Lake Erie

Walleye Management Plan

Lake Erie Committee

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Lake Erie Committee
Great Lakes Fishery Commission

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TABLE OF CONTENTS

Section 1. Introduction

1.1 Lake Erie Fisheries Management Through the LEC

The Lake Erie Committee (LEC) is a bi-national committee of state and provincial fisheries agencies operating under the auspices of the Great Lakes Fisheries Commission (GLFC) to manage fish communities and fisheries in Lake Erie. The LEC agencies include the Michigan Department of Natural Resources (MDNR), the New York State Department of Environmental Conservation (NYSDEC), the Ohio Department of Natural Resources (ODNR), Ontario Ministry of Natural Resources (OMNR), and the Pennsylvania Fish and Boat Commission (PFBC). The LEC uses the Joint Strategic Plan for Management of Great Lakes Fisheries as a guide for managing internationally shared resources. One such resource is the Lake Erie fishery. This fishery is composed of a number of species that are highly sought by commercial and sport fisheries. The U.S. Jurisdictions all have sizable sport fisheries and, to a lesser extent, commercial fisheries for walleye, yellow perch, white bass, lake whitefish and coarse fish. Ontario maintains a large commercial fishery and, to a lesser extent, recreational fishery that utilizes these species as well. Both walleye and yellow perch are managed on an allocation basis, with portions of biologically determined total allowable catches (TAC) shared between jurisdictions.

In the case of walleye on Lake Erie, this species is of enormous economic importance to all jurisdictions. It is therefore imperative that any management objectives for this species be aimed first at the sustainability of the population and second to maximize societal benefit for all jurisdictions. Further, the fishery must be allocated fairly and in a transparent and biologically justifiable fashion. In order to achieve this, managers require a decision making process that has clear objectives both for the fish population and the harvests associated with it. These objectives need to be supported by a management regime that will ensure that resource sustainability is maintained, that the walleye population continues to support fisheries of a high quality, and is in keeping with the LEC's Fish Community Goals and Objectives for Lake Erie. To this end, this document presents a brief recent history of walleye management on Lake Erie, the current status of this important species, fishery and fish population objectives, and management tools for the LEC will use to ensure that the objectives are met.

1.2 Recent Walleye Management on Lake Erie

In the early to late 1980s, water quality, excellent recruitment, and fisheries management actions allowed the walleye population in the lake to achieve a population abundance of approximately 40 – 70 million fish. In the late 1980s and through the 1990s, the walleye population began a decline that lasted for 10 – 15 years. It is thought that this decline was precipitated by a combination of fishing pressure, poor recruitment, and environmental changes. The latter brought about by invasive species such as dreissenid mussels. In order to stop this decline and attempt to restore the state of the walleye population to a favourable condition, the LEC initiated the Coordinated Percid Management Strategy (CPMS). During the CPMS, the TAC was set at a ceiling level of 3.4 million fish. In response to continued declines in population abundance, the TAC was set at 30% below this level. A summary of this strategy is presented below, with a detailed treatment presented in *Coordinated Percid Management Strategy* (LEC, final document). A detailed description of walleye management on Lake Erie prior to CPMS can be found in Section 3.1 of this document.

1.3 Coordinated Percid Management Strategy

The annual total allowable catch (TAC) was set at no more than 3.4 million walleye throughout the three years of the 2001-2003 CPMS. To ensure that the lake-wide TAC was not exceeded, each LEC agency took steps to decrease walleye harvest. The specific actions of each agency to achieve this end are listed in the CPMS document (LEC, final document). Additional efforts involving the timing of harvest were put in place to reduce fishing pressure on segregated spawning stocks. In 2003, the CPMS was evaluated to determine if the Strategy met the intended objectives.

The first objective, to ***reverse declines and rebuild percid stocks to achieve a broad distribution of benefits throughout the lake,*** was only partially achieved. With good management decisions (i.e., the implementation of the CPMS and changes to harvest levels) the three year CPMS period was long enough to stop the decline in walleye abundance. Unfortunately, year class failures, just prior to and during the CPMS time frame, prevented walleye stocks from increasing in abundance within the three year time frame.

The second objective of the CPMS, to ***improve approaches used to estimate percid abundance and determine sustainable harvest levels*****,** was achieved. Changes were made that improved the approach to estimating abundance and determining sustainable harvest levels. Reliance on strong information sources and up-to-date fish population models is imperative to understanding fish stock status. By moving to state-of-the-art population modeling techniques, and having them independently reviewed by fisheries experts, the LEC was able to better their understanding of walleye stock status.

1.4 Scope and Purpose of the Walleye Management Plan

To help ensure that the walleye population would not need such rapid and drastic management action as that taken during the CPMS, the LEC determined that it required a plan that it could implement to manage walleye. This plan establishes fishery sustainability and quality objectives that the LEC will employ as a basis for walleye management. This plan focuses primarily on the walleye stocks that spawn on shoals and in tributaries of the Western Basin, and generally inhabit the West and Central Basins of Lake Erie. This is the primary population of interest to the LEC management exercise as it provides most of the benefits to users throughout Lake Erie. There are additional stocks within the Lake, and these are found in Presque Isle Bay, East of Long Point, in the Eastern Basin. Catch at age modelling and population estimates for this Eastern population remain problematic, but it is clear (Ryan et al. 2005) that the population is small relative to the Western population. The Eastern Lake Erie walleye population is briefly described in this document, but fisheries management on this population was determined through separate processes, as described in Ryan et al. (unpublished). This will occur once the eastern basin management plan has been finalized by Ontario and New York, and will be published separately as a companion to this document at that time.

This new plan takes advantage of lessons learned and models developed during the CPMS. This management plan will form the basis for all future work towards managing walleye stocks in Lake Erie. This plan will be dynamic and continue to change with advances in assessment technology and fisheries theory.

It will be important for future sustainability of walleye that this population has an age structure that allows it to consistently provide stable fisheries and sufficient spawner biomass. In order to accomplish this, a more thorough understanding of population dynamics is necessary so that effective management actions can be implemented accordingly. The LEC and the Walleye Task Group (WTG) are working to increase understanding of population dynamics such as the walleye stock-recruit relationship, quantifying uncertainties in the models and evaluating risk strategies for various rates of exploitation, and mortality. Research initiatives are underway to delineate stocks and understand the influences of stock size and environmental variability on percid recruitment. These efforts, and others, such as the Decision Analysis (DA) initiative strengthen the WMP in that they inform managers as to the options available to them, and help them to understand the potential effects of their management actions.

Central to the WMP are two main components. The first are population objectives that define the biological and fishery quality characteristics that the LEC has set for the Lake Erie walleye population in cooperation with stakeholders. The second is an exploitation policy that has been designed to help meet these objectives and at the same time recognize the economic importance of the walleye fishery to stakeholders. This exploitation policy does so by marrying state of the art population and harvest simulation modelling with lessons learned from other fisheries and the recent history of walleye management on Lake Erie. Both of these components are described below in their respective sections.

1.5 Limitations and Uncertainties

When managing walleye in Lake Erie, managers must take into account several limitations and uncertainties with respect to estimates of the walleye stock. Managers must understand that regardless of their actions, these limitations and uncertainties can affect the year class strength and production of walleye and may be barriers to increasing the carrying capacity of walleye in the system. Because these extrinsic controlling factors can play a much greater role in controlling population abundance and dynamics than harvest (particularly at low exploitation rates), managers must be acutely aware of them as they are an ever-changing backdrop to fisheries management on Lake Erie.

The limitations to the production of strong year classes of walleye are primarily environmental (Madenjian et al. 1996). For instance, recent research by Ludsin et. al. (unpublished) has indicated that rainfall and freshet volume and duration may play a role in influencing primary production in Lake Erie during spring by increasing the amount of nutrients. Another limiting factor of year class strength is predation by other fish. Predation on young walleye is reduced after cold winters when there are fewer clupeids (gizzard shad and alewives) and white perch. Furthermore, the impact of spawning stock size on recruitment is masked by environmental influences. These influences can include variations in water temperature, rainfall, or severe wind events. The minimum threshold for spawner biomass to produce a strong year class is unknown. In recent years, large year classes have been produced from moderate to large sized standing stocks. The extent to which variations in available forage modify year class strength is also not fully understood.

Uncertainties relating to reduced productivity and barriers to increased carrying capacity of the system include such factors as invasive and non-indigenous species, changes in the environment and loss of spawning habitat. The introduction of non-indigenous species, such as dreissenid mussels and the round goby, to Lake Erie has shifted energy from the pelagic food web to the benthic food web, and reduced fish production and growth rates in many important fish species (Ryan et al. 2003). However, these changes have not necessarily been observed in walleye throughout the lake. Nutrients and the timing of nutrient pulses in the lake have been decreased as a result of dreissenid mussel invasion and phosphorous abatement programs. This in turn, has reduced the amount of phytoplankton and resulted in shifts of the depth distribution of walleye (Ryan et al. 2003). Furthermore, walleye spawning habitat has been lost through urban development, river barriers, and degradation of rivers by point and non-point source pollution. These factors have contributed to shifts in Lake Erie walleye carrying capacity through time (see section 3.2).

Section 2. Walleye Fishery and Fish Population Objectives

The LEC manages the entirety of the Lake Erie Resource using the *Fish Community Goals and Objectives for Lake Erie* (Ryan et al. 2003). As a terminal predator, walleye are a key component of the Lake Erie Ecosystem, and any management of this species must take this fact into consideration. For example, mismanagement of this species, to either end of the population abundance spectrum, could potentially lead to instability in the fish community, and have subsequent negative impacts on the integrity of the ecosystem or on other economically important species. Moreover, as an important commercial food fish, and a desirable sport fish species, walleye need to be managed for these uses as well. Ideally, this management objective should occur within the context of first sustainability, second ecosystem integrity, and human benefit third. The following describes these three paradigms of objectives and/or the resulting states of nature or population objectives that are associated with them.

2.1 Sustainability Thresholds for Walleye

Defining a minimum population size (a level of abundance from which a population can not recover in a reasonable time frame) is difficult if not impossible. For walleye in Lake Erie, the relationship between numbers or biomass of spawners and subsequent recruits is typically weak, with environmental influences greatly masking the effects of stock size on recruitment. In the case of other fisheries, the only time these thresholds are observed is after they have been exceeded. It may be simpler, therefore, to set a level for sustainability at a population size that causes fisheries to take on negative attributes. These attributes can include, but are not limited to a reduction in catch rates that lead to declining angler interest, or make the economics of the commercial fishery problematic. Additionally, when populations are reduced to low levels of abundance, they tend to take on other attributes that increase the risk of overexploitation. These include a reduced number of year classes causing a simple age structure that can lead to low levels of spawner biomass, or dependence of fisheries on single year classes. This can cause TACs and harvest to vary wildly on an annual basis (particularly at fixed exploitation rates), and is extremely risky from a stock conservation standpoint.

The population abundance of walleye in recent years (1999 – 2000) was a level of abundance that created the negative attributes described above. Both commercial and sport fishery catch rates were at 10-year lows, and all jurisdictions had difficulty attaining their portions of the TAC. The LEC has determined that the population abundance observed in 2000 was a critical minimum for the quality of fisheries, and was problematic for the sustainability of the resource. Therefore, the LEC maintains that dramatic management action in the form of reduced harvest levels will be warranted should the population fall below this level.

2.2 Fish Community Goals and Objectives Relevant to Walleye

The following are the goals and objectives from the *Fish Community Goals and Objective for Lake Erie* (Ryan et. al. 2003) that are relevant to walleye.

Relevant Goal

- *Secure a balanced, predominantly cool water fish community with walleye as a key predator in the western basin, central basin, and the nearshore waters of the eastern basin*

The extent to which this goal is achieved is largely dependent on the status of the rest of the fish community. The numbers of walleye required to affect this goal are greatly dependent on annual and spatial variations in prey distribution. Moreover, some feedback is expected since the characteristics of the prey fish community will act in concert with habitat variability, thereby changing the carrying capacity for walleye. This is additionally complicated if one considers that walleye share the terminal niche with several other species such as burbot, introduced salmonids, or bass species whose abundance is controlled by other factors (e.g., different environmental and food web factors or stocking). Provided that walleye abundance does not decline below levels that are sustainable, and a diverse stock structure is maintained, this objective will continue to be achieved. (Note – burbot and salmonine species have a colder thermal optimum relative to walleye, it's not clear these species share the same niche as walleye. Eastern basin sampling suggests spatial separation for walleye and burbot.)

