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Assessment of proposed harvest decision rules for the Atlantic Salmon recreational fishery: Miramichi River case study

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Fisheries and Oceans Canada (DFO) is developing a precautionary approach (PA) framework for the management of the Atlantic Salmon recreational fisheries for DFO Gulf Region rivers. A DFO Fisheries Management-led working group (DFO-WG) convened over the previous year to discuss and develop candidate harvest decision rules (HDRs) for the Atlantic Salmon recreational fishery using the Miramichi River as a case study. The candidate HDRs for the recreational fishery are evaluated for compliance to the PA policy and supporting science advice. The candidate HDRs specify management measures for different levels of abundance prior to recreational fisheries rather than being specific about exploitation rates. There is insufficient information to determine the extent to which the described management measures will change the exploitation rates and losses due to fishing. Using historical exploitation rates and assumed catch and release mortality rates from the Miramichi River, the management measures in the candidate HDRs are translated into the proportion of the total eggs lost from recreational fishing. The losses for similar management measures are higher in the Northwest Miramichi compared to the Southwest Miramichi because of differing biological characteristics and seasonal catch profiles between the two rivers. Several elements of the candidate HDRs, such as adjusting losses for three status zones and maximum losses being less than the removal rate reference, comply with the PA policy. Other elements of the candidate HDRs may not comply with the PA policy, subject to interpretation. One key element is the interpretation of the PA statements that removals be kept to the lowest level possible and no tolerance for preventable decline when the stock is in the critical zone. Both candidate rules would allow a directed catch and release recreational fishery when the abundance is in the critical zone; directed fisheries would only be closed if the abundance before fishing was < 15% or < 25% of the Limit Reference Point (LRP), dependent on the rule. The losses from a catch and release fishery in the critical zone would be approx. 1% of the eggs prior to the fishery but could be as high as 4 to 7% if the season-adjusted catch and release mortality rate was in the range of 16 to 25% as indicated from a wider meta-analysis of studies and mean water temperatures in the Miramichi, rather than 3% mortality rate that has been used to date. The implementation of the candidate HDRs requires a forecast of expected abundance prior to the fishery. The performance of the candidate HDRs and compliance to the PA policy will need to be re-evaluated to take account of the uncertainties and biases of the forecast model and the decision making process.

INTRODUCTION

The Sustainable Fisheries Framework encompasses a number of policies to guide management decisions for ensuring that Canadian fisheries are conducted in a manner which supports conservation and sustainable use objectives (DFO 2009). One of the policies of the framework is “A Fishery Decision-Making Framework Incorporating the Precautionary Approach” that applies directly to fisheries harvest strategies (DFO 2009). There are three components to the decision framework for the Precautionary Approach (PA):

- Reference points that define stock status zones (Healthy, Cautious and Critical),
- A defined harvest strategy and associated harvest decision rules, and
- The need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules.

In support of the development of the PA for Atlantic Salmon, DFO (2015) provided advice on the development of reference points including consideration of candidate reference points, the appropriateness of using reference points specific to variations in productivity, and methods to transfer reference points from monitored rivers to data limited rivers. DFO (2018) defined river-specific Limit Reference Points (LRPs) for Atlantic Salmon rivers in Fisheries and Oceans Canada (DFO) Gulf Region. In a second science peer review process, an approach to define the Upper Stock Reference (USR) and maximum removal rate (RR) in the healthy zone was reviewed and proposed reference values for the salmon rivers of DFO Gulf Region agreed (Chaput et al. 2023, DFO 2022).

This document addresses the final component of the PA framework related to the development of candidate harvest decision rules (HDRs) for the recreational Atlantic Salmon fishery. A DFO Fisheries Management-led working group (DFO-WG) convened over the previous year to discuss and develop candidate HDRs for the Atlantic Salmon recreational fishery using the Miramichi River as a case study. In recognition of the constitutionally recognized and protected right of the Indigenous peoples of Canada for priority right of access to natural resources after conservation, the DFO-WG agreed to consider candidate HDRs specific to the recreational fishery after Indigenous peoples access to the Atlantic Salmon resource. Hence the candidate HDRs for the recreational fishery take into consideration the status of the Atlantic Salmon stock within the PA framework after Indigenous peoples salmon removals have occurred.

As described in DFO (2015, 2018, 2022), the reference points for Atlantic Salmon of DFO Gulf Region rivers are defined in units of eggs from all size groups and sea-ages of anadromous Atlantic Salmon. The candidate HDRs are similarly expressed as the proportion of the eggs of returning salmon (post-Indigenous fisheries) that are lost due to the recreational fisheries. DFO (2015) stated that the USRs would correspond to the objectives of the users and the risk profile and risk tolerance of the management strategy but that, at a minimum, the USR must be set at a level above the LRP with a very low probability (< 5%) of the spawners (after fishing) falling below the LRP when a stock that is at or above USR is exploited at the maximum removal rate.

The purpose of this manuscript is to review and evaluate two candidate HDRs developed by the DFO-WG for their compliance with the PA policy and the updated guidance on stock rebuilding. The intent of the PA policy (DFO 2009) as well as recently published guidance and advice related to the development of rebuilding plans and associated harvest decisions (DFO 2021a, 2021b) are considered.

The assessment presented in this manuscript is organized as follows:

- The two candidate HDRs submitted for review by the DFO-WG are presented and contrasted. Versions of decision rules used in Quebec and in the Newfoundland and Labrador regions are summarized. We clarify which management measures can be assessed with available data versus those that have limited to no information on their consequence to assess removal rates. Other management elements in the rules such as inseason adjustments, warmwater protocols and the use barbless hooks are discussed.
- The conditions for compliance with the PA policy are presented.
- The candidate HDRs are assessed relative to characteristics that would comply with the PA and simulations are used to assess the compliance performance of the candidate rules when uncertainty in status is included.
- Finally, the limitations of the assessment conducted and the numerous uncertainties regarding the implementation of the candidate HDRs in the recreational Atlantic Salmon fishery are discussed.

DEFINITIONS

The following terms are used in this document.

- small salmon: anadromous adult salmon of fork length < 63 cm, also referred to as grilse in some decision rule descriptions.
- large salmon: anadromous adult salmon of fork length >= 63 cm.
- bright salmon: anadromous adult returning to the river to spawn in October to December of the same year; it includes both first time spawning anadromous salmon (maiden fish) and reconditioned repeat spawning salmon.
- kelt: also referred as black salmon, is a salmon that spawned the previous fall, overwintered in the river and is returning to sea in the spring. The black salmon fishery in the Miramichi takes place between April 15 and May 15, annually.
- rod-day: unit of effort in the recreational fishery equal to one day per angler, regardless of the number of hours spent fishing for salmon that day.
- catch: refers to a fish that is captured in the recreational fishery. The catch includes both retained and released fish.
- retained: refers to salmon which are caught and harvested.
- catch and release: refers to the fisheries practice of capturing a salmon and releasing it back to the river after capture, i.e. not retained.
- losses: refers to the number of fish or estimated eggs which are lost due to the fishing activity. The losses are the sum of the fish retained and the fish that die or do not contribute to spawning due to mortality and /or stress associated with having been captured and released.
- exploitation rate: as used here, refers to the proportion (0 to 1) of the assessed salmon (small or large) abundance which is captured (including retained and released fish) in the fishery. The estimated abundance may include salmon that return to the river outside the recreational fishery season.
- removal rate: the proportion (or percentage) of the fish or estimated total eggs lost due to fishing.

- Limit Reference Point (LRP): as defined in the Precautionary Approach policy, is the stock abundance that delineates the critical and cautious zones and below which serious harm to the stock is occurring.
- Upper Stock Reference (USR): as defined in the Precautionary Approach policy, is the stock abundance that delineates the cautious and healthy zones and below which exploitation rate on the stock should be progressively reduced to avoid reaching LRP. The USR should be far enough from LRP for management to detect stock declines and allow for action.
- Harvest Decision Rule (HDR): may be referred to as a harvest control rule, is a profile on the two-dimensional plot of abundance versus removal rate that indicates the removal rate that would be applied for various abundance levels in the PA diagram.

CANDIDATE HARVEST DECISION RULES

The DFO-WG developed and submitted for review two candidate harvest decision rules (HDRs) for the recreational Atlantic Salmon fishery (Table 1; Appendices 1, 2). The candidate HDRs are specific to the recreational fishery after Indigenous peoples access. The DFO-WG focused their deliberations using the Miramichi River, New Brunswick, as a case study. The Miramichi River historically had the largest annual Atlantic Salmon run in eastern Canada but the estimated annual abundance of anadromous Atlantic Salmon has declined to reach the lowest assessed abundance in 2019 for the period 1971 to 2019 (Douglas et al. in prep.[1]). Estimated returns to the Miramichi River for the ten-year period 2010 to 2019 ranged from 8,000 to 50,000 small salmon and 10,600 to 30,600 large salmon (DFO 2019a). For context, the estimated abundance of small salmon in the Gulf Region rivers of NB, prior to any homewater removals in Indigenous peoples and recreational fisheries, ranged from 15,400 to 72,000 small salmon and 19,100 to 59,000 large salmon over the same period (DFO 2020a).

MANAGEMENT MEASURES AND EFFECTS ON EXPLOITATION RATE

The candidate HDRs developed by the DFO-WG specify recreational fisheries management measures for different stock status categories rather than exploitation rates. The status categories are defined on the scale of abundance as a proportion of the LRP after Indigenous peoples harvests and before recreational fishing.

The suite of management measures considered by the DFO-WG are those applied historically to manage the recreational Atlantic Salmon fishery. Recreational fisheries for Atlantic Salmon are managed at the provincial level with some river-specific measures. Key components of the Atlantic Salmon recreational fisheries management framework in New Brunswick (NB) include:

- A provincially issued recreational fishing licence is required to fish for Atlantic Salmon in NB. With the provincial licence, an individual can fish in any Atlantic Salmon river in the province that is open to recreational fishing for salmon. Closed water, leased and riparian waters, and Crown Reserve Waters restrict access by the general public to some of these areas.
- There is no limit on the number of angling licences issued by the province. An average of just over 20,000 salmon angling licenses were sold annually in NB between 1996 and 2014, but the number decreased to approximately 10,000 annually since 2015 when catch and

[1] Douglas, S., Underhill, K., Horsman, M., and Chaput. G.Information on Atlantic salmon (*Salmo salar*) from Salmon Fishing Area 16 (Gulf New Brunswick) of relevance to the development of a 2nd COSEWIC report. DFO Can. Sci. Advis. Sec. Res. Doc. In preparation.

release restrictions were implemented throughout the DFO Gulf Region (Douglas et al. in prep.[1], Figure 1).

- Angling licences can be purchased by residents and non-residents of the province.
- The gear is restricted to fly fishing only with prohibition on the use of lures and bait.
- A fixed number of carcass tags are issued with each licence (there are also catch and release only licences that have no tag allowance) and any retained salmon must be tagged; this limits the total annual harvest of salmon by an individual angler. The use of carcass tags for identifying retained salmon was introduced in the early 1980s. The season bag limit in NB was 15 in 1980-1981, decreased to 10 tags in 1982 (Appendix 1 in Randall 1990), to 8 tags in 1991, and 4 tags in 2014. Since 2015, there have been mandatory catch and release measures for all anadromous Atlantic Salmon in the DFO Gulf Region jurisdiction.
- In addition to the season retention limits, there are daily retention limits which were historically two fish per day and reduced to one fish per day in 2006 (DFO Atlantic Salmon Integrated Management Plan 2008-2021 Gulf Region), but earlier (1998) for the Miramichi River watershed.
- There are daily catch and release limits for salmon, size groups combined, and these have generally declined over time. Since 2015, the limit has been 4 fish per day. Daily catch and release limits are higher during the black salmon fishery.
- Management measures vary among rivers in NB including season opening and closing dates, specific areas of rivers that close at different dates in the season, daily retention limits, and inseason closures associated with warm/low water protocols.
- A ‘general’ recreational fishing licence allows an individual to fish in designated Atlantic Salmon rivers for other species, such as Brook Trout, provided restrictions on salmon fishing gear are respected and no retention of salmon is permitted. Directing for salmon with this licence is not allowed.

To evaluate the candidate HDRs, the management measures must be translated into removal rates, expressed as the percentage of the eggs lost for the corresponding decision rule management measures. Required inputs for this are the exploitation rate, the retention rate, and the assumed catch and release mortality rate.

The a priori expectation is that the total effort in the recreational fishery would be responsive to the management measures, with reductions in fishing effort when management measures are more restrictive. The exploitation rate is also expected to be positively associated with the total effort (rod-days) in the recreational fishery.

The information available that would be informative of how fishing effort and exploitation rate would change with management measures is reviewed. The key management measures considered in the DFO-WG candidate HDRs include:

- variations in the number of tags issued for retention by licence, and including catch and release only; and
- variations in the maximum daily catch and release limit.

Consequences of Changes in Season Retention Limits, Including Mandatory Catch and Release

There is limited information available to determine how consequential changes in season retention limits are on licence sales and effort. There is evidence from the annual licence sales data from the province of NB that the introduction of mandatory catch and release measures in 2015 resulted in an important and instantaneous decline, by almost half, in licences sold (Douglas et al. in prep.[1], Figure 1). The number of recreational Atlantic Salmon licences sold in Nova Scotia (NS) declined from > 6000 per year prior to 1994, to between 1,900 and 2,600 licences during 1998 to 2014 (Figure 2). The decline in licence sales in NS began well before the imposition of mandatory catch and release in 2015. The mandatory catch and release measures resulted in an initial decline in license sales (-9% from 2014 to 2015) followed by an increase to an average of approximately 2,100 licences sold per year during 2016 to 2019.

The effect of changes in season bag limits on licence sales and effort is not clear. In NB, the reduction in the season retention limit per licence did not affect the number of licences sold but the information is sparse; over most of the time series of licence sale data, a similar season limit of 8 tags per licence had been in effect (1991 to 2013) and the reduction to 4 tags per licence in 2014 did not result in a decline in licence sales (Figure 1, Douglas et al. in prep.[1]). The decline in licence sales in NS does not match the reductions in seasonal retention limits (Figure 2).

The decline in licence sales in NS does not correspond to changes in daily catch and release limits; from 1984 to 2019, the daily catch and release limit in Salmon Fishing Area (SFA) 18 was consistently 4 salmon per day (changed to 2 salmon per day in 2020; DFO Fisheries and Aquaculture Management, personal communication) and the decline in licence sales occurred despite no change in this management measure.

The reduction in licences sold in NS resulted in a reduction in the total estimated effort, overall for the province and in the Margaree River (Figure 2). Further, during the years with mandatory catch and release, the estimated effort was lower than would have been expected based on licence sales (Figure 2).

Bourgeois and Veinott (2012) reported on the potential effect of the river classification system on licence sales and effort in the Newfoundland Atlantic Salmon recreational fishery. Based on data for the years 1988 to 2009, there is no statistically significant linear relationship between licence sales and effort in the Newfoundland recreational fishery (Figure 2).

Consequences of Changes in the Maximum Daily Catch and Release Limit

The candidate HDRs scale the maximum catch and release daily limit to status categories, from a maximum of two fish per day for abundances of < 50% or < 75% of LRP to a maximum of 4 fish per day at higher abundances. Catch and effort reporting in NB and NS has not collected the creel information at that scale; requested reports are total season catch and total season effort by river. A reduction in the daily catch and release limit might be expected to reduce the total catch if there was compliance with the measure because an angler that had reached a lower daily limit would stop fishing earlier. However, compliance with the maximum daily release limit is difficult to enforce. There are no data that could inform on this expectation and in the evaluation of the candidate HDRs, this measure is assumed to have no effect on exploitation rate.

The practice of catch and release fishing is increasing in popularity, even when retention of salmon is allowed. With daily and seasonal retention limits, there will be a portion of the small salmon catch that would not be retained. The proportion of the reported catch that would be released is expected to increase as the daily retention limits are decreased (from two fish to one fish for ex.) and possibly as a result of the reduction in the daily season retention limit. An analysis of the angler reports for NS SFA 18 and the Margaree River shows a clear association between the proportion of the small salmon catch that is released and the seasonal retention bag limit (Figure 3). Similarly high proportions of the small salmon catches were reported released in SFA 18 overall, with an inverse association to the total season retention limit of small salmon.

Information on the proportion of the small salmon catch which was released is available from NB Miramichi Crown Reserve angler reports (Figure 4). Crown Reserve regulations differ somewhat from regular angling, with trip limits that prescribe how many fish an individual could retain during the 48 hour slot (over 3 days). Details on the trip limits over the years for the Crown Reserve Waters are not available. However, looking at daily retention limits in effect over the period 1985 to 2009, the proportion of the small salmon catch which was released increased from a mean of 0.19 during the years with a 2 small salmon daily retention limit to 0.27 during the years with a one small salmon daily retention limit introduced in 1998 (Figure 4). When mandatory release of all salmon catch was introduced, early in the season of 2010 and 2011, essentially all the small salmon catch was released. Mandatory release of small salmon has been in effect all season since 2014.

Association Between Effort and Exploitation Rate

The a priori expectation that interest in the fishery (licences sold) would be responsive to a management measure of mandatory catch and release but not to variations in season retention limits was confirmed, as noted for the licence sale data for NB. The NS data show a strong correlation between licences sold and estimated total effort.

The expectation is that the exploitation rate would be positively associated with the total effort (rod-days) in the recreational salmon fishery. The association between estimated effort (rod-days) and exploitation rates was examined using three sources of data:

- Data from the Northwest Miramichi River (NW) and the Southwest Miramichi River (SW) for the years 1984 to 1995 and 1997; years with estimates of both exploitation rates from the assessment and recreational fisheries catches and effort (Figure 5). These time series overlap the years with seasonal retention limits of small salmon decreasing from 10 to 8 fish, a minor change.
- Data from the Crown Reserve Waters of effort and estimated exploitation rates (as proportion of total return to the NW) from the assessment model for the period 1984 to 2019 (Figure 6).
- Estimated total effort and exploitation rates for the Margaree River, 1987 to 2019. The exploitation rates are estimated from the modelled returns of small salmon and large salmon (Figure 7).

The estimated total effort in the NW and SW increased over the period 1984 to 1995, but was low again in 1997 (Figure 5). The effort in both rivers for these time series varied by a factor of 2+, providing a good contrast in effort to associate with exploitation rates. There is no statistically significant ($p < 0.05$) linear association between effort and estimated exploitation rate for small salmon or large salmon in the NW, and there is no association for small salmon and a negative association for large salmon in the SW. For these limited data, there is no apparent positive association between effort and exploitation rate.

Annual effort in the Crown Reserve Waters is variable, with no consistent temporal trend except for the almost continuous decline over the period 2013 to 2019 (Figure 6). The decline post-2013 reflects a combination of several factors including the prohibition on retention of small salmon and environmental closures due to warm and low water conditions that reduced the available fishing periods in those years. The lack of a trend in the earlier part of the time series is likely due to the cap on effort (fishing stretches by available periods) in Crown Reserve Waters and the attractive angling experience which these fishing waters provide for NB residents. There has been a near continuous decline in catches of small salmon, and a decline nonetheless in large salmon but there is limited evidence of any temporal trend in the estimated exploitation rate for either size group (Figure 6). There is no statistically significant relationship between the exploitation rate and the effort for small salmon but there is a significant positive association for large salmon, although the large effort value for 2009 is highly influential in the fit. When the 2009 data point is omitted, the p-value for the linear association is 0.055.

The Margaree River assessment uses a model that estimates a catchability coefficient (per unit of effort, rod day) from angler logbook reports and from voluntary returns of licence stubs using mark and recapture experiments for the years 1988 to 1996 (Breau and Chaput 2012). Using these estimated catchability coefficients, the annual returns for other years (1987, 1997 to 2019) are estimated using the reported catch and effort of logbook anglers and from the voluntary licence stub returns. The assessment model links the effort to the exploitation rate using the following equation:

$$ER_{t,s,y} = 1 - \exp\left(-q_{t,s}E_{t,y}\right) \text{ with}$$

$ER_{t,s,y}$ the exploitation rate on salmon of size group s (small salmon, large salmon) in year y,

$q_{t,s}$ the catchability coefficient for salmon of size group s by angler t (logbook, licence stub), and

$E_{t,y}$ the reported effort by angler group t in year y.

By implicitly modelling exploitation rate as a function of effort, there would be a strong correlation between the two parameters, even though the effort values used to estimate the $ER_{t,s,y}$ differs from the total effort estimated for each year (raised effort of licence stubs to account for partial catch reporting). Indeed, there is a strong linear association between the exploitation rate (total catch divided by estimated returns, median) and the estimated total annual effort, with model-derived exploitation rate decreasing with decreased effort (Figure 7). Note that the catch is also related to effort, as might be expected, but there are years where catch is higher than would be predicted by effort alone due to differences in abundance (Figure 7).

Proportion of Catch by Season

Some of the inseason management interventions include opening a fall fishery if the inseason adjusted expectation exceeds the pre-season forecast or closing the fishery in the fall if the inseason adjusted expectation is lower than the pre-season forecast (Appendices 1, 2). To assess the consequence of this measure, information on the proportion of the catch (or prop of the season exploitation rate) that would occur in the autumn (or vice versa, in the summer) is required. Historical angling catch data are available by season for the years 1969 to 1994 (Figure 8, Moore et al. 1995). The estimated proportions of the catch that occurred in the autumn vary by year, but increased in the last part of the times series 1984 to 1994. The proportion of the catch in the fall is higher in the SW and generally higher for large salmon compared to small salmon in both rivers. The proportion of the catch in the autumn was assumed as the mean of the proportions of 1984 to 1994 (Table 2).

CATCH AND RELEASE MORTALITY

Van Leeuwen et al. (2020a, 2020b) conducted a meta-analysis on the effect of river temperature and other factors on post-angling mortality that confirmed previous studies on this issue: the probability of mortality increased with river temperature, the mortality rate was highly variable (from 0 to 80%) and influenced by the fishing technique and less so by gear, and the mortality rate was higher for smaller salmon than larger salmon. They concluded that mortality ranged from 1% to 5% at water temperatures less than 12 °C, 4% to 16% at water temperatures between 12 °C and 18 °C, and 7% to 33% at water temperatures between 18 °C to 20 °C. To circumvent the limitations in previous studies (i.e. short temporal window, low sample size, lack of a control, confounding effects of release techniques and gear types), Keefe et al. (2021, 2022) undertook a multi-year telemetry study to quantify post-angling mortality in relation to water temperature. The conclusions in Keefe et al. (2022) agree with those from the meta-analysis; post-release mortality for angled salmon was 3% at temperatures from 10-18 °C, and increased to 11% at 18 °C, 22% at 20 °C, and above 21 °C mortality jumped to 42%.

The current warm water protocol in the Gulf Region triggers angling closures on rivers when the minimum water temperature exceeds 20 °C for two consecutive days (DFO 2012). This may not be sufficient to avoid significant losses particularly if fish are being angled during the warmer times of day when maximum temperatures exceed 20 °C. Even below 20 °C, losses of 7% to 33% (Van Leeuwen et al 2020a, 2020b) of caught and released salmon could imperil a population that is in the critical zone. Although catchability decreases as temperature increases, several studies have now demonstrated that Atlantic Salmon continue to be captured by anglers at river water temperatures above 20 °C (Mowbray and Locke 1999, DFO 2012, Breau 2013, Van Leeuwen et al. 2021, Keefe et al. 2022).

Finally, the estimates of mortality for both the meta-analysis and the multi-year study are based on the assumption that best angling practices are implemented thus the mortality estimates are a best-case scenario. The meta-analysis of Van Leeuwen et al. (2020a, 2020b) indicated that there was no statistically significant difference in the predicted catch and release mortality rates due to gear type (lures, fly) (see Tables 6 and 7 in Van Leeuwen et al. 2020a). If catch and release angling is permitted for stock at critical levels, as suggested in the candidate HDR (Appendices 1, 2), managers should consider measures to increase compliance with best angling practices. Best practices are currently understood to be: limiting gear to barbless, single-hooked artificial flies, instruction on use of appropriate strength of fly rod, reel and leader, use of rubber knotless rubber nets, handling of fish with bare wet hands only (no gloves), minimizing the handling time and exposure to air of fish (summarized in Keefe et al. 2022).

Post-Angling Mortality Rates Assumed in the Analyses

In the DFO assessments of returns and spawners, a 3% catch and release mortality rate is assumed in the recreational fishery of the Miramichi (Douglas et al. in prep.[1]). The 3% value was first used by Randall et al. (1986, Appendix 3). A value of 6% is assumed for the Restigouche River (Courtenay et al. 1991), and 3% for the Nepisiguit River (Locke and Mowbray 1996) in NB. A value of 5% is assumed for the Margaree River and other rivers of NS (Breau and Chaput 2012).

To illustrate the candidate HDRs and to quantify the expected losses associated with catch and release mortality, the following adjustments were made. It is assumed that the catch and release mortality rate would be higher on summer caught fish than autumn caught fish because of warmer water temperatures in the summer. As autumn temperatures are cool, the catch and release mortality in the autumn season was assumed to be 1% in both the NW and SW. The season total catch and release mortality rate was calculated as the weighted proportion of the catch that occurred in each season. The angling catches in the Miramichi River are most important in the summer months (June to August), especially for the NW (Figure 8). Based on the proportions of the catches that were reported in the autumn, and for a season mortality rate of approx. 3%, the catch and release mortality rates in the summer equate to 5% in SW, 4% in the NW (this gives seasonal values of 3.4% and 3.5% for SW and NW respectively) (Table 2).

Mean summer river water temperatures at 21 monitored sites in the Miramichi River varied from 18 to 21.2 °C (except Sisters Brook at 16.5 °C and Rocky Brook at Cold Spring at 17.3 °C; Caissie et al. 2013). In the autumn (September 1 to October 31), mean river temperature at the Upper Oxbow (NW) and Doaktown (SW) monitoring stations during 2018 to 2020 ranged from 11.4 to 12 °C.

Van Leeuwen et al. (2020a, 2020b) produced a model-predicted mortality rate of 16% (95% C.I. 7% to 33%) for salmon angled at river temperatures of 18 to 20 °C. For salmon angled at water temperatures of 0 to 12 °C, the model-predicted mortality rate was 3% (95% C.I. 1% to 5%). A higher post-angling mortality rate (to 30 days post-release) of 25% (19% to 32%) for Atlantic salmon angled at river temperatures between 18 and 20° C was also considered (from Table 4 in Keefe et al. 2021).

