.3.2 *Sport Fishery*

Projected yield will be maintained at current levels within the MSY (Table 6.1) for those Lac Seul basins currently underharvested. Further exploitation of these basins is not recommended at present as these basins may provide a significant "fish reservoir" function, contributing to the rehabilitation of adjacent overharvested basins.

For basins currently experiencing overharvest due to excessive angling pressure, rehabilitative management tactics (Section 6.2.1 and 6.2.3) will be necessary to bring future yields within the MSY. Management tactics designed to reduce angling pressure and limit harvest must be employed

Table 6.1: Management Emphasis for the Implementation of New Management Strategies, Lac Seul, Basins and Fish Community.

	Walleye				Northern Pike				Lake Whitefish		
Basin	MSY (kg/yr)	Current State of Harvest[a]	Percent(%) Overharvest	Management Emphasis[b]	MSY (kg/yr)	Current State of Harvest	Percent(%) Overharvest	Management Emphasis	MSY (kg/yr)	Current State of Harvest	Management Emphasis
1	9,076	under	-	maint.	5,236	over	190	rehab-sp	7,680	n/a by basin	maint.
2	1,555	under	-	maint.	897	over	300	rehab-sp	1,316		maint.
3	16,441	under	-	maint.	9,601	over	243	rehab-sp	14,081	-	maint.
4	2,382	under	-	maint.	1,374	under	-	maint.	2,051	-	-
5	1,981	under	-	maint.	1,143	under	-	maint.	1,677	-	-
6	24,696	under	-	maint.	14,248	under	-	maint.	20,896	-	-
7	2,328	over	7	rehab-sp	1,343	over	173	rehab-sp	1,970	-	-
8	703	over	86	rehab-sp	405	over	210	rehab-sp	595	-	-
9	3,753	over	280	rehab-sp	2,165	over	138	rehab-sp	3,176	-	-
10	2,736	over	33	rehab-sp	1,578	over	100	rehab-sp	2,315	-	-
11	5,767	under	-	maint.	3,327	over	60	rehab-sp	4,880	-	-
12	1,709	over	278	rehab-sp	986	over	548	rehab-sp	1,446	-	-
13	322	over	33	rehab-sp	186	under	-	maint.	272	-	-
14	1,951	under	-	maint.	1,126	under	-	maint.	1,651	-	-
15	3,347	under	-	maint.	1,931	under	-	maint.	2,832	-	-
16	520	under	-	maint.	300	under	-	maint.	440	-	-
17	4,622	over	46	rehab-sp	2,667	over	20	rehab-sp	3,911	-	-
18	10,048	over	60	rehab-sp comm	5,797	under	-	maint.	8,502	-	-
19	1,785	under	-	maint.	1,030	under	-	maint.	1,510	-	-
20	2,995	under	-	maint.	1,728	under	-	maint.	2,534	-	-
21	4,325	under	-	maint.	2,495	under	-	maint.	3,660	-	-
22	3,008	under	-	maint.	1,735	under	-	maint.	2,545	-	-
23	3,952	under	-	maint.	2,280	under	-	maint.	3,344	-	-
Total	110,002	92,375 (under)	-	maint.	63,578	92,211 (over)	-	rehab-sp	93,248	51,275 (under)	maint.current comm. harvest quotas(52,935 kg)

a - under → 1979 basin harvest < MSY
over → 1979 basin harvest > MSY

b - maint. → management emphasis aimed at maintaining current harvest levels
rehab → management emphasis aimed at rehabilitating overharvest
sp → sportfish rehabilitation; comm → commercial fishery rehabilitation

with specific attention to these basins (Appendix 6.1, Figure 5.1). Once tactics have achieved harvest levels within the potential yield, management emphasis on these basins can revert to sportfish harvest maintenance.

In accordance with the Northwestern Ontario Strategic Land Use planning targets, the projected demand to the year 2000 for Lac Seul sportfish will be 90,416 kg (45,208 angler-days x angler satisfaction level of 2 kg per angler day--Section 5.2.1, Table 5.3) This target appears achievable given the production potential of 173,580 kg for Lac Seul sportfish. It is important, however, to consider that the majority of angler-day demand will be concentrated on those basins traditionally used by anglers--basins presently in need of rehabilitative management. Therefore, the degree to which future sportfish demand is realized will directly depend upon the relative success of rehabilitative management strategies aimed at controlling basin-specific demand and overharvest.

6.4 Allocation

The procedure used to allocate Lac Seul fishery resources parallels methods described in Wepruk (1981). SPOF Working Group Five (1978) allocational priorities have been outlined in Section 6.1.

The first priority implies maintenance and/or rehabilitation of the fishery resource to the benefit of Ontario residents for present and future generations. Management tactics aimed at achieving this objective have been addressed in Section 6.2.

Provision of adequate fish stocks for native subsistence consists the second allocational priority. Current allocation to native users, based on estimates derived in Section 5.2.3 is 18,795 kg of fish, including a walleye allocation of 6,202 kg. Allocation to the year 2000 based on future demand is 35,000 kg of fish, including 11,550 kg of walleye. Table 6.2 illustrates allocation of Lac Seul fish stocks to the domestic fishery and residual harvest available for allocation to subsequent user groups.

Table 6.2: Domestic Fishery Allocation of Lac Seul Fish Resources Present (1982) and Future. All Values in kg.

	M.E.I. Allowable	Estimated Harvest & Allocation 1982	Allocation Year 2000	Residual Harvest Available 1982	Residual Harvest Available 2000
Walleye	110,002	6,202	11,550	103,800	98,452
Northern Pike	63,578	uK[b]	uK	63,578	63,578
Whitefish	93,248	uK	uK	93,248	93,248
All Species	423,855[a]	18,795	35,000	405,060	388,855

[a] "All species" - includes top predators, coregonids and coarse fish values taken from Table 4.3.

[b] uK - species composition of domestic harvest unknown. Allocation proceeds assuming no pike or whitefish harvested within the domestic fishery.

Resident anglers receive next allocational priority. In 1979 this user group accounted for 24.1 percent of the sportfish harvest, based on number of fish kept (Hough, et al., 1981). The major portion of the resident harvest (1979) was top predators with approximately 17,316 kg walleye and 3,043 kg northern pike harvested (Hough, et al., 1981). Resident angler demand is expected to remain constant to the year 2000 (Section 5.2.1.1). However, reduction of current resident angler harvest will be necessary in order to achieve future harvest targets based on an angler satisfaction level of 2 kg of fish per angler day. Table 6.3 indicates current allocation based on 1979 harvest data (Hough, et al., 1981) and future allocation (based on NWSLUP targets) for resident anglers of the Lac Seul fishery.

The fourth allocational priority is to the non-resident angler component. Non-resident anglers can further be divided into contributors and non-contributors (as discussed in Section 5.4.2). SPOF (1978) states that no fish should be allocated to non-contributing, non-resident anglers. Hence this group must be identified within the non-resident angler component and restricted with respect to allocational priority. Appendix 6.2 presents a method for distinguishing non-resident non-contributors from non-resident contributors, based on 1979 creel survey data (Hough et al., 1981).

Table 6.3: Resident Angler Allocation of Lac Seul Fish Resources, Present (1979) and Future (2000). All values in kg.

	Residual MEI Allowable.		Estimated Harvest & Allocation	Allocation	Residual Harvest Available	
	1982	2000	1979	2000	1982	2000
Walleye	103,800	98,452	17,316[a]	6,464	86,484	91,988
Northern Pike	63,578	63,578	3,043	1,136	60,535	62,442
Whitefish	93,248	93,248	uK	uK	93,248	93,248
All Species	405,060	388,855	20,359	7,600[a]	384,521	381,255

[a] 7,600 kg based on projected demand (2000) of 3800 angler-days x angler satisfaction level (2 kg/angler-day).

[b] species breakdown of future harvest allocation based on % species harvested in 1979.

[c] harvest figures based on number fish kept (Hough et al., 1981 - Table 6.14).

Appendix 6.2 determines the non-resident contributor component to range from 65-76 percent of all non-resident anglers. Therefore a mean value of 70% non-resident anglers will be used here to allocate fish stocks to non-resident contributors.