Relevant Objectives

- *Provide sustainable harvests of walleye for all areas of the lake*

Provided that the goal of maintaining walleye as a key predator is upheld, and provided that sustainable levels of fishing mortality are maintained, walleye population abundance above that seen in 2000 will meet this objective.

- *Genetic diversity – maintain and promote genetic diversity by identifying, rehabilitating, conserving, and/or protecting locally adapted stocks.*

Several research projects have been undertaken in partnership with the LEC and its member jurisdictions. These projects include the documenting and describing of discrete stocks of walleye based on genetic or other biometric attributes (see section 3.5). There is always the potential that smaller stocks or sub stocks within the Lake Erie walleye population can be variably impacted and/or over fished. This is particularly the case if fisheries are exploiting stocks during spawning or staging for spawning. To ensure that exploitation does not impinge on the population sustainability or fishery objectives, action should be taken to first understand the impact of the fishing activity on discrete stocks, and to control or eliminate it when detrimental effects are observed. Efforts to better understand the effects of spring fisheries on walleye stocks should continue.

2.3 LEC Fishery Goals and Objectives

In order to ensure that the walleye population is sustainable and is of sufficient abundance to meet fishery quality objectives, the LEC has developed the following objectives:

- ***Maintain walleye catch rates at average or better levels,***
- ***Maintain sport and commercial walleye harvest to average or better levels***

To satisfy these objectives, the walleye population should have an average size of approximately 26-40 million fish. Additionally, the age and size structure of the fishery should be sufficient to:

a) Promote migration of walleye towards the Eastern Basin of the lake,
b) Provide diverse fishing opportunities to anglers; and
c) Provide sufficient numbers of commercially desirable fish.

These objectives should be achieved when the population size is between 26 and 40 million fish, and the fishery is not dominated by only one year class. The following population abundance categories have been identified by the LEC:

Age 2 and Older Walleye	Category
<15 million	Crisis
15-19 million	Rehabilitation levels
20-25 million	Low quality
26-40 million	Maintenance
>40 million	High quality

Ancillary management tools that act to promote genetic diversity, and generally act to buffer or enhance the effect of management actions should also be implemented, but due to the difficulty in measuring their impact on reproduction (e.g., their place as a modifier of the spawner recruit relationship), they extent to which they should be employed can't be adequately described. Therefore, the LEC chose to focus on methods that could be simulated and/or reviewed within the context of contemporary knowledge of Lake Erie Walleye.

In order to influence walleye population abundance to the extent that it is possible using direct management tools, it is clear that an exploitation policy should be central to any management plan for the species. This policy should do four basic things:

1) Ensure the sustainability of the walleye population

2) Help to maintain walleye within the maintenance threshold set out by LEC
3) Allow user groups to take advantage of large walleye populations
4) Be straightforward enough that its implementation will be simple to understand, and can rely on current stock status information.

To do these things, it is critical that the current knowledge of the walleye population be described and understood, and that past management actions be reviewed. Further, examining this information using simulation modelling in conjunction with decision analysis, it is possible to generally predict the impacts management actions on the population that could be expected in the future. By doing so, an exploitation policy that fulfills the above four criteria can be created. The process that the LEC took to carry this out is described below.

Section 3. Actions and Tasks in Supporting Plan Creation and Implementation

In order to proceed with creating and ultimately implementing the Walleye Management Plan, the LEC identified several working tasks for the Walleye Task Group to complete. A number of these items have been recognized as continuing actions in support of the plan. These tasks have informed the WMP as described in this document, and have been particularly useful in the creation of the exploitation policy that the LEC used starting in March of 2005. These tasks are listed and expanded upon below.

3.1 Carrying Capacity for Walleye in Lake Erie

Two different methods were used to estimate the carrying capacity (K) of walleye in Lake Erie. The first method utilized a logistic model to identify changes in carrying capacity through time, while the second model utilized Schaefer's surplus production model (Hilborn and Walters, 1992).

The Logistic Equation

A logistic production model was fitted to part of the time series of Ontario commercial fishery data for walleye in order to estimate r_m (initial rate of growth) and K for the years 1978-1982 and 1994-1998. A second line was drawn by inspection to indicate the relative increase in K for the years 1983-1988. This produced two isoclines (Figure 3.1.1). The early data (1978-82) conform to a low walleye production isocline, then break away to conform to a high walleye production isocline (1983-1988), before making a slow return (1989-1993) to the low walleye production isocline (1994-1998). The temporal organization of the data suggests a higher productivity of the stock, and consequently a higher K, during the 1983-88 period compared to the 1978-82 period, and a decline of stock productivity, thus a decline in K, in the 1990s of the same magnitude.

Surplus Production Model

Lake Erie walleye population biomass estimates from catch-age analysis, interagency sampling, and harvest data was fitted to Schaefer's surplus production model using three different time series of data (Hilborn and Walters 1992). Model parameters r (a growth rate parameter) and K were estimated using non-linear least squares regression and the Gauss-Newton method for calculating derivatives (SAS v8.02). Data from 1978-2000 was used to represent the entire modeled time series of data for Lake Erie, 1984-2000 data was used to illustrate changes in the population as a result of reduced phosphorus loading, and 1994-2000 data was used to demonstrate the most recent status of the walleye population. Data from 2001 to 2003 were not used due to harvest constraints during those years. The three different time series of data produced three very different models (Figure 3.1.2). The long time series of data (1978-2000) indicated a high estimate of K (~ 170×10^6 kg), whereas the 1984-2000 time series estimated a lower K (~ 110 x 10^6 kg), while the most recent data (1994-2000 time series) suggested a further decline in K (~ 75 x 10^6 kg).

All models indicated that walleye carrying capacity has changed over time in Lake Erie. Estimates of K utilizing recent time data show that K has decreased from the early 1980's to the late 1990's. There are several factors which may have instigated this decline including a reduction in phosphorus loading, the introduction of non-indigenous species to the lake (i.e., dreissenid mussels), habitat loss (lower lake levels), and shifts in climatic conditions. These models integrate the effects of factors affecting walleye and should shape our understanding of change in carrying capacity for walleye through time.

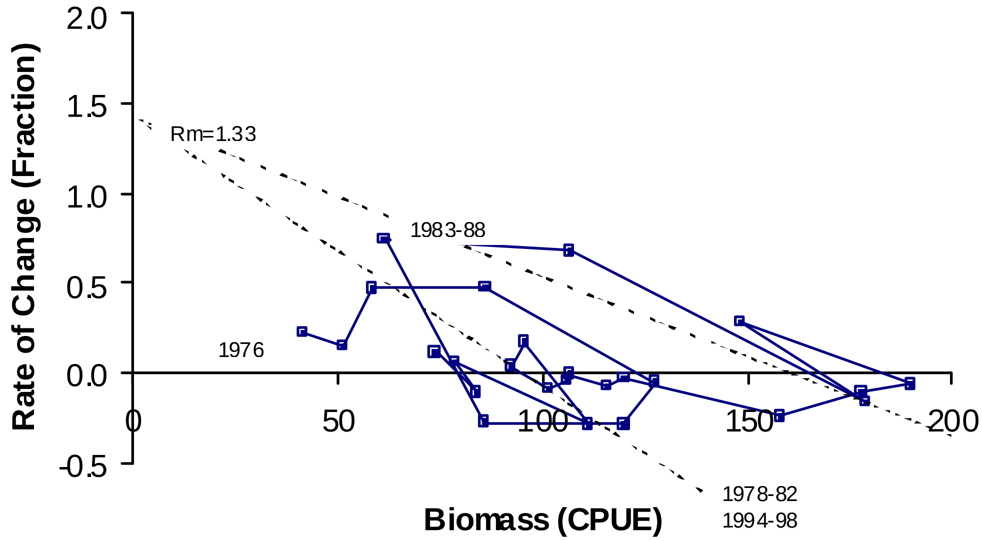

Figure 3.2.1. Logistic models of walleye from commercial CPUE (kg/km) data from Ontario commercial fishery.

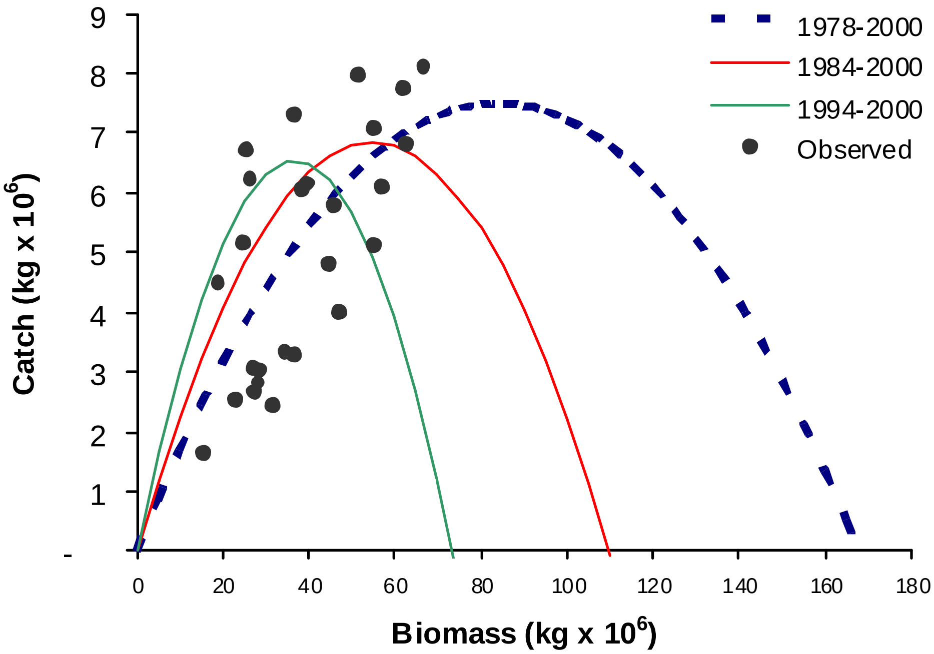

Figure 3.2.2. Lake Erie walleye surplus production model utilizing three different time series 1978-2000, 1984-2000, and 1994-2000.

3.2 Biological Reference Points and Exploitation Policies

Historic Lake Erie Walleye Harvest Strategies

International walleye quotas on Lake Erie were introduced in 1976 following a walleye moratorium in 1970 due to high levels of mercury in walleye and subsequent limited harvest after 1972 (Hatch et al. 1987). Initially, the Walleye Task Group estimated walleye abundance by sequential projection using harvest data and estimated mortality rates (assumed natural mortality =0.218) and U.S. Fish and Wildlife Service west basin young-of-the-year trawl indices (WTG 1979). Total allowable catch (TAC) was initially derived from Gulland (1971) based on ½(B_o)(M) where B_o and M are biomass and natural mortality at carrying capacity (Hatch et al. 1987).

In 1977 and 1978, the WTG used Gulland's (1970) approach to derive the TAC. This method calculated the maximum yield as derived from B_o using two ratios. The first ratio was the size at first capture to maximum size, and the second ratio was that of natural mortality to growth (Hatch et al. 1987). After the TAC was exceeded in 1979, the target fishing rate (F=0.1) was doubled (F=0.2) in 1980 (Hatch et al. 1987). In 1981, the target fishing rate was increased to a level at which the TAC in 1980 would have approximated the harvest in 1980 (F=0.285) and was maintained from 1981-1983 (Hatch et al. 1987). In 1984, target fishing mortality rates were conditional on three categories of walleye abundance (Hatch et al. 1987).

- Category (1): 40-50 million fish in two successive years: F=0.285
- Category (2): >50 million in two successive years: F=0.285+(Abundance–50 million)
- Category (3): <20 million fish in two successive years:

For any one year-	15-20 million:	F=0.20
	10-15 million:	F=0.15
	<10 million:	F=0.10

In 1985 and 1986, the surplus condition (category 3) was ignored. In 1986, the 1982 year class was considered to be underestimated by the model, and was adjusted upwards in proportion with fishery catch rates with F=0.285 (WTG 1985, 1986). In 1988, population estimates were derived by sequential projection, CAGEAN and RECQUEST, with the latter producing the highest estimates, which were subsequently accepted that year (WTG 1988). RECQUEST was a form of virtual population analysis (VPA) that used fishery catch and assessment catch rates. Constant natural mortality (M=0.218) was assumed and selectivity was not part of the model (WTG 1989). In 1989, the task group lost confidence in the YOY trawl index and sequential projection, instead favouring yearling gill net indices. CAGEAN methodology was chosen over RECQUEST with average annual exploitation rates applied for the TAC (WTG 1989,1990).

