Decision Analysis Application

for Lake Erie Walleye Management:

Final Report to the Lake Erie Committee

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INTRODUCTION

Fisheries science is not exact. Fish populations vary naturally both in space and over time. Data collected are not always precise and can be plagued by measurement error, missing data points, and limited sample sizes. Predictive tools may rely on broad assumptions or on data with much variability. Tools available to managers and researchers and their analytic and predictive capabilities become more refined over time. New technologies, techniques or shifts in thinking may change the way populations are defined and managed. Management goals or policies may change over time or may be different between adjacent jurisdictions. All of the above factors, and many more, can influence fisheries management decisions. Recently, fisheries managers have begun to explore the use of formal Decision Analysis tools used frequently in business situations, to help with complex or controversial issues.

Decision Analysis (DA) models are developed to help reduce complex decisions into manageable components, allowing for the 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. To break complex problems into manageable portions, DA uses a series of steps:

1. Management objectives,
2. Management options,
3. Unresolved uncertainties (uncertain states of nature),
4. Probabilities on the uncertainties,
5. Model to calculate the outcome of each management option for each uncertainty,
6. Decision tree,[1]
7. Ranked management options,
8. Sensitivity analysis (Peterman and Anderson, 1999).

The DA process forces managers to clearly identify, to themselves and to stakeholders, management objectives and management options. A formal process enables managers to recognize how uncertainty is included in complex issues, how uncertainties can be quantified, and how they are used to inform fisheries management decisions. In the end, DA will not give final management policies to managers. However, DA will help managers make more informed decisions by taking into account more information in ways not previously quantified or available.

The Lake Erie Committee (LEC) decided to explore the use of DA to help incorporate uncertainty into decision making, to include the knowledge of risks involved in various decision alternatives, and to improve the transparency to stakeholders regarding the decision process and the rationale that supports decisions regarding walleye quotas.

[1]This step was not used in the LEC DA initiative.

FORMAT OF THE DECISION ANALYSIS INITIATIVE

Management objectives

Management objectives are defined so they are clear and unambiguous criteria for ranking management options. The LEC agencies developed objectives for their own respective walleye fisheries. The objectives were targets based on harvest and abundance targets rather than ecosystem objectives. These objectives were then combined by the LEC into population categories in 2004[2] as follows:

<15 million walleye	- population in crisis
15-20 million walleye	- population in rehabilitation
20-25 million walleye	- population provides low quality fisheries
25-40 million walleye	- population in maintenance and provides fisheries that meet the objectives stated by LEC member agencies
> 40 million walleye	- population provides high quality fisheries.

An explicit LEC 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

Management options are the alternatives from which the recommended management action will be chosen. Variation in target fishing mortality rates were chosen to be modeled. This included the use of a fixed management option approach and a feedback management option approach. With a fixed approach, the target fishing mortality rate remains constant regardless of the abundance of walleye. In contrast, a feedback, or state-dependent approach, allows the fishing mortality rate to vary with population abundance (e.g., a lower fishing mortality rate is used when the walleye population is small and a higher fishing mortality rate is used when the walleye population is large).

There are advantages and disadvantages to both approaches. An advantage of the fixed approach is that it is simple to implement and may, depending on the dynamics of the fish population, result in more stable harvests than a feedback approach. In addition, under constant rate policies, errors in abundance estimates lead to fishing rates that depart less from target fishing rates compared to feedback policies under the same circumstances. The main disadvantage to a fixed approach is that harvest is likely to be lower at high population abundances and higher at low population abundances than if a comparable feedback approach was used. The use of higher exploitation rates used at low population abundance levels has the potential to inhibit or delay rehabilitation.

An advantage of the feedback approach option is that it allows the fishery to safely exploit the resource when abundance is high, while limiting exploitation during low population abundances. Another advantage is that this option enables harvest to be reduced during periods of lower abundance to allow for more rapid recovery when combined with suitable recruitment. The main disadvantage of a feedback approach is that altering fishing rates with changing abundance may

[2]The population abundances shown here refer to AD Model Builder runs using data up to, and including, 2003.

result in larger decreases (or increases) in harvest from year to year than a constant fishing rate, making this option potentially difficult to implement.

Unresolved uncertainties (uncertain states of nature)

Uncertain states of nature are the parts of an analysis that are explicitly considered unsure. Several uncertainties were incorporated into the DA including: catchability, selectivity-at-age, natural mortality, current abundance, stock-recruitment relationship, and the relationship between angler effort and abundance. The DA Team contributed to discussions on each uncertainty incorporated into the decision analysis.

