Lake Erie Yellow Perch Management Plan
2020-2024

Lake Erie Committee
Great Lakes Fishery Commission

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Table of Contents

1. Introduction

The Lake Erie Committee's (LEC) Yellow Perch Management Plan 2020-2024 (YPMP) establishes objectives for population and fishery sustainability and quality based upon historic population status and fishery performance, along with fishery metrics developed in consultation with the Lake Erie Percid Management Advisory Group (LEPMAG). The YPMP will be evaluated in five years to determine if it has met fisheries performance objectives. Acronyms and abbreviations used in the YPMP are defined in Table 1.

2. Yellow Perch in Lake Erie

Since the early 1900s, Lake Erie yellow perch (*Perca flavescens*) populations and fisheries have undergone dramatic changes. Wide fluctuations in harvest have been attributed to highly variable recruitment patterns, changing lake productivity conditions, high levels of exploitation, and changes in targeted fishing rates (Leach and Nepszy 1976; Nepszy 1977). Yellow perch have demonstrated resilience to several invasions of exotic species, including white perch (*Morone americanus*), dreissenid mussels (*Dreissena polymorpha*, *D. rostriformis bugensis*), the spiny water flea (*Bythotrephes longimanus*), and the round goby (*Neogobius melanostomus*). Lake Erie does not have a large population of alewife (*Alosa psuedoharengus*), sparing its yellow perch from the deleterious effects of alewives evident in other Great Lakes populations (Eck and Wells 1987).

In general, Lake Erie yellow perch exist at high abundances in the west and central basins where waters are shallow, warm, and productive. In the deeper east basin, yellow perch exist at lower abundance, mostly confined to the nearshore zone (depth < 30 m) including in and adjacent to Long Point Bay (MacGregor and Witzel 1987; OMNR 2006). Because yellow perch are relatively short-lived (rarely > age-10), fisheries performance generally tracks strong year classes and declines are inevitable following several years of poor recruitment.

For fisheries management purposes, the Lake Erie population of yellow perch consists of four discrete sub-populations (stocks) of differing biological characteristics (e.g., recruitment, growth, movements). These stocks are classified under four Management Units (MU): west basin (Management Unit 1 or MU 1), west-central basin (Management Unit 2 or MU 2), east-central basin (Management Unit 3 or MU 3), or east basin (Management Unit 4 or MU 4) (Fig. 1). All four stocks and their associated fisheries are assessed annually by LEC agencies to generate estimates of stock abundance (Fig. 2, see later sections for details) and fishery performance, which generally track changes in recruitment patterns over years. Assessment data are summarized in annual reports of the Yellow Perch Task Group (YPTG) to the LEC (http://www.glfc.org/lake-erie-committee.php).

Through the 1970s and 1980s, stock abundance was relatively high in western areas (MU 1, MU 2) and low in eastern areas (MU 3, MU 4). All stocks were of relatively low abundance in the mid-1990s but became increasingly abundant during the 2000s (except MU 1), before declining again through 2015. Since 2015, abundance has increased in some areas (MU 1, MU 4) or remained consistent (MU 2, MU 3). Most recently (2019), abundance was below-average in western areas (MU 1, MU 2) and above-average in eastern areas (MU 3, MU 4) relative to 1975-2018 average values.

3. Fisheries Management through the Lake Erie Committee

3.1 Agency involvement

The LEC is a bi-national committee of state and provincial fisheries agencies operating under the auspices of the Great Lakes Fishery Commission (GLFC) and guided by *A Joint Strategic Plan for Management of Great Lakes Fisheries* (GLFC 2007) to cooperatively manage fish communities and fisheries in Lake Erie. The LEC agencies include the Michigan Department of Natural Resources, the New York State Department of Environmental Conservation, the Ohio Department of Natural Resources, the Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry, and the Pennsylvania Fish and Boat Commission. The LEC has developed Fish Community Objectives (FCOs; Francis et al. 2020) to guide cooperative management of shared fishery resources. Staff members from each agency serve on various sub-committees that advise the LEC, including the YPTG and an over-arching Standing Technical Committee (STC).

Sustainable yellow perch fisheries of high-quality are enormously important to all LEC jurisdictions. Fishery mortality is managed cooperatively through an annual designation of Total Allowable Catch (TAC) for stocks of the four MUs, as described earlier. The TAC is allocated as harvest quotas among agencies within a MU, in accordance with agency proportional shares of lake surface area in that MU (Table 2; STC 2007; YPTG 2020). Agencies are responsible for regulating their fisheries as necessary to not exceed quotas. When designating the annual TACs, the LEC considers sustainability of the yellow perch population and social-economic benefits to all jurisdictions through a fair, transparent, and biologically-justified process. This process requires a management strategy with clear objectives to help the LEC reach informed consensus on TAC decisions, in concert with prescribed FCOs.

3.2 Indigenous Communities

Lake Erie is within the traditional territory of Attawandaron, Anishnaabeg and Haudenosaunee peoples. Fish and the waters of Lake Erie are important to many First Nations and Metis communities. Indigenous communities possess a wealth of multi-generational knowledge and understandings of Lake Erie’s ecosystem and fish populations. Many Indigenous communities also hold Aboriginal and treaty rights to fish in the waters of Lake Erie. Ontario is committed to respecting these constitutionally protected rights in management planning.

3.3 Stakeholder Involvement

Involving stakeholders in percid management has been a long-term goal of the LEC. Previously, stakeholders were invited to provide comments at the annual LEC meetings, but often the feedback could not be thoughtfully considered at this late stage of the annual TAC setting process. Stakeholders frequently voiced concerns about a lack of transparency and the inability to express their concerns in a timely and official manner. In 2010, the LEC solicited the assistance of Michigan State University’s Quantitative Fisheries Center (QFC) to develop a formalized process for engaging stakeholders (commercial fishers, fish processors, recreational fishers, and charter captains) in walleye and yellow perch management decisions (Kayle et al. 2015, Jones et al. 2016). The interjurisdictional LEPMAG was created from this process and has provided a collective voice from concerned and informed stakeholders.

In 2011, the LEC included agency-appointed stakeholders in a facilitated Structured Decision Making (SDM) process for percid management. Stakeholders represented the commercial and/or recreational fishing interests of their respective jurisdictions, while acknowledging the statutory responsibilities of LEC agencies to manage fisheries, and provided input on harvest policies, fishery performance metrics that informed a Management Strategy Evaluation (MSE), social-economic impacts of a TAC or the TAC-setting process, and informed others in their constituency of the LEPMAG progress.

In 2013, the LEC began an iterative MSE process in coordination with the YPTG, QFC, and the LEPMAG, with a goal of developing a formal Lake Erie Yellow Perch Management Plan. Accomplishments during this process include:

- review of existing YPTG models and data sources and potential modifications,
- review of potential modifications to the YPTG modeling approach, including:
    - incorporating contemporary methods for estimating selectivity, catchability, and multinomial age distribution
    - assessment surveys and spatial differences in the Eastern Basin
    - evaluation of the utility of sex-based models
- implementation of a multi-model inference approach for predicting age-2 recruitment,
- developed stakeholder objectives,
- LEPMAG consultation during QFC development of a new Peterson-Reilly stock assessment model (PR model) and retrospective comparison of performance between the PR model and traditional YPTG model, and

  implementation of a hierarchical stock recruitment curve (MUs 1-3) during the annual target and limit reference point update process for the four stocks.

Beginning in 2017, the LEC directed the YPTG to use output from the PR model for the TAC-setting process. Additional evaluations and refinements of the PR model and its implementation have been ongoing and are detailed below.

4. Developing Harvest Policy

4.1 Harvest Control Rules

Harvest control rules (HCR) are pre-defined management actions designed to achieve fisheries objectives (Acoura 2015). The FCO for yellow perch is to maintain populations that support sustainable commercial and recreational fisheries (Francis et al. 2020). To help achieve this objective, management actions are guided by a series of biologically-based limit reference points that help define the status of the fish stock (Acoura 2015; Cooper 2006; Appendix A). Facilitated by the QFC, the LEC and the LEPMAG explored the impacts of a range of harvest control rules on fishery performance and stock sustainability. Based on this input, the LEC selected harvest control rules for use by the YPTG to estimate an annual Recommended Allowable Harvest

(RAH) range for each MU, consisting of a mean value and range (± one standard error of the mean), by setting the fishing mortality rate relative to stock status and limit reference points. The RAH (mean and range) is informative to the LEC when setting the TAC for each MU.