In 1979, non-resident anglers accounted for 51% of walleye sportfish harvest and 50% of northern pike sportfish harvest, based on number of fish kept (Hough et al., 1981, Table 6.14). To allocate fish resources to non-resident contributors only, these figures are modified by 70%, thereby allocating 29,895 kg of walleye and 32,016 kg of northern pike to this group (Table 6.4).

Table 6.4: Non-resident Contributor Angler Allocation of Lac Seul Fish Resources, Present (1979) and Future (2000). All Values in kg.

	Residual MEI Allowable		Estimated Harvest & Allocation	Allocation	Residual Harvest Available	
	1982	2000	1979[a]	2000	1982	2000
Walleye	86,484	91,988	29,895	39,990	56,589	51,998
Northern Pike	60,535	62,442	32,016	42,826	28,519	19,616
Whitefish	93,248	93,248	uK	uK	93,248	93,248
All Species	384,521	381,255	61,911	82,816[b]	322,610	298,439

[a] Species harvest based on number of fish kept for each species modified by 70% for non-resident contributors. NB: If non-resident non-contributor component was included, combined with Hough, Stansbury and Michalski's (1981) 50% mortality factor for fish released, an over-harvest would be apparent for northern pike leaving 1982 northern pike residual at -28,634 kg.

[b] Species break-down of future harvest allocation based on % species harvested in 1979; 82,816 = (41,408 angler-days x 2 kg/angler day) as per West Patricia Land Use Plan (WPLUP) targets.

As management strategies intend to transform non-resident non-contributors into future contributors to the local and regional economy, these two components of the non-resident angler group are expected to coalesce during the fisheries management planning period. Therefore, allocation to non-resident anglers to the year 2000 is based on the projected demand level (41,408 angler-days-Section 5.2.1.1) times the target angler satisfaction level of 2 kg per angler day (Table 6.4).

Final allocation of Lac Seul fish stocks goes to the commercial fishery. Table 6.5 illustrates the allocation of residual harvest to the commercial fishery after the needs of domestic and sport fishery user groups have been satisfied. Present allocation is based on average harvests from 1976 - 1981, within existing quotas, as outlined in Section 5.2.2.1. Future allocation is based on the WPLUP (OMNR, 1982) target of maintaining existing quotas for species on quota (9,092 kg walleye, 52,935 kg whitefish) and average harvest (1976-1981) for species not on quota (i.e. 46,680 kg). Therefore, the total harvest target projected for the commercial fishery is 108,706 kg.

Table 6.5: Commercial Fishery Allocation of Lac Seul Fish Resources, Present (1981) and Future (2000). All values in kg.

	Residual MEI Allowable		Estimated Harvest & Allocation (Average 1976-1981)[a]	Allocation 2000[b]	Residual Harvest Available	
	1982	2000			1982	2000
Walleye	56,589	51,998	6,698	9,092	49,891	42,906
Northern Pike	28,519	19,616	0	0	28,519	19,616
Whitefish	93,248	93,248	50,543	52,935	42,705	40,313
All species	322,610	298,439	104,393	108,706	218,217	189,733

[a] Data from Table 5.4

[b] Based on WPLUP target - to maintain present quotas.

A final summary of present and future allocation of fish stocks to the Lac Seul user groups is provided in Appendix 6.3 and 6.4.

6.5 Concluding Comments

Although both present and future "residual harvest available" values indicate a surplus of fish resources remaining following allocation, it is important to note the following:

1. In order to achieve the projected harvest target for resident sportfishermen (Table 6.3), current harvest levels by this group must be reduced by 63 percent. It appears, in the case of Lac Seul, that allocation rationale for resident sportfishermen is in conflict with the prime allocational priority of maintaining fishery resources to the benefit of Ontario residents. Thus, it may be in order to re-evaluate the angler satisfaction level of 2 kg per angler-day or at least acknowledge that resident anglers will have to adjust their expectations of sportfish harvest during the planning period.

2. Non-resident sportfish allocation (present) is indicated for non-resident contributors only. An additional 30% of the present harvest is harvested by non-resident non-contributors.

3. The amount of illegal fish harvest is unknown.

Although the residual harvest appears to indicate ample available fish stocks, it is important to consider that these residual stocks will be necessary to absorb the above externalities during the implementational transition from present to future management planning strategies. In light of these considerations, fisheries managers are cautioned against any initiatives intended to redirect excess angling demand from more southerly, heavily exploited districts within Northwestern Region, to Lac Seul.

The economic contributions that the Lac Seul fishery provides to the local and regional economies of northwestern Ontario are directly attributable to the quality of that fishery. It has been the intent of this report to provide fishery managers with strategies to maintain a quality fishery while reconciling the demands for fish and fishing opportunities with the available supply of Lac Seul fish stocks. Fishery managers are challenged to implement these management strategies, as they see fit, with a sound sensitivity to the vagaries of the resource, and with the flexibility to acknowledge environmental changes and changes in societal demand. Acceptance of this challenge will ensure that economic contributions and quality of the Lac Seul fishery will be maintained.

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APPENDICES

APPENDIX 2.1

Annotated Bibliography, Water Level Fluctuations

INTRODUCTION

This annotated bibliography was compiled to supplement the development of a fisheries management plan for Lac Seul, northwestern Ontario. Lac Seul is a large, irregular, crescent-shaped reservoir approximately 190 km long with a surface area of 1,437 km^2. Water levels in Lac Seul are controlled by a hydro dam at the extreme west end of the lake at the town of Ear Falls, Ontario. The fish community of Lac Seul contains three fish species of major commercial value: walleye, northern pike and lake whitefish. Concern has been expressed over changes in the abundance of northern pike and walleye populations as a result of water-level fluctuations. However, little data has yet been compiled relating water-level fluctuations in Lac Seul to direct and/or indirect impacts on the inhabiting fish species.

This document will serve as a useful collation of studies in which the effects of water level manipulation on fisheries are described. The annotated bibliography will be organized under the following areas of concern:

I - Regulation, Economic Effects and Interagency Cooperation
II - Environmental Impact
III - Habitat Effects
IV - Reservoir Management Practices
V - Fisheries Productivity in Reservoirs
VI - Life Histories

In addition to the perusal of journals (e.g. J. Fish. Aquat. Sci., Trans. Am. Fish. Soc.) held in the libraries of the University of Manitoba, Manitoba Department of Natural Resources and Freshwater Institute DFO, references were acquired through the mail from agencies in Ohio, Ontario, Manitoba and Missouri. The American Fisheries Society main office in Bethesda, Maryland provided a number of references as well.

I. REGULATION, ECONOMIC EFFECTS AND INTER-AGENCY COOPERATION

1.1 Allen, G.W. 1970. Pool fluctuations in Corps impoundments in relation to fish spawning. Proc. Annu. Conf. Southeast Assoc. Game Fish Comm. 23:553-558.

This paper provides a useful example of interagency cooperation in the regulation of water levels for a variety of purposes. Each spring and early summer the Corps of Engineers and the associated conservation agencies of the various states work together to program and operate the Corps reservoir levels so that a minimal alteration of environment will occur during the spawning period of game fish in these reservoirs. The demands of flood control, navigation, hydro-electric power and fisheries resources must be coordinated to produce a condition in which these varied interests are working together to produce the required results to the benefit of all. Communications between all involved agencies during the time of gamefish spawning and notification of operational procedures is the major contribution to failure or success at this time. In spite of coordinated efforts, this reservoir level manipulation has not been proven to have either a beneficial or detrimental effect on the fisheries resources. In areas where such activities have taken place desirable fish populations have continued to increase, and maintain high populations. This correlation between the fish populations and intensive water level management is such however, that it will be continued until proven to have no effect.

1.2 Doan, K.H. 1979. Commercial catch of the fishery at Cedar Lake, Manitoba, before and after the Grand Rapids hydro-electric project. Man. Dept. Mines, Nat. Res. and Envir., Fish Mgt. Branch. MS Report No. 79-48.

