WORKSHOPS TO REVISE AND IMPROVE THE LAKE MICHIGAN RED FLAGS ANALYSIS

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ABSTRACT:

The Red Flags Analysis (RFA) is an annual procedure to help monitor and communicate the progress of Chinook salmon *Oncorhynchus tshawytscha* stocking policies in Lake Michigan. It was developed by the Salmonid Working Group (SWG) under the Lake Michigan Technical Committee (LMTC). A critical review of the analysis was conducted in 2011 and concluded that the procedure had a number of analytical and structural problems and gave recommendations for making changes. We conducted two facilitated workshops to consider the recommendations and also to solicit other ideas from the participants to improve the analysis. The first workshop was held March 4–6, 2013 in Charlevoix, MI and focused on the Chinook salmon part of the analysis. The second workshop was held April 22–24, 2013 in Ann Arbor, MI and focused on the alewife *Alosa pseudoharengus* part. We invited SWG members and other experts in Chinook-alewife biology. Participants included biologists working on Lake Huron who were familiar with the Chinook-alewife collapse in that lake, a situation the RFA was designed to help avoid in Lake Michigan. Final decisions on how to change the analysis were made by consensus of the participants. The changes recommended were more extensive than anticipated. Most of the revisions suggested by Clark (2012) were adopted, and the analysis was further redesigned to focus on a single, primary indicator – the Chinook salmon-alewife predator-prey ratio (P-P ratio). This new approach was only recently made possible by the completion of supportive research focusing on estimating the abundances of Chinook salmon (Tsehaye et al. 2014a) and alewives (Tsehaye et al. 2014b). The new analysis was renamed the Predator-Prey Ratio Analysis (PPRA). Other important decisions included defining specific goals and objectives for the analysis and converting the control rule (red flags) triggering mechanism from one based on statistical percentiles to one based on target and limit reference points. The target reference point for the P-P ratio would be considered as the management objective for predator-prey balance, and the difference between that target and the estimated P-P ratios (including a 6-year projection of future P-P ratios) would be quantitative measures of the expected performance of the current stocking policy. An upper limit reference point would be considered the P-P value that should be avoided. When the current or projected P-P ratio exceeds this limit, managers should consider this an indication that adjustments to stocking rates are called for. Values of 0.050 and 0.100 were recommended by the SWG and the LMTC as the target and upper limit. These values were based on applying the risk assessment methods of Caddy and McGarvey (1996) to our Lake Michigan problem and verifying the reasonableness of those results by comparing them to historical estimates of P-P ratios in lakes Huron and Ontario. The PPRA has been approved and recommended for use by the SWG and the Lake Michigan Technical Committee (LMTC). The proposed plan was to update the PPRA every year. Members of SWG would be responsible for completing the Chinook salmon SCA and associated indicators, and members of PWG would be responsible for completing the alewife SCA and associated indicators. The QFC will supply technical support as needed. Ideally, the analysis should be completed before the annual meeting of the LMC in late March. This would allow time to adjust stocking rates if necessary for the next season. We have prepared an instruction manual for those involved in conducting the PPRA (Clark et al. 2014). This manual should help maintain consistency in methods in future years and also includes advice on interpreting the PPRA results. The LMC is currently considering official adoption of the PPRA.

INTRODUCTION:

By 2011, the protocol for managing Chinook salmon *Oncorhynchus tshawytscha* in Lake Michigan had evolved into a two-step process. First, stocking policies were developed in a series of meetings which occurred about every 5 years (Claramunt et al. 2008). Management agencies organized the meetings..
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which were designed to incorporate input from fishery stakeholders. Sophisticated risk assessment models (Szalai 2003) and structured decision analysis techniques (Jones et al. 2008) were used to support collaborative decision making. Second, after decisions were made and stocking policies were put in place, their performance was monitored every year. Managers and researchers all around the lake collected data on the fishery and then shared it through the lake committee structure of the Great Lakes Fishery Commission (GLFC). The Red Flags Analysis (RFA) was developed as a way to organize and analyze that data on a lake-wide basis. The intended purpose of the RFA in the overall protocol was to identify problems in the fishery that might justify more immediate attention than would otherwise have occurred under the 5-year policy development cycle. In other words, it was intended as a fail-safe monitor of the management policy.

A critical review of the RFA was conducted in 2011 (Clark 2012). It concluded that the procedure had a number of analytical and structural problems that should be fixed. In addition, Clark suggested that the RFA suffered from “mission creep”. That is, managers continued to make new demands on the procedure which has had the effect of expanding its scope and objectives. For example, besides acting as a fail-safe monitor, managers also wanted the RFA to help measure progress towards meeting the objectives of the stocking policy. The Salmonid Working Group (SWG), who developed and ran the RFA, was not able to keep pace in modifying the procedure to address these new demands.

The review gave eight specific recommendations for fixing and updating the RFA. The Lake Michigan Committee (LMC) expressed interest in implementing these recommendations and continuing the use of the RFA. Doing so would require technical work, such as revising the list of biological indicators, developing biologically-based target and limit reference points for indicators, and developing continuous indices to evaluate success of management strategies. Clark (2012) suggested making the revisions in a workshop setting because any changes would be better accepted if management agency representatives had the opportunity to discuss and endorse or reject specific changes. Organizing and conducting the proposed workshops was the focus of this study.

OBJECTIVES:

Our primary objective was to modify the Lake Michigan RFA as recommended by Clark (2012) in a series of facilitated workshops with appropriate representation from scientific and management agencies. The MSU Quantitative Fisheries Center organized and led the workshops and developed consensus decisions regarding how to modify the procedure for future use. The changes recommended were more extensive than anticipated. Most of the revisions suggested by Clark (2012) were adopted, and the analysis was further redesigned to focus on a single, primary indicator – the Chinook salmon-alewife Alosa pseudoharengus predator-prey ratio (P-P ratio). This new approach was only recently made possible by the completion of supportive research focusing on estimating the abundances of Chinook salmon (Tsehaye et al. 2014a) and alewives (Tsehaye et al. 2014b) in Lake Michigan. The new analysis was renamed the Predator-Prey Ratio Analysis (PPRA). We developed the PPRA based on the results of our workshops and conducted a number of follow-up meetings with the SWG and the LMTC to review and refine the PPRA. The PPRA has been approved and recommended for use by the SWG and the Lake Michigan Technical Committee (LMTC). The PPRA is currently under consideration by the LMC.

METHODS:

We organized and conducted two, facilitated workshops designed to review and modify the RFA. We used the recent critical review (Clark 2012) as a starting point for discussion, but also solicited other ideas from the participants. Decisions at the workshops were made by consensus. Mike Jones, Co-Director, Quantitative Fisheries Center (QFC), Michigan State University (MSU), and John Dettmers, Senior
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Fisheries Biologist, GLFC, shared the facilitator duties.

The first workshop focused on Chinook salmon and was held at the Charlevoix Great Lakes Station, Michigan Department of Natural Resources (MIDNR), Charlevoix, Michigan from March 4-6, 2013. The second workshop focused on alewife and was held at the Great Lakes Science Center, US Geological Survey (USGS), Ann Arbor, Michigan from April 22-24, 2013. We invited all members of the SWG to the Chinook salmon workshop and all members of the Planktivore Working Group (PWG) to the alewife workshop.

Workshops were designed to elicit input from all participants by asking each to prepare and present a short summary of the status of the Chinook or alewife fisheries in the jurisdictions they represented, or a summary of the relevant area of their research expertise. These initial presentations also provided a foundation of up-to-date information upon which to evaluate proposed changes to the RFA. The rest of the workshops were designed to generate facilitator-led discussions to evaluate recommended changes to RFA (see workshop agendas in Appendices A and B). Summary notes were prepared to help document the results of the workshops, and they were circulated to all participants with a request for review and corrections.

After the workshops, we made the changes to the RFA as proposed and conducted several follow-up meetings to have the new procedure reviewed and refined. The new procedure was renamed the Predator-Prey Ratio Analysis (PPRA). We used MS-Excel spreadsheets as templates to organize and request data from the agencies and to make analyses and graphics. We used AD Model Builder (Fournier et al. 2012) to make abundance estimates for Chinook salmon as described by Tsehaye et al. (2014a) and for alewives as described by Tsehaye et al. (2014b). As part of the review and approval process we assisted the SWG in writing a draft report for the LMC describing the PPRA and the procedures used in its development. In addition, we wrote an instruction manual for those involved in conducting the PPRA in the future.

RESULTS:

Both workshops were well attended, with appropriate representation from the management agencies. Lists of the participants are given in the summary notes for the Chinook salmon workshop (Appendix C and D) and the alewife workshop (Appendix E).

