Gillnet selectivity of Lake Winnipeg walleye (*Sander vitreus*) and sauger (*S. canadensis*) and evaluation of the effects of changes in south basin minimum mesh size regulations

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Executive Summary

Manitoba Agriculture and Resource Development (hereinafter, ARD) regulates maximum and minimum allowable mesh sizes (hereinafter, MMS) on license as a primary means to manage the commercial catches of walleye and sauger in Lake Winnipeg.

Concerned principally about the state of the walleye commercial fishery, ARD increased the MMS permitted in the south basin of Lake Winnipeg from 3” to 3.5” in the spring of 2020. ARD suggested that the larger MMS would “improve the fishery by allowing more immature fish to escape the fishery, grow larger and spawn once before being removed by the fishery [which would] increase the reproductive potential of the walleye stock and at the same time increase the size of fish caught, which will both ensure maximal walleye yield from the fishery.” Fishers countered that the regulation change was unnecessary, as the walleye population was not at risk, and would cause significant economic hardship.

The regulation change focused attention on the selectivity of the commercial gillnets and the potential effects of larger MMS on the walleye and sauger population abundance and length compositions of both the commercial catch and populations. Unlike what takes place in industrial-scale, certified commercial fisheries, ARD does not gather effort and commercial catch sample data from the Lake Winnipeg commercial fishery. Therefore, there is no direct way to estimate the selectivity of the commercial gillnets. However, there are data available from ARD index surveys using gillnets of various mesh sizes over each of two periods, 1980-2003 and 2009-2019. The estimated selectivities of these meshes were assumed to be similar to those of commercial nets. Effects of changes in the selectivity of commercial gillnets on abundance and age composition of commercial catches, and on populations of walleye and sauger, were simulated lake-wide using the same modelling framework used for stock assessment (AOFRC 2020) and “stepped down” to the south basin.

We used management strategy evaluation (MSE) to explore the implications of a change in MMS from 3.0” to 3.5” in the south basin fishery. In scenarios S1G1 and S1G2, estimated fishing mortality from 2017-2019 was held constant (management scenario S1) while selectivity varied between 3” MMS (gear scenario G1) and 3.5” MMS (gear scenario G2). It was assumed that the south basin commercial fishers would increase their fishing effort to maintain walleye and sauger catch levels despite the reduced MMS. Therefore, in scenario S2G2, fishing effort was increased (management scenario S2) under the larger MMS (gear scenario G2) as required to match the catches of walleye and sauger prior to the change in MMS.

To achieve the same catch with 3.5” MMS (scenario S2G2), fishing effort had to increase by about 1.45 and 1.40 times that with the 3” MMS, for walleye and sauger, respectively. In this scenario, the south basin walleye and sauger biomasses under S2G2 were essentially the same (1.02 times) as the south basin walleye and sauger biomasses under S1G1 (minimum 3” mesh). Therefore, the move to the larger MMS had no meaningful effect on the walleye biomass or the sauger biomass.

These results are based on the characteristics of the ARD index survey gillnets and must be considered provisional until there is a better understanding of the actual commercial fishing effort and the selectivity of the commercial gillnets. Further studies on the selectivity of commercial gillnets are needed to better understand the effectiveness of commercial gillnet mesh size changes as a management

tool. Going forward, the effects of changes in gear regulations should be examined further using a state-of-the-art MSE approach to stock assessment and informed by actual commercial catch at age/length data obtained by commercial catch monitoring. Until then, it cannot be ruled out that there is a risk of perverse, unintended consequences as a result of the change in MMS for fish and fishers.

Summary of the long-term influence of MMS changes in south basin from 3” to 3.5” on Lake Winnipeg commercial fishery catch and population biomass changes under three scenarios.

Walleye

Scenarios	Harvest Policy	Proportion of small mesh and large mesh gear effort in south basin fishery	Mean catch (1000 tonnes)	Mean biomass (1000 tonnes)
S1G1	Constant fishing mortality (F) equal to mean F between 2017-2019	50% ≥ 3” and 50% ≥ 3.5”, i.e., pre-MMS change	1.53	18.40
S1G2		100% ≥ 3.5”; i.e., post-MMS change	1.27	20.23
S2G2	Catch equivalent to that under S1G1 by increasing F	100% ≥ 3.5”; i.e., post-MMS change	1.53	18.72

Sauger

Scenarios	Harvest Policy	Proportion of small mesh and large mesh gear effort in south basin fishery	Mean catch (tonnes)	Mean biomass (tonnes)
S1G1	Constant F equal to mean F between 2017-2019	50% ≥ 3” and 50% ≥ 3.5”, i.e., pre-MMS change	22.18	311.60
S1G2		100% ≥ 3.5”; i.e., post-MMS change	18.67	333.62
S2G2	Catch equivalent to that under S1G1 by increasing F	100% ≥ 3.5”; i.e., post-MMS change	22.18	316.54

1. Introduction

Manitoba Agriculture and Resource Development (hereinafter, ARD) regulates maximum and minimum allowable gillnet mesh sizes on license as a primary means to manage the commercial catches of walleye and sauger in Lake Winnipeg. Based principally on information about the walleye commercial fishery, ARD increased the minimum mesh size (hereinafter, MMS) permitted in the south basin of Lake Winnipeg from 3" (76.2mm) to 3.5" (89mm) in the spring of 2020. ARD suggested that the larger MMS would "improve the fishery by allowing more immature fish to escape the fishery, grow larger and spawn once before being removed by the fishery [which would] increase the reproductive potential of the walleye stock and at the same time increase the size of fish caught, which will both ensure maximal walleye yield from the fishery."

Commercial fishers countered that the regulation change was unnecessary, as the walleye population was not at risk, and it would cause significant economic hardship. The Pioneer Commercial Fishers of Manitoba (PCFM) supported a 2-part, arm's length research project by the Anishinabek/Ontario Fisheries Centre to conduct (1) assessments of the status of the walleye, sauger and lake whitefish fisheries and (2) evaluate, to the extent possible, the effects of a change in the MMS in the south basin on walleye and sauger populations and commercial catches. The first report indicated that the probabilities that overfishing of walleye was occurring, and that walleye were overfished in 2019, were 0.01 and 0.06, respectively. For sauger, the respective probabilities were 0.39 and 1.00.

The goal of this second report is to explore the potential implications of the increased MMS for the south basin walleye and sauger population biomasses as well as for the commercial catches of walleye and sauger in the south basin. We used management strategy evaluation (MSE) to estimate the effect of the change in MMS on the age compositions, yields of the commercial catches and the population biomasses of walleye and sauger. MSE effectively compares alternative management strategies (Punt et al. 2016) in a wide range of applications in natural resource management, particularly, in the case of data-poor or -limited fisheries (Bunnefeld et al. 2011; Carruthers et al. 2014; Dowling et al. 2015).

2. Data and methods

A structured stock assessment using MSE to analyze the effects of alternative MMSs requires information about the selectivity of the commercial gillnets for walleye and sauger. However, there are no data about ages and/or lengths of walleye or sauger from commercial catches. Consequently, we used fishery-independent data from the 1980-2003 and 2009-2019 ARD gillnet index surveys to estimate gillnet selectivities for each of walleye and sauger and assumed that the selectivity of the commercial gillnets is similar to that of the survey gillnets.

For walleye and sauger, lengths of fishes in the catches from the index surveys, given each mesh size and each set, were analyzed to estimate the selectivity of the index gillnets for each species. Gillnet selectivity was estimated based on the index gillnet meshes that were consistently used among the various years of the two surveys (1979-2003 and 2009-2019). Meshes of 3'', 3.25'', 3.5'', 3.75'', 4'' and 4.25'' were used consistently from 1980-2003, and meshes of 1.5'', 2.5'', 3'', 3.5'', 3.75'', 4.25'', 5'' and 6'' were consistently used from 2009-2019.

The estimated selectivities from the ARD survey data during the period 2009-2019 were used in the MSE to simulate population abundance and age composition of the commercial walleye and sauger catches, as well as walleye and sauger population abundance and age structure, over time under smaller and larger MMSs.

2.1 Selectivity estimation

Selectivity of the index gillnets was first diagnosed through Jensen's selection plots (Baranov 1948; Jensen 1973) and then estimated using a maximum likelihood estimate (MLE) approach (Millar and Holst 1997).

The selectivity curve was assumed to be lognormal and the uncertainty of the catch from the gear was assumed to follow either a Poisson or lognormal distribution (Millar and Holst 1997). The survey gear selectivities based on the index survey gear meshes were estimated by summing the selectivity of each mesh, which was then scaled to the maximum selectivity of 1 for the selectivity at length.

2.2 Simulation of the effects of the MMS regulation change

2.2.1 Gear and management scenarios.

The effects of changing the MMS from 3" to 3.5" were evaluated in three scenarios designed to explore the effects of increasing MMS on the lake-wide walleye and sauger populations with particular emphasis on south basin walleye and sauger population biomasses and catches (Table 1).

Table 1: Scenarios used in the simulation study to investigate the effects of changing south basin MMS from 3" to 3.5".

Scenarios	Harvest Policy	Proportion of small mesh and large mesh gear effort in south basin fishery
S1G1	Constant F equal to mean F between 2017-2019	50% ≥ 3" and 50% ≥ 3.5", i.e., pre-MMS change
S1G2		100% ≥ 3.5"; i.e., post-MMS change
S2G2	Catch equivalent to that under S1G1 by increasing F	100% ≥ 3.5"; i.e., post-MMS change

The simulations were based on the selectivities estimated from the ARD 2009-2019 index gillnets, the average walleye and sauger biomasses between 2017-2019 (A/OFRC 2020), and the age structure of the walleye and sauger populations from the ARD surveys between 2017-2019. MMS in the north basin and Narrows remained at 3.5". Walleye and sauger populations were assumed to be panmictic lake-wide, though the effects of the gear change on the south basin walleye and sauger fisheries were of primary interest. Thus, the simulations assumed the properties of the lake-wide populations and the results for the south basin were "stepped down", based on the proportions of each of walleye and sauger lake-wide populations in the south basin, to infer south basin-specific effects of alternative MMS regulations.

We simulated two management policy scenarios. S1, constant fishing mortality, and S2, constant catch. S1G1 further simulated the effects of changes in selectivity when the ranges of mesh sizes included 3.0", and S1G2, when the range of mesh sizes excluded 3.0”. The constant fishing mortality rate (F) was based on the mean F between 2017-2019 estimated by A/OFRC (2020) in part 1 of this project. S2 simulated changes in fishing effort required to obtain the same catch without (G2) as with 3.0” mesh.

G1 assumed that 50% of the gillnet effort included 3” as well as larger meshes (3.25”, 3.375, 3.5”, 3.75”, 4”, 4.25”, 5”, 5.25”), and 50% of the gillnet effort included only meshes, $\geq$ 3.5” (3.5”, 3.75”, 4”, 4.25”, 5”, 5.25”) prior to the regulation change in 2020. G2 assumed all the gillnet effort in the south basin included only meshes $\geq$ 3.5” after the regulation change in 2020. For walleye and sauger aged 3 and older, population biomass, age structures, commercial catches and age composition of the catches were estimated under each of the three scenarios to evaluate the effects of the MMS regulation change

2.2.2 *Population structure and dynamics used in the simulation scenarios*.