This report documents beneficial socio-economic changes and improvement in fish quantities as a result of the implementation of a hydro-electric generator at Grand Rapids, Manitoba. Relocation of an isolated fishing community was undertaken in advance of elevated water levels at Cedar Lake associated with hydro generation at Grand Rapids. The fishery has marketed three times as much fish since flooding than in an equivalent previous period, andhas yielded $1.3 million more to the people of Easterville than when they formerly lived at Chemahawin. The improved fishing has attracted an average of 19 more fishermen in summer and 32 more winter fishermen. A fisherman who fished both seasons average 3 times the fishing gross income annually after the reservoir became operational than before. The fishery has also benefitted from better transporation and increased fish prices.

Before impoundment, some predictions were made about changes in fish stocks and yield that might be expected after flooding. A doubling of total yield and short term increases in catches in pickerel, pike and goldeye were correctly forecast, as was the subsequent decline of goldeye. Reduction of whitefish did not occur, nor did pickerel and pike decline in the intermediate run.

1.3 MacLaren, J. F. Ltd. 1978. Report to Manitoba Hydro on changes in quality of whitefish fishery on Southern Indian Lake. J.F. MacLaren Consulting Engineers, Planners and Scientists, 435 McNicholl Avenue, Willowdale, Ontario, M2H 2R8. 16 pp.

This report provides an insight into the possible effects that changes in water levels, brought about by the development of hydro-electric power, may have had on the whitefish fishery of South Indian Lake, Manitoba. It was concluded that the water quality of this lake has indeed been affected by changes in water levels, which may have disrupted the integrity of the fishery. As a result of shoreline restructuring, attendant increases in sedimentation may have affected spawning success. Further, the spawning movements of adults may have been confused by the changes in water quality. These changes in whitefish quality have negative economic impacts in terms of marketing and net returns to the fishermen.

1.4 Munro, D. A. and P. A. Larkin. 1950. The effects of changes to natural water levels and water courses on wildlife. Trans. Third British Columbia, Nat. Res. Conf. p. 267-272.

The fundamental effects of water level changes are reviewed in general terms. Some of the items include: the area and depth of a lake are primary factors in determining its relative productivity. In general, bigger areas and greater depths are associated with lower productivity. There is an optimum size for a lake, insofar as the production of any species of fish such as trout is concerned. Flooding may produce more shoals than previously existed. The immediate effect of a large rise in water level is the virtual elimination of a large number of fur-bearing animals. Lowering of lake levels in late winter may strand semi-aquatic mammals between ice and water. The development of a good littoral zone is essential to the production of fish. Authors stress the need for early liaison and consultation between the various agencies concerned in order to facilitate compromises between original water development proposals and wildlife needs.

1.5 Nelson, R. W., G. C. Horak, and J. E. Olson. 1978. Western Reservoir and Stream Habitat Improvements Handbook. Biological Services Program FWS/OBS-78/56, p. 250.

The handbook is a guide for selecting more effective measures to recommend and negotiate among administrators, biologists and engineers of fish and game and construction agencies. The guide is based primarily on measures shown to be effective in the past at a representative selection of 90 dam and reservoir projects in 19 western states. It presents measures believed to be potentially effective by investigators involved in current research, or authors of recent literature. The measures considered generally involved structural and operational features as well as direct habitat modification and population control. Various aspects of water level fluctuations are evaluated and discussed.

1.6 Neth, P. C. 1978. An analysis of the International Champlain-Richilieu Board proposal to water level regulation in Lake Champlain. N.Y. State Dept. Envir. Cons. p. 1-62.

A review of documentation supporting the International Champlain-Richilieu Board's recommendations and criteria for water level regulation in Lake Champlain was completed. The review yielded a number of conclusions concerning the expected impacts of regulation on fish, wildlife and wetland resources and the suitability of support studies. Losses of grass and sedge meadows of up to 100 percent would adversely affect northern pike spawning to a considerable degree. Short-comings of the Board's recommendations and criteria are noted, in particular, the failure to assign dollar values to wetland losses in the benefit/cost analysis. The literature cited section is a valuable guide to a complex legal, institutional, biological resource-use problem.

(see also 4.3)

II. ENVIRONMENTAL IMPACT

2.1 Duthie, H. C. and M. L. Ostrofsky. 1975. Environmental impact of the Churchill Falls (Labrador) hydro-electric project: A preliminary assessment. J. Fish. Res. Board Can. 32:117-125.

The Churchill Falls hydro-electric project in western Labrador involved the creation of reservoirs totalling 6,500 km^2 in area. Flooding began in 1971 and full pond was expected in 1974. A study of the impact of flooding on water quality and biology was begun before damming and will be continued after impoundment. Preliminary findings show little evidence for humification or oxygen deficiency even in newly flooded areas, but conductivity and many dissolved ions have increased and changed qualitatively since impoundment, particularly in shallow water. The primary productivity of the phytoplankton has increased significantly in flooded areas. The ecological impact on the Naskaupi River of the loss of its headwaters is being investigated.

2.2 Estes, R. D. 1972. Ecological impact of fluctuating water levels in reservoirs. Ecological Impact of Water Resources Development, Bureau of Reclamation Rept. REC-ERC-72-17, p. 7-9.

This article is a summary of some of the literature concerning fluctuating water levels in reservoirs. The importance of the littoral zone in terms of spawning, protection and food for young fish, higher aquatic plants as substrate for other plants and animals, and as a site for nutrient exchange between land and water is stressed.

2.3 Gaboury, M. N. and J. W. Potalas. 1982. The fisheries of Cross, Pipestone and Walker Lakes, and effects of hydro-electric development. Man. Dept. Nat. Res. MS Dept. No. 82-14, 198 pp.

A very good document assessing the fish stocks of Cross, Pipestone and Walker Lakes and describing impacts of the current water level regime, as regulated by the Jenpeg hydro-electric impoundment. Under regulation, water level drawdown has contributed to a decrease in the absolute abundances of Cross and Pipestone lakes fish by causing a winterkill in March 1981, and by detrimentally affecting coregonid hatching success and recruitment, apparently through a de-watering of their spawning areas and dessication of eggs. Low spring water levels have prevented walleye and pike access to their spawning areas, while low summer levels have reduced the available habitat for plankton, benthos and fish. Walker Lake fish stocks do not appear to be impacted by Jenpeg regulation. Changes to the commercial quotas on Cross and Pipestone lakes are recommended. A minimum Cross Lake stage of 206.5 m is recommended if the outlet control structure is constructed and an interim water level regulation scheme is proposed.

2.4 Jenkins, R. M. 1969. The influence of engineering design and operation and other environmental factors on reservoir fishery resources. Water Res. Bull. 6 (1):110-119.

The apparent effect of selected reservoir environmental variables - including surface area, mean depth, outlet depth, thermodine depth, water level fluctuation, storage ratio, shoreline development, total dissolved solids, growing season and age of reservoir - on fish standing crop in 140 large impoundments has been explored through partial correlation and multiple regression analyses. At the species level partial correlation revealed a negative effect of water level fluctuation on pike and pickerel, redear sunfish and gizzard shad.

III. HABITAT EFFECTS

3.1 Benson, N. G. 1980. Effects of post-impoundment shore modifications on fish populations in Missouri River reservoirs. U.S. Dept. of Interior Fish and Wildlife Serv., Res. Rep 80. Wash., D.C. 32 pp.