Chinook salmon workshop – One important issue discussed at the beginning of the Chinook salmon workshop was the use of management control rules (or feedback policies). The management control rule currently in place is to monitor the average weight of female Chinook salmon at the Strawberry Creek weir in Wisconsin, and then to potentially adjust stocking rates every 3 years depending on the findings. If the average weight goes below 15.4 pounds, then stocking would be reduced. If the average weight goes above 17.6 pounds, then stocking would increase. The participants expressed concern that this rule might be too limited in scope both biologically and spatially. Particularly, because Strawberry Creek was only a single, small, stocked stream that might not fully represent the population in the entire Lake Michigan. Hope was expressed that the LMC might replace this Strawberry Creek control rule with rules generated by the new and improved RFA that we are working on. Developing RFA control rules will necessitate consensus decisions on what specific management actions should be taken when red flags are triggered. Control rules for the RFA cannot really be decided until the RFA is finalized and the potential consequences of triggering specific red flags can be evaluated.

Details of the presentations at the Chinook salmon workshop are presented in Appendix C. Only a few highlights will be given here. On the first day, background information on the status of the Chinook
salmon fishery in each management jurisdiction was presented and discussed, including those in Lake Huron. In general, catch rates of Chinook salmon in 2012 were very good all over Lake Michigan, but concern was expressed about how the alewife population was holding up. The information presented about the Chinook-alewife collapse in Lake Huron provided insights and objective data on changes in abundance, mean weight, condition and harvest both before and after the collapse. These data will help provide quantitative measures of specific conditions to avoid in Lake Michigan (limit reference points).

Chuck Bronte, US Fish and Wildlife Service (USFWS), described plans for mass marking of Chinook salmon. All Chinook stocked in US waters of lakes Michigan and Huron will be marked with coded-wire tags (CWTs) by USFWS conditional on continuation of funding. Thus, it should be possible to use CWTs to estimate the proportions of stocked versus wild fish in each year class into the future, a key element in the future management of Chinook salmon. In addition, CWTs can be used to evaluate movements within and between lakes. Clark presented a preliminary analysis of CWT-tagged fish from 1995 to 2010 that suggested that movements of Chinook salmon from Lake Huron to Lake Michigan increased over time in parallel with the reduction of alewives in Lake Huron. The significance of these between-lake movements is yet to be evaluated, but Chinook salmon from Lake Huron could be an additional stressor on the Lake Michigan forage base.

On the second and third days of the Chinook salmon workshop, specific goals and objectives for RFA were defined (Appendix D). Each of the recommendations made by Clark (2012) was debated. Participants decided to reduce the biological indicators used in RFA from fifteen (Clark 2012) to three: 1) the Chinook-alewife P-P ratio; 2) the lake-wide condition factor of Chinook salmon from mid-summer creel surveys; and 3) the lake-wide mean weight of age-3-and-older female Chinook salmon at weirs. (Note: Later, at the SWG meeting on October 3, 2013, committee members decided to reduce the analysis to a single, primary indicator – the P-P ratio. The other indicators were to be maintained as auxiliary biological information.)

Participants agreed to convert the red flags triggering mechanism from one based on statistical percentiles to one based on target and limit reference points. Target reference points would be considered as management objectives for each indicator, and the difference between targets and estimated annual values would be a quantitative measure of the expected performance of the current stocking policy. Limit reference points would be considered values of indicators that should be avoided. When the annual value of an indicator is outside its defined limits, a red flag would be triggered. The job of defining specific values for target and limit reference points was left for a later date after a prototype analysis could be completed and reviewed and after the results of the alewife workshop were known.

Participants decided to continue to monitor the performance of the salmon-trout fishery as an auxiliary analysis, using the lake-wide catch-per-hour of charter boat fishing and the proportion of each salmonine species in the catch as indicators.

Participants agreed to conduct a quantitative evaluation of the success in achieving the Lake Michigan Fish Community Objectives (FCOs) using the methods described by Clark (2012). This would also be an auxiliary analysis and not part of the main RFA. This analysis uses an age-structured model to estimate the potential harvest of present-day salmonine populations given that they would be exploited by the average fishing effort present in the late 1980s. Fishing effort has since declined, but the effort present in the late 1980s was what the authors of the FCOs considered when they defined the harvest expectations supporting the Salmonine Objectives. Thus, the difference between the model-predicted harvest and the FCO harvest expectations can be considered a measure of performance in achieving the FCOs.

Participants of the Chinook salmon workshop realized that in order to calculate a Chinook-alewife P-P ratio, it would be necessary to make estimates of abundance for both Chinook salmon and alewifes. They
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proposed using the statistical catch at age analysis (SCA) of Tsehaye et al. (2014a) as the method to compute estimates of Chinook salmon abundance in Lake Michigan. They also suggested that the participants of the alewife workshop should consider using the multispecies integrated analysis of Tsehaye et al. (2014b) as the method to compute estimates of alewife abundance in Lake Michigan.

Participants concluded the workshop with a commitment to supply data and to work together to revise the RFA to focus more directly on assessing the Chinook-alewife predator-prey balance.

**Alewife workshop** – More detailed summary notes on the alewife workshop are presented in Appendix E. Only a few highlights will be given here. On the first day, background information on the results of the Chinook salmon workshop and the status of alewife populations was presented for both lakes Michigan and Huron. Lake Michigan alewives continue to persist at relatively low abundance levels. Lake Huron alewives essentially disappeared in 2003-2004 and have not recovered to date.

On day two of the alewife workshop, each of the recommendations suggested by Clark (2012) were discussed and evaluated. In the end, the participants decided that the abundance estimate of alewife from the multispecies integrated analysis of Tsehaye et al. (2014b) and its use in the Chinook-alewife P-P ratio was the only indicator needed for alewife. Most of the other indicators (e.g. recruitment, growth, and mortality) for alewife that were suggested by Clark (2012) would be part of that abundance analysis, and so would be redundant if they were included again separately. (Note: Later, at the SWG meeting on October 3, 2013, committee members decided to include one additional auxiliary indicator for alewives – the age structure of the population.)

**Follow-up work and meetings** – In the weeks following the workshops, a prototype analysis was developed based on the decisions and discussions at the workshops, and it was presented for review at a special SWG meeting on July 22, 2013 in Green Bay, WI. The results presented were similar to those in Figure 1, which is from the most recent update of PPRA and illustrates the estimated (1968-2013) and predicted (2014-2018) Chinook-alewife P-P ratio. Methods for calculating these future values will be described later.

After making minor revisions as suggested by SWG members, the prototype analysis was presented at the LMTC meeting the next day for additional review and comment. The SWG and the LMTC agreed to continue with prototype development and to address target and limit reference points in a meeting in fall of 2013. (Note: The target and limit reference points presented in Figure 1 were not developed until after the SWG meeting on October 3, 2013. They are presented in Figure 1 to avoid redundancy in figures and to facilitate later discussions in this report.)

We continued to refine the prototype during summer 2013 and then presented the results at a follow-up SWG meeting held at the QFC in East Lansing on October 3, 2013 (notes from the meeting are attached as Appendix F). The SWG members suggested a few additional revisions to the analysis, most notably to use the P-P ratio as a single, primary indicator and to maintain the other indicators as supplementary, auxiliary indicators. Thus, this led to the final restructuring of the old RFA. The result will be referred to as the PPRA. The SWG voted to adopt the PPRA for future use in place of the RFA.

Methods for defining target and limit reference points were also discussed and approved at the October 3rd SWG meeting (Appendix F). We suggested an approach used in ocean fisheries as described by Caddy and McGarvey (1996). This method sets up a probability framework for risk assessment in fisheries management based on choosing a limit reference point for the management standard (e.g. a level of fishing effort or fish population biomass) and an acceptable level of risk in exceeding or undershooting the limit. Basically, the estimated or predicted values for the management standard are treated as probability distributions rather than point values. Doing so allows one to determine the probability that
any value in the distribution is either exceeded or undershot. The limit reference point is defined as the value giving the acceptable risk level, as chosen by managers, and the target reference point is defined as the mean of that distribution.

We suggested that the Caddy and McGarvey method could be used in our analysis by first identifying the management standard in terms of alewife biomass and then linking it to P-P ratios with the existing risk assessment model (Szalai 2003). The risk assessment model can be used to characterize the uncertainty in the predator-prey system and to generate probability distributions for obtaining specific outcomes for alewife biomasses and P-P ratios. We noted that basing the analysis on alewife biomass as the initial management standard was more intuitively understandable than basing it directly on a P-P ratio. Also, the lower limit for alewife biomass (100 kts) and the acceptable risk for going below that limit (15%) had already been defined in previous meetings with managers and stakeholders. The committee members decided this Caddy-McGarvey method was a good approach and that the QFC should pursue it further.