The AD Model Builder stock assessment model used by the Walleye Task Group (a statistical catch-at-age model) was used to obtain point estimates of all parameters after which a Monte Carlo Markov Chain (MCMC) algorithm was used to obtain samples from the joint posterior probability distribution of these parameter estimates. These samples represent our uncertainty about the true values of each parameter. Parameters included catchability, selectivity at age, current abundance, natural mortality, and recruitment (abundance at age 2).

The parameters of a Ricker stock-recruitment model were also estimated based on recruitment and spawning stock abundance estimates from the stock assessment model. Again, uncertainty about the stock-recruitment parameters was evaluated using an MCMC algorithm to generate one thousand combinations of stock-recruitment parameters from their joint posterior probability distributions. The range of stock-recruitment curves produced from these parameters indicated that walleye abundance could be very low before recruitment was substantially affected. Also, the DA model predicted extreme recruitment events that were beyond anything previously observed in Lake Erie. These results stemmed from the assumption that variation in recruitment was lognormally distributed in the Ricker stock-recruitment model. While recruitment patterns from the DA model may be more optimistic than warranted, the model was intended to compare the outcomes of various management strategies. As such, relative performance measures from various management strategies were considered more important than comparisons between historic and modeled recruitment.

Angler effort, in the DA model, was determined from a linear regression of observed angler effort on walleye abundance. However, high angler effort calculated by the DA model at high population abundance values was considered to be inconsistent with current trends in the recreational fishery. In addition, the lognormal error around the stock-recruitment relationship led to unrealistic, high sport harvests in rare instances. Therefore, the upper bound on angler effort was constrained in the model at 15.2 million angler hours.

Lake Erie walleye tag data and literature values were initially used to model the uncertainty in natural mortality (M) of walleye with the recognition that the impact of tag loss, tag induced mortality, and the relevance of literature values to the Lake Erie walleye population, were likely to influence the data set. A distribution of 31 data values was generated with a mean = 0.35 and standard deviation = 0.15. The distribution was composed of values derived from subsets of the full tagging data set, including both riverine and shoal spawning stocks with a wide range in estimates of natural mortality. Because we had limited confidence that the stock assessment data were fully informed and because we felt it was not unreasonable to exclude certain data points in the distribution of M based on information specific to Lake Erie walleye (e.g., that there are old fish in the lake), values of M = 0.6 and M = 0.0 were removed from the distribution. Ultimately, natural mortality was estimated from a prior distribution based on the remaining data, with assumptions of no change in M over time and fidelity to the distribution. Monte Carlo Markov Chain analysis was used to generate a probability distribution for M. The distribution was assumed to be normal with a mean = 0.332 and standard deviation = 0.053. The variation among M values was minor, so M was fixed at 0.332. Since natural mortality was not independent of the stock-recruitment estimates, sensitivity analysis was deemed a better approach to addressing the uncertainty surrounding natural mortality.