Bensons' report provides a useful demonstration of how hydrodynamic processes in reservoirs have influenced fish abundance and species composition by affecting the quality and quantity of suitable habitat available for spawning and nursery activity. In the Missouri mainstem reservoirs in Montana, North Dakota, and South Dakota, hydrodynamic processes have decreased the lengths of shorelines and changed their configuration during the first 20 to 25 years of impoundment. Banks slumped, embayments filled, and stumps and debris were covered by sediment. Glacial till tended to armor the shorelines and deter their degradation in all reservoirs. Water level fluctuation retarded the development of stable shores. Some aquatic vegetation developed along shorelines and in shallow sections of reservoirs in which water levels fluctuated little. Substrate suitable for terrestrial vegetation did not develop along the shores of fluctuating reservoirs, except where alluvial deposits were present. Physical changes of the shore probably influenced fish abundance and species composition primarily by changing the quality and quantity of spawning and nursery habitat. Species that appeared to be adversely affected by shore changes required protected embayments or flooded vegetation for reproduction. These included yellow perch (Perca flavescens), northern pike (Esox lucius) and some members of the Catostomid and Cyprinid families. Fish that spawn in tributaries or along rocky shores were not greatly influenced by shore changes (although the growth rate of several species was slowed) e.g. sauger (Stizostedion canadense) and goldeye (Hiodon alosoides). One species, the walleye (Stizostedion vitreum) appeared to be benefitted by the shore changes. Physical changes along shores have not been adequately addressed in reservoir ecological planning. Fish population data collected before reservoir shores have reached a reasonable degree of stability do not provide a reliable estimate of the ultimate species composition of a reservoir.

3.2 Hunt, P. C. and J. W. Jones. 1972. The effect of water level fluctuations on a littoral fauna. J. Fish. Biol. 4:385-394.

The littoral fauna of Llyn Tegid, North Wales, in 1968-69 is compared with the results of similar faunal investigations in 1951-52 and 1957 and 1959. The results show the long term effects upon the littoral fauna of the change in mean water level and the increased water level fluctuations produced by the controlled outflow scheme, which was first implemented in 1951. In 1961, Hynes reported large reductions in the numbers and varieties of littoral fauna as compared to pre-impoundment conditions. The reduced water level fluctuations since 1965 have resulted in re-establishment of some of the fauna. Crustaceans such as Grammarus pulex and Assellus meridianus, are perhaps the most sensitive of invertebrates to increased water level fluctuation and their re-establishment is indicative of the decreased fluctuation.

3.3 Murphy, G. I. 1962. The effect of mixing depth and turbidity on the lake productivity of freshwater impoundments. Trans. Am. Fish. Soc. 91: p. 69-76.

Mixing depth and turbidity negatively affect the productivity of an aquatic environment through the control they exert on the effective energy available for photosynthesis. A feedback equation is developed that defines the interaction of these two quantities with the production by phytoplankton. Calculated relative production corresponded very well with observed production for a series of 33 small shallow ponds. The possibility is advanced that the same principles apply to reservoirs when thermocline depth can be regarded as mixing depth. Further, it is suggested that the productivity of reservoirs might be increased by reducing the depth of the mixed layer by withdrawing from the surface. In addition, this practice might enhance production by mixing deeper water, richer in nutrients, into the trophogenic zone during the productive season.

IV. RESERVOIR MANAGEMENT PRACTICES

4.1 Benson, N. G. 1968. Some effects of water management on biological production in Missouri River mainstem reservoirs. Presented at Am. Soc. Civil Engineers Specialty Conf., Jan. 1968, Portland, Oregon; mimeo, p. 1-17.

This paper is a general review of some of the information gathered in a study of the relationships between reservoir environments and fish growth, mortality, abundance and reproduction in Missouri River mainstem impoundments. The water management practices considered to be factors affecting reservoir biota are water level fluctuation, water exchange rate, and depth and timing of discharges from powerhouses. The data discussed were collected on Oahe reservoir, Lake Francis Case, and Lewis and Clark Lake.

4.2 Benson, N. G. 1973. Evaluating the effects of discharge rates, water levels and peaking on fish populations in Missouri River mainstem impoundments. Man-made Lakes: their problems and environmental effects. Geographical Monograph Series 17:683-689.

This paper reviews effects of water level fluctuations on fish populations in Missouri River impoundments and describes a preliminary model to predict effects of water management. Declining water levels will affect reproductive success of a variety of species of fish which spawn between April 1 and July 1. Periphyton develops on submerged plant stems in 25 days following inundation, and insect populations develop in 40 days. If these fish food organisms develop late, not only is there loss of total fish food production, but it will not be there early when the demand is high. Those species that are less influenced by water levels during this same spawning period have had more consistent reproduction. Walleye spawn at depths below the effects of water level fluctuation.

4.3 Benson, N. G. 1976. Water management and fish production in Missouri River mainstem reservoirs. in J. F. Osborn, C. H. Alman, eds., Instream flow needs. Amer. Fish. Soc. 2:141-147.

The Missouri River reservoirs are managed by the U.S. Army Corps of Engineers primarily for flood control, power production and navigation, but there is enough flexibility in water management during some years to modify water levels or peaking schedules to benefit fish. Recommendations to enhance fish production are developed through a committee of state and federal fishery biologists in consultation with the reservoir control center, Corps of Engineers. The primary biological information needs for each major fish species are habitat types required for reproduction and spawning time and temperature. Modification of water levels and peaking schedules has been shown to benefit northern pike, sauger, walleye, yellow perch, white crappie, and bigmouth buffalo. Factors affecting development of terrestrial vegetation around reservoir shorelines are discussed. Water levels should be dropped after 1 July to develop vegetation on the shoreline for the following year.

4.4 Culver, D. A., J. R. Triplett, and G. B. Watesfield. 1980. The evaluation of reservoir water-level manipulation as a fisheries management tool in Ohio. Ohio DNR, Div. of Wildlife, Federal Aid in Fish Restoration Project, F-57-R, Study-8.

The dual problems of high fishing pressure and the predictable decline of fishing success associated with the aging of reservoirs currently confront the fishery manager in Ohio. It has been proposed that water level fluctuation (drawdowns and subsequent reflooding) can do much in an older lake to restoring the fishery to a higher productive level. This fisheries management technique attempts to revert the lake to an earlier sere of succession when the fish populations were expanding into new habitat. As part of the study an exhaustive literature review and annotated bibliography was compiled. Fishery administrators were interviewed throughout the northeastern U.S. to ascertain current use of water level manipulation in the region. Using all this information the authors generated a list of important studies that might be performed in Ohio to assess the utility of water level manipulation there.

4.5 Goddard, J. A. and L. C. Redmond. 1978. Northern Pike, Tiger Muskell unge and walleye populations in Stockton Lake, Missouri: A Management Evaluation. Am. Fish. Soc. Spec. Publ. 11, p. 313-319.

A three stage filling of 10,072 ha. Stockton Lake coupled with spring releases of walleye and northern pike fry and fingerlings into the flooded terrestrial vegetation in 1970, 1971 and 1972 resulted in good survival, exceptional growth and a quality fishery. The success of survival and growth of the stocked fry of both species appeared to be due to the abundance of flooded terrestrial vegetation in the three succeeding spring periods. This three-stage filling of the basin provided a fertile environment as the flooded plants slowly decayed. Zooplankton was plentiful. Small forage fishes were abundant every year throughout the growing season.

4.6 Hulsey, A. H. 1958. A proposal for the management of reservoirs for fisheries. Proc. Ann. Conf. Southeast Assoc. Game Fish Comm., 122:132-143.

A fisheries management plan for reservoirs is proposed which is dependent upon having a fish management pool and provision for drainage incorporated into the basic design. Justification is given to support the cost of having a cleared management pool in the bottom of the reservoir as well as drainage facilities. The use of a fall and winter drawdown is advantageous to an overall fisheries management plan in many ways. The lake should be full of water during spring spawning and summer growing seasons. In the arly fall the water level is lowered and fish concentrated. The predator fish will eat most of the small forage fishes. As a result, the predator fishes should grow faster, coincident with the thinning of panfish. When the reservoir refills in the spring, a successful spawning of bass and crappie usually occurs because the small fishes that prey on their eggs and young have been drastically reduced in numbers. In addition, bottom mucks are exposed during drawdown and mineralization of the organic matter proceeds rapidly. Clean-up and maintenance operations can be carried out best following drawdown. Angling may be excellent during and following drawdown. Specific examples of the benefits of drawdown are given.

