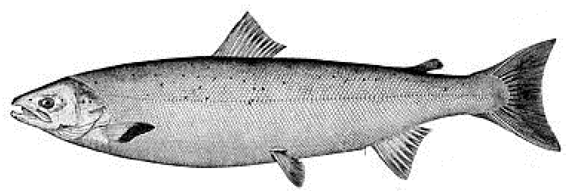
DEFINITION OF PRECAUTIONARY APPROACH REFERENCE POINTS FOR ATLANTIC SALMON, DFO GULF REGION



*Atlantic Salmon (*Salmo salar)

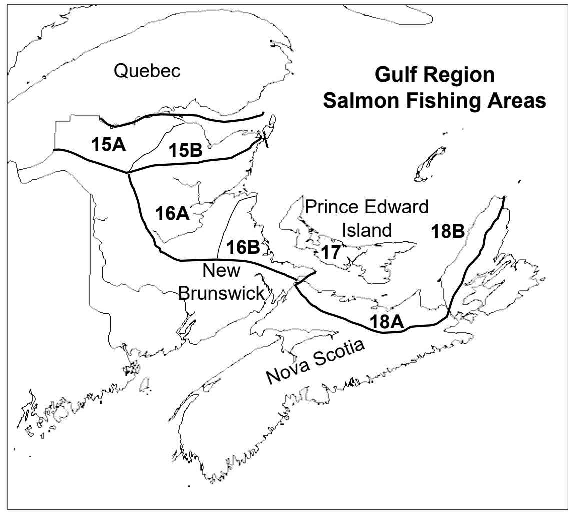


Figure 1. Salmon fishing areas (SFA) in DFO Gulf Region.

Context:

*All rivers flowing into the southern Gulf of St. Lawrence are included in Fisheries and Oceans Canada (DFO) Gulf Region (Figure 1). Atlantic Salmon (*Salmo salar*) is broadly distributed in most rivers of the southern Gulf of St. Lawrence and salmon from the region can undertake long seaward migrations to feed, as far as Greenland and occasionally in the northeast Atlantic (east of Iceland) where they are also exploited in marine fisheries targeting salmon.*

Atlantic Salmon management areas in DFO Gulf Region are defined by four salmon fishing areas (SFA 15 to 18) encompassing portions of the three Maritime provinces (New Brunswick, Nova Scotia, and Prince Edward Island). In DFO Gulf Region, salmon is exploited by Indigenous communities and in recreational fisheries. Since 2015, mandatory catch and release of salmon of all size groups has been in effect for the recreational fisheries in rivers of DFO Gulf Region that are open to directed salmon fisheries.

In support of the initiative to develop a precautionary approach (PA) framework for the management of Atlantic Salmon fisheries in DFO Gulf Region rivers, DFO Ecosystems and Fisheries Management Branch (EFM) Gulf Region requested advice on the definition of reference points that conform to the PA and a review of candidate harvest decision rules for the Atlantic Salmon recreational fishery for their conformity to the PA. The information and analyses in support of this request for advice were reviewed during a regional peer review meeting held virtually in Moncton (N.B.) during February 23-24, 2022. Participants at the meeting included DFO Science and EFM from Gulf, Maritimes, Newfoundland and Labrador, and National headquarters regions, from Indigenous communities, recreational fishery and salmon conservation organizations, provincial governments, and invited external experts. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Upper Stock Reference (USR), Target Reference (TR) and Removal Rate (RR) reference points are defined for 98 Atlantic Salmon rivers in DFO Gulf Region. The abundance reference points are defined in units of eggs from all anadromous age and size groups.
- The USR and TR values are defined using the ratio of these reference points to the Limit Reference Point (LRP) from an analysis of adult to adult stock and recruitment data. The ratios quantify the spread between the LRP and corresponding USR and TR, of 3.8 and 4.7, respectively.
- These ratios are applied to the previously defined LRP values based on the egg to salmon smolt freshwater phase to quantify the river-specific USR and TR points.
- The removal rate equivalent to fishing at maximum sustained yield (MSY) when the recruitment is at MSY defines the RR reference for all the rivers, a mean value of 0.6.
- Candidate harvest decision rules (HDR) for the recreational Atlantic Salmon fishery after the constitutionally recognized right of first access to natural resources for the Indigenous peoples is respected, are evaluated for compliance to the Precautionary Approach (PA) policy.
- The candidate HDRs reviewed, using the Miramichi River as a case study, have several elements that conform to the PA policy and guidance for harvest strategies while other elements do not conform to the PA.
- The candidate HDRs would allow a directed catch and release recreational fishery when the abundance is in the critical zone, as low as 15% of the LRP. 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 exploitation rate and 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.
- Our ability to develop and implement robust HDRs is limited due to the lack of a full evaluation of the performance of candidate HDRs, that includes forecast models and the effect of management measures on removal rates.

INTRODUCTION

Fisheries and Oceans Canada (DFO) Ecosystems and Fisheries Management Branch Gulf Region is developing a precautionary approach (PA) framework for the management of Atlantic Salmon (*Salmo salar*) fisheries in DFO Gulf Region rivers (DFO 2009). Canada's Wild Atlantic Salmon Conservation Policy (DFO 2018a) and its associated implementation plan (DFO 2019a) identified the development and implementation of the Precautionary Approach as a priority action for the conservation of Atlantic Salmon in eastern Canada.

The first step in the process that defined Limit Reference Points (LRP) for Atlantic Salmon of DFO Gulf Region rivers was completed in 2018 (DFO 2018b) based on the zonal advice on reference points and the precautionary approach for Atlantic Salmon (DFO 2015). River-specific LRPs were defined for 98 Atlantic Salmon rivers in DFO Gulf Region. The LRPs are defined in terms of the total eggs in spawners of all sea-age / size groups that result in a low probability (25% or less) of the resulting recruitment of smolts from freshwater being less than 50% of maximum smolt recruitment.

The next step in the process is the development of the Upper Stock Reference (USR), the Target Reference (TR) and the Removal Rate (RR) reference for the three status zones of the

PA framework. The last step in the PA framework involves the development of harvest decision rules (HDR). A DFO Fisheries Management-led working group (DFO-WG) convened to develop candidate HDR for the Atlantic Salmon recreational fishery. 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 developed by the DFO-WG would apply in consideration of the remaining abundance. Candidate HDRs developed by the DFO-WG using the Miramichi River as the case study are evaluated for their compliance to the PA policy.

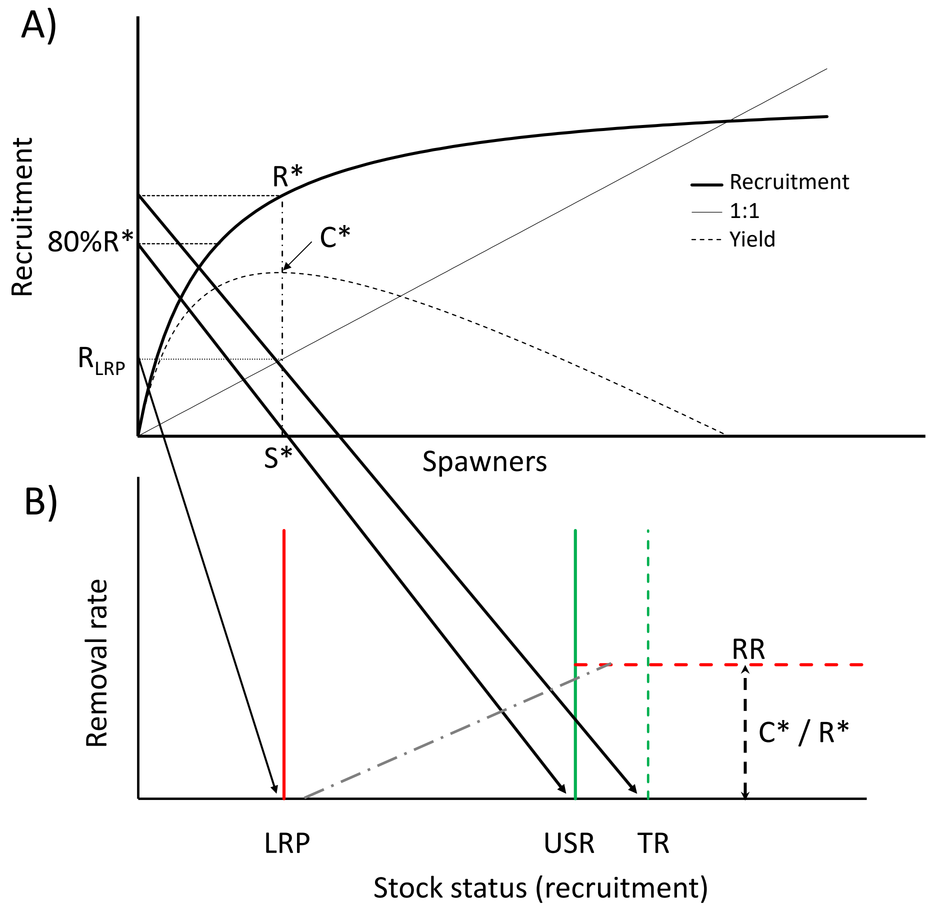


Figure 2. Transposing a spawning stock to recruitment relationship (upper panel A) to the removal rate and stock status axes (lower panel B) within the PA framework. The example is for a limit reference point equal to S (spawners that result in R*), an upper stock reference corresponding to 80%R*, a target reference point of R*, and a removal rate corresponding to h* (= C*/R*), where C* is catch at MSY, and R* is recruitment at MSY. The exploitation rate in the cautious zone (grey dash-dotted line in panel B) could be defined on the basis of a risk analysis of the chance that abundance after exploitation would be less than the LRP.*