The predicted catch and mortality rates by season, weighted by the proportion of the catch by season, were used to derive season adjusted catch and release mortality rates for the NW and SW (Table 2). The assumptions on the catch and release mortalities are revisited in the assessment section.

TRANSLATING HDR IN PERCENTAGES OF EGGS LOST DUE TO RECREATIONAL FISHING

Overall, there is no information on annual effort and exploitation rate in the Miramichi River recreational fishery, and their association with licence sales, season retention limits, daily retention limits, and catch and release limits to translate the management measures described in the decision rules to expected exploitation rates. For the purpose of illustration and evaluation of the candidate HDRs, the following assumptions were made to translate the management measures to percentages of eggs lost:

- The USR is set at 373% of LRP (DFO 2022).
- The average proportions of the total eggs attributed to the large salmon returns for the NW and the SW (DFO 2018) are assumed to be the same over the entire abundance range prior to the fishery.
- Differences in daily catch and release limits do not change the overall season exploitation rate.
- For a bright salmon season of May 15 to October 15, the exploitation rate by size group is assumed to be independent of any management measure and to be the same over the abundance range prior to the fishery.
- If retention of small salmon is allowed but no conditions (number of tags per licence, quota) are indicated (Rule 1, Appendix 1), then the retained small salmon equals the catch of small salmon and there is no catch and release of small salmon.
- If retention of small salmon is allowed with a season limit of one fish (one tag per licence; Rule 2, Appendix 2), it is assumed that 75% of the catch is retained and 25% of the catch is released.
- If season retention limits for small salmon are 2 or greater (Rule 2, Appendix 2), it is assumed that the retained small salmon equals the catch of small salmon and there is no catch and release of small salmon.
- For the inseason components, if the fishery is initially closed but opens in the autumn pending an inseason review, the exploitation rate in the autumn is the product of the total season exploitation rate and the proportion of the catch that occurs in the autumn.

- For situations where the fishery is only open for the summer, i.e. is closed for the autumn or adjustments are made after the inseason review, the exploitation rate for the summer is the product of the total season exploitation and one minus the proportion of the catch in the autumn.
- Losses from catch and release that occur exclusively in the summer or exclusively in the autumn are calculated as the season-adjusted exploitation rate and the season specific catch and release mortality rate.
- The black salmon fishery is ignored in this exercise. The eggs from repeat spawning salmon are included in the large salmon contribution.

The profiles of the percentages of the eggs lost for different abundances prior to the fishery for the two candidate HDRs are shown in Figure 9 for the preseason rule, and in Figure 10 accounting for the inseason adjustments.

COMMENTS ON PRESEASON DECISION RULES AND INSEASON ADJUSTMENTS

The two HDRs are similar in many aspects but differ in others.

- Both candidate HDRs maintain the prohibition on harvest of large salmon in the recreational fishery, a management measure that has been in effect in the recreational fisheries of the Maritime provinces and Newfoundland since 1984. This effectively reduces the impact of the recreational fishery on egg depositions as the large salmon account on average for 78% of the total eggs in returning salmon in the NW and 93% in the SW (DFO 2018). The loss of large salmon due to fishing occurs as a result of catch and release mortality.
- Both HDRs incorporate inseason adjustments for warm temperatures and low water levels as per the established warmwater protocol, intended to preclude higher losses of fish due to higher catch and release mortality rates under those stressful conditions.
- Neither candidate HDR specifies annual river-specific quotas for retention of small salmon. Season limits per licence are not equivalent to an annual quota because the maximum removal that could theoretically occur is the product of licences sold and retention tags per licence, which in most years exceeded the total abundance before fishing of small salmon to NB rivers.
- Both HDRs would allow a directed recreational fishery when the abundances before the fishery are below the LRP. Rule 1 would open the fishery on bright salmon when expected abundances before the fishery are >= 25% of LRP whereas rule 2 would allow exploitation when abundances are >= 15% of LRP.
- Because of differences in biological characteristics (prop. of eggs from large) and exploitation rates of small salmon and large salmon between rivers, the profiles of the percentage of eggs lost differ between the rivers (Figure 9), with higher maximum losses in the NW of 10.1% compared to 3.8% in the SW when the catch and released mortality rate is assumed to be ~3%.
- The maximum losses when the abundances are below the LRP are 1.3% in the SW and 1.1% in the NW, at an assumed catch and released mortality rate of ~3% (Figure 9).
- The maximum percentages of eggs lost in the critical zone occur at lower abundances for rule 2 whereas the maximum percentages of eggs lost in the cautious zone occur at lower abundance for rule 1.

- Both candidate HDRs are characterized by stepped decreases in the percentages of eggs lost rather than gradual decreases as abundance declines through the cautious zone.
- For both rules, the maximum loss of eggs first occurs at the lower end of the cautious zone.
- Inseason adjustment rules could provide an opportunity for a fishery in the autumn when revised abundance expectations exceed the preseason abundances that had prescribed no fishing.
- In all other cases, the inseason adjustment at most reduces the percentage of eggs lost when inseason expectations are below the pre-season forecast that allowed a directed fishery (Figure 10). This reflects the risk prone characteristic of these decision rules that open a fishery based on the preseason forecast.

There are inconsistencies in the inseason triggers and pre-season abundance levels that would allow fisheries. For rule 1:

- When preseason abundances are less than 25%, the fishery is closed pending an inseason update and the autumn catch and release only fishery may open if the updated abundance is expected to be >= 50% of LRP.
- When the preseason abundances are expected to be >= 25%, the autumn catch and release fishery would be allowed to stay open if the inseason update was of an expected abundance > 25%, inconsistent with the > 50% of LRP trigger to open the autumn fishery in the previous status category.

To be consistent, the pre-season / inseason steps for rule 1 could be simplified:

- < 50% of LRP: bright salmon fishery closed May 15 pending inseason update. If inseason expectation is > 50% of LRP, allow a catch and release fishery in the autumn.
- 50% to 120% of LRP: bright salmon catch and release fishery opens May 15. If the inseason update expectation is < 50% of LRP then the autumn fishery is cancelled.
- > 120% of LRP: bright salmon catch and release fishery opens May 15 with prescribed retention options for small salmon. If the inseason update expectation is < 50% of LRP then the autumn fishery is closed. If the inseason update expectation is > 50% and < 120% of LRP, the autumn catch and release fishery stays open but the retention of small salmon in the autumn is prohibited.

Similar inconsistencies are noted for rule 2.

- When preseason abundances are < 15%, the fishery is closed pending an inseason update. A catch and release fishery in the autumn may open if the updated abundance is expected to be >= 50% of LRP.
- When the preseason abundances are >= 15%, the bright salmon fishery opens May 15. The autumn fishery would be allowed to stay open if the inseason update was of an expected abundance > 15%, inconsistent with the > 50% of LRP trigger to open the autumn fishery in the previous category.
- For other status categories, adjustments would be made to the autumn fishery measures if the abundances were below 50% or other specified values but regardless of the inseason update values, the autumn fishery would not close.

To be consistent, the pre-season/inseason steps for rule 2 could be simplified:

- < 50% of LRP: bright salmon fishery closed May 15 pending inseason update. If inseason expectation is > 50% of LRP, allow an autumn catch and release fishery.
- 50% to 120% of LRP: bright salmon catch and release fishery opens May 15. If the inseason update expectation is < 50% of LRP then the autumn fishery is cancelled.
- > 120% of LRP: bright salmon catch and release fishery opens May 15 with prescribed retention options for small salmon. If the inseason update expectation is < 50% of LRP then the autumn fishery is cancelled. If the inseason update expectation is > 50% and < 120% of LRP, the autumn catch and release fishery stays open but the retention of small salmon in the autumn is prohibited.

HARVEST DECISION RULES IN OTHER JURISDICTIONS

In Newfoundland and Labrador, DFO has implemented a river classification system for scheduled salmon rivers that essentially functions as a HDR. The classification system categorizes the rivers in classes with class-specific regulation on season and daily bag limits for the catch and release and small salmon retention fisheries. The assigned river class is based on a number of factors, including salmon population, spawner returns, river size, angling pressure, and remoteness of the river (DFO 2020b). Specific colours of tags are used to identify retention options by class of river. The management plan also includes inseason criteria for closing and opening rivers to angling based on water temperatures.

Bourgeois and Veinott (2012) indicated:

> “The purpose of the River Classification System was to allow DFO to manage the fishery on a river by river basis. Seasonal and daily bag limits could vary based on the size of a river’s population and/or its status with respect to conservation limits. However, DFO does not set quotas in the Atlantic salmon recreational fishery. Therefore, although there is a daily bag limit there is no limit on the number of residents that can purchase a licence and no limit to the number of anglers that could fish a particular river. River Classification approach limits the harvest on smaller watersheds which have a lower class designation and this management approach protects these smaller watersheds through limiting the retained harvest.”

Since the inception of the River Classification System the number of licenses issued and the overall number of small salmon retained has decreased (Bourgeois and Veinott 2012). In 2021 and 2022, essentially three river categories were defined (https://www.nfl.dfo-mpo.gc.ca/nfl-tnl/en/NL/AG/SalmonSeasonDates):

- Class 0: no retention is allowed, catch and release only.
- Class 2: max. retention of one fish per licence holder, one red tag (tag # 1).
- Class 4: max. retention of two fish per licence holder, red or green tag (tag # 1, 3)
- Class 6: max. retention of two fish per licence holder, red or green tag (tag # 1, 3).

The province of Quebec also applies a HDR based on a Precautionary Approach model with inseason assessments and adjustments reliant on stock abundance (MFFP 2016). Salmon stocks are classified in three categories based on stock abundance zones: healthy, cautious and critical zones. Depending on stock status, a set of decision rules are applied to adjust exploitation rate on a stock.

- Healthy zone: exploitation rates on stocks in the healthy zone are relatively constant and do not put the stock at risk.

- Cautious zone: exploitation rates on stocks in the cautious zone are reduced in order to increase stock abundance.
- Critical zone: management measures on stocks at low abundances are put in place to minimize exploitation rates.

In the province of Quebec, management targets account for both conservation (LRP) and socioeconomic considerations with targets set above conservation requirements (MFFP 2016). To retain large salmon, the attainment of both conservation requirements and the management target is required. The provincial government undergoes discussions with the watershed organization to establish management targets for that river. In situations where the management target is set near the conservation requirements, the short-term benefit is larger (higher number of fish retained) however, there is a greater risk that stock abundance falls into the critical zone resulting in no large salmon retention. For other watershed organizations with a preference to maximize salmon abundance in the river, the management targets are set much farther from the conservation requirements and only catch and release of large salmon is allowed. As for small salmon, retention is permitted on rivers where egg deposition rate is, based on a five-year mean, above management targets and on rivers where egg deposition rate is, based on a five-year mean, below management targets but above conservation requirements. For stocks below conservation requirements, recreational fisheries are closed in two situations: a watershed angling association is absent on the river and, if an association is present, the small salmon contribute to more than 30% of the egg deposition rate. On rivers with stock abundance below conservation requirements, with a watershed angling association present and small salmon contributing less than 30% of the egg deposition rate, there is the mandatory release of large salmon and restricted harvest of small salmon (MFFP 2016).

CRITERIA FOR HARVEST DECISION RULE COMPLIANCE WITH THE PA FRAMEWORK

Our objective is to evaluate whether the candidate HDRs conform to the PA and affiliated policies (DFO 2019b). We evaluate conformity relative to the characteristics of candidate HDRs as described in various policies and science advisory reports and we quantify the performance of the rules when some uncertainties associated with the assessment of abundance are taken into account.

Under Section 6.2(1) of the Fish Stock Provisions, a major fish stock that falls to or below their LRP requires a rebuilding plan to promote stock growth (DFO 2021a). Atlantic salmon of DFO Gulf Region is currently not listed in the priority list of species under the revised Fisheries Act and a rebuilding plan is not currently prescribed even if its status falls to the critical zone. However, the policy elements of DFO (2009, 2019b) and the advice in DFO (2016, 2021a, 2021b) are considered in the development of HDRs and actions to prevent or reverse a stock decline to the critical zone.

DFO (2006) states that harvest strategies (harvest decision rules) are intended to be applied to any resource exploited in commercial, recreational, and subsistence fisheries and that the removal rate pertains to all losses associated with fishing including by-catch, discards, incidental mortality, or losses to reproductive potential such as through the disruption of spawning success. Generally, harvest strategies are implemented by regulating the removal rate (losses) by either controlling effort (input control) or controlling catches / losses (output control).

DFO (2006; 2009) outline the minimal elements that a harvest strategy for fisheries on exploited species must have to comply with the PA:

- Includes reference points that delineate three stock status zones and a reference point that defines the maximum removal rate (or proportion) of the stock when it is in the healthy zone (DFO 2009).
    - The Limit Reference Point is the stock level below which productivity is sufficiently impaired to cause serious harm but above the level where the risk of extinction becomes a concern. In this context, serious harm could be due to over-fishing, other human induced mortality, or changes in population dynamics not related to fishing.
    - The Upper Stock Reference point is the stock level threshold below which the removal rate is reduced. This reference point is determined by productivity objectives for the fishery, will vary among species and fisheries and include biological, social and economic factors. The stock status zone above the Upper Stock Reference is called the Healthy zone.
    - The Removal reference is the maximum acceptable removal rate. The removal rate is the ratio of all human induced removals and total exploitable stock size. To comply with the United Nations Fish Stock Agreement (UNFSA), it must be less than or equal to the removal rate associated with maximum sustainable yield.
- Management decisions must respect the indicated actions in each of the stock zones (DFO 2006) including:
    - In the Critical zone, fishery management actions must promote stock growth. Removals by all human sources must be kept to the lowest possible level and there should be no tolerance for preventable decline (also expressed in DFO 2009).
    - In the Cautious zone, fisheries management actions should promote stock rebuilding towards the Healthy zone. The removal reference (Harvest rule) should progressively decrease as the stock level approaches the Critical zone. Any progressively decreasing removal rate in the Cautious zone is permissible.
    - In the Healthy zone, the stock status is considered to be good and the removal rate should not exceed the Removal reference.

REMOVALS FROM ALL SOURCES KEPT TO THE LOWEST LEVEL POSSIBLE

The DFO (2009) policy specifies that when a stock is below the LRP removals from all sources must be kept to the lowest level possible. Keeping removals to the lowest level possible could be interpreted as closing directed fisheries on the species while ensuring that incidental bycatch and mortality either in fisheries directing for other species or associated with monitoring activities are kept to the lowest level possible.

Both candidate HDRs would allow a directed catch and release fishery on Atlantic Salmon when the abundance before fishing is below the LRP (Table 1). A directed catch and release fishery for salmon can be interpreted as a preventable loss and if allowed would not be consistent with keeping removals to the lowest level possible, regardless of the percentage of salmon lost from catch and release mortality. To date, a 3% mortality rate over the entire season's catch is assumed for the recreational salmon fishery of the Miramichi River although higher mortality rates are expected given the evidence from studies on mortality rate associations with water temperature. Using the assumed values of 3% for the Miramichi (Table 2), the losses in the critical zone from this directed activity would be just above 1% of the anadromous adult reproductive potential in the NW and SW (Figure 10a). At higher catch and release mortality rates of 11% to 14% and 17% to 22% informed from published studies and mean water temperatures in the summer and fall (Table 2), losses to the reproductive potential due to a directed catch and release fishery in the critical zone of 4% to 7% could be anticipated (Figure 10b, c).

Activities that incidentally impact anadromous Atlantic Salmon include the gaspereau fisheries that occur in numerous estuaries and tidal waters of southern Gulf (although the interaction is acute in rivers with early runs of salmon in particular the Miramichi River), the recreational fisheries for Brook Trout in freshwater, and scientific / monitoring activities conducted by DFO, the province of New Brunswick at headwater barriers, and research activities by non-government organizations. Retention of salmon is prohibited in the gaspereau and trout fisheries but mortality of released fish due to handling and stress definitely occurs. There are incidental mortalities of salmon recorded at the DFO and provincial monitoring facilities (meshing, injury, warm water stress) and in other research activities (see DFO 2019a for an example of mortalities at these facilities) but measures are in place (minimal handling of fish, ceasing trapping activities for monitoring) to reduce to the lowest level possible the incidental mortality of salmon under stressful environmental conditions.

NO TOLERANCE FOR A PREVENTABLE DECLINE

DFO (2009) illustrates what is meant by tolerance of a preventable decline with an example:

> "Management decisions should be explicit about the risk of decline associated with a management action by deciding on a risk tolerance for a particular management decision (Annex. 2b contains a draft table of risk tolerance designations). As an illustration, if a stock's abundance is in the Cautious zone, near the Critical zone, it may be decided that there is a low tolerance for a risk of the abundance declining from its current level. According to the table, a low tolerance for risk is where the risk of a stock's decline from its current level is estimated to be between 5% and 25%. Management actions would then aim to be consistent with this level of risk tolerance."

Closure of directed salmon fisheries has occurred under the Fisheries Act and provincial regulations in response to low abundance of salmon. The Indigenous and recreational fisheries in the Inner Bay of Fundy rivers closed in 1990 (DFO 2010) and the majority of the rivers in the DFO Maritimes Region were closed to fishing beginning in 1998 (DFO 1999) when the majority of the assessed rivers had achieved less than 25% of the conservation limits (LRP at that time). On several small rivers in the province of Quebec where the expected total abundance of anadromous salmon is less than 200 fish per river, directed salmon fishing is prohibited (MFFP 2016).

There is also a circumstance for a species under the governance of the Species at Risk Act and regulations when preventable harm from a directed fishery and incidental losses from non-directed activities may not be tolerated. Activities in the Inner Bay of Fundy Designatable Unit area that potentially interact with salmon are subject to review and permitting under the Species at Risk Act; directed fisheries for salmon in this area are not permitted (DFO 2004, 2010).

Angling is a recreational activity (with direct employment related to outfitters and guides) and the engagement of anglers may wane or be diverted to other activities if access to salmon fishing is reduced or prohibited. This is evident in the reduction of salmon recreational licence sales in NB when mandatory catch and release measures for all rivers of DFO Gulf Region were introduced in 2015. In the footnotes of Decision Rule 2 (Appendix 2), the proponents state that there are benefits to maintaining the directed catch and release fishery that exceed the losses from the activity when abundance falls into the critical zone:

> "Sustaining a recreational fishery ensures that people remain engaged in protecting and caring about the resource, including deterring poaching and supporting restoration action to help the stock recover. The angling community supports conservation programs and ensures Atlantic salmon restoration remains a political priority, which ensures resources

> are directed to salmon conservation. On the poaching issue alone, the conservation benefits of having anglers on the water far outweigh the biological consequences from poaching that occur in the absence of anglers”

When abundance falls into the Critical zone, a directed recreational fishery for Atlantic Salmon may be justified if maintaining the directed fishery results in a reduced risk to conservation of the salmon population in the river. There could be a reduced conservation risk to the salmon population from a directed fishery if keeping the directed fishery open supports stewardship engagement, such as habitat restoration, that improves survival of salmon in river. Additionally, if the losses from poaching activities in the absence of anglers on the river exceeds the total losses from a directed salmon fishery and the associated reduced losses from poaching because of angler presence, then there can be a reduced conservation risk of maintaining directed fisheries open when abundance declines (Figure 11).

Angling, watershed and conservation organisations contribute to conservation activities directly through a fishing licence fee and in volunteer hours and donations. In 1997, the government of NB established a non-government agency to further wildlife conservation in the province of NB and to fund a range of programs for the enhancement of New Brunswick’s wildlife, fish and their habitats. The main source of revenue is from a conservation fee on hunters, anglers and fur harvesters licences. The NB Wildlife Trust Fund, along with other funds including the Atlantic Salmon Conservation Fund, support watershed and community driven projects related to aquatic habitat restoration and stocking, which may benefit Atlantic Salmon.

Illegal fishing for salmon is an old and ongoing irritant. Canada annually reports to the North Atlantic Salmon Conservation Organisation on unreported catches of salmon and estimates for DFO Gulf Region provided for 2015 were of greater than 2000 small salmon and large salmon combined lost to primarily poaching in tidal and freshwater areas. Limiting illegal removals through effective enforcement or other management actions are important conservation measures; particularly so when a stock is in the critical zone. Critics state that there is insufficient enforcement and conservation groups have sponsored the installation of cameras at key locations to deter illegal activities. Coté (2005) and Coté et al. (2021) report on a successful community based initiative in the Northwest River (NL) to restore a salmon run. Community engagement led to reductions in losses of salmon in illegal and bycatch marine fisheries motivated by the proviso of recreational fishery access based on an abundance threshold for the river. The recreational fishery access remained closed if the anticipated returns of salmon were below a defined threshold with a small (max. 10%) allocation of the returns to recreational fishery when abundance permitted. In these studies, evidence that the presence of anglers on the river during the day reduced the intensity of poaching and other illegal activities is lacking.

QUANTIFYING RISK OF FALLING INTO THE CRITICAL ZONE

DFO (2019a) emphasizes that the overarching goal of the PA is to prevent stocks from declining into the Critical zone in the first place, particularly as a result of fishing. DFO (2021a, 2021b) provide some additional guidance on characteristics of HDRs that would comply with the intent of the PA policy.

DFO (2021a, 2021b) reiterated that the LRP represents the stock status below which “serious harm” to the stock may be incurred and that serious harm is considered to include recruitment overfishing or other impairment to productive capacity with potentially resultant impacts to the ecosystem and a long-term loss of benefits to resource users. To avoid breaching the LRP, a phrase introduced by DFO (2021a), management actions to prevent further decline in status should be implemented before this point is reached, again emphasizing that the LRP is considered to be a threshold reference point to be avoided.

DFO (2021a) speaks to the issue of risk and probabilities of exceeding thresholds and attaining targets; in the case of the LRP they refer to the need to define criteria for determining the occurrence of a LRP breach.

> "Unless otherwise defined in stock-specific precautionary approach frameworks, the LRP should be considered breached if the terminal year stock status indicator is estimated to be at or below the LRP with a greater than 50% probability, or if the projected stock status indicator falls below the LRP with a greater than 50% probability under a zero catch scenario in a 1 year projection. This should be used to determine stock status relative to the LRP."

Accepting up to a 50% chance of the abundance before fishing being below the LRP before concluding that the LRP is breached seems inconsistent with the intent of a threshold that stocks should have a very low chance of falling to the LRP due to anthropogenic removals. In an evaluation of HDRs for the snow crab fishery, DFO (2014) interpreted PA compliance as a very low probability (<= 5%) of the stock falling into or remaining in the critical zone due to fishing exploitation.

Considering that the LRP is a threshold reference point and that being below the LRP constitutes a zone where there is increased likelihood of serious and irreversible harm occurring or having occurred, a threshold of < 5% risk of being below the LRP for Atlantic Salmon was also considered. This is appropriate because the reference points for Atlantic Salmon are defined on a river-specific basis and with many salmon runs to rivers in DFO Gulf Region being of low numbers; 78% of the 102 rivers with defined LRPs would require on average <= 200 anadromous adult spawners to meet the LRP (DFO 2018).

Assessing Performance of Decision Rules due to Assessment Uncertainties

The implementation of the candidate HDRs for the Miramichi River will require a forecast of abundance before the recreational fishery. The biological characteristics, including relative abundances of small salmon and large salmon and the eggs per fish, vary annually. We considered how the uncertainties in the assessed abundances and biological characteristics of the fish modify the performance of the decision rules with regards to the intent of the PA policy.

We examined the performance of the candidate HDRs by simulating a fisheries management decision based on preseason abundance forecasts of small salmon and large salmon to each of the NW and SW. The preseason abundance forecast is the median of the posterior distributions of the estimated returns, i.e. an excellent forecast of the annual abundance before fishing and assumed that the forecast represents the abundance after the Indigenous peoples' access has been agreed. The characteristics of the angling fishery by river, size group, and season that were applied are summarized in Table 2. Catch and release mortality values were simulated with uncertainty for the approximately 3% rate reported in Randall et al. (1986, Appendix 3). Considering evidence from a wide range of studies that catch and release mortality rates (and effects on spawning success) increase with water temperatures, the performance of the rules using higher simulated mortality rates that could apply to the situation in the Miramichi was also examined (Table 4, Appendix 4).

No assessment of inseason performance was done hence the proportion of catch in the late season and the season specific catch and release mortality rate values are not used. The details of the simulation procedure are summarized in Appendix 4.

The candidate HDRs were assessed using two risk criteria:

- whether there was greater than 5% probability that the estimated abundance after fishing fell below the LRP when the probability of the abundance before fishing being below the LRP was < 5%, and
- the rule resulted in a breach of the LRP, i.e. prior to fishing there was less than 50% chance that abundance was below the LRP versus after fishing when the abundance was below the LRP with > 50% chance.

Results

The summaries of the exploitation rates, catch and release mortality rates, and losses of small salmon and large salmon by river, decision rule, and for two assumed catch and release mortality rates are presented in Appendix 4, Figures A4.1 to A4.3. The summaries of the percentage of LRP for eggs in returns, eggs in spawners, and percentage of eggs lost due to fishing are shown in Appendix 4, Figures A4.4 to A4.6.

The largest differences in number of fish lost annually is for small salmon because retention options are possible when the forecast abundance exceeds 120% of LRP for both rules (Appendix 4, Figures A4.1 to A4.3). For the years with retention, losses of small salmon ranged from 2000 to 10,000 fish in the NW, 2000 to 20,000 fish in the SW. For periods of catch and release only, the losses ranged from 50 to a thousand fish depending on the river and the assumed catch and release mortality rate (Appendix 4, Figures A4.1 to A4.3). At the assumed low catch and release mortality rate of 3%, the losses of large salmon are estimated to be less than 100 fish annually (median value) in the NW and between 100 to 200 fish for the SW (Appendix 4, Figure A4.1), but rises to several hundred large salmon annually in the SW at assumed season adjusted catch and release mortality rates of approximately 14% (Appendix 4, Figure A4.2).

The percentages of the eggs lost from fishing are approximately similar in the NW and SW (Appendix 4, Figures A4.4 to A4.6). At an assumed 3% catch and release mortality rate for the season, the percentages of eggs lost are in approximately two groups for the NW, based on the different management measures in the decision rule; a loss of 5% to 10% of the eggs when retention of small salmon would be allowed, and a loss of approximately 1% when catch and release only is permitted (Appendix 4, Figure A4.4a). The losses occur over a more continuous range for the SW, with maximum losses of over 10% when retention of small salmon is allowed to just over 1% with mandatory catch and release (Appendix 4, Figure A4.4b). At the higher assumed catch and release mortality rate, the losses in the NW are either between 6% and 15% with small salmon retention and approximately 4% with catch and release only (Appendix 4, Figures 5a, 6a) whereas for the SW, there are no clear groups, losses ranging between 4% and less than 15% (Appendix 4, Figures A4.5b and A4.6b).