The lake wide and south basin walleye and sauger population biomasses and age structures were estimated based on the biomass estimates from the state space biomass dynamic models used in part 1 of this study (AOFRC 2020) and the observed age frequency and age-weight relationships from the 2017-2019 ARD index netting survey data (Figure 1),

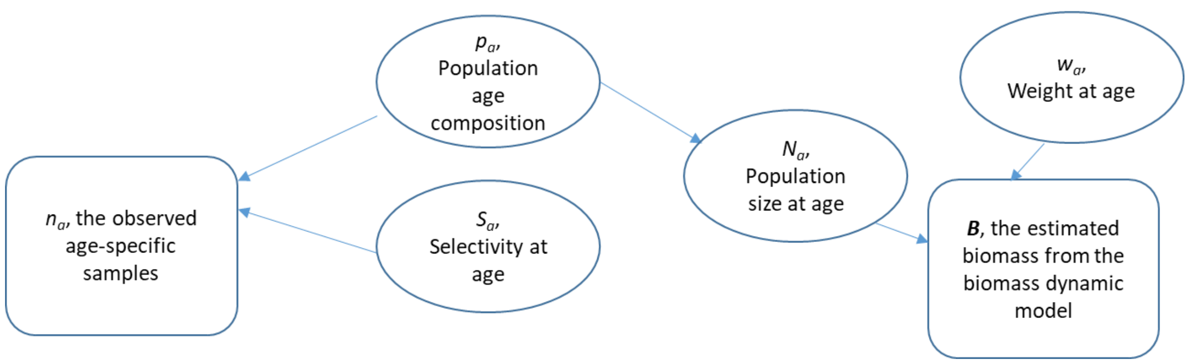

Figure 1: Flowchart to indicate the process of estimating population age structure in a specific year. See equations below also.

$$B = \sum_a N_a \times W_a$$

$$n_a = q \times E \times \sum_a N_a \times S_a$$

$$n_a \sim dmulti(p_a \times S_a, \sum_a n_a)$$

The estimated selectivity at age *a* (S_a), using all meshes in the index survey gear, was based on

$$S_a = \frac{\sum_{\text{mesh types}} S_a \mid \text{mesh type } i}{\max(0 \sum_{\text{mesh types}} S_a \mid \text{mesh type } i)}$$

where n_a is the average observed number of fishes at age *a* in the most recent 3 years of the available index survey data. n_a is assumed to follow a multinomial distribution with the sample size $\sum_a n_a$ and p is the estimated population age structure in the most recent 3 years (2017-2019).

Uncertainty of the abundance (N) in the years 2017-2019 was estimated based on the uncertainty of the estimated biomass (B) and weight at age (W_a). Recruitment per spawner (RPS) assumed that fecundity was proportional to body weight (King 2007; Quinn and Deriso 1999), and the weight-at-age relationship was used to estimate age-specific fecundity, and then further scaled the RPS at age 1 according to the assumption that the current absolute population growth rate is 1 given the current fishing intensity and natural mortality (assumed to be constant =0.32; Akcakaya et al 1999; Caswell 2008). The projections were based on the population biomass in 2019 (A/OFRC 2020) and the RPS given the weight of the fish and the fishing pressure in 2017-2019 (A/OFRC 2020).

2.2.3 *Proportions of lake-wide walleye and sauger populations in the south basin*.

Because the walleye and sauger populations were assumed to be panmictic throughout the lake, the proportions of the populations in the south basin was assumed to be proportional to the catch (deliveries) from the south basin. According to data from the Freshwater Fish Marketing Corporation (FFMC), the percentage of deliveries in the south basin between 2008-2019 varied between 33%-46% with an average of 40% (Figure 2). The catch per unit effort (CPUE) of walleye in the three basins have similar trends but not the same scale, indicating a potential density difference between the basins. The CPUE of sauger in the two basins have similar trends and scale, indicating similar densities, although there are variations in the trend between 2012-2014. Therefore, the simulations assumed that 40% of the sauger and walleye populations occur in the south basin of the lake based on the idea that if the lake wide density is close to homogenous, then the CPUE should reflect the change of the lake wide population in both basins similarly.

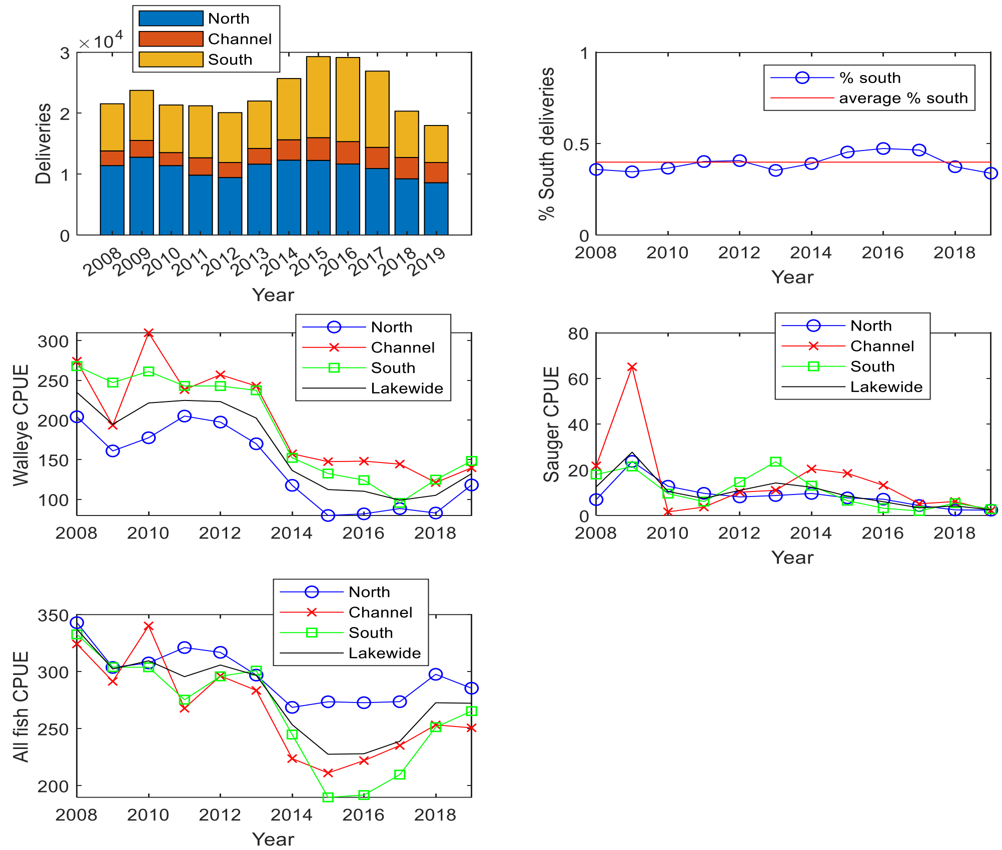

Figure 2:
Deliveries from the commercial gillnet fishery, and the commercial gillnet CPUEs of walleye and sauger in the north basin, narrows and the south basin.

3. Results

3.1 Walleye

3.1.1 Selectivity estimation

The lognormal error assumption resulted in a much smaller Akaike information criterion (AIC) than when the Poisson error structure was used (Table 2).

Table 2: Models used in the walleye selectivity studies for the two time periods of the ARD index gillnet surveys.

Models	1979-2003		2009-2019	
	lognormal error	Poisson error	lognormal error	Poisson error
AIC	383.68	2395.60	641.33	4751.19

The analysis indicated that the selectivity of the index gillnet gear for walleye was different in the two index survey periods, i.e., 1979-2003 and 2009-2019 (Figures 3 and 4), with the selection biased towards larger walleye during the later survey period. The estimated differences in the selectivity were supported by the observed catch length-frequency plot by mesh size (Figure 5). For mesh sizes that were consistent across the two surveys, such as mesh sizes 3'', 3.5'', 3.75'', and 4.25'', the observed catch length-frequency shows more larger walleye in the 2009-2019 survey than in the 1979-2003 survey.

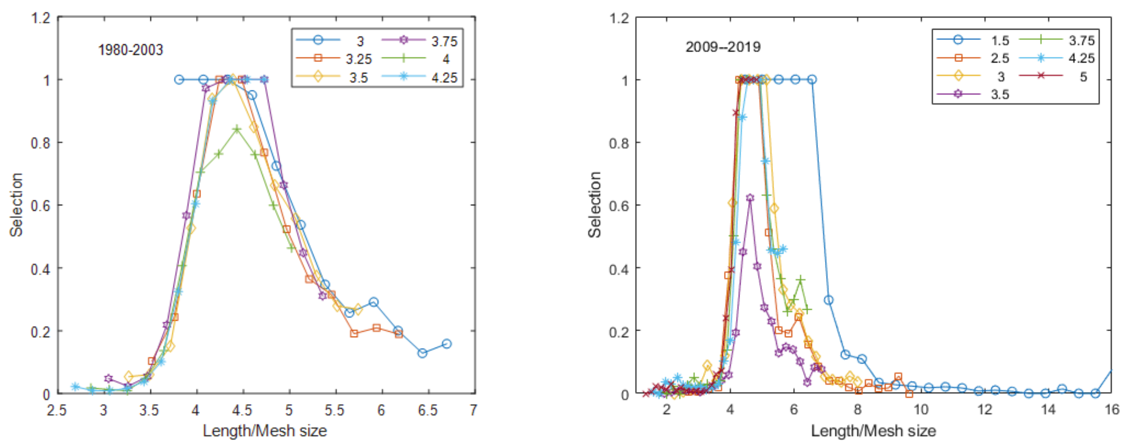

Figure 3: Jensen's selection plots for walleye based on the two index gillnet surveys.

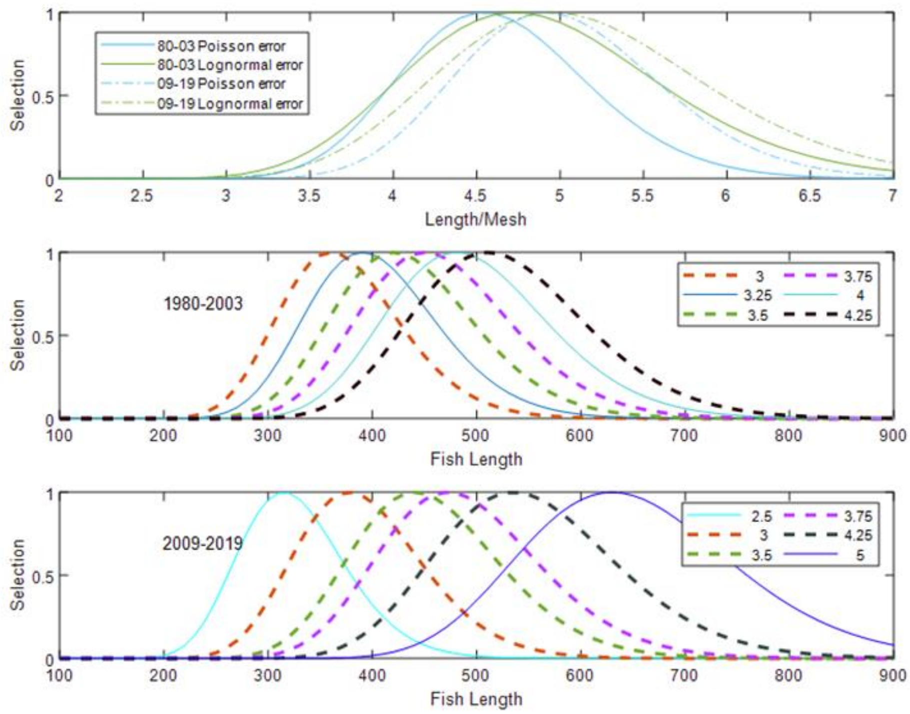

Figure 4: Estimated gillnet selectivity for walleye in the two index surveys.