Stock dynamics of Atlantic Salmon are frequently presented as spawner to recruit relationships with spawners on the x-axis and recruits on the y-axis (panel A Figure 2), in contrast to the PA framework where stock status, or an index of total abundance, is presented on the horizontal axis and the removal rate on the vertical axis (panel B Figure 2). Reconciling these two perspectives simply involves transferring the recruitment axis from the stock and recruitment frame (spawners to recruitment) to the stock status axis of the PA frame (stock abundance and removal rate) (Figure 2). In this way, the stock status axis of the PA diagram is interpreted as the stock abundance prior to the anthropogenic losses which are being managed, the harvest decision rule adjusts the removal rate (losses) to this abundance. When stock abundance before exploitation is at or below the defined LRP, the removals and removal rate must be at the lowest level possible (DFO 2009), i.e., recruitment essentially equals spawners. When stock abundance before exploitation is in the healthy zone of the PA, removals can occur at a maximum rate that does not result in the abundance after exploitation (i.e., spawners) falling to or below the LRP. Removal rates in the cautious zone (when the abundance is above the LRP but below the USR) are adjusted to minimize the probability that the abundance of spawners after exploitation are less than the LRP and to promote stock rebuilding to the healthy zone (DFO 2009, 2021a).

ASSESSMENT

A number of terms used in this report are defined below:

- small salmon: anadromous adult salmon of fork length < 63 cm, also referred to as grilse.
- large salmon: anadromous adult salmon of fork length >= 63 cm.
- bright salmon: anadromous adult salmon returning to the river from May to November to spawn in October to December. 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 River takes place between April 15 and May 15, annually.
- catch: refers to a fish that is captured in a fishery. The catch may be retained or it may be released back to the water.
- exploitation rate: as used here, refers to the proportion (0 to 1) of the salmon component (small or large) which is captured in the fishery, including retained and released fish.
- retained: refers to salmon that 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 quantity 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 otherwise do not contribute to spawning due to mortality and /or stress associated with having been captured and released.
- removal rate (RR): the proportion (or percentage) of the fish or total eggs lost due to fishing.
- Limit Reference Point (LRP): a threshold reference point, intended to be exceeded greater than 50% of the time, that defines the boundary between the Critical Cautious zones of the PA framework and below which serious harm to the stock is occurring (DFO 2009).
- Upper Stock Reference (USR): a threshold reference point, intended to be exceeded greater than 50% of the time, that represents the boundary between the Cautious and Healthy zones. When abundance before fishing is below the USR, the exploitation rate on the stock should be progressively reduced to avoid reaching the LRP.
- Target Reference (TR): represents a desirable stock status state, above the USR, intended to be met on average, i.e., approx. 50% of the time.

- Harvest Decision Rule (HDR): may be referred to as a harvest control rule; a removal rate profile on the plot of abundance versus removal rate that indicates the removal rate that would be applied for various abundance levels in the PA framework.

Definition of Upper Stock Reference, Target Reference and Removal Rate references

As was the case for the LRPs, the biological unit for defining PA reference points for Atlantic Salmon in DFO Gulf Region is an individual river (Appendix 1).

DFO (2009, 2015) stated that the USRs and TRs 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.

Retention of Atlantic Salmon in Indigenous and recreational fisheries is desired and by default, reference points defined using Maximum Sustainable Yield (MSY) concepts are presented. MSY reference points consider both the biological aspects of the resource (from the stock and recruitment relationship) and socio-economic considerations (maximizing yield from the fishery). Alternate management objectives and reference points could be considered.

Candidate USR points corresponding to socio-economic management objectives include:

- 80%R*: abundance corresponding to 80% of the recruitment that provides maximum sustainable yield (MSY). This is equivalent to the 80%Bmsy value described in DFO (2009) and is proposed as the USR for Atlantic Salmon for rivers in DFO Gulf Region.
- 80%Rmax: abundance corresponding to 80% of maximum recruitment. This could support fisheries objectives of maximizing fishing opportunities and values, as in recreational fisheries that allow the practice of catch and release and/or may be selective for size or sea age groups.

Candidate TR points include:

- R*: recruitment corresponding to MSY, expressed as the maximum difference between recruitment and spawners. This would support consumptive fisheries objectives. This is proposed as the TR for Atlantic Salmon for rivers in DFO Gulf Region.
- %Rmax: abundance corresponding to a high percentage of the estimated maximum recruitment. For the Ricker stock and recruitment function, the value could be Rmax. For the Beverton-Holt function, Rmax is a theoretical value that is realized when spawners are infinitely large and a value of 90% Rmax could be a potential TR.

DFO (2009) states that the maximum removal rate in the healthy zone should not exceed the rate corresponding to Fmsy (fishing rate that results in maximum sustainable yield). The maximum removal rate reference (RR) is the rate corresponding to the TR. With the TR set at R*, the maximum removal rate is h^* (= C^*/R^*), where C* is catch at MSY.

Derivation of Reference Values from Stock and Recruitment Data

Variations in survival at sea have the greatest consequence on abundance of returning adults, and the MSY reference values (C*, R*, and S* as spawners that result in R*) increase as marine survival increases. There is substantial evidence of non-stationarity in the North Atlantic Ocean conditions that have affected anadromous Atlantic Salmon (Olmos et al. 2020) with the abundance of anadromous Atlantic Salmon from eastern North America over the past four decades having declined by 62% overall, 36% for small salmon and 82% for large salmon (ICES 2021). The factors that have contributed to the reduced productivity of Atlantic Salmon in the North Atlantic are not fully known but are considered to be acting predominantly at sea and affecting survival that is not density-dependent. The lower productivity state of recent decades is not considered to be irreversible.

Considering the association between reference points and sea survival, and that the LRP for salmon in DFO Gulf Region rivers has been defined using egg to smolt recruitment data exclusively from the freshwater phase of the life cycle, defining the USR and TR directly from adult to adult relationships was not considered appropriate. Rather, ratios of USR (80%R*) and TR (R*) to the LRP (based on spawners that result in 50% of Rmax with >= 75% probability; S_halfRmax@75) estimated from adult to adult stock and recruitment data are used. The ratios characterize the expected spread between the LRP and USR, or TR which are then applied to the defined LRPs from the egg to smolt recruitment relationship, to define the USR and TR.

Adult to adult stock and recruitment reconstructions from two rivers in DFO Gulf Region were analyzed jointly with stock and recruitment data from 10 rivers in the province of Quebec; the Quebec rivers are proximate to rivers of the southern Gulf of St. Lawrence and have comparable life history characteristics, especially the important contributions of multi-sea-winter fish to returns and spawners (Figure 3). The stock and recruitment data covering a comparable time series extending from the 1972 to 2004/2005 cohorts were analyzed with a Bayesian hierarchical Ricker stock and recruitment model (as described in Dionne et al. 2015). The predicted fits (median line and confidence interval envelopes) for the 12 rivers are shown in Figure 4.

