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Gulf Region

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Science Response 2018/015

LIMIT REFERENCE POINTS FOR ATLANTIC SALMON RIVERS IN DFO GULF REGION

Context

Fisheries and Oceans Canada (DFO) Ecosystems and Fisheries Management Branch asked DFO Science to develop reference points for Atlantic Salmon that conform to "A fishery decision-making framework incorporating the Precautionary Approach" (DFO 2009a). That request followed on an action item associated with the implementation of the Wild Atlantic Salmon Conservation Policy (WASCP; DFO 2009b) to review benchmarks / reference points for Atlantic Salmon which conform to the Precautionary Approach (PA). As a first step, DFO (2015) provided advice on the development of limit reference points (LRP) for Atlantic Salmon that conform to the PA. Specifically, DFO (2015) stated that the LRP should be determined based on a risk analysis of the spawning escapement that results in a low probability (25% or less) of the recruitment being less than 50% of maximum recruitment. Based on this advice and supporting analyses, LRPs in units of eggs per m² of fluvial habitat area are defined for Atlantic Salmon rivers in DFO Gulf Region. A stock and recruitment model with a covariate corresponding to the proportion of the eggs in the returns contributed by large salmon was used to define river specific values. This Science Response Report results from the Science Response Process of February 8, 2018 on Limit Reference Points for Atlantic Salmon rivers in Salmon Fishing Areas 15 to 18, DFO Gulf Region. This is a step in the development of the PA framework. Further work is required to complete the PA framework including the definition of the Upper Stock Reference point(s), harvest strategies, and harvest decision rules.

Background

A fishery decision-making framework incorporating the Precautionary Approach (PA framework; DFO 2009a) has three components:

1. Reference points and stock status zones (Healthy, Cautious and Critical),
2. Harvest strategy and harvest decision rules, and
3. The need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules.

DFO (2015) provided advice on some aspects of the first element of the PA framework including development of reference points for Atlantic Salmon including consideration of candidate reference points, the appropriateness of using reference points specific to variations in productivity, analyses and candidate values of reference points for Atlantic Salmon, and methods to transfer reference points from monitored rivers to data limited rivers. The Limit Reference Point (LRP) is defined as the stock level below which productivity is sufficiently impaired to cause serious harm (DFO 2009a). The LRP is based on biological criteria and established by Science through a peer reviewed process (DFO 2009a). The Upper Stock Reference (USR) is the stock level below which losses must be progressively reduced in order to avoid reaching the LRP. The USR would be developed by fishery managers informed by consultations with the fishery and other interests, with advice and input from Science (DFO 2009a).

DFO (2015) advice is summarized as follows:

- The Limit Reference Point (LRP) is defined taking into account biological and population dynamics aspects of the salmon population unrelated to fishery exploitation objectives (DFO 2009a, 2015).
- Changes in productivity in either the freshwater or marine phase of the life cycle will have consequences on the derivation of reference points. If the average productivity conditions in freshwater have not changed over time, then limit reference points defined on the basis of maintaining a portion of the freshwater carrying capacity (a portion of maximum recruitment; Rmax) would be robust to changes in productivity in the marine phase.
- The LRP for Atlantic Salmon in this report is defined on the basis of maintaining production of the life stages in freshwater. At a minimum, the LRP is defined as the abundance of spawners that results in 25% or less chance of recruitment (as smolts or adults) being less than half of maximum recruitment.
- There are no data to estimate river-specific stock and recruitment relationships from all the rivers with Atlantic Salmon populations in eastern Canada. The transfer of reference points requires that the covariates which are used to model the stock and recruitment parameters from monitored rivers be equally available for the unmonitored rivers. Covariates that could be considered include the amount of habitat, the latitude of the river, the presence and amount of lacustrine habitat (lakes), the mean age of smolts, and the proportion of the eggs which are contributed by large (multi-sea-winter) salmon.
- The appropriateness of transporting reference points to rivers which are larger and smaller than those included in the stock and recruitment analyses is not known. For small rivers with small spawner population sizes, other considerations based on effective population sizes and maintaining genetic variability should be considered.

The definition of LRPs for Atlantic Salmon rivers of DFO Gulf Region in this report is the initial step in the development of the PA framework. Further work is required to complete the PA framework including definition of the Upper Stock Reference Point(s), harvest strategies, and harvest decision rules.

Analysis and Response

Following on the advice in DFO (2015), Limit Reference Points (LRPs) for Atlantic Salmon rivers in DFO Gulf Region were defined using the following approach:

- Analyses of data from 14 rivers of eastern Canada with egg deposition and smolt production data as described by Chaput et al. (2015). This data set includes observations from two rivers in DFO Gulf Region, the Margaree River (SFA 18) and the Kedgwick River (tributary of the Restigouche River, SFA 15).
- The model selected was a Beverton-Holt stock recruitment relationship.
- Considered in the model was a covariate that accounted for the proportion of eggs in the returns contributed by large salmon.
- The LRP is the egg deposition rate that results in a low probability (<= 25%) that resulting recruitment will be less than 50% of maximum recruitment (Fig. 1).

- A river is defined as a fluvial system with its outlet directly into tidal water.
- Habitat areas considered are wetted fluvial areas, unadjusted for habitat characteristics, type, quality, and other features.

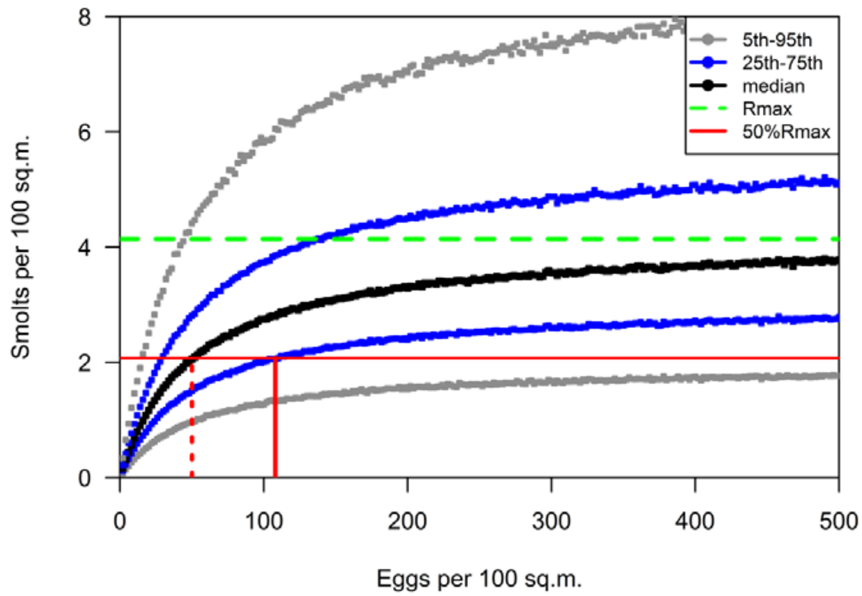

Figure 1. Predicted egg to smolt stock recruitment dynamic based on a Beverton-Holt model. The egg deposition that results in a 75% chance that the predicted recruitment will be at least 50% of maximum recruitment is shown as the solid vertical red line in contrast to the egg deposition that results in a 50% chance of being at half of maximum recruitment (dashed vertical red line).