4.7 Jenkins, R. M. 1970. Large reservoirs - management possibilities. Proc. Ann. Midwest Fish and Game Comm. 36:82-89.

The major possibilities for improvement in mid-western reservoir fish management include: angling regulation changes based on better knowledge of population dynamics factors such as production and mortality rates; introduction of suitable species in warmwater reservoirs with an oxygenated hypolimnion; extreme drawdown or dewatering of suitable flood control and recreational reservoirs followed by planting the exposed bottom, refilling and reintroduction of desired species; controlled water level fluctuation and improved substrate to enhance spawning and survival of pike, bass, and crappie; improved designs for timber clearing, brush shelters, piers and floating fishing docks; pollution control; improved access and zoning for undisturbed angling.

4.8 Jenkins. R. M. 1970. Reservoir fish management in N. G. Benson, ed., A Century of Fisheries in North America, Spec. Publ. No. 7, Amer. Fish. Soc., p. 178-182.

The history and extent of reservoirs in North America is discussed. Management accomplishments through techniques such as stocking, harvest regulations, drawdown and rough fish control are reviewed. Management needs are listed. It is suggested that short periods (2-3 months) of drawdown rarely have measurable effects. Soundly conceived, water level fluctuation is potentially the most effective management tool for the reservoir biologist.

4.9 Walburg, C. H. 1976. Changes in the fish population of Lewis and Clark Lake, 1956-1974, and their relation to water management and the environment. U.S. Fish and Wildlife Serv. Res. Rep. 79, p. 1-34.

Annual sampling of the reservoir fish population of Lewis and Clark Lake on 11,300 ha mainstem Missouri River reservoir, in 1956-74 indicated that fish abundance decreased about 66% and the number of species about 20% between 1956, the first year of impoundment, and the early 1970's. Poor fish reproduction and decreasing recruitment to adult stocks were caused by the water management regime and related shoreline modification. Low and fluctuating water levels during May and June were detrimental to fish spawning and survival of young. If this schedule of water management continues the lake will be dominated by species that do not depend on reservoir shore areas for reproduction. Due to a high water exchange time (4 or 5 days in 1969-72) large numbers of young-of-the-year are lost from the reservoir in the discharge. This loss of young not only decreased the potential abundance of adults of this species, but also had a detrimental effect on the growth and survival of predator species for which they served as prey. Management alternatives are considered too costly or inconsistent with the primary flood-control function of the reservoir.

V. FISHERIES PRODUCTIVITY IN RESERVOIRS

5.1 Aggus, L. R. and S. A. Lewis. 1978. Environmental conditions and standing crops of fishes in predator stocking evaluation reservoirs. Proc. Ann. Conf. Southeast. Assoc. Game Fish Comm. 30:131-140.

The authors examined the relationship between fish standing crops and two environmental variables in reservoirs. Of the two environmental variables tested, storage ratio, outflow volume, growing season and dissolved solids were consistently related to fish standing crop components. Except for growing season, these variables were influenced by high 1973 inflows. Although responses of fish crops to increased water levels were generally positive, they were highly variable and could not be quantified. Six of eight reservoirs with much higher water levels in spring and early summer 1973 showed marked increases in both total and small fish standing crop. Storage reservoirs generally experienced increased fish standing crops associated with increased flow-through, whereas mainstream impoundments generally produced slightly diminshed standing crops. The authors conclude that, overall, the highly variable responses of fish populations in different reservoirs to environmental change reflect the importance of variables not measured in this analysis.

5.2 Bodaly, R. A., T. W. Johnson and R. J. Fudge. 1980. Post-impoundment changes in commercial fishing patterns and catch of lake whitefish (Coregonus clupeaformis) in Southern Indian Lake, Manitoba. Can. MS Rep. Fish. Aquat. Sci. 1555:iv + 14 pp.

Prior to flooding, the commercial lake whitefish catch from South Indian Lake was composed almost totally of light coloured, export or Grade A fish. Following flooding, dark coloured lake whitefish have made up 12-72% of the catch. (Dark coloured lake whitefish are graded as continental or B grade fish on the basis of darker external colouration and higher average Triaenophorus crassus cysts counts). The authors hypothesize that these fish are entering the commercial catch because of a major shift in the geographical location of the majority of fishing effort, as a result of decreased catches in traditional fishing areas. They suggest that the decreased catches may be due to changes in fish movement brought about by decreased light penetration resulting from higher post-impoundment turbidity levels from extensive shore erosion.

5.3 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.

Trend-through-time information on annual commercial harvests of walleye from Rainy Lake in northwestern Ontario is examined in this article. Annual commercial harvests of walleye steadily declined from the 1920's to the early 1970's; total (all species harvests) over the period 1924-1975 averaged 45% greater than the MEI allowable harvest. Spring water levels and broad stock abundance were identified as significant factors in determining walleye abundance 5 years later; these same two variables accounted for 65% of the variation in commercial walleye catch-per-unit-effort.

5.4 Cooper, G. P. 1966. Fish production in impoundments. Michigan Dept. Cons. Research and Development. Rept. No. 104:1-21.

This is a review of general information on fish production in impoundments in temperate North America. The authors conclude that productivity in impoundments depends on: nutrients in inflow waters, nutrients from reservoir basin soils, rate of volume displacement in the reservoir, and character of the dominant plant-animal food chain. Reservoirs lose their initial high fertility in 5 to 10, or even up to 25 years as nutrients are locked up in bottom deposits, lost to outflow, or to fish harvest. The authors suggest that periodic drawdown and/or aeration of basin sediments in order to manage impoundments for fish, particularly sport fish, production.

5.5 Crooks, S. 1972. Water level fluctuations and yellow pickerel, northern pike and lake whitefish in Lake Seul. Ont. Min. Nat. Res., Sioux Lookout Dist. Off.

The flooding history of Lac Seul and water level fluctuation regulations are discussed as they pertain to commercially valuable fish species within the lake: walleye, northern pike and whitefish. The study was undertaken to determine whether yearly water level variations were indeed affecting purported decreases in the abundance of sport and commercial fish stocks. Crooks maintains that the declining trends observed since 1942 is consistent with classical population trends exhibited by fish species in reservoirs (as described by Ellis, 1942). He concludes, based on year-class strength and growth rate studies, that Lac Seul walleye and northern pike populations have since stabilized.

5.6 Derksen, A. J. 1967. Variations in abundance of walleyes, Stizostedion vitreum vitreum (Mitchell), in Cedar and Moose Lakes, Manitoba. M.Sc. Thesis, Univ. of Manitoba, Winnipeg.

Data from experimental gill-netting and sampling of commercial fish catches from Cedar and Moose Lakes, Manitoba, were used to determine estimates of relative strength of year classes in both populations. These estimates were correlated with annual fluctuations in walleye catches of the commercial fisheries six years after hatching; year class strengths for both lakes, were positively correlated with spring (April-June) discharges from the Saskatchewan River during the first year of life of the year classes. The author speculates that water levels may affect year class strength through a number of mechanisms, including: availability of spawning areas, changes in survival of young due to changes in competition, changes in temperature regimes and changes in production of zooplankton (i.e., food for larval walleye).

5.7 Ellis, M. M. 1941. Fresh-water impoundments. Trans. Am. Fish. Soc. 71:80-93.

Ellis discusses fresh-water impoundments from the viewpoint of the physical characteristics of impoundments, physical and chemical characteristics of impounded waters, biological productivity, pollution hazards and effects of the impoundment on the parent stream. Ellis identifies several characteristics of impoundments, including extensive fluctuation of water level, which can limit biological productivity (and hence fish production). In addition, the author suggests such methods as maintenance of water level (through controlling the draw-off) during nesting season of certain species, re-stocking and the construction of certain structures to enhance habitat as means of offsetting limitations on fish productivity.

5.8 Hanna, E. J. and M. F. P. Michalski. 1982. Fisheries productivity and water level fluctuations in Lac Seul, Northwestern Ontario. Hough, Stansbury & Michalski Limited/J. E. Hanna Associates Inc. Unpublished MS prepared for Ont. Min. Nat. Res., Sioux Lookout, Ontario. 42 pp.

Since 1935, the outlet from Lac Seul has been regulated for power production. Beginning in 1958, annual water levels have varied by as much as 3.7 m. Hanna and Michalski conducted correlations betwen water level fluctuations and fisheries productivity. Two factors were identified to account for the major trends in fish yield. First, after the original flooding in 1934, a classical increase in total harvest was recorded, attributed to the release of soil nutrients and resultant elevation in primary and secondary production. Second, with spawning occurring either during water draw-downs or at the period of lowest lake level, recruitment can be negatively and/or reduced spawning and nursery habitat. Correlations demonstrated a relationship between changes in water levels and reduced commercial fishery yields.