In 1990, the WTG decided to use the existing CAGEAN – TAC approach over an alternative Beverton Holt Yield per Recruit method (WTG 1990). In 1991, the walleye tag recapture program suggested M=0.38, but a conservative value of two standard errors below this estimate was adopted (M=0.32), along with continued use of CAGEAN. The Beverton Holt Yield per Recruit approach was used for generating F_{opt} (0.326) for recommending allowable harvest (RAH) in 1991. The F_{opt} was scaled such that vulnerable age groups would be fished above the target fishing rate while younger fish would be fished below the target rate (WTG 1991). Although F_{opt} was equal to 0.326, the true targeted fishing mortality rate was approximately 0.4 after the scaling method (WTG 1993-1997). This assessment/allocation process continued until 1998 at which time, the method of scaling F_{opt} was dropped so that age groups would not be fished at rates higher than the targeted level. In 1998, the task group assumed a more conservative M=0.25 based on alternative analyses (this reduced F_{opt} to 0.259), but M=0.32 was reinstated in 1999 and 2000 after additional consideration, with F_{opt} = 0.326.

Catch-age analysis using Auto Differentiation Model Builder (ADMB) C++ software was introduced in 2001. This model accepts survey data and offers greater flexibility. An independent review was conducted later in 2001 by Ransom Myers and Jim Bence, who endorsed this process as an improvement over the former CAGEAN assessment (Myers and Bence, 2001). The three-year Coordinated Percid Management Strategy (CPMS) began in 2001 to stop the apparent decline in walleye stocks and promote rebuilding the population. During this time TAC was set at a ceiling level of 3.4 million fish. In 2004, in response to further declines in estimated biomass of walleye, the TAC was set 30% below the CPMS level.

Abundance and TACs

Accurate abundance estimates are essential to the development of meaningful population abundance reference points (Hilborn 2002). Lake Erie walleye population estimates (and estimators) have varied over time, and they have described gross changes in magnitude and relative abundance fairly well. The estimates and models have elicited greater concerns about absolute abundance (Figures 3.2.1 and 3.2.2). Parma (2002) noted that CAGEAN overestimated, and then underestimated, halibut abundance due to changes in catchability that were not recognized by the model. Changes in population scaling appear to have improved since the WTG adopted ADMB for catch-age analysis that included survey gear (Figure 3.2.2).

The annual TAC setting exercise of the LEC is typically influenced by population estimates, variance, the target fishing rate, stakeholder input and manager/agency perceptions of risk associated with uncertainty in the assessment process or in a particularly year's assessment (e.g., conflicting signals between indices or fisheries). The target fishing rate, from 1991-2000, was derived from the Beverton-Holt yield per recruit model (Pauly 1984) which is influenced by Von Bertalanffy growth parameters, natural mortality, and parameters associated with a knife edge recruitment assumption.

This model is considered a conservative replacement of MSY (Hilborn and Walters 1992) that optimizes yield given tradeoffs between growth and natural mortality. The principal targeted fishing rate applied during the early 1990s (F=0.323) was scaled such that the targeted fishing rate on some age groups was approximately 0.4 (WTG 1991). Recommended Allowable Harvest (RAH) ranges were calculated by applying this targeting fishing rate to the mean, minimum, and maximum population estimates from catch at age analysis. This range of possible harvest levels was used to pick a TAC from in the LEC annual decision making process. During the 1990s, TACs were frequently set below the mean RAH value, and close to the minimum of the RAH range (Figure 3.2.3). Based on task group population estimates from 1978 to 2003, fully selected fishing rates oscillated around a mean of 0.35 and exceeded 0.4 in the latter half of the 1990s (Figure 3.2.4).

Reference Point Estimation and Managing Harvest for Targets

The Walleye Task Group has identified several steps necessary to set TACs and fulfill the Walleye Management Plan based on the methods of setting reference points, identifying thresholds, and managing exploitation to managers-specified objectives and targets. These steps are to:

1) Estimate the current and virgin stock size,
2) Estimate the target catch by using reference exploitation rates based on current and virgin stock size, and;
3) Manage the fishery to achieve the target catch using a variety of tactics (Hilborn 2002).

The Schaefer surplus production model was used to define carrying capacity for Lake Erie walleye (west-central stock). Survey weight-at-age data was applied to catch-age analysis in order to generate population biomass estimates for use in the model (see section 3.1 for methods). Shifts in the carrying capacity of percids have likely occurred over the past 30 years in Lake Erie, such that one logistic model cannot describe population growth (Ryan et al. SCOL draft document). To accommodate these changes, several time periods were modeled 1978-2000, 1984-2000, and 1994-2000 in order to define F_{MSY} reference points. An intermediate time segment (1984-1993) would not fit the non linear model, since the relationship between catch and population biomass was strongly linear. Data from 2001 to 2003 were not used due to harvest constraints during the Coordinated Percid Management Strategy.

Parameter estimates are presented in Tables 3.2.1 and 3.2.2 for two versions of ADMB (version 1 for age groups 2-7+ and version 2 for age groups 2-11+). The models are presented graphically in Figure 3.2.5, with diagonal lines representing MSY fishing rates and dashed diagonals representing arbitrary rates 20% below the MSY fishing rate. The short time series (1994) produced the smallest value of carrying capacity (K), followed by the middle (1984-2000) and longest time series (1978-2000) (Table 3.2.1, Figure 3.2.5). In contrast, the short time series produced the highest population growth rate estimate (r) followed by the middle time series and longest times series. The maximum sustainable yield (MSY) ranged from 6.5 to 11.7 million kg depending on the time series and ADMB version (Table 3.2.2). The rate of exploitation (biomass) at MSY equals r/2 ranging from 8% to 19% depending on the time series and model used. The long time series had the highest MSY, but due to the value of r, had the lowest fishing rate at MSY. In contrast, the recent time series had the lowest MSY, but the highest fishing rate at MSY due to estimates of r and K (Table 3.2.1, Figure 3.2.5). If fishing was excessive during the 1990s, r may have been inflated, since the time series was not long enough to see the effects of overfishing because it was interrupted by the CPMS.

Converting an exploitation rate in biomass into a fishing mortality rate (F_{MSY}) is highly dependent on the age composition and mean weight at age, due to the effects of gear selectivity. Assuming an average age composition (1978-2003) and average weight at age in the population, F_{MSY}=0.18, 0.26 and 0.42 for the 1978-2000, 1984-2000 and 1994-2000 approaches (ages 2-7+ version) respectively.

MSY is literally defined as the maximum constant yield that can be taken year after year (Mace and Sissenwine 2002). The modern dynamic interpretation of MSY describes it as the maximum average yield (MAY) that can be achieved by varying annual yields in response to fluctuations in stock size. One way to accommodate MAY is to apply a constant fishing mortality rate F_{MSY} (Mace and Sissenwine, 2002). F_{MSY} is now generally regarded as an upper limit for exploitation rather than as target reference point (Gerrodette et al. 2002, Mace and Sissenwine 2002). Lake Erie walleye have frequently been fished above the fishing rate at MSY according to all three time period scenarios presented (Figure 3.2.5). In only a few instances was the MSY biomass exceeded. Plotting observed exploitation rate against harvest implies that F_{MSY} could be higher than predicted by the Schaeffer model (Figure 3.2.6).

Reference points based on carrying capacity estimates are presented in Table 3.2.1. A threshold of 10% of virgin biomass for closing fisheries (Hilborn 2002) would range from 7 to 29 million kg, depending on the ADMB version and time period. Target fishing rates could occur when the population was at 40% of K or greater (Hilborn 2002) equal to 28 – 117 million kg for Lake Erie walleye. At levels of biomass between 10% and 40%, target exploitation would increase from 0 to some reference exploitation rate. Reference points would be highly dependent on assumptions about which data are most likely to be representative of current and future walleye population dynamics.

Recent harvest of walleye and historic harvest of walleye are compared to MSY yields from the Schaefer models (Figure 3.2.7). MSY values (rK/4) based on the long time series appear out of range for walleye in the present era, and possibly in the past (Figure 3.2.7). Given Lake Erie walleye recruitment patterns and the influence of environmental conditions, a realistic MSY yield would only be attainable for a very brief period of time.

In theory, fishing at the MSY rate of fishing should promote population growth towards $Biomass_{MSY}$ (K/2) and population decline when K/2 is exceeded. A retrospective analysis applying MSY fishing rates (biomass) to the population from 1978 to 2000 suggests that current fishing rates (circa CPMS) are near the MSY rate based on the 1984-2000 model. Based on the other time block methods, fishing rates during the last several years may be above or below the MSY exploitation rate (Figure 3.2.8). The 1994-2000 MSY rate is the most aggressive fishing rate (Figure 3.2.8) since the higher level of abundance (pre 1994) was not within the range of the model. There are periods of historic harvest which clearly stand out as being greater than F_{MSY} including the late 1990s and for two of the time period scenarios, from the late 1980s to 2000 (Figure 3.2.8). In these examples, the lower MSY fishing rates would have left more fish alive, resulting in positive feedback to the population in terms of growth, production of biomass, and possibly recruitment.

Choosing a precautionary approach based on MSY fishing rates and virgin population biomass is problematic. This is due to the assumptions and limitations of the Schaeffer model, catch-age analysis and their inputs. Use of virgin spawner biomass (SSB) as a reference point would be complicated due to the fact that the maturity schedule and age composition of such a reference population are not completely known. Additionally, understanding the virgin biomass of a stock at carrying capacity is contingent on knowing the underlying ecological conditions supporting that stock, and how changes in these conditions affect walleye biomass. Given that this is not the case, and that MSY within the context of a Schaefer model can be considered somewhat aggressive as a long term policy, for walleye management. Therefore, fishing at a rate more conservative than the higher F's during in the 1990's would seem appropriate (Figure 3.2.8).

Fixed exploitation rates have been shown to cope well with the effects of climate change, by allowing the stock to fluctuate in phase with productivity (Parma 2002).

Fixed exploitation rates, when applicable, may be appropriate for Lake Erie fish populations subject to frequent perturbations. While the commercial walleye fishery may function well under a constant harvest rate strategy, it is unlikely that a sport fishery can function in this manner. Quotas, mesh size restrictions, seasonal and spatial closures can effectively regulate commercial harvest. Bag limits, size limits and seasonal-spatial restrictions limit angler harvest.

A plan that initiates a change in targeted fishing rate or sport regulations based on reference points should not rely exclusively on models (i.e., catch-age analysis). Under a considerable range of circumstances, data based rules will perform better than reference points (Hilborn 2002). Population and fishery status indicators associated with pre and post CPMS are useful in defining a target fishing rate that promotes population growth.

Table 3.2.1. Schaefer model parameter estimates based on ADMB catch-age biomass estimates with age groups 2-7+ and 2-11+. (Models based on data from west and central basins only.)

			Years Included in Model		
ADMB Ages	Parameter		78-00	84-00	94-00
2 to 7+	Carrying Capacity	K (kg x 10^6)	182	129	70
	Maximum expl. Rate (biomass)	r	0.20	0.24	0.37
	Stock Size (kg) at MSY	K/2	91	64	35
	MSY Surplus Production (kg)	rK/4 (kg x 10^6)	9.1	7.8	6.5
	Exploit. Rate (biomass) at MSY	r/2	10%	12%	19%
		SE k	76	34	14
		SE r	0.03	0.04	0.06
	% of Virgin Biomass Reference Point	10%	18	13	7
		40%	73	52	28
2 to 11	Carrying Capacity	K (kg x 10^6)	293	133	75
	Maximum expl. Rate (biomass)	r	0.16	0.23	0.35
	Stock Size (kg) at MSY	K/2	147	66	37
	MSY Surplus Production (kg)	rK/4	11.7	7.6	6.5
	Exploit. Rate (biomass) at MSY	r/2	8%	11%	17%
		SE k	278	32	11
		SE r	0.03	0.04	0.04
	% of Virgin Biomass Reference Point	10%	29	13	7
		40%	117	53	30

Table 3.2.2. Ranges for Schaefer model parameter estimates according to time blocks. (Models based on data from west and central basins only.)