In salmon populations in DFO Gulf Region with multiple sea ages at maturity, males are more abundant in the returns of one-sea-winter salmon (or small salmon) and females are more abundant in the returns of multi-sea-winter salmon (or large salmon; >= 63 cm fork length) (O'Connell et al. 2006). There are also important differences in the relative abundances of the sea age groups in the annual returns to a river (Chaput et al. 2006). For this reason, stock status in Atlantic Salmon is generally assessed relative to the estimated total number of eggs, with adjustments for increasing fecundity with body size and proportion female by size or age group.

The model used to define the LRP includes a covariate associated with the biological trait of the adult salmon population as the proportion of the total eggs in the annual returns contributed by multi-sea-winter salmon (or large; >= 63 cm fork length). As the proportion of eggs from large salmon increases, the egg deposition rate required to achieve 50% of maximum recruitment decreases. This is consistent with scientific literature that egg survival is positively associated with egg size, with survival of eggs from small salmon less than the survival of eggs from large salmon, at least under hatchery conditions. As well, large salmon are able to use more diverse spawning habitat which can impart a survival advantage for their offspring.

The LRP values from the model with the proportion of eggs from large salmon as a covariate, as described in Chaput et al. (2015), are summarized in Table 1. None of the rivers in DFO Gulf Region have lacustrine habitat which is considered important for the production of Atlantic Salmon juveniles, as is the case for rivers in Newfoundland.

Table 1. Limit Reference Point egg deposition rates (eggs per m² of fluvial wetted area) from the egg to smolt stock and recruitment model without and with covariates.

Covariate			Egg deposition rate (eggs per m²)
No covariates			2.72
Presence/absence of lacustrine habitat	with lacustrine habitat		3.72
	without lacustrine habitat		2.72
For rivers without lacustrine habitat and proportion of eggs from large salmon	prop. eggs from large salmon	0.10	3.20
		0.15	3.16
		0.20	3.00
		0.25	2.74
		0.30	2.54
		0.35	2.48
		0.40	2.32
		0.45	2.30
		0.50	2.18
		0.55	2.08
		0.60	1.94
		0.65	1.86
		0.70	1.78
		0.75	1.76
		0.80	1.64
		0.85	1.58
		0.90	1.52
		0.95	1.52
		1.00	1.46

Habitat Areas and Biological Characteristics

Habitat areas are total wetted fluvial area, unadjusted for habitat type, gradient or habitat quality. Estimates of habitat areas, compiled from various sources, are described for each each river by Salmon Fishing Area and referenced in Appendix Tables 1a to 1d. Biological characteristics data are available from a small number of rivers in the region (Table 2). Biological data from sampled rivers were applied to rivers without detailed data by considering proximity and similarity in river sizes.

SFA 15

Habitat area estimates are available for all 19 rivers of SFA 15 with confirmed populations of Atlantic Salmon (Appendix Table1a; Appendix Figure 1a). Fluvial area estimates for the Restigouche River (NB portion of the watershed) were derived from aerial photograph interpretations (DFO Science Gulf Region, Unpublished Data). The fluvial area estimates of the Eel, Jacquet, Tetagouche, Middle, Nepisiguit, Pokemouche and Tracadie Rivers are from Anon. (1978). Estimates for all other rivers are based on the average proportion (0.0015) of fluvial area to watershed area estimated from the seven rivers reported in Anon. (1978). The Restigouche River (NB) is the largest river in this SFA, representing 72% of the total estimated fluvial area of all rivers (Appendix Table 1a). Only the Nepisiguit River and Jacquet River have estimated fluvial habitat areas that exceed 1 million m² and the majority of the remaining rivers are small with fluvial habitat areas less than 1 million m² (Appendix Table 1a).

There has not been any systematic sampling for biological characteristics from any rivers in this SFA. Randall (1989) published size and fecundity relationships for salmon from the Restigouche River and the characteristics as reported are used for this river. Fecundity estimates for the Nepisiquit River are from Lutzac (1985). Where available, river specific data were used, such as the proportion large salmon from the barrier fence counts of the Jacquet River and the counting fence of the Nepisiquit River.

The average proportions of total eggs contributed by large salmon in this SFA are estimated to be 0.99 for the Restigouche River and 0.93 for the Nepisiguit River (Table 2).

Table 2. Reference rivers with biological data that were used to transfer the LRP egg deposition rates to rivers in the southern Gulf of St. Lawrence. For SFA 17, the proportion of returns that are large salmon are assumed to be either 0.5 or 0.9 based on history of stocking and size of river (Cairns et al. 2012).

		Biological data						
SFA	Reference river	Prop. of returns that are large salmon	Prop. female in large salmon	Prop. female in small salmon	Eggs per large salmon female	Eggs per small salmon female	Prop. eggs from large salmon	Reference
15	Restigouche	0.61	0.63	0.02	8,978	3,193	0.993	Randall (1989)
15	Nepisiguit	0.50	0.71	0.17	7,568	2,464	0.928	Lutzac (1985)
16	Tabusintac	0.53	0.78	0.06	7,589	3,826	0.967	Douglas and Swasson (2000)
16	Northwest Miramichi system	0.34	0.81	0.24	7,427	3,612	0.78	Douglas et al. (2015)
16	Southwest Miramichi system	0.45	0.81	0.11	7,508	3,651	0.93	Douglas et al. (2015)
16	Buctouche	0.62	0.75	0.11	7,549	3,513	0.96	Atkinson and Peters (2001)
17	Morell	0.50; 0.90	0.811	0.214	4,963	3,143	0.86; 0.98	Davidson and Bielak (1992); Cairns et al. (1995, 2010, 2012)
18	East River (Pictou)	0.70	0.60	0.05	10,760	2,999	0.990	Chaput and Jones (1994)
18	South	0.49	0.50	0.03	6,527	2,293	0.979	Chaput and Jones (1994)
18	Margaree	0.76	0.75	0.16	8,644	2,999	0.978	Marshall (1982); LeBlanc et al. (2005); DFO (2017)
18	Cheticamp	0.84	0.65	0.16	7,215	2,999	0.981	Landry et al. (2005)

SFA 16

Habitat area estimates are available for 23 of 30 rivers (including a composite of five rivers as the Richibucto River) in SFA 16 with confirmed populations of Atlantic Salmon (Appendix Table 1b; Appendix Figure 1b). The habitat area estimates for the Miramichi River watershed were derived from aerial photography interpretation (Amiro 1983). Habitat area estimates for the Tabusintac and Buctouche rivers are from NB provincial government surveys and published in Atkinson and Hooper (1995) and Atkinson et al. (1995a), respectively. For the five rivers collectively identified as Richibucto River in Table 1b, the habitat area estimate is for the complex (Anon. 1978; Atkinson et al. 1995b). Habitat area estimates for all other rivers in SFA 16 are from Anon. (1978). There are four rivers in this SFA with habitat area estimates that exceed five million m²; all four are in the Miramichi River system and the largest of all is the Southwest Miramichi River at 29.5 million m² (Appendix Figure 1b). The majority of the remaining rivers are small with fluvial habitat areas less than one million m² (Appendix Table 1b; Appendix Figure 1b).