A comparison of measured and predicted yield based on 1979 harvest data and Ryder's morphoedaphic index indicated that catches have been less than or slightly greater than Lac Seul's predicted annual sustainable yield. This, coupled with information on the biological health of the fishery, indicating a stable community, suggests that the morphoedaphic index is not overestimating the sustainable yield and may be underestimating it for the Lac Seul reservoir.

5.9 Henderson, H. F., R. A. Ryder, and A. W. Kudhongania. 1973. Assessing fishery potentials of lakes and reservoirs. J. Fish. Res. Board Can. 30:2000-2009.

Timeliness in estimating fishery potentials seems more important than precision, at least in the earlier periods of development of specific fisheries. Comparative studies of several sets of lakes, particularly of those supporting developing fisheries in Africa, suggest that potential yield may be related to several simple indices of production. The morphoedaphic index, derived from measures of total dissolved solids and the mean depth, has provided the simplest and most general approach to the problem of initial estimates of potential yield in lakes and reservoirs. Other methods of relating yield to nutrient concentration and primary production reinforce the concept of dependence of potential yield on lake productivity. Programs of monitoring relative abundance of stocks over time have been useful, both in indicating the approach of actual yield to potential yield and, after "calibration" against actual yields, as indices of stock and total biomasses.

5.10 Il'Ina, L. K. and N. A. Gordeyev. 1972. Water-level regime and the spawning of fish stocks in reservoirs. J. Icthyol. 12(3):373-381.

The possibility of integrating the interests of the fishing industry and of other water users such as agriculture and hydro-electric power generation is considered on the basis of an analysis of the spawning conditions of the phytophilous fish in the existing lowland reservoirs. Recommendations are made concerning the regulation of water-level regime in reservoirs of different types in relation to their position in the chain of reservoirs and to the stage of formation. The concept of implementing a summer drawdown to facilitate development of terrestrial vegetation in the littoral zone early in a lake's lifetime, before severe erosion has occurred is stressed. A winter drawdown is recommended to evacuate young into deeper water, reduce winterkill by emptying shallows containing humic material, and prevent the destruction of the vegetation by ice during the spring flood period. The literature cited section of this paper is a good representation of the Russian literature concerning the effect of water-level fluctuation on fisheries.

5.11 Jenkins, R. M. 1982. The morphoedaphic index and reservoir fish production. Trans. Am. Fish. Soc. 111:133-140.

The morphoedaphic index (MEI) developed by R. A. Ryder in the mid-1960's as an estimator of potential fish yield in lakes, can be used to predict both fish harvest and standing crop in U. S. reservoirs. The relation of reservoir sportfish harvest to the index is curvilinear, with maximum yields expected at index values of 50 to 100. Fish standing crops in 290 reservoirs was also significantly correlated with the MEI, maximum crops would be expected at values of 50 to 200. Predictive value was increased when the sample was divided into four subsets on the basis of the reservoir operational type and water chemistry. The MEI crop relationships were also curvilinear; predicted crops were highest in hydropower mainstream reservoirs and lowest in nonhydropower reservoirs where sulfate-chloride ions were dominant. Coefficients of determination in the subsets ranged from 0.47 to 0.72. The MEI should be of practical utility to reservoir managers who must make decisions on the basis of minimal field data.

5.12 Jenkins, R. M. and D. I. Morais. 1971. Reservoir sport fishing effort and harvest in relation to environmental variables. G. E. Hall, ed., Reservoir Fisheries and Limnology, Am. Fish. Soc. Spec. Pub. No. 8, p. 371-384.

Water level fluctuation was included as an environmental variable in an analysis of reservoir sport fishing effort and harvest. Little effect was found, probably because only mean annual vertical fluctuation was considered rather than timing or duration of fluctuation. The effects of other variables -- area, mean depth, outlet depth, thermodine depth, storage ratio, shore development, total dissolved solids, growing season, and age of impoundment were also considered.

5.13 Johnson, F. H., R. D. Thomasson, and B. Caldwell. 1966. Status of the Rainy Lake walleye fishery, 1965. Minn. Dept. Conserv. Div. Game Fish, Sec. Res. Plann. Invest. Rep. 292, p. 1-22.

In 1965 the walleye population of Rainy Lake was considerably below that of 1959. A positive correlation of 0.81 was found between mean water levels during the walleye spawning period and the commercial catch per 1000 feet of net 4, 5 and 6 years later suggesting strongly that spring water levels have had an important influence on year-class abundance. The lake-wide decrease in walleye stocks has followed three consecutive years (1958, 1959, 1960) of low spring water levels and poor reproduction accompanied by competition between the sport and commercial fisheries for the available stock. It is advised that in the future that every effort be made to assure adequate spring water levels so that the best spawning shoals available can be used by the walleyes.

5.14 Jones, J. R. and M. V. Hoyer. 1982. Sportfish harvest predicted by summer chlorophyll-a concentration in mid-western lakes and reservoirs. Trans. Am. Fish. Soc. 111:176-179.

An index based on the relationship between angler harvest and mean summer phytoplankton standing crop (chlorophyll-a) is a basis for estimating the annual yield of sportfishes in mid-western lakes and reservoirs. The relationship is stronger than that between fish yield and total phosphorus, alkalinity, or the morphoedaphic index.

5.15 Ryder, R. A. 1978. Fish yield assessment of large lakes and reservoirs - a prelude to management, pp. 403-423 in S. D. Gerking (ed.). Ecology of Freshwater Fish Production. Wiley and Sons, N.Y.

Emphasis is placed on the derivation of yield estimates for large lakes and reservoirs prior to the implementation of any management scheme. The proposed modus operandi of preliminary fish yield assessment is at the community level, rather than at the traditional species or population levels. Major constraints on freshwater production systems include climatic and edaphic conditions, the morphology of the lake or reservoir (primarily area, volume and mean depth, and flushing rate since it regulates both the degree and regime of nutrient loading. Flushing rate (or one of its correlates (eg. water level fluctuation, storage ratio) may be one of the major distinguishing features between large natural lakes and reservoirs. Several community and subsystem approaches to yield estimation in large lakes and reservoirs are discussed. They include the following: morphoedaphic index, particle size hypothesis, gillnet monitoring, a systems approach and the estimation of asymptotic yield elvels in reservoirs.

VI. LIFE HISTORIES: WALLEYE, NORTHERN PIKE, WHITEFISH

6.1 Beard, T. D. 1971. Impact of an overwinter drawdown on feeding activities of northern pike. Bureau of Research Report No. 4, Wisconsin Dept. of Nat. Res., 6 pp.

During an overwinter drawdown involving 3 consecutive years, feeding activities of northern pike incrased. The author believes that, with the predator-prey ratio that existed in the reservoir, it was very unlikely that any increased predation by northern pike - due to the drawdowns - would have had any noticeable impact on the panfish populations.

6.2 Franklin, D. R. and L. L. Smith (Jr.). 1963. Early life history of the northern pike, Esox lucius L., with special reference to the factors influencing the numerical strength of year classes. Trans. Amer. Fish. Soc. 92(2):91-110.

This study contributes to an understanding of the relationship of adult pike abundance to the strength of resulting year classes, the existence and chronology of critical survival periods, and the nature and origins of mortality mechanism involved. Results show that the greatest survival of naturally-reared fingerlings results from stabilization of water in the nursery areas. The authors conclude that water levels must be quickly attained and held at least until July 1, and preferably until August 1. The management techniques for maintaining spawning and nursery areas are described.

6.3 Hassler, T. J. 1969. Biology of the northern pike in Oahe Reservoir, 1959 through 1965. U.S. Bur. Sport Fish. Wildl. Tech. Paper 29, p. 1-13.