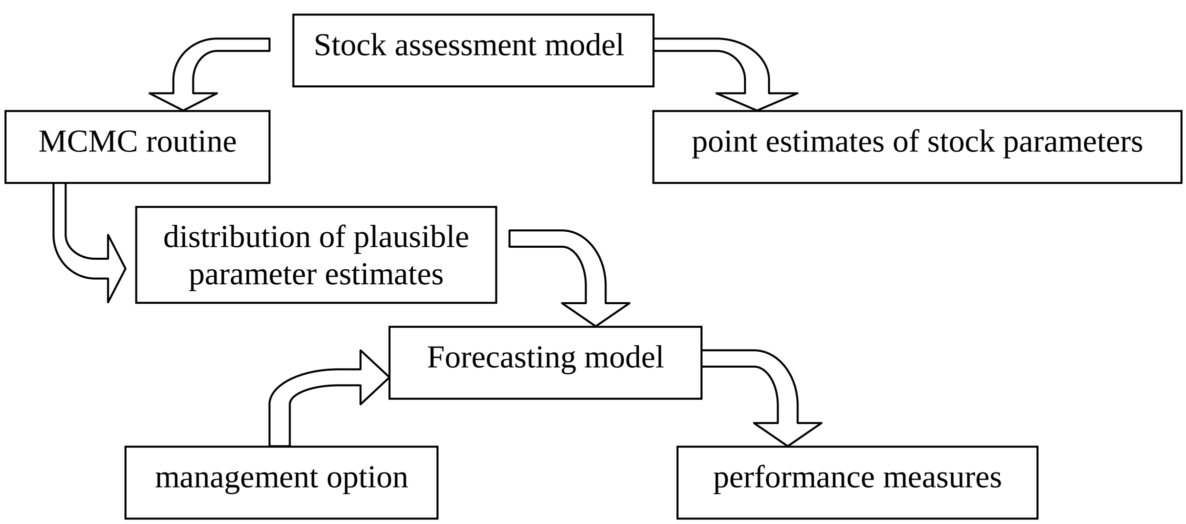
Probabilities on the uncertainties

Probabilities, or measures of how often a particular state will occur, were placed on the uncertainties of the parameters discussed above (catchability, selectivity at age, current abundance, stock size-recruitment relationship, angler effort-abundance relationship, and natural mortality). A probability distribution for all possible values for each uncertain parameter was generated using the MCMC method. This distribution described all possible alternative values for each parameter and the probability that these values would occur in the real world experienced by the Lake Erie walleye population. The DA model used this distribution to obtain a large number of samples of plausible combinations of parameter values. Because of covariance among all parameters (i.e., some parameters may be correlated with others), all parameters were described simultaneously.

Model to calculate the outcome of each management option for each uncertainty

A model was used to calculate the consequences of each combination of a particular management option and each possible state of nature. The model was developed by fishery modeling experts Michael Jones and Wenjing Dai at Michigan State University. Additional assistance was provided by Jim Bence, Michigan State University. Funding for the development came from Great Lakes Fishery Commission Coordinated Activities Program grants. The DA Team provided input during the development of the model.

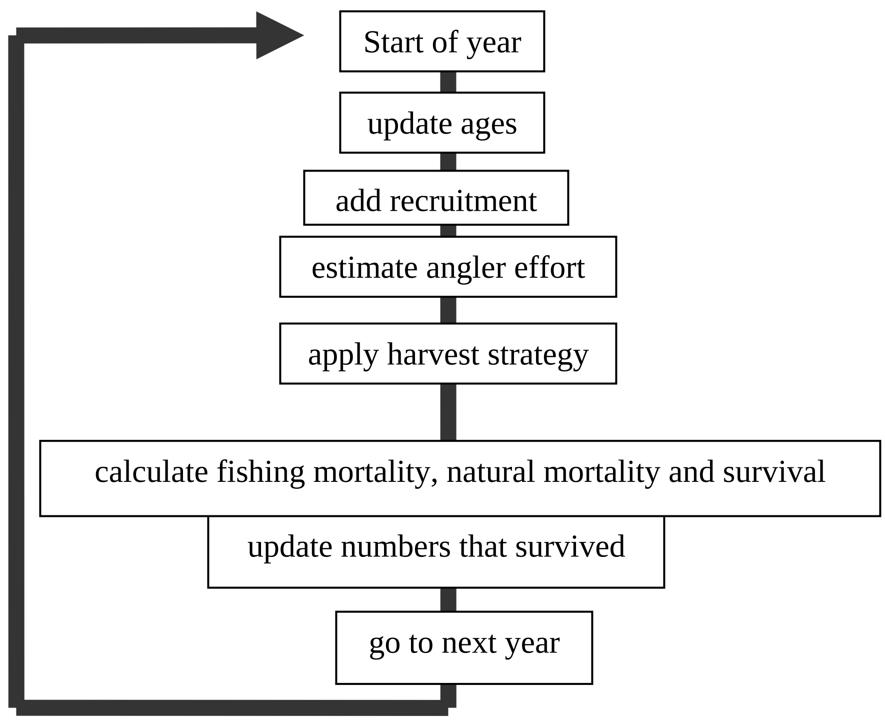
The DA model framework is as follows (from Jones' presentation to the DA Team, June 2004):



The point estimates of stock parameters are the best estimates generated from the stock assessment model. The forecasting or DA model relies on several assumptions. One assumption is that the walleye population will follow a trajectory that is consistent with the historical trajectory for this population. Consequently, the model implicitly assumes there will be no substantial food web changes and no changes to the population structure beyond what has been observed previously.

The DA model is written in Visual Basic embedded into a Microsoft Excel workbook environment. The model uses outputs generated from the statistical catch-at-age stock assessment model and incorporates the outputs into a stochastic forecasting system. In this way the DA model is state dependant and not time dependent. The model evaluates the performance of management options from a variety of performance measures and estimates the risks (e.g., probabilities of persistent low population abundances) associated with management options.