	78-00	84-00	94-00
K (carrying capacity millions kg)	182 - 293*	129 - 133	70 - 75
rK/4 (MSY millions kg)	9.1 - 11.7	7.6 - 7.8	6.5
r/2 (MSY exploitation rate kg)	8 - 10%	11-12%	17-19%

** very senstive to pooled age groups in ADMB catch-age analysis*

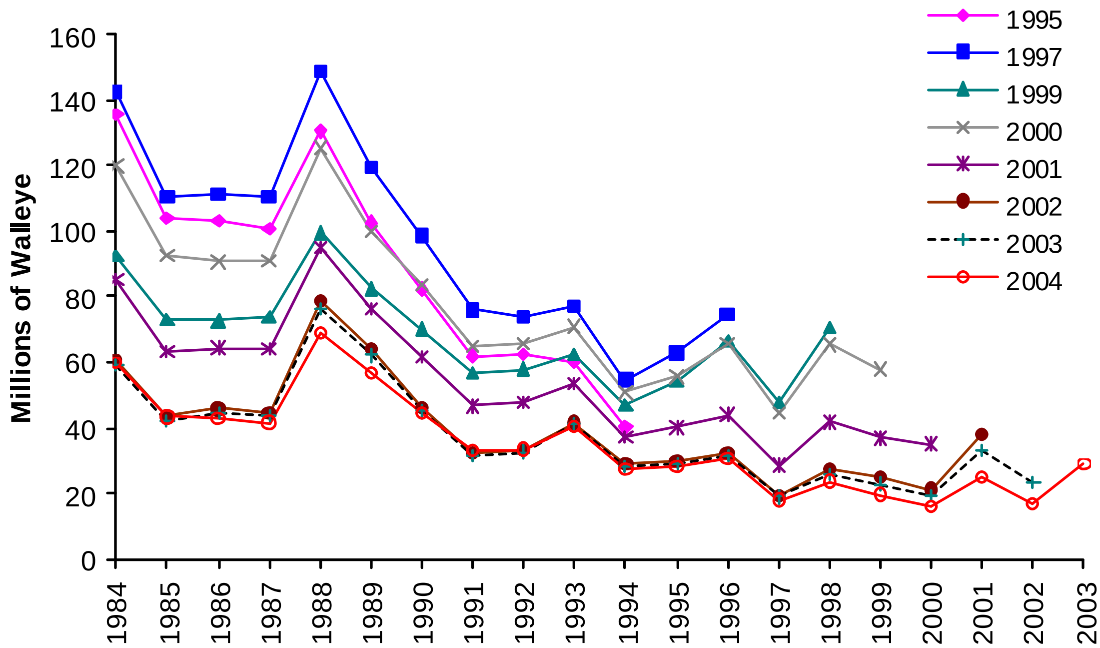

Figure 3.2.1. Walleye population estimates using CAGEAN from 1995, 1997, 1999, 2000 WTG reports, and using ADMB (2001-2004). Models based on data from west and central basins only.

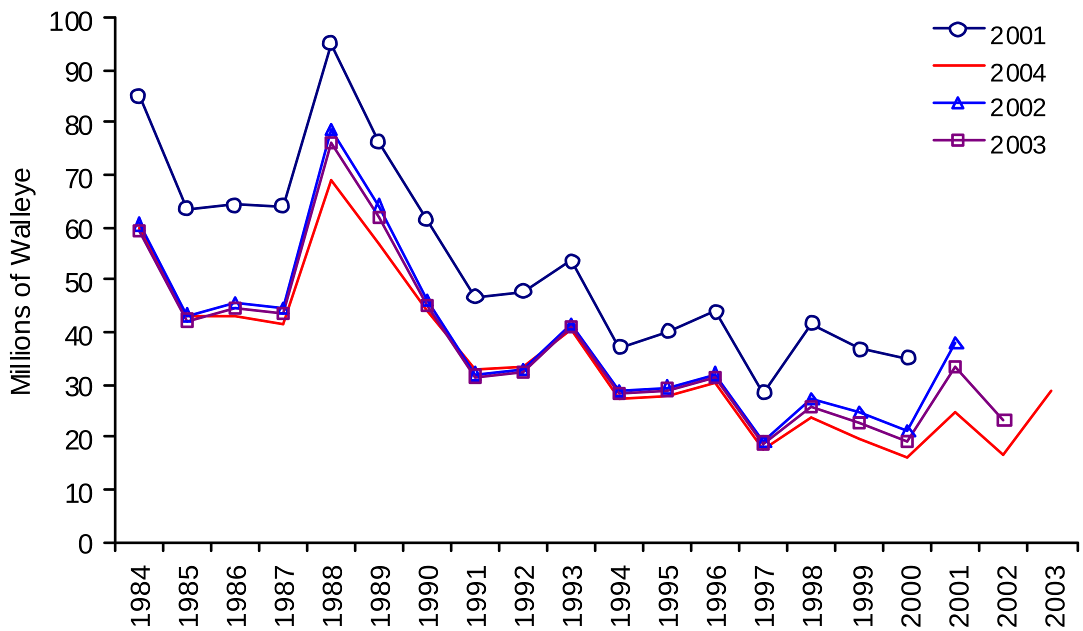

Figure 3.2.2. Walleye population estimates from 2001 - 2004 task group reports based on catch-age analysis using ADMB. Models based on data from west and central basins only.

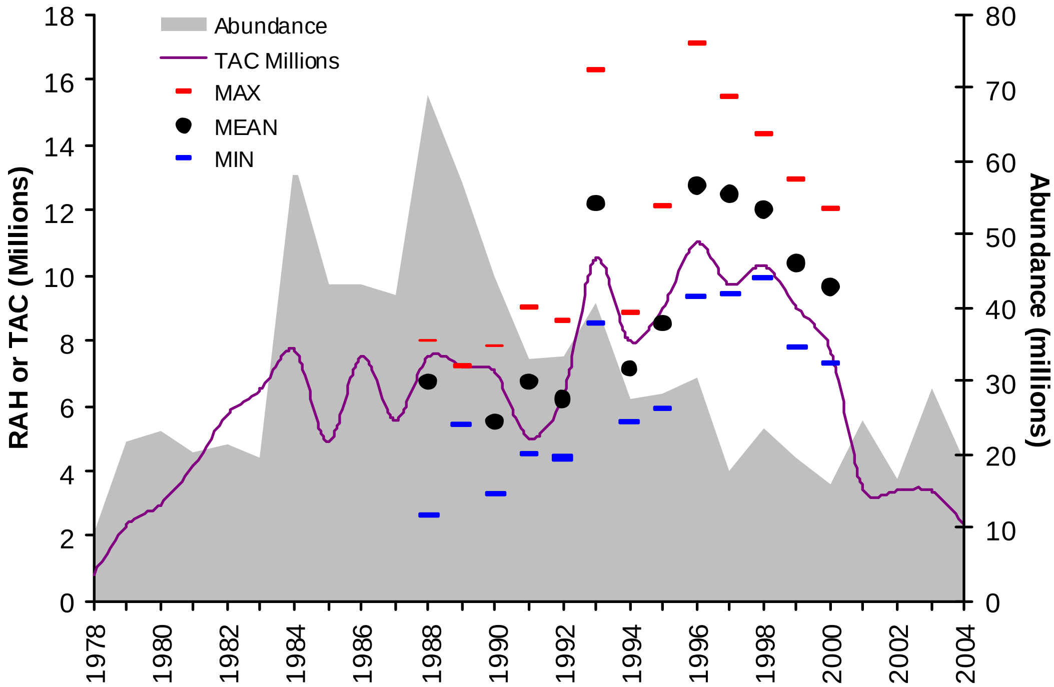

Figure 3.2.3. Total allowable catch (TAC), recommended allowable harvest (RAH) levels (minimum, maximum, and mean) and abundance of walleye (second Y axis). The CPMS was applied from 2001-2003. Models based on data from west and central basins only.

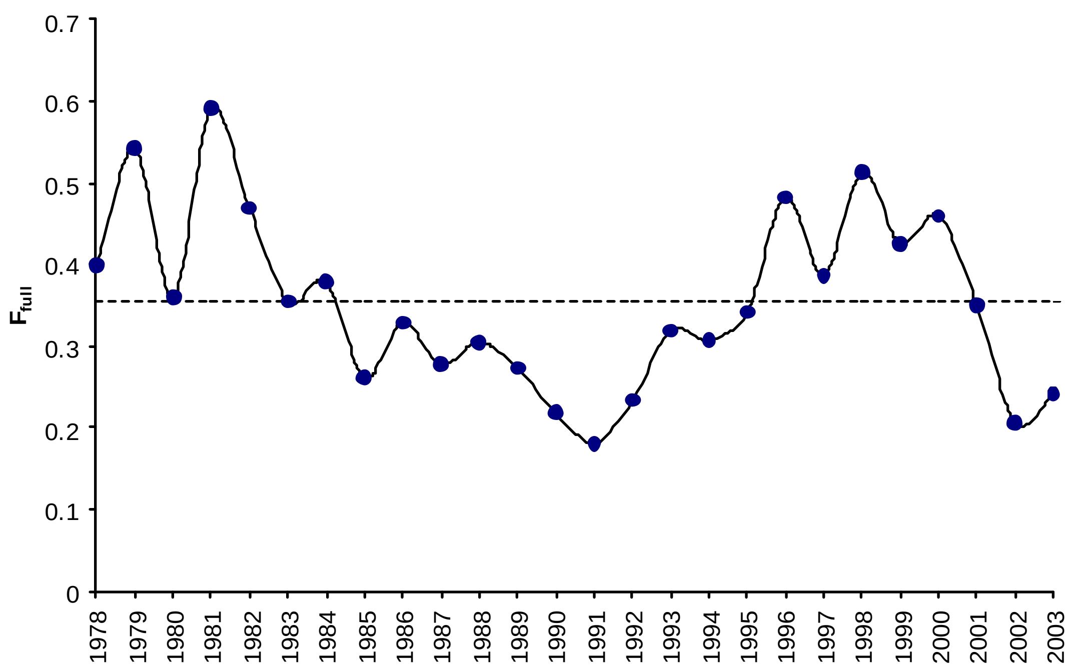

Figure 3.2.4. Estimated annual fully selected total fishing mortality from ADMB catch-age analysis (WTG 2004). Dashed line represents the average fishing rate over the series (0.35). Models based on data from west and central basins only.

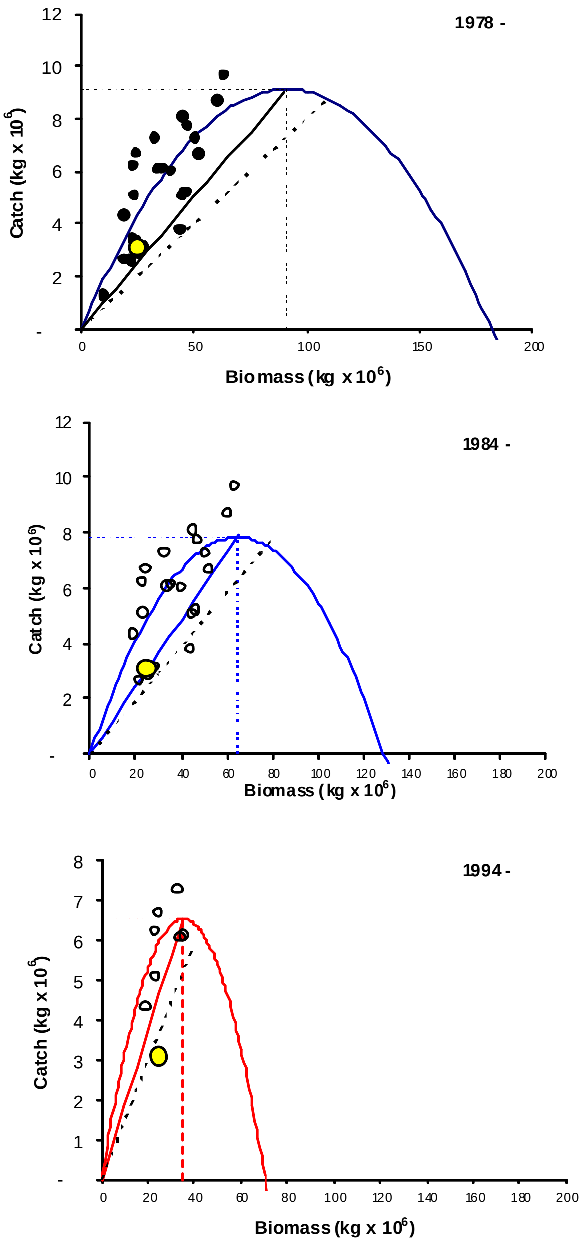

Figure 3.2.5. Schaefer surplus yield models for Lake Erie walleye based on biomass estimates from catch-age analysis. Three time periods used in the model include 1978-2000, 1984-2000 and 1994-2000. Diagonal solid line represents MSY fishing rate (biomass) and dashed diagonal line represents 80% of MSY fishing rate. Large circle represents 2004 quota.