This article examines variations in length, weight and maturity of northern pike in a reservoir with sex and year class. Results show that females were larger and more numerous than amles, annulus formation began in April and was completed by July and some females matured at Age II which makes generally matured at Age I. Perhaps most importantly it was rated that, since impoundment large year classes have been associated with a rise in water level, above previous spring highs, and continuation of the high level through early summer.

6.4 Hassler, T. J. 1970. Environmental influences on early development and year-class strength of northern pike in Lakes Oahe and Sharpe, South Dakota. Trans. Amer. Fish. Soc. 99(2):369-375.

Survival of artificially fertilized ova and larvae of northern pike was estimated from embryos held in natural spawning areas in two reservoirs. Mortalities approached 100% during early embryonic development were associated with sudden drops in water temperature below 10°C on prolonged temperatures near 5°C. Silt deposition of 1.0 mm per day was associated with mortality of 97% or above. Following hatching, available food appeared to be a more important factor in survival than temperature change or silt deposition. The author suggests that large year classes were associated with stable to rising water levels and temperature, flooded vegetation and calm weather during the spawning season. Conversely, small year classes were associated with abrupt water temperature fluctuations, dropping water level and high silt deposits.

6.5 Johnson, F. H. 1957. Northern pike year-class strength and spring water levels. Trans. Amer. Fish. Soc. 86: 285-293.

In this article, the relatinships between spring water levels and the strength of year classes of northern pike in a reservoir in Minnesota are examined and compared for a period of seven years. The years are ranked according to water conditions, including height during spawning and fluctuation during egg incubation and according to the strength of year classes produced. The author concludes that a high spring water level during spawning and a small decline in the levels during egg incubation represeth good conditions for the production of a strong northern pike year class.

6.6 Johnson, F. H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Trans. Amer. Fish. Soc. 90(2):312-322.

The differential survival of walleye eggs on several bottom types was determined using natural spawning eggs. Egg survival on improved gravel-rubble bottom was high while survival on muck bottom was very low. In addition, abundance of eggs on sand bottom to which gravel and rubble had been added was more than 10 times that observed previously; survival of eggs on the improved bottom type increased five fold. One factor in determining egg survival was length of incubation period which was, in turn, determined by water temperature. Walleyes selected gravel bottom for spawning when it was available, and most eggs were deposited in water 12-30 inches deep. In years of low water level, numerous eggs were spawned on gravel inwater as shallow as 2 inches.

6.7 June, F. C. 1970. Atresia and year-class abundance of northern pike, Esox lucius, in two Missouri River impoundments. Jour. Fish. Res. Board Can. 27:587-591.

Atresia in northern pike ovaries (i.e. involution of a part of an ovarian follicle not destined to produce a functional ovum) was associated with low year-class abundance in these successive years in two large Missouri River impoundments. Atresia was associated with fluctuations in water temperature and level that apparently interrupted spawning.

6.8 June, F. C. 1976. Changes in young-of-the-year fish stocks during and after filling of Lake Oahe, an Upper Missouri River storage reservoir, 1966-1974. U.S. Fish and Wildl. Serv. Tech. Pap. 87, 25 pp.

This article documents the changes in species numbers and composition both during and after filling of a reservoir. In general, species numbers declined after the reservoir filled. Forage fishes, mostly those produced in littoral areas, determined the trends and levels of total fish abundance. Abundance of species produced in littoral areas was greater while the reservoir was filling - particularly when spring water levels covered vegetation, fluctuated little, and were maintained through May or longer. The yellow perch was the most abundant species in every year; its abundance increased during filling and decreased after. Growth rate of yellow perch increased after the reservoir had filled. Most significant was the author's assertion that reduction and generalized degradation of the littoral spawning and nursery habitats were probably responsible for the general decline in species numbers and abundance after filling. Finally, it is concluded that future prospects for most commercial species (primarily littoral spawners) are poor, whereas those for most sport species are good.

6.9 Machniak, K. 1975. The effects of hydro-electric development on the biology of northern fishes (Reproduction and Population Dynamics). I. Lake Whitefish, Coregonus clupeaformis. A Literature Review and Bibliography. Fish and Man. Serv. Tech. Rep. No. 527, DOE Canada. 67 pp.

The spawning and early life history of the lake whitefish is reviewed. Lake whitefish spawn at different depths in different lakes, although it appears that in shallow inland lakes they generally spawn in less than 5 m of water. Spawning substrata can be quite varied but in the main consists of boulders and coarse stones. The potential impact of reservoirs on whitefish spawning success are outlined. Among the hazards to reproduction in impoundments are: water level fluctuations, altered water quality (thermal, current and chemical), predation and erosion silt. Swedish and USSR studies point out areas of concern for the population dynamics of lake whitefish in impoundments. Factors which could influence the growth and numbers of the species are: food supply, competition, predation and parasitism. An excellent bibliography is provided.

6.10 Machniak, K. 1975. The effects of hydro-electric development on the biology of northern fishes. II. Northern Pike (Esox lucius). A. Literature Review and Bibliography. Fish. and Man. Serv. Tech. Rep. No. 528. DOE Canada, 82 pp.

This report is essentially a literature review providing quite good coverage of the European and Russian literature. Information on the reproduction and population biology of the northern pike is reviewed. Among the many hazards to successful spawning in both nature and reservoirs are: fluctuating water levels, cold weather, water quality, disease, predation, cannibalism and siltation. Terrestrial or dense aquatic vegetation are the most preferred substratum types; the depth of spawning usually being less than 50 cm. High water levels during spawning and a small decline during egg incubation, represent ideal conditions for the production of a strong year class. For this reason, reproduction of northern pike is highly favored during the initial filling period of an impoundment; after filling reproductive success fluctuates with water level regulation. Growth and numbers increase following impoundment but the ultimate supply of forage species regulate the production. Erosion and silt deposition is identified as a serious mortality factor to developing pike embryos. If silt depositions are accompanied by abrupt temperature or water level changes complete mortalities of an entire year class can occur.

6.11 Machniak, K. 1975. The effects of hydro-electric development on the biology of northern fishes (reproduction and population dynamics). III. Yellow Walleye, Stizostedion vitreum vitreum. A Literature review and bibliography. Fish. Mar. Serv. Res. Dev. Tech. Rep. 529, DOE Canada, 68 pp.

The reproduction and early life of the yellow walleye is reviewed. Walleye commonly spawn in riffles of streams or along shorelines of lakes. Although they have been reported to spawn on a wide variety of substrata it appears they prefer clean gravel bottoms at depths less than 1.5 metres. In impoundments, walleye are less influenced by water levels during the spawning period than other littoral spawners. Stable or slightly rising levels during spawning and incubation are recommended if spawning is to be successful. The silting over of spawning beds due to erosion is probably the major cause of spawning failure in impoundments. Growth and numbers could increase but will be dependent upon the availability of forage species and spawning habitat.

6.12 Nelson, W. R. 1968. Reproduction and early-life history of sauger, Stizostedion canadense, in Lewis and Clark Lake. Trans. Amer. Fish. Soc. 97:159-166.

Sauger reproduction and early life history were studied to determine factors affecting year-class strength. Sauger were found to spawn over a rubble substrate in the Missouri River below a dam. Details are given of optimum water temperature and depth for spawning and egg survival, and on larval and adult feeding regimes. Adult year-class strength was determined to be inversely related to water level fluctuations over the spawning grounds; year class strength is therefore determined before young-of-the-year enter the lake. Abundance of larval was 15 times greater when water levels fluctuated 2.67 ft/day than when water levels fluctuated 4.44 ft/day.

6.13 Nelson, W. R. and C. H. Walburg. 1977. Population dynamics of yellow perch (*Perca flavescens*), Sauger (*Stizostedion canadense*), and Walleye (*S. vitreum vitreum*) in four mainstream Missouri River reservoirs. J. Fish. Res. Board Can. 34:1748-1763.