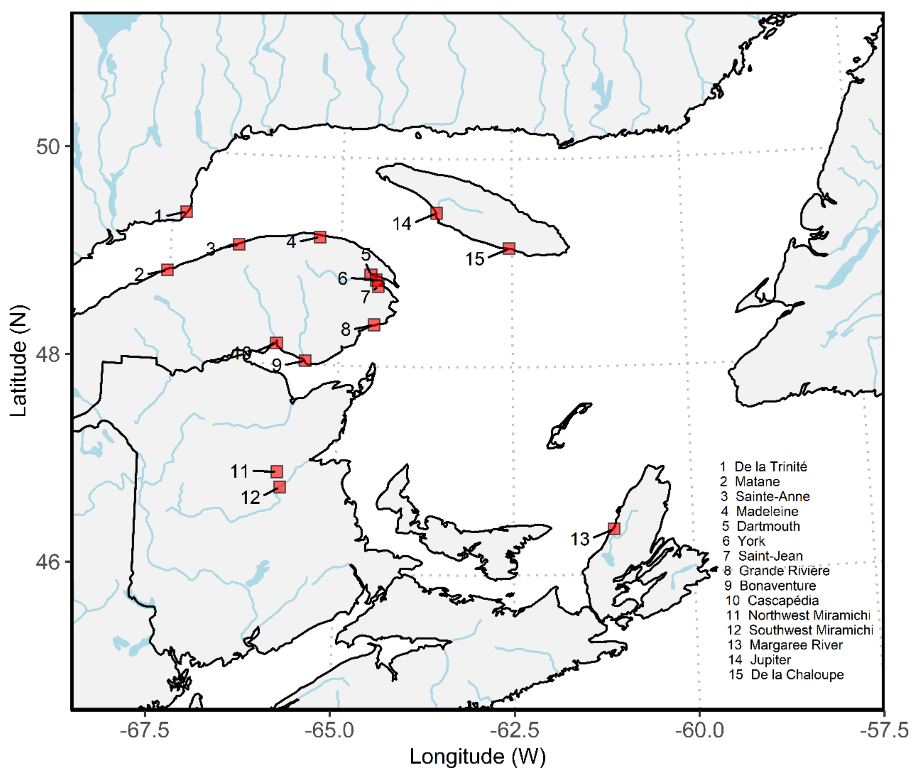


Figure 3. Geographic location of rivers with reconstructed adult to adult stock and recruitment data analysed in this study. The Northwest Miramichi and Southwest Miramichi rivers have a common confluence in tidal waters and become the Miramichi River. The Jupiter and De la Chaloupe rivers of Anticosti Island are not included in the hierarchical analysis because of their shorter time series of data.

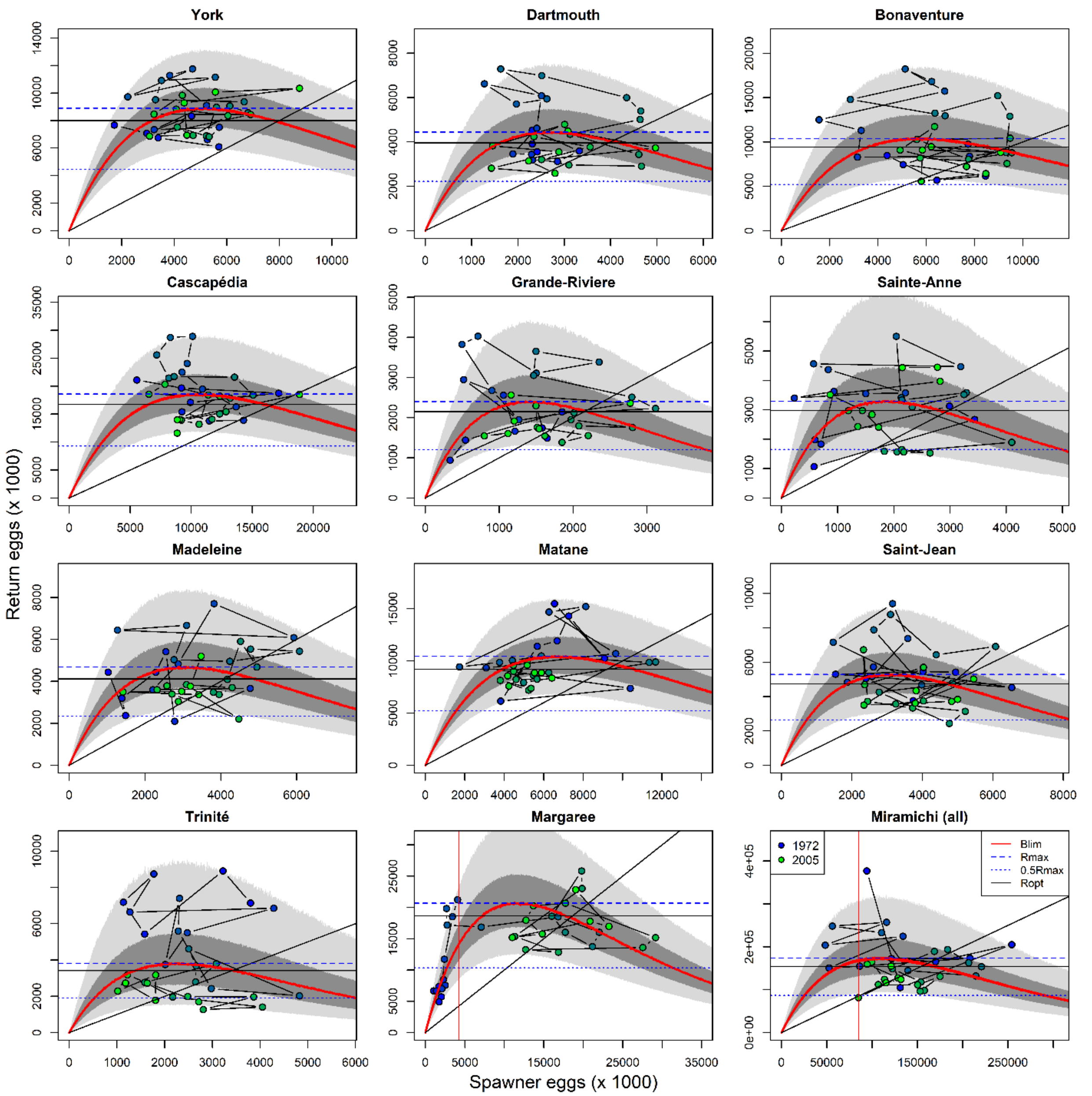


Figure 4. Ricker (hierarchical) stock and recruitment function fits to the egg to egg time series for the ten Quebec rivers and two DFO Gulf Region rivers, 1972 (dark blue) to 2015 (bright green) cohorts. The total eggs in spawners (horizontal axis) and in returns (vertical axis) by cohort are expressed as thousands of eggs. The thick red curve indicates the median Ricker stock and recruitment relationship, the dark and light grey areas indicate 25^{th}-75^{th} and 2.5^{th}-97.5^{th} interquantile envelopes, respectively. The black diagonal line is the 1:1 line, the black horizontal line indicates R, and the dashed and dotted blue horizontal lines indicate Rmax and 0.5Rmax, respectively. The vertical red line indicates Blim (the LRP) when available.*

The shrinkage (river-specific values regressing towards the overall mean) of the posterior estimates from the hierarchical model relative to fitting the river data independently is most important for h* and less visible for S* and R* (Figure 5). The hierarchical model median estimates of h* range from 0.58 to 0.62 (Table 1). Shrinkage of the ratios of R*/S*, 80%R*/S_halfRmax@75, and R*/S_halfRmax@75 are also noted with the hierarchical model (Figure 5).

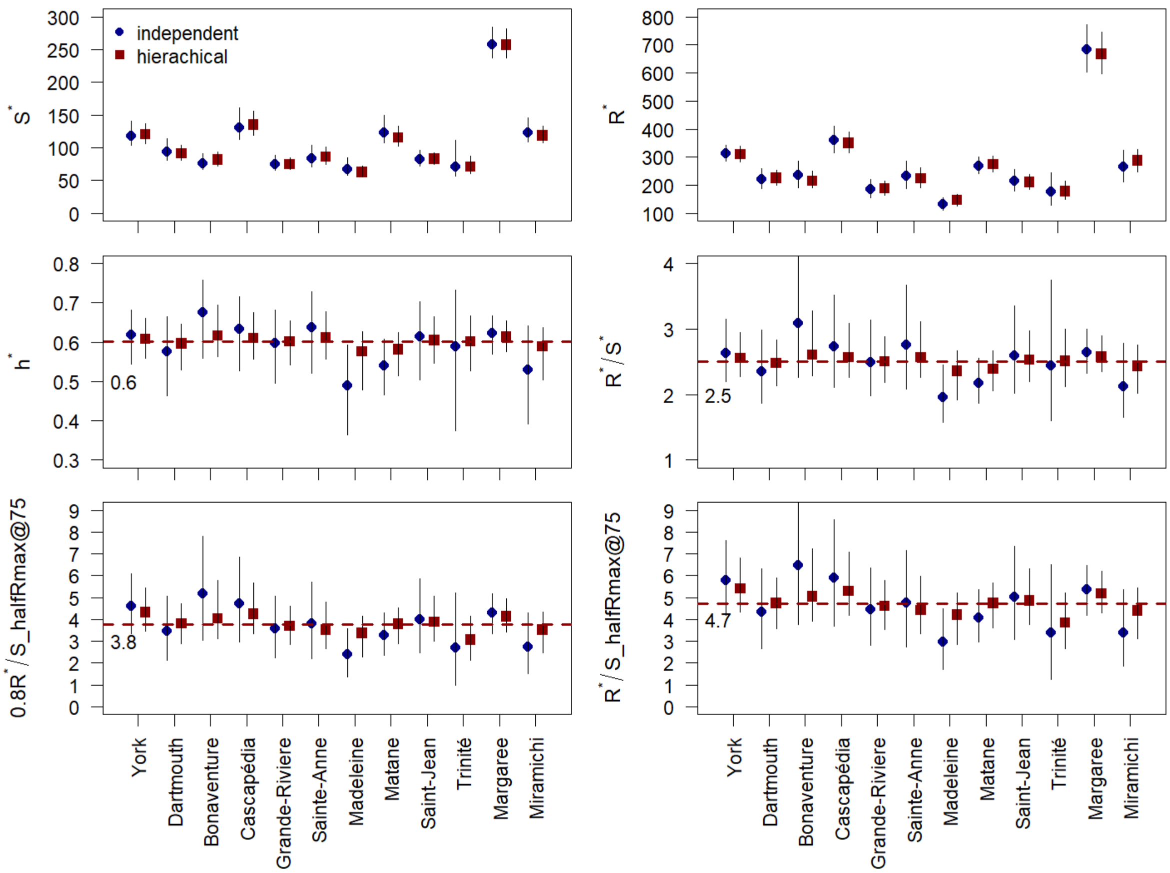


Figure 5. Posterior summaries (median as symbol, 2.5th to 97.5th percentile range as vertical bars) of S and R* (eggs per 100 m²), h*, and different ratios from the independent (blue circle) and hierarchical (red square) model fits to the Ricker stock and recruitment function for ten rivers in Quebec and two Gulf rivers (Margaree and Miramichi) for the cohort years 1972 to 2005. The horizontal red dashed lines and the numbers correspond to the averages of the hierarchical fits across rivers.*