To guide the selection of HCR, the QFC, with the assistance of the YPTG and input from the LEPMAG, developed the PR model. The PR model is a statistical catch-at-age (SCAA) model built using the Automatic Differentiation Model Builder (ADMB) program. The PR model, as described in YPTG (2020), uses fishery-dependent harvest and effort data from the commercial (gill net and trap net) and recreational fisheries, along with fisheries-independent assessment data (Table 3), to produce age-specific (i.e., ages 2-6+) estimates of yellow perch relative abundance, biomass, survival, and the instantaneous fishing mortality rate (F). Fisheries-independent data also provide recruitment estimates for age-0 and age-1 incoming year classes. Importantly, each MU has a unique PR model that uses MU-specific data input from fisheries dependent and independent surveys.

These stock assessment models form the foundation of the MSE. A MSE for each MU was developed by the QFC to test the possible range of HCR that could be used to set the TAC. A set of fishery-based performance metrics, developed through the LEPMAG, were used to assess which HCRs would best meet management objectives. The following fisheries-based performance metrics were developed for each individual MU:

<u>Sustainability:</u>

- Probability that the spawning stock biomass (SBB) falls below a limit reference point (LRP)

<u>Recreational Fishery:</u>

- Probability that angler harvest per hour (HPE) exceeds three age 2+ fish in MUs 1, 2 & 3
- Probability that angler harvest of fish per hour (HPE) exceeds one age 4+ fish in MU 4

<u>Commercial Fishery:</u>

The Ontario Commercial Fisheries' Association (OCFA) provided a set of probability-threshold performance metrics for each MU, as "a minimum probability for output that is consistent with a desired state of the fishery" (Fig. 3). The QFC used a target distribution to determine whether the probability that a fishing policy meets or exceeds expectations.

- Probability commercial harvest will be greater than the 25th percentile from the OCFA target distribution
- Probability commercial harvest will be greater than the 50th percentile from the OCFA target distribution.
- Probability commercial harvest will meet or exceed the OCFA target distribution.

The Ohio trap net fishery's allocation within an MU has historically been diverted to other MUs if the Ohio quota drops below certain thresholds that cause reductions in recreational fishery daily limits; therefore, these thresholds provide useful performance metrics:

- Probability of Ohio's share of the MU1 TAC falling below 1 million pounds

- Probability of Ohio's share of the MU 2 TAC falling below 700 thousand pounds
- Probability of Ohio's share of the MU 3 TAC falling below 500 thousand pounds

In addition, the results of several other metrics were examined, including mean total abundance and biomass, mean recruitment, mean harvest and effort under various HCR scenarios.

4.1.1 Target Reference Point (TRP)

The TRP establishes the fishing mortality rate when the status of yellow perch biomass is at a sustainable level and fishing quality is considered desirable by stakeholders (Acoura 2015; Cooper 2006). A series of target fishing mortality rates based on a theoretical exploitation rate at maximum sustainable yield (F_{msy}) were explored within the MSE. Initial target fishing rates ranged from 50, 70, 100 and 120% of F_{msy}. Derivation of F_{msy} and B_{msy} (theoretical stock biomass at maximum sustainable yield) are discussed under "*Determining Annual RAH and TAC using HCR*".

Initial MSE results indicated that TRPs between 50 to 120% F_{msy} were not meeting all performance targets. The LEC proposed a suite of alternative TRP scenarios that were more aligned with current exploitation policies and provided a broader range of choices for LEPMAG consultation. Updated fishing rates ranged from 9% to 120% of F_{msy} and varied by MU.

4.1.2 Limit Reference Point (LRP)

The LRP establishes a stock status threshold that represents the point at which reproduction might become impaired (Acoura 2015; Cooper 2006). HCRs should respond to the status of stocks to reduce the level of harvest and ensure that the stock remains productive (Cooper 2006; Jones et al. 2016). Various biomass-based limit reference points were explored and, with LEPMAG endorsement, the LEC adopted an LRP based on a % of yellow perch biomass that promotes maximum growth rate and to deliver the maximum sustainable yield (B_{msy}).

4.1.3 Probabilistic Control Rule (P)*

A probabilistic control rule establishes our risk tolerance of the yellow perch stock falling below the LRP in the year following TAC implementation. This probabilistic control rule is known as P* and is defined prior to any model runs (Jones et al. 2016). If the probability of the spawning stock biomass falling below the LRP is equal to or greater than P*, then the target fishing rate is reduced until the probability is less than P* (Jones et al. 2016).

The LEPMAG initially explored a range of P* from 0.05 to 0.5. However, because yellow perch is managed across four management units, growing concerns were raised about the LEPMAG's capacity to effectively evaluate 40+ scenarios; therefore, the LEC requested that QFC focus on a P* = 0.05. In September 2019, the LEC continued to explore ranges of P*. With the assistance of QFC, additional scenarios were simulated with P* values of 0.1, 0.2 and 0.5, including comparisons between whether P* should override a TAC change constraint (see below) or not.

4.1.4 Annual TAC Change Constraint

Stability in the TAC from one year to the next was identified by the LEPMAG as being beneficial and a desirable outcome to be achieved through the HCRs. TAC stability reduces the frequency of wide swings in annual quota, which helps to preserve market supply and limits fluctuations in annual recreational daily limits. The TAC constraint was not applied to all MSE scenarios during the initial MSE model runs and was further evaluated during subsequent model runs. For yellow perch, a 20% TAC constraint was applied to all MUs.

4.2 MSE Results and Harvest Control Rule(s)

Formalized MSE is one of several structured tools used to guide management decisions. The process of conducting MSE entails construction of a model of the entire management and assessment process, to account for uncertainties in information gathering and implementation, as well as "system uncertainties", culminating in an evaluation of the performance of alternate management procedures through simulations. MSE model runs were completed for 250 iterations over a 25-year time horizon. The ranges and distribution of the simulation results were presented in the form of graphic box- and trade-off plots (Figs. 4-7).

Model results of fisheries performance measures and yellow perch population indicators (abundance, total biomass, recruitment, etc.) were plotted against various fishing rates. Trade-off plots between the probability of angler HPE not achieving its benchmark for a management unit versus the probability of the commercial yield falling below the OCFA harvest target were provided. Trade-off plots between probability of the commercial yield falling below the OCFA target versus the probability that the yellow perch SSB would fall below the LRP were also developed. These summaries were completed for each MU. The QFC also provided the LEPMAG with graphic box-plots comparing the MSE scenario results for specific fisheries performance indicators against current policy, the past 5 years, and over the past 18 years, which reflects a recent period of quality yellow perch fishing (Figs. 4-7).

In November 2018, all LEPMAG members were asked to rank their relative preference (Definitely Don't Favor, Don't Favor, Neutral, Do Favor, Definitely Favor) for each HCR-MSE scenario for each MU. Each MU included 11-13 scenarios spanning a range of target fishing mortalities, each with a fixed LRP (B_{msy}) and risk tolerance (P*=0.05). The LEPMAG survey results were compiled by the LEC and results were shared with the LEPMAG members in January 2019. Although P* of 0.05 was used in 2019, the risk tolerance (P*) was modified to P*=0.2 following additional LEPMAG consultation in October 2019. P*=0.2 will be implemented along with other HCRs starting in 2020 (Table 4).

After careful consideration of LEPMAG members' advice and survey responses, input from the YPTG members, and the LEC's desire for stable, long-term sustainability of yellow perch fisheries, the LEC decided to implement the process and exploitation policies identified below after the explanation of the process used to develop policy options.

4.3 Determining an Annual RAH and TAC using HCR

Using the updated PR model, the YPTG will use the three-step process described in YPTG (2020) to generate reference points and a RAH:

1) Estimates of recruitment and spawning stock biomass generated by the PR model along with other parameters (natural mortality, maturity, weight, and selectivity) will be used to inform the ADMB model that estimates the parameters of the Ricker stock recruitment

relationship and the abundance of spawning stock biomass without fishing (SSB_0) (YPTG 2020). A hierarchical model will be used to fit the stock-recruitment relationships for MUs 1, 2, and 3; the relationship will be fit independently in MU 4.

2) A model with input data for natural mortality, maturity, weight, and selectivity at age, along with the parameters generated by the stock-recruitment relationship, will be used to estimate F_{msy} and B_{msy}.
3) Generated values of F_{msy}, F_{target} (targeted fishing rate as a percentage of F_{msy}; Table 4) and B_{msy} will be entered into the PR model to produce a mean RAH and range (± one standard error of the mean) for consideration by the LEC. The TAC constraint (± 20% bounds from the previous year's TAC for each MU) are calculated outside of the model. If fishing at the estimated F_{target} meets or exceeds the probability (P*=0.2) that the projected spawning stock biomass will be equal to or less than the limit reference point (B_{msy}) during the year following TAC implementation, then the fishing rate is reduced until P* is less than 0.2.