The model was developed to progress through a series of calculations (from M. Jones' presentation to LEC, September 2004, and modified to reflect changes made to the model):



The series of steps shown represents one simulation. For each DA output generated, hundreds of simulations are executed. Fishing mortality was modeled such that effective effort was modified to achieve a target fishing mortality. Ages are updated so that last year's age 4 fish become the following year's age 5 fish. The Ricker model was used to estimate recruitment and the Baranov catch equation was used to estimate harvest. Fishing mortalities for commercial and recreational fisheries were modeled separately and harvests for both fisheries were estimated separately. Commercial fishing mortality was controlled by the management option being evaluated and recreational fishing mortality was controlled by population abundance.

The DA model parameters are based on data up to, and including, 2003. Commercial fishing mortality was modeled using scaling factors that scaled the commercial effort set within the DA model to effort observed in 2003.

It was recommended by the DA modelers that the method used by the Walleye Task Group to calculate lambda weighting values of the data sets used in the statistical catch-at-age assessments be re-evaluated. Lambda values were changed in the DA model to reflect how a few members of the DA Team thought the lambda values should be weighted. However, the DA Team recognized that further work was needed to properly re-evaluate and define the procedures for calculating and presenting lambda values. The Walleye Task Group is expected to take on this task as a formal charge from the LEC in 2005-06.

The stock assessment model and the DA model are used together. Therefore any refinements to one model must be made to the other. The DA model simulations begin at year 3. Population estimates for the first two years of the DA model come from the last two years of data in the stock assessment model. This allows the DA model to begin with the most recent stock abundance estimates available and uses them to generate recruitment values in the simulation. The DA model forecasts for 50 years, thus it generates hundreds of simulations for each year from years 3 through 50. The DA model is informed by data that came from the 2004 stock assessment model runs (i.e., data up to, and including, data collected in 2003)[3].

The majority of work to develop the model took place between November 2003 and December 2004 and was completed at Michigan State University by Michael Jones and Wenjing Dai.

Ranked management options

Management options were ranked by a series of performance measures based on model output that describe 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 >25 million). Performance measures included the average population abundance over time, percent of time the population was below a target threshold (15 million and 25 million 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.

Average and median population abundances over time are shown using output data, but it is also possible to show a single possible future or the variability of possible abundance estimates in any one future year.

The percent of time the population was below a target threshold is a performance measure that quantifies risk. If the population is estimated to be in the crisis category or outside of the objective maintenance/high quality categories for a high proportion of time, the management option associated with the output will not be supported. There is additional risk associated with the population abundance being below a target threshold and remaining below that threshold for

[3]Versions v 5.0, v 6.5 and v 6.6 of the DA model discussed in this report include data from the 2004 stock assessment model that incorporates data up to, and including, data collected in 2003. These versions of the DA model also contained the temporary changes made to weightings on likelihoods (lambda values).

an extended period of time. Three years was chosen as the recovery period because female walleye begin to attain sexually maturity at age 3, changes to sport fishing regulations require 1 to 2 years per jurisdictional procedures, and the desire by fishery managers to take actions to limit poor fishery performance to only that duration (e.g., poor fishery performance for >3 consecutive years was not acceptable for achieving agency objectives).

Additional performance measures were produced for consideration. They included average commercial and recreational harvests over time, distributions of estimated abundance for a particular year, the average number of age classes that contributed to the estimated population and estimated harvests, the age composition of the estimated population and estimated harvests, and the number of times a feedback option is triggered.

Sensitivity analysis

A key step in decision analysis is a thorough sensitivity analysis, which indicates whether the rank order of management options changes under different assumptions. A few members of the DA Team assessed the sensitivity of the DA model during the fall of 2004. During this process the DA model was updated to better reflect observed trends in the Lake Erie walleye population.

Additional sensitivity analyses were suggested during the course of the development of the DA model. One suggestion was to evaluate a series of natural mortality values such as 0.2, 0.3, and 0.4 or to evaluate a range of values from 0.15 – 0.45. Another suggestion was to evaluate how changes to walleye population structure might alter the performance of a management option. A third suggestion was to evaluate the method currently used to weight data sets (i.e., lambda values).

FUNDING FOR DECISION ANALYSIS

Funding for the DA initiative came from the Great Lakes Fisheries Commission Coordinated Activities Program (CAP). The first CAP grant to Michael Jones supported the September 2002 Workshop and supported the initial development of the DA model at Michigan State University. The second CAP grant to Elizabeth Wright and Kurt Newman supported the completion of the model and the second Workshop held in September 2004.

CHRONOLOGY OF DECISION ANALYSIS DEVELOPMENT

Meetings and workshops were held as needed to assist in the development of the DA model.