A follow-up SWG meeting was held on January 27, 2014 in Michigan City, IN. Clark reported that the results of applying the Caddy-McGarvey method to the P-P-ratio management standard gave an upper limit reference point of 0.105 and a target reference point of 0.053. This result was based on 100 hypothetical outcomes of the risk assessment model forecasted 25 years into the future. That is, 0.105 was the P-P ratio that was exceeded in 15% of outcomes and 0.053 was the mean of those outcomes. As expected, most of the hypothetical outcomes for which the P-P ratio had exceeded 0.105 led to the collapse of the hypothetical alewife population.

Clark also reported that estimates of P-P ratios for similar fisheries in other lakes seemed to support these values. The Chinook salmon-alewife P-P ratio in Lake Ontario was estimated to be 0.065 from 1999 to
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2005 (based on biomass estimates of Murry et al 2009) and the average P-P ratio in Lake Huron for 2001-2005 was estimated to be 0.112 (based on biomass estimates of James Bence, QFC, Michigan State University, personal communication). The ratio for Lake Ontario is reasonably close to the proposed target reference point for Lake Michigan, while the ratio in Lake Huron exceeded the proposed upper limit. Some concern has been expressed about the sustainability of the predator-prey system in Lake Ontario, but it has not collapsed. On the other hand, the Chinook salmon-alewife predator-prey system did collapse in Lake Huron (Johnson et al. 2010).

Clark also presented a retrospective analysis as a test of the new procedure. He considered the past years (1998, 2005, and 2011) in which decisions were made to reduce stocking of Chinook salmon to determine if the PPRA, had it been available in those years, would have supported the previous decisions to reduce stocking rates. Results showed that the PPRA would have supported the decisions in every case. The most important finding was that the estimated P-P ratio for the current year of analysis was always within an acceptable range, but that projections of P-P ratios for the near future were predicted to exceed the proposed upper limit. For example, Figure 2 shows the results for 2005. The results of the retrospective analysis clearly demonstrated the value of the projection model.

Other considerations for identifying suitable target and limit reference points were also discussed. The choice of the upper limit reference point and the probability for exceeding it are the most important decisions in this analysis. The target reference point is derived from these two values along with the uncertainty in the system, and this target is the single most important guide to defining the number of Chinook salmon to stock. Also, the limit reference point is the trigger for implementing the control rule. These choices can be supported by data and biology, but they remain somewhat subjective in nature. For example, it was noted that if the management objective was to prevent a collapse of the alewife

![Figure 2](image-url)
population, then a reasonable range for an upper limit reference point would be from 0.070 to 0.090. This range would keep the risk of collapse even lower than the 15% estimated at 0.105 by the Caddy-McGarvey method and would lead to cuts in Chinook salmon stocking even below the current 1.76 million per year. However, alewives have been implicated in suppressing native species recovery (Madenjian et al. 2008). Consequently, managers might want to consider trying to maintain the alewife population at a lower level of abundance ($\leq 100$ kt), which would require the Chinook salmon population be maintained at a higher level of abundance and would justify an increase in stocking rates above 1.76 million. Choosing an upper limit reference point in the range of 0.100 to 0.120 would be more appropriate under this scenario. Thus, when selecting an upper limit reference point, one of the things managers should consider is the trade-off between Chinook-alewife population stability and the degree of success in native species recovery. As the upper limit for the P-P ratio is increased the risk of alewife population collapse, and hence the Chinook salmon fishery collapse, and the likelihood of native species recovery increases, and *visa versa*. The question remains: is there a level of alewife population abundance that will allow both a significant Chinook salmon fishery and native species recovery?

Another important decision to consider involves defining the control rule. What management action should be taken if the P-P ratio or projected P-P ratio exceeds the limit reference point? Action could be in the form of an immediate, pre-defined cut in stocking or rather an urgent and thorough reevaluation of the problem. This is probably a decision that is best made by managers in consultation with stakeholders. For the present, we would recommend that at minimum, a serious discussion should be launched to debate reductions in stocking rates of salmonines if the limit reference point is exceeded. We also note that a control rule based on the estimated P-P ratio is preferable to one based on measurements of Chinook salmon weights obtained from a single weir, because it more effectively integrates the conditions in the entire lake.

Based on the discussion and analysis presented, the SWG decided to round off the values derived by the Caddy-McGarvey method to 0.050 for the target and 0.100 for the upper limit for the Chinook salmon-alewife P-P ratio and to recommend these values as starting points for the LMTC and the LMC to consider. Also, it was decided not to develop targets or limits for the auxiliary indicators.

The SWG Chairperson presented the PPRA to the LMTC on January 28, 2014 in Michigan City, Indiana, and the LMTC voted to approve the PPRA and to recommend its use to the LMC. On March 26, 2014, the SWG Chairperson presented the PPRA to the LMC at their meeting in Windsor, ON and recommended that they formally adopt the procedure. The SWG Chairperson also drafted a written report with our assistance that describes the PPRA and the process used in its development (Lake Michigan Salmonid Working Group and Collaborators 2014).

We have prepared an instruction manual for those involved in conducting the PPRA (Clark et al. 2014). This manual should help maintain consistency in methods in future years and also includes advice on interpreting the PPRA results. The PPRA should be updated every year. Members of SWG would be responsible for completing the Chinook salmon SCA and associated indicators, and members of PWG would be responsible for completing the alewife SCA and associated indicators. The QFC will supply technical support as needed. Ideally, the analysis should be completed before the annual meeting of the LMC in late March. This would allow time to adjust stocking rates if necessary for the next season.

The LMC is currently considering official adoption of the PPRA.

**DISCUSSION:**

We successfully organized and conducted a series of workshops and meetings geared to improve the Lake Michigan RFA. This effort led to an extensive overhaul of the analysis, which was renamed the
PPRA. Participants of those workshops and meetings agreed with many of the changes recommended by Clark (2012), but also recommended a fairly radical change in the goal of the analysis – to annually assess the predator-prey balance in the lake. This change requires making annual estimates of abundance of Chinook salmon and alewives instead of using more simple abundance indices as in the old RFA. Participants concluded that the best methods presently available for estimating abundance were through the SCA and integrated analysis methods of Tsehaye et al. (2014a and 2014b). Participants recognized that these methods use much of the data previously used as separate indicators (e.g. estimated harvest, fishing effort, number stocked, number of wild recruits, and indices of abundance of alewives in trawl and acoustic surveys) and combines them in a biologically meaningful way. These new methods were computationally more demanding, and so we could not develop the abundance estimates and finalize revisions to the computer tools within the workshops as originally envisioned. However, we did develop prototypes of the proposed analysis after the workshops in follow-up meetings and ultimately develop the procedures, software, and instructions needed for the new PPRA.

The P-P ratio and its target and limit reference points are the central features of the PPRA. It seems obvious that annual monitoring and forecasting of the P-P ratio would help to maintain the predator-prey balance in the lake. But this assumes that we have a reliable method to estimate and forecast the P-P ratio. The reliability of any new product is difficult to assess. However, the methods and estimates we used in the PPRA pass at least three critical tests of reliability. First, we showed that the PPRA would have supported past management decisions to cut stocking rates. Much effort in terms of biological analysis and public relations went into making those decisions, and the preponderance of biological evidence and opinion at the time supported those decisions. Most biologists even today think that those decisions were good ones.

Second, the PPRA passes a simple ecological test. When we compared annual P-P ratios to annual values of the relative condition of Chinook salmon (the first auxiliary indicator), we found that an inverse relationship existed between them (Figure 3). Such a relationship would be expected based on ecological theory. That is, the weight of predators at a given length should increase as the number of prey per predator increases, because it would increase their potential ration size. We think these results provide evidence that our P-P ratio estimates must be reasonably accurate and should be a reliable management tool. Had the condition of Chinook salmon been unrelated to the P-P ratio, we would have been more skeptical of the value of the P-P ratio to management.