The YPTG will provide the above information to the LEC and stakeholders in presentation and reports leading up to and during spring GLFC LEC annual meetings. The LEC will solicit additional information from stakeholders regarding the social and economic factors for the TAC decision-making process. The LEC will deliberate at the annual meeting and will utilize the information provided by the YPTG (RAH mean, RAH range, 20% constraints and P*) to arrive at consensus TAC decisions using the following sequence:

1) ***If P* is equal to or exceeds 0.2:***
   - the RAH range will be calculated using a reduced fishing rate that will ensure that the probability of the projected spawning stock biomass falling below the LRP is less than P*. The LEC will determine a TAC from within the RAH range.

2) ***If P* is less than 0.2 and the RAH mean is outside the ± 20% constraint bounds based on the previous year TAC:***
   - the RAH will be set at the ± 20% constraint bounds. For example, if the mean RAH is more than 20% greater than the previous year TAC, then the current TAC will be set at 20% more than the previous year TAC.

3) ***If P* is less than 0.2 and the RAH mean is within the ± 20% constraint bounds of the previous year's TAC:***
   - the LEC will establish TAC at the RAH mean.

4) ***In a year following a single year P* TAC reduction when P* is no longer in effect:***
   - the TAC from 2 years prior will be used as a benchmark against which to employ the 20% TAC constraint.

5) ***In a TAC year where P* is not invoked, but P* has persisted for multiple years prior***:
   - the LEC will determine what the TAC would have been using the target F and the 20% TAC constraint for each of the years during that period, thus establishing what can be considered an "assumed TAC". The previous years assumed TAC can then be used as a benchmark for the implementation of the 20% TAC constraint and a new TAC moving forward.

Appendix A provides examples of the five TAC decision scenarios.

4.4 Deviating from HCR and RAH Range

The LEC intends to implement TACs according to the HCR. Deviation from the HCR will only be considered in cases if there is compelling evidence to indicate the sustainability of the yellow perch population is at risk, or if there is strong social or economic rationale to do so. If the LEC chooses this option, clear and fully transparent justification will be provided to stakeholders.

5. Plan Evaluation

As indicated in this plan, key metrics identified by the LEPMAG relate to performance of the fisheries, namely, harvest rates of the recreational and commercial fisheries, the stability of the TACs, and maintaining SSB. If the YPMP exploitation policy works as intended, these metrics should be achieved, with variance from initial TACs driven primarily by short-term annual population fluctuations. Managers and stakeholders are aware that stochastic and often highly variable recruitment patterns will largely dictate the direction of the Lake Erie yellow perch population and its associated fisheries. Any dramatic shift from this paradigm will be driven primarily by changes in carrying capacity or other major ecosystem changes. Because such changes typically occur over multiple years, the effect of the YPMP cannot be understood without the benefit of allowing those years to pass. Therefore, the true test of the policy will be not only to examine whether these objectives are met on an annual basis, but also over a longer time period.

The YPTG will be responsible for preparing a status report evaluating the performance of the YPMP 2020-2024 before the end of 2024. The scope and nature of this evaluation will be determined by the LEC with consultation and involvement of the YPTG and the LEPMAG. The review will include evaluation of plan performance and reporting on fishery performance metrics including:

- Performance of the assessment models.
- Impacts of the exploitation policy implementation on population abundance during the review period.
- Any exceptional circumstances that have been identified over the review period

The next iteration of the YPMP will begin upon completion of the review of this YPMP. Any resulting changes to performance metrics and exploitation policy should, where required, include MSE to fully inform the LEC and the LEPMAG. The LEC reserves the right to adjust any element of the YPMP to protect stock sustainability or adapt to unforeseen stock status during the plan cycle.

6. References

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7. Tables

Table 1. Acronyms and abbreviations used in the Yellow Perch Management Plan 2020-2024.

ADMB	Automatic Differentiation Model Builder
B_{msy}	Biomass at maximum sustainable yield
F	instantaneous fishing mortality rate
FCOs	Fish Community Objectives
F_{msy}	Fishing mortality rate, F, at maximum sustainable yield
F_{target}	targeted fishing mortality rate, F
GLFC	Great Lakes Fishery Commission
HCR	Harvest Control Rules
HPE	Harvest Per unit of Effort
LEC	Lake Erie Committee
LEPMAG	Lake Erie Percid Advisory Group
LRP	Limit Reference Point
MSE	Management Strategy Evaluation
MU	Management Unit
OCFA	Ontario Commercial Fisheries' Association
P*	Probabilistic control rule
PR	Peterson-Reilly
QFC	Quantitative Fisheries Center
RAH	Recommended Allowable Harvest
SCAA	Statistical Catch at Age Model
SDM	Structured Decision Making
SSB	Spawning Stock Biomass
SSB_0	Unfished Spawning Stock Biomass
STC	Standing Technical Committee
TAC	Total Allowable Catch
TRP	Target Reference Point
YPMP	Yellow Perch Management Plan
YPTG	Yellow Perch Task Group

Table 2. Relative yellow perch habitat by surface area and percent in each Management Unit (MU) and jurisdiction used for quota allocation. Yellow perch habitat includes total area within each MU.

Management Unit	Jurisdiction	Surface Area (km^2)	Percent
MU 1	Ohio	1,905.6	50.3
West Basin	Ontario	1,537.1	40.6
	Michigan	344.8	9.1
	Total	**3,787.5**	
MU 2	Ohio	4,175.3	54.4
West-Central Basin	Ontario	3,497.4	45.6
	Total	**7,672.7**	
MU 3	Ontario	4,749.9	52.3
East-Central Basin	Ohio	2,943.7	32.4
	Pennsylvania	1,385.8	15.3
	Total	**9,079.4**	
MU 4	Ontario	2,818.7	58.0
East Basin	New York	1,507.2	31.0
	Pennsylvania	535.6	11.0
	Total	**4,861.4**	

Table 3. Lake Erie agency fishery-independent and -dependent assessment data inputs into SCAA yellow perch models for four Management Units.

<table>
<tr><th rowspan="2">Management Unit</th><th colspan="2"><u>Fishery-Independent Data</u>
(catch per unit of effort)</th><th colspan="3"><u>Fishery-Dependent Data</u>
(harvest and effort)</th></tr>
<tr><th>Bottom Trawl</th><th>Gill Net (fall)</th><th>Commercial Gill Net (effort = km)</th><th>Commercial Trap Net (effort = # lifts)</th><th>Recreational (effort = hrs)</th></tr>
<tr><td>MU 1</td><td>OH/ON August., ages 0,1
OH fall, ages 0,1,2+</td><td>ON Partnership ages 1,2+</td><td>ON annual</td><td>OH annual</td><td>OH annual
MI annual</td></tr>
<tr><td>MU 2</td><td>OH June, age 1
OH fall, ages 0,1,2+</td><td>ON Partnership ages 1,2+</td><td>ON annual</td><td>OH annual</td><td>OH annual</td></tr>
<tr><td>MU 3</td><td>OH June, age 1
OH fall, ages 0,1,2+</td><td>ON Partnership ages 1 2+</td><td>ON annual</td><td>OH annual
PA annual</td><td>OH annual
PA annual</td></tr>
<tr><td>MU 4</td><td>NY fall, ages 0,1 (15-30 m depths)
ON Long Point Bay fall, ages 0,1</td><td>ON Partnership ages 1,2+
ON Long Point Bay ages 1,2+
NY age 1</td><td>ON annual</td><td>PA annual
NY annual</td><td>PA annual
NY annual</td></tr>
</table>

Table 4. Harvest control rules by Management Unit. Reference points (B_{msy} & F_{msy}) are updated annually.

Management Unit	Limit Reference Point (LRP)	Risk Tolerance (P*)	TAC Constraint	Target Fishing Rate (%F_{msy})
MU 1	B_{msy}	0.2	20%	28% of F_{msy}
MU 2	B_{msy}	0.2	20%	35% of F_{msy}
MU 3	B_{msy}	0.2	20%	32% of F_{msy}
MU 4	B_{msy}	0.2	20%	34% of F_{msy}

8. Figures

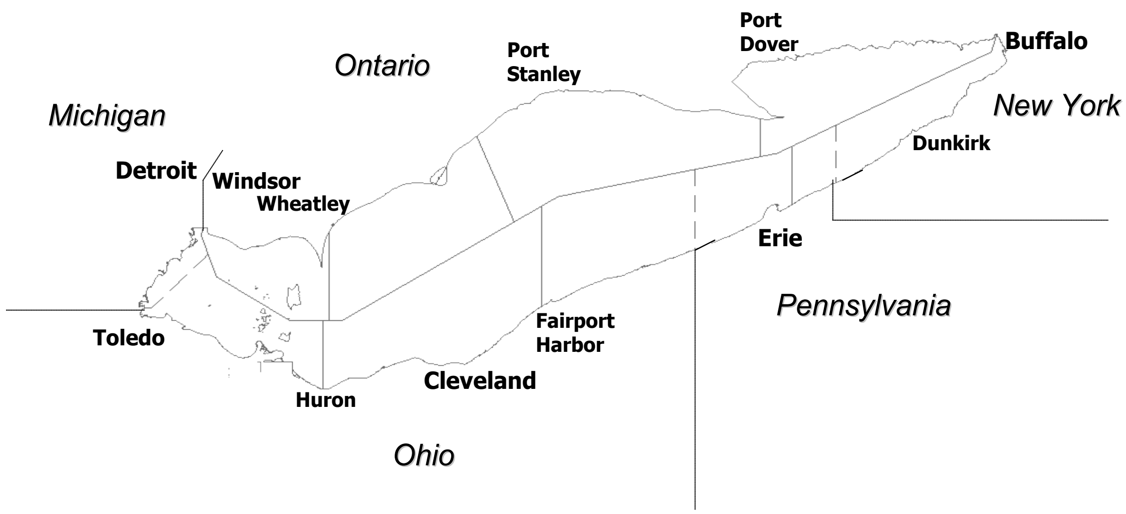


Figure 1. Lake Erie yellow perch Management Units (MUs) defined by the Lake Erie Committee and the Yellow Perch Task Group.