The summaries in Figures 12 to 14 characterize the estimated total abundance of eggs in returns being below the LRP (preseason forecast) and in spawners after fisheries based on the decision rule management measures that would have applied for the preseason forecast.

Over the period 1984 to 2019, the estimated abundance of eggs in returns to the NW was above the LRP with greater than 95% probability in 20 years, whereas in 4 of those years, there was greater than 50% probability of the abundance being below the LRP (LRP breach) (Appendix 4, Figure A4.4a). At an assumed catch and release mortality rate of 3%, the implementation of rule 1 in the NW would have resulted in a reduction of egg abundance after fishing being below LRP with > 5% chance in 8 of the 20 years whereas for rule 2, this occurred in 5 of the years (Table 4). In all cases, these non-compliance events resulted from allowing a retention fishery for small salmon, i.e. the median of the assessed abundance before fishing > 120% of LRP (Table 1).

For the SW, the estimated abundance of eggs in returns exceeded the LRP with greater than 95% probability in 21 years but there was greater than 50% probability of the abundance being below the LRP (LRP breach) in 2 of those years (Appendix 4, Figure A4.4b). For the SW, neither of the rules resulted in a reduction in abundance that would result in a > 5% probability of the abundance being below the LRP. In no cases, for either the NW or the SW, was the abundance after fishing below the LRP with > 50% probability (Table 4, Figure 12).

At the higher catch and release mortality rates, the implementation of rule 1 or rule 2 resulted in the same risk in the NW of the abundance after fishing being below the LRP (Table 4; Figures 13 and 14). In 8 of the 20 years, there was > 5% probability of the abundance being below the LRP and there was an LRP breach (abundance below LRP with > 50% probability) in one or two of the 32 years (Table 4; Figures 13 and 14). For the SW, there was a LRP breach in 1 of 34 years for both rules and in 2 of 21 years, the abundance after fishing was below the LRP with > 5% probability for rule 1 but no such occurrence for rule 2 (Table 4; Figure 13). At the highest catch and release mortality considered, the number of events with greater than 5% probability of the abundance after fishing being below the LRP was 3 of 20 years for rule 1, and 2 of 20 years for rule 2 (Table 4) and there was one LRP breach resulting from fishing (Figure 14).

The seemingly poorer performance of rule 1 compared to rule 2 in terms of reducing the abundance below the LRP with > 5% probability is because of the assumption on the proportion of the small salmon catch that would be released when the preseason abundance was > 120% of LRP (Tables 1, 2). Because in rule 1, retention of small salmon was allowed if the abundance was > 120% of LRP but no limits were identified, it was assumed that all the small salmon caught would be retained. For rule 2, when abundance was >= 120% and < 180% of LRP, the management measure was one retention tag per licence and under this scenario it was assumed that 25% of the small salmon catch would be released, which is why rule 2 with a lower removal rate on small salmon for that abundance level performs better. Otherwise, there is nothing to distinguish between the two rules in terms of their performance relative to the two risk criteria considered (Table 4).

SUMMARY OF COMPLIANCE

Several characteristics of the candidate HDRs for salmon comply with the characteristics of harvest strategies under the PA but there are deficiencies (Table 5):

- Three status zones are defined, delineated by a LRP (DFO 2018), an USR and TR (DFO 2022) [complies].
- A maximum removal rate has been defined (DFO 2022) [complies].
- Management measures are identified that would apply at different abundance levels in the three zones and the management measures result in a decrease (translated) in the removal rate from the healthy zone towards the critical zone [complies].
- The maximum anticipated removal rate in the healthy zone is less than the maximum defined removal rate. This is primarily because the management measures prohibit the harvesting of large salmon which are the majority of the egg bearing females [complies].
- The condition that abundance must exceed 120% of LRP before retention of small salmon is allowed is a proposed Operational Control Rule to reduce the risk of fishing lowering the abundance below the LRP [complies].
- The removal rate profile in the cautious zone occurs as steps with large differences in status levels between increments. The maximum anticipated removal rate, under the conditions

assumed for quantifying losses, occurs in the lower portion of the cautious zone [does not comply].

- Are the control points sufficient to prevent decline into the critical zone due to fishing? The analysis suggests not completely. The uncertainties in the assessments of abundance are such that using the median as the point estimate of the prefishery forecast (the best forecast possible), the removal rates in some years result in the stock falling into the critical zone with > 5% probability and in some cases, a breach of the LRP occurred [does not comply].
- Other measures in place to prevent losses above assumed values: warm water protocol to guard against conditions that would lead to higher than assumed mortality from catch and release fishing however the entire river is never closed to directed salmon fishing.

The prohibition on retention of large salmon in the recreational fishery currently in place in the DFO Gulf Region and applied in the two candidate HDRs has the greatest consequence on limiting the losses of total eggs, given that the majority of the eggs are contributed by large salmon. Unless the mortality rates due to catch and release fishing are substantially higher than what is assumed, the losses associated with catch and release mortality represent a small percentage, 1% to 7%, of the total estimated egg producing potential.

The harvest strategy characteristic that engenders the greatest debate is whether a directed salmon fishery when the abundance is in the critical zone qualifies as a management measure that promotes stock growth, keeps removals to the lowest possible level, and shows no tolerance for preventable decline. The estimated losses in the critical zone from a directed catch and release recreational fishery are in the range of 1% to 7% and are dependent on the assumptions made regarding the exploitation rates (that are the same at all abundance levels) and the catch and release mortality rates (including rates as high as 25% for the summer catches). If maintaining a directed salmon fishery when the abundance is in the critical zone indeed reduces the conservation risk to the salmon population by improving survival (at various life stages) through stewardship engagement and reduced illegal removals above what is lost due to the directed fishery, then the activity might be considered acceptable within the PA (Figure 11).

UNCERTAINTIES

The candidate HDRs identify input control (to regulate effort) management measures which would apply at different levels of abundance. There is little to no information to translate the management measures into exploitation rates and losses. Of the available information, exploitation rates are weakly to not at all associated with rod-days of effort or licence sales and do not change linearly with season retention limits for small salmon. But the data specific to the Miramichi River are sparse and dated. In absence of informative data, assumptions from historical periods with effort and exploitation rates are used to translate the management measures into removal rates, which is unlikely to be appropriate as abundance declines and interest in the recreational fishery wanes.

The candidate HDRs do not consider retention of large salmon and when at abundances of < 120% there is mandatory catch and release of all Atlantic Salmon. There is mortality resulting from the practice of catch and release in recreational fisheries and a broad range of studies are unequivocal in the finding that post-release mortality increases as the water temperature at time of capture increases. The Miramichi River Atlantic Salmon assessment assumes a 3% catch and release mortality rate applied to the total season catch of salmon. Higher values for catch and release post-angling mortality rates in this document (3% seasonal ; 16% in summer and 3% in autumn; 25% in summer and 4% in autumn) were taken from published literature.

Historically, the catch in the summer has been higher than the catch in the autumn, due in large part to the shorter period of time and closures of sections of the river in the autumn than is otherwise available in the summer. The assumed value for catch and release mortality affects the evaluation of the performance of the candidate HDR, and in particular, determining if the positions of the operational control points (e.g. no retention of small salmon when abundance < 120% of LRP) are sufficient to prevent a decline of the abundance below the LRP because of fishing. Climate change predictions are for warmer river temperatures in the summer and early autumn possibly leading to more days when fish are exposed to higher post-release mortality rates than assumed.

The performance of the candidate HDRs was evaluated relative to the uncertainties of the assessment of abundance. A perfect forecast, the median of the assessed abundance and the biological characteristics of the salmon specific to the forecast year, was used which severely underestimates the risks to the salmon population of implementing the candidate HDRs.

There has not been any systematic method since 1997 to estimate the catch and effort in the Atlantic Salmon recreational fishery of NB. The only reliable source of angling data is from the Crown Reserve Waters reports, which does not have 100% report compliance. The implementation of the candidate HDRs and the auditing of its performance are constrained by the absence of such data.

There is essentially no data on the extent of poaching/illegal losses in the rivers although estimates of several thousand salmon per year being lost to illegal activities in DFO Gulf Region has been provided by DFO Ecosystem and Fisheries Management. It has been stated by angling groups that a directed salmon fishery, even catch and release, can reduce the risk to conservation because the presence of anglers on the river will reduce the level of illegal activities. The evidence supporting a greater benefit of maintaining a directed fishery compared to the risk of illegal activities is uncertain.

CONCLUSIONS AND NEXT STEPS

The candidate HDRs for the Atlantic Salmon recreational fishery developed by the DFO-WG are intended to take into consideration the status of the Atlantic Salmon stock within the PA framework after salmon removals from Indigenous peoples have occurred. The candidate rules in that sense do not fully conform to the PA policy which applies to any resource exploited in commercial, recreational, and subsistence fisheries and that the removal rate pertains to all losses associated with fishing. However, the DFO-WG treated the Indigenous peoples' fisheries and the recreational fisheries as sequential fisheries. Once the constitutionally recognized right of first access, after conservation, to natural resources for the Indigenous peoples is respected, then the decision rules of the DFO-WG would apply in consideration of the remaining abundance.

The candidate HDRs developed by the DFO-WG consist of variations of management measures that have historically been used in the NB recreational fisheries and which can be modified by Variation Order rather than by changes to regulation. The Variation Order is a very effective tool for modifying management measures among years, and within season with options that include season retention limits, daily retention limits, daily catch and release limits, season opening and closing dates, within season closures by time and within areas of the river, and gear type (e.g. fly fishing only). Only small salmon retention limits based on the number of tags issued per provincial licence were included in the candidate HDRs. Season quotas by river, such as setting a catch limit for small salmon, were not included. Specified total river catch limits would have been easier to translate to a removal rate for assessing the HDRs.

The decision rules are described as risk-prone because fisheries would open at the start of the season in mid-May provided the forecast abundance was >= 15% or >= 25% of the LRP and it would only be adjusted inseason if the revised forecast was of the abundance being < 50% (or lower in some cases). A more risk-adverse strategy would not open the fishery unless the expected abundance was above the LRP and wait for an inseason update to determine if there could be directed fishing opportunities in the autumn because of a more optimistic expectation. For the candidate rules described, the effect of the inseason update would at best reduce the overall losses for the year but the majority of losses would already have occurred, due to the dominance of the summer season catches in the Miramichi River recreational fishery.

Based on biological characteristics of the anadromous salmon population and the recreational fisheries characteristics specific to the Northwest Miramichi and Southwest Miramichi rivers, the same candidate HDR results in different removal profiles, with removal rates higher in the Northwest Miramichi River compared to the Southwest Miramichi River. This implies that a general HDR of the type proposed by the DFO-WG will not have the same performance for different rivers. An evaluation of the performance of the HDR will be required for each river using the river-specific biological and recreational fisheries characteristics.

The candidate HDRs have several elements that conform to the PA policy and guidance for harvest strategies. These include management measures that vary within three status zones (critical, cautious, healthy), a removal rate in the healthy zone that is substantially less than the removal rate reference (due primarily to the prohibition on retention of large salmon that contribute the majority of the eggs), and expected losses due to fishing that decline as stock abundance declines. Additional attributes of the rules include operational control points to reduce the risk of breaching the LRP and the use of warmwater protocols to reduce excessive post-release mortality rates under warm and low water conditions.

Other elements of the candidate HDRs may not comply with the PA policy, subject to interpretation. The translated removal rates for the decision rules are characterized by a step profile rather than a continuously declining profile as the abundance declines in the cautious zone. The result is that the maximum expected removal rate occurs early in the cautious zone and does not change as abundance increases into the healthy zone.

A key element is the interpretation of the PA policy (DFO 2009) statements and the subsequent guidance in the stock rebuilding provisions (DFO 2019b) and science advice (DFO 2021a, b) that when the abundance is in the critical zone, the removals should be kept to the lowest level possible and there is no tolerance for preventable decline. Both candidate rules would allow a directed catch and release recreational fishery when the abundance is in the critical zone. Although the losses from a catch and release fishery may potentially represent a small percentage of the total eggs, 1% to 7% depending upon the post-release mortality assumptions, any loss due to directed fishing in the critical zone could be interpreted as not conforming to policy of lowest level possible and preventable decline.

Closure of the directed salmon fishery would only occur when the abundance before fishing is expected to be <= 15% or <= 25% of the LRP, which begs the question, what does the defined LRP for Atlantic Salmon actually represent. DFO (2009, 2015, 2018) are quite clear in the definition of the LRP, representing the status below which serious harm is occurring to the stock and there may be resultant impacts to the ecosystem, associated species and a long-term loss of fishing opportunities. The LRP for the rivers of the DFO Gulf Region has been defined as the eggs from spawners that would result in a greater than 75% chance of obtaining half of the potential maximum production of smolts from freshwater. It was intended as a reference point to conserve the biological potential of the species and we are unable to articulate a position that would defend using a value less than 100% of the defined LRP as consistent with policies.

Arguments are made that the closure of the directed recreational salmon fishery will result in greater losses and increased risk to the conservation of Atlantic Salmon than if the fishery is allowed to stay open. If by allowing a directed recreational fishery for salmon, there is sustained community and angler engagement in stewardship programs that for example protect and restore habitat, the increased productivity and survival of freshwater life stages resultant of stewardship engagement may offset some of the losses from the directed recreational fishery. As further articulated in the footnotes of rule 2, the presence of anglers on the river deters illegal fishing activities. If the total mortality from the combination of the directed salmon fishery and illegal fishing is less than the mortality from illegal fishing when the directed fishery is closed, then the conservation risk to salmon at low abundance may be reduced. An example of the utility curves of benefit and risk to conservation and the net value function when these are combined is illustrated in Figure 11. The utility curves shown in Figure 11 are hypothetical and are not based on a model that quantifies the elements, however, several aspects of the curves are worth noting:

- The conservation risk to salmon increases exponentially as population abundance declines below the LRP. Small and declining populations are vulnerable to stochastic variations in inter-stage survivals, depensation and Allee effects of small population numbers (in large rivers, salmon may disperse and not find sufficient number of mating opportunities), to inbreeding depression at very low abundance.
- The benefits of maintaining a directed salmon fishery may increase with declining abundance of salmon, but it is unlikely that the survival rates of the life stages would increase exponentially and sufficiently to offset the conservation risk associated with small population numbers.

The implementation of the candidate HDRs requires a forecast of expected abundance prior to the fishery. In the limited evaluation of the performance of the candidate HDRs conducted in this report, a near perfect forecast model was used and only the uncertainties with the assessment of abundance were considered when assessing the performance of the management measures including the operational control points to prevent a LRP breach or other defined non-compliant conditions to the PA policy. A fuller evaluation of the candidate HDRs will be required before the rules can be implemented. The fuller evaluation would need to consider the biases and uncertainties of the candidate forecast models, the inseason models, and any improved information that would be informative of exploitation rates expected for the different effort controls of the management measures. The candidate rules may have to be adjusted, including modifying the operational control points, if the anticipated removal rates result in LRP breaches or declines below the LRP that exceed defined probability thresholds.

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TABLES

Table 1. Summary of the preseason management measures for the status categories within the harvest decision rules relative to percentage of LRP represented by eggs in the returns for the harvest decision rules (HDR) 1 and 2. Text in bold highlights the changes in management measure from the previous status category.

HDR	Status category	Status before fishery (eggs relative to LRP;USR)	Management measure
1	1	< 10% of LRP	no directed salmon recreational fisheries
	2	>= 10% and <= 25% of LRP	**kelt fishery April 15 – May 15, C&R max 2 fish per day** directed bright salmon fishery closed May 15 pending inseason review
	3	> 25% and <= 75% of LRP	kelt fishery April 15 – May 15, **C&R max 5 fish per day** **directed bright salmon fishery May 15 to Oct. 15**; **catch and release only for small and large, max 2 fish per day**
	4	> 75% and <= 120% of LRP	kelt fishery April 15 – May 15, **C&R max 10 fish per day** directed bright salmon fishery May 15 to Oct. 15; catch and release only for small and large, **max 4 fish per day**
	5	> 120% of LRP to USR	kelt fishery April 15 – May 15, C&R max 10 fish per day, **small salmon retention (kelt or bright): total tag allocation, number and mechanism TBD** directed bright salmon May 15 to Oct. 15; catch and release only large salmon catch and release max 4 fish per day any size Assumption: retained catch of small = catch, released catch of small = 0
	6	> USR	kelt fishery April 15 – May 15, **C&R max 25 fish per day**, small salmon retention (kelt or bright): total tag allocation, number and mechanism TBD directed bright salmon May 15 to Oct. 15; catch and release only large salmon catch and release max 4 fish per day any size Assumption: retained catch of small = catch, released catch of small = 0
2	1	< 15% of LRP	no directed salmon recreational fisheries
	2	>= 15% and <= 50% of LRP	**kelt fishery April 15 – May 15, C&R max 5 fish per day** **directed bright salmon fishery May 15 to Oct. 15**; **catch and release only for small and large, max 2 fish per day**
	3	> 50% and <= 120% of LRP	kelt fishery April 15 – May 15, **C&R max 10 fish per day** directed bright salmon fishery May 15 to Oct. 15; catch and release only for small and large, **max 4 fish per day**
	4	> 120% and <= 180% of LRP	**small salmon retention (kelt or bright): 1 small salmon tag per licence** kelt fishery April 15 – May 15, C&R max 10 fish per day, directed bright salmon May 15 to Oct. 15; catch and release only large salmon catch and release max 4 fish per day any size

HDR	Status category	Status before fishery (eggs relative to LRP;USR)	Management measure
			Assumption: retained catch of small = catch * 0.75, released catch of small = catch * 0.25
	5	> 180% of LRP to USR	**small salmon retention (kelt or bright): 4 small salmon tags per licence** kelt fishery April 15 – May 15, C&R max 10 fish per day, directed bright salmon May 15 to Oct. 15; catch and release only large salmon catch and release max 4 fish per day any size Assumption: retained catch of small = catch, released catch of small = 0
	6	> USR	**small salmon retention (kelt or bright): 8 small salmon tags per licence (number of tags TBD)** kelt fishery April 15 – May 15, C&R max 10 fish per day, directed bright salmon May 15 to Oct. 15; catch and release only large salmon catch and release max 4 fish per day any size Assumption: retained catch of small = catch, released catch of small = 0

Table 2. Atlantic Salmon angling characteristics by river, size group and season used in the simulation model of decision rule performance. The average characteristics in terms of the proportion of returns, eggs per fish, and proportion of eggs are from DFO (2018).

Characteristic	**Specific**s	**N**orthwest Miramichi	**S**outhwest Miramichi
Proportion of returns	small salmon	0.66	0.55
	large salmon	0.34	0.45
Eggs per fish	small salmon	867	402
	large salmon	6016	6081
Proportion of eggs	small salmon	0.22	0.07
	large salmon	0.78	0.93
Exploitation rate (entire season)	small salmon	0.423	0.361
	large salmon	0.283	0.392
Proportion catch late season	small	0.124	0.337
	large	0.179	0.397
Catch and release mortality 3% all year	early season	0.04	0.05
	late season	0.01	0.01
	all season	0.0363 (small) 0.0346 (large)	0.0362 (small) 0.0341 (large)
Catch and release mortality 16% in summer and 3% in autumn	early season	0.16	0.16
	late season	0.03	0.03
	all season	0.144 (small) 0.137 (large)	0.116 (small) 0.108 (large)
Catch and release mortality 25% in summer and 4% in autumn	early season	0.25	0.25
	late season	0.04	0.04
	all season	0.179 (small) 0.167 (large)	0.224 (small) 0.212 (large)

Table 3. Summary of information to inform on effects of management measures (changes in annual retention limits; imposition of mandatory catch and release) in the Atlantic salmon recreational fisheries on license sales, fishing effort, proportion of small salmon released, and exploitation rate in rivers of New Brunswick (NB) and Nova Scotia (NS) portions of DFO Gulf Region from 1984 to 2019. NW = Northwest Miramichi River, SW = Southwest Miramichi River. Daily catch and release limits have remained at 4 salmon per day during 1984 to 2019.

Management measure	Province	License sales	Fishing effort	Proportion of small salmon released	Exploitation Rate (ER)
Reductions of small salmon retention limit	NB	Stable from 1996 to 2014	Minor change in effort (available data: 1984 to 1995 and 1997)	Unknown	NW: stable exploitation of small and large vs effort SW: stable exploitation rate of small salmon but declining trend of exploitation rate of large salmon vs effort
	NB (Crown Reserve)	NA	Effort declined in 2010, 2 years prior to introduction of daily retention limit of 0	Increasing trend of small salmon released with reductions in daily retention limits; proportion released was 100% from 2012 to 2019 with only catch and release	Higher in recent years (> 2005) for both size groups; Small salmon: ER did not significantly increase with effort; Large salmon: ER significantly increased with effort
	NS	Declining trend over time not linked to the retention limit	Declining trend over time not linked to the retention limit	Declining trend over time linked to the retention limit	For Margaree River, assessment model implicitly uses effort to estimate exploitation rate
Introduction of mandatory catch and release for all size groups in 2015	NB	License sales declined by almost half in 2015	NA	100%	Unknown
	NS	Initial decline in license sales (-9% from 2014 to 2015) followed by an increase to an average of 2,100 licences sold per year from 2016 to 2019	A reduction in total estimated effort; Estimated effort was lower than would have been expected based on licence sales	Increased to reach 100% in recent years	Unknown

Table 4. Summaries of risks of the estimated abundances after fishing being below the LRP with > 5% probability and > 50% probability by Harvest Decision Rule for the Northwest Miramichi River (NW) and the Southwest Miramichi River (SW) under three assumed catch and release mortality rate scenarios. The summary is compiled from Figures 12 to 14.

Assumed catch and release mortality rate	Condition	Number of occurrences (1984 to 2019)			
		NW		SW	
		Rule 1	Rule 2	Rule 1	Rule 2
Low (~3%) (Figure 12)	Pre-fishery forecast below LRP with <= 5% prob	20	20	21	21
	Post-fishery estimate below LRP with > 5% prob	8	5	0	0
	Pre-fishery forecast below LRP with <= 50% prob	32	32	34	34
	Post-fishery estimate below LRP with > 50% prob	0	0	0	0
High (7% - 33% summer) (1% - 3% autumn) (Figure 13)	Pre-fishery forecast below LRP with <= 5% prob	20	20	21	21
	Post-fishery estimate below LRP with > 5% prob	8	8	2	0
	Pre-fishery forecast below LRP with <= 50% prob	32	32	34	34
	Post-fishery estimate below LRP with > 50% prob	1	1	1	1
Highest (19% - 32% summer) (2% to 4% autumn) (Figure 14)	Pre-fishery forecast below LRP with <= 5% prob	20	20	21	21
	Post-fishery estimate below LRP with > 5% prob	8	8	3	2
	Pre-fishery forecast below LRP with <= 50% prob	32	32	34	34
	Post-fishery estimate below LRP with > 50% prob	2	2	1	1

Table 5. Summaries of characteristics of harvest strategies and an assessment of conformity of the candidate harvest decision rules to the PA policy (DFO 2009) and stock rebuilding guidance (DFO 2019b, 2021a, 2021b).

Characteristic	Compliance to the PA
Three status zones are defined	**Comply**
Maximum removal rate defined	**Comply**
Maximum anticipated removal rate in the healthy zone is less than the maximum removal rate reference	**Comply**
	Estimated at 4% to 14% dependent on river and catch and release mortality assumptions relative to a maximum removal rate of 60% (proposed) for all fisheries (Indigenous and recreational).
Defined operational control points to reduce the risk of LRP breach	**Comply**
	Retention of small salmon prohibited when abundance < 120% of LRP.
Other measures to reduce incidental losses due to fishing	**Comply**
	Warmwater protocols that close access to cold water pools or limits fishing to particular times of the day are intended to reduce catch and release mortalities, but the fishery is never entirely closed.
Management measures reduce rate of loss as abundance declines from healthy through cautious towards critical zone	**Partial compliance**
	Comply
	Step decline in the cautious zone as abundance declines.
	Does not comply
	Loss rate in much of the cautious zone is the same as in the healthy zone.
	Maximum anticipated removal rate occurs in the lower portion of the cautious zone.
Do operational control points effectively reduce the risk of falling below the LRP given uncertainties?	**Does not comply**
	Dependent upon assumed catch and release mortality rates.
	Abundance after fishing falls below LRP with > 5% probability in 8 of 20 events, one LRP breach in 32 events for NW Miramichi.
In the Critical zone, actions must promote stock growth, removals must be kept to the lowest possible level, and no tolerance for preventable decline	**Subject to interpretation**
	Directed fishery closed only if abundance < 25% of LRP (rule 1) or < 15% of LRP (rule 2).

Characteristic	Compliance to the PA
	Losses from the directed fishery in the critical zone of 1% to 7% are expected based on catch and release mortality assumptions.
	Losses of that quantity do not promote stock growth, unless total losses (directed salmon fishery losses plus illegal fishery losses) are much less than losses (from illegal activities) in absence of the directed catch and release fishery.

FIGURES

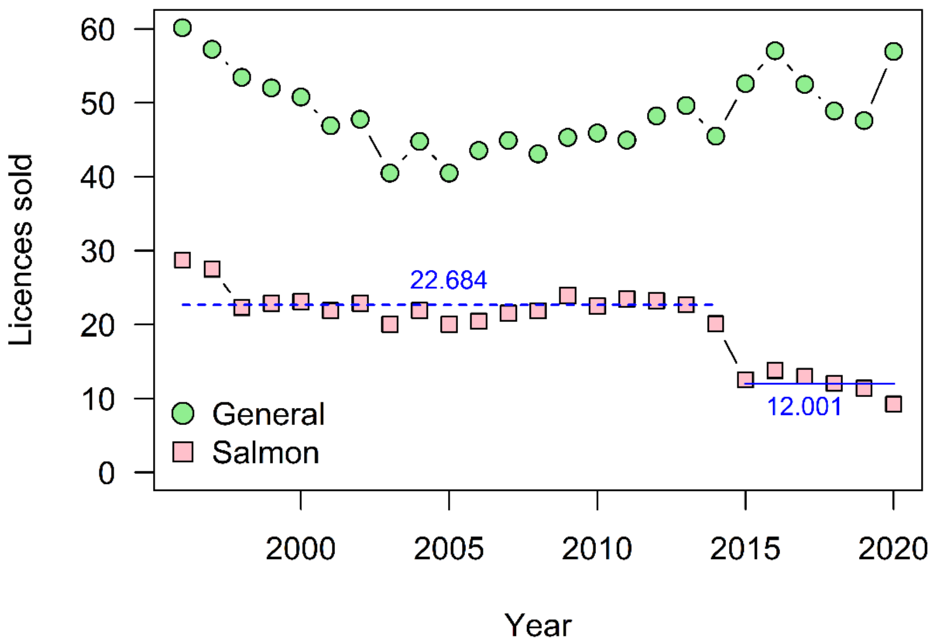

Figure 1. Annual recreational fisheries licence sales in New Brunswick, 1996 to 2020, by type of licence (general, salmon). The horizontal lines and the label show the mean number of salmon licence sales for the period where retention of small salmon was allowed (pre-2015) and when mandatory catch and release of all salmon was imposed (2015-2020). The licence sale data were provided by C. Connell (NB Dept. of Natural Resources and Energy Development).