The estimates of R* range from 146 to 667 eggs per 100 m² for the twelve rivers, a factor of 4.6, with the lowest value for the Madeleine River and the highest value for the Margaree River (Table 1). The ratios of R* to S_halfRmax@75 range from 3.84 to 5.41, a lower factor of 1.4, with the lowest value estimated for de la Trinite River and the highest value for the York River (Table 1). The posterior medians of 80%R*/S_halfRmax@75 over the 12 rivers in the hierarchical model range from 3.07 to 4.33 (Figure 5; Table 1).

The river-specific USR is calculated as the product of the ratio of 80%R*/S_halfRmax@75 and the defined LRPs for the rivers of the DFO Gulf Region. The ratio used is the mean of the median values of the 12 rivers from the hierarchical model fits, equal to 3.78 (Table 2; Figure 5). The river-specific TR is calculated as the product of the ratio of R*/S_halfRmax@75 and the defined LRPs for the rivers of the DFO Gulf Region. The ratio used is the mean of the median values of the 12 rivers from the hierarchical model, equal to 4.73 (Table 2; Figure 5).

Table 1 Summary (median with 25th to 75th percentiles range) of the abundance reference values (eggs per 100 m²), removal rate, and ratios from hierarchical fitting of the Ricker function to the reconstructed egg to egg time series by river.

River (time period)	Abundance reference values (eggs per 100 m²) S_halfRmax @75 (LRP)	S*	R*	Rmax	h*	Ratios of USR or TR to LRP USR (80%R*) / S_halfRmax@75	TR (R*) / S_halfRmax@75
Gulf Region rivers							
Miramichi River 1972 – 2005	66 (62 – 70)	119 (115 – 123)	287 (274 – 301)	324 (313 – 336)	0.59 (0.57 – 0.61)	3.52 (3.19 – 3.80)	4.40 (3.98 – 4.75)
Margaree River 1972 – 2005	129 (123 – 134)	257 (250 – 265)	667 (642 – 693)	739 (715 – 763)	0.61 (0.60 – 0.63)	4.14 (3.89 – 4.40)	5.17 (4.86 – 5. 50)
Quebec rivers							
York 1972 – 2004	57 (53 – 61)	120 (116 – 125)	309 (300 – 319)	343 (334 – 353)	0.61 (0.59 – 0.62)	4.33 (4.04 – 4.65)	5.41 (5.05 – 5.81)
Dartmouth 1972 – 2004	47 (44 – 51)	91 (87 – 95)	225 (217 – 234)	253 (244 – 262)	0.60 (0.58 – 0.61)	3.80 (3.52 – 4.07)	4.75 (4.40 – 5.09)
Bonaventure 1972 – 2004	42 (39 – 46)	82 (78 – 85)	216 (206 – 226)	238 (229 – 248)	0.62 (0.60 – 0.64)	4.03 (3.70 – 4.49)	5.04 (4.63 – 5.61)
Cascapedia 1972 – 2003	65 (61 – 70)	135 (129 – 141)	349 (337 – 362)	387 (376 – 400)	0.61 (0.59 – 0.63)	4.24 (3.93 – 4.61)	5.30 (4.91 – 5.77)
Grande-Riviere 1972 – 2004	41 (38 – 44)	75 (72 – 78)	188 (180 – 196)	210 (202 – 218)	0.60 (0.58 – 0.62)	3.68 (3.41 – 3.96)	4.60 (4.26 – 4.95)
Sainte-Anne 1973 – 2005	50 (47 – 55)	86 (82 – 91)	223 (211 – 236)	247 (236 – 260)	0.61 (0.59 – 0.63)	3.52 (3.23 – 3.86)	4.41 (4.04 – 4.82)
Madeleine 1972 – 2005	35 (33 – 38)	62 (60 – 65)	146 (139 – 153)	167 (161 – 173)	0.58 (0.55 – 0.60)	3.37 (3.01 – 3.68)	4.21 (3.76 – 4.60)
Matane 1972 – 2005	58 (54 – 63)	115 (110 – 120)	275 (266 – 284)	311 (302 – 321)	0.58 (0.56 – 0.60)	3.79 (3.49 – 4.08)	4.74 (4.36 – 5.09)
Saint-Jean 1972 – 2005	43 (40 – 46)	83 (80 – 86)	211 (202 – 219)	235 (227 – 243)	0.60 (0.59 – 0.62)	3.88 (3.61 – 4.20)	4.85 (4.51 – 5.24)
De la Trinité 1976 – 2005	46 (42 – 51)	71 (67 – 75)	178 (168 – 190)	199 (188 – 212)	0.60 (0.58 – 0.62)	3.07 (2.77 – 3.35)	3.84 (3.47 – 4.19)

As the proposed TR (R*) is a value corresponding to the maximum sustainable yield, the removal rate is the value that results in maximum sustainable yield when the abundance is at R*. The maximum removal rate in the healthy zone is set at h*, and is similar for all rivers with a value of 0.6 (Figure 5; Table 2).

Table 2. Summary of ratios to define the USR and the TR references and summary of the removal rate (RR) reference obtained from the Bayesian hierarchical stock and recruitment Ricker function for Atlantic Salmon. R is the recruitment at maximum sustainable yield and h* is the exploitation rate that gives the maximum sustainable yield when the abundance is at R*.*

Reference	MSY equivalent	Mean ratio	Range of ratios (median) over rivers
USR (upper stock reference)	80% of R*	3.78	3.07 to 4.32
TR (target reference)	R*	4.73	3.84 to 5.41
RR (maximum removal rate in the healthy zone)	h*	0.60	0.58 to 0.62

The PA graph with the LRP, USR, TR, and RR values for DFO Gulf Region rivers is shown in Figure 6. The total eggs equivalent to the LRP, USR, and TR for rivers of DFO Gulf Region are provided in Appendix 1.

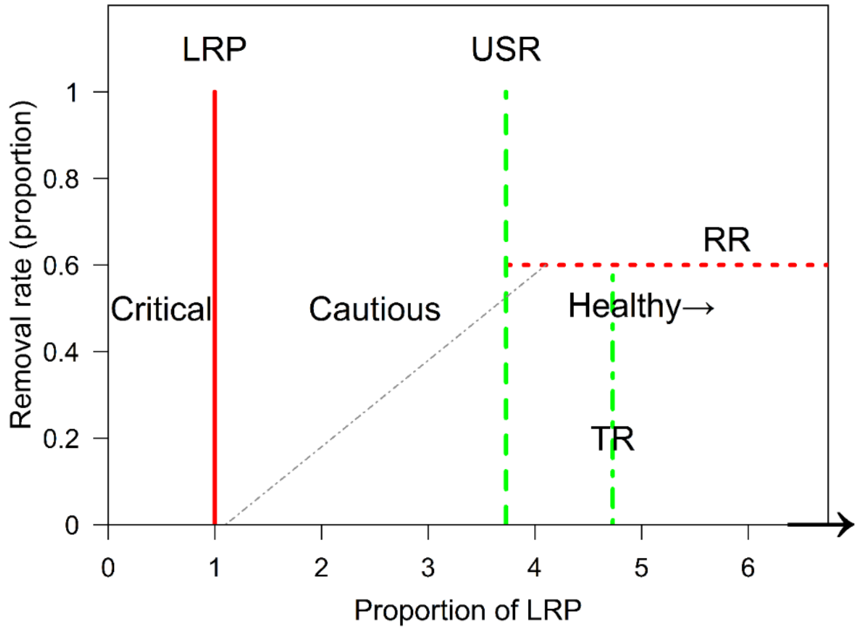


*Figure 6. PA plot of reference points and the three status zones for Atlantic Salmon of DFO Gulf Region rivers. The acronyms in the plot are: LRP = Limit Reference Point, USR = Upper Stock Reference (3.78*LRP), TR = Target Reference (4.73*LRP), and RR = Removal Rate reference (0.6). The stock status axis is shown as a proportion of the LRP. The light grey diagonal dash dotted line is an example of a potential harvest decision rule with a linear decline anchored by two Operational Control Points that are offset from LRP and USR to account for uncertainties in the estimated abundances before fishing.*

Harvest Decision Rules

A DFO Fisheries Management-led working group developed HDRs for the Atlantic Salmon recreational fishery using the Miramichi River as a case study. The candidate HDRs specify recreational fisheries management measures for different stock status categories. The status categories are defined on the scale of the proportion of the LRP of the abundance after Indigenous peoples harvests and before recreational fishing. The two rules are similar in many respects.