<u>September 26-27, 2002</u> <u>Workshop I</u>
The first workshop was held to introduce the LEC members and staff to the DA tool and describe how DA could be included in the decision making process when determining annual walleye total allowable catch.

<u>November 5-6, 2003</u> <u>DA Team/Michigan State University Meeting</u>
The first meeting of DA Team members from the LEC agencies and Michigan State University. Model version 4.5 was presented and discussions focussed on Workshop I, modeling sport and commercial fishing mortalities separately, stock-recruitment and natural mortality.

<u>February 2-3, 2004</u> <u>DA Team/Michigan State University Meeting</u>
An updated version of the model was presented and discussions focussed on analysis of spawner stock biomass trends, approaches to modeling sport fishing mortality, alternative harvest options, natural mortality, and the modeling of recreational fishing regulations.

<u>March 8, 2004</u> <u>Presentation to LEC</u>
Michael Jones gave a presentation at the pre-LEC meeting to update LEC members on progress to date on the DA model.

<u>June 29, 2004</u> <u>LEC Meeting</u>
The LEC defined agency objectives and agreed to the objective levels for Lake Erie walleye.

<u>June 30, 2004</u> <u>DA Team/Michigan State University Meeting</u>
An updated version of the model was presented and discussion focussed on recent changes to the model, management scenarios, gaming with the model, model refinement, natural mortality, performance measures, and how average estimated recruitment might trigger a management action.

<u>August 19-20, 2004</u> <u>DA Team Training Workshop</u>
An updated version of the model (v 5.0) was presented and the remaining meeting time was used to tutor a few DA Team members on the functioning and use of the model. Discussions focussed on model functions and on the method used to calculate weighting on likelihoods (lambda values) used in the model. Temporary changes were made to lambda values in the DA model.

<u>September 1-2, 2004</u> <u>Workshop II</u>
The second workshop was held to update the LEC members and staff on the progress to date developing the DA tool and to describe how the LEC could use the DA model to better inform their decisions regarding walleye total allowable catch.

October 19-20, 2004 Walleye Task Group Meeting
The development and gaming with the most recent version of the DA model was discussed at the Walleye Task Group meeting. Several policies with associated risks were presented and discussed.

November 18-19, 2004 LEC Meeting
An update on the gaming progress using the DA model was provided to the LEC. Guidance was given from the LEC to the Walleye Task Group to concentrate on simple feedback options.

December 17, 2004 DA Model Distributed
An updated version of the DA model (v 6.5) was circulated by Michael Jones to the DA Team for use in modeling fishing rate scenarios.

January 20, 2005 LEC Meeting
A meeting was held to describe to LEC members and staff specifically how the LEC could use the DA model in decision making. The LEC members were also given information about how a long-term forecasting tool could be applied to current, short-term, management decisions. Broad management options and associated risks were presented. A sliding fishing mortality approach was developed.

March 7, 2005 Presentation to LEC
The Walleye Task Group presented two feedback management options using sliding fishing mortality, with associated risk outputs from the most recent version (v 6.6) of the DA model to LEC members and staff at the pre-LEC meeting. Another feedback management option was developed that was the product of the two options presented by the Walleye Task Group.

March 18, 2005 Final DA Model Distributed
The final version of the DA model (v 6.8[4]) was provided by Michael Jones to the DA Team.

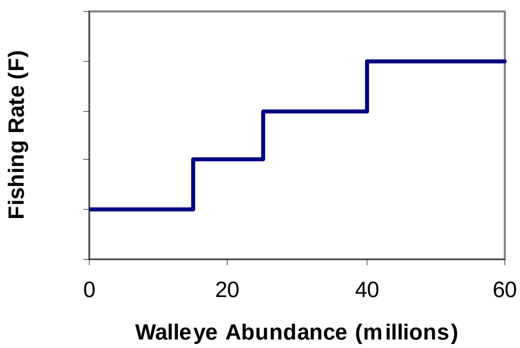
[4]Version v 6.8 of the DA model includes data from the 2005 stock assessment model that incorporates data up to, and including, data collected in 2004. This version of the DA model reverted back to the original method used to calculate weightings on likelihoods (lambda values).

MANAGEMENT OPTIONS

Evaluation of the DA model output showed that there were minor, though not irrelevant, differences, in reaching population targets and thresholds, between fixed and feedback approach options. The LEC decided to use a feedback approach to reduce fishing mortality when the population abundance was low and take advantage of high abundance by increasing fishing mortality. Five management options developed by the LEC, all using a feedback management approach are outlined[5].

Option 1

In the first option fishing mortality (F) changed at clearly delineated stepped intervals. In this option, actual F values were not identified but were multiples of F from the last year of the AD Model Builder run (i.e., 2003).