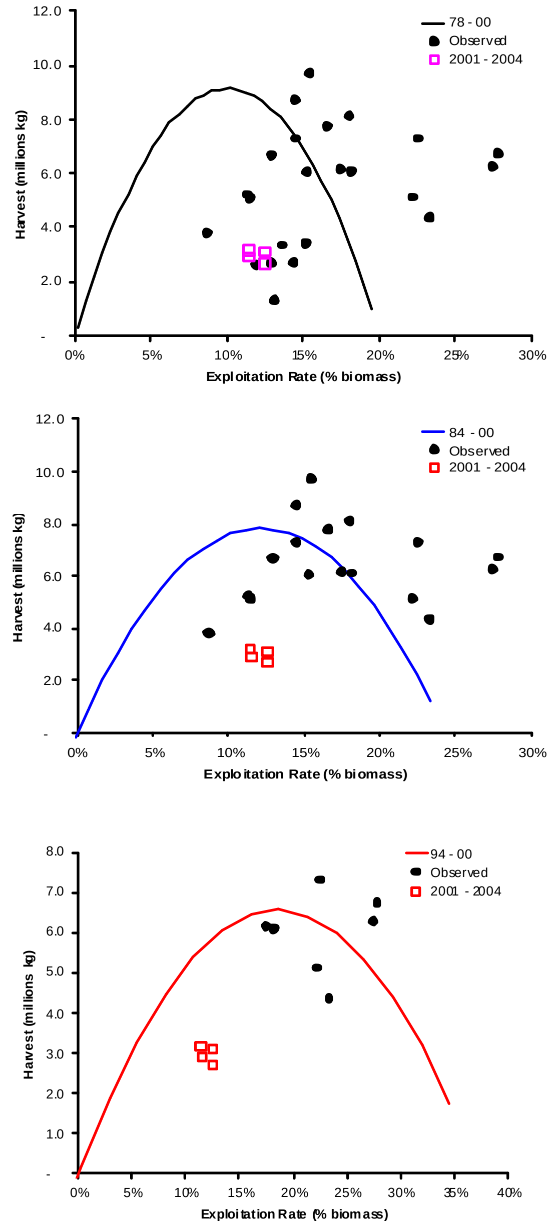

Figure 3.2.6. Harvest related to exploitation rate according to Schaefer model using time blocks 1978 - 2000, 1984 - 2000 and 1994-2000. Solid dots represent observed harvest weight and exploitation rate based on ADMB catch-age analysis biomass estimates for those time blocks. Squares are the same for 2001-2003 (CPMS) and the TAC for 2004. Assuming average age composition and 10 year mean weights from catch-age analysis, Fmsy for each time block would be 0.18, 0.26 and 0.42 for the 1978-2000, 1984-2000 and the 1994-2000 blocks respectively.

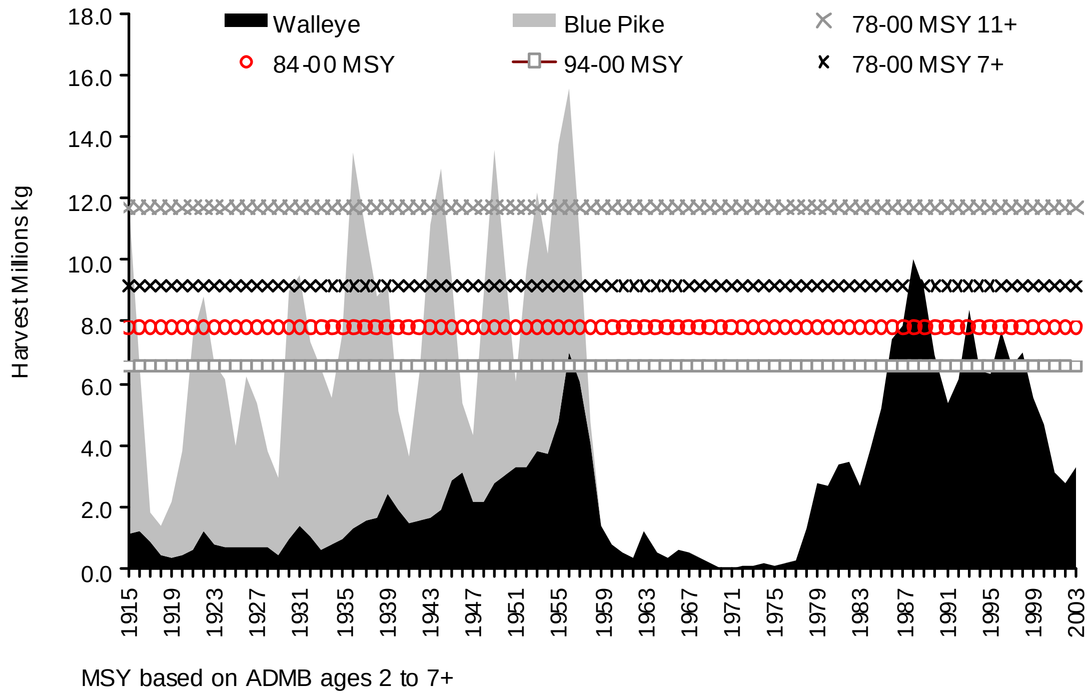

Figure 3.2.7. Historic harvest of walleye, along with Schaefer model MSY values based on 1978-2000, 1984-2000 and 1994-2000 time blocks.

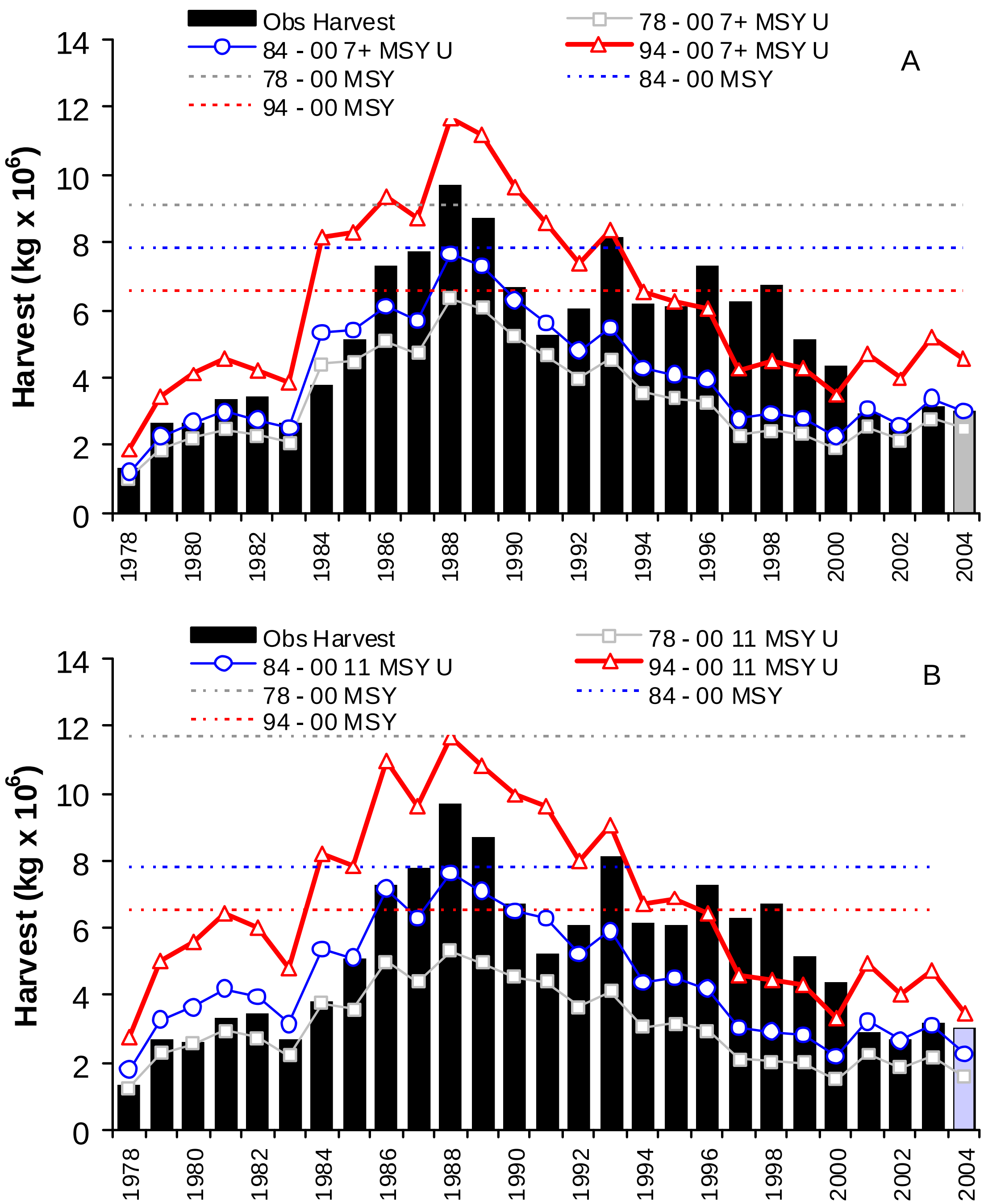

Figure 3.2.8. Observed harvest (black bars) and estimated harvest based on MSY fishing rates derived using biomass estimated from catch-age analysis with ages 7 and older pooled (A) and 11 and older pooled (B). Lines represent different time blocks used in Schaefer model: 1978-2000 (squares), 1984-2000 (circles) and 1994-2000 (triangles), represented different periods of walleye productivity. Dashed lines represent MSY yield values for these time blocks with 1978-2000 as the greatest, followed by 1984-2000 and 1994-2000. Grey bars represent 2004 TAC in kg. Models based on data from west and central basins only.

3.3 Incorporation of Simulation Modelling and Decision Analysis

The use of DA in fisheries management has increased in recent years and it is intended to help managers make better informed decisions and help them to share the rationale for their decisions with stakeholders. Modeling uncertainty has helped to quantify unknowns specific to the Lake Erie walleye population and provided managers with critical information about the variability of walleye recruitment and mortality. Management objectives were developed and shared with stakeholders reflecting a substantial move toward increased transparency with stakeholder groups.

Decision Analysis (DA) models are developed to help reduce complex decisions into manageable components, allowing for formal recognition of objectives, the incorporation of options and uncertainties, and the assessment of risks. Unique to the DA approach is that it includes key uncertainties. Decision analysis breaks complex problems into eight manageable steps; management objectives, management options, unresolved uncertainties (uncertain states of nature), probabilities on the uncertainties, model to calculate the outcome of each management option for each uncertainty, decision tree, ranked management options, and sensitivity analysis (Peterman and Anderson, 1999). Decision analysis was initiated by LEC in 2003 through 2005 in order to evaluate the potential risks and expected outcomes (relative to explicit management objectives) of various exploitation policies and management options for walleye in Lake Erie. Management objectives are clear and unambiguous criteria for ranking management options.

The DA process forces managers to clearly identify management objectives and management options. A formal process enables managers to recognize how uncertainty is included in complex issues and how uncertainties can be quantified and used to inform fisheries management decisions. The LEC decided to explore the use of DA to help incorporate uncertainty into decisions on total allowable catch of walleye. This is described briefly here, and is expanded upon in more detail in (Wright et al. 2005)

Each of the LEC agencies developed objectives for their respective walleye fisheries. The objectives were harvest and abundance targets rather than ecosystem objectives. The WMP – LEC objectives were then combined into population categories in 2004 described earlier in the document. Subsequently an explicit management objective (to maintain the abundance of walleye at a specific level, preferably in the maintenance or high quality fisheries levels) was used to drive the DA model.