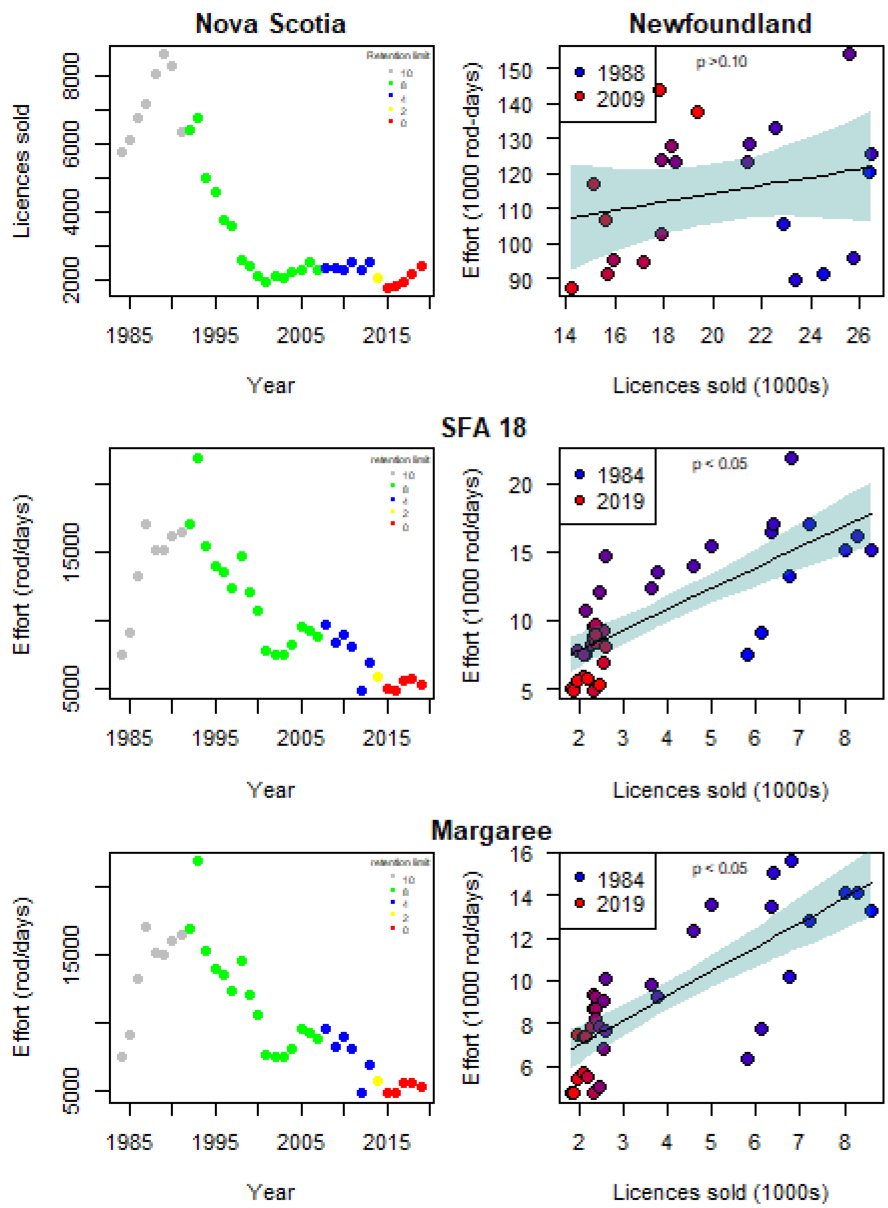

Figure 2. Recreational Atlantic Salmon fishing licences sold in NS with coloured symbols indicating season retention limits for small salmon, 1984 to 2020 (upper left panel), association between annual number of Atlantic Salmon recreational fishing licences sold and estimated total rod-days of effort in the province of Newfoundland (1988 to 2009; upper right panel), estimated annual effort (rod-days; middle and bottom row left panels) and associations between number of licences issued and estimated total effort (middle and bottom row right panels) in NS Salmon Fishing Area 18 (middle row) and the Margaree River (bottom row) for the years 1984 to 2019. The figure for Newfoundland is drawn from data presented in Table 2 of Bourgeois and Veinott (2012). The mean predicted line, the 95% confidence intervals of the predicted effort (shaded polygon), and the p-value of the linear regression are shown in the panels on the right.

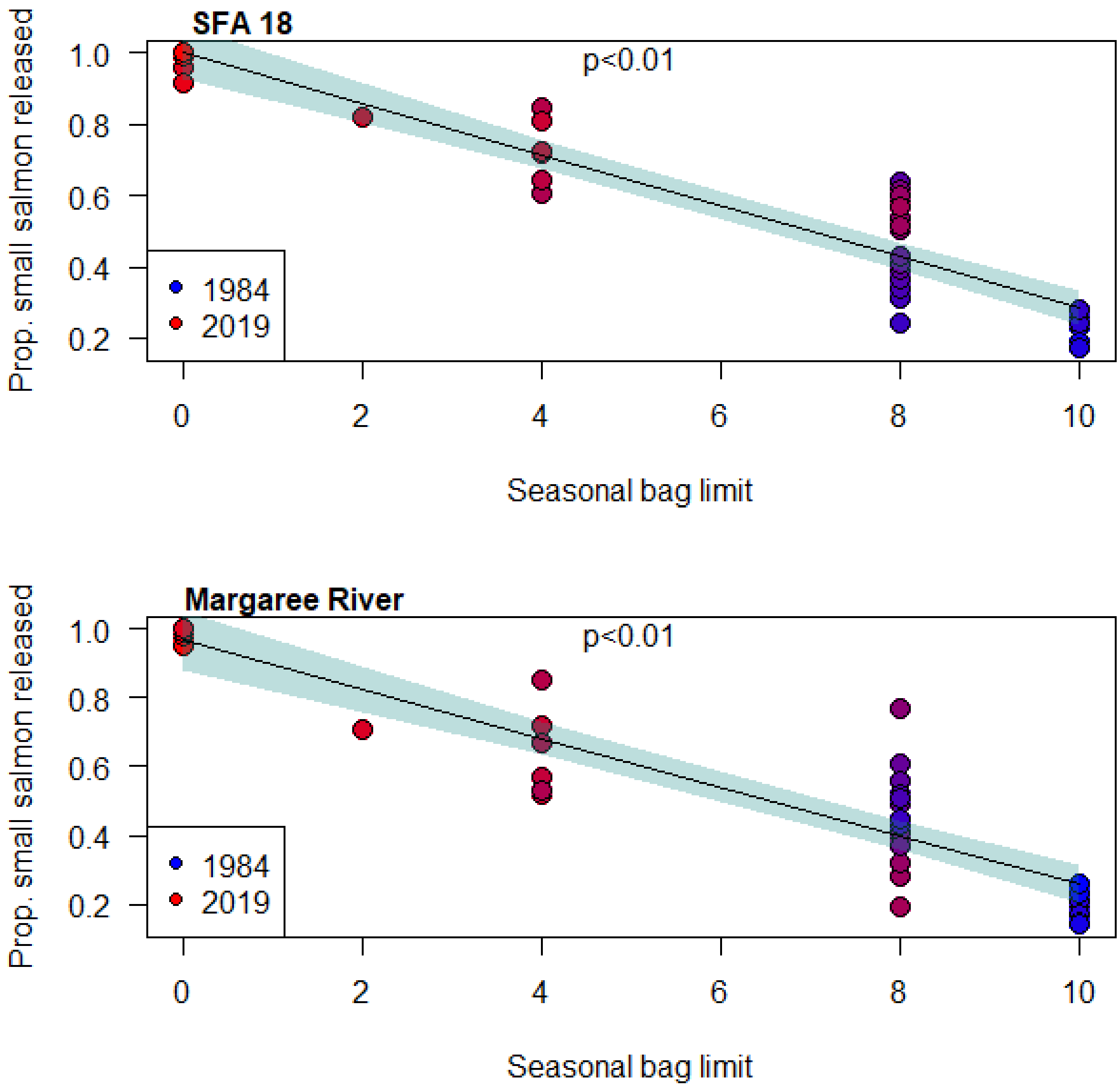

Figure 3. The estimated proportion of small salmon released in the Atlantic Salmon recreational fisheries for SFA 18 (upper panel) and the Margaree River (lower panel) obtained from license stubs returns.

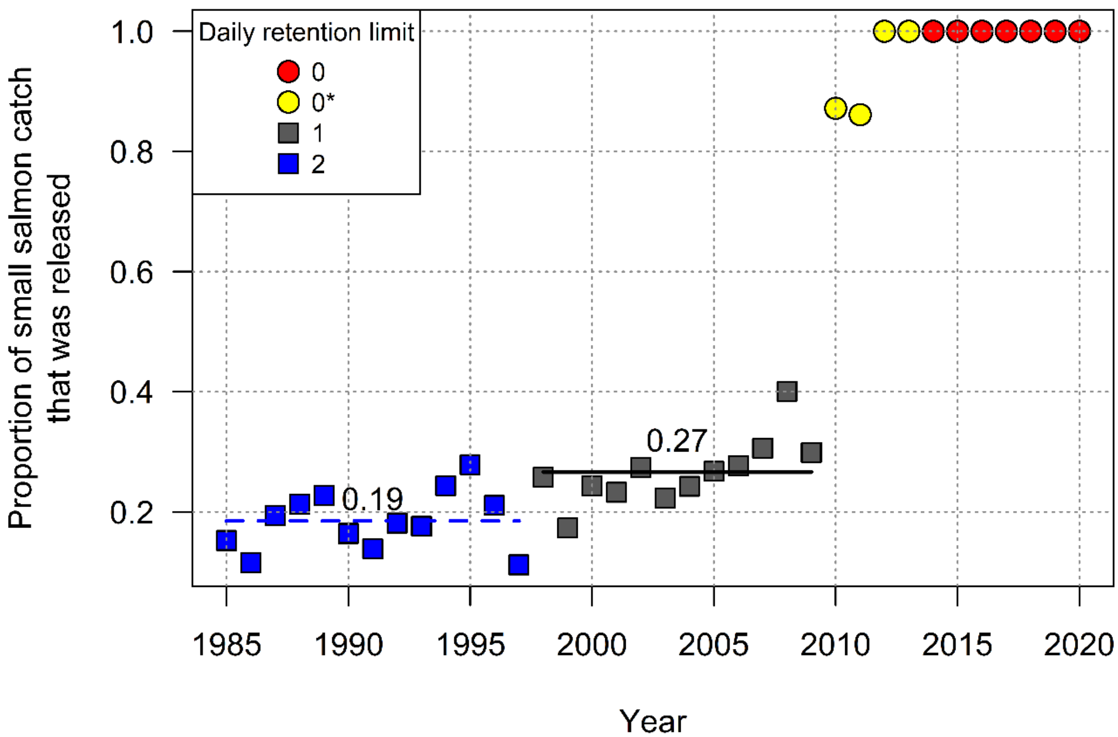

Figure 4. The estimated proportion of the small salmon catch which was released in the Atlantic Salmon recreational fisheries of the Crown Reserve Waters of the Miramichi (NB). The symbols referring to '0' are the years when retention was initially allowed but mandatory release was introduced early in the season, usually in June. The mean proportion released for the two periods corresponding to daily retention limits of one fish or two fish are shown as horizontal lines and labels in the panel. The data were extracted from annual summary reports provided by R. MacEachern, NB Dept. of Natural Resources and Energy Development.*

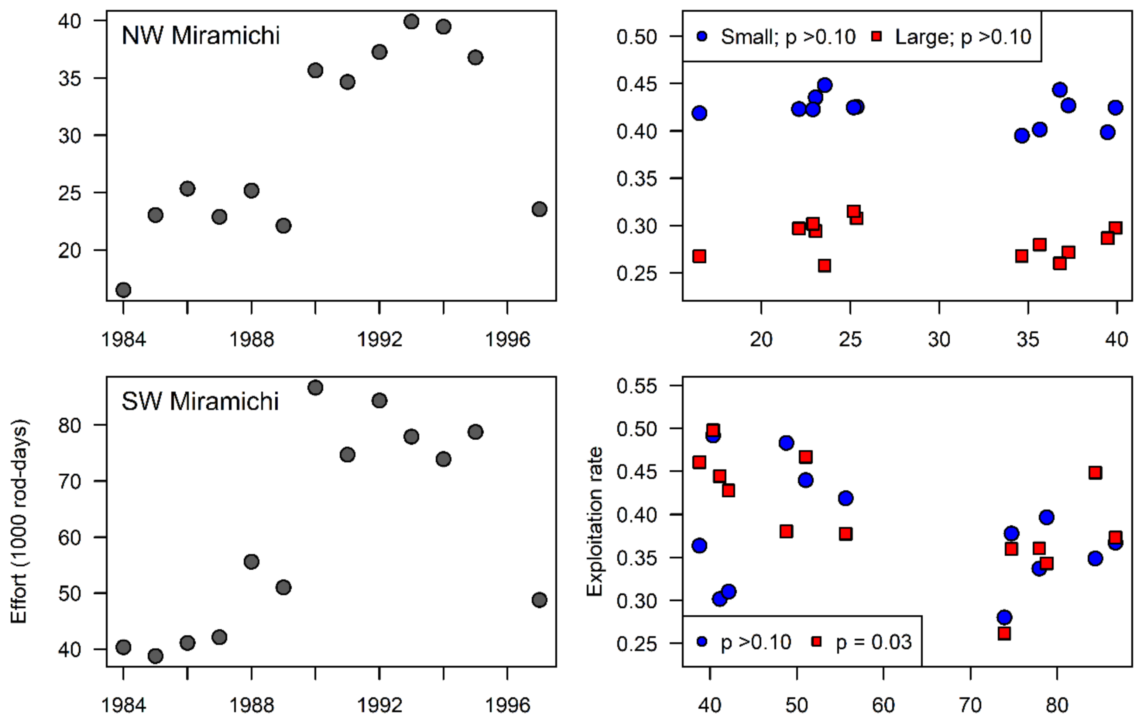

Figure 5. Available time series of estimated total effort (1000 rod-days; left column) and the association between effort and estimated exploitation rate of small salmon and large salmon (right column) for the Northwest Miramichi River (top row) and the Southwest Miramichi River (bottom row). The p values for small salmon and large salmon of a linear regression of exploitation rate on effort are shown in the legend of the panels of the right column.

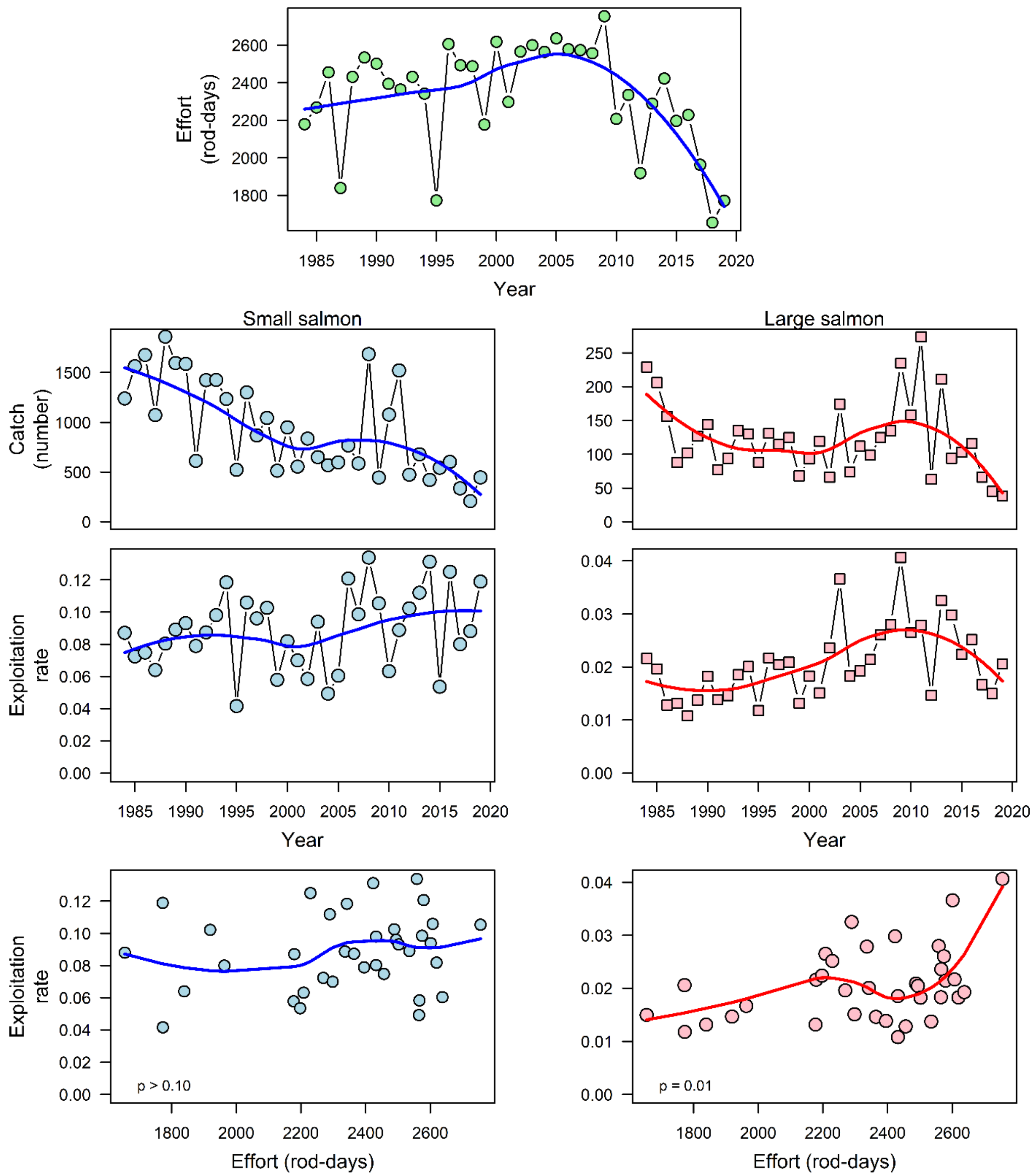

Figure 6. Available time series of estimated total effort (rod-days; top row), catches (second row), exploitation rate (third row) and association between exploitation rate and effort (bottom row) for small salmon (left column) and large salmon (right column) from the Crown Reserve Waters of the Northwest Miramichi River. The p values of a linear regression of exploitation rate on effort for small salmon and large salmon are shown in the panels of the bottom row. The smoothed line in each panel is a LOESS regression with a span setting of 0.8.

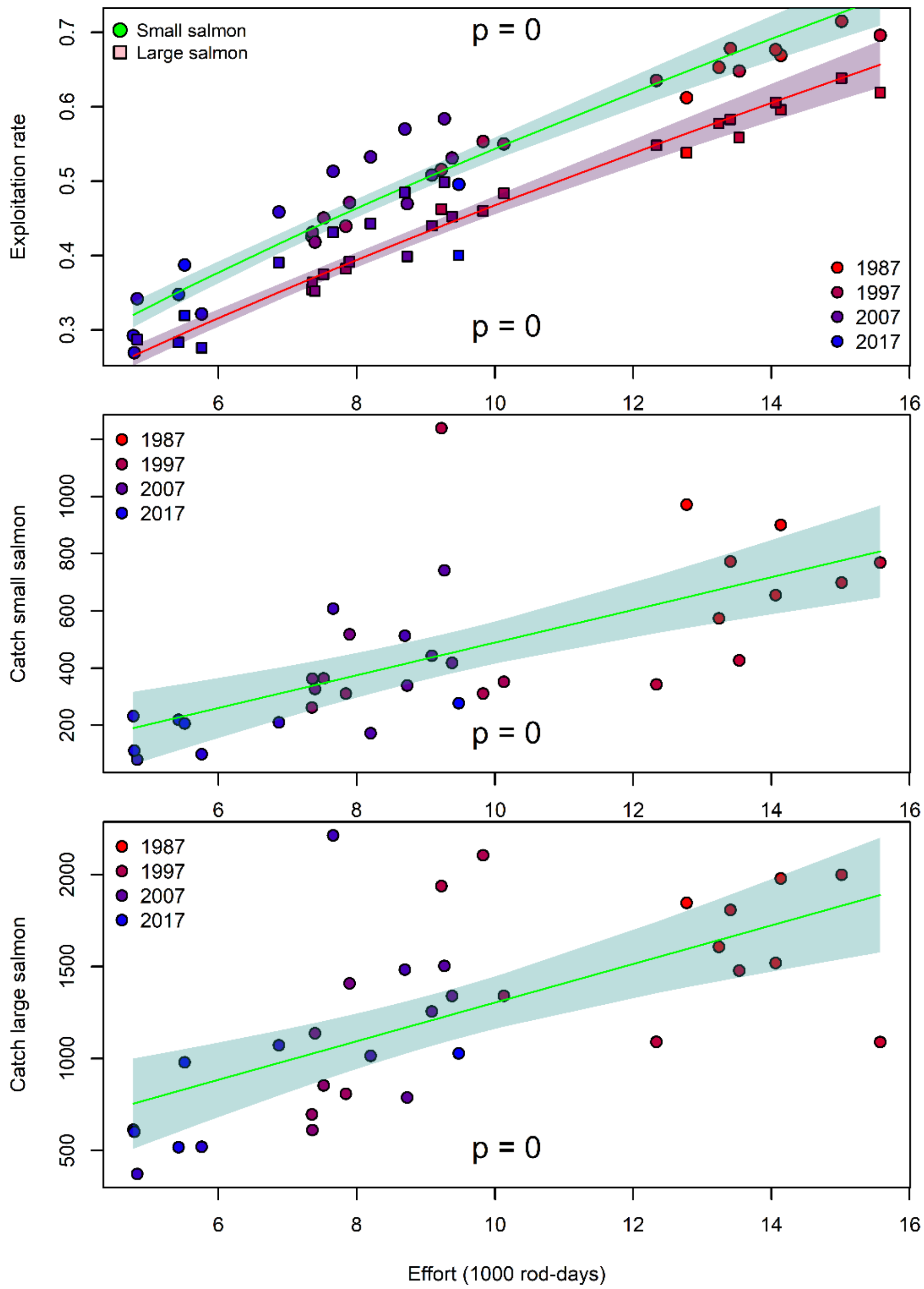

Figure 7. Association between the model derived annual exploitation rate (catch / return) of small salmon and large salmon and the estimated annual effort in the Atlantic Salmon recreational fishery of the Margaree River, 1987 to 2019 (top panel) and associations between catch of small salmon (middle panel) and catch of large salmon (bottom panel) to effort.

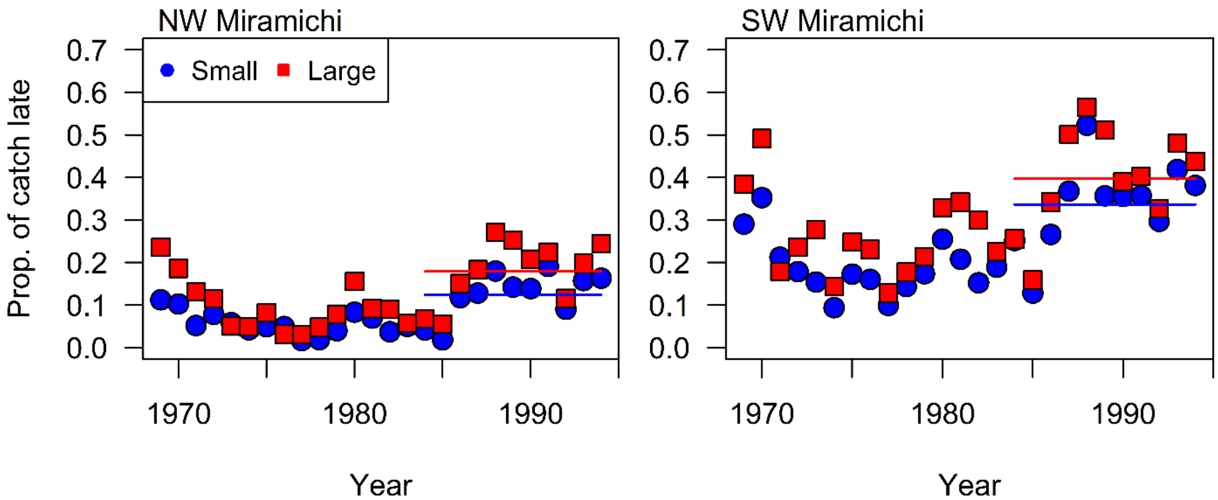

Figure 8. The proportion in the late season (Sept. and Oct.) of the estimated annual angling catch of small salmon and large salmon from the Northwest Miramichi River (left panel) and the Southwest Miramichi River (right panel). The horizontal lines in each panel are the mean proportions of small salmon and large salmon catches that occur in the late season for the years 1984 to 1994. The data are from Moore et al. (1995).