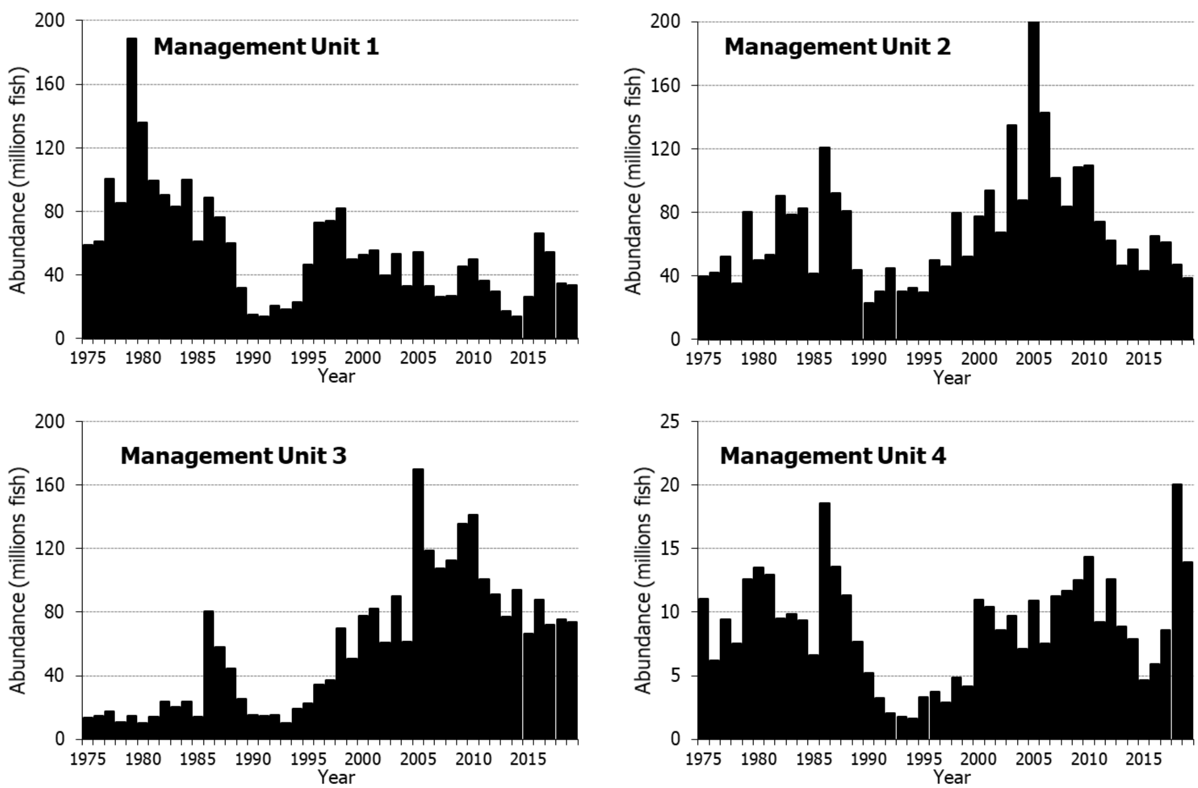


Figure 2. Lake Erie Age 2+ yellow perch population abundance estimates by Management Unit, 1975-2019, from the 2020 PR ADMB model run (YPTG 2020).

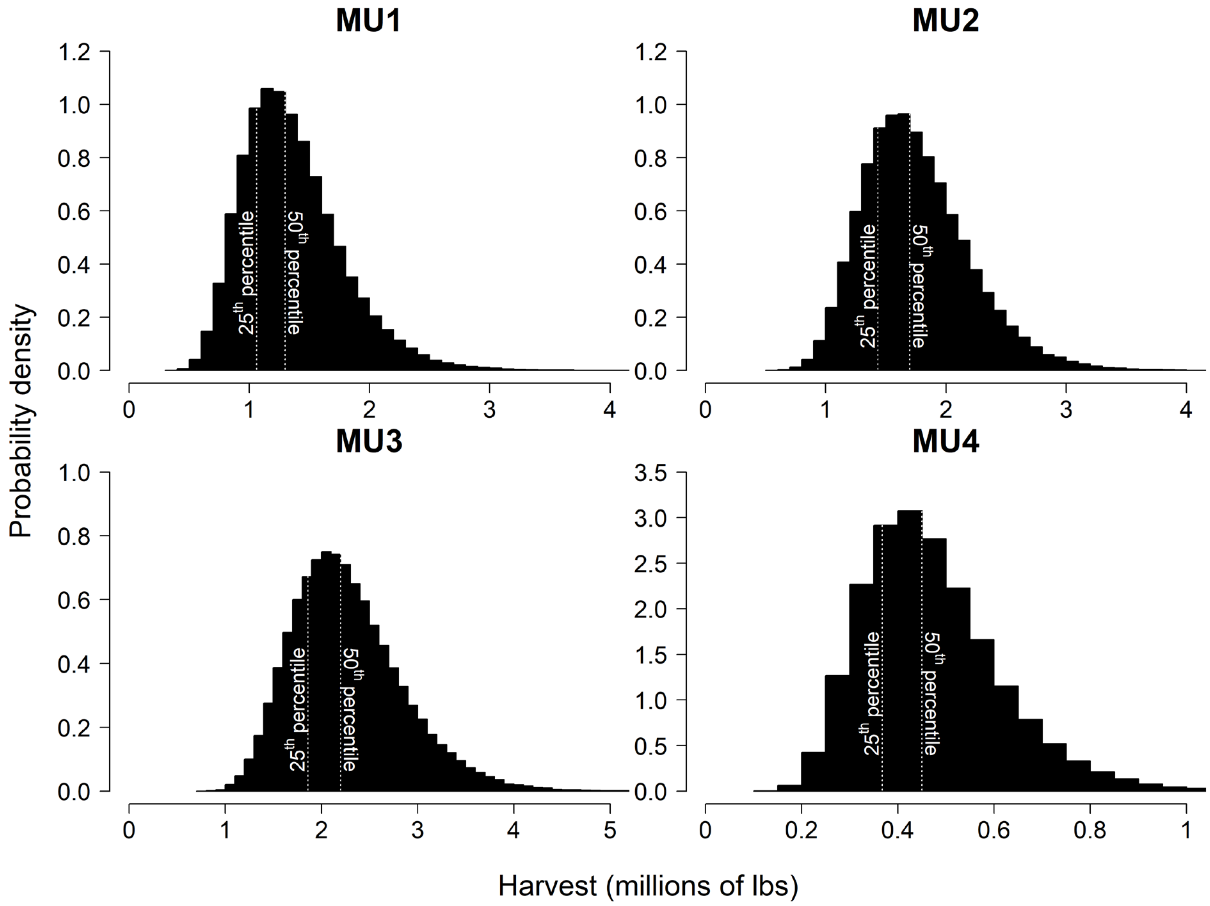


Figure 3. Ontario commercial fishery performance targets based on the probability that commercial harvest will be greater than the 25th or 50th percentile within MUs 1-4 in Lake Erie.