Management options are the alternatives from which the recommended management action will be chosen. Different exploitation policies were described as those with different targeted fishing mortality rates. Both fixed and feedback policies were examined. A fixed policy can be described as one in which the fishing mortality remains constant regardless of the abundance of walleye. In contrast, a feedback, or state-dependent approach, allows the targeted fishing mortality rate to vary with population abundance (e.g., a lower fishing mortality rate is used when the walleye population abundance is low relative to the time series, and a higher rate is used when the walleye population is more abundant).

Several uncertainties were incorporated into the DA including: catchability, selectivity at age, current abundance, stock size vs recruitment, angler effort vs. abundance, and natural mortality. A statistical catch-at-age model is used to estimate the uncertainty in all of the parameters for which point estimates are obtained using posterior parameter estimates. This includes estimates for catchability, selectivity at age, and current abundance. This DA model was developed to mainly use the uncertainty associated with stock status, natural mortality rate and recruitment as a basis for its simulations.

Probabilities can be placed on uncertain states of nature, and probability distribution for all possible values for each uncertain parameter can be generated. The area under the curve contains all possible alternative values for the parameter and the probability that these values are true. A model then calculates the consequences of each combination of a particular management option and each possible uncertainty.

Management options are ranked by a series of performance measures based on model output that described possible future states. In this way, output from the DA model was used to evaluate the performance of each management option at achieving the management objective (i.e., a walleye population >25M). Performance measures included the average population abundance over time, percent of time the population was below a target threshold (15M and 25M walleye were used), and the percent of time the population was below a target threshold and remained below that threshold for three or more years. Average commercial and recreational harvests over time were also used as performance measures.

Decisions are made using the output of the model to rank alternative options based on their performance at achieving clear management objectives. Once a management option has been endorsed, it is recommended it be used for several years before the model is updated and used again. The DA model is applicable to the Lake Erie walleye population until additional information is known that might change what is currently known about this population (e.g., additional information on natural mortality, stock structure changes). The outcomes of the DA simulation model with respect to the exploitation policy for the WMP are illustrated in Section 3.5.

The DA stochastic forecasting model was developed by fishery modeling experts Michael Jones and Wenjing Dai of Michigan State University. Additional assistance was provided by Jim Bence also of Michigan State University. Funding for the initiative came from a Great Lakes Fisheries Commission Coordinated Activities Program grant. The DA team provided input during the development of the model. The majority of model development activities took place between November 2003 and December 2004.

3.4 Current Status (2004) of the Lake Erie Walleye Population

In order to evaluate the status of the Lake Erie walleye population, various population parameters were compared to literature references. Parameters that were examined include biomass, angling catch per hectare, commercial catch per hectare, angling catch per unit effort (CUE), exploitation, survival rates, natural mortality rates, body condition, and length at age. Values for each of these parameters were taken from the literature for various populations of walleye in different lakes, and calculated by the WTG for the Lake Erie walleye population. When comparing Lake Erie walleye population parameter estimates with those found in the literature the authors were mindful of the caveats associated with doing so. In particular, none of the literature references provided information from lakes containing ecosystems similar to Lake Erie in terms of their size and biological complexity. A majority of the references dealt with walleye populations in relatively small lakes where the entire basin could be classified as suitable walleye habitat and large-scale migrations and movement did not occur. Fish community structure and food web dynamics in most of the reference systems were far less complex than in Lake Erie (typically oligotrophic lakes or Northern river systems).

In this section the status of the Lake Erie walleye resource is described separately for two regions of the lake that markedly differ in habitat and trophic state, and have different walleye population characteristics. Data from the west and central basins of the lake were pooled, while the data from the east basin was summarized on its own. Mean and median values were calculated for each of the parameters both from the literature and from Lake Erie data. This data was summarized for the entire available time series of available data, and the last three years of data from the Annual Report of the Walleye Task Group (WTG, 2004). Mean values of each of the west and central basin parameters and Lake Erie's percent rank among the values can be found in Table 3.4.1, the accompanying east basin parameter values and rankings are found in Table 3.4.2. Length at age data from the west and central basins can be found in Table 3.4.3.

Overall, the west and central basins of Lake Erie had higher biomass, angling CUE, and commercial yield in comparison to other walleye populations. However, the overall angling yield was lower when compared to other populations. This may be due to the large area of Lake Erie in comparison to lakes in this literature review. It remains notable that the walleye habitat, and accompanying fisheries of the central and western basins of Lake Erie, are much larger than any of lakes cited in this literature review. The Lake Erie eastern basin parameter values were generally lower when compared to western and central Lake Erie as well as those of other walleye populations reviewed. Lower rankings for the walleye resource in the eastern basin likely reflect a less productive environment for walleye, particularly in offshore waters with characteristically ultra-oligotrophic conditions. Long term and recent mean Lake Erie walleye population and fisheries measures have remained well within ranges reported from other lakes, and over the last 25 years Lake Erie's walleye resource has generally remained in good condition relative to other walleye populations.

Table 3.4.1. Summary of evaluation of the past and present status of the Lake Erie walleye population (west and central basins) with respect to the literature.

Metric	Number of References	Reference Mean	Reference Median	Years of Lake Erie data	Lake Erie Mean (all years)	Lake Erie Median (all years)	Lake Erie Percent Rank (all years)	Lake Erie Mean (2001-03)	Lake Erie Percent Rank (2001-03)
Biomass (kg/ha) [a]	33	13.33	11.10	1978-2003	16.51	14.77	73%	12.18	56%
Angling CUE (#fish/hr)	103	0.21	0.13	1975-2003	0.43	0.42	84%	0.36	83%
Angling Yield (kg/ha) [b]	53	2.34	1.8	1978-2003	1.26	1.05	37%	0.59	14%
Commercial Yield (kg/ha)	92	0.64	0.48	1984-2003	1.60	1.51	90%	0.84	79%
Exploitation [c]	16	0.18	0.18	1978-2003	0.22	0.22	69%	0.18	50%
Natural Mortality (M) [d]	29	0.37	0.28	na	0.32	na	65%	na	na
Condition $(W \times 10^5) / L^3$	25	1.41	1.47	1978-2003	1.10	1.10	16%	1.12	17%
Survival [c]	29	0.55	0.54	1978-2003	0.54	0.54	50%	0.58	64%

[a] Lake Erie Biomass value was calculated from ADMB population abundance at age estimates multiplied by survey weight at age for management units 1, 2, and 3

[b] Lake Erie angling yield (kg/ha) was estimated using only Ohio and Michigan sport harvest (MUs 1, 2, and 3).

[c] Exploitation and Survival were estimated using the walleye ADMB population abundance model (MUs 1, 2, and 3).

[d] Lake Erie natural mortality value of 0.32 was estimated using tagging mark recapture studies. This is the value of M used by the Lake Erie Walleye Task Group for population modelling purposes

Table 3.4.2. Summary of evaluation of the current status of eastern Lake Erie's walleye resource with respect to the literature.

Metric	Number of References	Reference Mean	Reference Median	Years of East Basin Lake Erie data	East Basin Lake Erie Mean (all years)	East Basin Lake Erie Median (all years)	East Basin Lake Erie Percent Rank (all years)	East Basin Lake Erie Mean (2001-03)	East Basin Lake Erie Percent Rank (2001-03)
Biomass (kg/ha) [a]	33	13.33	11.10	1996-2003	3.37	3.25	14%	2.66	12%
Angling CUE (#fish/hr)	103	0.21	0.13	1996-2003	0.19	0.18	62%	0.18	60%
Angling Yield (kg/ha) [b]	53	2.34	1.8	1996-2003	0.29	0.29	9%	0.20	6%
Commercial Yield (kg/ha)	92	0.64	0.48	1996-2003	0.16	0.16	17%	0.08	7%
Exploitation [c]	16	0.18	0.18	1996-2003	0.11	0.10	19%	0.09	14%
Natural Mortality (M) [d]	29	0.37	0.28	na	0.18	na	24%	na	na
Survival [c]	29	0.55	0.54	1996-2003	0.72	0.74	87%	0.67	81%

[a] Lake Erie Biomass value was calculated from ADMB population abundance at age values multiplied by survey weight at age for management units 4 and 5

[b] Lake Erie angling yield (kg/ha) was estimated using only NY and PA sport harvest (MUs 4 and 5).

[c] Exploitation and Survival were estimated using the walleye ADMB population abundance model (MUs 4 and 5).

[d] Lake Erie natural mortality value of 0.18 was estimated using tagging mark recapture studies for eastern spawning stocks. This is the value of M used by the Lake Erie Walleye Task Group for population modelling purposes

Table 3.4.3. Length at age summary of evaluation of the current status of the Lake Erie walleye population with respect to the literature (average percentile rank=94%, 33 references, Lake Erie data from 1978-2003).

	Length at Age (mm)									
	1	2	3	4	5	6	7	8	9	10
Reference Mean	218	287	342	391	429	466	497	525	552	564
Reference Median	215	274	333	382	422	452	495	511	537	561
Lake Erie Mean	335	415	469	504	532	561	587	619	652	658
Lake Erie Median	337	417	469	504	532	558	583	618	655	662
Lake Erie Percent Rank	98%	100%	100%	94%	94%	94%	94%	88%	85%	88%

3.5 WMP exploitation policy

As discussed earlier in this document, the WMP seeks to set exploitation policy using both a historical approach (to examine empirical and theoretical ramifications of various levels of harvest) in combination with decision analysis and population simulation modeling (for policy evaluation). To do this, the LEC examined fishing rates that it has applied or observed for Lake Erie walleye, and looked to the literature for guidance. Simulation models from the DA then tested/ forecasted the impact of the resulting policy.

The LEC walleye population objectives outlined earlier in this document lend themselves well to exploitation policies that vary depending on population abundance estimates. The DA team, and the LEC have dubbed this type of approach a feedback approach. Feedback refers to the fact that the exploitation policy is informed by population abundance, is used to set exploitation rate, then is re-informed in the subsequent year by the new population abundance, and a new and different exploitation policy is set.

This approach enables the LEC to reduce fishing mortality when the population abundance is low and take advantage of periods of high abundance by increasing fishing mortality. Several approaches were discussed and or tested using simulation models using a variety of levels of fishing mortality. For example Figure 3.5.1 shows an early feedback policy tested by LEC and the DA team.

It was decided that empirically derived levels of fishing mortality (F) should be used to begin setting out the policy. Figure 3.5.1 uses a low level of F between15 and 20 million walleye (approximately 0.2) that is comparable to the exploitation rates used during the CPMS. These levels of fishing mortality were sufficiently low that they arrested population decline, and all but eliminated the influence of harvest on the population. In contrast, the upper level selected for this early policy is set at a level corresponding to F_{opt} . This level is the maximum that LEC feels is safe, and is an excellent analogue for an optimal MSY rate harvest (as discussed earlier, this is considered to be a maximum and risky level of fishing rate). In the policy, levels of fishing mortality decrease from this high F with population size in steps (created by the population stages of the LEC policy) in order to promote population growth and maintain spawner biomass.

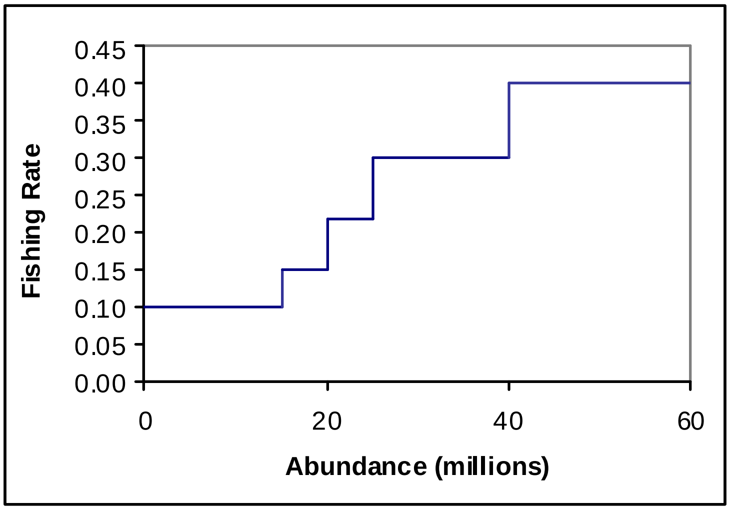

Figure 3.5.1. An early feedback policy tested and discussed by LEC. Notice that the steps on the curve approximate the changes from one population state to another (as described above).