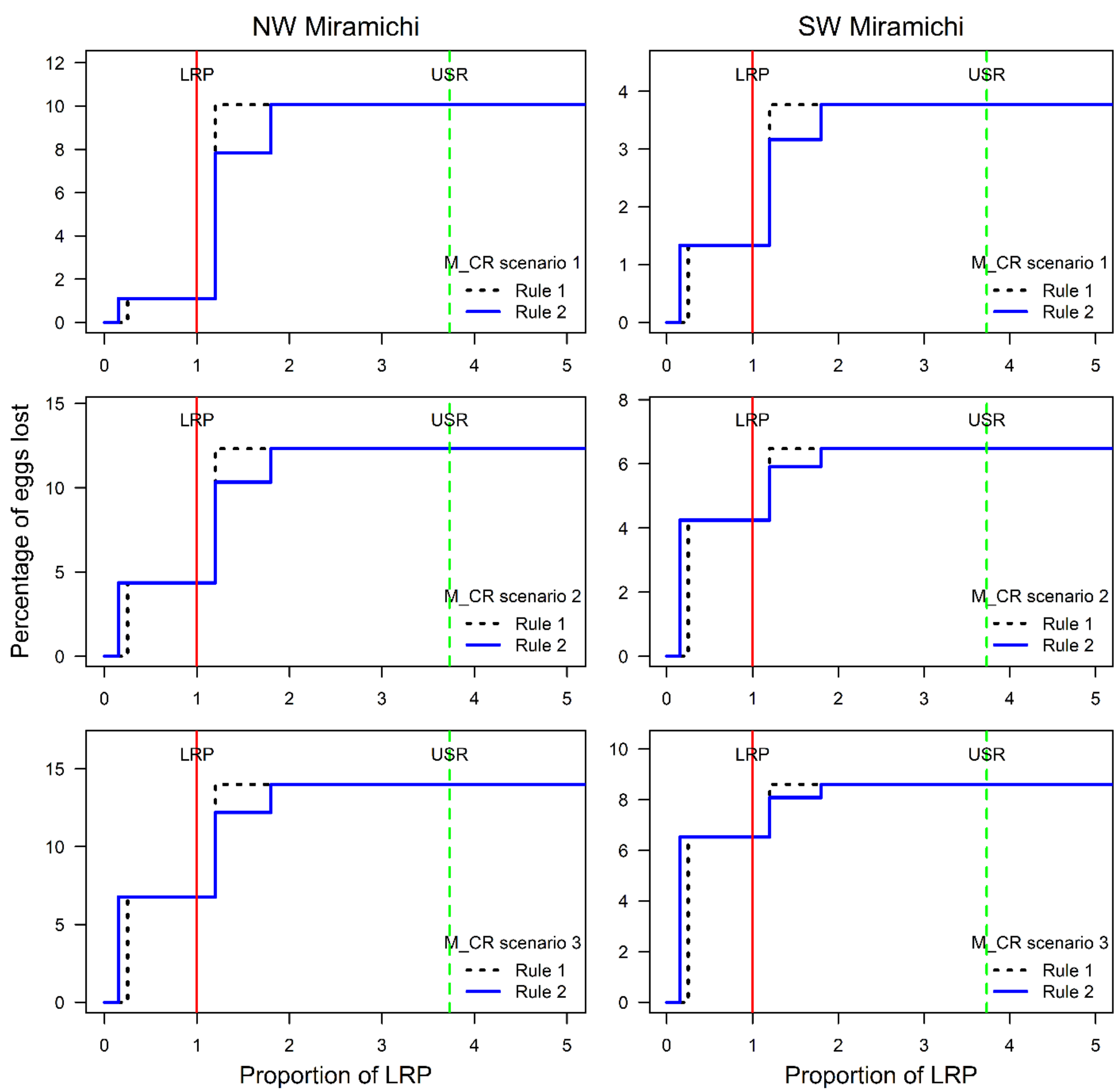

Figure 9. Preseason decision rule profiles relative to prefishery stock status (proportion of LRP) of the percentage of total eggs lost due to recreational fishing based on average and deterministic values of biological and fisheries characteristics (Table 2) of the Northwest Miramichi River (left column) and the Southwest Miramichi River (right column) for three assumed catch and release mortality scenarios. The annual catch and release mortality scenarios are: ~3% (top row), 14% (middle row) and 18% (bottom row).

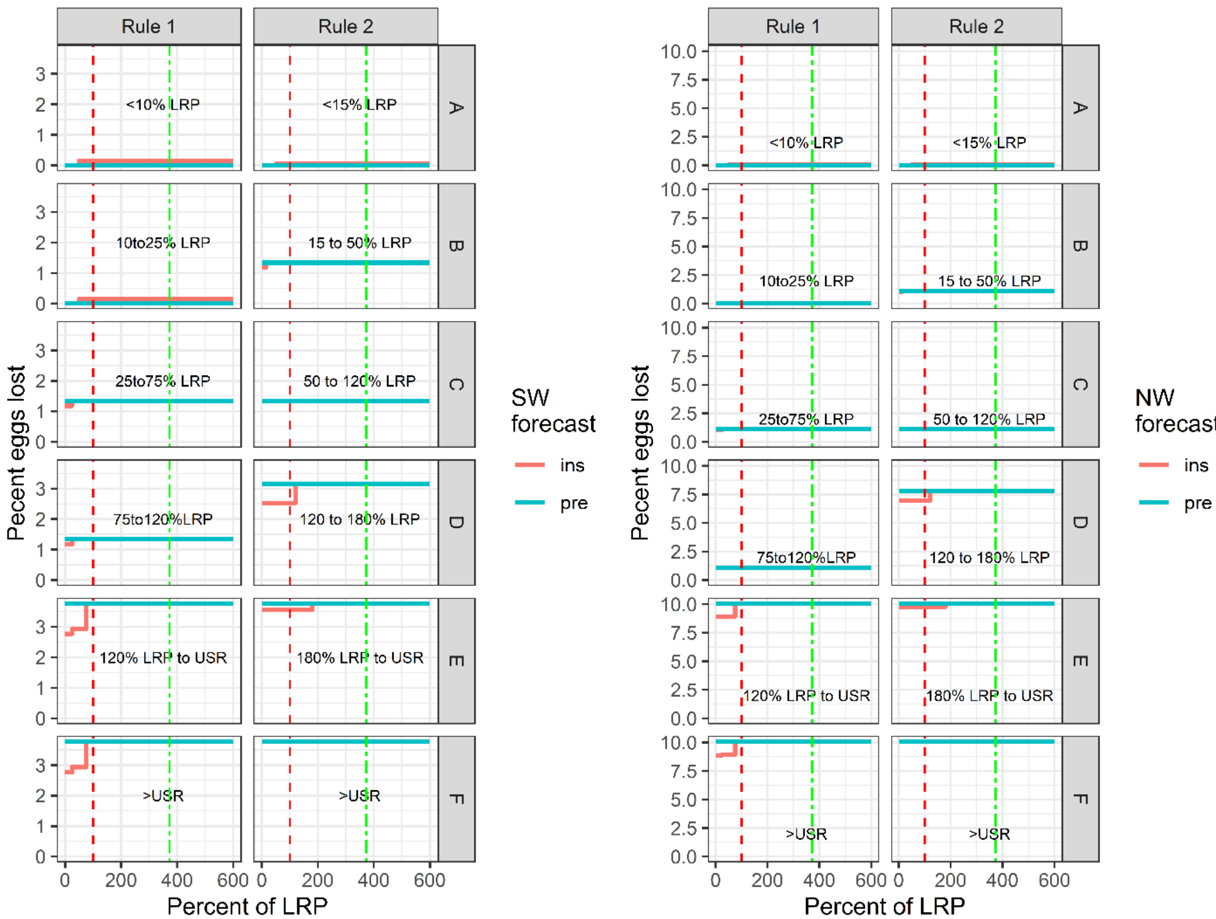

*Figure 10a. Contrast in the percentage of eggs lost for the preseason rule (blue horizontal line in each panel) and if the inseason adjustment (orange line in each panel) is applied for the six status categories of rules 1 and 2, for the Southwest Miramichi River (left panel) and the Northwest Miramichi River (right panel) for an assumed catch and release mortality of 3% for the year. The dashed vertical red line is the LRP (100%) and the dot-dashed vertical green line is the USR (3.73 * LRP).*

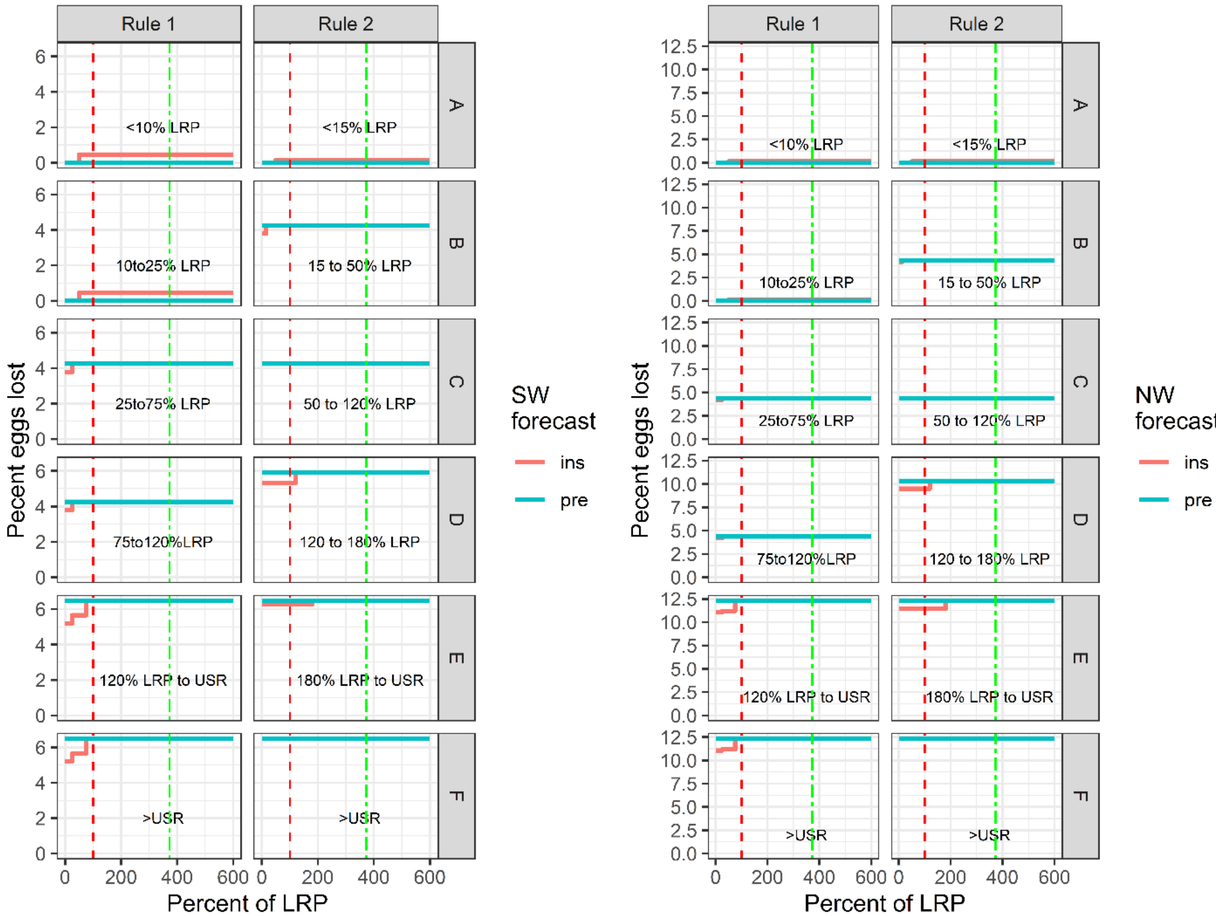

*Figure 10b. Contrast in the percentage of eggs lost for the preseason rule (blue horizontal line in each panel) and if the inseason adjustment (orange line in each panel) is applied for the six status categories of rules 1 and 2, for the Southwest Miramichi River (left panel) and the Northwest Miramichi River (right panel) for an assumed catch and release mortality of 16% for the summer and 3% for the autumn seasons. The dashed vertical red line is the LRP (100%) and the dot-dashed vertical green line is the USR (3.73 * LRP).*

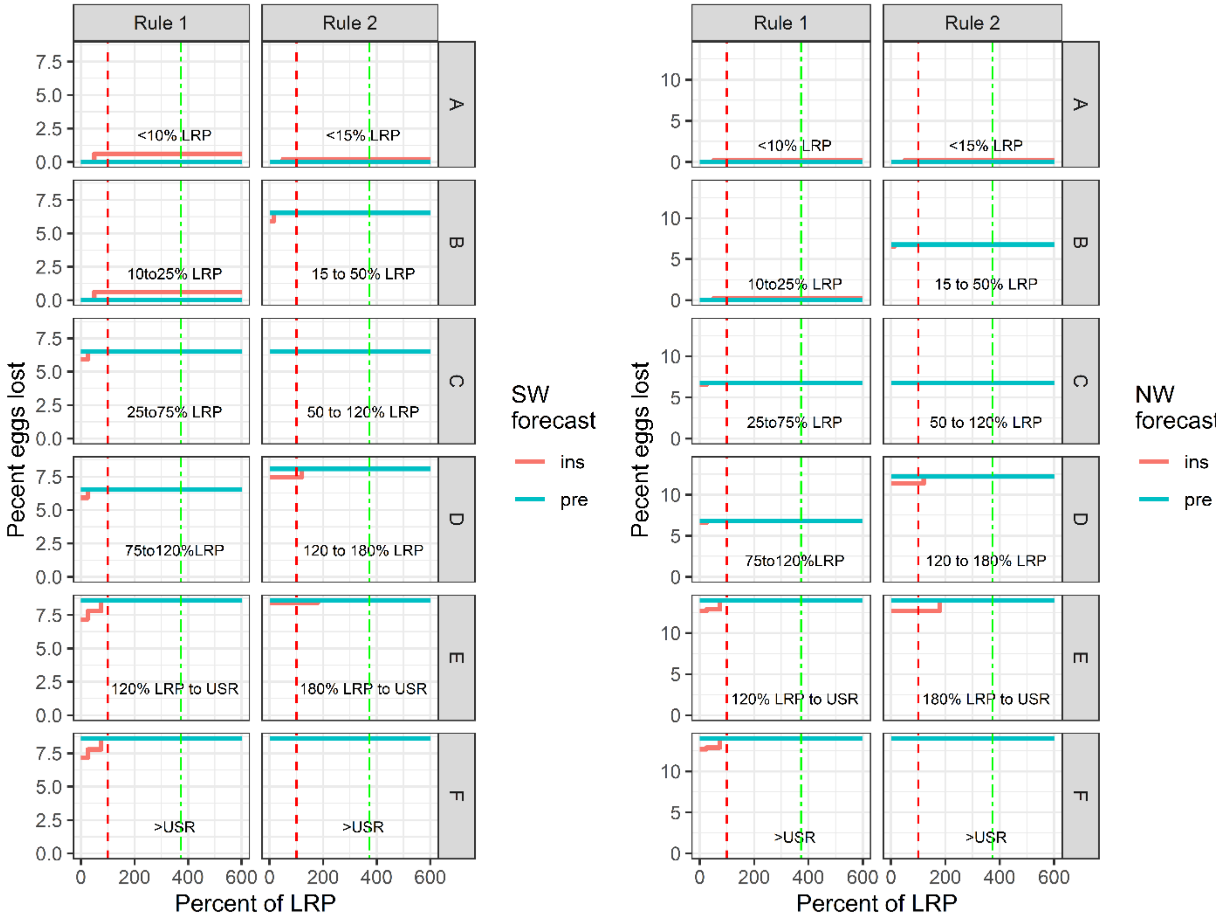

*Figure 10c. Contrast in the percentage of eggs lost for the preseason rule (blue horizontal line in each panel) and if the inseason adjustment (orange line in each panel) is applied for the six status categories of rules 1 and 2, for the Southwest Miramichi River (left panel) and the Northwest Miramichi River (right panel) for an assumed catch and release mortality of 25% for the summer and 4% for the autumn seasons. The dashed vertical red line is the LRP (100%) and the dot-dashed vertical green line is the USR (3.73 * LRP).*

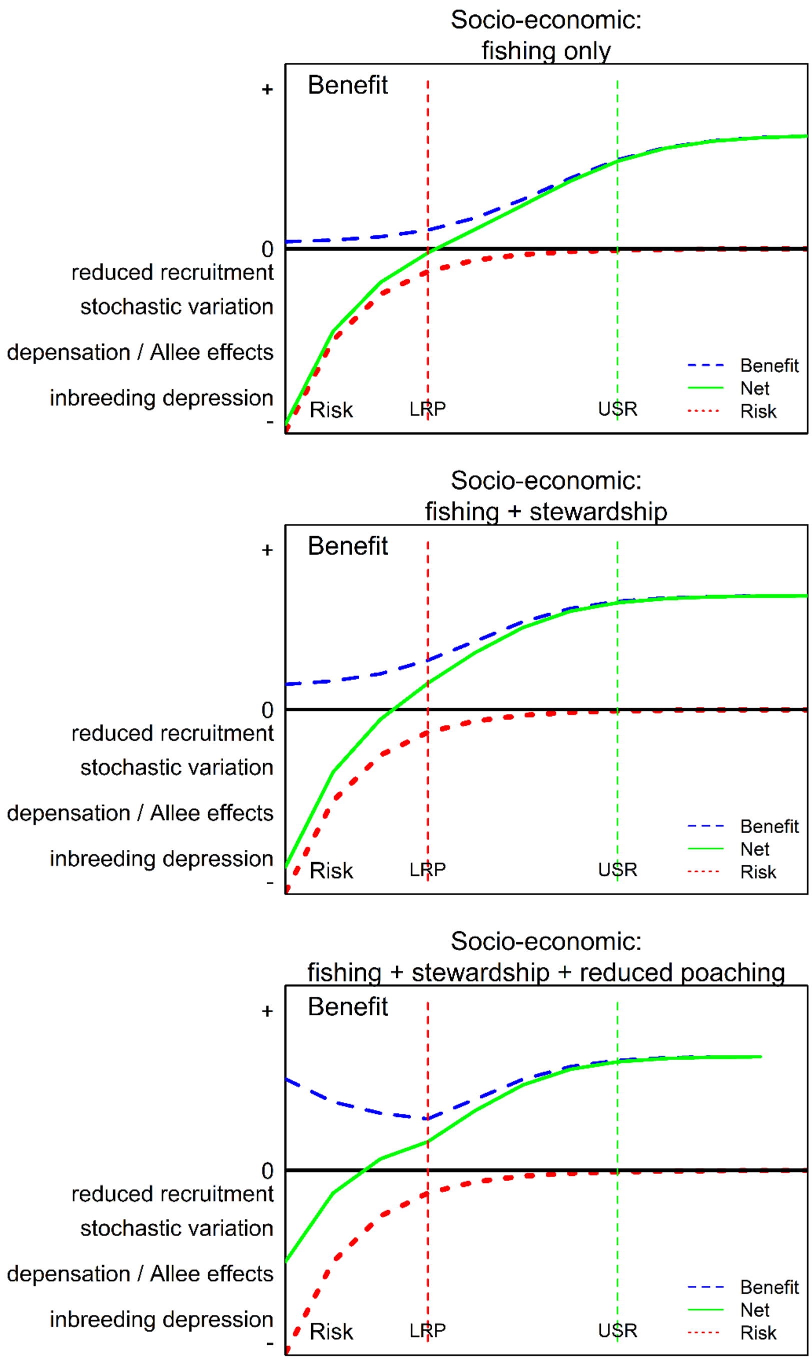

Figure 11. Hypothetical example to visualize the risk (negative scale) to salmon conservation (population level for the river) and the benefits (positive scale) extracted from the resource by keeping directed recreational fisheries open when the stock is in the critical zone. The sum of the benefits and risks (Net) relative to salmon abundance (x-axis) represents the net risk to conservation of the directed fishing activity. The hypothetical risk, benefit, and net profiles are shown for conditions of fishing only (top row), fishing and stewardship engagement of anglers (middle row), and the combined benefits from fishing, stewardship and reduced losses from poaching because of angler presence (bottom row).

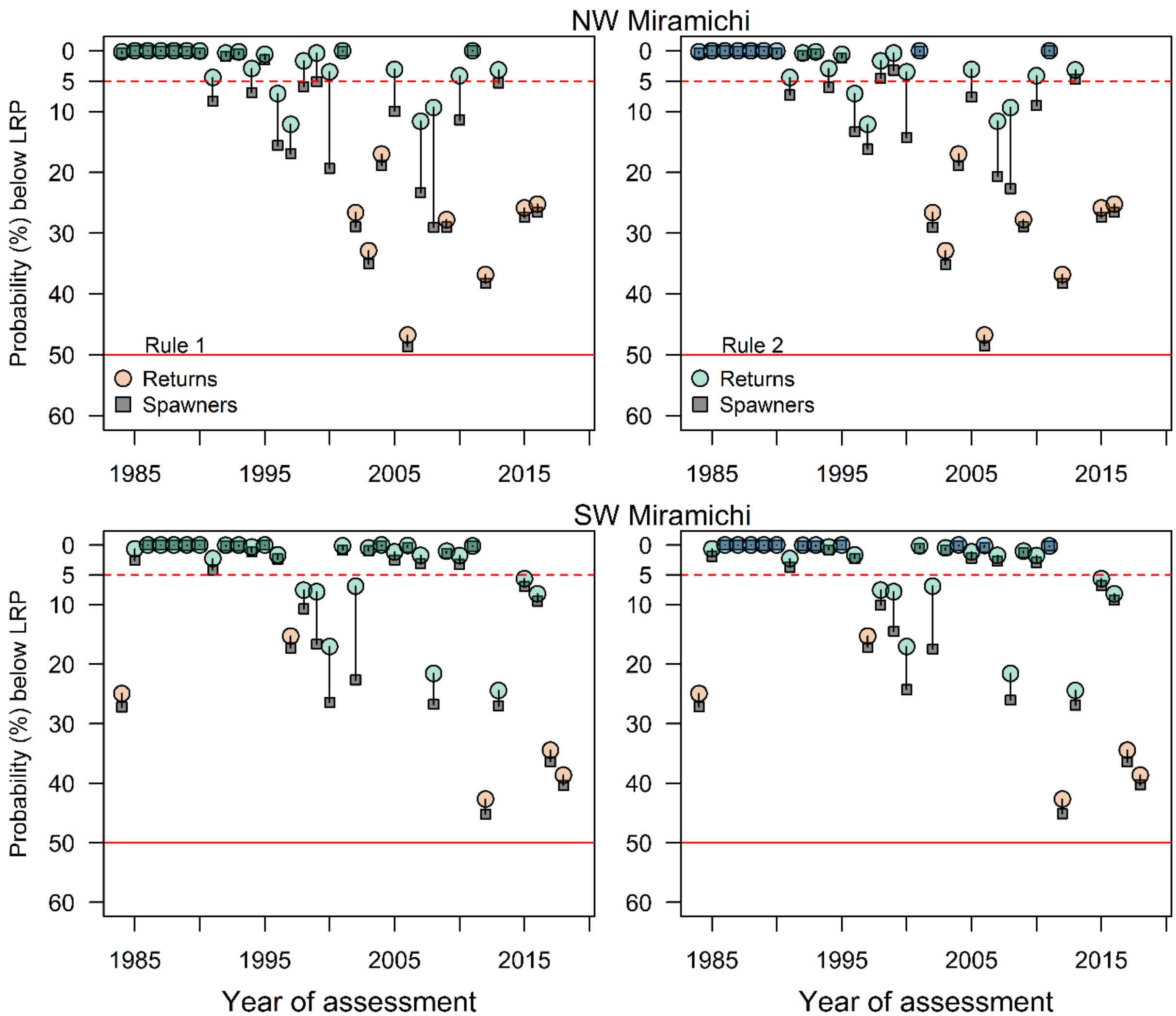

Figure 12. The performance of the harvest decision rules illustrated as the probability of the total eggs in returns and the total eggs in spawners after the recreational fishery being below the LRP by decision rule (columns) and for the Northwest Miramichi River (top row) and the Southwest Miramichi River (bottom row) with catch and release mortality rates of 3% for the season based on Randall et al (1986). The horizontal red lines in the panels highlight the 5% probability (dashed)and the 50% probability (solid; LRP breach) of the returns or spawners being below the LRP. The years when the probability of the eggs in returns being below the LRP exceed 60% are offscale.

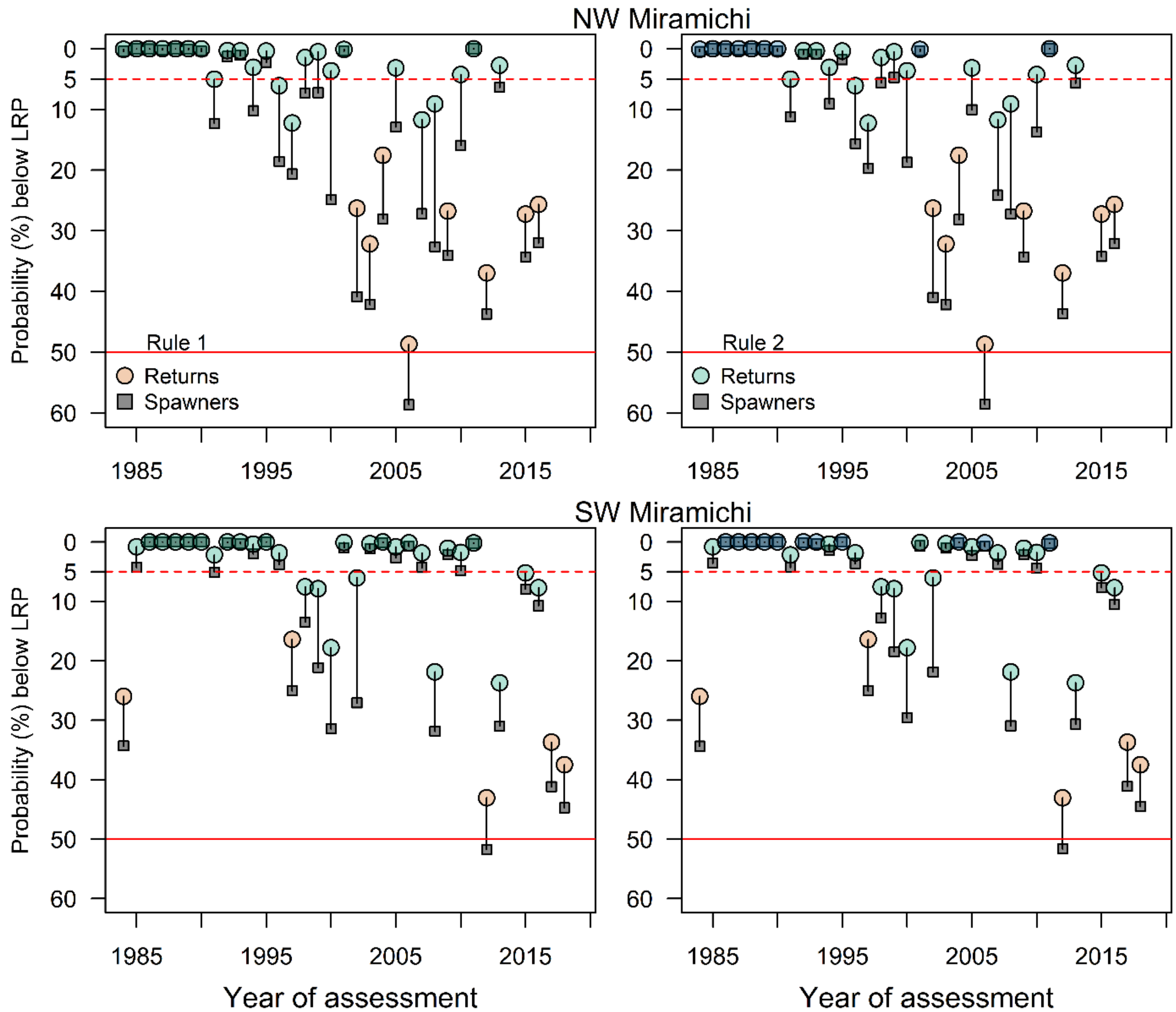

Figure 13. The performance of the harvest decision rule illustrated as the probability of the total eggs in returns and the total eggs in spawners after the recreational fishery being below the LRP by decision rule (columns) for the Northwest Miramichi River (top row) and the Southwest Miramichi River (bottom row) with catch and release mortality rates of 16% (7% to 33%) in the summer, and 3% (1% to 5%) in the autumn. The horizontal red lines in the panels highlight the 5% probability (dashed)and the 50% probability (solid; LRP breach) of the returns or spawners being below the LRP. The years when the probability of the eggs in returns being below the LRP exceed 60% are offscale.