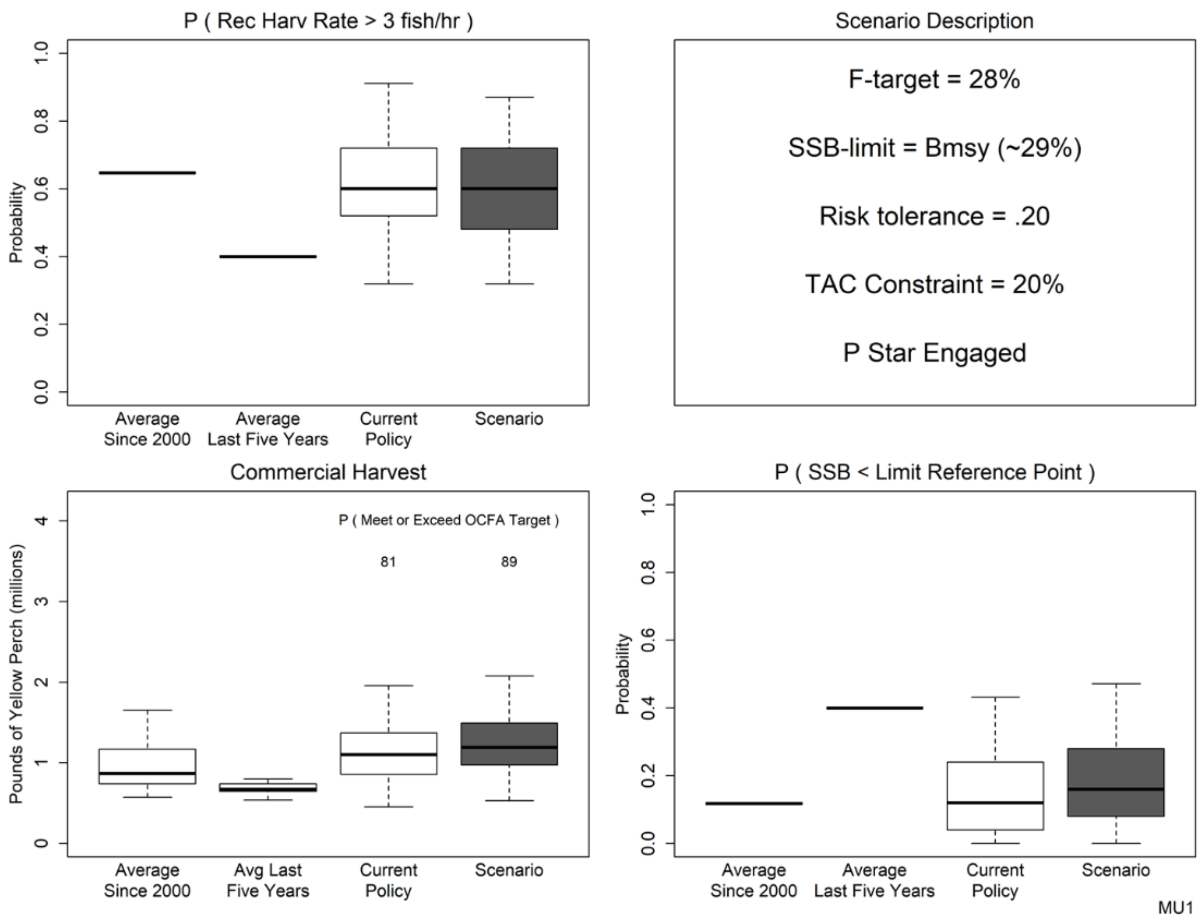


Figure 4. Example of graphic box-plots comparing MSE scenario results for specific fisheries performance indicators against current policy, past 5 years and over the past 18 years for MU1.

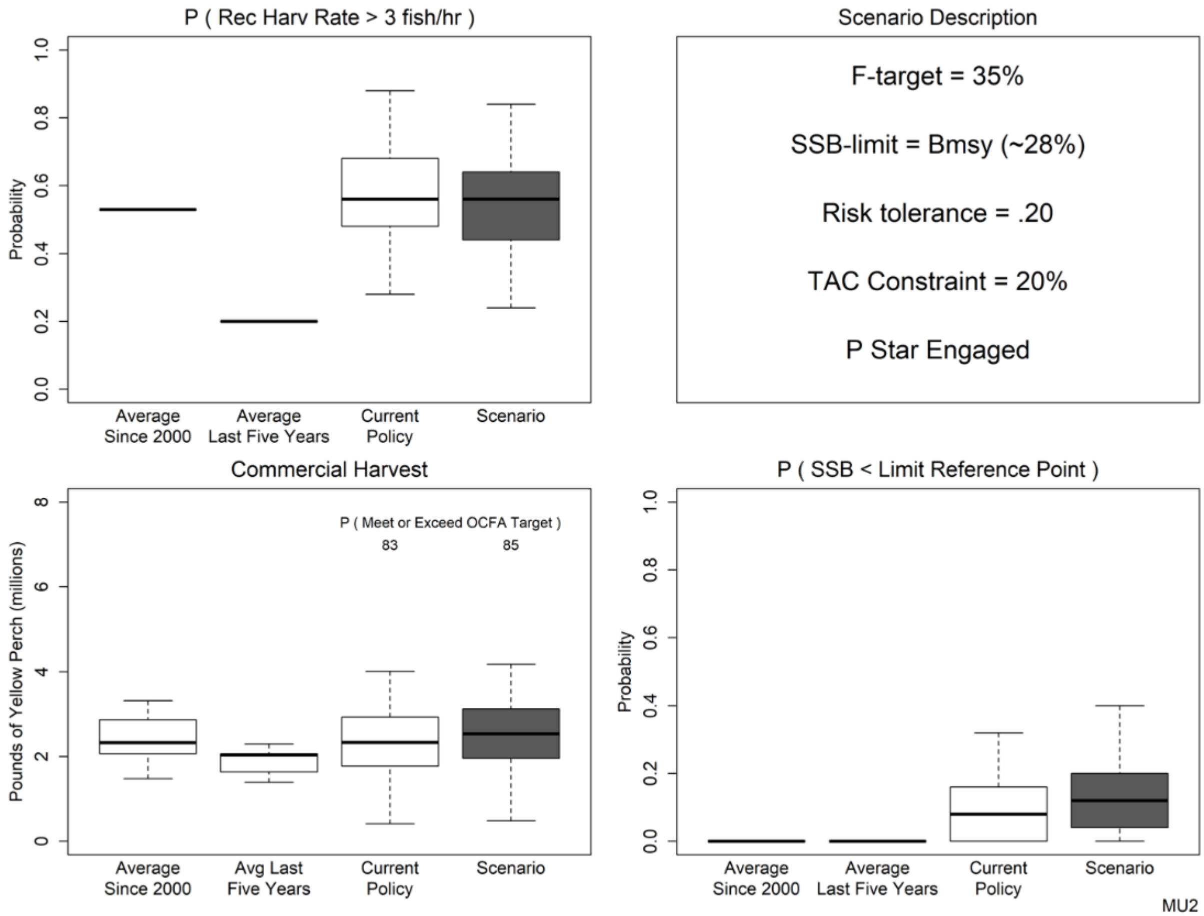


Figure 5. Example of graphic box-plots comparing MSE scenario results for specific fisheries performance indicators against current policy, past 5 years and over the past 18 years for MU2.