![Chinook Condition versus Predator-Prey Ratio](image)

Figure 3. – Scatter plot of predator condition (regression-predicted weight of a 35-inch Chinook salmon) versus Chinook-alewife predator-prey ratio. Solid line is a regression of the values in the plot (P<0.01; \( R^2=0.58 \).
Based on the results of the PPRA through 2013, the current stocking rate of 1.76 million Chinook salmon smolts is expected to perform well (Figure 1). Of course, this assumes that rates of recruitment, growth, and mortality of predator and prey remain similar to those occurring in recent history. Only continued monitoring of these rates can detect unforeseen changes. For example, results of recent netting surveys have suggested that the proportion of untagged lake trout *Salvelinus namaycush* in Lake Michigan is increasing (Charles Madenjian, USGS, personal communication), which could mean natural reproduction is increasing. Naturally reproduced lake trout would be expected to increase the predation mortality rate on alewives, so at some point, it might be necessary to account for this in the PPRA. Currently, consumption of alewives by lake trout is accounted for in the alewife SCA, but natural reproduction is assumed to be negligible.

Finally, the PPRA passed third important test. Members of the SWG and the LMTC expected the analysis would be easy for stakeholders and other laypersons to understand, which is important in obtaining support for stocking decisions.

We think making a direct estimate of the P-P ratio to help manage the balance between Chinook salmon and alewife is a very promising new approach. Besides being immediately useful to measure the performance of Chinook salmon stocking policies, it also provides a framework for future enhancements. One enhancement that is already under study is to evaluate the necessity of modifying the SCA abundance estimate for Chinook salmon to account for movement between lakes Huron and Michigan. Another potential enhancement would be to add other predators (e.g. lake trout, steelhead *Oncorhynchus mykiss*, coho salmon *Oncorhynchus kisutch*, and brown trout *Salmo trutta*) or other prey (e.g. rainbow smelt *Osmerus mordax*) to the ratio. Adding these other species would be more demanding of data and computational power, and might not be an analysis that SWG could accomplish in an annual analysis. However, adding these other species in some sort of evaluation would be a logical next step for research, given that the integrated analysis in Tsehaye et al. (2014b) already includes these other salmonines and prey fishes. And finally, while we made the simple, but reasonable assumption that age 1-and-older Chinook salmon feed primarily on age 1-and-older alewives, including more detail on the size selectivity of predators for prey and changes in sizes due to seasonal growth patterns might further improve the ratio.

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DELIVERABLES:

1. Summaries of the workshop proceedings are given in Appendices.
2. Organized computer files representing the current version of the PPRA are available on request. These include relevant data supplied by management agencies, spreadsheets and models for conducting analyses, results of previous model analyses, and supporting graphs. Final versions of these computer files will be given to SWG and PWG to support future operation of the analysis.

3. Instruction manual for those running the analysis in the future (Clark et al. 2014).
PRESS RELEASE:

Workshops are held to make improvements to the Lake Michigan Red Flags Analysis

The Lake Michigan Red Flags Analysis (RFA) was developed in the 1990s by the Salmonid Working Group (SWG) under the Lake Michigan Technical Committee (LMTC). Both of these groups are part of the Lake Committee structure of the Great Lakes Fishery Commission (GLFC). The RFA was designed to help monitor the performance of the lake-wide, salmon-trout stocking plan, but it focuses primarily on Chinook salmon because they are the primary consumers of forage fishes in the lake. The RFA was a way to assemble and organize field data collected from creel surveys, weir returns, and other biological studies and to analyze them from a lake-wide perspective. Results helped managers keep track of these fisheries and helped them explain what was happening to interested anglers and the general public. A review of the biological and statistical components of the RFA was conducted in 2011. It concluded that the procedure had a number of analytical and structural problems, and it recommended specific improvements. Recently, two workshops were held to consider these recommendations and to solicit additional ideas from the participants to improve the analysis. The workshops were led by scientists from the Quantitative Fisheries Center, Michigan State University and were funded by a GLFC Science Transfer Grant. The workshops were attended by SWG members and other experts in Chinook-alewife biology. Some of the experts were biologists with data and knowledge from the Chinook-alewife fishery collapse in Lake Huron, a situation the RFA was designed to help avoid in Lake Michigan. The most significant result of the workshops was a decision to revise the analysis to focus on an estimate of the Chinook-alewife predator-prey ratio as the sole, primary biological indicator in the analysis. Analytical work and follow-up meetings of the SWG led to the development of a new procedure, the Chinook-alewife Predator-Prey Ratio Analysis (PPRA), which is being proposed to replace the old RFA. The main objective of the PPRA is to annually provide a lake-wide assessment of the Chinook salmon fishery and the predator-prey balance in Lake Michigan to help managers make decisions on stocking rates and fishing regulations and to provide a framework to help explain the decisions to stakeholders. The new PPRA should deliver better feedback on the success of the lake-wide stocking plan. Pending formal approval of the Lake Michigan Committee, the SWG could begin using the new procedure as early as 2014.
APPENDICES:

Appendix A

Agenda for Lake Michigan Red Flags
Chinook Salmon Workshop

Charlevoix, MI
March 4-6, 2013

March 4, 2013 (1 PM – 5 PM)

➢ Introductions

➢ Present background information in informal round table discussion

- Report on recent decision analysis process and resulting stocking policy – Steve Robillard, ILDNR

- Overview of risk assessment model used in decision analysis – Iyob Tsehaye, MSU

- Reports on current status of Chinook salmon fishery in each jurisdiction (provide handouts as requested)
  
  Lake Michigan
  o Michigan – Randy Claramunt and Mark Tonello, MIDNR
  o Illinois – Steve Robillard, ILDNR
  o Wisconsin – Nick Legler, WIDNR
  o Indiana – Ben Dickinson, INDNR

  Lake Huron
  o Michigan – Jim Johnson and Je Hi, MIDNR
  o Ontario – Dave Gonder, ONMNR
  o Chippewa-Ottawa Tribes – Greg Wright, Sault Tribe

- Recent past and future marking plans (Chuck Bronte and Rob Elliott, USFWS)

- Overview of Red Flags Review Recommendations – Rick Clark, MSU
  o What is good about analysis
  o What is not so good about analysis
  o Recommended changes

➢ Conduct facilitated discussion regarding the appropriateness of the recommendations (Facilitator – John Dettmers, GLFC)

- Discuss each recommendation and decide whether to endorse as is, endorse with changes, or reject.
- Solicit and consider additional recommended changes from the group.
March 5, 2013

- Facilitator leads group in making changes in analysis as endorsed by previous discussion
  (Facilitator – Mike Jones, MSU; Modeling assistance – Iyob Tsehaye, MSU; Spreadsheet development – Rick Clark, MSU)

March 6, 2013 (8:30 AM – 12 Noon)

- Continue making changes in analysis. When changes are completed, review modified analysis.
- Final thoughts
Appendix B

Agenda for Lake Michigan Red Flags
Alewife Workshop

Ann Arbor, MI
April 22-24, 2013

April 22, 2013 (1 PM – 5 PM)

➢ Introductions & introductory remarks – Rick Clark, MSU

➢ Present background information in informal round table discussion

  • Current Chinook salmon stocking plans – Rick Clark, MSU (borrowed from Steve Robillard, ILDNR)

  • Overview of risk assessment model used in decision analysis – Iyob Tsehaye, MSU

  • Report on recent past and present status of alewife population and other off-shore prey fishes in Lake Michigan – Chuck Madenjian and Dave Warner, USGS and Randy Claramunt, MIDNR

  • Report on recent past and present status of alewife population and other off-shore prey fishes in Lake Huron – Stephen Riley, USGS

  • Summary of Chinook Salmon Workshop and recommendations for changing the Red Flags Analysis – Rick Clark, MSU

➢ Conduct facilitated discussion regarding the appropriateness of the recommendations (Facilitator – John Dettmers, GLFC or Mike Jones, MSU)

  • Discuss each recommendation and decide whether to endorse as is, endorse with changes, or reject.

  • Solicit and consider additional recommended changes from the group.

April 23, 2013

➢ Facilitator leads group in making changes in analysis as endorsed by previous discussion

  (Facilitator – John Dettmers, GLFC or Mike Jones, MSU; Modeling assistance – Iyob Tsehaye, MSU; Spreadsheet development – Rick Clark, MSU)

April 24, 2013 (8:30 AM – 12 Noon)

➢ If needed, continue making changes in analysis. When changes are completed, review modified analysis.

➢ Final thoughts
Appendix C
Agenda for Lake Michigan Red Flags Chinook Salmon Workshop
With Notes of the Proceedings Inserted

I inserted brief notes under each of the agenda items below. I cited each of the presentations and handouts you prepared in the notes and included them as .pdf-file references. The files are not enclosed with this completion report but copies are available from the authors.

– Rick Clark

March 4, 2013 (1 PM – 5 PM)

➢ Introductions

In attendance were John Dettmers (GLFC), Rick Clark (MSU), Iyob Tsehaye (MSU), Randy Claramunt (MIDNR), Steve Robillard (ILDNR), Nick Legler (WIDNR), Ben Dickinson (INDNR), Jim Johnson (MIDNR), Je Hi (MIDNR), Dave Gonder (ONMNR), Greg Wright (Sault Tribe), Chuck Bronte (USFWS), and Rob Elliott (USFWS).