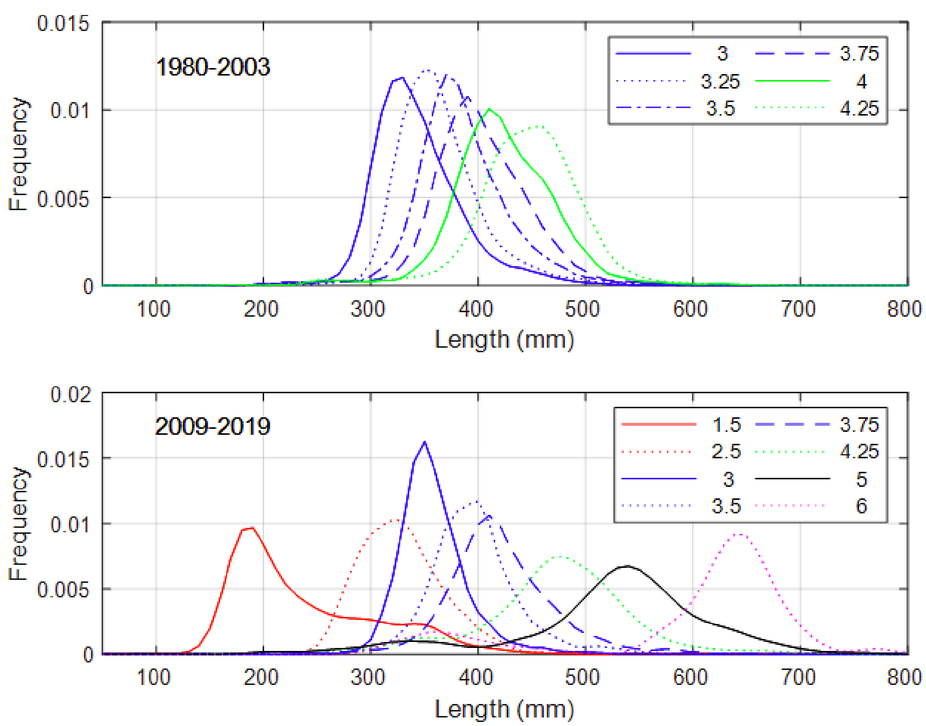

Figure 5: Length frequency of walleye by mesh size as observed in the two index gillnetting surveys.

The integration of the survey gear selectivity with all the meshes ≥ 1.5” combined (Figure 6) was used to estimate the population age structure based on the frequencies of walleye of different ages from different mesh sizes. Here the survey gear included 1.5", 2.5", 3", 3.5", 3.75", 4.25", and 5" meshes. The 2" and 6" meshes were not included because they were not consistently used among years. The selectivities of the ≥ 3” and ≥ 3.5" gears was estimated based on the survey gear selectivity by summing the selectivity of each mesh in the ≥ 3” or ≥ 3.5” mesh sets, and scaling to the maximum selectivity of 1 for the selectivity at length (Figure 7).

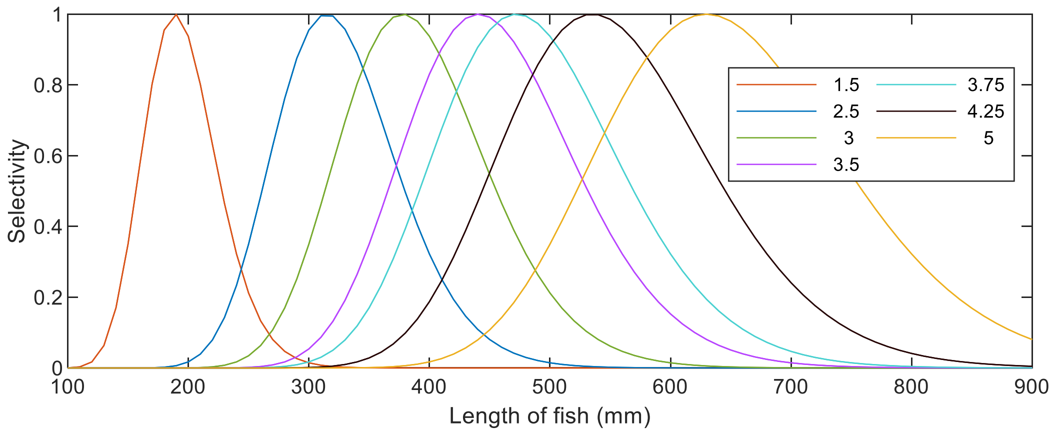

Figure 6: Estimated selectivity of the index gillnet survey gear for walleye showing all individual meshes from 2009-2019 surveys.

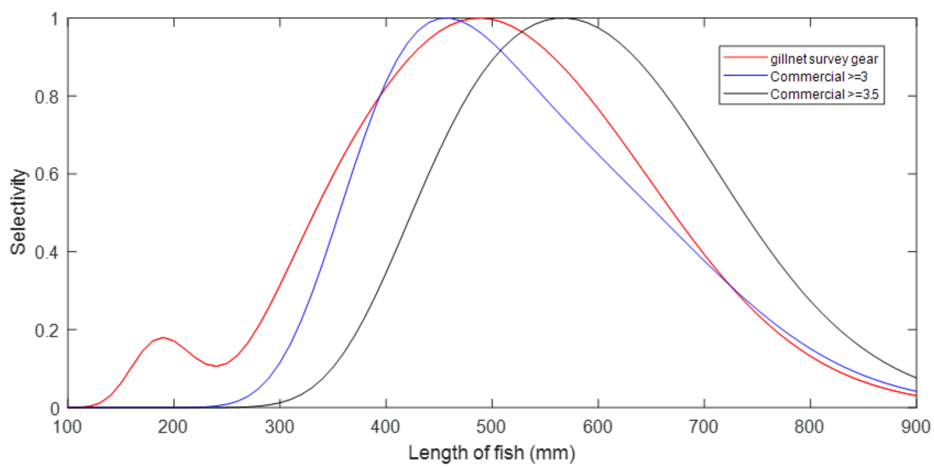

Figure 7: Selectivity of ARD survey gear (includes meshes of 1.5, 2.5, 3, 3.5, 3.75, 4.25, and 5), selectivity of commercial gear with mesh sizes ≥3” (includes meshes of 3, 3.25, 3.375, 3.5, 3.75, 4, 4.25, 5 and 5.25) and commercial gear with mesh sizes ≥3.5” (includes meshes of 3.5, 3.75, 4, 4.25, 5 and 5.25) for walleye.

3.1.2 Walleye population and catch simulations

The results of the three simulation scenarios demonstrate the effects of alternate MMS regulations and management policies on the south basin walleye age structure, biomass and catch.

The selectivity of the commercial gear with meshes ≥ 3” was assumed to be the same as that of the index gear and included meshes of 3", 3.25", 3.375", 3.5", 3.75", 4", 4.25", 5" and 5.25", and the selectivity of the commercial gear with meshes ≥ 3.5” was also assumed to be the same as that of the index gear and included meshes of 3.5", 3.75", 4", 4.25", 5" and 5.25". The assumed selectivity of commercial gear with meshes ≥ 3.5” was also toward larger and older walleye than that for the gear with meshes ≥ 3” (Figure 6). The greatest selectivity was in the range of 400-500mm total length (TL) for gear with ≥ 3” mesh, and 500-600mm TL for gear with ≥ 3.5” mesh.

Any effects of the MMS regulation change on the lake wide walleye population were much smaller than the effect on the south basin portion of the population; therefore, we present results only for the south basin. Because gillnet selectivity on walleye age groups of 0 to 2 was low, only ages three and older (3+) were used in comparing biomass and commercial catches across the management and MMS scenarios.

3.1.2.1 *Effect of alternate MMSs on south basin biomass and catch using the constant F catch policy, i.e., scenarios S1G1 and S1G2*

Assuming fishing mortality F = 0.2041 estimated by A/OFRC (2020), a natural mortality rate of M=0.32, and the above selectivity at age under the two MMS regulations (G1 vs G2), the simulated lake wide walleye population biomass and commercial catch stabilized (i.e., reached equilibrium) after 10-15 years. The equilibrium south basin walleye biomass (Figure 8) under S1G2 (minimum 3.5” mesh) was 1.1 times the south basin biomass under S1G1 (minimum 3” mesh). The south basin commercial walleye catch under S1G2 was 1.27 thousand tonnes, 0.83 times those under S1G1 which was 1.53 thousand tonnes (Figure 8).

In both scenarios, the age structure and catch composition stabilized sooner, in 8-10 years. Due to the high uncertainty in the estimated initial (2019) population age structure, the effects of the change in MMS on the age composition of the walleye catch should be inferred from the equilibrium status, after about 10 years. The simulated effects of the MMS change in the first 10 years suggest potential short-term effects and those beyond 10 years suggest long-term average effects when recruitment variability is small or random (Figures 9-10). The effects of the MMS change on the age composition of the south basin walleye catch reflect the selectivity of the 3” mesh for smaller, younger walleye (Figure 11).

3.1.2.2 *Effects of scenario S2G2, i.e., 3.5” MMS in south basin, with effort and thus F increased to achieve same catches as under scenario S1G1, on south basin biomass and catch composition*

This scenario simulated the effects of using MMS 3.5”, but with F increased to achieve catches equivalent to when the MMS was 3”, on the south basin biomass and the age composition of the commercial catch. As with the previous scenarios, the simulated walleye population required about 10 years to stabilize. The influence of increasing the MMS from 3” to 3.5” MMS on the equilibrium biomass was limited (Figure 12) but the overall biomass was slightly lower under S1G1 (18.40 million Kg) than under S1G2 (20.23 million Kg) and S2G2 (18.72 million Kg) (see Figure 11). The south basin equilibrium biomass under S2G2 was essentially the same (1.02 times) as the south basin equilibrium biomass under S1G1 (minimum 3" mesh) (Figure 12). Again, due to the high uncertainty in the estimation of the initial (averaged among 2017-2019) population age structure, the differences in long-term age composition of the walleye catch (Figure 13) should be inferred from the equilibrium status. The simulation also showed that under S2G2 F would need to increase by 1.45 times that under S1G1, over a long-term average, to allow the industry to catch the same catch as before the MMS changed, i.e., S1G1 (Figure 12).