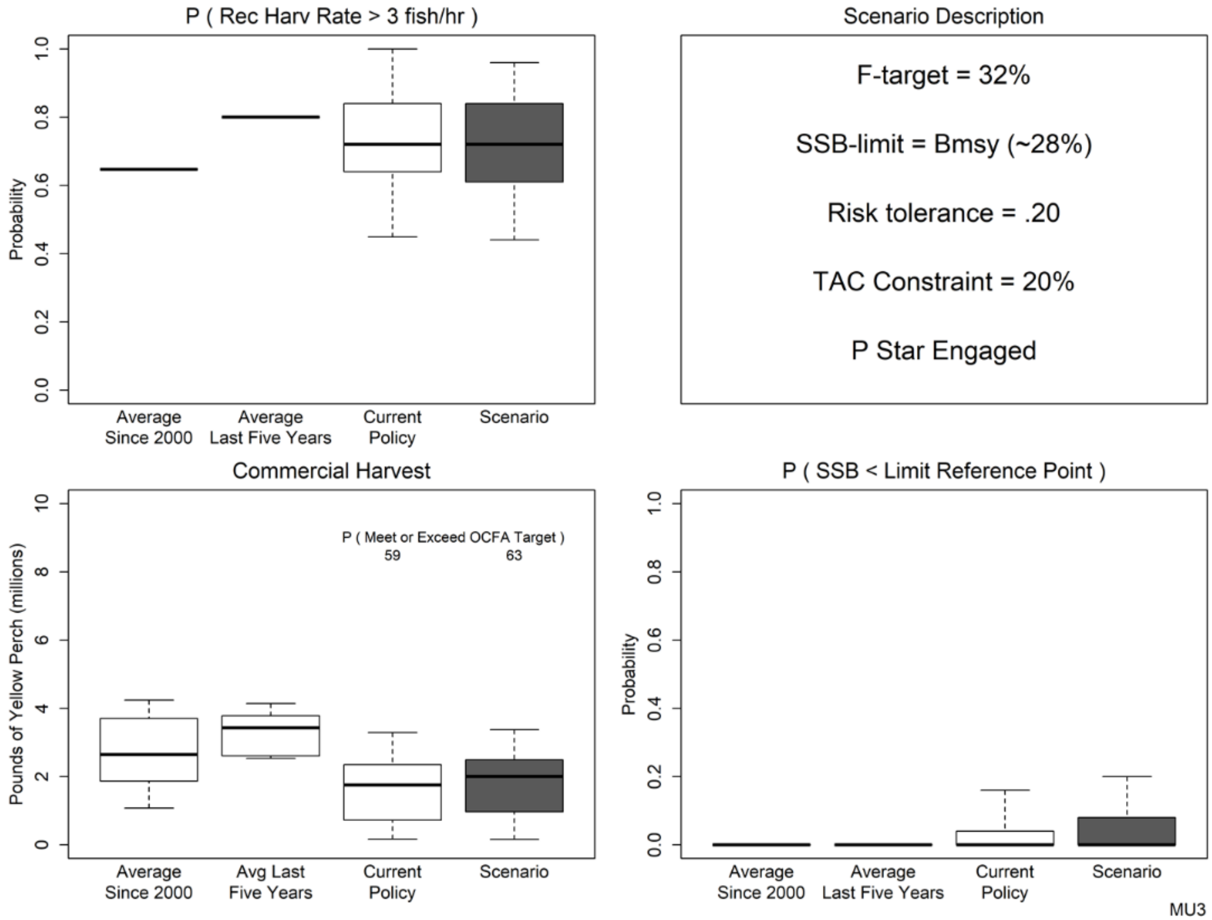


Figure 6. Example of graphic box-plots comparing MSE scenario results for specific fisheries performance indicators against current policy, past 5 years and over the past 18 years for MU3.

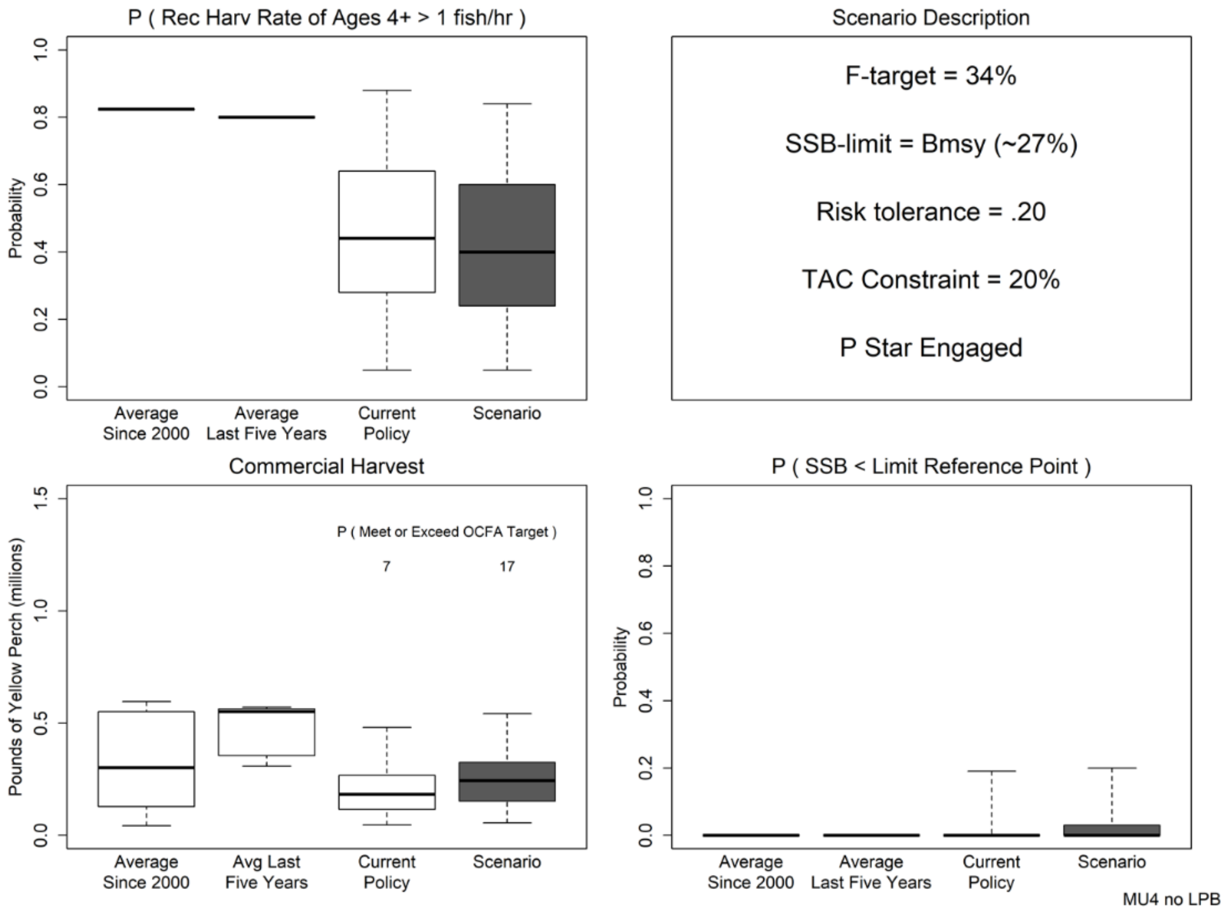
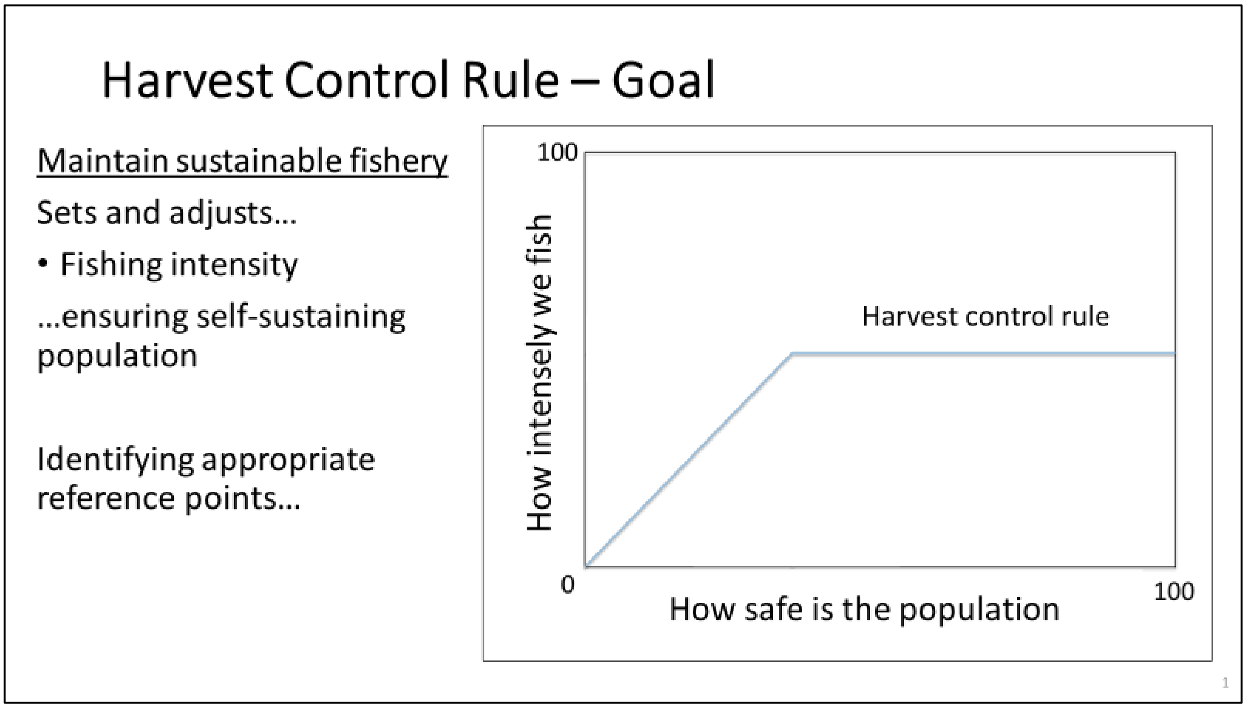
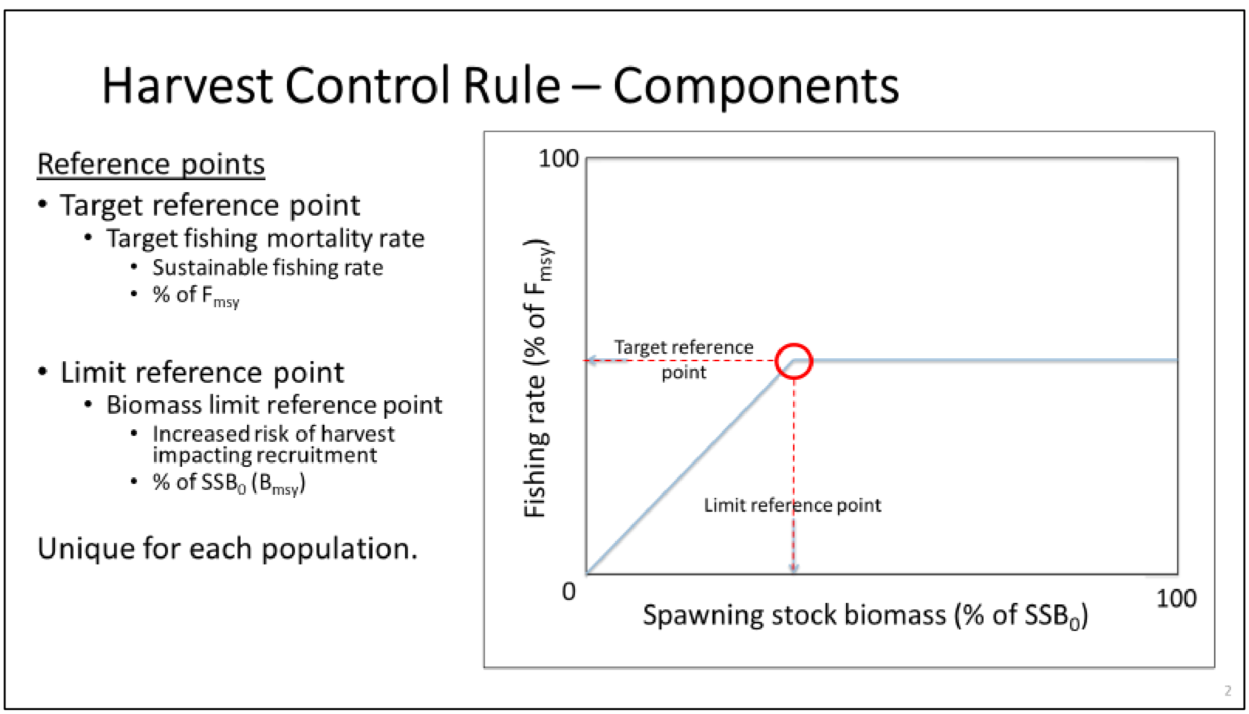