<15 million walleye - F = 0.5x, a lower fishing rate to cut back
15-20 million walleye - F = x, keeping the same fishing rate as in 20-25 million walleye category but prepare stakeholders if projections estimate future abundance to be below 15 million walleye
20-25 million walleye - F = x, conservative fishing rate
25-40 million walleye - F = 1.5x, a higher, constant fishing rate
> 40 million walleye - F = 2x, a higher fishing rate to take advantage when risk is low

This option was included to illustrate the stepped approach. Subsequent options did not include stepped intervals because the LEC decided that this approach may be more difficult to implement and had the potential to create confusion. For example, population abundances that were at the boundary between two fishing mortality rates could be argued to belong to different categories (e.g., 25 million walleye could be considered in the 20-25 million walleye category with an F=x, or in the 25-40 million walleye category that had an F=1.5x). Furthermore, the large decrease (or increase) in fishing rate between steps could negatively impact both the commercial and sport fishing industries.

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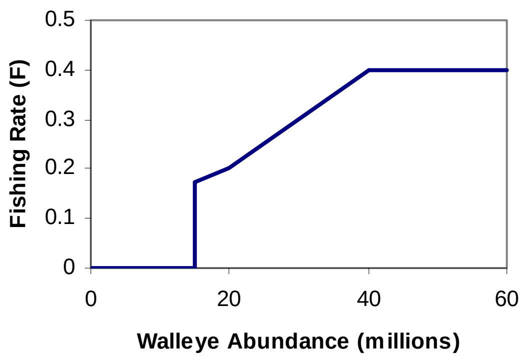
[5]During the development of the model, members of the DA Team did develop a variety of other management options that were not presented in this report.

Option 2

In the second option fishing mortality was fixed when the population abundance was <15 million or >40 million walleye. When the population abundance was in the crisis category of <15 million walleye, no fishing was permitted. The upper fixed fishing mortality, for population abundances in the high quality fisheries category, was set at a rate that was consistent with commercial harvest of $F_{0.1}$. At abundance levels in the middle range from 15-40 million walleye, the approach used variable fishing mortality, or sliding F, that scaled with the population abundance. In the rehabilitation category, there was a narrow range of F values chosen to allow a rapid response to lowering population abundances. A wider range of F values were used when the population abundance was in the low quality fisheries and maintenance categories.

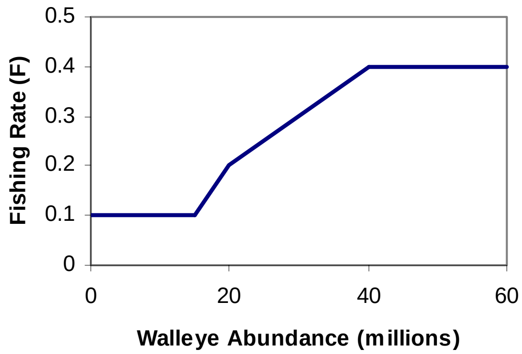


<15 million walleye - F = 0.0
15-20 million walleye - F = 0.175 – 0.2
20-40 million walleye - F = 0.2 – 0.4
> 40 million walleye - F = 0.4

Option 3

In the third option fishing mortality was fixed when the population abundance was within the crisis category, <15 million, at a rate that was lower than rates used during the Coordinated Percid Management Strategy[6]. A fixed rate was also used when abundance was >40 million walleye. As in the previous option, a fishing mortality rate consistent with commercial harvest of $F_{0.1}$ was applied in the high quality category. At abundance levels in the middle range from 15-40 million walleye, the approach used variable fishing mortality, or sliding F, that scaled with the population abundance. Fishing mortality in this option differed from the previous option when the population abundance was 15-20 million walleye by using a wider, and lower, range of F values. In the maintenance category fishing mortality remained the same as in the previous option, ranging from 0.2 to 0.4.

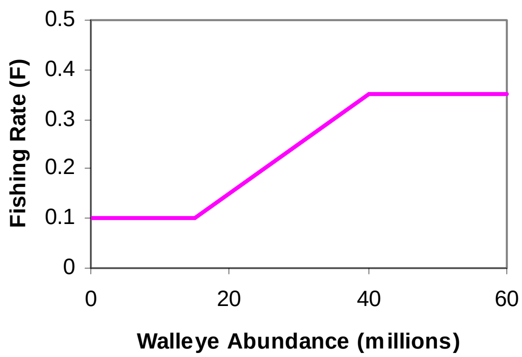
[6]Targeted F values for Coordinated Percid Management Strategy years 2001 targeted F=0.144; 2002 targeted F=0.187; 2003 targeted F=0.250. Mean F=0.194.