Annual systematic sampling for biological characteristics has been conducted in the Northwest Miramichi system and Southwest Miramichi system since 1998 (Table 2; Douglas et al. 2015). Randall (1989) published size and fecundity relationships for salmon from the Miramichi River and this relationship combined with annual mean fork lengths of small salmon and large salmon are used to estimate the average eggs per small and large female salmon (Douglas et al. 2015).

Average biological characteristics for these rivers are based on updated data for the period 1998 to 2017. Biological data from the Tabusintac River and the Buctouche River are from assessment activities during the 1993 to 1999 period (Atkinson and Peters 2001; Douglas and Swasson 2000). The average proportions of total eggs contributed by large salmon in this SFA range from a low of 0.78 for the Northwest Miramichi system to 0.93 for the Southwest Miramichi system and 0.96 or greater for the other rivers (Table 2).

SFA 17

There are 25 rivers in SFA 17 with confirmed Atlantic Salmon presence since 2008 (Appendix Table 1c; Appendix Figure 1c). Fluvial areas of the Mill (Cains and Carruthers), Morell, West, Valleyfield, and Dunk rivers were calculated from field measurements of the width of non-tidal, non-impounded waters at 30 m intervals collected between 1990 to 1993 (Cairns et al. 1995). Watershed areas were derived from the PEI government's GIS watershed layer. Fluvial areas were related to watershed areas using a linear regression forced through the origin (fluvial area (m^2) = 1,309.08 x watershed area (km^2); $r^2 = 0.78$, $p = 0.03$) (Cairns et al. 2010). All the rivers in SFA 17 are small and the total fluvial area of all rivers with Atlantic Salmon is approximately 2.0 million m^2 (Appendix Table 1c). Fluvial area estimates exceed 100 thousand m^2 in six of 25 rivers with the largest river (Morell) having an estimated fluvial area of 240 thousand m^2.

In the 1800s, salmon runs in SFA 17 were dominated by large, female, and late-run fish (Cairns et al. 2010). Stocking of Atlantic salmon in SFA 17 rivers began in the late 1800s. Since the 1970s, early-run, primarily small salmon, of Miramichi River heritage have been stocked in larger PEI rivers for the purpose of lengthening the recreational angling season. Smaller streams have been less stocked, and generally retain more of the original biological characteristics, including run-timing. Measurements on the percentage of large salmon in SFA 17 rivers are sparse, but in general, large salmon are a high proportion of returnees in small rivers with little stocking history and without an early-run component, and large salmon are a lower proportion of returnees in larger rivers with heavy stocking history and with an early-run component. It is assumed that large fish comprise 50% of runs in large rivers and 90% of runs in small rivers (Cairns et al. 2012).

The proportion of females in large and small salmon is based on samples taken from the Morell River in 1986 to 2005 (Cairns et al. 2010). Fecundity was measured in large and small salmon sampled from the Morell River in 1989 (Davidson and Bielak 1992). The average proportion of eggs contributed by large salmon was 0.86 for large rivers and 0.98 for small rivers (Table 2).

SFA 18

Habitat area estimates are available for 30 of 47 rivers with confirmed populations of Atlantic Salmon in SFA 18 (Appendix Table 1d; Appendix Figure 1d). The Margaree River is the only river in this SFA with habitat area estimates that exceed one million m^2 (Appendix Table 1d). With the exception of three other rivers, the remaining rivers are small with fluvial habitat areas less than 0.5 million m^2 (Appendix Table 1d).

In the Gulf Region of Cape Breton, habitat areas were determined for both Cheticamp and Margaree rivers. The fluvial habitat area for the Cheticamp River was determined through stream surveys in 1982 and 1983 (revised and summarized in Boates et al. 1985). Habitat area for the Margaree was estimated by surveys from 1976 to 1978, by spot surveys and profile maps, or by profile maps only (Marshall 1982) and verified by ortho-photo interpretation (Marshall et al. 1999). For rivers with no survey information, the following method was used and results can be found in O'Connell et al. (1997). Fluvial habitat areas were estimated from calculations of drainage area and measures of surveyed substrate in a near-by river basin.

Drainage areas were taken from maps and tables produced by Maritime Resource Management Services (Amherst, NS). Rearing area was derived as the product of the drainage area (km^2) and the proportion of the measured habitat area to drainage basin area (Anon. 1978).

Habitat areas, and watershed areas, for rivers in the mainland portion of SFA 18 were calculated for River Philip (Edwards 1956) and South River (Chaput and Jones 1994). For rivers with no survey information, habitat area is also based on the ratio of habitat area to watershed area (O'Neil et al. 1997).

Biological data from a few rivers in this SFA were obtained from assessment activities during the late 1980s to early 2000s (Table 2). For the Cheticamp River, the proportion of returns that are large salmon is based on data collected from a counting fence during 1984 to 1989 (Claytor 1996; Landry et al. 2005). The proportion of female in large salmon was calculated from creel census reports on the Cheticamp River from 1978 to 1983 (Landry et al. 2005). The small salmon characteristics are borrowed from the Margaree River. The proportion of large salmon on the Margaree is the average of annual proportions of large salmon caught in the estuary trapnet, fished from 1988 to 1996. The proportion of female in small salmon is the average of the annual proportions female from the trapnet catches (LeBlanc et al. 2005). Proportion of female in large salmon, average weights for small (1.7 kg) and large salmon (4.9 kg) are based on historical biological characteristics of large salmon in the Margaree River as well as from trap and creel surveys between 1973 and 1977 (Marshall 1982). More contemporary sampling indicated that the inter-annual variation in the proportion of female in large salmon ranges from 0.62 to 0.79 (LeBlanc et al. 2005).

Biological characteristics of the salmon from the mainland portion of SFA 18 were obtained from angling logbook records and broodstock seining from East River (Pictou) and from counting fence samples at South River (Chaput and Jones 1994). Return proportions of large salmon were calculated from angling licence stub returns (1984 to 2016), excluding data for a river with annual recorded catches of less than 30 salmon or for rivers with three years or less of data. South River angling data characteristics were applied to Wrights, Tracadie, Afton and Pomquet rivers. West River (Antigonish) was applied to North River. An average of Barneys, East River (Pictou), River John, River Philip, Wallace, Waugh and West River (Pictou) was used for all rivers from Doctors Brook to Shinimicas River (map index rivers 35 to 55 in Appendix Table 1d and Appendix Figure 1d).

The average proportion of total eggs contributed by large salmon in this SFA was very high, at 0.98 or 0.99 (Table 2).

Limit Reference Points

In the southern Gulf of St. Lawrence rivers, the average proportions of the annual returns that are large salmon range from 0.34 to 0.90. The majority of the large salmon are generally female (0.50 to 0.81) whereas the majority of small salmon size group have been categorized as male (0.76 to 0.98). When combined with the average fecundities by size group, the proportions of the annual eggs contributed by large salmon typically exceed 0.90, with exception of the Northwest Miramichi for which the proportion of eggs from large salmon is estimated to be on average 0.78 and for a number of small rivers in SFA 17 where the proportion of eggs from large salmon is 0.86.