- Both HDRs maintain the prohibition on harvest of large salmon in the recreational fishery.
- Both rules 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 allows exploitation when abundances are >= 15% of LRP.
- Neither candidate HDR specifies annual river-specific quotas for retention of small salmon; season limits per licence are not equivalent to an annual quota.
- Both rules include in-season review and abundance triggers, that could provide an opportunity for a fishery in the fall when revised abundance expectations exceed the pre-season abundances that had prescribed no fishing or alternatively that modify the fisheries management measures based on mid-season adjusted expectations that are lower than the pre-season expectations.
- Both rules have inconsistencies in the in-season triggers and pre-season abundance levels that would allow fisheries.

- Both rules incorporate the established warmwater protocol intended to preclude higher catch and release mortality rates under those stressful conditions.

The suite of management measures considered by the DFO-WG are those applied historically to manage the recreational Atlantic Salmon fishery including:

- catch and release only or retention options for small salmon;
- variations in the number of tags issued for retention by licence; and
- variations in the maximum daily catch and release limit.

To evaluate the performance of 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.

The number of recreational fishing licences sold in New Brunswick (NB) were reduced by almost half when mandatory catch and release measures were introduced in 2015. Licence sales and reported effort in the recreational fishery were strongly correlated in Nova Scotia (NS) but the limited information for NB shows no change in effort or exploitation rate in Crown Reserve Waters with declines in licence sales. A reduction in the daily catch and release limit might be expected to reduce the total catch if there was compliance with the measure. There are no data that could inform on this expectation and in the evaluation of the candidate HDRs, the above measures were assumed to have no effect on exploitation rate.

The practice of catch and release fishing has been increasing in popularity, even when retention of salmon was allowed. The proportion of the reported catch that would be released is expected to increase as the daily retention limits are reduced (e.g., from two fish to one fish) and possibly as a result of the reduction in the daily season retention limit. An analysis of the angler reports for SFA 18 and the Margaree River shows a clear association between the proportion of the small salmon catch that is released and the season retention bag limit.

A portion of the fish that are caught and released will not survive to spawn. Three catch and release mortality scenarios were considered, informed by studies and water temperature characteristics of the Miramichi River, with mortality rates dependent on the season of capture (Table 3). In the current assessment for the Miramichi River, a 3% mortality rate on the season total catch of salmon (small or large) is assumed (DFO 2020). A meta-analysis on the effect of river temperature on post-angling mortality confirmed the conclusions of 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 the mortality rate was higher for smaller salmon than larger salmon (Van Leeuwen et al. 2020). The modelled mortality rates ranged from 1-5% at water temperatures less than 12 °C, 4-16% at water temperatures between 12 °C and 18 °C, and ranged from 7-33% at water temperatures between 18 °C to 20 °C (Van Leeuwen et al. 2020). Based on the recent study of Keefe et al. (2022), a catch and release mortality scenario of 25% that would apply for water temperatures of 18 °C and greater was also considered.

Overall, there is insufficient information on annual effort and exploitation rate in the Miramichi River, and their association with licence sales, season retention limits, daily retention limits, and catch and release limits to be able to translate the management measures described in the decision rules to expected exploitation rates. Consequently, the exploitation rates for the decision rules were derived using a number of assumptions and data specific to the Northwest (NW) Miramichi and Southwest (SW) Miramichi rivers (Table 3):

- The exploitation rate by size group is assumed to be independent of any management measure, the same over the abundance range prior to the fishery, and assumed to be equal to the average of available estimates from the years 1984 to 1997 (excluding 1996).
- The average proportions of the total eggs attributed to the large salmon returns for the NW Miramichi and the SW Miramichi rivers (DFO 2018b) are assumed to be the same over the entire abundance range prior to the fishery.
- If retention of small salmon is allowed with a season limit of one fish (one tag per licence; rule 2), it is assumed that 75% of the catch is retained and 25% of the catch is released. For all other cases, it is assumed that the retained small salmon equals the catch of small salmon and there is no catch and release of small salmon.
- The kelt fishery is ignored in this exercise. The eggs from repeat spawning salmon are included in the large salmon contribution.
- Losses from catch and release are calculated as the season-specific mortality rates weighted by season proportions of the catch.

Table 3. Atlantic Salmon angling characteristics by river, size group and season used in the translation of management measures to exploitation rates and in the simulation model of decision rule performance. The average characteristics in terms of the proportion returns, eggs per fish and proportion eggs are from DFO (2018b).

Characteristic	Specifics	NW Miramichi	SW 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) (average 1984 to 1997 excluding 1996)	small salmon	0.423	0.361
	large salmon	0.283	0.392
Proportion catch late season (average 1984 to 1994)	small	0.124	0.337
	large	0.179	0.397
Catch and release mortality rate scenarios			
Scenario 1: ~ 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)
Scenario 2: based on 16% in summer and 3% in fall	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)
Scenario 3: based on 25% in summer and 4% in fall	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)

The profiles of the percentages of the eggs lost for different abundances prior to the fishery for the pre-season management measures of the two candidate HDRs are shown in Figure 7. Because of differences in biological characteristics (proportion of eggs from large salmon) and fisheries exploitation rates between rivers, the profiles of the percentage of eggs lost differ between the rivers with higher maximum losses in the NW Miramichi compared to the SW Miramichi rivers (Figure 7). Losses are more important for higher catch and release mortality rate assumptions.

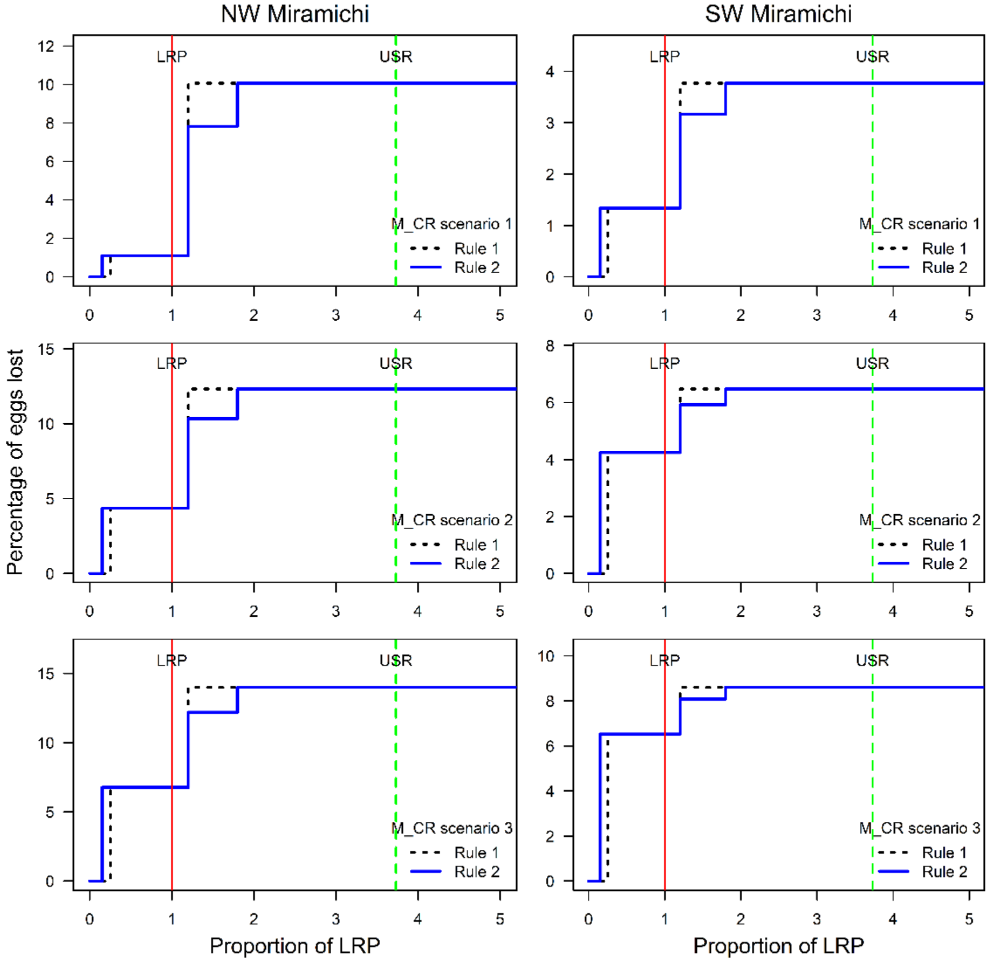


Figure 7. Pre-season decision rule profiles by river based on average and deterministic values of biological and recreational fisheries characteristics of the NW Miramichi (left column) and the Southwest Miramichi rivers (right column) from Table 3. The upper row assumes a season average catch and release mortality rate of approx. 3% whereas the middle and lower rows are based on higher assumed summer and fall catch and release mortality rates as described in Table 3.