This type of approach was ultimately rejected as there was some concern at LEC about the rapid changes in targeted fishing mortality that relatively small changes in abundance estimates would indicate. This would result in TACs that could vary wildly on an annual basis. Additionally, it is not uncommon for a subsequent year's population estimates to slightly revise past stock size estimates. This could result in rapid changes occurring in targeted fishing mortality that were found to be unnecessary in the year following allocation. This could have real economic ramifications for stakeholders, and would undermine the credibility of the process. Additionally, there was no mechanism to "decelerate" the levels of harvest when a transition level was being approached. It was also decided that fishing mortality rates above 0.39 are be excessive, and could compromise the broad distribution of benefits that are typically enjoyed as the walleye population peaks in abundance.

Upon further deliberation, the LEC described a feedback policy that is now referred to as the sliding-F policy. The resulting policy is illustrated in Figure 3.5.2, and will be used for the foreseeable future by LEC to manage walleye.

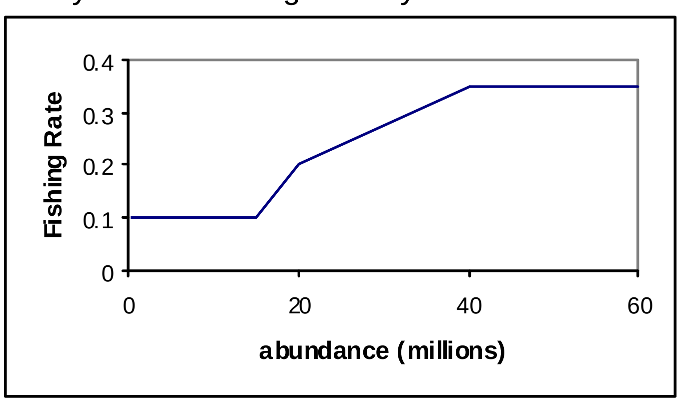

Figure 3.5.2. LEC sliding-F policy for walleye management in Lake Erie.

This policy uses the mean targeted walleye fishing mortality (described in an earlier section) as the maximum F allowed, and employs it when the population exceeds 40 million fish. At 20 million fish, the CPMS value of 0.2 is used, and the resulting curve will be used to set fishing mortality levels on an annual basis. The lowest level of F in this policy is 0.1, and will be employed when the population falls below 15 million fish.

This exploitation policy was tested using the Decision Analysis simulation model, with the results considered favorable by the LEC with respect to its objectives. The DA, its mechanisms, assumptions and methods is described in detail in Wright et al (2005). Table 3.5.1 summarizes the DA simulation outputs with respect to six parameters of interest that are key to understanding the impact of walleye exploitation policies on the population, and can be used to evaluate/compare different policies.

Table 3.5.1. Summary of DA simulation outputs for the LEC sliding F policy modified from Wright et al (2005)

	LEC Policy
Mean number of 2 year old and older walleye (over a 50-year simulation period)	47.4 M
Mean number of 4 year old and older walleye (over a 50-year simulation period)	15.8 M
Percentage of years below 15 million fish (over a 50-year simulation period)	1.0%
Percentage of years less than 15 million fish for greater than 3 years	4.0%
Percentage of years below 25 million fish (over a 50-year period)	15.3%
Percentage of years less than 25 million fish for more than 3 yrs (over a 50-year period)	11.5%

3.6 Contributions of Western Basin Walleye to Eastern Basin Fisheries

Several genetic investigations have found stock structure in the Lake Erie walleye resource both among and within the eastern and western basins of Lake Erie (Stepien and Faber 1998, Gatt et al. 2003, Wilson 2003). Collectively the western basin walleye spawning stocks remain genetically distinguishable from eastern basin stocks (Stepien and Faber 1998), and exhibit markedly different abundance, mortality, and distribution patterns within Lake Erie (Haas et al. 2003, Ryan et al. 2003, WTG 2004). An ongoing, long term inter-agency walleye tagging study carried out by Lake Erie's Walleye Task Group shows western basin walleye spawning stocks generate a lakewide distribution of tag recoveries from fisheries, while tag recoveries from eastern basin spawning stocks shows this group remains more confined to the eastern half of Lake Erie (Figure 3.6.1).

This study indicates that the source of the large walleye resource exploited in the western and central basins of Lake Erie remains western basin spawning stocks. In contrast, the smaller eastern basin walleye population includes spawning stocks that originate from both the western and eastern basins of Lake Erie. Distinguishing the relative contributions of western and eastern basin walleye spawning stocks to eastern basin fisheries remains an important information need for assessment and management of the eastern basin walleye resource.

Insights concerning the extent of contributions by western basin walleye spawning stocks to eastern basin fisheries can be gleaned through genetic stock discrimination studies, the long-term inter-agency tagging study, and characteristics of the eastern basin walleye harvest. Gatt et al. (2003) used genetic markers and mixed-stock analysis to suggest the sport and commercial fisheries in eastern Lake Erie were comprised mostly of western basin walleye spawning stocks in 1995 and 1996. In contrast, Wilson (2003) pursued a subsequent genetic investigation that described the western basin contribution to eastern basin fisheries in 1999 and 2000 as somewhat less than 25 percent. Interagency walleye tagging results have indicated the identifiable segment of western basin walleye spawning stocks contributing to eastern basin walleye fisheries is primarily composed of large female walleye. Haas et al. (2003) demonstrated that female walleye are typically recaptured further from their tagging location than are male walleye, and that walleye are recovered furthest from tagging locations during August and September (Figure 3.6.2). These observations correspond with prominent attributes of eastern basin walleye fisheries that traditionally produce peak yields in mid- to late summer and harvest predominately larger, older walleye.

From 1993 to 2003 New York State biologists have annually sampled the walleye sport harvest at fish cleaning stations in eastern Lake Erie and found the fraction of female walleye contributing to New York's harvest has been 80% during peak summertime fishing periods (Einhouse and Haas 1995, D. Einhouse – personal communication). In addition, on a lake-wide scale, the mean age of harvested walleye characteristically increases from west to east in Lake Erie and remains highest in eastern basin waters (WTG, 2004). Taken together, these observations from eastern basin fisheries remain consistent with tagging study results and underscore significant contributions by larger, and older, female walleye to eastern basin fisheries.

Several GLFC sponsored research initiatives remain ongoing with objectives to improve our understanding of the contribution of western basin walleye spawning stocks to eastern basin fisheries. In the interim, it is apparent that contributions by western walleye spawning stocks remain important to eastern basin fisheries, and the segments of these western basin spawning stocks that contribute most to eastern basin fisheries are principally larger, older individuals and female walleye. This knowledge remains useful for walleye assessment and management by identifying components of the walleye resource that make significant contributions to walleye fisheries in distant parts Lake Erie relative to spawning locations. In summary, harvest strategies that pursue a management objective of achieving lake-wide fisheries benefits will require maintaining a threshold density of larger, older walleye.

Ontario and New York State are currently working to finalize a technical document (Ryan et al. unpublished) that describes both the yellow perch and walleye populations of the eastern basins in detail. Subsequent to this and for the 2006 LEC public meetings a management plan that considers the mixed stock structure and population dynamics of the eastern basin walleye will be presented. This plan will include exploitation policy and fisheries management options for both the sport and commercial fisheries.

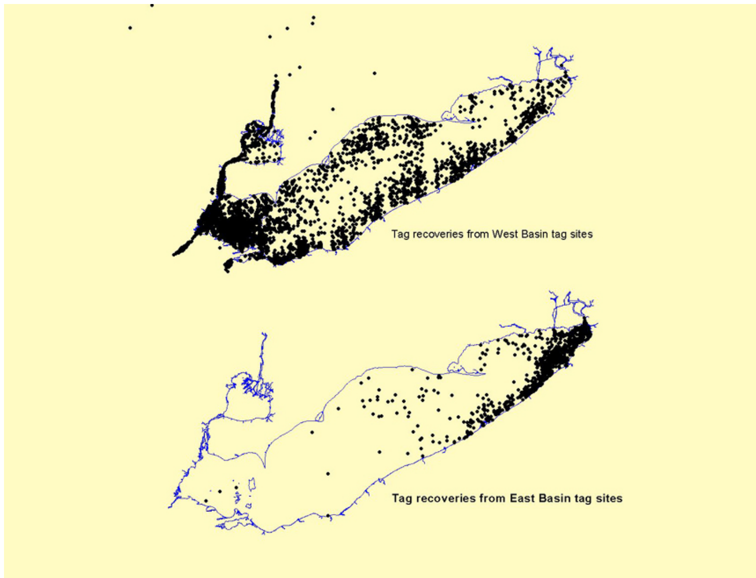

Figure 3.6.1. The distribution of walleye tag recoveries from western basin tag sites (top) and eastern basin tag sites (bottom) from 1986 to 2002. (Haas et al. 2003).

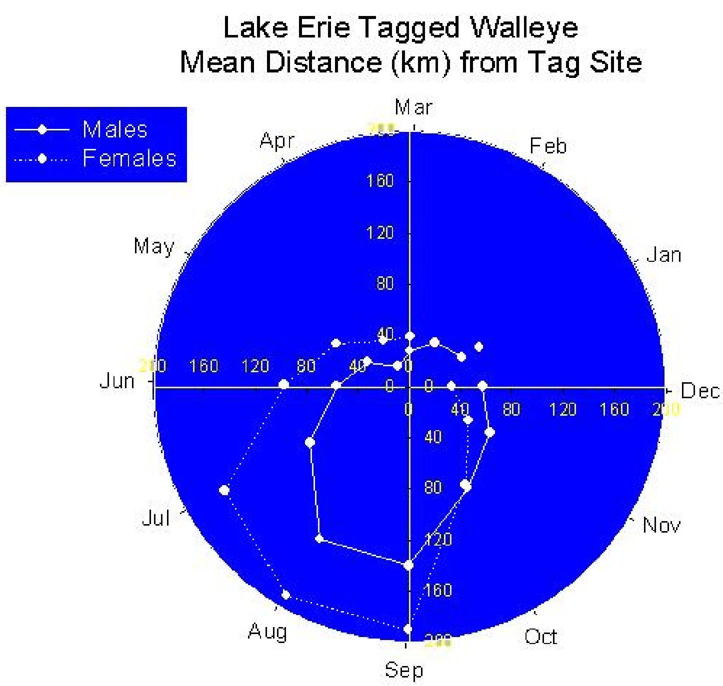

Figure 3.6.2. Polar plot of the average monthly distance from the tag site by walleye gender for the Lake Erie tag-recaptures. (Haas et al. 2003)

3.7 Areas of needed research

Several studies have been completed within the past few years investigating topics important to the management of walleye in Lake Erie; however, there are still information gaps to be filled. The purpose of this section is to highlight the areas where work has been done (Appendix A) and identify areas of needed research.

The LEC has expressed an interest in incorporating stock specific assessments into future management regimes to ensure that no single spawning stock is over represented or overexploited. This commitment to ensuring the maintenance of walleye stock diversity in the lake will help ensure the sustainability of the Lake Erie walleye population. Future research initiatives should use this as a guiding principle when relevant. Several areas have been identified by the LEC as areas of needed research, or investigation.

- *Mortality* – Determine if the current assessment programs are providing accurate estimates of the various components of total mortality (i.e., fishing mortality (F) and natural mortality(M)) both at the population and stock-specific levels.

- *Stock Contribution* – Continue to develop the tools needed to identify the stock specific origin of individual fish to determine the relative contribution of stocks to the Lake Erie Walleye population.

- *Size Selective Management* – Describe the utility and management implications of size selective management (Size limits in angling fisheries, mesh size restrictions) for achieving fishery objectives (harvest restriction, protection of spawner biomass etc) needs to be investigated.

- *Seasonal closures of fisheries/sanctuaries* – The value of these techniques (relative to constraining F) as a method of improving recruitment success and/or protecting spawner biomass needs to be investigated.

- *Fish Community Interactions* – Identify the interactions between fish populations that might impact production, including, but not limited to, walleye and yellow perch, walleye and round goby, walleye and rainbow smelt.