Rick Clark began by stating that the purpose of the Chinook salmon workshop was to make improvements to the Red Flags Analysis. This analysis has been used to organize lake-wide data to annually evaluate the status of the Chinook salmon-alewife predator-prey balance by the Lake Michigan Salmonid Working Group, a standing committee under the Lake Michigan Technical Committee. Rick described the analysis and conducted a critical review last year (QFC Technical Report T2012-1). He recommended several changes to improve the analysis, including using workshops as a means of soliciting additional ideas and making the changes. Another notable recommendation was to more closely examine the recent collapses of Chinook salmon and alewife populations in Lake Huron and to use that information to help prevent collapses in Lake Michigan. Consequently, biologists with firsthand knowledge of those events were invited to this workshop to share their perspectives. This Chinook salmon workshop is the first of two that are planned. The second will be in Ann Arbor in April and will focus on the alewife part of the analysis. John Dettmers (GLFC) and Mike Jones (MSU) will share facilitator duties. Rick thanked the MIDNR, Charlevoix Great Lakes Station for hosting this first workshop and the Great Lakes Fishery Commission for supplying the majority of the funding.

➢ Present background information in informal round table discussion

- Report on recent decision analysis process and resulting stocking policy – Steve Robillard, ILDNR

Steve gave an overview of the series of meetings that occurred during the decision analysis process in 2011 and 2012 (Robillard 1 - 03-04-13). He described how the risk assessment model and input from stakeholders were used to arrive at an agreement to cut Chinook salmon stocking by 50% with potential adjustments to stocking rates every 3 years according to a feedback policy. One suggested feedback policy was based on the average weight of age 3+ Chinook salmon. If the average weight goes below 15.4 pounds, then stocking should be reduced. If the average weight goes above 17.6 pounds, then stocking should be increased. Steve said the Lake Committee would be receptive to proposals for modifying and improving
the feedback policy by adding more and/or better biological indicators, such as the ones we are working on for this new and improved Red Flags Analysis.

- Overview of risk assessment model used in decision analysis – Iyob Tsehaye, MSU

Iyob described the decision analysis/risk assessment model and showed some of the results of the model runs that were done for the stocking decision analysis process (*Tsehaye 1 - 03-04-13*). The modeling results suggested that lower Chinook salmon stocking rates would result in improved growth and harvest of salmon and less risk of severe predator-prey imbalance. Iyob also provided a summary of the results of the stocking options that were tested in the model (*Tsehaye 2 - 03-04-13*).

- Recent past and future marking plans (Chuck Bronte and Rob Elliott, USFWS)

Chuck gave an overview of recent past and future mass marking plans of the USFWS (*Bronte - 03-04-13*). Basically, they are currently providing marking services to all US hatcheries and will possibly include Canadian fish in the future. All Chinook salmon and lake trout reared in hatcheries are being marked with fin clips and coded wire tags. This extensive marking effort began in 2010 and will continue as long as funding is available. Funding is reasonably secure through 2013. In addition, the USFWS is providing help with tag recovery, head processing, and data base management.

- Movement of Chinook salmon Between Lakes (Rick Clark, MSU)

Rick reported that the QFC at MSU received a grant from the Great Lakes Fishery Trust to study the movements of Chinook salmon between lakes Michigan and Huron. As part of that study, he obtained mark and recovery data for coded-wire-tagged fish from John Clevenger (MIDNR, Charlevoix) and targeted trout and salmon fishing effort data from Tracy Kolb (MIDNR, Lansing) and Dale Hanson (USFWS, Green Bay). Rick presented some preliminary results comparing inter-lake recapture rates for fish stocked at Swan River, Lake Huron and Medusa Creek, Lake Michigan (*Clark 1 - 03-04-13*). These two sites are about the same distance on either side of the Mackinaw Bridge. Recapture rates of Swan-stocked fish in Lake Michigan are much higher than recapture rates of Medusa-stocked fish in Lake Huron. In addition, it appears that recapture rates of Swan-stocked fish in Lake Michigan has increased over time and is related to feeding. Since 2002, 80-100% of the April through July recaptures of Swan-stocked fish came from Lake Michigan.

- Reports on current status of Chinook salmon fishery in each jurisdiction (provide handouts as requested)

  - Lake Michigan
    - Michigan – Randy Claramunt, MIDNR
      
      Randy provided a handout describing the status of the Chinook salmon fishery in Michigan waters of Lake Michigan (*Claramunt – 03-04-13*).

    - Illinois – Steve Robillard, ILDNR
Steve provided a handout describing the status of the Chinook salmon fishery in Illinois waters of Lake Michigan (Robillard 2 - 03-04-13).

- Wisconsin – Nick Legler, WIDNR

Nick provided a handout describing the status of the Chinook salmon fishery in Wisconsin waters of Lake Michigan (Legler - 03-04-13). He mentioned that Wisconsin’s Strawberry Creek weir was a very small stream and probably should not be chosen as the only place in Lake Michigan to collect biological indicators of salmon growth and condition. We should consider averaging the growth and condition across other weirs in the lake or using data from the creel surveys.

- Indiana – Ben Dickinson, INDNR

Ben provided a handout describing the status of the Chinook salmon fishery in Indiana waters of Lake Michigan (Dickinson - 03-04-13).

- Lake Huron

- Michigan — Jim Johnson and Je Hi, MIDNR

Jim provided a handout describing the status of the Chinook salmon fishery in Michigan waters of Lake Huron (Johnson 1 - 03-04-13). He also gave a presentation describing the collapses of Chinook salmon and alewife populations in the main basin of Lake Huron (Johnson 2 - 03-04-13). Alewife populations collapsed in 2003-04 followed by Chinook salmon in 2006. Based on his experience in Lake Huron, Jim suggested that Lake Michigan managers should try to prevent condition factors (Ktl) of age-3 Chinook salmon from going below 0.95 and/or average weights at age 3 from going below 5.5 kgs (12.1 pounds). If either of these occurs, it will probably be too late to prevent a population collapse.

- Ontario – Dave Gonder, ONMNR

Dave provided a handout describing the status of the Chinook salmon fishery in Ontario waters of Lake Huron (Gonder 1 - 03-04-13). He also gave a presentation describing the tributaries of Georgian Bay which are big producers of wild Chinook salmon in Lake Huron (Gonder 2 - 03-04-13). He reported that those tributaries continue to produce wild salmon, but the catches are smaller and are more seasonal (spring and fall) in nature since the collapse of the alewife population. Condition factor has recovered from the decline observed in the period 2003-2005. In addition, he presented some results of Stephen Marklevitz’s work at the University of Western Ontario. Stephen has developed a model using otolith microchemistry to determine the natal stream source of wild Chinook salmon in Lake Huron. At one fishing tournament near De Tour Village, Marklevitz found that 81% of the salmon caught were produce in the tributaries of southern Georgian Bay. Because of the close proximity of this site to Lake Michigan, it adds support to the idea that many wild Chinook salmon from Georgian Bay tributaries could be feeding in Lake Michigan.
Greg provided a handout describing the harvest and effort of the Tribal Chinook salmon fishery in the St. Martins Bay area of Lake Huron (Wright – 03-04-13). This fishery is very different from the others. Tribal fishers use large-mesh gill nets and try to catch salmon off the mouth of Nunns Creek as they are staging for their spawning run. They are also harvested at a weir on Nunns Creek, but the lake-caught fish are usually in better condition for marketing. Greg observed relatively consistent annual run sizes and average weights of fish at Nunns Creek during the collapse of the alewife population, which contrasts to the declines observed in other areas of Lake Huron.

Overview of Red Flags Review Recommendations – Rick Clark, MSU

Rick gave a brief overview of the recommendations regarding Chinook salmon (Clark 2 - 03-04-13). He suggested that the bulk of the work for the remainder of the workshop would involve selecting a list of appropriate indicators and identifying appropriate target and limit reference points for each.

Conduct facilitated discussion regarding the appropriateness of the recommendations (Facilitator – John Dettmers, GLFC)

- Discuss each recommendation and decide whether to endorse as is, endorse with changes, or reject.
- Solicit and consider additional recommended changes from the group.