DFO (2006, 2009) outline the minimal elements of a harvest strategy for fisheries on exploited species that 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).
- 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 Rate reference.

The performance of the candidate HDRs was also examined by simulating a fisheries management decision based on pre-season abundance forecasts of small salmon and large salmon to each of the Northwest Miramichi and Southwest Miramichi rivers. The pre-season abundance forecast scenarios chosen were the median of the posterior distributions of the estimated returns, i.e., a very accurate forecast. The characteristics of the angling fishery by river, size group, and season are those in Table 3. Catch and release mortality values were simulated with uncertainty for the default 3% mortality rate and for higher simulated mortality rates that could apply to the situation in the Miramichi River (Table 3). No assessment of in-season 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 performance of the candidate HDRs were evaluated using two risk criteria:

- whether there was greater than 5% probability that the estimated abundance after fishing fell below the LRP when the abundance before fishing was above the LRP with > 95% probability, 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.

HDR compliance to the PA

Several characteristics of the candidate HDRs for the recreational Atlantic Salmon fishery comply with the characteristics of harvest strategies under the PA but there are deficiencies (Table 4).

- Three status zones are defined [PA compliant].
- The maximum anticipated removal rate in the healthy zone is less than the defined maximum removal rate. This is primarily because the management measures prohibit the harvesting of large salmon that are the majority egg-bearing females [PA compliant].
- Management measures are identified that would apply at different abundance levels in the three zones [PA compliant].
- Management measures result in a decrease (translated) in the removal rate from the healthy zone towards the critical zone [PA compliant].
- 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 [PA compliant].
- Management measures allow for directed recreational fisheries in the critical zone [does not comply with PA; but see paragraph below].
- In terms of performance to manage the risk of falling into the critical zone because of fishing, in some years the removal rates result in the stock falling into the critical zone with > 5% probability and in a few cases, a breach of the LRP occurred [does not comply with PA].

The harvest strategy characteristic that engenders the greatest debate is whether a directed salmon fishery when the abundance is in the critical zone is consistent with promoting stock growth, keeping removals to the lowest possible level, and having 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% dependent on the assumptions of 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). Limiting illegal removals through effective enforcement or other management actions are important conservation measures; particularly so when a stock is in the critical zone. However, quantifying the potential conservation benefits resulting from a directed recreational fishery that may deter illegal fishing and support engagement and stewardship is challenging, with the limited data available.

Table 4. Summary of characteristics of harvest strategies and an assessment of compliance of the candidate harvest decision rules to the PA policy (DFO 2006, 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 6% or 12% dependent on river 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).
	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.

Sources of Uncertainty

Uncertainties in these analyses arise from the reconstruction of time series of stock and recruitment abundances, from incomplete accounting of fisheries activities, from the assumptions associated with model fitting, and from variations in life history characteristics and population dynamics resultant of the freshwater and marine environments occupied in the anadromous Atlantic Salmon life cycle.

In all the time series reconstructions, a number of simplifying assumptions were made to translate harvest weight in commercial fisheries to harvest by number, to estimate abundances by age class, and in the biological characteristics of the anadromous salmon. Using average values, such as the proportions at age, to estimate abundances of cohorts may result in auto-correlation in the returns and spawners data. The simplifying assumptions are expected to underestimate the uncertainties in the estimated abundances.

The reconstructed estimates of spawners and returns are not independent. This absence of independence is in part the result of the reconstruction of the data, the age lag used to attribute fish to their year-class, and the non-independent processes in nature acting on several cohorts of fish at similar times. Ignoring this lack of independence leads to more confident assessments than the data would justify.

In at least four rivers in the hierarchical analysis, the temporal trends in residuals provide evidence of a change in productivity which is considered to be occurring in the marine environment. The change in productivity has been noted in a relatively short time series of a few decades (1971 to 2004). Including periods of high productivity and low productivity in a joint analysis results in parameter estimates that are averaged over these productivity states. As the perceived trend in productivity is from a high state to a low state, the estimated reference values are higher than what would be calculated using only the data from the recent time period of low productivity. The factors acting after the smolt stage that are considered to be driving the reduced productivity of salmon at sea are considered to be reversible. The use of a longer time series is consistent with reviews and conclusions of DFO (2013, 2016) that reference points should not be changed due to changes in productivity but rather to adapt robust control rules for changing conditions.

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. In absence of informative data, assumptions from historical periods with effort and exploitation rates are used to translate the management measures into removal rates. This is unlikely to be appropriate due to abundance declines and expected waning of interest in the recreational fishery.

Under current management measures for the Atlantic Salmon recreational fishery and as maintained in the HDRs, no retention of large salmon is permitted and some to all of the small salmon catch may also be released. 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. As the HDRs propose maintaining directed recreational salmon fisheries when the abundance is in the critical zone, the resulting losses are very dependent upon the mortality from catch and release fishing. Climate change predictions are for warmer river temperatures in the summer and early fall possibly leading to more days when fish are exposed to higher post-release mortality rates than assumed.

There has not been any reliable 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. Implementation of the candidate HDR and the auditing of its performance are constrained by the absence of such data.

There is limited data on the extent of poaching/illegal fishery losses of salmon in the rivers. It has been stated by recreational fishing and conservation organizations that a directed recreational salmon fishery can reduce the risk to conservation because the presence of anglers on the river will reduce the level of illegal activities. There is limited evidence supporting this claim.

CONCLUSIONS AND ADVICE

Reference Points

Combined with the advice in DFO (2018b) that defines the LRPs, the first component of the PA framework requiring reference points to delineate critical, cautious and healthy zones has been completed for Atlantic Salmon of DFO Gulf Region rivers. A ratio approach of USR or TR to LRP references derived from adult to adult stock and recruitment data analyses is used to define the USR, TR references. The calculated ratios represent the spread between the LRP and the USR or TR obtained from adult to adult stock and recruitment data which are then applied to the defined LRP based on the freshwater phase.

The LRP, USR, and TR are defined for each river in DFO Gulf Region which is known or assumed to have an anadromous salmon run (Appendix 1). The reference points are expressed in units of eggs contributed by all anadromous sea age and size groups. Scaling the total eggs in the returns and spawners as well as the reference points by the size of the rivers, defined as the total wetted fluvial area used by salmon, is a practical way to compare the status of different sized rivers and salmon populations.

The boundary of the cautious / healthy zones (USR) is approximately four times higher than the boundary of the critical and cautious zones (LRP). The spread between the LRP and the TR is a value of 4.73. These spreads should provide ample time for management response to reduce exploitation rate when stock abundance declines and take action to move the stock toward the healthy zone (DFO 2009). At those reference values, the Miramichi River anadromous salmon returns may have been at or just above the USR in only 2 of 49 years during the period of 1971 to 2019 (excluding commercial fisheries removals in earlier years), and below the LRP (point estimate) in 2 of those years. The status of the Margaree River relative to the reference values is quite different from the Miramichi River; in most years post 1985, the abundance has been in the cautious and healthy zones.

The removal rate equivalent to h*, that results in maximum sustained yield (MSY) when the recruitment is at MSY, defines the RR reference for all the rivers. The mean value of h* is 0.6.

In DFO (2009), the LRP was considered to be a threshold to be avoided and since the LRP defines a point below which there is an increasing chance of serious and irreversible harm, it can be interpreted as a point to be avoided with high probability, as for example 95% chance of being above the LRP. DFO (2021a) states that science guidelines should establish consistency in the way that stock status is determined:

> “Unless otherwise defined in stock-specific precautionary approach frameworks, as general guidance, 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."

In previous stock status reports of Atlantic Salmon in eastern Canada, the status has generally been reported as being above or below the LRP (DFO 2020). These assessments of status were made based on the midpoint of the estimated abundance, consistent with advice in DFO (2021a). For some assessed rivers in DFO Gulf Region, the uncertainties in the abundances are quantified in which case the status relative to the defined reference points could be presented in terms of probabilities of exceeding the LRP, the USR and TR.

Harvest Decision Rule

The biological characteristics of the anadromous salmon runs and recreational fisheries characteristics (exploitation rates by season, harvest proportions by season) can differ among rivers with the consequence that the same candidate HDR can result in different removal rate profiles for different rivers. An evaluation of the performance of the HDR for a particular river will be required using river-specific biological characteristics and recreational fisheries characteristics information.