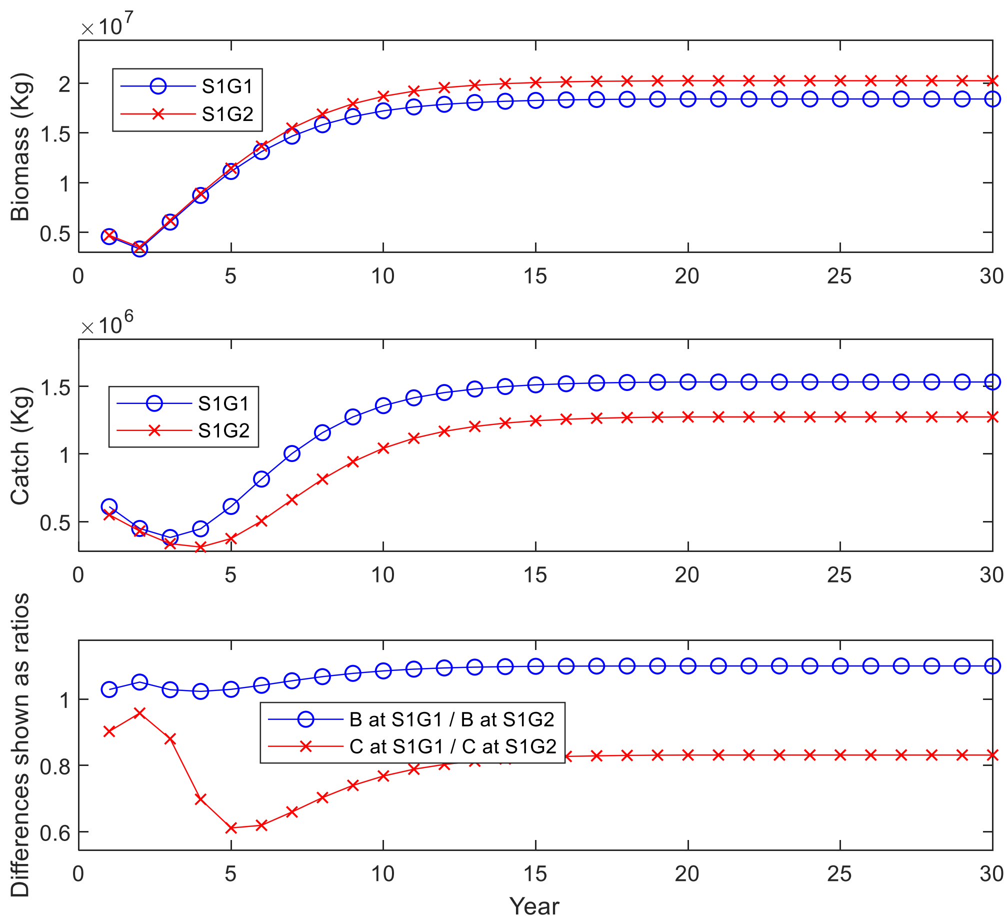

Figure 8: Comparison of the simulated south basin walleye biomass and catch under S1G1 (3" MMS in south basin) and S1G2 (3.5" MMS in south basin). B=biomass, C=commercial catch.

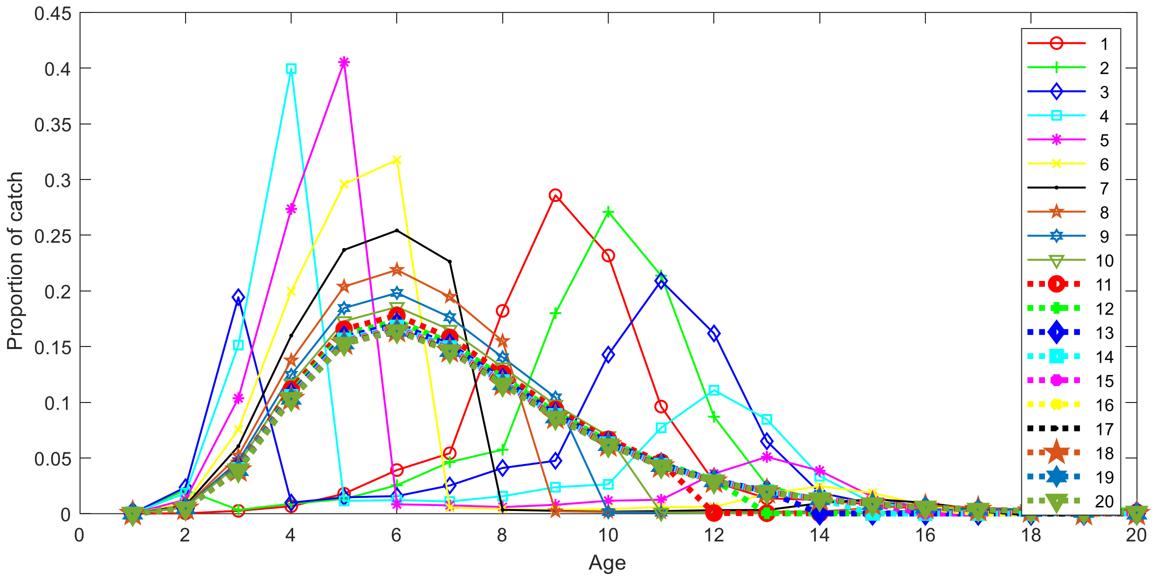

Figure 9: Simulated south basin walleye catch composition under S1G1 (minimum 3” mesh in south basin). Each line represents the # of years after the current population in the simulation.

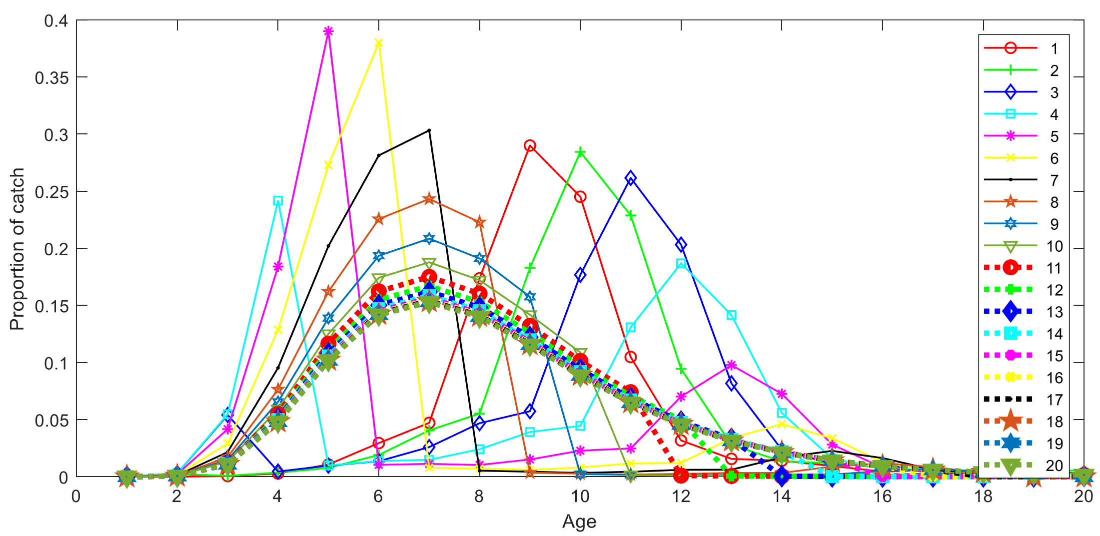

Figure 10: Simulated south basin walleye catch composition under S1G2 (minimum 3.5” mesh in south basin). Each line represents the # of years after the current population in the simulation.

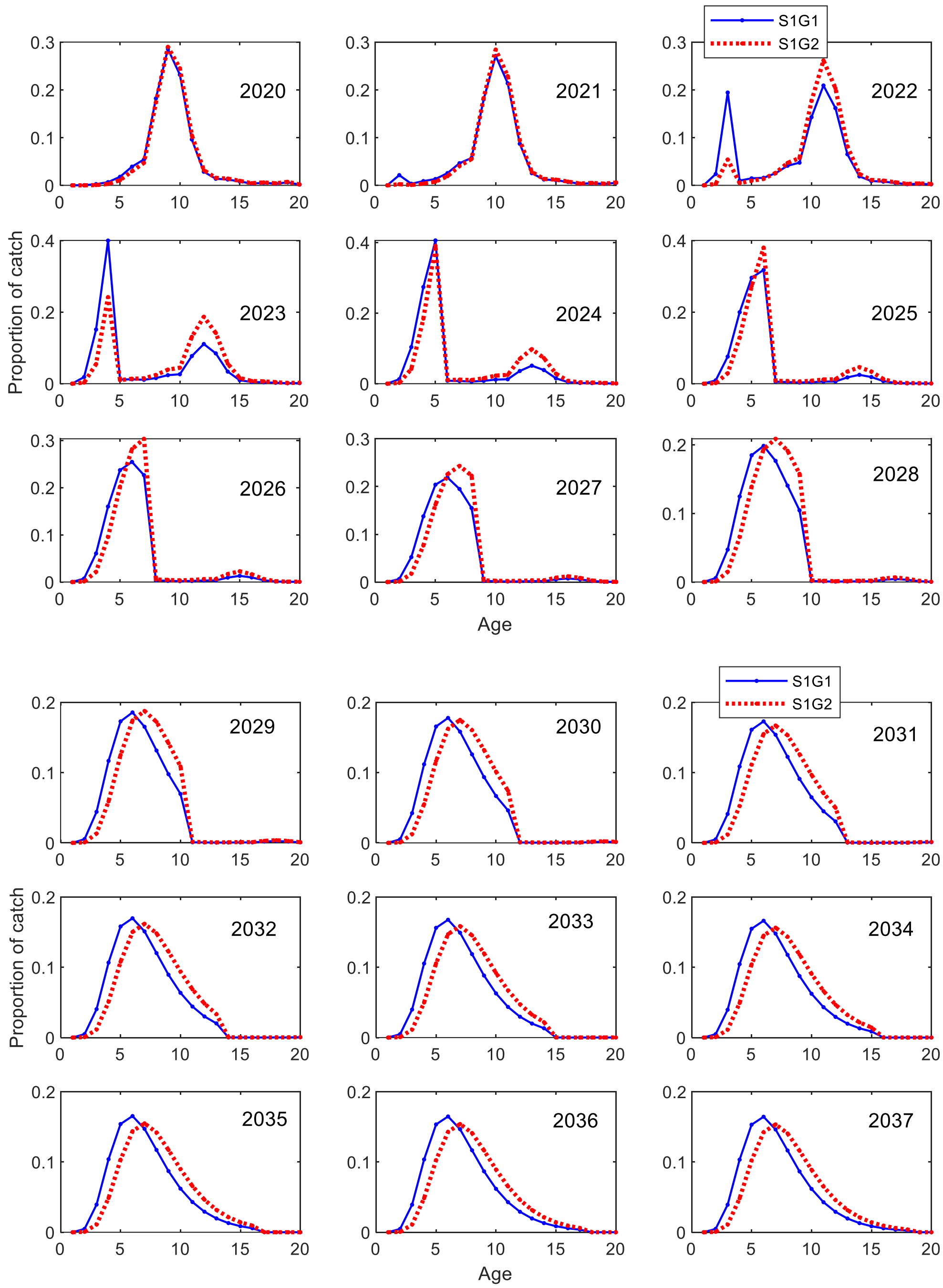

Figure 11: Comparison of the age composition of the commercial walleye gillnet catch in south basin between S1G1 (3” minimum mesh) and S1G2 (3.5” minimum mesh).