- *Social and Economic Effects of Population Abundance* – Information regarding the social and economic impacts of various fishery and harvest objectives would help managers maximize the social and economic benefits of fisheries, and rank or weigh the economic impact of management options.

Section 4. Measures of Success / Targets for Evaluation

4.1 Indices of Achievement of WMP Objectives

An evaluation of the WMP relative to its objectives will be best performed after a sufficient time period has passed. The outcome of simulation model runs using the sliding scale F policy endorsed by the LEC has indicated that walleye populations should generally fall within or above the maintenance population range most of the time. This simulation works on huge time scales, and smoothes out the variability of model outputs using means. In contrast, the walleye population abundance varies tremendously on a short time scale, and is driven by recruitment events. Therefore, an acceptable measure of success incorporates both of these disparate sources of information.

If the WMP exploitation policy works as it is intended, the walleye population abundance will remain within the maintenance zone most of the time, with variance from this state driven primarily bye short term fluctuations in recruitment. Any dramatic shift from this state will be driven primarily by changes in carrying capacity or other major ecosystem change. Because these changes typically occur over a span of years, the effect of the WMP can not be understood without the benefit of allowing those years to pass. Therefore, the true test of the policy will be to examine whether or not on average and over time, the abundance of walleye remained within the LEC maintenance range.

4.2 Tracking Plan Progress and Success

The WMP actions and outcomes of these actions need to be evaluated at regular interval. In order to do this, and to make this evaluation a key part of the annual LEC cycle, the following should be incorporated by the WTG within its annual list of charges:

- The status and outlook for the walleye population needs to be evaluated annually against population abundance and fisheries objectives.
- Overall status of walleye relative to changes in carrying capacity should be reviewed on a five-year basis
- The impact of long term exploitation policy implementation on population abundance and demographic attributes should be evaluated on a five-year basis.
- WTG should be responsible for preparing a status report for walleye within the context of WMP on a five-year basis. WTG should include an annual update of walleye population status relative to WMP as a short text piece in their annual update reports.

Section 5. Conclusion

This plan for the management of the walleye of Lake Erie is a cooperative and collaborative product of the LEC member jurisdictions. It is an example of all of the jurisdictions commitment to the ongoing sustainability and economic viability of this important fishery. This culture of collaboration is critical to the proper management of all fisheries in Lake Erie. It is not only present at the level of management and strategic planning exercises such as this, it permeates every level of management from data collection, analysis and research, to resource allocation decision making.

The LEC member jurisdictions support this process, and jointly recognize the need to continually refine and strengthen all of these processes in order to better manage fisheries to increasing levels of precision to an optimal benefit for all users. This is a difficult task that is complicated by the ever changing environmental conditions of Lake Erie. Stakeholders play an important role in these processes as well by commenting on management plans, and making their views known to the LEC through direct communication, and through the public consultation exercises that the LEC carries out.

The Lake Erie Walleye Management Plan uses the best information available to understand the status of walleye in Lake Erie. This information includes the past performance of walleye fisheries and populations under a wide range of exploitation rates and environmental conditions. Objectives set in conjunction will all jurisdictions and stakeholders are used to define fisheries and fish population objectives which in turn have been used to set a sliding rate exploitation policy for walleye. This policy was evaluated using walleye population simulation modelling, and was found to be reasonable with respect to fishery and fish population performance. Continued evaluation of walleye population and fishery performance by the LEC and it's science committees will help to determine the success of this plan, and illustrate the future need for and the direction of any new management requirements.

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Appendix A. Current/Completed Walleye Research on Lake Erie

TITLE: Population genetics of walleye in Lake Erie using mitochondrial and nuclear DNA markers

PRINCIPLE INVESTIGATOR(S): Carol A. Stepien, Ph.D.

POSTDOCTORAL ASSISTANT:

GRADUATE RESEARCH ASSOCIATE: Joseph Faber, Ph.D. (graduated 1998)
Clifford D. Taylor (present technician working on the project)

AFFILIATION: University of Toledo

YEAR STARTED: 1996
YEAR ENDED: ongoing
RESEARCH STATUS: On-going, completed, and future.

SUMMARY: Our laboratory was awarded a new NOAA Sea Grant to develop, test, analyze, and implement a high-resolution, low cost, and widely applicable DNA data base for analyzing walleye stock structure in Lake Erie, in relation to the other Great Lakes. Past research work by our lab using mitochondrial DNA control sequences, nuclear DNA intron sequences, and variation at 6 nuclear DNA microsatellite loci (Stepien 1995, Stepien and Faber 1998, Faber and Stepien 1998, Stepien et al. 2004) has shown that spawning groups of walleye genetically differ apparently due to spawning site philopatry (a tendency to return to natal sites) by both males and females. The new study builds upon the past studies to better understand fine-scale stock structure, allow unknowns to be genetically typed, and to produce a large interactive data base at low cost for use by fishery scientists and managers.

The product of the study will be a state-of-the-art interactive World Wide Web data base of 15 microsatellite loci for 1000 walleye, along with genetic analyses of their relationships, distribution patterns, and stock structures. The web program will show where each fish and population sample "fits in" to stock structure and patterns across the Great Lakes. The data base then will serve as a baseline for use by fisheries researchers and managers for years to come. An output target goal is to invite samples and continued use after the grant on an as-need and by-request basis at low cost (estimated as $25/fish), providing a growing interactive data base for widespread scientific and agency fisheries management.

The Stepien lab currently is completing analysis of 6 microsatellite loci and sequences from the entire mitochondrial DNA control region for 400 walleye, and is part of 2003-4 Great Lakes Fishery Commission Restoration Act project to test 200 new walleye unknowns using various genetic techniques (with 2 other labs, both Canadian). The new research extends and goes far beyond that work to analyze a much larger data set, implement a low-cost high-throughput procedure, and produce a working interactive genetic data base. The new project also will compare the other data sets and studies to the new one (for example, for many samples we will already have other data sets, including the mitochondrial DNA control region sequences for the 400 walleye analyzed during our completed Sea Grant project). The Ohio Division of Natural Resources and the Lake Erie Committee helped to develop the ideas for this project and will serve as initial testers/users.

TITLE: Quantifying how parental attributes influence characteristics of early life history stages of Ohio stocks of Lake Erie walleye.

PRINCIPAL INVESTIGATOR(S): Roy A. Stein, Konrad Dabrowski*, and Elizabeth A. Marschall

POSTDOCTORAL RESEARCHER(S): Jacques Rinchard*

GRADUATE RESEARCH ASSOCIATE(S): Jason J. Van Tassell

AFFILIATION(S): Aquatic Ecology Laboratory, Evolution, Ecology and Organismal Biology, The Ohio State University, 1314 Kinnear Road, Columbus, Ohio 43212-1156

*School of Natural Resources, The Ohio State University, 2021 Coffey Road, Columbus, Ohio 43210

YEAR STARTED: 2004
YEAR ENDED: 2010
RESEARCH STATUS: On-going research

SUMMARY: Our project seeks to quantify how parental attributes influence early life history characteristics of walleye progeny. By collecting data from four purported spawning groups (Maumee, Sandusky, and Grand rivers, and an open-water reef), we can determine the degree to which they differ, providing insight into their relative contributions to the Lake Erie population. Attributes of adult male and female walleye (length, mass, age, condition, etc.) will be compared to attributes of eggs and larvae (length, mass, lipids, etc.) in each system, attempting to determine if these parental effects predict egg/larval characteristics and if these relationships differ among spawning groups.

We will collect adult walleye using an electroshocking boat and gillnets. Each spawning site (Maumee, Sandusky, and Grand rivers, and an open-water reef) will be sampled weekly during the spawning run and, for a subset of weeks and sites, both males and females will be spawned (i.e., an individual of one sex will be spawned with multiple individuals of the opposite sex). During our preliminary field season in 2003, adult attributes, including length, weight, visceral fat, liver mass, fecundity and sperm concentration, eggs characteristics (e.g., size and lipids), and fertilization rates are being or were measured. Many of our relationships between attributes of adults and characteristics of early-life-history stages require more observations before any conclusions can be conclusively drawn. However, a few relationships have emerged. For example, mass of an egg decreased as the residual of fecundity becomes more positive, sperm concentration increased with a more positive visceral fat residual, and lipid content per egg increased with a larger individual egg mass. Our continuing research will collect many more samples under a more rigorous and expanded sampling design and may or may not confirm these preliminary results, or new relationships may emerge with our future work.

TITLE: Assessment of PIT tags for estimating exploitation of walleyes in Lake Erie and Saginaw Bay, Lake Huron

PRINCIPAL INVESTIGATOR(S): Chris Vandergoot[1], Dan Isermann[1], Brian Locke[2], Bob Haas[3], David Fielder[3], Don Einhouse[4], Roger Kenyon[5]

POSTDOCTORAL RESEARCHER(S):

GRADUATE RESEARCH ASSOCIATE(S):

AFFILIATION(S): [1]Ohio Department of Natural Resources, [2]Ontario Ministry of Natural Resources, [3]Michigan Department of Natural Resources, [4]New York Department of Environmental Conservation, [5]Pennsylvania Fish and Boat Commission

YEAR STARTED: 2005
YEAR ENDED: 2007
RESEARCH STATUS: Upcoming research

SUMMARY: Walleye in Lake Erie and Saginaw Bay, Lake Huron are tagged annually with jaw tags by the Ontario MNR, Michigan DNR, Ohio DNR and the New York DEC. The primary purpose of this interagency effort is to estimate survival, exploitation and movement of walleye within Lake Erie and Lake Huron and surrounding waters as an element of the Lake Erie Committee's (LEC) walleye stock assessment program. An ongoing issue among members of the LEC Walleye Task Group (WTG) concerns tag retention rates and implications for measurement of mortality parameters. Concerns stemmed from scientific studies documenting jaw tag loss in other walleye populations and field observations within Lake Erie. We will evaluate internal tags that exhibit relatively high retention rates and may mitigate errors associated with non-reporting. Harvested fish would be analyzed for tags by agency personnel rather than relying on fishers recognizing and reporting tags. Walleyes from several stocks in Lake Erie and Lake Huron will be tagged with an external jaw tag and an internal (passive integrated transponder) PIT tag. Biologists from the OMNR, MDNR, ODNR and NYSDEC will apply PIT tags to approximately fourteen thousand walleyes each year for three years;

both tag types will be applied to a sub sample of fish. Tagging will occur during the spawning period when stocks are spatially segregated. Fish harvested from both recreational and commercial fisheries will be examined for PIT and jaw tags. The objectives of the study are to: 1) assess the use of PIT tags for estimating walleye exploitation and mortality rates in Lake Erie and Saginaw Bay, Lake Huron, 2) assess temporal patterns in loss rates of jaw and PIT tags, 3) determine walleye exploitation rates and stock contribution for different fishery components and 4) obtain information regarding walleye movement patterns in each lake.

TITLE: Spatial and Temporal Dynamics of the Lake Erie Walleye Fishery

PRINCIPLE INVESTIGATOR(S): Dr. Patrick Sullivan

POSTDOCTORAL ASSISTANT:

GRADUATE RESEARCH ASSOCIATE: James Murphy

AFFILIATION: Cornell University, Department of Natural Resources

YEAR STARTED: 2002
YEAR ENDED: 2004
RESEARCH STATUS: On-going

SUMMARY: Seasonal movement models of adult Lake Erie walleye are being constructed through analysis of the intra-agency Lake Erie walleye tagging data. Spatial strata include areas upstream of Lake Erie (Detroit River-Lake St. Clair-St. Clair River-southern Lake Huron) and the three basins of Lake Erie, subdivided by the international boundary. Commercial and sport angling effort data are the primary data inputs in addition to the tagging data. Estimation of movement probabilities and their associated uncertainty terms, based on origin (spawning location), biological attributes of (length, sex) and season, is the primary objective of the project. Preliminary results show a large scale movement of western basin spawners out of the western basin (50 to 90 percent depending on size) soon after the spawning period to the eastern portions of the lake and to upstream areas. Fish length is significantly related to movement probabilities with more large fish moving further eastward and smaller fish moving more to upstream areas. Directed movements with basins are less resolved and significant patterns have not been detected. The incorporation of the estimated movement into future catch-at-age models will be analyzed. Expected completion date is July/August 2004.