The predicted LRP egg deposition rates for the rivers of the southern Gulf of St. Lawrence are in the range of 1.52 to 1.76 eggs per m^2 of fluvial area based on population characteristics with 75% or more of the eggs in the annual returns attributed to large salmon. For most of the reference rivers in the southern Gulf of St. Lawrence, the defined LRP egg deposition rate is

1.52 with exception of the small rivers in SFA 17 for which the LRP is 1.58 and for the Northwest Miramichi system with an LRP value of 1.76 eggs per m^2 of fluvial habitat area.

No age or size specific LRPs in terms of fish are provided as the relevant LRP is in terms of eggs from all salmon. The LRP is defined in units of eggs from all salmon regardless of size and this value will be considered in the assessment of status of stocks relative to this reference point. River-specific LRP values in terms of total eggs are the product of the LRP egg deposition rate and the estimated total fluvial area of the river. The approximate number of small salmon and large salmon that would be expected to provide the LRP value in total eggs for a river can be estimated using the life history characteristics that were used to calculate the proportion eggs from large salmon from the reference river.

Sources of Uncertainty

Biological characteristics of Atlantic Salmon for the rivers of the southern Gulf of St. Lawrence are based on varying quality and quantity of sampling information. The best information is available for salmon from the Miramichi River in SFA 16 for which annual systematic sampling of adult salmon has been undertaken since 1998 for the two main tributaries and back to 1971 for the Miramichi River composite. Despite less detailed and systematic sampling from other rivers, when such data were obtained during directed assessment programs, the proportion of total eggs from large salmon were consistently similar among the DFO Gulf Region rivers. Annual angling data from SFA 18 show a consistent pattern of size proportions which are dominated by large salmon. The estimated proportions of eggs from large salmon from sampled rivers are high (0.78 to 0.99) resulting in relatively small variations in LRP values (1.52 to 1.76) indicating that for these rivers, the river-specific LRP is relatively robust to expected variations in biological characteristics of salmon populations in unsampled rivers.

The estimation of the river-specific LRP in terms of total eggs depends upon the estimates of fluvial habitat areas of the rivers. There are several levels of uncertainty associated with the estimation of fluvial habitat areas. First, total accessible wetted area is used, regardless of habitat type, gradient, width, and other features. Wetted area was chosen because this is the habitat area measurement which was used in the stock and recruitment model (Chaput et al. 2015) and for consistency, the transfer of LRP values must be done using the same type of habitat. Second, fluvial habitat area estimates based on direct field surveys, aerial photo interpretation or other described methods are available for a small number of rivers. Third, many of the estimates of fluvial areas are taken from Anon. (1978) however the original data for these could not be found and the estimates could not be validated. Finally, for the remaining rivers, the estimates of fluvial area are calculated by applying the ratio of fluvial area estimates to drainage area estimates from a small number of reference rivers to drainage area estimates of the river of interest.

There is more to Atlantic Salmon population fitness than egg production. Even though the egg contribution (in terms of number of eggs) by small salmon may be minor in some stocks, the genetic composition and biological characteristics of all age, size, and sex groups are evolutionary legacies and all phenotypes should be assumed to be important elements of fitness of the population. DFO (2015) indicated that for small rivers with associated small population sizes, limits based on effective population sizes required to maintaining genetic variability, should be considered in addition to the LRP values in terms of eggs. A genetic conservation threshold of 200 adult spawners regardless of size has been defined as equivalent to an LRP for Atlantic Salmon rivers in the province of Quebec (MFFP 2016). Values which could apply to rivers in Gulf region, considering the likely exchanges that occur among neighbouring rivers, have not been considered in this report. River size and small population sizes and exchanges of salmon among rivers could be considered in the next steps of the PA framework development, particularly during discussions on harvest strategies. Information on population structuring, obtained from genetics, would be important to support these discussions.

Conclusions

Following the advice in DFO (2015), river-specific LRPs in terms of total eggs are provided for 98 rivers in the southern Gulf of St. Lawrence; 19 rivers in SFA 15, 24 rivers in SFA 16 (including a composite of five rivers as the Richibucto River), 25 rivers in SFA 17 and 30 rivers in SFA 18. Due to the absence of fluvial habitat area estimates, LRPs are not available for three rivers in SFA 16 and 16 rivers in SFA 18 with confirmed salmon presence. There are five rivers in SFA 16 for which the presence / absence of Atlantic Salmon has not been confirmed.

The predicted LRP egg deposition rates for the rivers of the southern Gulf of St. Lawrence are in the range of 1.52 to 1.76 eggs per m^2 of fluvial area corresponding to the general population characteristic as the majority (> 75%) of the eggs is contributed by large salmon.

No age or size specific LRPs in terms of fish are provided. The LRP is defined in terms of eggs and the egg contribution from all salmon regardless of size will be considered in the assessment of status relative to the attainment of LRPs.

The LRP values in terms of egg deposition rates are dependent on the biological characteristics of the salmon populations in each river and these are reasonably well defined, despite being drawn from a relatively small number of monitored populations. LRP values in terms of total eggs are dependent upon estimates of habitat areas and these are incomplete or missing for a number of rivers, mostly small rivers. There are large uncertainties and gaps in the estimates of fluvial habitat areas. As such the LRP values are presented based on the best available information and revisions to river-specific values should be provided as more appropriate information becomes available.

The development of the LRP for salmon rivers in DFO Gulf Region is the initial step in the development of the complete PA framework. Further work is required to define the Upper stock Reference Point(s), harvest strategies, and harvest decision rules. This further work would be developed by fishery managers informed by consultations with the fishery and other interests, with support from DFO Science.

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Sources of information

This Science Response Report results from the Science Response Process of February 8, 2018 on Limit Reference Points for Atlantic Salmon Rivers in Salmon Fishing Areas 15 to 18, DFO Gulf Region. No additional publications from this process are anticipated.

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Appendices

Appendix Table 1a. Characteristics of rivers in SFA 15. Map index refers to numbers in Appendix Figure 1a. The conservation egg requirement column is the value used to date, calculated as the product of 2.4 eggs per m² and fluvial area, except for the Restigouche River for which the egg deposition rate was 1.68 eggs per m². Biological data for reference rivers are in Table 2. Fluvial area estimate references are: 1 – DFO Science Gulf Region (Unpubl. data); 2 - Anonymous (1978); 3 - Drainage area from Data Warehouse Report Sept. 2014; fluvial area based on proportion equal to 0.0015 of watershed area (average of seven index rivers from Anonymous 1978); na indicates not available.

Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP (eggs; million)	Reference river for biological data
1	Restigouche (NB)	yes	44.34	6,589	26.390	1	0.993	1.52	40.113	Restigouche
2	Eel River	yes	1.01	217	0.422	2	0.928	1.52	0.641	Nepisiguit
3	Charlo	yes	1.02	282	0.423	3	0.928	1.52	0.643	Nepisiguit
4	South Charlo	yes	0.43	118	0.177	3	0.928	1.52	0.269	Nepisiguit
5	Blackland Brook	no	na	na	na	na	0.928	1.52	na	Nepisiguit
6	New Mills	no	na	na	na	na	0.928	1.52	na	Nepisiguit
7	Benjamin	yes	0.58	161	0.242	3	0.928	1.52	0.366	Nepisiguit
8	Nash Creek	no	na	na	na	na	0.928	1.52	na	Nepisiguit
9	Louison River	yes	0.51	142	0.213	3	0.928	1.52	0.324	Nepisiguit
10	Jacquet	yes	2.72	510	1.135	2	0.928	1.52	1.725	Nepisiguit
11	Armstrong Brook	no	na	na	na	na	0.928	1.52	na	Nepisiguit
12	Patapat Brook (Belledune)	no	na	na	na	na	0.928	1.52	na	Nepisiguit
13	Fournier Brook	no	na	na	na	na	0.928	1.52	na	Nepisiguit
14	Elmtree River	yes	1.07	297	0.446	3	0.928	1.52	0.678	Nepisiguit
15	Little Elmtree River	no	na	na	na	na	0.928	1.52	na	Nepisiguit
16	Nigadoo	yes	0.60	168	0.252	3	0.928	1.52	0.383	Nepisiguit
17	Millstream	yes	0.83	229	0.344	3	0.928	1.52	0.523	Nepisiguit
18	Peters River	no	na	na	na	na	0.928	1.52	na	Nepisiguit
19	Tetagouche	yes	0.72	364	0.299	2	0.928	1.52	0.455	Nepisiguit
20	Middle (Gloucester Co.)	yes	2.28	401	0.950	2	0.928	1.52	1.444	Nepisiguit
21	Little River	no	na	na	na	na	0.928	1.52	na	Nepisiguit
22	Nepisiguit	yes	9.54	2,312	3.973	2	0.928	1.52	6.039	Nepisiguit
23	Bass (Gloucester Co.)	yes	0.71	198	0.297	3	0.928	1.52	0.451	Nepisiguit
24	Miller Brook	no	na	na	na	na	0.928	1.52	na	Nepisiguit
25	Teagues Brook	yes	0.85	237	0.356	3	0.928	1.52	0.541	Nepisiguit
26	Little Pokeshaw River	no	na	na	na	na	0.928	1.52	na	Nepisiguit
27	Pokeshaw River	no	na	na	na	na	0.928	1.52	na	Nepisiguit
28	Riviere du Nord	no	na	na	na	na	0.928	1.52	na	Nepisiguit
29	Caraquet	yes	1.34	373	0.560	3	0.928	1.52	0.851	Nepisiguit
30	Pokemouche	yes	0.60	481	0.248	2	0.967	1.52	0.377	Tabusintac
31	Little Tracadie	yes	0.69	192	0.288	3	0.967	1.52	0.438	Tabusintac
32	Tracadie	yes	1.44	527	0.601	2	0.967	1.52	0.914	Tabusintac

Appendix Table 1b. Characteristics of rivers in SFA 16. Map index refers to numbers in Appendix Figure 1b. The conservation egg requirement column is the value used to date, calculated as the product of 2.4 eggs per m² and fluvial area. Biological data for reference rivers are in Table 2. The grey shaded cells in reference to rivers 23 to 27 include the value for the composite of five rivers collectively called Richibucto River. Fluvial area estimate references are: 1 – Anonymous (1978); 2 – Amiro (1983); 3 - Atkinson and Hooper (1995); 4 – Atkinson et al. (1995a); na indicates not available; tbd indicates to be determined; unk indicates unknown.

Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP (eggs; million)	Reference river for biological data
1	Tabusintac	yes	1.98	704	0.824	3	0.97	1.52	1.25	Tabusintac
2	Burnt Church	yes	0.72	135	0.299	1	0.97	1.52	0.46	Tabusintac
3	Oyster	yes	na	na	tbd	na	0.97	1.52	tbd	Tabusintac
4	Bartibog	yes	2.72	512	1.135	2	0.97	1.52	1.73	Tabusintac
6	Northwest Miramichi	yes	20.1	2,138	8.230	2	0.78	1.76	14.48	Northwest
5	Northwest Millstream	yes	1.2	210	0.479	2	0.78	1.76	0.84	Miramichi
7	Little Southwest Miramichi	yes	19.7	1,345	8.070	2	0.78	1.76	14.20	system
9	Southwest Miramichi	yes	70.9	5,840	29.530	2	0.93	1.52	44.89	Southwest
8	Renous	yes	14	1,429	5.820	2	0.93	1.52	8.85	Miramichi
10	Barnaby	yes	3.1	490	1.304	2	0.93	1.52	1.98	system
11	Napan	yes	0.28	115	0.115	1	0.96	1.52	0.17	Buctouche
12	Black (Northumberland Co.)	yes	0.67	277	0.277	1	0.96	1.52	0.42	Buctouche
13	Bay du Vin	yes	0.68	284	0.284	1	0.96	1.52	0.43	Buctouche
14	Eel River	unk	na	116	tbd	1	0.96	1.52	tbd	Buctouche
15	Portage River	no	na	na	na	na	0.96	1.52	na	Buctouche
16	Riviere au Portage	yes	na	na	tbd	na	0.96	1.52	tbd	Buctouche
17	Black (Kent Co.)	yes	0.82	343	0.343	1	0.96	1.52	0.52	Buctouche
18	Rankin Brook	yes	na	na	tbd	na	0.96	1.52	tbd	Buctouche
19	Kouchibouguac (Kent Co.)	yes	1.41	389	0.588	1	0.96	1.52	0.89	Buctouche
20	Ruisseau des Major	no	na	25	na	1	0.96	1.52	na	Buctouche
21	Kouchibouguacis	yes	1.32	360	0.549	1	0.96	1.52	0.83	Buctouche
22	Saint Charles	unk	na	149	tbd	1	0.96	1.52	tbd	Buctouche
23	Molus River	yes		172		1	0.96	1.52		Buctouche
24	Bass River	yes		115		1	0.96	1.52		Buctouche
25	Richibucto	yes	2.94	449	1.226	1	0.96	1.52	1.86	Buctouche
26	Coal Branch	yes		212		1	0.96	1.52		Buctouche
27	Saint Nicholas	yes		194		1	0.96	1.52		Buctouche
28	Chockpish	yes	0.31	129	0.129	1	0.96	1.52	0.20	Buctouche
29	Black	unk	na	na	tbd	na	0.96	1.52	tbd	Buctouche
30	Buctouche	yes	1.59	566	0.661	4	0.96	1.52	1.00	Buctouche
31	Cocagne	yes	0.68	333	0.283	1	0.96	1.52	0.43	Buctouche
32	Shediac	yes	0.52	219	0.216	1	0.96	1.52	0.33	Buctouche

Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP (eggs; million)	Reference river for biological data
33	Scoudouc	yes	0.35	159	0.146	1	0.96	1.52	0.22	Buctouche
34	Aboujagane	yes	0.29	120	0.120	1	0.96	1.52	0.18	Buctouche
35	Kinnear Brook	no	na	na	na	na	0.96	1.52	na	Buctouche
36	Kouchibouguac (Westmorland Co.)	no	na	346	na	1	0.96	1.52	na	Buctouche
37	Tedish River	unk	na	na	tbd	na	0.96	1.52	tbd	Buctouche
38	Gaspereau (Westmorland Co.)	yes	0.41	170	0.170	1	0.96	1.52	0.26	Buctouche
39	Baie Verte	unk	0.14	38	0.058	1	0.96	1.52	0.09	Buctouche

Appendix Table 1c. Characteristics of rivers in SFA 17. Map index refers to numbers in Appendix Figure 1c. The conservation egg requirement column is the value used to date, estimated as the product of 2.4 eggs per m² and fluvial area. Biological data for reference rivers are in Table 2. Fluvial area estimates are based on: 1 - method described in text and in Cairns et al. (2010).