<15 million walleye - F = 0.1
15-20 million walleye - F = 0.1 – 0.2
20-40 million walleye - F = 0.2 – 0.4
> 40 million walleye - F = 0.4

Option 4

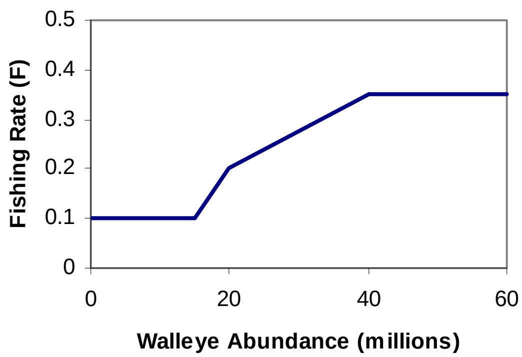
In the fourth option fishing mortality was fixed when the population abundance was <15 million or >40 million walleye. As in Options 2 and 3, when the population abundance was within the crisis category the fishing mortality rate was set at a rate that was lower than rates used during the Coordinated Percid Management Strategy. In the high quality fishing category fishing mortality rate was set at a level consistent with the mean F value for fully recruited walleye caught in 1978-2004. In this option the sliding F values extended from F=0.1 to F=0.35. This option was generally considered to be more conservative than Option 3 and provided more fish of older ages. The intention behind increasing the numbers of older walleye in the population was that more of the older walleye would migrate into the central and eastern basins and support fisheries in those basins.



<15 million walleye - F = 0.1
15-40 million walleye - F = 0.1 – 0.35
> 40 million walleye - F = 0.35

Option 5

The fifth option combines Options 3 and 4 with fishing mortality fixed in the crisis and high quality population categories. When the population was <15 million walleye, F was lower than rates used during the Coordinated Percid Management Strategy. At population abundances >40 million walleye the fishing mortality rate was set at a level consistent with the mean F value for fully recruited walleye caught in 1978-2004. At abundance levels from 15-40 million walleye, the approach used variable fishing mortality, or sliding F, that scaled with the population abundance. Fishing mortality in this option declined relatively quickly as abundance decreased from 20 million to 15 million walleye. When the population ranged from 20-40 million walleye the fishing mortality rate varied from 0.2 to 0.35.



<15 million walleye - F = 0.1
15-20 million walleye - F = 0.1 – 0.2
20-40 million walleye - F = 0.2 – 0.35
> 40 million walleye - F = 0.35

PERFORMANCE MEASURES

The outcomes from the DA model can be compared among management options to evaluate their performance at achieving management objectives (e.g., a walleye population >25 million), including the performance of each option at recovering from population abundances in the crisis level and return to maintenance or high quality fisheries categories. The performance measures can also be used to show differences among options.

Each execution of the DA model ran 990 simulations generating output that showed possible future states projected 50 years into the future. DA model version v 6.6 was used to generate output values for a variety of performance measures shown in the following table for each management option.

Performance measure[7]	No fishing	Option 1	Option 2	Option 3	Option 4	Option 5
mean number of 2+ walleye (in millions)	60.8	48.6	46.3	46.1	48.0	47.4
mean number of 4+ walleye (in millions)	33.7	16.9	14.9	14.8	16.2	15.8
% years below 15 million walleye	0%	0.9%	1.2%	1.3%	0.7 %	1.0 %
% of years <15 million walleye that abundance remained <15 million for 3 or more years	0%	3.7%	2.9%	2.7%	3.2 %	4.0 %
% years below 25 million walleye	2.7%	13.4%	16.9%	16.8%	13.8 %	15.3 %
% of years <25 million walleye that abundance remained <25 million for 3 or more years	7.8%	12.1%	11.9%	12.5%	11.5 %	11.5 %
Mean harvest for sport and commercial fisheries combined (in millions)	0	8.3	9.7	9.7	9.4	9.4

The long-term performance of a chosen management option is applied to the current knowledge of the walleye population using the statistical catch-at-age stock assessment model. Data on the current and projected short-term future of the walleye population will be used to calculate total allowable catch of walleye using the fishing mortality strategy outlined in the chosen management option.

[7] All performance measures data presented in this table was generated using DA model v 6.6 that includes data from the 2004 stock assessment model, incorporating data up to, and including, data collected in 2003, and includes the temporary changes made to weightings on likelihoods (lambda values).