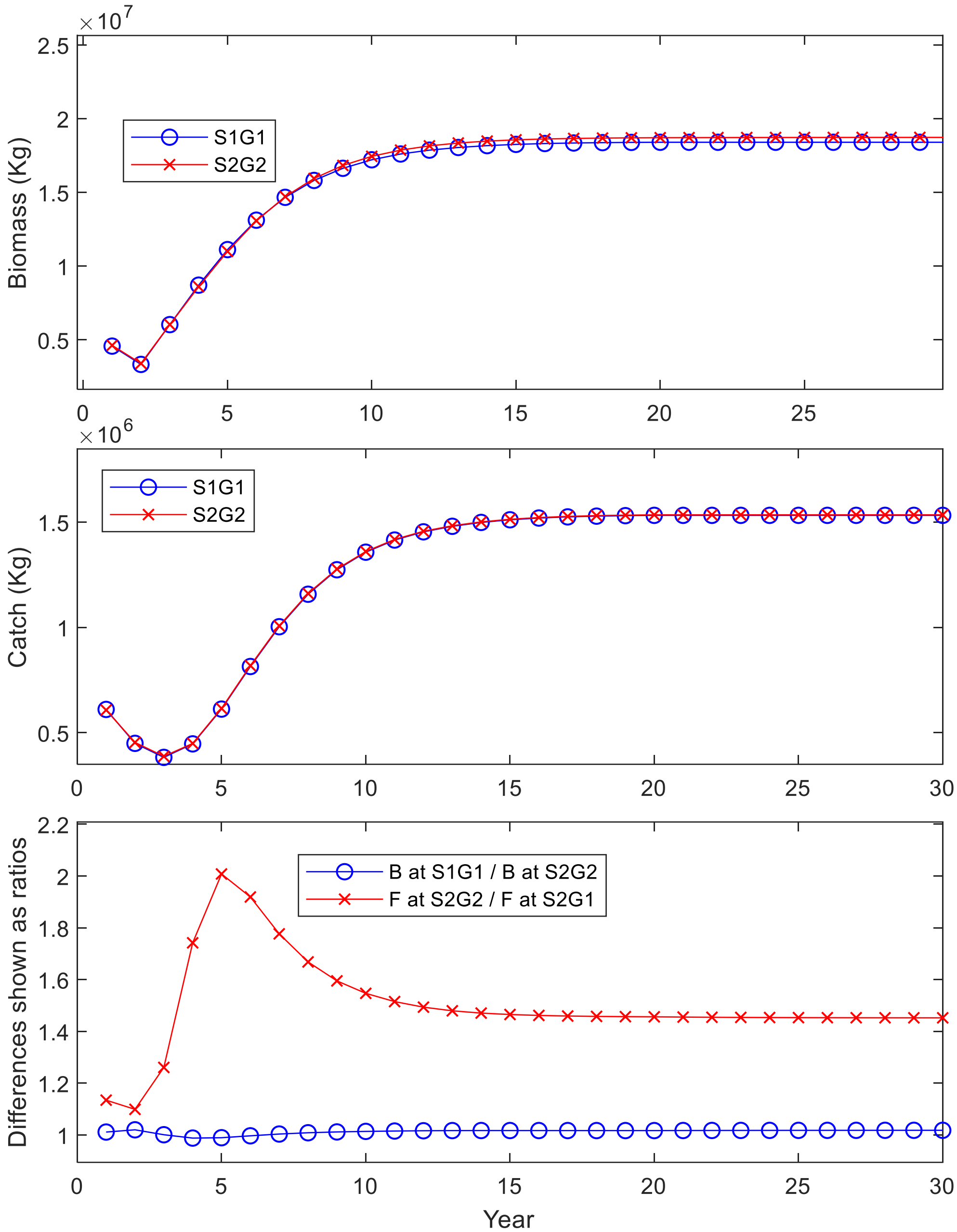

Figure 12: Comparison of the simulated south basin walleye biomass, catch and fishing mortality rate under S2G2 (3.5" MMS in south basin) and S1G1 (3" MMS in south basin). B=biomass, C=catch and F=fishing mortality rate.

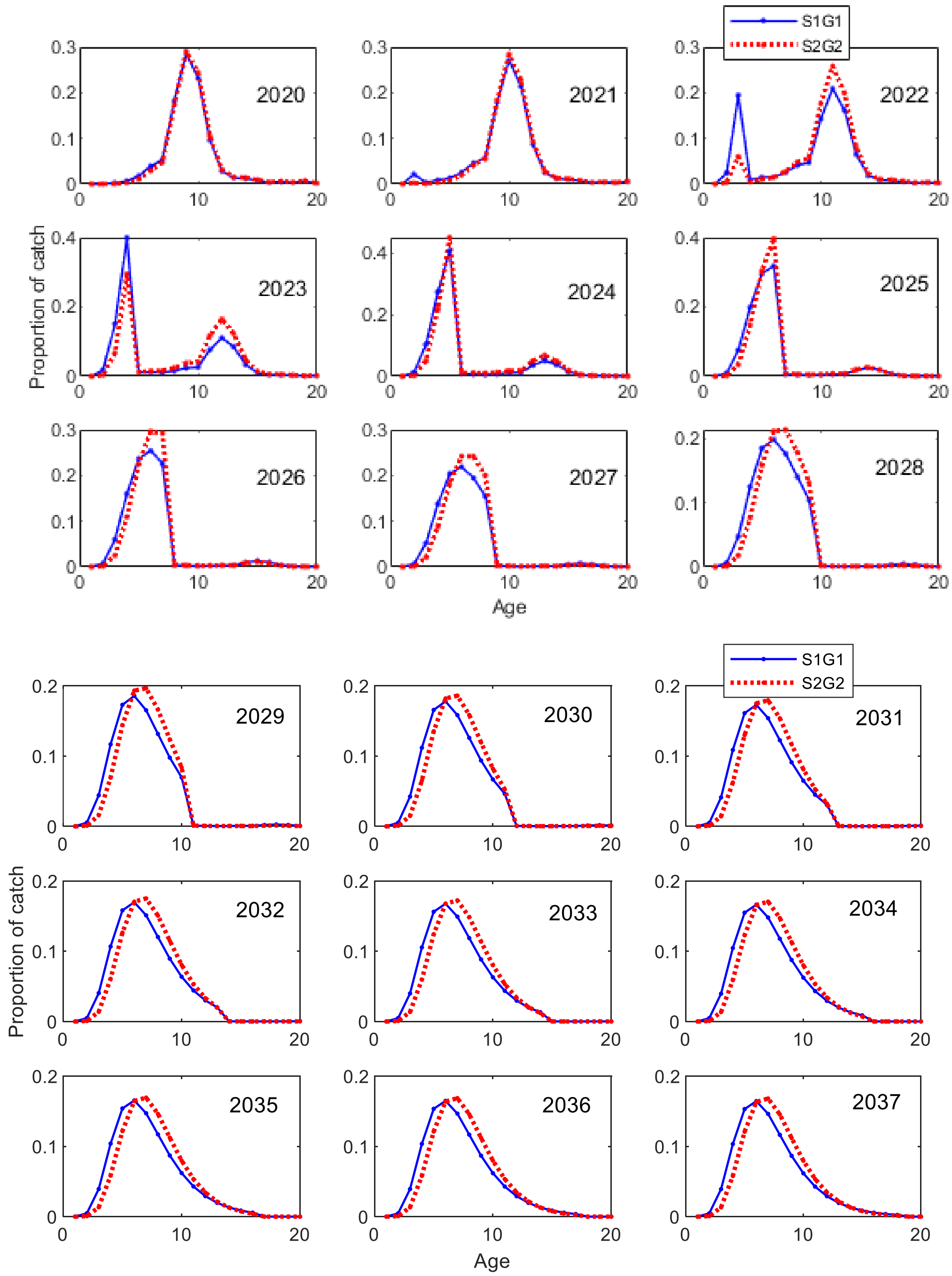

Figure 13: Comparison of the catch age composition of the commercial walleye gillnet fishery in south basin between S2G2 (3.5" minimum mesh with increased F to catch same catch as under S1G1) (3" minimum mesh).

In both scenarios, the population age structure and catch composition become stable after 8-10 years. Thus, the simulated effects in the first 10 years suggest potential short-term effects, and the differences beyond 10 years suggest long-term average effects when recruitment variability is small or random. The effects of the MMS change on the age composition of south basin walleye catches reflects the selectivity of the 3” mesh for smaller, younger walleye (Figure 13).

3.2 Sauger

3.2.1 *Selectivity estimation*

The Jensen’s selection plots based on the index gillnet survey catch data show that uncertainty about the selectivity of the gear for sauger was high especially in the 2009-2019 survey and that the pattern of selectivity in the 2009-2019 survey gear was different from that of the 1980-2003 survey gear (Figure 14-15).

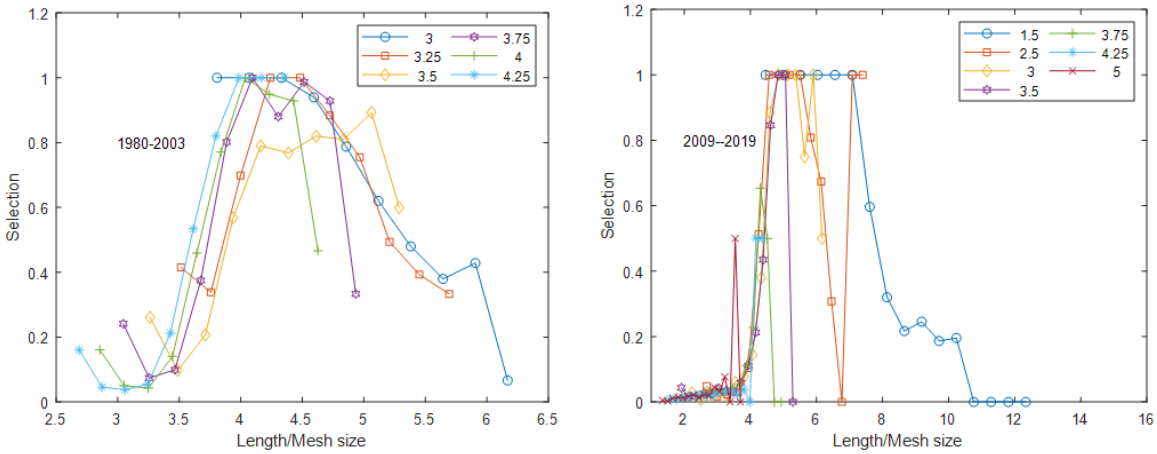

Figure 14: Jensen’s selection plots for sauger based on the two gillnet surveys.

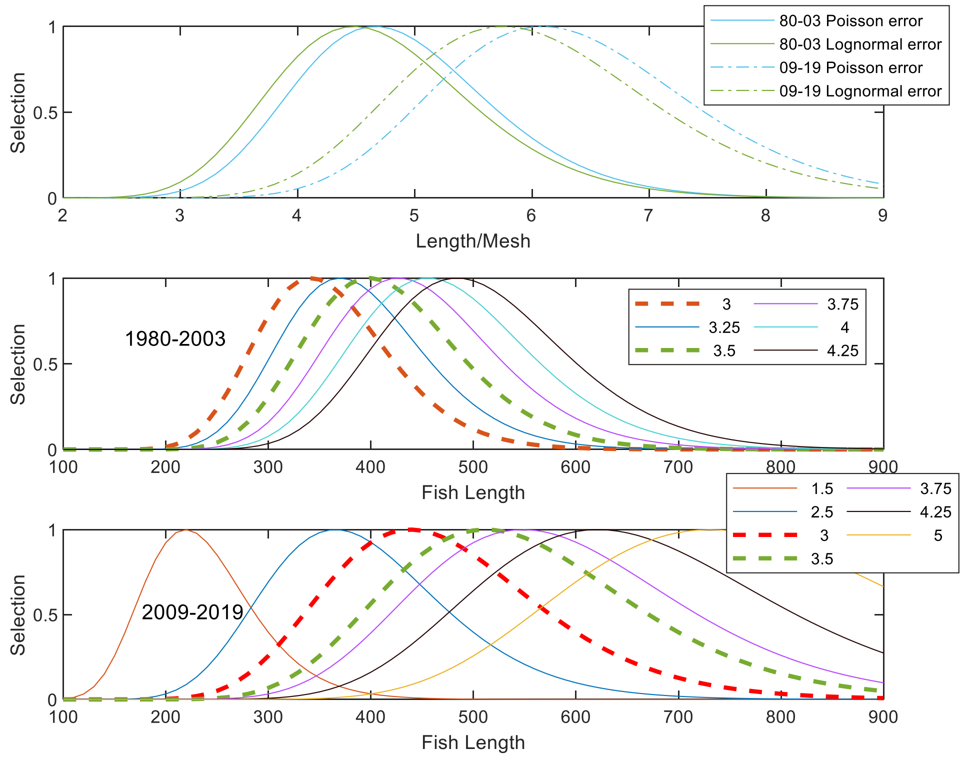

Figure 15: Estimated selectivity for sauger in the two index gillnet surveys.