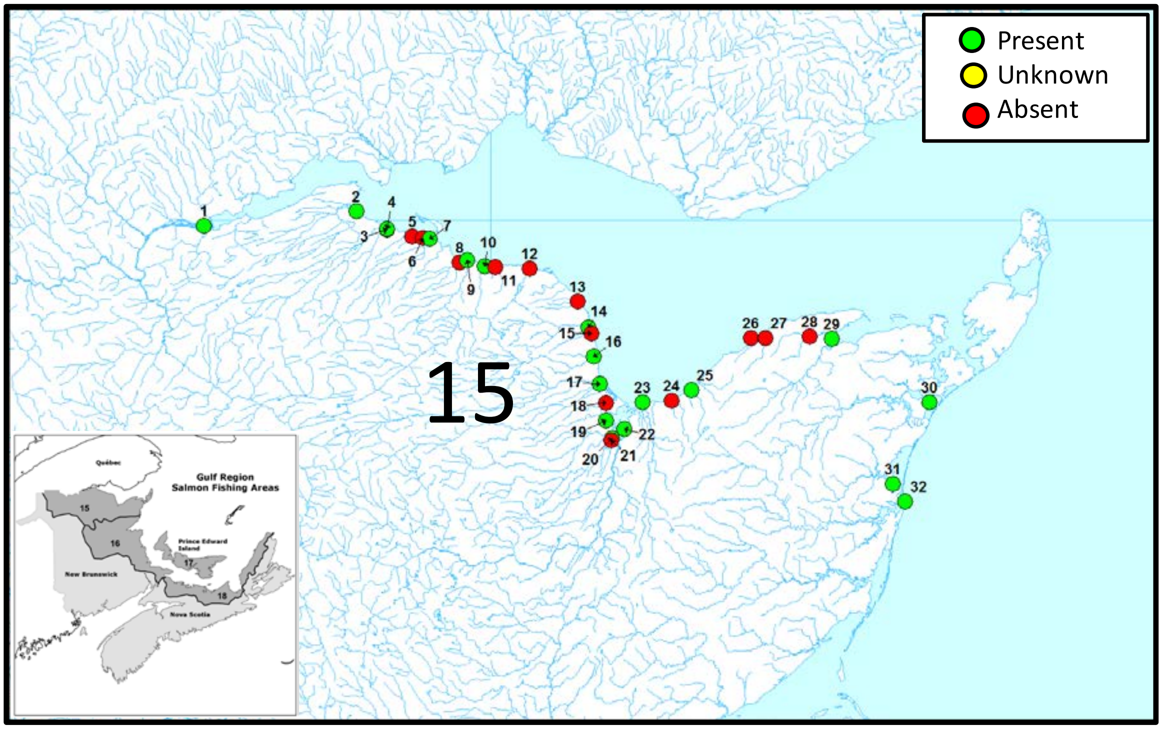
Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP (eggs; million)	Reference river for biological data
1	Cains Brook, Mill River	yes	0.055	30.9	22,845	1	0.86	1.58	0.036	Morell
2	Carruthers Brook, Mill River	yes	0.085	47.9	35,455	1	0.86	1.58	0.056	Morell
3	Trout River (Coleman)	yes	0.336	107.1	140,202	1	0.86	1.58	0.222	Morell
4	Trout River, Tyne Valley	yes	0.152	48.3	63,281	1	0.98	1.52	0.096	Morell
5	Little Trout River	yes	0.067	21.3	27,883	1	0.98	1.52	0.042	Morell
6	Bristol (Berrigans) Creek	yes	0.130	41.4	54,183	1	0.98	1.52	0.082	Morell
7	Morell River	yes	0.569	170.6	237,176	1	0.86	1.58	0.375	Morell
8	Midgell River	yes	0.200	63.8	83,532	1	0.98	1.52	0.127	Morell
9	St. Peters River	yes	0.140	44.6	58,333	1	0.98	1.52	0.089	Morell
10	Cow River	yes	0.072	22.8	29,886	1	0.98	1.52	0.045	Morell
11	Naufrage River	yes	0.137	43.6	57,037	1	0.98	1.52	0.087	Morell
12	Bear River	yes	0.054	17.2	22,477	1	0.98	1.52	0.034	Morell
13	Hay River	yes	0.081	25.7	33,696	1	0.98	1.52	0.051	Morell
14	Cross Creek	yes	0.139	44.3	57,992	1	0.98	1.52	0.088	Morell
15	Priest Pond Creek	yes	0.078	24.9	32,557	1	0.98	1.52	0.049	Morell
16	North Lake Creek	yes	0.150	47.7	62,495	1	0.98	1.52	0.095	Morell
17	Vernon River	yes	0.217	69.2	90,536	1	0.98	1.52	0.138	Morell
18	Clarks Creek	yes	0.145	46.3	60,610	1	0.98	1.52	0.092	Morell

Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP (eggs; million)	Reference river for biological data
19	Pisquid River	yes	0.149	47.6	62,247	1	0.98	1.52	0.095	Morell
20	Head of Hillsborough River	yes	0.167	53.1	69,512	1	0.98	1.52	0.106	Morell
21	North River	yes	0.311	99.0	129,651	1	0.98	1.52	0.197	Morell
22	Clyde River	yes	0.131	41.7	54,549	1	0.98	1.52	0.083	Morell
23	West River	yes	0.443	114.1	184,500	1	0.86	1.58	0.292	Morell
24	Dunk River	yes	0.463	165.7	193,078	1	0.86	1.58	0.305	Morell
25	Wilmot River	yes	0.262	83.4	109,177	1	0.98	1.52	0.166	Morell