In the 15-25 years four large reservoirs have been operational on the Missouri River in South Dakota, percid populations have generally increased in abundance relative to other groups of fishes. Saugers were initially the most abundant percid, but their numbers gradually declined, probably due to a reduction in river spawning habitat and an increase in water clarity. Yellow perch populations increased as the reservoirs filled but later declined. Walleye populations developed slowly, due to initial lack of suitable spawning habitat. Reproductive success was the primary factor regulating the abundance of percids. Above average precipitation presumably enhanced reproductive success, both through the increase of spawning substrate through higher stream flours and water levels and by providing a larger forage supply. The authors speculate that water level fluctuation can aid in removal of fine soil from potential walleye spawning areas.

6.14 Nelson, W. R. 1978. Implications of water management on Lake Oahe for the spawning success of coolwater fishes. Trans. Amer. Fish. Soc. Spec. Publ. 11, pp. 154-158.

The history of the impoundment of Lake Oahe is reviewed, especially pertaining to the effects of fish populations. Initially, northern pike and yellow perch were favoured as inundation provided ideal spawning habitat (.e. submerged vegetation). Later, water fluctuations within a narrow range and wave action have reduced the amount of this habitat and these 2 species have declined in abundance. Sauger and walleye deposit their eggs over gravel or rubble, and therefore spawn in tributary rivers rather than the reservoir. Diversions of water for human use will reduce both the inflows and the lake level, thereby affecting both riverine and reservoir spawning habitats. The author concludes that in order to maintain present fish populations, minimum spring stream flows must be assured and critical reservoir spawning areas protected and even artificially enhanced.

Appendix 5.1: Determination of sportfish target by species, using Hough et al., (1981) data.

Assumption: The ratio of fish caught is directly proportional to angler-days required to catch those fish.

Species	Fish Caught[a] (Numbers)	% of Total Catch	Angler-days (May-September)
Walleye	10,519.5	72	25,704
Northern Pike	3,880	26	9,284
Other	296	2	714
Total	14,695.5	100	35,700[b]

[a] Table 6.14, Hough et al., (1981)

[b] Table 9.10, Hough et al., (1981)

APPENDIX 6.1: GROUPING OF MANAGEMENT TACTICS[1]; TACTICS ARE NUMBERED AS THEY OCCUR IN CHAPTER V.

A. NEW MANAGEMENT TACTICS

Sport Fishery

Tactic 1: Decrease non-resident angler possession limit for northern pike from 6 to 3. New limit of 3 northern pike will further be restricted to include only 1 northern pike at trophy size.

Tactic 2: Encourage a redirection of non-resident northern pike angling effort to waters in the vicinity of Lac Seul capable of sustaining additional angling pressure for Northern Pike. This strategy may be employed under varying degrees of scale, e.g., restrictive zoning of basins incurring marked angling pressure or restrictions could be placed specifically on non-resident angler use of these basins (Neville Ward, pers. comm. February 4, 1983).

Tactic 3: Initiate a 3-year "Assessment Study" on Basin 9, Vaughan Lake.

Tactic 4: Conduct a "roving" creel survey on basins 1, 2 and 3 (through Red Lake District, OMNR) and basin 12, Deception Bay (through Sioux Lookout District, OMNR).

Commercial Fishery

Tactic 9: Encourage a redirection of demand to basins, or parts of basins capable of sustaining additional fishing pressure with particular attention to basins where conflicts may be anticipated with the sport fishery.

Tactic 12: Apply scientific knowledge, as it becomes available to refine the MEI determined potential yield of the commercial fishing blocks, such that accurate productivity determinations and quotas will ensure a sustained yield.

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[1] Further details of Management Strategies explained in Chapter V.

Domestic Fishery

Tactic 14: Conduct a survey on Lac Seul Indian Reserve #28 to determine consumption levels of all fish and the top predator component. Index net to determine percent fish biomass of domestic fishery.

Contributions to Society

Tactic 20: Support the proposed Crown Land Resource Access Permit as a means of generating more revenue from the fishing activities of non-resident anglers not identified with an established tourist lodge or Provincial Park.

Tactic 21: Restructure current non-resident angling permits.

Scientific Knowledge

Tactic 23: Apply and integrate "Assessment Study" data to areas of Lac Seul exhibiting similar conditions.

Tactic 24: Utilize assessment study data from other assessment units which can contribute to resource improvements for Lac Seul.

B. CONTINUATION OF MANAGEMENT TACTICS CURRENTLY IN PLACE

Sport Fishery

Tactic 6: Continue walleye spawning sanctuary status of Adamhay Lake.

Tactic 7: Continue Adamhay Lake walleye tagging program.

Tactic 8: Continue Adamhay Lake winter creel survey.

Commercial Fishery

Tactic 10: Continue to promote greater utilization of fish species other than top predators.

Tactic 11: Continued monitoring of commercial fishery.

Tactic 13: Encourage full utilization of fish stocks allocated toward commercial fishery.

Water Quality/Fish Habitat

Tactic 15: Utilize water quality data in fisheries management schemes.

Tactic 17: Continue shoreline development regulations.

Tactic 18: Continue Modified Management Area programs.

Tactic 19: Continue road construction evaluations.

Tactic 23: Public Information and participation.

C. TACTICS REQUIRING FURTHER CONSIDERATION

Tactic 16: Assessment of northern pike spawning and nursery habitat thermal regimes using LANDSAT imagery and IR photography.

D. TACTICS DEEMED NOT FEASIBLE

Tactic 5: Promote a greater utilization of fish species other than top predators (deemed not feasible based on present social angling attitudes).

APPENDIX 6.2: DETERMINATION OF THE NON-RESIDENT CONTRIBUTOR PORTION OF ALL NON-RESIDENT ANGLERS SURVEYED DURING 1979.

A. Hough, Stansbury and Michalski (1981) report that 99% of all lodge guests were from the U.S.A. and 1% from Canada, outside Ontario (p. 261). Contributors to the local/regional economy are assumed to represent those non-resident anglers staying at tourist lodges or camping at some revenue-collecting campground. The weighted average for anglers staying at lodges was 73%, and 14% for anglers camping (Hough, Stansbury and Michalski, 1981, p. 457). However, Hough, Stansbury and Michalski (1981) do not indicate whether camping anglers camped on crown land or at a revenue generating campground. Therefore the following calculation to determine non-resident contributors will be presented in two scenarios:

1. assuming all campers are camping at revenue producing campgrounds, and
2. assuming all camping is on Crown land, therefore generating no revenue to the province.

B. CALCULATIONS

1. Assuming camping component generating revenue to the Province:

% contribution
% Non-Resident Contributors = (% lodge guests + % campers) x % non-resident anglers
= (73 + 14)% x 88%
= 76%

2. Assuming camping component not generating revenue to Province (i.e. all camping on Crown Land)

% contribution
% Non-Resident Contributors = (73% + 0%) x 88%
= 65%

Summary: Non-Resident Contributors/Non-Contributors

	Non-Resident Contributors	Non-Resident Non-Contributors	Total
1.	76%	24%	100%
2.	65%	35%	100%
Average	70%	30%	100%

Appendix 6.3: Present Allocation of Lac Seul Fish Stocks, by species. *

	SPECIES			
User Group	Walleye	Northern Pike	Whitefish	All Species
DOMESTIC FISHERY	6,202	uk	uk	18,795
RESIDENT ANGLERS	17,316	3,043	uk	20,359
NON-RESIDENT CONTRIBUTOR ANGLERS	29,895	32,016	uk	61,911
COMMERCIAL FISHERY	6,698	0	50,543	104,393
TOTAL ALLOCATION	60,111	36,059	50,543	206,458
MEI POTENTIAL PRODUCTION	110,000	63,758	93,248	423,855

* All values in kilograms

Appendix 6.4: Future Allocation of Lac Seul Fish Stocks, by species. *

	SPECIES			
User Group	Walleye	Northern Pike	Whitefish	All Species
DOMESTIC FISHERY	11,550	uk	uk	35,000
RESIDENT ANGLERS	6,464	1,136	uk	7,600
NON-RESIDENT CONTRIBUTOR ANGLERS	39,990	42,826	uk	82,816
COMMERCIAL FISHERY	9,092	0	52,935	108,706
TOTAL ALLOCATION	60,096	42,962	52,935	234,122
MEI POTENTIAL PRODUCTION	110,000	63,758	93,248	423,855

* All values in kilograms