The candidate HDRs reviewed, that are specific to the Miramichi River, 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 in the cautious zone. 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.

A key element in the PA policy (DFO 2009) and in the subsequent guidance in the stock rebuilding provisions (DFO 2019b) and science advice (DFO 2021a, 2021b) is 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 evaluated would allow a directed catch and release recreational fishery when the abundance is in the critical zone; one rule would open a directed fishery when the abundance is >= 15% of LRP and the other rule would do so when the abundance is >= 25% of LRP. 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 exploitation rate and 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. The decision must ultimately be made by management.

The implementation of the candidate HDRs requires a forecast of expected abundance prior to the fishery. A fuller evaluation of the performance of a candidate HDR, that considers the biases and uncertainties of the candidate forecast models, the in-season models, and any improved information that would be informative of exploitation rates expected for the different effort controls of the management measures, will be required before the HDR can be implemented. 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 after fishing that exceed defined probability thresholds.

LIST OF MEETING PARTICIPANTS

Name	Affiliation
Jenni McDermid (chair)	DFO Science Gulf Region
Cindy Breau (science author)	DFO Science Gulf Region
Guillaume Dauphin (science author)	DFO Science Gulf Region
Gérald Chaput(science author)	DFO Science Gulf Region
Sunci Avlijas (science author)	DFO Science Gulf Region
Julien April (science author)	Ministère des Forêts, de la Faune et des Parcs Province of Quebec
Alan Walker (external reviewer)	Center for Environment Fisheries and Aquaculture Science, Lowestoft, UK
Jonathan Gillson (external reviewer)	Center for Environment Fisheries and Aquaculture Science, Lowestoft, UK
Dustin Raab (DFO internal reviewer)	DFO Science Maritimes Region
John Bagnall	New Brunswick Salmon Council
Fréderic Butruille	DFO Fisheries Management and Indigenous Affairs Gulf Region
Kathryn Collet	NB Dept. of Natural Resources and Energy Development
Chris Connell	NB Dept. of Natural Resources and Energy Development
Abby Daigle	DFO Science Gulf Region
Jason Daniels	Atlantic Salmon Federation
Christina Davis	New Brunswick Aboriginal Peoples Council
Scott Douglas	DFO Science Gulf Region
Michelle Fitzsimmons	DFO Science Newfoundland Region
Carole-Anne Gillis	Listiguij First Nation
Matthew Hardy	DFO Science Gulf Region
Matt Horsman	DFO Science Gulf Region
Sam Hudson	DFO Science Gulf Region
Malian (Tamara) Joseph	Mi’gmawe’l Tplu’taqnn Incorporated
Nick Kelly	DFO Science Newfoundland Region
Mark LaFlamme	DFO Science Gulf Region
Eric Leblanc	DFO Fisheries Management Gulf Region
Andrew Lowles	NS Dept. of Fisheries and Aquaculture
Shannan May-McNally	DFO Science Ottawa
Colin MacFarlane	DFO Science Gulf Region
Robyn McCallum	Miramichi Salmon Association
Kelsey McGee	DFO Science Gulf Region
Scott Roloson	DFO Science Gulf Region
Amelie Rondeau	DFO Science Gulf Region
Chantal Roussel	DFO Science Gulf Region
Andrew Taylor	DFO Science Maritimes Region
Mary Thiess	DFO Science Ottawa
Kari Underhill	DFO Science Gulf Region
Devin Ward	Anqotum Resource Management
Nathan Wilbur	Atlantic Salmon Federation

SOURCES OF INFORMATION

This Science Advisory Report is from the February 23-24, 2022 regional peer review on Upper Stock Reference Points for Atlantic Salmon Rivers in DFO Gulf Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2006. A Harvest Strategy Compliant with the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2006/023.

DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach. (Date modified: 2009-03-23).

DFO. 2013. Proceedings of the National Workshop for Technical Expertise in Stock Assessment (TESA): Maximum Sustainable Yield (MSY) Reference Points and the Precautionary Approach when Productivity Varies; December 13-15, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/055.

DFO. 2015. Development of reference points for Atlantic salmon (*Salmo salar*) that conform to the Precautionary Approach. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/058.

DFO. 2016. Proceedings of the National Peer Review on the Development of Technical Guidelines for the Provision of Scientific Advice on the Various Elements of Fisheries and Oceans Canada Precautionary Approach Framework; February 28-March 1, 2012. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2015/005.

DFO. 2018a. Canada's Wild Atlantic Salmon Conservation Policy. (Date modified: 2018-04-11).

DFO. 2018b. Limit Reference Points for Atlantic Salmon Rivers in DFO Gulf Region. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/015.

DFO. 2019a. Wild Atlantic salmon conservation: Implementation plan 2019 to 2021. (Date modified: 2019-05-27).

DFO. 2019b. Guidance for the development of rebuilding plans under the Precautionary Approach Framework: Growing stocks out of the critical zone. (Date modified: 2019-09-27).

DFO. 2020. Update of indicators of Atlantic Salmon (*Salmo salar*) in DFO Gulf Region Salmon Fishing Areas 15 - 18 for 2019. DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/028.

DFO. 2021a. Science Advice for Precautionary Approach Harvest Strategies under the Fish Stocks Provisions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/004.

DFO. 2021b. Science Guidelines to Support Development of Rebuilding Plans for Canadian Fish Stocks. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/006.

Dionne, M., Dauphin, G., Chaput, G., et E. Prévost. 2015. Actualisation du modèle stock-recrutement pour la conservation et la gestion des populations de saumon atlantique du Québec, ministère des Forêts, de la Faune et des Parcs du Québec, Direction générale de la gestion de la faune et des habitats, Direction l'expertise sur la faune aquatique, 66 p.

ICES. 2021. Working Group on North Atlantic Salmon (WGNAS). ICES Scientific Reports. 3:29. 407 pp.

Keefe, D., Young, M., Van Leeuwen, T.E., and Adams, B. 2022. Long-term survival of Atlantic salmon following catch and release: Considerations for anglers, scientists and resource managers. Fish. Manag. Ecol. 2022;00:1–12. DOI: 10.1111/fme.12533.

Olmos, M., Payne, M.R., Nevoux, M., Prévost, E., Chaput, G., Du Pontavice, H., Guitton, J., Sheehan, T., Mills, K., and Rivot, E. 2020. Spatial synchrony in the response of a long range migratory species (*Salmo salar*) to climate change in the North Atlantic Ocean. Global Change Biology 26: 1319–1337.

Van Leeuwen, T.E., Dempson, J. B., Burke, C. M., Kelly, N. I., Robertson, M. J., Lennox, R. J., Havn, T. B., Svenning, M.-A., Hinks, R., Guzzo, M. M., Thorstad, E. B., Purchase, C. F., and Bates, A. E. 2020. Mortality of Atlantic salmon after catch and release angling: Assessment of a recreational Atlantic salmon fishery in a changing climate. Can. J. Fish. Aquat. Sci. 77: 1518-1528.

APPENDIX 1

Appendix 1. List of Atlantic Salmon rivers in DFO Gulf Region and their corresponding abundance reference points. The list is taken from DFO (2018b) with new values for the USR and TR points.

Salmon Fishing Area	River	Drainage area (km²)	Fluvial area (million m²)	LRP (eggs; million)	USR (eggs, million)	TR (eggs, million)
15	Restigouche (NB)	6,589	26.390	40.113	152.429	189.333
15	Eel River	217	0.422	0.641	2.436	3.026
15	Charlo	282	0.423	0.643	2.443	3.035
15	South Charlo	118	0.177	0.269	1.022	1.270
15	Blackland Brook	na	na	na	na	na
15	New Mills	na	na	na	na	na
15	Benjamin	161	0.242	0.366	1.391	1.728
15	Nash Creek	na	na	na	na	na
15	Louison River	142	0.213	0.324	1.231	1.529
15	Jacquet	510	1.135	1.725	6.555	8.142
15	Armstrong Brook	na	na	na	na	na
15	Patapat Brook (Belledune)	na	na	na	na	na
15	Fournier Brook	na	na	na	na	na
15	Elmtree River	297	0.446	0.678	2.576	3.200
15	Little Elmtree River	na	na	na	na	na
15	Nigadoo	168	0.252	0.383	1.455	1.808
15	Millstream	229	0.344	0.523	1.987	2.469
15	Peters River	na	na	na	na	na
15	Tetagouche	364	0.299	0.455	1.729	2.148
15	Middle (Gloucester Co.)	401	0.950	1.444	5.487	6.816
15	Little River	na	na	na	na	na
15	Nepisiguit	2,312	3.973	6.039	22.948	28.504
15	Bass (Gloucester Co.)	198	0.297	0.451	1.714	2.129
15	Miller Brook	na	na	na	na	na
15	Teagues Brook	237	0.356	0.541	2.056	2.554
15	Little Pokeshaw River	na	na	na	na	na
15	Pokeshaw River	na	na	na	na	na
15	Riviere du Nord	na	na	na	na	na
15	Caraquet	373	0.560	0.851	3.234	4.017
15	Pokemouche	481	0.248	0.377	1.433	1.779
15	Little Tracadie	192	0.288	0.438	1.664	2.067
15	Tracadie	527	0.601	0.914	3.473	4.314
16	Tabusintac	704	0.824	1.25	4.750	5.900
16	Burnt Church	135	0.299	0.46	1.748	2.171
16	Oyster	na	na	na	na	na
16	Bartibog	512	1.135	1.73	6.574	8.166
16	Northwest Miramichi	2,138	8.230	14.48	55.024	68.346
16	Northwest Millstream	210	0.479	0.84	3.192	3.965
16	Little Southwest Miramichi	1,345	8.070	14.2	53.960	67.024
16	Southwest Miramichi	5,840	29.530	44.89	170.582	211.881
16	Renous	1,429	5.820	8.85	33.630	41.772