Table 3: Models used in the sauger selectivity studies for the two ARD gillnet index surveys.

Models	1979-2003		2009-2019	
	lognormal error	Poisson error	lognormal error	Poisson error
AIC	291.64	3208.07	2083.24	5954.27

The lognormal error assumption resulted in a much smaller AIC than when the Poisson error structure was used. The analysis showed that the selectivity of the index gillnet gear was different in the two ARD index survey periods, i.e., 1979-2003 and 2009-2019, with the selection biased towards larger sauger during the later survey period (Figure 15). The estimated differences in the selectivity are supported by the catch length-frequency plot given mesh size (Figure 16).

Clearly, for mesh sizes that were consistent, such as 3’’, 3.5’’, 3.75’’, and 4.25’’, the observed catch length-frequency shows more larger sauger in the 2009-2019 survey than in the 1979-2003 survey. The 2009-2019 survey gear selectivity was estimated by summing the selectivity of each mesh, and then scaling to the maximum selectivity of 1 for the selectivity at length (Figures 17-18).

The fishery selectivities of the ≥3” and ≥3.5” meshes were estimated based on the survey gear selectivity estimation by summing the selectivity of each mesh, and then scaling to the maximum selectivity of 1 for the selectivity at length (Figure 18). The selectivity of the commercial gear with meshes ≥3” was assumed to be the same as that of the index gear and included meshes of 3", 3.25", 3.375", 3.5", 3.75", 4", 4.25", 5" and 5.25", and the selectivity of the commercial gear with meshes ≥3.5” was also assumed to be the same as that of the index gear and included meshes of 3.5", 3.75", 4", 4.25", 5" and 5.25". The assumed selectivity of commercial gear with meshes ≥3.5” was also toward larger and older sauger than that for the gear with meshes ≥3”. The differences of the selectivity for sauger were obvious with the highest selectivity in the 500-600mm TL range for the ≥ 3” gear and in the 600-700mm TL range for the ≥ 3.5” gear (Figures 17-18).

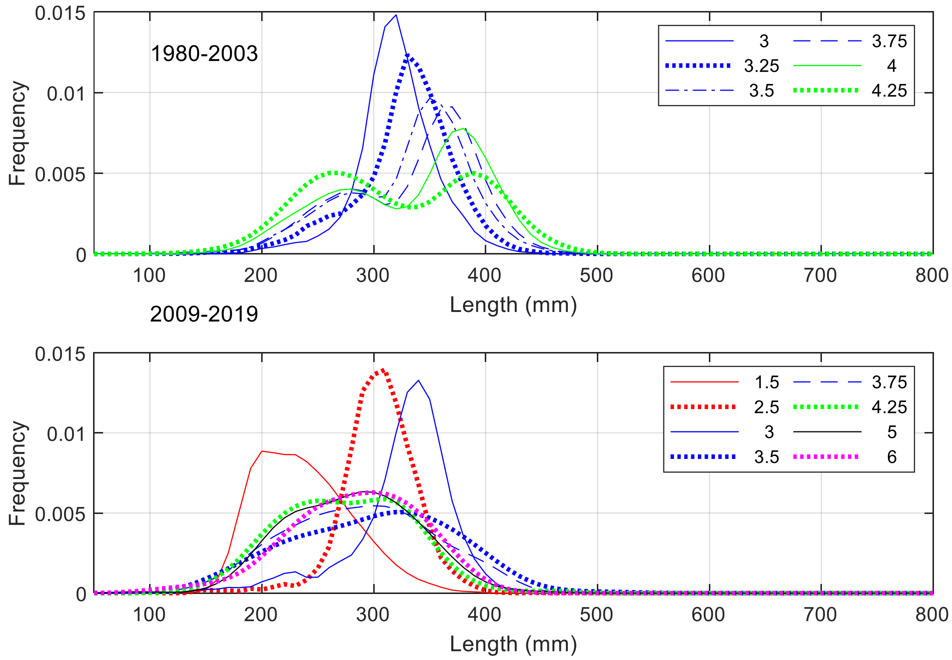

Figure 16: Length frequency of sauger by mesh size as observed in the two index gillnet surveys.

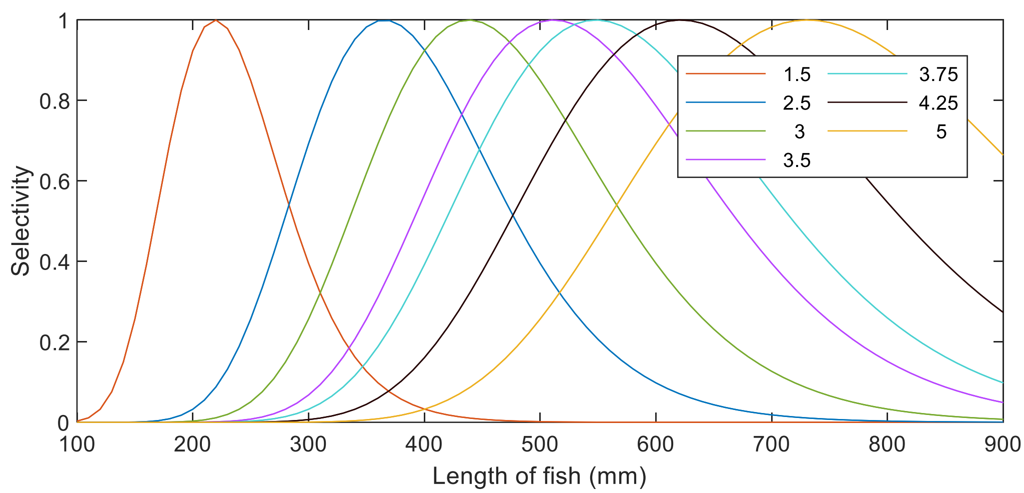

Figure 17: Estimated selectivity of the 2009-2019 index gillnet survey gear for sauger given each individual mesh.

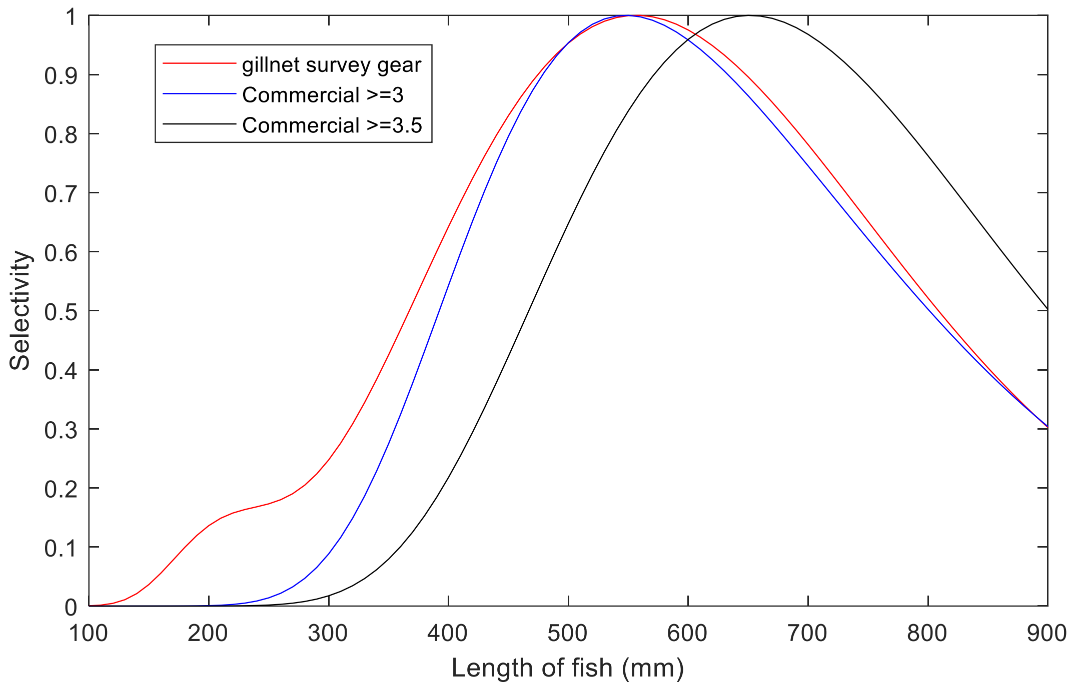

Figure 18: Selectivities of ARD survey gear (includes meshes of 1.5, 2.5, 3, 3.5, 3.75, 4.25, and 5), selectivity of commercial gear ≥3” (includes meshes of 3, 3.25, 3.375, 3.5, 3.75, 4, 4.25, 5 and 5.25) and ≥3.5” (includes meshes of 3.5, 3.75, 4, 4.25, 5 and 5.25) meshes for sauger.

3.2.2 *Sauger population and catch simulations*

The detailed results of the three simulated scenarios (Table 1) are described below and demonstrate the effects of alternate MMS regulations on south basin sauger biomass and catches. Effects of the MMS regulation change on the lake wide sauger population were much smaller than any effects on the south basin proportion of the population; therefore, we present results only for the south basin. Gill net selectivity on sauger age groups 0 to 2 were low, thus only ages 3+ were used in comparing catch and population biomass among simulated scenarios.

3.2.2.1 *Effect of alternate MMSs on south basin biomass and catch using constant F, i.e., scenarios S1G1 and S1G2*

Assuming the current F (F=0.2115) (A/OFRC 2020), a natural mortality rate of M=0.32, and the selectivity at age from the 2009-2019 index gillnet survey, the simulated sauger population, and gillnet catch stabilized after 10-15 years, and the corresponding population biomass, catch and age composition of the catch from the south basin are shown in Figures 22-25. The long-term south basin sauger biomass under S1G2 (minimum 3.5” mesh) was 1.07 times the south basin biomass under S1G1 (minimum 3” mesh). The long-term south basin commercial sauger catches under S1G2 were about 18.7 tonnes, 0.84 times those under S1G1, which was about 22.2 tonnes (Figure 19).