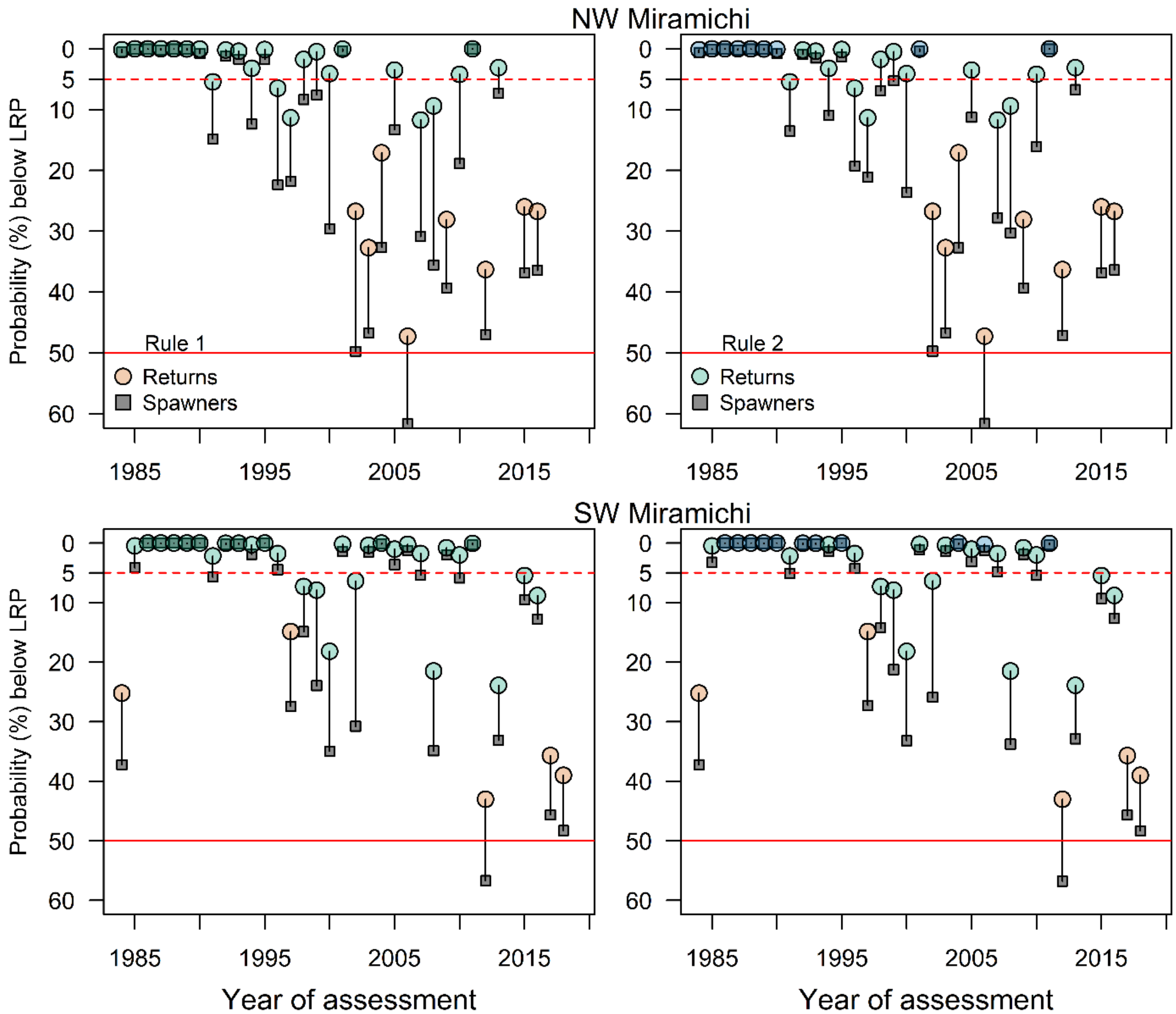

Figure 14. The performance of the harvest decision rule illustrated as the probability of the total eggs in returns and the total eggs in spawners after the recreational fishery being below the LRP by decision rule (columns) and for the Northwest Miramichi River (top row) and the Southwest Miramichi River (bottom row) with catch and release mortality rates of 25% (95% C.I. 19% to 32%) in the summer, and 4% (2% to 6%) in the autumn. The horizontal red lines in the panels highlight the 5% probability (dashed) and the 50% probability (solid; LRP breach) of the returns or spawners being below the LRP. The years when the probability of the eggs in returns being below the LRP exceed 60% are offscale.

APPENDICES

APPENDIX 1. DECISION RULE TABLE FOR THE MIRAMICHI ATLANTIC SALMON RECREATIONAL FISHERY, VERSION 1

Table A1. Decision rule table, version 1 (December 4, 2020), for the Miramichi Atlantic Salmon recreational fishery AFTER Indigenous Peoples fisheries.

<table>
<tr><th>Predicted abundance</th><th>PA status zone</th><th colspan="3">Beginning of Season Decision / Inseason Trigger and Decision</th></tr>
<tr><td rowspan="4">< 10% of LRP*
Expected Total Run at < 10% LRP
NW (< 744 small, < 383 large)
SW (< 1,036 small, < 848 large)
Expected Early run (to July 31)
NW (< 484 small, < 211 large)
SW (< 560 small, < 305 large)</td><td rowspan="4">Critical zone</td><td colspan="3">- Closure of directed recreational fisheries for Atlantic salmon (see inseason review)
- Closure of salmon pools (warmwater protocol list) to fisheries for all species June 1st [or closure of river sections, to be discussed]
- “River Under Recovery” status[1]
- Barbless hooks in all inland waters for other recreational fisheries (e.g., trout, striped bass)</td></tr>
<tr><td>Inseason review</td><td>Trigger</td><td>Inseason adjustments based on updated forecast of total abundance</td></tr>
<tr><td rowspan="2">July 31</td><td><= 50% of LRP</td><td>- Status quo (preseason management measures retained)</td></tr>
<tr><td>Over 50% of LRP</td><td>- Catch and release fishery in Fall (sept 1) . 1 per day. Pools open
Note: when the preseason predicted abundance is low, an inseason update suggesting a much larger return than anticipated is required before directed salmon fishing is considered, in order to provide a rebuilding opportunity</td></tr>
<tr><td rowspan="3">>= 10% to 25% of LRP
Expected Total Run at 25% LRP
NW (< 1,861 small, < 959 large)
SW (< 2,590 small, < 2,119</td><td rowspan="3">Critical zone</td><td colspan="3">- Spring salmon season (max. catch and release of 2 fish/day) April 15 to May 15
- Closure of directed recreational fisheries for Atlantic salmon after May 15 (see inseason review)
- Closure of salmon pools (warmwater protocol list) to fisheries for all species June 1st [or closure of river sections, to be discussed]
- “River Under Recovery” status[1]
- Barbless hooks in all inland waters for other recreational fisheries (e.g., trout, striped bass)</td></tr>
<tr><td>Inseason review</td><td>Trigger</td><td>Inseason adjustments based on updated forecast of total abundance</td></tr>
<tr><td>July 31</td><td>Up to to <u>50%</u> of LRP</td><td>Status quo (preseason management measures retained)</td></tr>
</table>

<table>
<tr><th>Predicted abundance</th><th>PA status zone</th><th colspan="3">Beginning of Season Decision / Inseason Trigger and Decision</th></tr>
<tr><td rowspan="1">large)
Expected Early run (to July 31)
NW (< 1,210 small, < 527 large)
SW (< 1,399 small, < 763 large)</td><td></td><td></td><td>Over 50% of LRP</td><td>Catch and release fishery in Fall (Sept 1), max 1 fish per day.
Note: when the preseason predicted abundance is this low, an inseason update suggesting a much larger return than anticipated is required before directed salmon fishing is considered, in order to provide a rebuilding opportunity</td></tr>
<tr><td rowspan="4">> 25% to 75% of LRP
Expected Total Run at 110% LRP
NW (< 8,188 small, < 4,218 large)
SW (< 11,398 small, < 9,326 large)
Expected Early run (to July 31)
NW (< 5,322 small, < 2,320 large)
SW (< 6,155 small, < 3,357 large)</td><td rowspan="4">Critical zone/low Cautious zone</td><td colspan="3">- Spring salmon season (max. catch and release of 5 fish/day) April 15 to May 15
- Bright salmon season (max. catch and release of 2 fish/day) in entire river opens May 16(see inseason review)
- No grilse retention
- Warm water protocol in place to minimize impacts during warm water periods (currently in place and functioning well)
- Barbless hooks</td></tr>
<tr><td>Inseason review</td><td>Trigger</td><td>Inseason adjustments based on updated forecast of total abundance</td></tr>
<tr><td rowspan="2">July 31</td><td>< 25% of LRP</td><td>- Cancel catch and release fishery (September 1)- Closure of salmon pools (warmwater protocol list) to fisheries for all species Sept 1 [or closure of river sections, to be discussed]</td></tr>
<tr><td>Greater than 25% of LRP</td><td>- Status quo (preseason management measures retained)</td></tr>
<tr><td rowspan="4">> 75% to 120% of LRP
Expected Total Run at 110% LRP
NW (< 8,188 small, < 4,218 large)
SW (< 11,398 small, < 9,326 large)
Early run (to</td><td rowspan="4">Critical zone/low Cautious zone</td><td colspan="3">- Spring salmon season (max. catch and release of 10 fish/day) April 15 to May 15
- Bright salmon season (max. catch and release of 4 fish/day) in entire river opens May 16 (see inseason review)
- No grilse retention
- Warm water protocol in place to minimize impacts during warm water periods (currently in place and functioning well)
- Barbless hooks</td></tr>
<tr><td>Inseason review</td><td>Trigger</td><td>Inseason adjustments based on updated forecast of total abundance</td></tr>
<tr><td rowspan="2">July 31</td><td>< 25% of LRP</td><td>- Cancel the directed salmon fishery in the fall (Sept 1)
Closure of salmon pools (warmwater protocol list) to fisheries for all species Sept 1 [or closure of river sections, to be discussed]</td></tr>
<tr><td>25 to 75% of LRP</td><td>- Catch and release fishery reduced to max. of 2 fish per day (Sept 1)</td></tr>
</table>

Predicted abundance	PA status zone	Inseason review	Trigger	Beginning of Season Decision / Inseason Trigger and Decision
July 31) NW (< 5,322 small, < 2,320 large) SW (< 6,155 small, < 3,357 large)			**Greater than 75%**	- Preseason management measures retained (eg 4 fish per day);
> 120% of LRP to USR (TBD) Expected Total Run at 200% LRP NW (< 14,887 small, < 7,669 large) SW (< 20,724 small, < 16,956 large) **Early run (to July 31)** NW (< 9,676 small, < 4,218 large) SW (< 11,191 small, < 6,104 large)	Cautious zone			- Grilse retention fishery (kelts or brights). Total tag allocation, number and mechanism TBD[2] - Spring salmon season (max. catch and release of 10 fish/day) and retention of small salmon with tag, April 15 to May 15 - Bright salmon season (max. catch and release of 4 fish/day) in entire river opens May 16 (see inseason review) - Warm water protocol in place to minimize impacts during warm water periods (currently in place and functioning well) - Barbless hooks
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		July 31	**< 25% of LRP**	- Cancel the directed salmon fishery in the fall (Sept 1) Closure of salmon pools (warmwater protocol list) to fisheries for all species Sept 1 [or closure of river sections, to be discussed]
			25 to 75% of LRP	- Cancel the retention fishery; Catch and release fishery reduced to max of 2 fish per day (Sept 1)
			Greater than 75%	- Preseason management measures retained
Above USR (TBD) *(USR is yet to be defined, assumes USR >= 200%LRP)*	High cautious zone / low healthy zone			- Grilse retention fishery (kelts or brights) . Total tag allocation, number and mechanism TBD[2] - Spring salmon season (max. catch and release of 25 fish/day) April 15 to May 15 - Bright salmon season (max. catch and release of 4 (or 6?) fish/day) in entire river opens May 16 (see inseason review) - Warm water protocol in place to minimize impacts during warm water periods (currently in place and functioning well) - Barbless hooks
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		July 31	**< 25% of LRP**	- Cancel the directed salmon fishery in the fall (Sept 1)
			25 to 75%	- Cancel the retention fishery; Catch and release fishery reduced to max. 2 fish per day (Sept 1);
			Greater than 75%	- Preseason management measures retained

[1]"River Under Recovery" is a concept that aims to retain important angler presence on the water to serve as a conservation measure and maintain engagement while stocks are very low. Anglers deter poachers, report habitat issues and invasive species, and provide stewardship for the rivers and the salmon. This concept would include a requirement for anglers to take a course and obtain a special license to fish. The course would include education on Atlantic salmon biology, proper live release techniques, education on the issues facing salmon and what anglers can do to help conservation efforts currently underway and plans for the future. The course could also include education on indigenous connection to the resource, including a historical overview, Indigenous rights, and education on Food, Social, Ceremonial fisheries. The course could be jointly carried out by government agencies, indigenous groups, and conservation NGOs. Non-residents will not be required to have the course because they will be accompanied by a guide who is required to have the course.

[2] The potential retention strategy for small salmon would include a total tag allocation approach, rather than a number of tags per licence but the actual annual catch quotas for each river are not yet determined.

Additional considerations: Mandatory catch, effort, harvest reporting to be developed in future in support of PA.

APPENDIX 2. DECISION RULE TABLE FOR THE MIRAMICHI ATLANTIC SALMON RECREATIONAL FISHERY, VERSION 2

Table A2.1. Decision rule table, version 2, for the Miramichi Atlantic Salmon recreational fishery AFTER Indigenous Peoples fisheries described as the stakeholder decision rule table (version 5; December 3, 2020).

Predicted abundance	PA status zone	Beginning of Season Decision / Inseason Trigger and Decision		
< 15% of LRP* **Expected Total Run at < 10% LRP** NW (< 744 small, < 383 large) SW (< 1,036 small, < 848 large) **Expected Early run (to July 31)** NW (< 484 small, < 211 large) SW (< 560 small, < 305 large**)**	Critical zone	- Closure of directed recreational fishery for Atlantic salmon - Warm water protocol (currently in place and functioning well) - **NEW** “River Under Recovery” status[1] - **NEW** Barbless hooks in all recreational fisheries in scheduled waters (e.g., trout, striped bass) - **NEW** Increase in enforcement effort to reduce impacts of poaching in absence of anglers		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		Aug. 15	**<= 50% of LRP**	- Status quo (preseason management measures retained)
			Over 50% of LRP	- Catch and release fishery in Fall (Sept. 1), 1/day Note: when the preseason predicted abundance is low, an inseason update suggesting a much larger return than anticipated is required before directed salmon fishing is considered, in order to provide a rebuilding opportunity
>= 15% to 50% of LRP* **Expected Total Run at 25% LRP** NW (< 1,861 small, < 959 large) SW (< 2,590 small, < 2,119 large) **Early run (to July 31)**	Critical zone	- Catch and release fishery - 5/day C&R limit (spring) April 15 to May 15 - 2/day C&R limit (summer and fall) after May 15 - Warm water protocol - **NEW** “River Under Recovery” status[1] - **NEW** Barbless hooks in all recreational fisheries in scheduled waters (e.g., trout, striped bass)		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		Aug. 15	**< 15% LRP**	Directed salmon fishery closed

Predicted abundance	PA status zone			Beginning of Season Decision / Inseason Trigger and Decision
NW (< 1,210 small, < 527 large) SW (< 1,399 small, < 763 large)			**> 15% LRP**	Status quo (preseason management measures retained)[2]
> 50% to 120% of LRP **Expected Total Run at 110% LRP** NW (< 8,188 small, < 4,218 large) SW (< 11,398 small, < 9,326 large) **Early run (to July 31)** NW (< 5,322 small, < 2,320 large) SW (< 6,155 small, < 3,357 large)	Critical zone/low Cautious zone	- Catch and release fishery[2] - 10/day C&R limit (spring) April 15 to May 15 - 4/day C&R limit (summer and fall) after May 15 - Warm water protocol - **NEW** Barbless hooks		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		Aug. 15	**< 50% LRP**	Catch and release fishery reduced to max. of 2 fish per day (Sept. 1)
			> 50% LRP	Preseason management measures retained (eg, 4 fish per day);
> 120% to 180% of LRP **Expected Total Run at 200% LRP** NW (< 14,887 small, < 7,669 large) SW (< 20,724 small, < 16,956 large) **Early run (to July 31)** NW (< 9,676 small, < 4,218 large) SW (< 11,191 small, < 6,104 large)	Cautious zone	- 1 grilse tag per license optional by angler[2] - 10/day C&R limit (spring) April 15 to May 15 - 4/day C&R limit (summer and fall) after May 15 - Warm water protocol - **NEW** Barbless hooks		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		August 15	**< 120% LRP**	Cancel retention fishery Catch and release fishery to max of 4 fish/day (Sept. 1)
			> 120% LRP	Preseason management measures retained
> 180% of LRP to USR (TBD but assumed to be 250% of LRP) **Expected Total Run at 200% LRP** NW (< 14,887 small, < 7,669 large) SW (< 20,724 small,	Cautious zone	- 4 grilse tags per license optional by angler[2] - 10/day C&R limit (spring) April 15 to May 15 - 4/day C&R limit (summer and fall) after May 15 - Warm water protocol - **NEW** Barbless hooks		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		August 15	**< 180% LRP**	Reduce retention limit to 1 tag per license

Predicted abundance	PA status zone	Beginning of Season Decision / Inseason Trigger and Decision		
<1 6,956 large) **Early run (to July 31)** NW (< 9,676 small, < 4,218 large) SW (< 11,191 small, < 6,104 large)			**> 180% LRP**	Preseason management measures retained
Above USR (TBD) *(USR is yet to be defined, assumes USR >= 250%LRP)*	healthy zone	- 8 (?) grilse tags per licence optional by angler [number of tags, options for tags to be discussed.] [2] - 10/day C&R limit (spring) April 15 to May 15 - 4/day C&R limit (summer and fall) after May 15 - Warm water protocol - **NEW** Barbless hooks		
		Inseason review	**Trigger**	**Inseason adjustments based on updated forecast of total abundance**
		August 15	<USR	Reduce to retention limit to 4 tags per license
			>USR	Preseason management measures retained

[1] "River Under Recovery" is a concept that aims to retain important angler presence on the water to serve as a conservation measure and maintain engagement while stocks are very low. Anglers deter poachers, report habitat issues and invasive species, and provide stewardship for the rivers and the salmon. This concept would include a requirement for anglers to take a course and obtain a special license to fish. The course would include education on Atlantic salmon biology, proper live release techniques, education on the issues facing salmon and what anglers can do to help conservation efforts currently underway and plans for the future. The course could also include education on indigenous connection to the resource, including a historical overview, Indigenous rights, and education on Food, Social, Ceremonial fisheries. The course could be jointly carried out by government agencies, indigenous groups, and conservation NGOs. Non-residents will not be required to have the course because they will be accompanied by a guide who is required to have the course.

[2]Additional considerations:

- Mandatory catch, effort, harvest reporting to be developed in future in support of PA.
- Maintaining a low impact catch and release fishery even at low abundance is beneficial for conservation and is in-keeping with the Precautionary Approach. Sustaining a recreational fishery (and other fisheries like FSC) ensures that people remain engaged in protecting and caring about the resource, including deterring poaching and supporting restoration action to help the stock recover. The angling community supports conservation programs and ensures Atlantic salmon restoration remains a political priority, which ensures resources are directed to salmon conservation. On the poaching issue alone, the conservation benefits of having anglers on the water far outweigh the biological consequences from poaching that occur in the absence of anglers. A recreational fishery helps keep removals in the Critical Zone to the lowest level possible which is a key principle of the Precautionary Approach. This approach is also consistent with DFO's Wild Atlantic Salmon Conservation Policy. The biological impacts of a catch and release fishery at > 15% LRP are very low (see table below) and present an acceptable level of risk to the stock, keeping in mind that under a closure scenario the impacts from poaching would be far greater. Based on DFO-accepted figures of assuming 30% of the run is caught in the recreational fishery, and a 3% incidental mortality on caught and released fish, the impacts can be quantified as shown in the table below. For comparison, increasing the minimum threshold of fishery closure from 15% LRP to 25% LRP would result in negligible biological gain of just 7 grilse and 4 salmon on the NW Miramichi and 9 grilse and 8 salmon on the SW Miramichi, while significantly increasing the risk of biological consequences from poaching. There are major conservation losses for salmon that accompany a fishery closure.

Table A2.2. Biological impacts of a catch and release fishery with minimum thresholds of 15% and 25% LRP.

% LRP	River	Total Run		30% of Run caught & Released		3% Incidental Mortality of Caught & Released fish	
		Grisle	Salmon	Grisle	Salmon	Grisle	Salmon
15% LRP	NW Miramichi	1116	575	335	172	10	5
	SW Miramichi	1554	1272	466	382	14	11
25% LRP	NW Miramichi	1861	959	558	288	17	9
	SW Miramichi	2590	2119	777	636	23	19

APPENDIX 3. DATA AND BASIS FOR THE ASSUMED 3% CATCH AND RELEASE MORTALITY RATE FOR THE ATLANTIC SALMON RECREATIONAL FISHERY

The study and data used to derive the 3% catch and release mortality in the angling fishery for the Miramichi River is reported in Randall et al. (1986). The data originate from a study conducted by Currie (1985) that estimated angling catches and mortalities in the North Pole Stream section of the NW Miramichi. Details of the study are missing and the report by Currie (1985) has not been found. Currie (1985) reported a total of 2 salmon mortalities and 44 released fish in 1982, and no mortalities and a total of 19 released fish in 1983 (Appendix 3, Table 1). Over the two years, the mortality rate as a percentage of the total reported fish released is 3%. Based on this very small sample size, the distribution of the mortality rates that can generate those data (2 dead, 61 alive, 63 released total) has a median value of 2.7% with a 95% confidence interval range of 0.4% to 8.7%.

Table A3.1. Number of fish released, and number of mortalities recorded from the North Pole Stream (NW Miramichi) study in 1982 and 1983. The reference of this study is Currie (1985) as reported by Randall et al. (1986).

Year	Number of fish released	Number of mortalities observed	Proportion mortalities of released fish
1982	44	2	0.05
1983	19	0	0.00
Total	63	2	0.03

APPENDIX 4. EQUATIONS AND SEQUENCE USED TO INCORPORATE UNCERTAINTIES IN THE ASSESSMENT OF THE HARVEST DECISION RULES

The assessments of performance were done for each year (1984 to 2019) and river (NW Miramichi, SW Miramichi) as follows:

- pick a river and year with estimated abundances of small salmon and large salmon (e.g. NW Miramichi, 1984).
- based on the point estimates (median value from the posterior distribution) of returns of small salmon and large and the eggs per fish (annual point estimate), determine the percentage of the LRP represented by the total eggs in the returns of small salmon and large salmon.
- based on percentage of LRP of eggs in returns, choose the corresponding harvest decision rule feature (Table 1).

Uncertainties in realized returns of small salmon, large salmon, eggs per fish (by size group), exploitation rates, catch and release mortality rates, catches, and losses were considered using Monte Carlo simulations. A total of 5000 simulations were run for each river and year combination. The input data and uncertainty assumptions are presented in Table 2.

The results of the Monte Carlo simulations are presented as boxplots (2.5th, 25th, 50th, 75th, 97.5th percentiles) of the percent of LRP for returns and spawners, catches, losses, and percent of eggs lost due to fishing for the two rules and for the two rivers based on estimated abundances of 1984 to 2019.

Uncertainties in the realized returns of small salmon and large salmon were derived from the assessment model outputs (Douglas et al. in prep.[1]). Specifically,

$$Ret'_{s,r,y} \sim N(u.Ret_{s,r,y}, \sigma.Ret_{s,r,y})$$

with $Ret'_{s,r,y}$ = one simulated value of returns for size group = s (small, large), river = r (NW Miramichi, SW Miramichi), and year = y (1984 to 2019)

$u.Ret_{s,r,y} = median\ from\ model\ posterior\ estimates$

$\sigma.Ret_{s,r,y} = standard\ deviation = CV_{s,r,y} * u.Ret_{s,r,y}$, and

$CV_{s,r,y} = \frac{\sigma_{s,r,y}}{mean_{s,r,y}}$ with

$\sigma_{s,r,y}, mean_{s,r,y}$ = standard deviation and mean of the model posterior estimates.

To trap simulated values of returns from the normal distribution that are negative, the simulated returns ($Ret'_{s,r,y}$) were censored to minimum values of 0.01 * $u.Ret_{s,r,y}$

Eggs per fish by year and river are derived annually from sampling data (Douglas et al. in prep.[1]). The uncertainties in the eggs per fish were simulated using a normal distribution with the mean as the point estimate from the assessment and assuming a CV of 0.1:

$$Eggs'_{s,r,y} \sim N(u.Eggs.fish_{s,r,y},\ 0.1 * u.Eggs.fish_{s,r,y})$$

with $Eggs'_{s,r,y}$ = one simulated value of eggs per fish of size groups, river r, and year y, and

$u.Eggs.fish_{s,r,y}$ the point estimate of eggs per fish from the assessment.