We ran out of time. Participants were asked to think about the recommendations overnight and we will begin with the facilitated discussion in the morning.
Facilitator leads group in making changes in analysis as endorsed by previous discussion
(Facilitator – Mike Jones, MSU; Modeling assistance – Iyob Tsehaye, MSU; Spreadsheet development – Rick Clark, MSU)

In attendance were Mike Jones (MSU), Rick Clark (MSU), Iyob Tsehaye (MSU), Randy Claramunt (MIDNR), Steve Robillard (ILDNR), Nick Legler (WIDNR), Ben Dickinson (INDNR), Jim Johnson (MIDNR), Je Hi (MIDNR), Dave Gonder (ONMNR), Greg Wright (Sault Tribe), Chuck Bronte (USFWS), and Rob Elliott (USFWS).

Mike Jones led the group in an assessment of the recommended changes to the Red Flags Analysis.

Clarity the Objectives
The first recommendation was to clarify the objectives of the Red Flags Analysis. After considerable discussion the group agreed to define the following goal for the analysis.

*The goal of the Red Flags Analysis is to assess the Chinook salmon fishery and the balance between salmonine predators (especially Chinook salmon) and planktivore prey (especially alewives) in Lake Michigan.*

Then a consensus was reached to make some revisions in the objectives recommended in Clark’s review. The new objectives of the Red Flags Analysis are as follows.

1. To annually assemble, organize, and discuss lake-wide data for Lake Michigan salmonines and their forage base, with a main focus on Chinook salmon and alewife.
2. To annually provide a lake-wide assessment of the Chinook salmon fishery and the predator-prey balance in Lake Michigan to help managers make decisions on stocking and regulations and to provide a framework to help explain the decisions to stakeholders.
   a. Annually monitor a series of relevant biological indicators to help identify problems in the fishery or the predator-prey balance and, if necessary, make recommendations for appropriate corrective action.
   b. Provide a quantitative measure of progress in achieving the objectives of the current Chinook salmon management policy.
   c. Provide a quantitative measure of progress in achieving the Salmonine Fish Community Objective.
Revise List of Indicators
The second recommendation was to revise the list of primary indicators. A lively discussion ensued. The matters discussed included: 1) the desirability of using specific (e.g., thiamine levels, BKD testing) versus general (e.g., recruitment, mortality) indicators; 2) the spatial limitations of some of the indicators (e.g., using Strawberry Creek weir weights to represent the entire lake, using charter boat catch rates from Michigan waters only); and 3) the cost and ability of the agencies to continuously provide various indicators. The group discussed the appropriateness of the categories (abundance, recruitment, growth, and mortality) and specific indicators recommended in Clark’s review.

The discussion led to the following decisions. First, it was decided to include an abundance indicator in the analysis and that a Statistical Catch at Age Analysis (SCA) would give the best estimate of Chinook salmon abundance. SCA uses much of the data previously used as biological indicators (estimated catch by age, targeted fishing effort, number stocked, number of wild recruits, etc.) and combines them in a biologically meaningful way. Movement of fish between lakes could also be built into the SCA if future studies prove that movement is significant. It seems quite feasible to use SCA to calculate abundance every year in a timely manner as the input data is already being collected. Many of the lake trout and whitefish fisheries from around the lake already use this method. Another advantage of the SCA method is that it gives an estimate of the total population size and is not just an index of abundance like a catch rate. Thus, the SCA could be used to estimate other things like forage demand.

The most recent SCA for Lake Michigan Chinook salmon was conducted by Iyob Tsehaye but only includes data up to 2008. Iyob said he would update the analysis and the others agreed to help provide the necessary data.

Second, it was decided to include the following growth/condition related indicators in the analysis: 1) a condition factor calculated from lengths and weights of fish collected in mid-summer (July 1 – Aug 15) from the creel surveys; and 2) an average weight of females at age 3 for fish collected at weirs from around the lake. Data were not available to calculate a time series of these indicators at the workshop. Rick Clark will assemble the data and make the calculations before the final review in July.

Third, it was decided that separate indicators for population recruitment and mortality were no longer necessary because they were already represented in the SCA estimate of abundance. However, it was proposed that the percent return to the creel might be a good indicator to help monitor the general performance of hatchery fish. Return rates of hatchery fish declined markedly in Lake Huron after the collapse of the alewife population. The best way to use the return rates might be to use them in a separate but parallel “hatchery fish performance” evaluation. Clark will investigate this matter further before the final review and make a recommendation.

Fourth, it was decided to use charter boat catch rates and estimates of the proportion of Chinook salmon in the harvest as measures of “fishery performance” rather than including them in the main Red Flags Analysis. While catch rates can be an index of abundance, including them in the Red Flags Analysis would be redundant with the SCA estimate of abundance. In addition, it was suggested that a catch rate was more a consequence of the proper management of the predator-prey balance than something to manage for directly. However, catch rates do measure the performance of the fishery, and they are well understood by anglers, so they should continue to be monitored. It was decided to use charter boat catch rates from all the states surrounding the lake, rather than only those from Michigan. Regarding the proportion of Chinook salmon in the harvest, it was suggested that this was a reasonable measure of the diversity of the fishery, and the FCOs state that we should provide a diverse fishery. Exactly how to calculate the proportion Chinook was not discussed, but the implication was that it would be done using lake wide data from agency creel surveys. Clark will investigate this matter further before the final review and make a recommendation.
Finally, another indicator was proposed – a Chinook salmon-alewife predator-prey ratio. The group agreed that this single indicator was central to achieving the goal of management and the goal of this analysis. The Chinook-alewife ratio could be calculated by combining the Chinook abundance estimate from the SCA and an estimate of alewife abundance. Several measures of alewife abundance are available from hydroacoustic and trawl surveys, or perhaps an alewife abundance estimate could be calculated from population modeling or an alewife SCA. The alewife workshop will be asked to address this issue. Much discussion ensued about the problems involved in making the calculations for the ratio and interpreting the ratio. For example, we must be careful to distinguish between ratios based on estimates of standing stock in numbers or weights (biomass at a given time) versus ratios based on estimates of production (biomass produced over time). Just for the sake of argument Iyob was able to use the decision analysis model to estimate the Chinook-alewife ratio from 1965 to present (Figure 1). Based on Figure 1 and the idea that the predator-prey ratio should be the primary focus of management, everyone thought the ratio looked like a promising new indicator.

![Figure 1 - Ratio of Abundance - Chinook/Alewife](image)

**Revise Triggering Mechanism**
The third recommendation was to replace the statistical percentile based triggering mechanism with a target-limit-reference-point based mechanism. There was some skepticism that such a change would improve the analysis, but a consensus was finally reached to use target and limit reference points and to use the Lake Huron data to help define some of the limit reference points. The targets and limits for the new indicators cannot be determined until a full time series of values can be calculated. However, based on available information from the decision analysis model and the Lake Huron collapse, upper and lower limits for condition factor (Fulton’s) should be about 1.25 and 0.95, respectively, and upper and lower limits for mean weights at age 3 should be about 19.8 and 14.3 pounds, respectively. Clark will investigate targets and limits further and make recommendations before the final review in July.

**Develop explicit metrics of management success**
This was generally supported, but could not be calculated because the values and targets for all the primary indicators were not available at the workshop. When the values and targets are available, Clark will produce a management success index based on relative deviations between values and targets, similar to the one in his review paper.
In order to evaluate the progress in achieving the Salmonine Fish Community Objective (2.c. above), it was decided to annually update the CONNECT model analysis as presented in Clark’s review paper. Steve Robillard made the point that the authors of the State of the Lake report always struggle to measure and address the progress being made. Updating this analysis on an annual basis would help. This FCO evaluation would be done separately, but in parallel with the Red Flags analysis. In addition, participants wondered if there was a similar, quantitative way to evaluate the prey-planktivore FCO. This should be brought up at the upcoming alewife workshop.

Develop a projection model
There was little discussion of the projection model at the workshop, except that it was mentioned that the SCA abundance estimates would be a year behind because the estimates of natural reproduction would be a year behind. Thus, it would be useful to use a model to project abundance to current year and, perhaps, a few future years.

Conclusion
The consensus of the participants was that the main Red Flags Analysis should be focused on monitoring the Chinook-Alewife predator-prey balance and on measuring the performance of the current management policy in achieving the desired balance. Table 1 gives a summary of the proposed structure of the new Red Flags Analysis. Figure 2 gives a summary of the suggested steps in the procedure for making annual estimates of Chinook salmon and alewife biomass and applying them to estimate the predator-prey ratio.