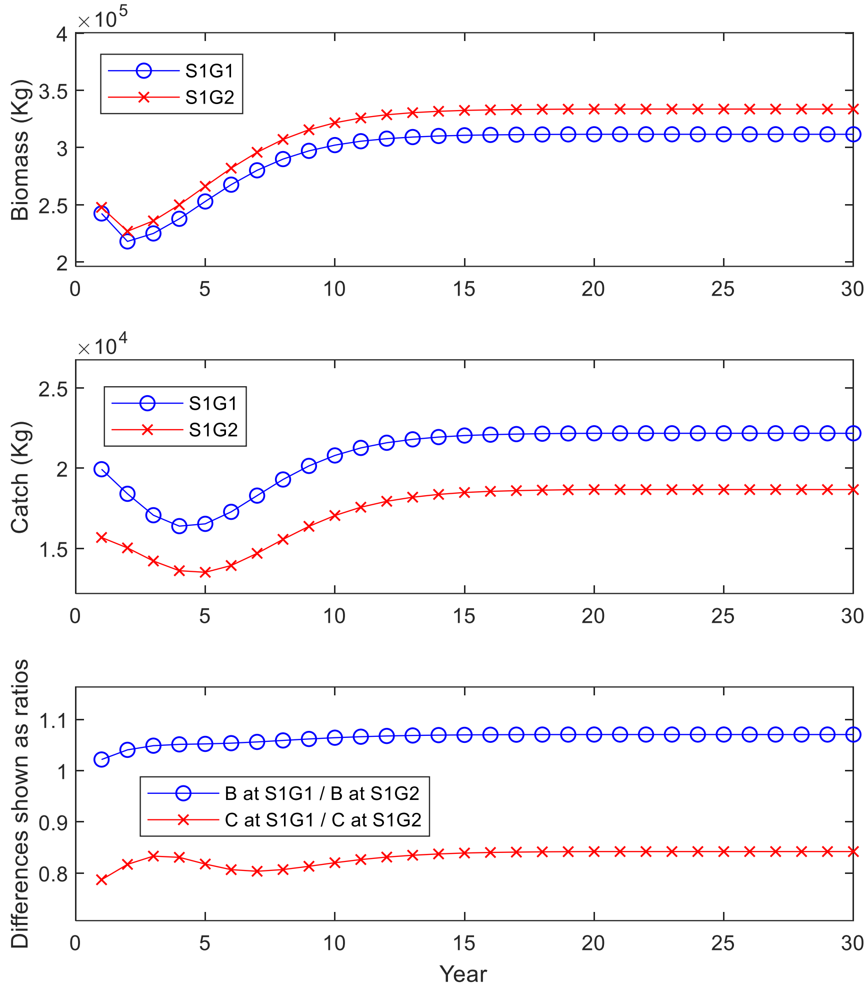

Figure 19: Comparison of the simulated south basin sauger biomass and catch under S1G1 (3" MMS in south basin) and S1G2 (3.5" MMS in south basin). B=biomass and C=catch.

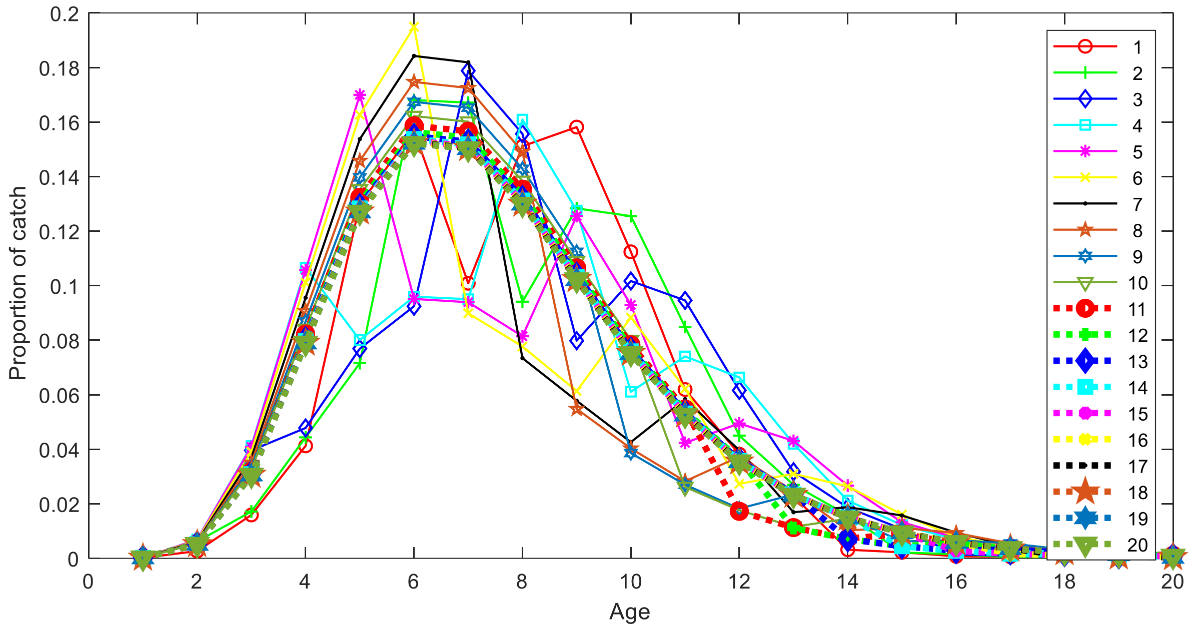

Figure 20: Simulated south basin sauger catch composition under S1G1 (minimum 3" mesh in south basin). Each line represents the # of years after the current population in the simulation.

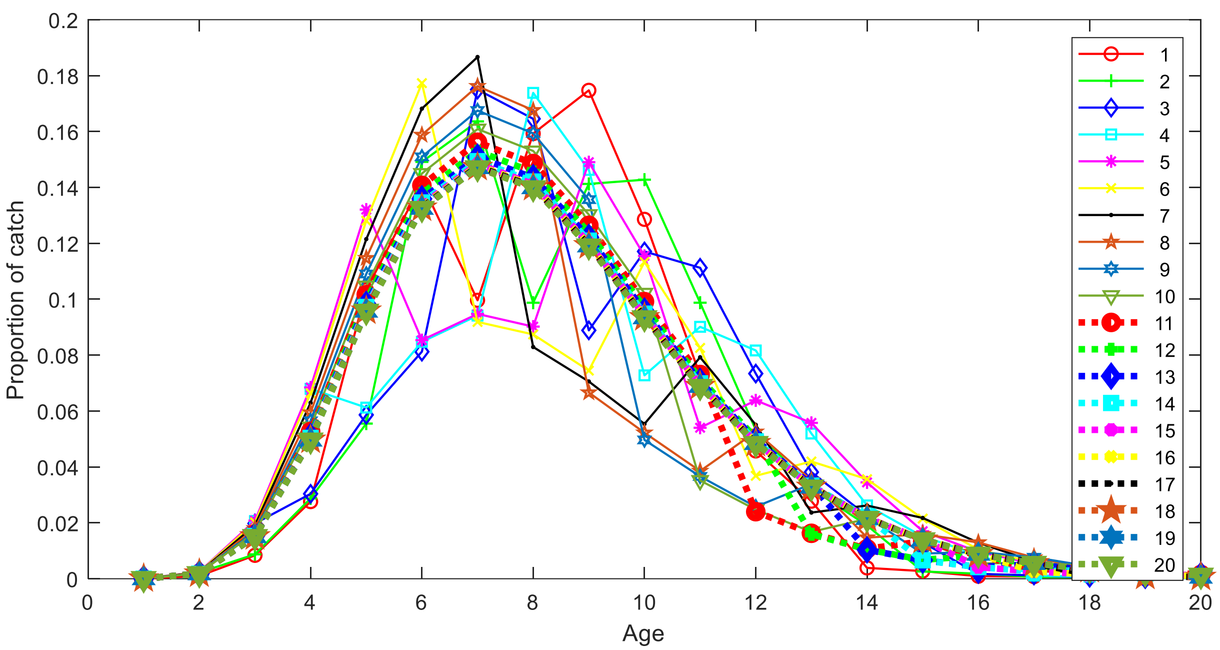

Figure 21: Simulated south basin sauger catch composition under S1G2 (minimum 3.5" mesh in south basin). Each line represents the # of years after the current population in the simulation.

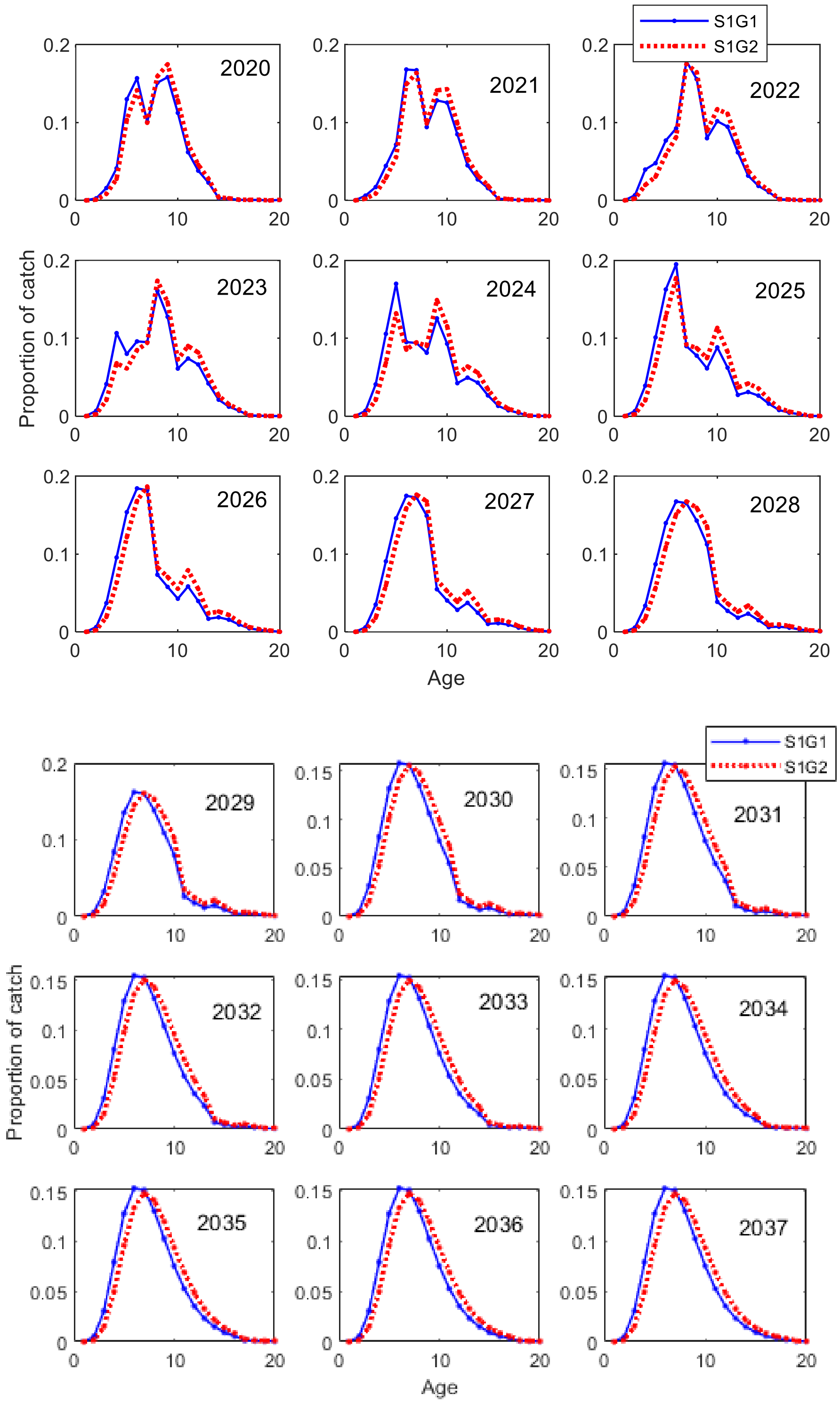

Figure 22: Comparison of the catch age composition of the commercial sauger gillnet fishery in south basin between S1G1 (minimum 3” mesh) and S1G2 (minimum 3.5” mesh).