Figure 7. Example of graphic box-plots comparing MSE scenario results for specific fisheries performance indicators against current policy, past 5 years and over the past 18 years for MU4.

Appendix A. Introducing LEC Harvest Control Rules, Application, and Examples for Establishing a Lake Erie Yellow Perch TAC.

The following are slides developed by representatives of QFC, LEC, STC, and YPTG to introduce HCR to stakeholders during the LEPMAG process. These slides describe the purpose and components of HCR, how HCR are applied during the annual TAC-setting process, and provide examples for anticipated TAC scenarios.





Harvest Control Rule – Components

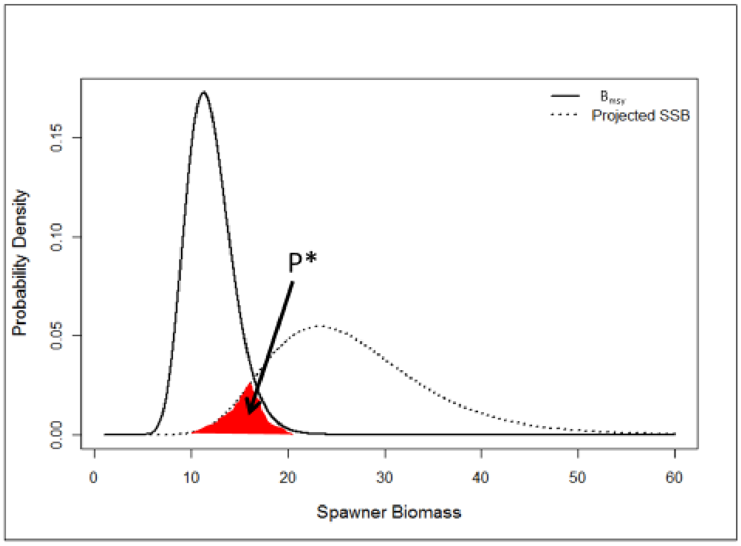
Risk tolerance (P*)

- Probability that **Projected SSB** is less or equal to $\mathbf{B_{msy}}$
  - If **P* ≥ 0.20** then we reduce fishing rate

Why do we need this?

- Estimates inherently include uncertainty

Consistent across populations.



3

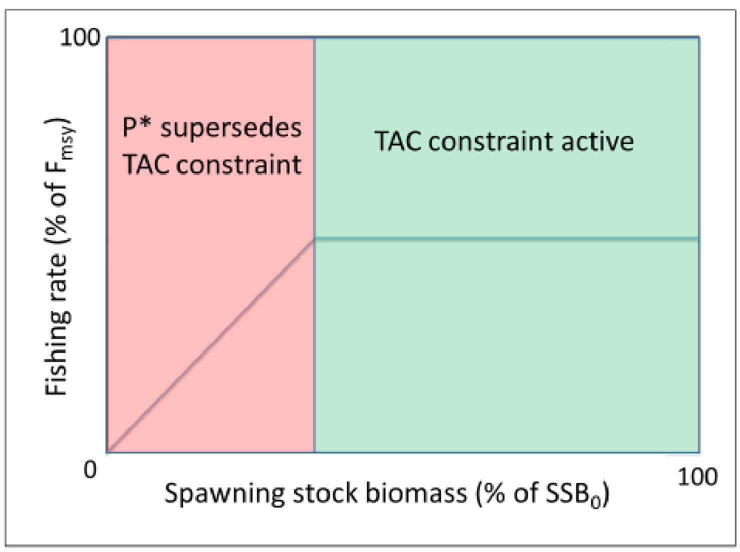
Harvest Control Rule – Components

TAC constraint

- Maintains predictability in TAC from year to year
- Restricts the magnitude of this year's TAC based on last years TAC
  - +/- 20% change

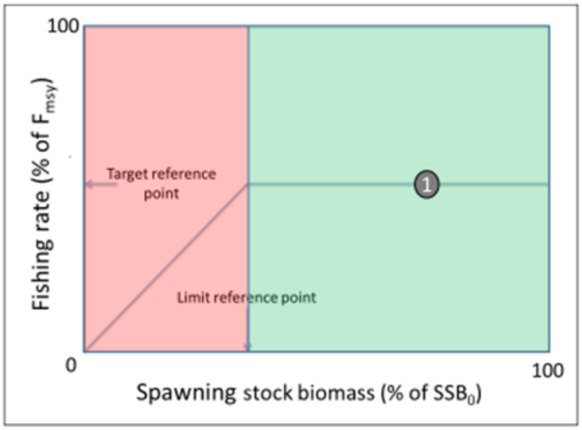
Does not apply when fishing mortality rate is reduced to meet P*<0.20.

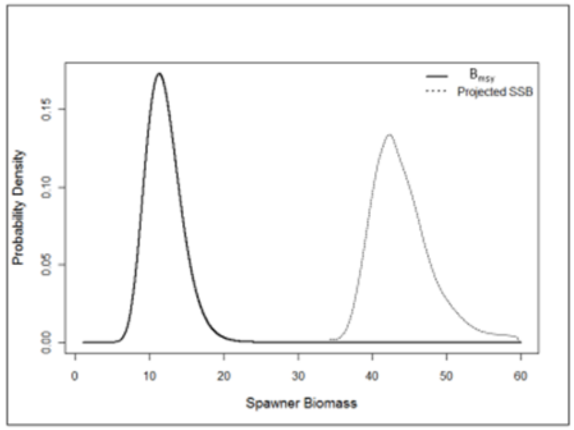
Consistent across populations.