Other important aspects of the lake wide management problem will be monitored in separate but parallel analyses. These include: 1) the Performance of Hatchery Fish Analysis, which will make annual estimates of the rates of return to the creel of fish marked with Coded Wire Tags; 2) the Performance of the Fishery Analysis, which will make annual lake wide estimates of charter boat catch rates and annual estimates of the proportions of Chinook salmon and other salmonines in the harvest; and 3) the Salmonine FCO Analysis, which will annually update the CONNECT model to estimate the performance of lake wide stocking of all salmonines in achieving FCOs (see Clark 2012).
Table 1 – Proposed Red Flags indicators, targets, and limits.

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Target</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook salmon</td>
<td>Abundance as estimated by SCA</td>
<td>To be proposed after time series is calculated. Should be a population that can reasonably be sustained by annual forage production.</td>
<td>To be proposed after time series is calculated. Consideration of past “problem” years in Lake Michigan and Lake Huron should provide insight.</td>
</tr>
<tr>
<td></td>
<td>Condition factor of fish collected from creel from July 1 – Aug 15</td>
<td>To be proposed after time series is calculated. Could be an average of years in Lake Michigan when fishery was considered to be in good balance.</td>
<td>Lower – Fulton’s condition factor should be above 0.95 based on Lake Huron collapse. Upper – Fulton’s should be below 1.25 based on Lake Huron collapse.</td>
</tr>
<tr>
<td></td>
<td>Mean weight of age-3 females at weirs</td>
<td>8.0 kgs (17.6 pounds) based on modeling and past performance</td>
<td>Lower – 6.5 kgs (14.3 pounds) based on Lake Huron collapse. Upper –9.0 kgs (19.8 pounds) based on collective judgment and past performance.</td>
</tr>
<tr>
<td>Predator-Prey</td>
<td>Ratio of the standing stock of Chinook salmon to the standing stock of alewives</td>
<td>To be proposed after time series is calculated</td>
<td>To be proposed after time series is calculated</td>
</tr>
<tr>
<td>Alewife</td>
<td>Abundance (methods to be determined at alewife workshop)</td>
<td>To be determined at alewife workshop</td>
<td>To be determined at alewife workshop</td>
</tr>
<tr>
<td></td>
<td>Condition (methods to be determined at alewife workshop)</td>
<td>To be determined at alewife workshop</td>
<td>To be determined at alewife workshop</td>
</tr>
<tr>
<td></td>
<td>Others? (To be determined at alewife workshop)</td>
<td>To be determined at alewife workshop</td>
<td>To be determined at alewife workshop</td>
</tr>
<tr>
<td>Index of Management Success</td>
<td>Some cumulative measure of the differences between targets and annual values for each indicator</td>
<td>Zero – If the cumulative deviations from all targets are zero, then management is perfect.</td>
<td>Na</td>
</tr>
</tbody>
</table>
Figure 2 – Proposed procedure for calculating predator-prey ratio.

**Chinook**

1. Estimate proportion wild at age 1 in year $i$
2. Project total smolts in year $i-1$
3. Estimate abundance and biomass in year $i-1$ with SCAA
4. Use CONNECT model approach to estimate Chinook abundance and biomass in year $i$
5. Future Projections - Use CONNECT model approach to estimate Chinook abundance and biomass for years $i+$
6. Calculate predator-prey ratio for year $i$
7. Calculate predator-prey ratio for year $i+$

**Alewife**

1. Estimate prey biomass in year $i$
2. Future Projections - Use a model to estimate Alewife biomass for years $i+$
3. Calculate predator-prey ratio for year $i$
4. Calculate predator-prey ratio for year $i+$
Appendix E

Agenda for Lake Michigan Red Flags
Alewife Workshop

With Notes of the Proceedings Inserted

April 22, 2013 (1 PM – 5 PM)

In attendance were John Dettmers (GLFC), Rick Clark (MSU), Iyob Tsehaye (MSU), Chuck Madenjian (USGS), Dave Warner (USGS), Bo Bunnell (USGS), and Stephen Riley (USGS).

- Introductions & introductory remarks – Rick Clark, MSU
- Present background information in informal round table discussion
  Presentations were given to bring the group up to date on the results of the Chinook salmon workshop and the status of alewives in lakes Michigan and Huron.
- Conduct facilitated discussion regarding the appropriateness of the recommendations (Facilitator – John Dettmers, GLFC or Mike Jones, MSU)
  - Discuss each recommendation and decide whether to endorse as is, endorse with changes, or reject.
  - Solicit and consider additional recommended changes from the group.

John Dettmers led discussions on the results of the Chinook salmon workshop, the status of alewives, and potential problems with some of the sampling gears and modeling approaches. We ran out of time to address the specific recommendations made by Clark (2012). We decided to take up the discussions the next day.

April 23, 2013

- Facilitator leads group in making changes in analysis as endorsed by previous discussion (Facilitator – John Dettmers, GLFC or Mike Jones, MSU; Modeling assistance – Iyob Tsehaye, MSU; Spreadsheet development – Rick Clark, MSU)

In attendance were John Dettmers (GLFC), Rick Clark via phone (MSU), Iyob Tsehaye (MSU), Chuck Madenjian (USGS), Dave Warner (USGS), Bo Bunnell (USGS), and Mike Jones (MSU).

John Dettmers continued with facilitator duties. We organized this second Day by going over “Status of Major Recommendations from Review” provided by Rick. The following notes of the proceedings were taken by Bo Bunnell.

1. Clarify the overall goals and objectives (Chinook salmon/alewife balance) that came from the Review and modified at the Charlevoix workshop.
   a. Mentioned that the overall goal is singularly focused on Chinook salmon and alewife, despite the fact that other fish consume alewife. John mentioned that the LMC is most interested in Chinook salmon and alewife, even though there have been previous discussions at the LMTC regarding developing Red Flags analyses regarding other salmonine species (steelhead, lake trout). We agreed it wouldn’t be hard to develop red flags for the other species, if the LMC wanted to go in that direction. In the Objectives, we noted that b) and c) would be combined if other salmonines were included in a red flags analysis.
2. Modify the analysis to address objective.
   a. Iyob and QFC will look to do this. For example- develop target and limit reference points for fishery harvest.
3. Quantitatively interpret and evaluate Salmonine FCO. No discussion
4. Replace percentile triggers with biological reference points.
   a. Rick elaborated on the rationale to move away from statistical deviations towards more objective biological or socioeconomic criteria.
   b. Now- think about this in terms of prey fish- or alewife, in fact.
      i. Yearling and older (YAO) abundance/biomass. What is the best measure of YAO alewife biomass to use in some predator/prey ratio indicator?
         1. Talked about how sometimes the estimates of consumption exceed the biomass of alewife (even after calculating catchability coefficient).
         2. Drivers of absolute alewife biomass. Mike suggested that Iyob might want to see how well these three estimates of alewife abundance track each other.
3. Prey assessment model. The abundance/biomass of alewife is estimated based on Chinook consumption, SCA Chinook abundance, and the acoustic and bottom trawl surveys. Recall that this prey assessment model develops an estimate of q for each survey. How much uncertainty do we have in the SCA abundance and bioenergetics estimates of Chinook consumption? Jones argues that the SCA models for LM Chinook abundance are actually quite good, given that we know recruits (stocking) and age structure of spawners (from weirs). Chuck mentioned that the Chinook and lake trout bioenergetics models are solid. We also track growth well. Might want to explore temperature (archival tags) and prey energy density inputs.
   a. Acoustic survey- Probably a better indicator, given that all age classes are sampled with less bias than the bottom trawl survey. Dave also mentioned that when he corrects for blind zone under the Research Vessel (based on estimates in inland lakes from Rudstam), the biomass he comes up with is similar to the model estimate (using q).
   b. Bottom trawl survey- Talked about varying q through time (two time blocks??). Chuck mentioned that q may have changed in the early 1990s for age-0 alewife. Chuck and Bo also agreed that older alewife catchability may have changed in the mid-2000s with mussels.
4. Indicator for YAO alewife abundance (biomass)?
   a. We talked about the timing work for the March meetings. As a simple exercise, we could use the q from the prey assessment models (one for age-0 alewife for each survey, one for age-3+ for the bottom trawl, one for age-1+ for the acoustics survey). Planktivore committee could come up with a biomass estimate each spring after age-specific estimates are derived from bottom trawl and acoustic surveys. Question is how often the prey assessment model is updated. Each year- after the March meetings. Mike suggested that the Planktivore working group should consider this. And at this point, we would think that this annual update should involve the Planktivore and Salmonid working groups and the QFC.
      i. Reference point for YAO alewife biomass. To be determined. Use Iyob’s model to determine the alewife spawning stock biomass that is associated with a sufficiently low probability (>10%) of alewife
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collapse as the target. The limit reference point would be YAO biomass associated with a >25% chance of alewife collapse. Iyob should be able to get at this through a simulation exercise where you start the alewife YAO biomass at different levels and run it for 25-years (range of stock/recruitment parameters, current stocking levels) and see what proportion of the 1000 runs that alewife collapses. This could reveal that you need to get to a really low YAO biomass for collapse to happen. Rick points out that it also might also identify Chinook abundance/biomass targets, predator/prey ratios, and maybe even the mean weight at age 3 for Chinook.