Salmon Fishing Area	River	Drainage area (km²)	Fluvial area (million m²)	LRP (eggs; million)	USR (eggs, million)	TR (eggs, million)
16	Barnaby	490	1.304	1.98	7.524	9.346
16	Napan	115	0.115	0.17	0.646	0.802
16	Black (Northumberland Co.)	277	0.277	0.42	1.596	1.982
16	Bay du Vin	284	0.284	0.43	1.634	2.030
16	Eel River	116	na	na	na	na
16	Portage River	na	na	na	na	na
16	Riviere au Portage	na	na	na	na	na
16	Black (Kent Co.)	343	0.343	0.52	1.976	2.454
16	Rankin Brook	na	na	na	na	na
16	Kouchibouguac (Kent Co.)	389	0.588	0.89	3.382	4.201
16	Ruisseau des Major	25	na	na	na	na
16	Kouchibouguacis	360	0.549	0.83	3.154	3.918
16	Saint Charles	149	na	na	na	na
16	Molus River	172				
16	Bass River	115				
16	Richibucto	449	1.226	1.86	7.068	8.779
16	Coal Branch	212				
16	Saint Nicholas	194				
16	Chockpish	129	0.129	0.2	0.760	0.944
16	Black	na	na	na	na	na
16	Buctouche	566	0.661	1	3.800	4.720
16	Cocagne	333	0.283	0.43	1.634	2.030
16	Shediac	219	0.216	0.33	1.254	1.558
16	Scoudouc	159	0.146	0.22	0.836	1.038
16	Aboujagane	120	0.120	0.18	0.684	0.850
16	Kinnear Brook	na	na	na	na	na
16	Kouchibouguac (Westmorland Co.)	346	na	na	na	na
16	Tedish River	na	na	na	na	na
16	Gaspereau (Westmorland Co.)	170	0.170	0.26	0.988	1.227
16	Baie Verte	38	0.058	0.09	0.342	0.425
17	Cains Brook, Mill River	30.9	0.023	0.036	0.137	0.170
17	Carruthers Brook, Mill River	47.9	0.035	0.056	0.213	0.264
17	Trout River (Coleman)	107.1	0.140	0.222	0.844	1.048
17	Trout River, Tyne Valley	48.3	0.063	0.096	0.365	0.453
17	Little Trout River	21.3	0.028	0.042	0.160	0.198
17	Bristol (Berrigans) Creek	41.4	0.054	0.082	0.312	0.387
17	Morell River	170.6	0.237	0.375	1.425	1.770
17	Midgell River	63.8	0.083	0.127	0.483	0.599
17	St. Peters River	44.6	0.058	0.089	0.338	0.420
17	Cow River	22.8	0.030	0.045	0.171	0.212
17	Naufrage River	43.6	0.057	0.087	0.331	0.411
17	Bear River	17.2	0.022	0.034	0.129	0.160
17	Hay River	25.7	0.034	0.051	0.194	0.241
17	Cross Creek	44.3	0.058	0.088	0.334	0.415
17	Priest Pond Creek	24.9	0.033	0.049	0.186	0.231
17	North Lake Creek	47.7	0.062	0.095	0.361	0.448
17	Vernon River	69.2	0.091	0.138	0.524	0.651
17	Clarks Creek	46.3	0.061	0.092	0.350	0.434

Salmon Fishing Area	River	Drainage area (km²)	Fluvial area (million m²)	LRP (eggs; million)	USR (eggs, million)	TR (eggs, million)
17	Pisquid River	47.6	0.062	0.095	0.361	0.448
17	Head of Hillsborough R.	53.1	0.070	0.106	0.403	0.500
17	North River	99.0	0.130	0.197	0.749	0.930
17	Clyde River	41.7	0.054	0.083	0.315	0.392
17	West River	114.1	0.185	0.292	1.110	1.378
17	Dunk River	165.7	0.193	0.305	1.159	1.440
17	Wilmot River	83.4	0.110	0.166	0.631	0.784
18	Salmon River	na	na	na	na	na
18	Blair River	58	0.097	0.148	0.562	0.699
18	Red River	35	0.059	0.089	0.338	0.420
18	Grande Anse River	51	0.085	0.13	0.494	0.614
18	Mackenzies River	75	0.124	0.189	0.718	0.892
18	Fishing Cove River	31	0.052	0.079	0.300	0.373
18	Corneys Brook	na	na	na	na	na
18	Anthony Aucoin’s Brook	na	na	na	na	na
18	Rigwash Brook	na	na	na	na	na
18	Chéticamp River	298	0.319	0.489	1.858	2.308
18	Aucoin Brook	na	na	na	na	na
18	Fiset Brook	na	na	na	na	na
18	Farm Brook	na	na	na	na	na
18	Margaree River	1,100	2.798	4.252	16.158	20.069
18	Smiths Brook	na	na	na	na	na
18	Broad Cove River	na	na	na	na	na
18	Mill Brook	na	na	na	na	na
18	Northeast Mabou River	254	0.424	0.645	2.451	3.044
18	Southwest Mabou River	123	0.154	0.234	0.889	1.104
18	Mabou River	188	0.235	0.357	1.357	1.685
18	Captains Brook	34	0.057	0.086	0.327	0.406
18	Judique Intervale Brook	44	0.074	0.112	0.426	0.529
18	Graham River	na	na	na	na	na
18	Campbells Brook	na	na	na	na	na
18	Chisholm Brook	17	0.028	0.042	0.160	0.198
18	Mill Brook (Strait of Canso)	na	na	na	na	na
18	Wrights River	na	na	na	na	na
18	Tracadie River	120	0.053	0.08	0.304	0.378
18	Afton River	43	0.019	0.029	0.110	0.137
18	Pomquet River	176	0.077	0.117	0.445	0.552
18	South River	217	0.095	0.144	0.547	0.680
18	West River (Antigonish)	353	0.480	0.73	2.774	3.446
18	North River	na	na	na	na	na
18	MacInnis Brook	na	na	na	na	na
18	Doctors Brook	na	na	na	na	na
18	Vameys Brook	na	na	na	na	na
18	Baileys Brook	na	na	na	na	na
18	Barneys River	156	0.213	0.323	1.227	1.525
18	French River (Merigomish)	128	0.174	0.264	1.003	1.246
18	Russell Brook	na	na	na	na	na
18	Sutherlands River	na	0.067	0.101	0.384	0.477

Salmon Fishing Area	River	Drainage area (km²)	Fluvial area (million m²)	LRP (eggs; million)	USR (eggs, million)	TR (eggs, million)
18	Pine Tree Brook	na	na	na	na	na
18	East River (Pictou)	536	0.729	1.108	4.210	5.230
18	Middle River (Pictou)	217	0.295	0.449	1.706	2.119
18	West River (Pictou)	245	0.333	0.506	1.923	2.388
18	Haliburton Brook	na	na	na	na	na
18	Big Caribou River	na	na	na	na	na
18	Toney River	na	na	na	na	na
18	River John	292	0.397	0.604	2.295	2.851
18	Waughs River	230	0.313	0.476	1.809	2.247
18	French River	206	0.280	0.426	1.619	2.011
18	Wallace River	458	0.623	0.947	3.599	4.470
18	Pugwash River	182	0.247	0.375	1.425	1.770
18	River Philip	726	0.962	1.462	5.556	6.901
18	Shinimicas River	na	na	na	na	na

THIS REPORT IS AVAILABLE FROM THE:

Centre for Science Advice (CSA)
Gulf Region
Fisheries and Oceans Canada
P.O. Box 5030
Moncton, NB E1C 9B6

E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

ISSN 1919-5087
ISBN 978-0-660-44175-7 N° cat. Fs70-6/2022-027E-PDF

Correct Citation for this Publication:

DFO. 2022. Definition of Precautionary Approach Reference Points for Atlantic Salmon, DFO Gulf Region. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2022/027.

Aussi disponible en français :

MPO. 2022. Définition des points de référence de l'approche de précaution pour le saumon atlantique, région du Golfe du MPO. Secr. can. des avis sci. du MPO. Avis sci. 2022/027.