4

Harvest Control Rule – In action

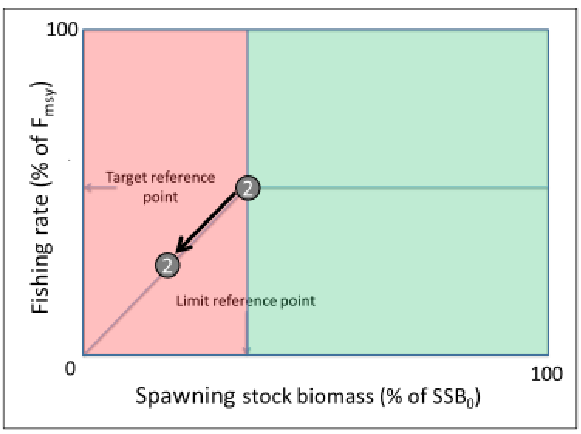


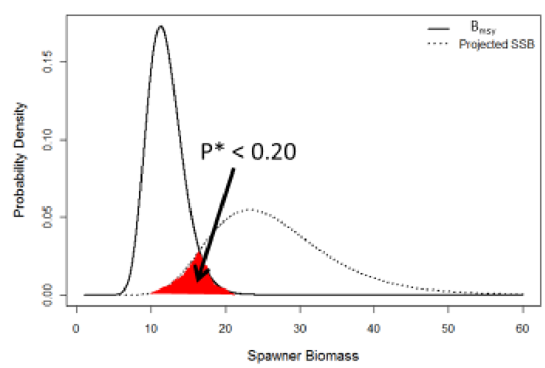


If **Projected SSB** is above the limit reference point, then we fish at **target reference point (% of F_{msy})**

5

Harvest Control Rule – In action



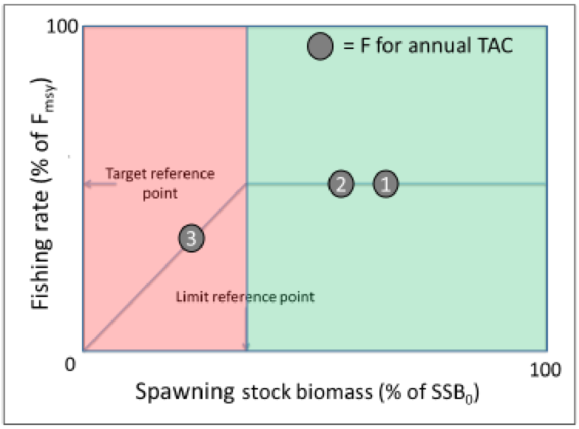


If **Projected SSB** overlaps **limit reference point (B_{msy})**, then we reduce **fishing rate** until **P* < 0.20**.

6

YPMP Harvest Control Rule Scenarios

- 1) ***If P* is equal to or exceeds 0.2:***
  - the RAH range will be calculated using a reduced fishing rate that will ensure that the probability of the projected spawning stock biomass falling below the LRP is less than P*. The LEC will determine a TAC from within the RAH range.

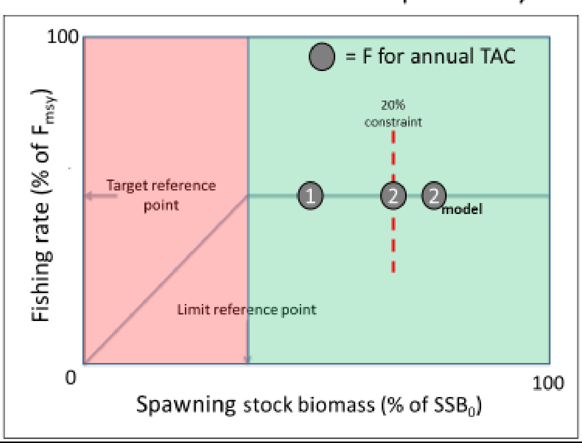


Year	RAH*	Previous RAH	-20% constraint	+20% constraint
1	2.40	2.50	2.00	3.00
2	2.20	2.40	1.92	2.88
3	1.55	NA	1.24	1.86

7

YPMP Harvest Control Rule Scenarios

- 2) ***If P* is less than 0.2 and the RAH mean is outside the + 20% constraint bounds based on the previous year TAC:***
  - the RAH will be set at the + 20% constraint bounds. For example, if the mean RAH is more than 20% greater than the previous year TAC, then the current TAC will be set at 20% more than the previous year TAC.

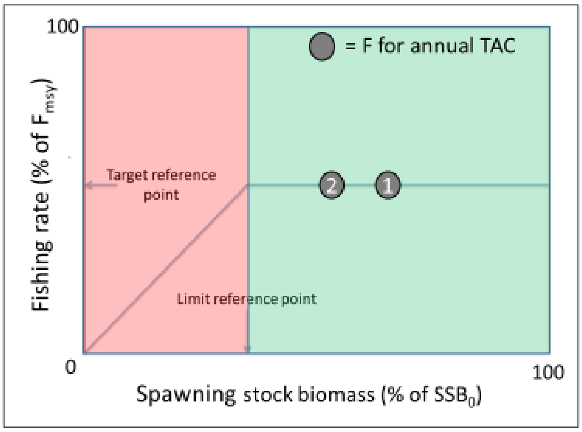


Year	RAH*	Previous RAH	-20% constraint	+20% constraint
1	2.40	2.50	2.00	3.00
2_{model}	3.20	2.40	1.92	2.88
2	2.88	2.40	1.92	2.88

8

YPMP Harvest Control Rule Scenarios

- 3) ***If P* is less than 0.2 and the RAH mean is within the + 20% constraint bounds of the previous year's TAC:***
  - the LEC will establish TAC at the RAH mean.

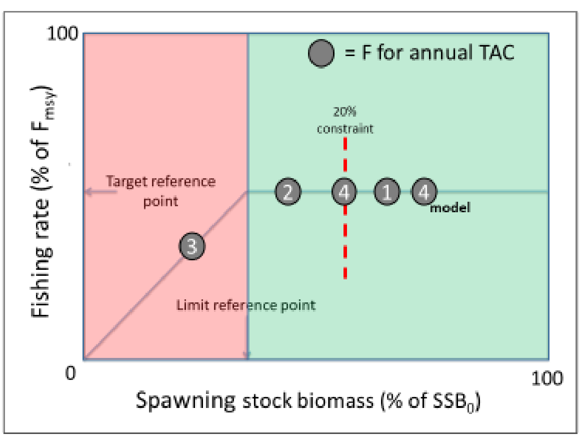


Year	RAH*	Previous RAH	-20% constraint	+20% constraint
1	2.40	2.50	2.00	3.00
2	2.20	2.40	1.92	2.88

9

YPMP Harvest Control Rule Scenarios

- 4) ***In a year following a single year P* TAC reduction when P* is no longer in effect:***
  - the TAC from 2 years prior will be used as a benchmark against which to employ the 20% TAC constraint.



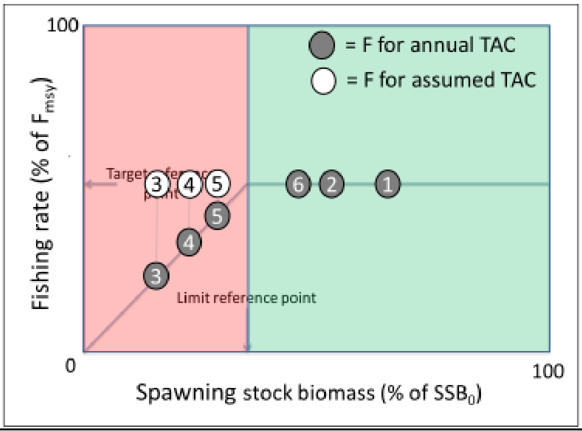
Year	RAH	Previous TAC	-20% constraint	+20% constraint
1	2.40	2.50	2.00	3.00
2	2.20	2.40	1.92	2.88
3	1.55	NA	NA	NA
4_{model}	3.20	2.20	1.76	2.64
4	2.64**	2.20	1.76	2.64

**The YPTG will recommend the Year 4 RAH and range using the PR model outputs. LEC will select a Year 4 TAC within +/-20% of Year 2 TAC. For this example, we will assume the Year 4 modeled mean RAH falls above 2.64 (Year 2 TAC +20%), so the maximum TAC possible for Year 4 would be 2.64 (Similar to Scenario 2).

10

YPMP Harvest Control Rule Scenarios

- 5) ***In a TAC year where P* is not invoked, but P* has persisted for multiple years prior:***
  - the LEC will determine what the TAC would have been using the target F and the 20% TAC constraint for each of the years during that period, thus establishing what can be considered an "assumed TAC". The previous year's assumed TAC can then be used as a benchmark for the implementation of the 20% TAC constraint and a new TAC moving forward.



Year	TAC*	Previous TAC	Assumed TAC	-20% constraint	+20% constraint
1	2.40	2.50		2.00	3.00
2	2.20	2.40		1.92	2.88
3	1.30	NA	1.80	1.44	2.16
4	1.50	NA	1.90	1.52	2.28
5	1.70	NA	**2.00**	**1.60**	**2.40**
6	2.10	**2.00**		**1.60**	**2.40**

11

Lake Erie Yellow Perch – HCR components

Management Unit	Target Fishing Rate (% F_{msy})	Limit Reference Point (% SSB_0)	Risk Tolerance (P*)	TAC Constraint
MU1	28% of F_{msy}	B_{msy} (~28% of SSB_0)	0.20	20%
MU2	35% of F_{msy}	B_{msy} (~28% of SSB_0)	0.20	20%
MU3	32% of F_{msy}	B_{msy} (~28% of SSB_0)	0.20	20%
MU4	34% of F_{msy}	B_{msy} (~28% of SSB_0)	0.20	20%

These reference points were identified to maintain sustainability by balancing:

1. The biological capacity of the stocks (i.e., productivity and stock size)
2. Fishery performance (i.e., harvest rate metrics and stability)
3. Risk tolerance

12