ii. Alewife recruitment (age-0 abundance/biomass).
   1. Indicator: we have already estimated this to input into the above total biomass estimate.
   2. No need to predict from a stock/recruitment relationship.
   3. Mike asked if we needed to consider recruitment/biomass of other prey species. Dave reminded us that Iyob’s model provide an estimate of q for rainbow smelt as well, so we could provide it relatively easily if asked.
   4. Target reference point: What level of recruitment is sustainable, such that recruitment + production equals (or exceeds) predation (and natural) mortality? In the simulation, you start out with different levels of recruitment (divorced from stock size) and then run the model forward and see what level(s) of recruitment leads to alewife collapse. Definition of collapse in this sense may need to be based on Chinook growth (hard to collapse alewife is recruitment is constant at some level). In essence, we are interested in the average level of recruitment that avoids collapse under the assumed consumption/stocking scenario. We also talked about whether this was even a useful indicator for managers. Might be better to use recruitment from year x (and YAO biomass from year x) to forecast YAO biomass in year x+1- and then give managers a heads up for the following year. Decision was not to develop a Target (or limit) reference point for recruitment. Recruitment must be placed within too many contexts.

iii. Alewife Condition (growth) using fish collected from bottom and midwater trawls. Rick said that we should try to keep this as limited a list as possible.
   1. Indicator: Predicted weight at length. Chuck suggested this one would be best by developing a length/weight regression for each year (pooling all fish) and predicting weight for a 165-mm TL alewife. Everyone agreed on this one. Would be easy to develop from last year’s survey.
   2. Fulton’s condition factor. Could be dependent on the size distribution of the population.
   3. Energy density (or dry weight). More work….
   4. Target reference point for predicted weight at 165 mm TL. This qualitatively changed (dropped) in the mid 1990s- but it does not appear to have negatively influenced their reproductive potential. Chuck also noted that Lake Michigan alewife have always been in better condition than Lake Ontario alewife (although they are closer in condition now). Decision: Not a need for a target or limit reference
point to influence salmon stocking. We do, however, need to track alewife energy
density for its effect on Chinook consumption.

iv. Alewife Mortality. Mike suggested that this piece was unnecessary. We discussed whether
this might be diagnostic for an imminent collapse. Also, could mortality (predation) be
increasing to the point that abundance of age-1 can no longer be reliably predicted from the
abundance of age-0 in the fall? The fear is that the level of biomass was relatively high but
that it was all concentrated in one year-class.

1. USGS will continue to describe age distributions in their annual reports.
2. A useful indicator could be % of the adult population in one age-class. Could we
look to Lake Huron to see what that % could be? Could also consider the proportion
of the population that was older than age-2. Could also consider the maximum age,
which influences the number of spawning opportunities for the adult alewife
population. No decision was reached here. Dave went back and looked at the time
series of maximum age and the number of age-classes \geq 2 in Lake Huron. There
were definitely higher values in the 1990s than in the early 2000s. Can we use these
metrics to inform Lake Michigan? Probably not.

v. In the end, we are left with a single indicator and reference point. YAO adult alewife
biomass presented in the spring, from the previous year. In the spring, we can also forecast
YAO adult alewife biomass for the coming spring, summer, fall, using recruitment biomass
from previous year and some assumed level of mortality (informed by either catch curve
analyses or from Iyob’s retrospective model and those most recent years. Would be worth it
to compare the Z from the catch curve to those estimated by Iyob’s model) and predicted
weight at age. Rick noted that this simplicity also allows us to relatively easily include
additional predators and prey. We also agreed that stock assessment models should be
updated, at minimum, at the frequency in which stocking assessments were made. Currently
set to revisit every 5 years, but discussion in Charlevoix indicated it may be every 3 years.
The onerous part of this process is the discussions with the public and among the managers to
reach consensus.

April 24, 2013 (8:30 AM – 12 Noon)

This final day was cancelled.
Notes of meeting at QFC concerning new Red Flags Analysis

Meeting date: October 3, 2013

Present: Randy Claramunt, MIDNR; Ben Dickinson, INDNR; Nick Legler, WIDNR; Steve Robillard, ILDNR; Greg Wright, Sault Tribe; John Dettmers, GLFC; Rick Clark, QFC; Mike Jones, QFC; Iyob Tsehaye, QFC.

- Five primary indicators and 3 auxiliary indicators were selected for the new analysis during the Chinook and alewife workshops. All the data available for these indicators were assembled and presented for review.

- The group noted that two of the primary indicators, Chinook body condition and mean weights at weirs, were correlated with each other and with the predator-prey ratio. This raised the question as to why it would be necessary to include 3 correlated indicators in the analysis. In addition, it was noted that the abundance indicators were used to calculate the predator-prey ratio, so abundances were essentially used twice. As a result of this discussion, the Salmonid Working Group (SWG) members decided to select the Chinook-Alewife predator-prey ratio as the sole primary indicator in the analysis. All of the other indicators will also be calculated but considered as auxiliary indicators or supportive information.

- The group noted that the predator-prey ratio might be improved by including estimates of mean weights at age for alewives for individual years. It has been documented that alewife growth and condition declined in the mid-1990s, and it could decline in the future given reports of declining lake productivity and changes in the plankton community. The current predator-prey ratio uses the same mean weights at age for all years. Rick Clark will check with Chuck Madenjian to see if year-specific mean weights are available. If so, he will use them to update the ratio.

- The group discussed target and limit reference points. Although it seemed possible to identify reasonable values subjectively, it was decided that it would be better to try to take a more rigorous approach, such as one similar to that suggested by Caddy and McGarvey (1996 – NAJFM 16:3, 479-487). Such an approach would identify a limit reference point for the predator-prey ratio that managers should avoid exceeding. One variation of this approach would be for managers to select an alewife biomass that would be considered unacceptably low and a maximum risk (e.g. 10% 15%, or 20%) of falling below this biomass. The SWG and/or the LMTC would help managers by providing recommendations for these management decisions. Once this alewife biomass limit and risk threshold has been identified, the risk assessment (decision analysis) model can be used to identify: 1) a range of Chinook salmon stocking rates which would maintain the alewife population above the biomass limit and below the given risk threshold; and 2) a limit reference point for the predator-prey ratio, which would be associated with the alewife biomass limit and risk threshold. Then, the new Red Flags analysis would annually estimate the predator-prey ratio, and when the ratio exceeds the limit reference point, it would signal that management action may be needed. An upper limit and risk threshold for alewife biomass (and associated lower limit for the predator-prey ratio) could be handled in similar fashion. Rick Clark and Iyob Tsehaye will explore using the existing risk assessment model to help identify appropriate targets and limits for the predator-prey ratio. They will report their findings back to the group before the winter LMTC meeting.
The group discussed the list of data required for the new analysis and the approximate time of the year the data would be available (see Attachment 2). The group agreed that the new analysis could be completed by mid to late winter.

The group agreed that the new analysis should be run annually, considering the variability of alewife year-class strength.

The group decided to explore adding another auxiliary indicator to track the age structure of the alewife population. The concern was that high predation rates could eliminate older alewives and, thereby, truncate the alewife population age structure to a small number of young age groups. This could increase the variability in alewife abundance from year to year. Generally, a larger number of age groups tend to dampen the year-to-year variability in abundance.

The group decided to ask the Lake Michigan Planktivore Working Group (PWG) to help run the analysis. The general idea was that the SWG could estimate Chinook salmon abundance and the PWG could estimate alewife abundance. Both of these efforts could get assistance from the QFC if problems arise. Only one member of the PWG was present (Claramunt), so this idea will have to be discussed with them at a later date.

The SWG members present agreed to adopt the new analysis, with the changes described at this meeting.

The SWG will hold a meeting on the afternoon of January 27, 2014 prior to the LMTC meeting in Indiana. They will make a test run of the new procedure using 2013 data. The primary purpose of the test run is to give SWG members hands-on experience in using the new analysis. Also, at this meeting, the SWG will prepare recommendations regarding the use of the new procedure for discussion with and recommendation by the LMTC on January 28th. The Chair of the SWG, Nick Legler, will present the recommendations. Rick Clark will help provide slides and information for Nick’s report and will be available for assistance and questions as necessary.