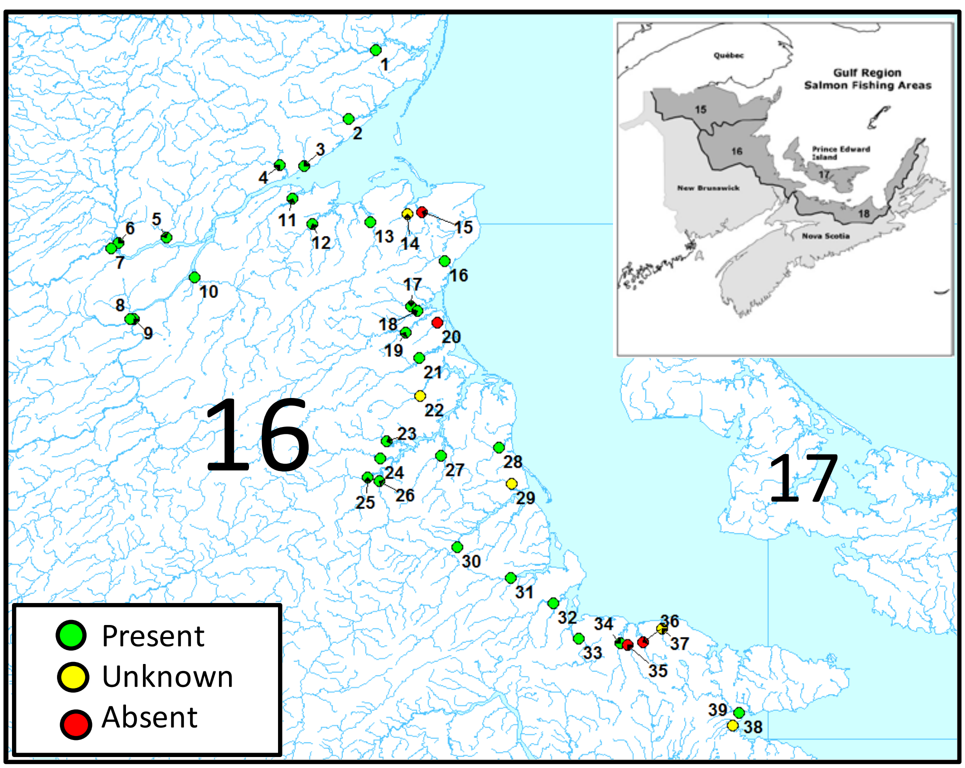
Appendix Table 1d. Characteristics of rivers in SFA 18. Map index refers to numbers in Appendix Figure 1d. The conservation egg requirement column is the value used to date, estimated as the product of 2.4 eggs per m² and fluvial area. Biological data for reference rivers are in Table 2. Fluvial area estimate references are: 1 – Drainage area from Maritime Resource Management Service, rearing units per sq. km from named river a) O'Connell et al. (1997), b) O'Neil et al. (1997) ; 2 – Boates et al. (1985); 3 - Marshall (1982); 4- Chaput and Jones (1994); 5 - Edwards (MS 1956); na indicates not available; tbd indicates to be determined.

Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP egg requirement (million)	Reference river for biological data
1	Salmon River	yes	na	na	tbd	na	0.981	1.52	tbd	Cheticamp
2	Blair River	yes	0.23	58	0.097	1a	0.981	1.52	0.148	Cheticamp
3	Red River	yes	0.14	35	0.059	1a	0.981	1.52	0.089	Cheticamp
4	Grande Anse River	yes	0.20	51	0.085	1a	0.981	1.52	0.130	Cheticamp
5	Mackenzies River	yes	0.30	75	0.124	1a	0.981	1.52	0.189	Cheticamp
6	Fishing Cove River	yes	0.13	31	0.052	1a	0.981	1.52	0.079	Cheticamp
7	Corneys Brook	yes	na	na	tbd	na	0.981	1.52	tbd	Cheticamp
8	Anthony Aucoin's Brook	no	na	na	na	na	0.981	1.52	na	Cheticamp
9	Rigwash Brook	no	na	na	na	na	0.981	1.52	na	Cheticamp
10	Chéticamp River	yes	0.77	298	0.319	2	0.981	1.52	0.489	Cheticamp
11	Aucoin Brook	yes	na	na	tbd	na	0.981	1.52	tbd	Cheticamp
12	Fiset Brook	yes	na	na	tbd	na	0.981	1.52	tbd	Cheticamp
13	Farm Brook	yes	na	na	tbd	na	0.981	1.52	tbd	Cheticamp
14	Margaree River	yes	6.71	1,100	2.798	3	0.978	1.52	4.252	Margaree
15	Smiths Brook	no	na	na	na	na	0.978	1.52	na	Margaree
16	Broad Cove River	yes	na	na	tbd	na	0.978	1.52	tbd	Margaree
17	Mill Brook	no	na	na	na	na	0.978	1.52	na	Margaree
18	Northeast Mabou River	yes	1.02	254	0.424	1a	0.978	1.52	0.645	Margaree
19	Southwest Mabou River	yes	0.37	123	0.154	1a	0.978	1.52	0.234	Margaree