The total eggs in returns of small salmon and large salmon by river and year for each simulation are calculated as:

$$Eggs.returns'_{r,y} = \sum_{s} Ret'_{s,r,y} * Eggs'_{s,r,y}$$

Exploitation rates by size group and river have been estimated in the assessment model (Douglas et al. in prep.[1]) for the years with estimated recreational fisheries, 1984 to 1995, 1997. The exploitation rates were simulated (ER') using a normal distribution with the mean and a CV of 0.1 on the logit scale as:

$$logit.ER_{s,r,y} \sim N\left(u.logit.ER_{s,r}, \sigma.logit.ER_{s,r}\right),$$

with $u.logit.ER_{s,r} = \log\left(\frac{ER_{s,r}}{(1 - ER_{s,r})}\right)$

$ER_{s,r}$ the mean exploitation rate over years from the assessment model (Table 2),

$\sigma.logit.ER_{s,r} = 0.1 * u.logit.ER_{s,r}$ and

$ER'_{s,r,y} = \frac{1}{(1 + e^{-logit.ER_{s,r,y}})}$

The data provided in Randall et al. (1986) was used to simulate catch and release mortality rates based on a beta distribution:

$$M\_CR'_{s,r,y} \sim Beta(dead, alive)$$

with dead = 2, alive = 61.

For higher values based on the meta-analysis study of Van Leeuwen (2020a), catch and release mortality was modelled (CR') in a similar way, using a normal distribution on the logit scale with the logit mean and logit σ of the summer and autumn seasons based on the reported mean and 95% confidence intervals as:

Summer: mean = 16%, 95% C.I. = 7% to 33%
mean = 25%, 95% C.I. = 19% to 32%

Autumn: mean = 3%, 95% C.I. = 1% to 5%
mean = 4%, 95% C.I. = 2% to 6%

$$logit.M_{CR_{s,r,y}} \sim N\left(u.logit.M_{CR_{s,r}}, \sigma.logit.M_{CR_{s,r}}\right)$$

$$u.logit.M.CR = \log\left(\frac{mean}{1 - mean}\right)$$

$$\sigma.logit.M\_CR = \frac{\left(\log\left(\frac{C.I.upper}{1 - C.I.upper}\right) - \log\left(\frac{C.I.lower}{1 - C.I.lower}\right)\right)}{4}$$

$$M\_CR'_{s,r,y} = \frac{1}{(1 + e^{-logit.M\_CR_{s,r,y}})}$$

Catches of small salmon and large salmon were simulated assuming a binomial distribution from the simulated return and the simulated exploitation rate as:

$$Catch'_{s,r,y} \sim Bin(Ret'_{s,r,y}, ER'_{s,r,y})$$

Retained catch of fish was calculated as the proportion of the catch which is retained (Table 1) as:

$$Retained'_{s,r,y} = Catch'_{s,r,y} * prop.retained_s$$

with $prop.retained$ = {0, 0.75, 1} for s = small salmon (depending on the rule), 0 for s = large salmon.

Released catch of fish was calculated as the proportion of the catch which is released (Table 1) as:

$$Released'_{s,r,y} = Catch'_{s,r,y} * (1 - prop.retained_s)$$

Losses from fishing were calculated as:

$$Losses'_{s,r,y} = Retained'_{s,r,y} + Released'_{s,r,y} * M\_CR'_{s,r,y}.$$

Spawners and eggs in spawners were calculated as:

$$Spawner'_{s,r,y} = Ret'_{s,r,y} - Losses'_{s,r,y}$$

$$Eggs.spawners'_{r,y} = \sum_{s} Spawner'_{s,r,y} * Eggs'_{s,r,y}$$

We also calculated the percentage of eggs lost from fishing as:

$$Eggs\_lost'_{r,y} = \frac{\left(Eggs.returns'_{r,y} - Eggs.spawners'_{r,y}\right)}{Eggs.returns'_{r,y}}$$

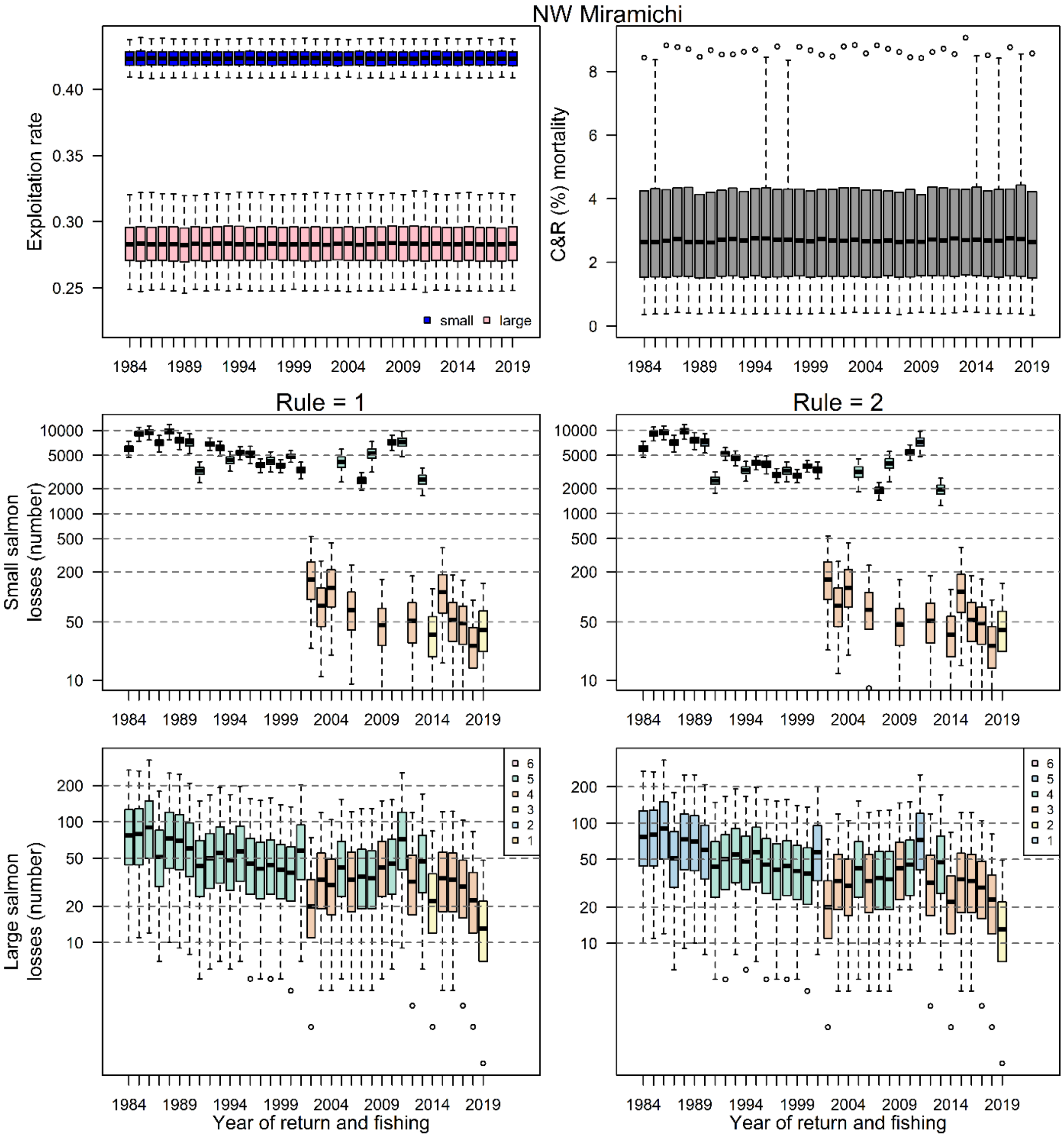

Figure A4.1a. Northwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for low catch and release mortality rates of 3% for the season based on Randall et al. (1986). The boxplots in the middle and bottom rows are coloured based on the status category of the decision rule (Table 1) which was applied to the year, 1984 to 2019. The box plots summarise the 2.5th to 97.5th percentiles range as the whiskers, the 25th to 75th percentiles range as the rectangle and the 50th percentile (median) as the black dash.

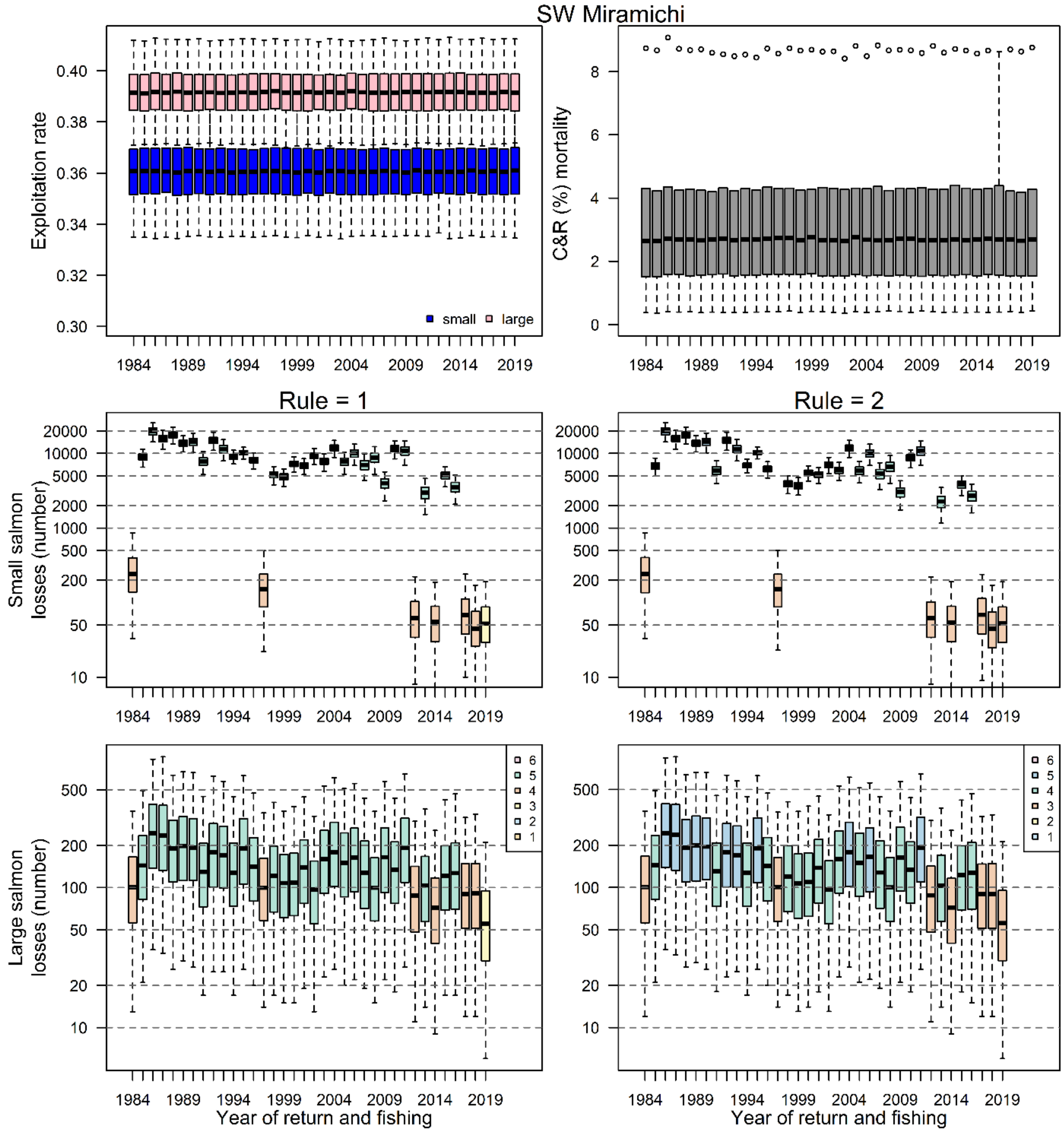

Figure A4.1b. Southwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for low catch and release mortality rates of 3% for the season based on Randall et al. (1986). The boxplot colours and features are described in the caption to Figure A4.1a.

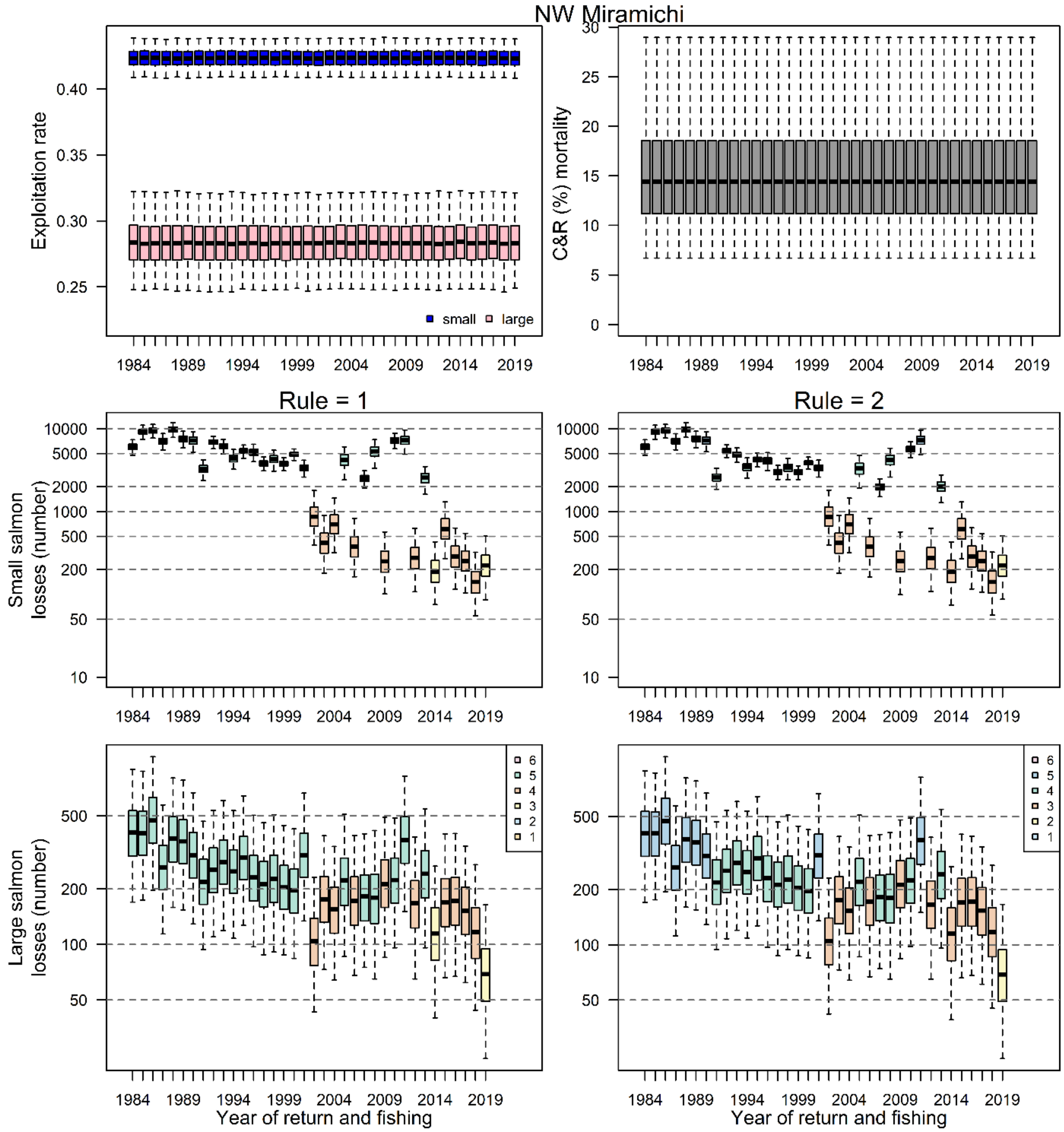

Figure A4.2a. Northwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for high catch and release mortality rates of 16% (7% to 33%) in the summer, and 3% (1% to 5%) in the autumn. The boxplot colours and features are described in the caption to Figure A4.1a.

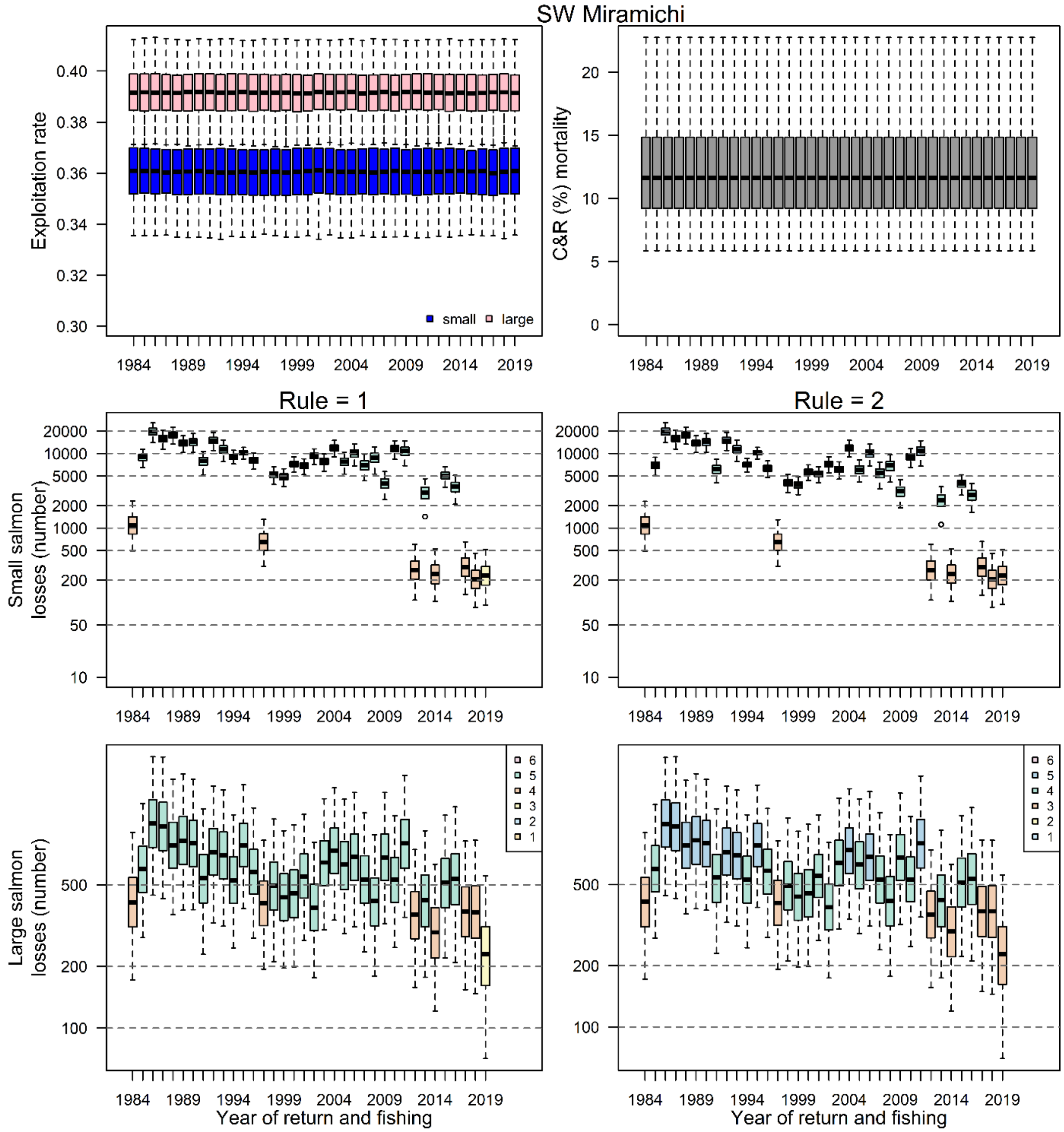

Figure A4.2b. Southwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for high catch and release mortality rates of 16% (7% to 33%) in the summer, and 3% (1% to 5%) in the autumn. The boxplot colours and features are described in the caption to Figure A4.1a.

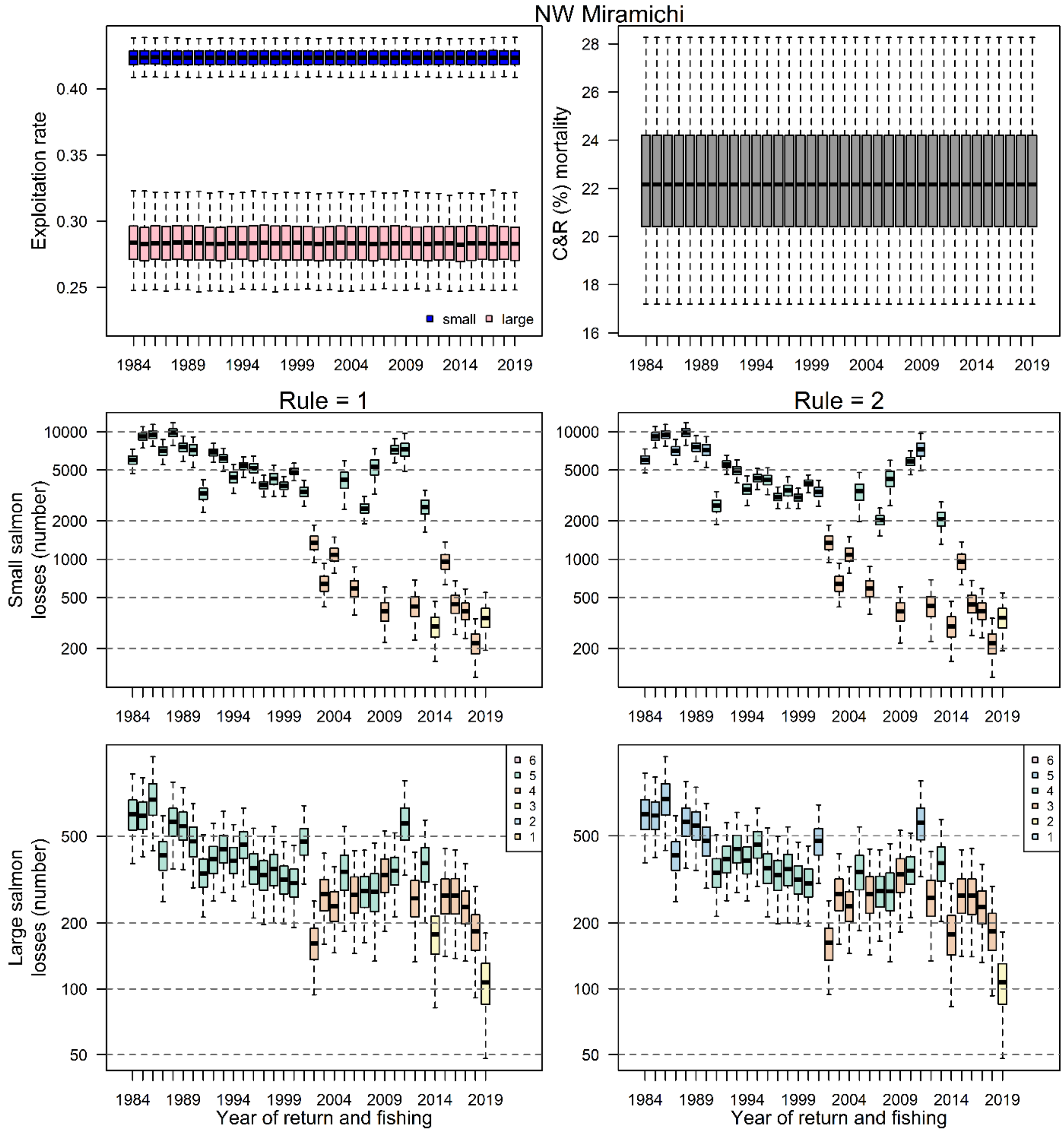

Figure A4.3a. Northwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for the highest catch and release mortality rates of 25% (19% to 32%) in the summer, and 4% (2% to 6%) in the autumn. The boxplot colours and features are described in the caption to Figure A4.1a.

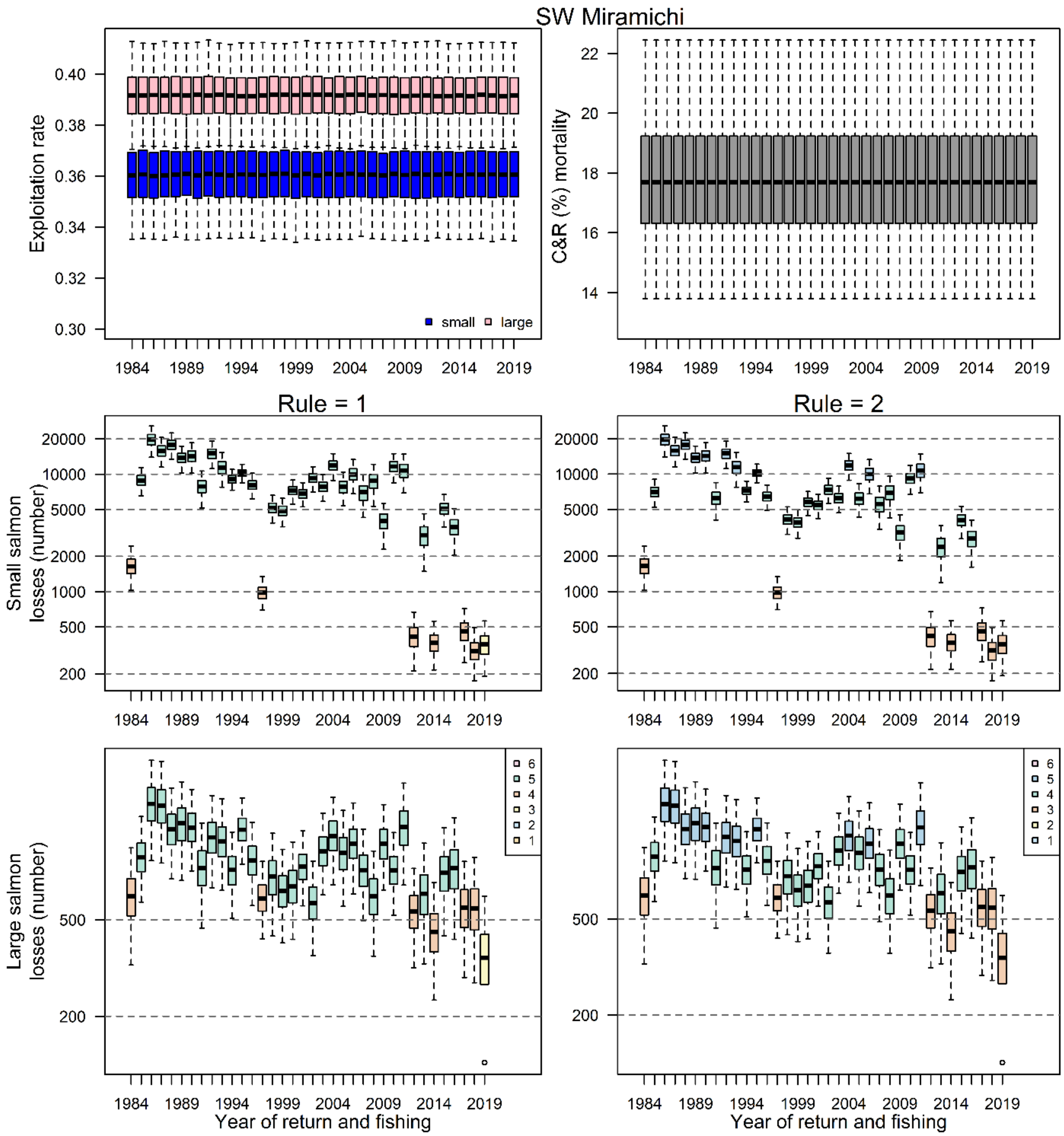

Figure A4.3b. Southwest Miramichi River summaries of simulated exploitation rates of small salmon and large salmon (top left panel), the simulated catch and release mortality rates (top right panel), the losses (retained catch plus catch and release mortality) of small salmon (second row) and large salmon (bottom row) for rule 1 (left column, middle and bottom rows) and rule 2 (right column, middle and bottom rows). The simulations are for the highest catch and release mortality rates of 25% (19% to 32%) in the summer, and 4% (2% to 6%) in the autumn. The boxplot colours and features are described in the caption to Figure A4.1a.