3.2.2.2 *Effect of alternate MMSs on south basin biomass and catch composition with F increased to achieve same catches as under scenario S1G1*

This scenario evaluated the effects of a MMS of 3.5", but with F increased to achieve catches equivalent to when the MMS was 3", on the south basin sauger biomass, catch and the age composition of the catch. As with the previous scenarios, the simulated sauger biomass and catches required about 10 years to stabilize (Figure 20-21). The effect of the different MMSs on south basin sauger biomass was smaller under S2 (Figure 23) than under the constant F scenarios (Figure 19). The south basin sauger biomass under S2G2 was 1.02 times that under S1G1 (minimum 3" mesh with constant F) (Figure 23).

The age composition of the catch reflects the selectivity of the 3" mesh for slightly smaller and younger sauger age classes (Figure 24). As for previous south basin cases, the high uncertainty in the estimation of the current (2019) population age structure, suggests that the differences in long-term sauger catch composition should be inferred from the equilibrium status.

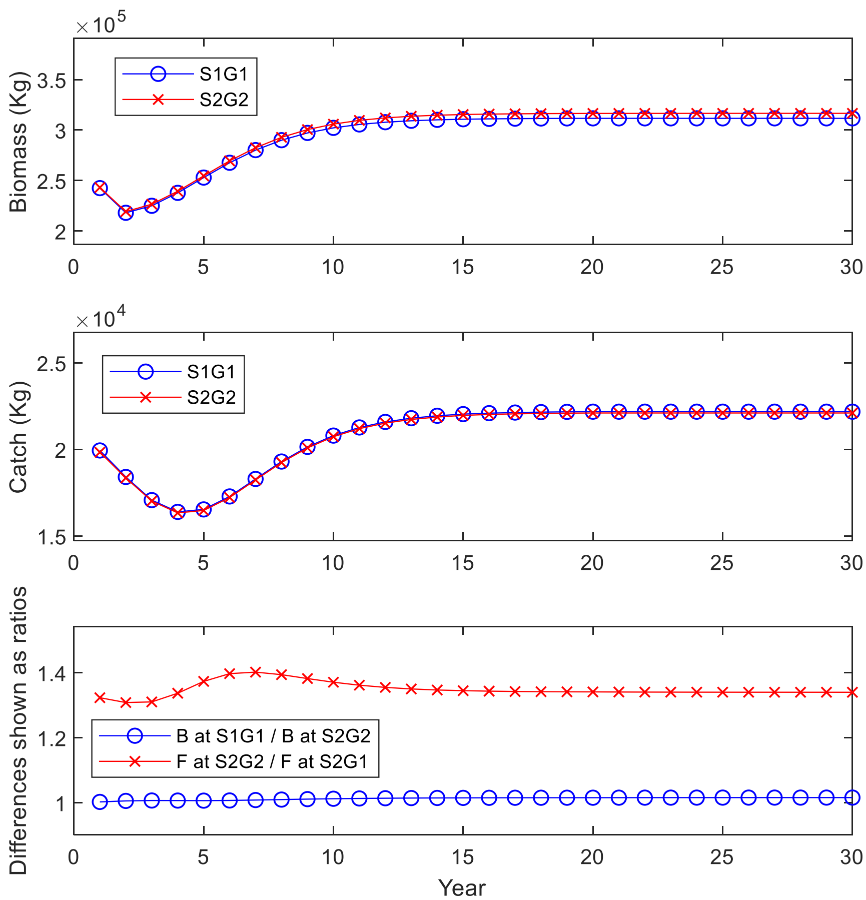

Figure 23: Comparison of the simulated south basin sauger biomass, catch and fishing mortality rate under S2G2 (3.5" MMS in south basin with same catch as S1G1) (3" MMS in south basin). B=biomass and F=fishing mortality rate.

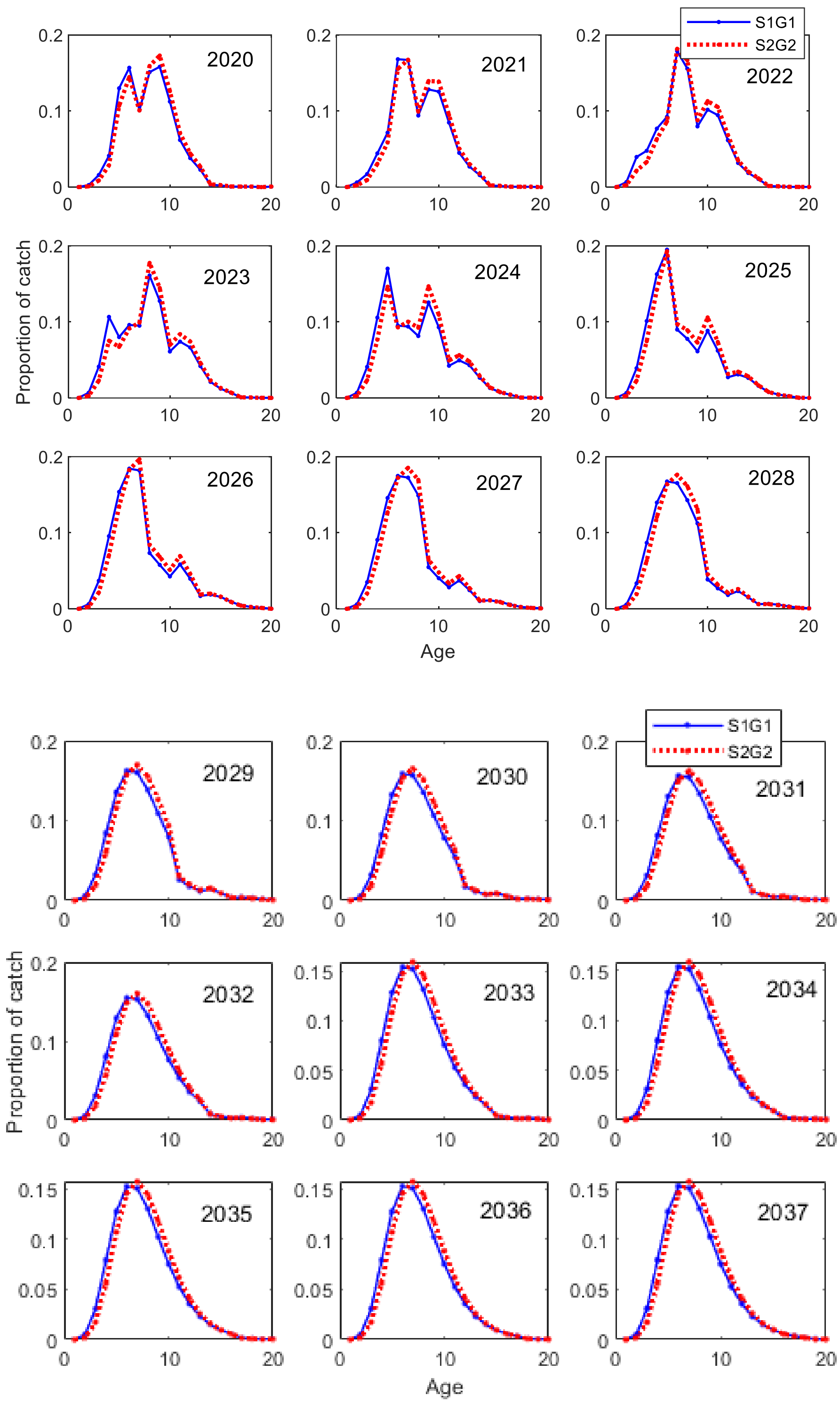

Figure 24: Comparison of the age composition of the commercial sauger catch in the south basin between S2G2 (3.5” minimum mesh with same catch as S1G1) and S1G1 (3” minimum mesh).

4.0 Discussion

The selectivity estimates for walleye were similar to that from the Minnesota standard index gillnet gear, where the estimated selectivity increased with increasing walleye length to a peak relative selectivity of 1.0 at 535 mm TL and then decreased to about 0.34 at 800 mm TL (Radomski et al.2019). The walleye estimates were also similar to those from index gillnets in Mille Lacs where selectivity peaked in the range of 400 to 500 mm TL (Anderson 1998).

Selectivity estimates for sauger were not available from the literature. The uncertainty for the 2009-2019 sauger selectivity was high compared with the selectivity derived from empirical data from the ARD 1980-2003 survey (Figure 17). We are not aware of any previous reports on the selectivity of index or commercial gillnets for Lake Winnipeg sauger. Further study to explore the influence of the sauger body shape and/or gear configuration such as hang ratio, e.g., capture via entangling versus being meshed, should help to reduce this uncertainty and better understand the implications of mesh size-based fisheries management.

The change in MMS from 3" to 3.5" increased the biomass of the walleye and sauger populations but any such increases were limited to a maximum of about 7%, assuming no further reduction of effort or F. The equilibrium south basin catches of ages 3 and above decreased to about 83% for the walleye fishery and about 84% for the sauger fishery when fishing effort was not increased to maintain catches before the change in MMS. If the fishery was to increase the effort to match the catch before the MMS change, then the effort would need to increase to around 1.45 and 1.40 times that before the MMS change for walleye and sauger, respectively, suggesting that changing the MMS may not be sufficient to allow for recovery of the sauger population.

The simulations were based on the data from the ARD surveys, but the survey gear selectivity changed significantly between the 1980-2003 and 2009-2019 surveys. Such differences might be attributable to varying gear configurations and/or deployment differences and/or changes in catchability between the two time periods. Further studies on the actual commercial gillnet selectivity are needed to better understand the effectiveness of commercial gillnet mesh size changes as a management tool.

The simulation was based on the age structure estimated from the survey gear age sampling and tends to underestimate the abundance of younger age groups or be influenced by the most recent age structures of the populations. As a consequence, projected recruitment of walleye may have been overestimated by using the 2017-2019 data and assuming a stable population size.

Further age and length sampling in the commercial gillnet fishery are highly recommended as such sampling will provide the data required to develop age/size-structured models and will facilitate improved stock assessment and fisheries management. Whether commercial gear catchability changed because of environmental changes in Lake Winnipeg could also be explored in the future to better understand the impacts of gear regulations.

The simulation was based on the growth of walleye and sauger in the most recent 3 years, although both walleye and sauger growth and maturity varied widely over time (A/OFRC 2020). How mesh size changes may influence life history (Winemiller 2005), and how to include life history variation in the prediction of future walleye and sauger catches and population age and length composition, s should be further studied over time based on realistic commercial catch at age/length monitoring and through quantitative estimation of the population.

It should be possible to develop a more systematic management strategy evaluation by including the best available information on walleye and sauger in Lake Winnipeg using a theoretical population model with some information borrowed from other sources. Such an approach and process would provide better insight into the advantages and limitations of alternative management strategies for the walleye and sauger fisheries.

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