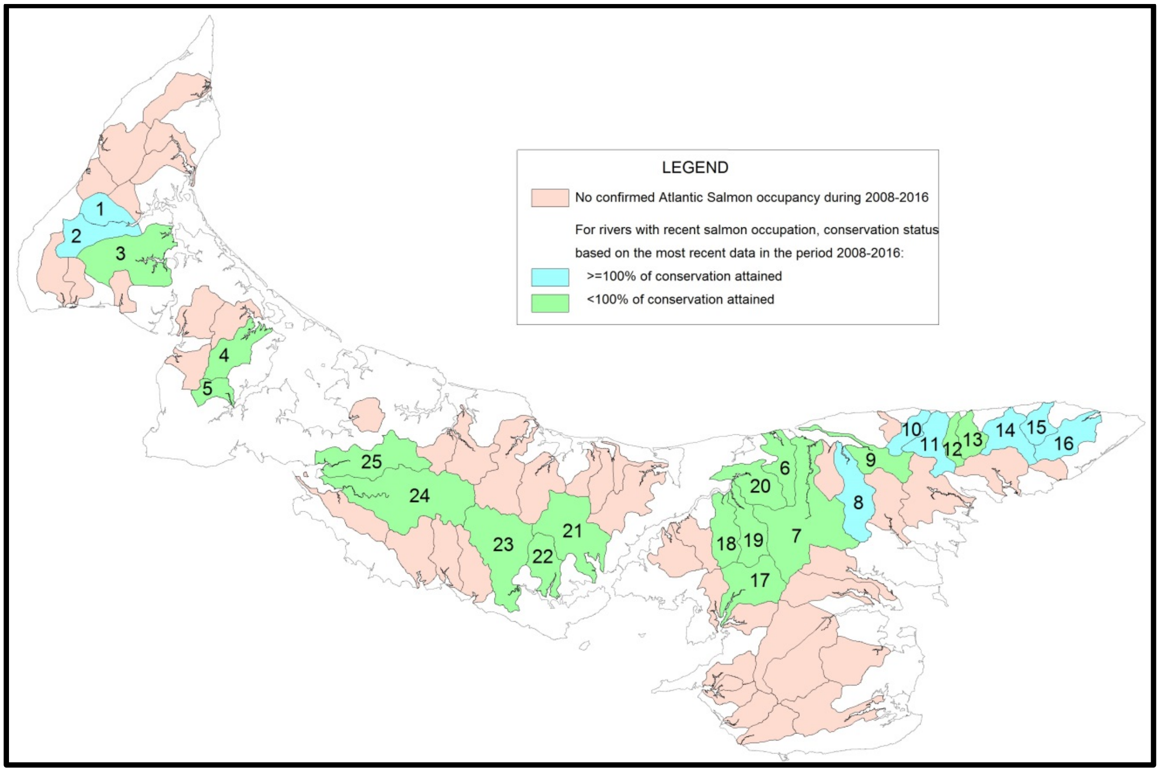
Map index	River	Salmon present	Conservation egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Fluvial area estimate reference	Prop. eggs from large salmon	LRP (eggs per m²)	LRP egg requirement (million)	Reference river for biological data
20	Mabou River	yes	0.56	188	0.235	1a	0.978	1.52	0.357	Margaree
21	Captains Brook	yes	0.14	34	0.057	1a	0.978	1.52	0.086	Margaree
22	Judique Intervale Brook	yes	0.18	44	0.074	1a	0.978	1.52	0.112	Margaree
23	Graham River	yes	na	na	tbd	na	0.978	1.52	tbd	Margaree
24	Campbells Brook	yes	na	na	tbd	na	0.978	1.52	tbd	Margaree
25	Chisholm Brook	yes	0.07	17	0.028	1a	0.978	1.52	0.042	Margaree
26	Mill Brook (Strait of Canso)	yes	na	na	tbd	na	0.978	1.52	tbd	Margaree
27	Wrights River	yes	na	na	tbd	na	0.979	1.52	tbd	South
28	Tracadie River	yes	0.13	120	0.053	1b	0.979	1.52	0.080	South
29	Afton River	yes	0.05	43	0.019	1b	0.979	1.52	0.029	South
30	Pomquet River	yes	0.19	176	0.077	1b	0.979	1.52	0.117	South
31	South River	yes	0.23	217	0.095	4	0.979	1.52	0.144	South
32	West River (Antigonish)	yes	1.15	353	0.480	1b	0.979	1.52	0.730	South
33	North River	yes	na	na	tbd	na	0.979	1.52	tbd	South
34	MacInnis Brook	no	na	na	na	na	0.979	1.52	na	South
35	Doctors Brook	yes	na	na	tbd	na	0.990	1.52	na	East (Pictou)
36	Vameys Brook	yes	na	na	tbd	na	0.990	1.52	tbd	East (Pictou)
37	Baileys Brook	yes	na	na	tbd	na	0.990	1.52	tbd	East (Pictou)
38	Barneys River	yes	0.51	156	0.213	1b	0.990	1.52	0.323	East (Pictou)
39	French River (Merigomish)	yes	0.42	128	0.174	1b	0.990	1.52	0.264	East (Pictou)
40	Russell Brook	yes	na	na	tbd	na	0.990	1.52	tbd	East (Pictou)
41	Sutherlands River	yes	0.16		0.067	4	0.990	1.52	0.101	East (Pictou)
42	Pine Tree Brook	yes	na	na	tbd	na	0.990	1.52	tbd	East (Pictou)
43	East River (Pictou)	yes	1.75	536	0.729	1b	0.990	1.52	1.108	East (Pictou)
44	Middle River (Pictou)	yes	0.71	217	0.295	1b	0.990	1.52	0.449	East (Pictou)
45	West River (Pictou)	yes	0.80	245	0.333	1b	0.990	1.52	0.506	East (Pictou)
46	Haliburton Brook	no	na	na	na	na	0.990	1.52	na	East (Pictou)
47	Big Caribou River	no	na	na	na	na	0.990	1.52	na	East (Pictou)
48	Toney River	no	na	na	na	na	0.990	1.52	na	East (Pictou)
49	River John	yes	0.95	292	0.397	1b	0.990	1.52	0.604	East (Pictou)
50	Waughs River	yes	0.75	230	0.313	1b	0.990	1.52	0.476	East (Pictou)
51	French River	yes	0.67	206	0.280	1b	0.990	1.52	0.426	East (Pictou)
52	Wallace River	yes	1.50	458	0.623	1b	0.990	1.52	0.947	East (Pictou)
53	Pugwash River	yes	0.59	182	0.247	1b	0.990	1.52	0.375	East (Pictou)
54	River Philip	yes	2.31	726	0.962	5	0.990	1.52	1.462	East (Pictou)
55	Shinimicas River	yes	na	na	tbd	na	0.990	1.52	tbd	East (Pictou)



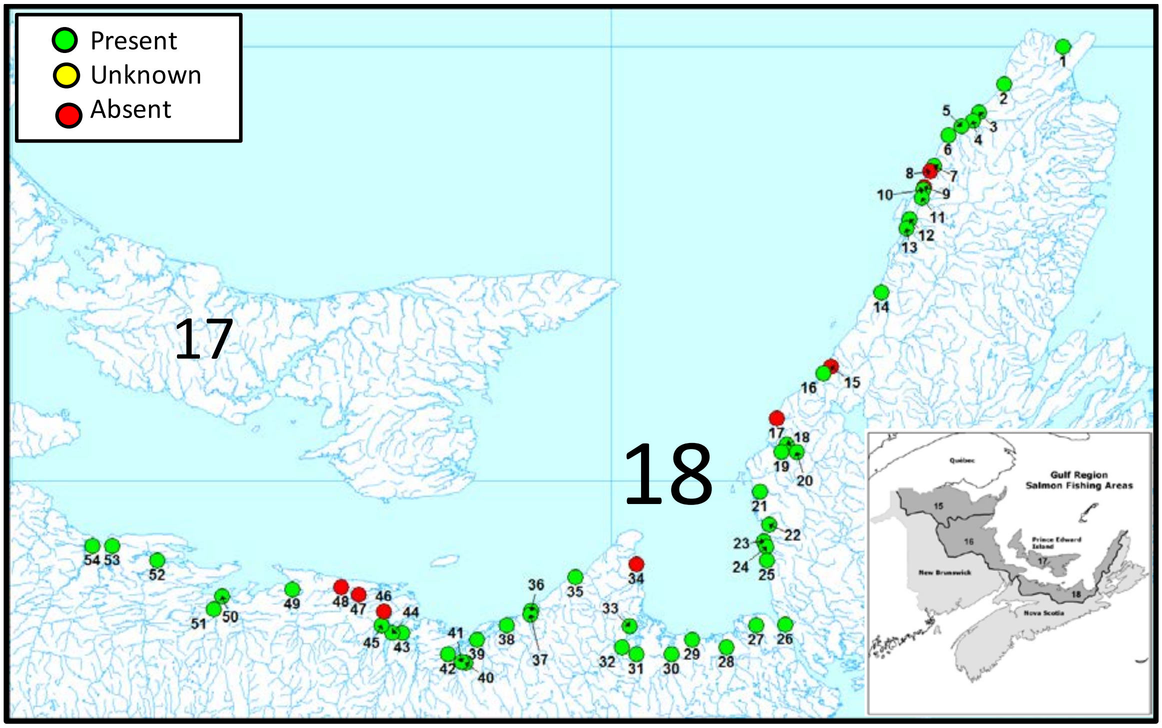
Appendix Figure 1a. Location of rivers in SFA 15, DFO Gulf Region. Numbers correspond to rivers in Appendix Table 1a



Appendix Figure 1b. Location of rivers in SFA 16, DFO Gulf Region. Numbers correspond to rivers in Appendix Table 1b.



Appendix Figure 1c. Location of rivers in SFA 17, DFO Gulf Region. Numbers correspond to rivers in Appendix Table 1c. The percentage of conservation requirements attained are from DFO (2017).



Appendix Figure 1d. Location of rivers in SFA 18, DFO Gulf Region. Indices reference rivers in Appendix Table 1d.

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