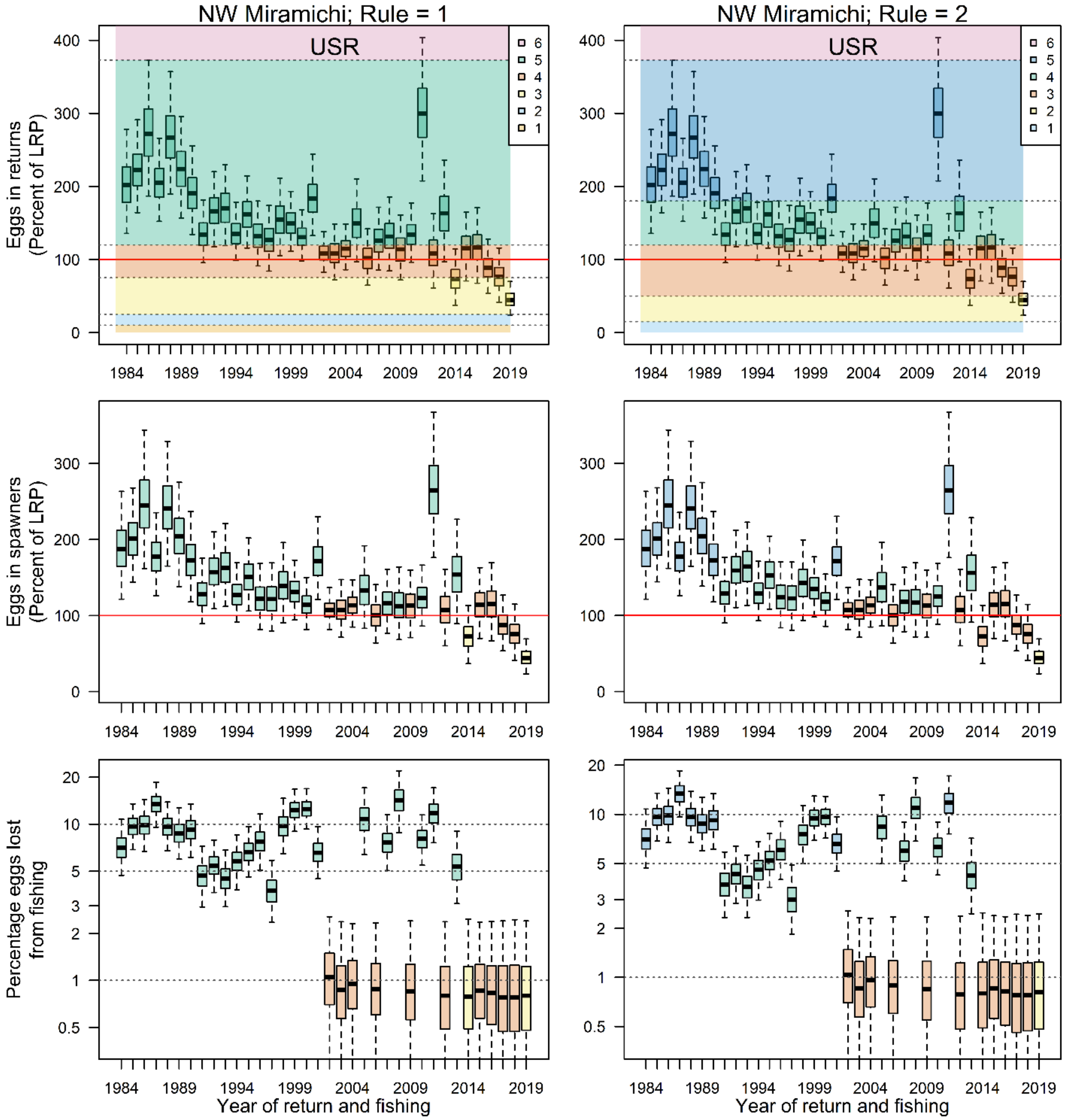

Figure A4.4a. Northwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for low catch and release mortality rates of 3% for the season based on Randall et al. (1986). The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The box plots summarize the 2.5th to 97.5th percentiles range as the whiskers, the 25th to 75th percentiles range as the rectangle and the 50th percentile (median) as the black dash.

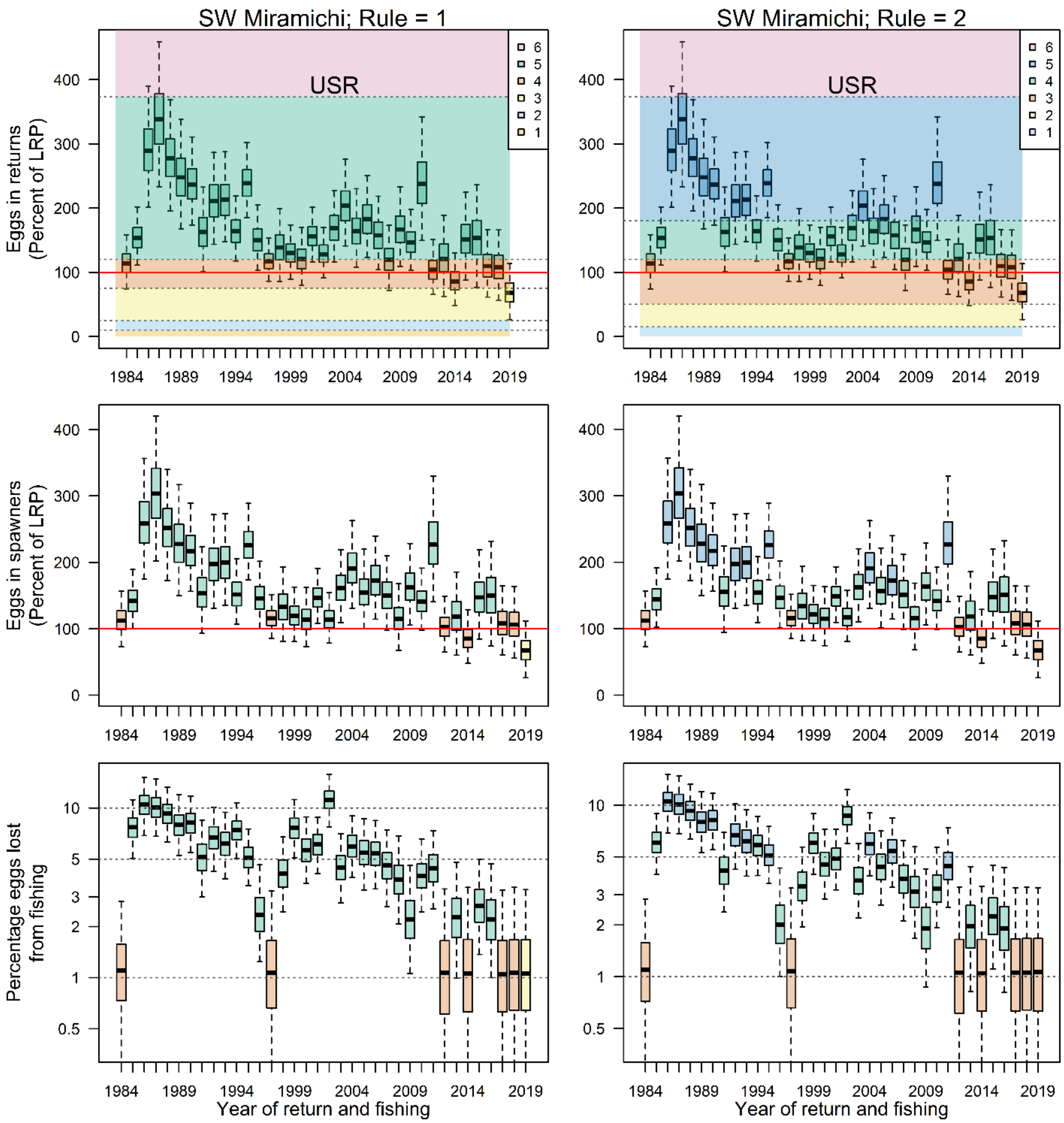

Figure A4.4b. Southwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for low catch and release mortality rates of 3% for the season based on Randall et al. (1986). The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The boxplot colours and features are described in the caption to Figure A4.4a.

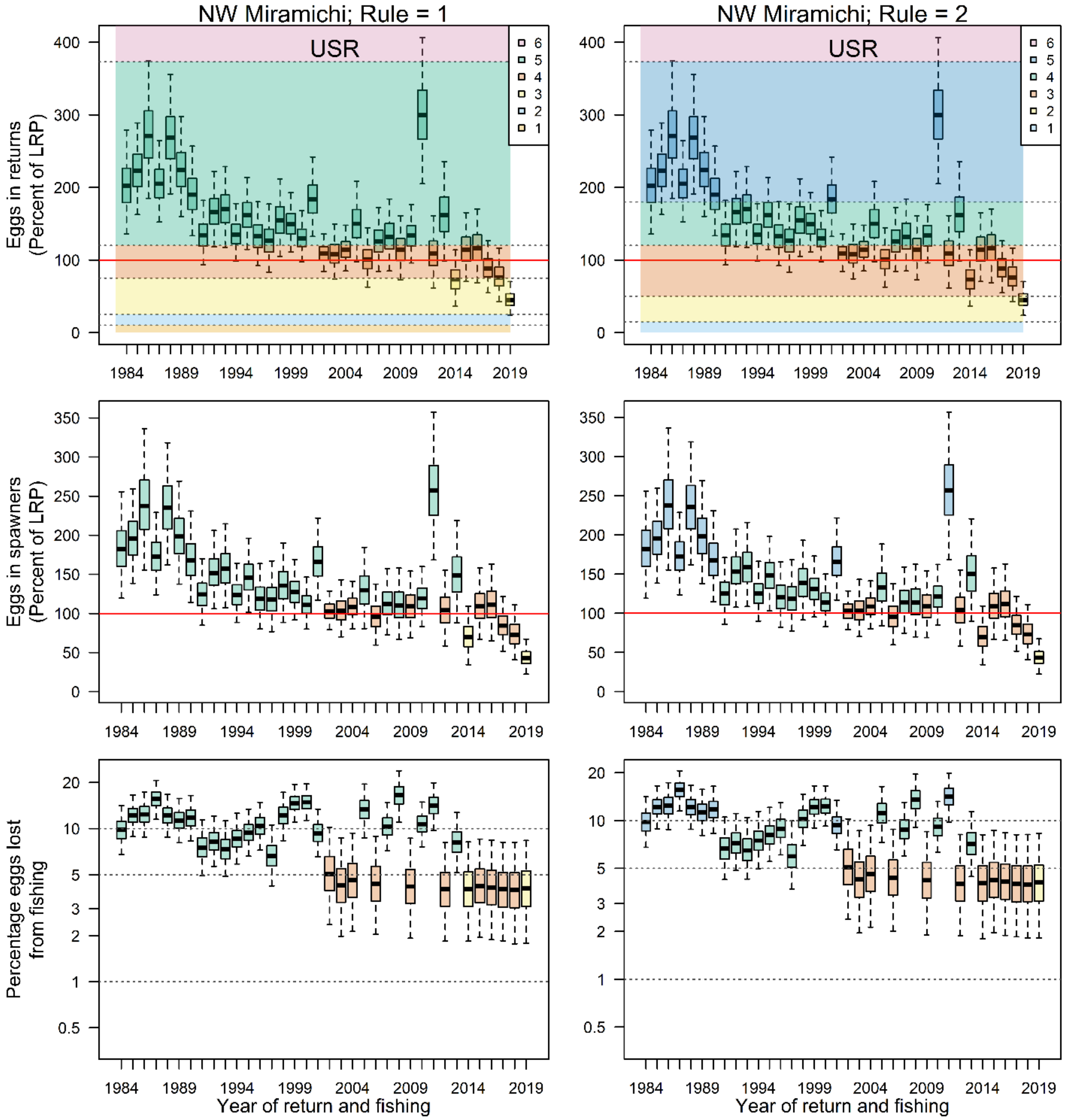

Figure A4.5a. Northwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for high catch and release mortality rates of 16% (7% to 33%) in the summer, and 3% (1% to 5%) in the autumn. The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The boxplot colours and features are described in the caption to Figure A4.4a.

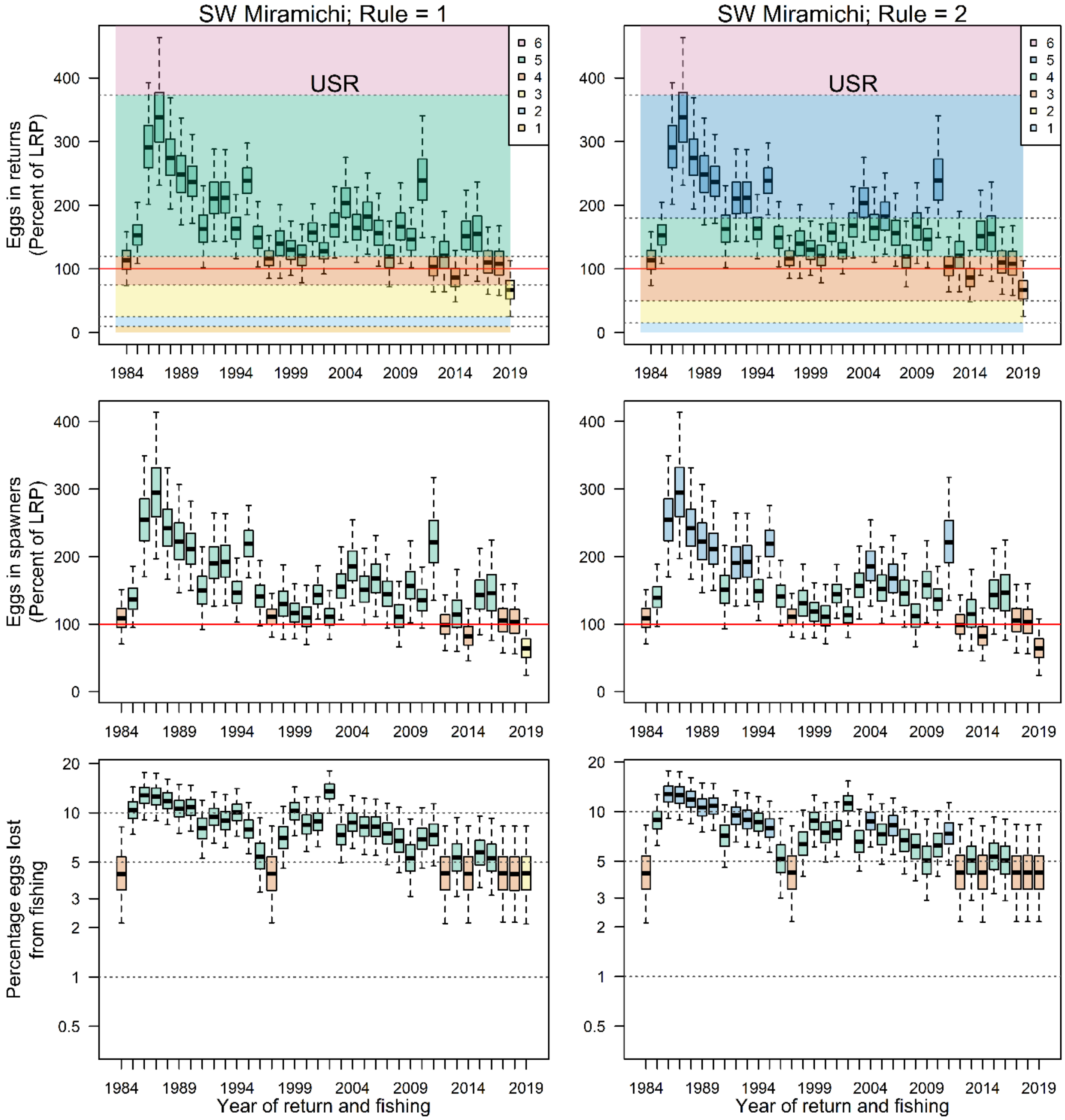

Figure A4.5b. Southwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for high catch and release mortality rates of 16% (7% to 33%) in the summer, and 3% (1% to 5%) in the autumn. The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The boxplot colours and features are described in the caption to Figure A4.4a.

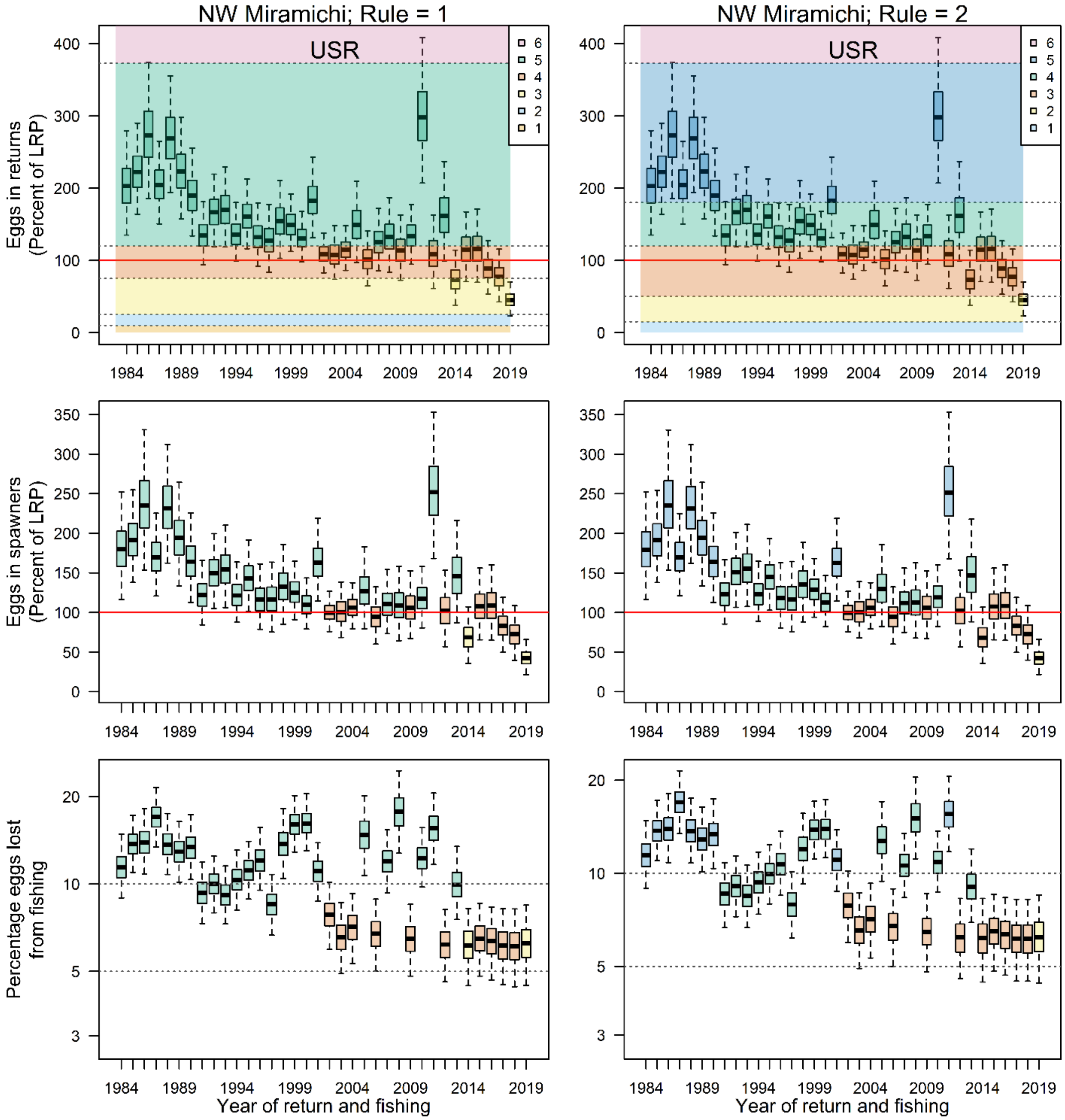

Figure A4.6a. Northwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for the highest catch and release mortality rates of 25% (19% to 32%) in the summer, and 4% (2% to 6%) in the autumn. The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The boxplot colours and features are described in the caption to Figure A4.4a.

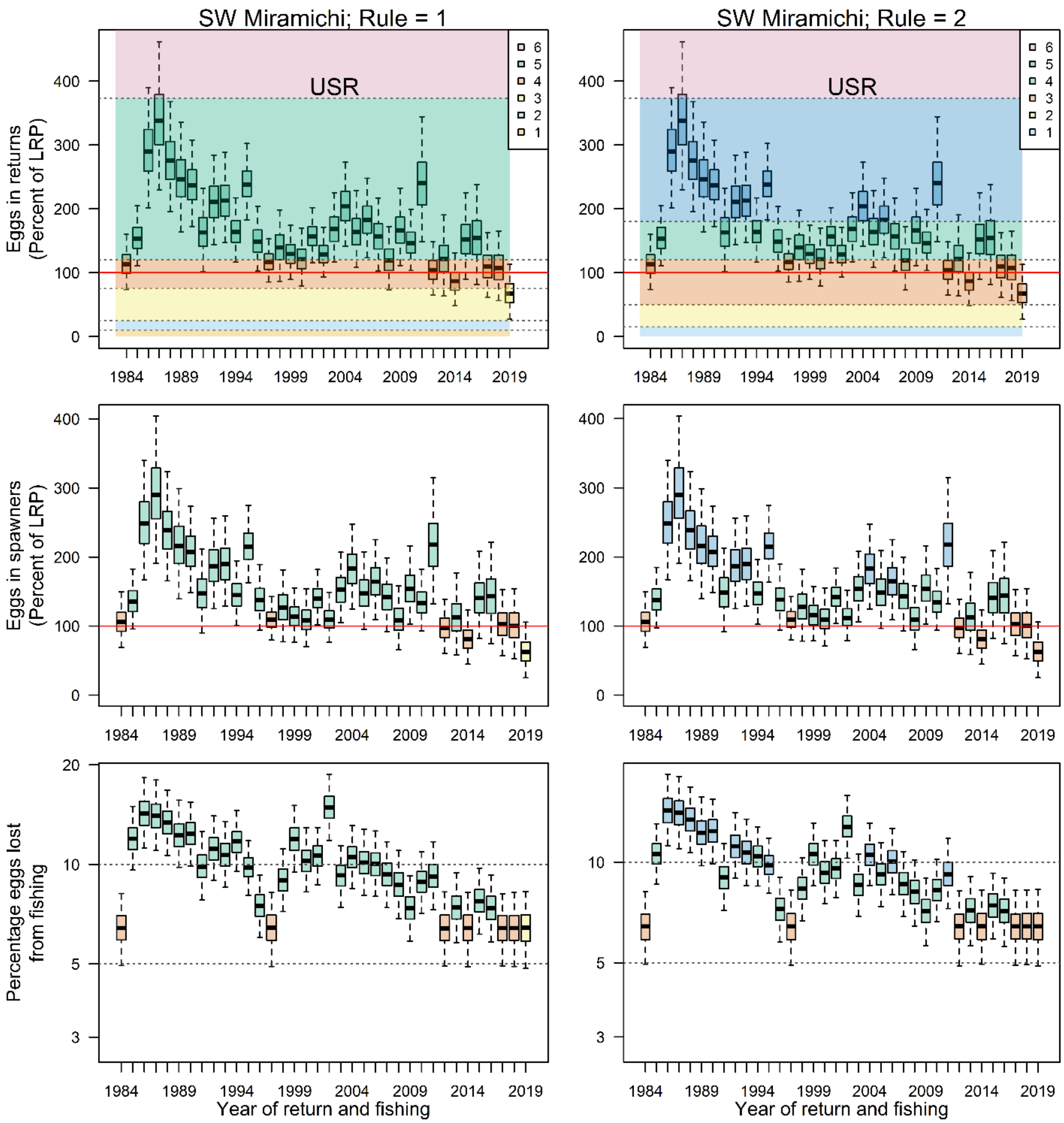

Figure A4.6b. Southwest Miramichi River summaries of simulated total eggs in returns (top row), total eggs in spawners after recreational fisheries losses (middle row) and percentage of eggs lost due to recreational fishing (bottom row) for rule 1 (left column) and rule 2 (right column). The simulations are for the highest catch and release mortality rates of 25% (19% to 32%) in the summer, and 4% (2% to 6%) in the autumn. The boxplots in all panels and the shading of the panels in the upper row correspond to the status category of the decision rule (Table 1) which was applied to the preseason expectation (point estimate) of that year, 1984 to 2019. The boxplot colours and features are described in the caption to Figure A4.4a.