2005 CHANGES TO THE DA MODEL

The final version (v 6.8) of the DA model was updated in March 2005 to incorporate 2004 walleye data. Natural mortality was no longer modeled as an uncertainty upon recommendation from the Walleye Task Group. The Walleye Task Group decided that the DA modeled point estimate of natural mortality was not substantially different from the value that had been used in recent years (i.e., M=0.32) and that there was insufficient rationale for a change to the modeled value for natural mortality. The value M=0.32 had good foundation when determined originally using tag data and had consistently been used for stock assessment. Therefore, the value used in catch-at-age assessments would continue to be M=0.32 and this value of M would also be used in the DA model.

Version 6.8 used the original method of calculating data set weighting lambdas, as used by the Walleye Task Group in the stock assessment model. Alteration to the method used to calculate lambdas was deferred to 2006 when a complete evaluation could be made.

Changes to the DA model meant that the model needed to be run again for each management option. Option 1 was not modeled again. Each execution of the DA model ran 990 simulations generating output that showed possible future states that projected 50 years into the future. DA model v 6.8 was used to generate output values for the performance measures shown in the following table.

Performance measure[8]	No fishing	Option 2	Option 3	Option 4	Option 5
mean number of 2+ walleye (in millions)	51.5	42.1	41.9	43.0	42.6
mean number of 4+ walleye (in millions)	29.1	14.1	14.1	15.2	14.8
% years below 15 million walleye	0	1.3	1.4	0.8	1.1
% of years <15 million walleye that abundance remained <15 million for 3 or more years	2.9	1.7	2.0	2.8	3.5
% years below 25 million walleye	8.6	20.2	20.1	17.8	18.0
% of years <25 million walleye that abundance remained <25 million for 3 or more years	15.5	14.0	14.1	13.7	14.2
Mean harvest for sport and commercial fisheries combined (in millions)	0	8.3	8.3	7.8	8.0

[8]Performance measures data presented in this table was generated using DA model v 6.8 that incorporated data from the 2005 stock assessment model up to, and including, data collected in 2004 and the original method used to calculate weightings on likelihoods (lambda values).

CONCLUSIONS

The DA model describes the long-term outcome of simulated fishing management options. Decisions should be made using the output of the model to rank alternative options based on their performance at achieving clear management objectives. The performance of one option relative to one another may provide valuable information.

The DA model simulations indicated that the Lake Erie walleye population is influenced more by recruitment than by fishing mortality at rates examined by the group. As a result, more than one management option can perform well and meet stated management objectives. Management options may have similar simulated future trajectories, which makes ranking management options difficult particularly when the population abundance is in the crisis level (i.e., <15 million walleye).

Once a management option has been approved, we recommend that it be used for several years before the model is updated and used again. The DA model is designed to be used as a strategic tool, rather than a tactical tool, and should be used to evaluate new management options or to re-evaluate a management option based on new information. The DA model is applicable to the Lake Erie walleye population until additional information is provided that might change what is currently known about this population (e.g., additional information on natural mortality, stock structure, etc.).

It is important to recognize that in the first few years of implementation of a new management option, the walleye population will be driven by the current situation (i.e., the structure and abundance of the population at the time that a new management option is initiated). Therefore, the effects of a new management option on the population may not be evident for several years.

The LEC decided to proceed with Option 5 in 2005 (<15 million walleye F = 0.1; 15-20 million walleye F = 0.1 – 0.2; 20-40 million walleye F = 0.2 – 0.35; > 40 million walleye F = 0.35). This option was designed to reduce exploitation when walleye abundance was low, and safely exploit the resource when abundance is high. This option enabled older walleye to survive and migrate eastward to support central and eastern basin fisheries and create a broad distribution of benefits throughout the lake consistent with Lake Erie Fish Community Goals and Objectives (Ryan et al., 2003).

The use of DA in fisheries management has increased in recent years and is intended to help managers make better informed decisions and help them to share the rationale for their decisions with stakeholders. Implementing management options that have been evaluated using a DA model does not guarantee a specific outcome. Despite better informed decision making, poor recruitment or errors in estimations could still occur. However, modeling uncertainty has helped to quantify unknowns specific to the Lake Erie walleye population and has provided managers with informed expectations of a resource that is constrained by recruitment and mortality. Perhaps more importantly, the DA process has been openly discussed among LEC managers and with stakeholders. Management objectives were developed and shared with stakeholders reflecting a substantial move toward increased transparency with stakeholder groups.

Performance measures used to evaluate management options were identified and shared with stakeholders, further improving the transparency of the decision making process.

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