Reconciling Atlantic Salmon Fisheries Harvest Reference Points with Conservation-Based Limit Reference Points
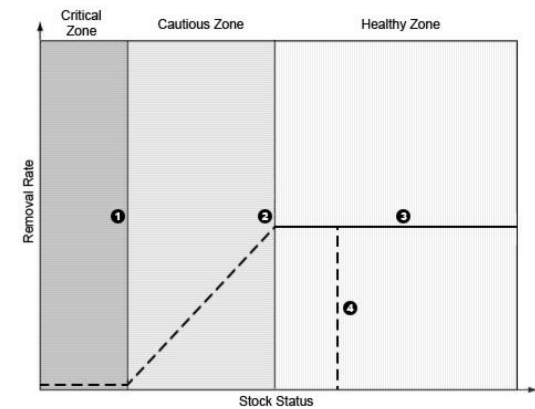
Guillaume Dauphin, Julien April*, Suncica Avlijas, Cindy Breau, and Gérald Chaput
Science Branch, Gulf Fisheries Center, Moncton, NB

*Ministère des Forêts, de la Faune et des Parcs, Québec, QC

Guillaume.Dauphin@dfo-mpo.gc.ca

Background

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

"A Fishery Decision-Making Framework Incorporating the Precautionary Approach" is one of the policies of the Government of Canada's Sustainable Fisheries Framework.

There are three main components to the Precautionary Approach Framework (PA):

– Reference points that define three stock status zones (Healthy, Cautious and Critical),

– A defined harvest strategy and associated harvest decision rules, and

– The need to consider uncertainty and risk when developing reference points and developing and implementing decision rules.

DFO. 2018a. Canada's Wild Atlantic Salmon Conservation Policy
DFO. 2019a. Wild Atlantic salmon conservation: Implementation plan 2019 to 2021

Fisheries and Oceans Canada / Pêches et Océans Canada

Precautionary Approach - Terminology

LRP as boundary between the critical and cautious zone

- Defined based on biology and population dynamics
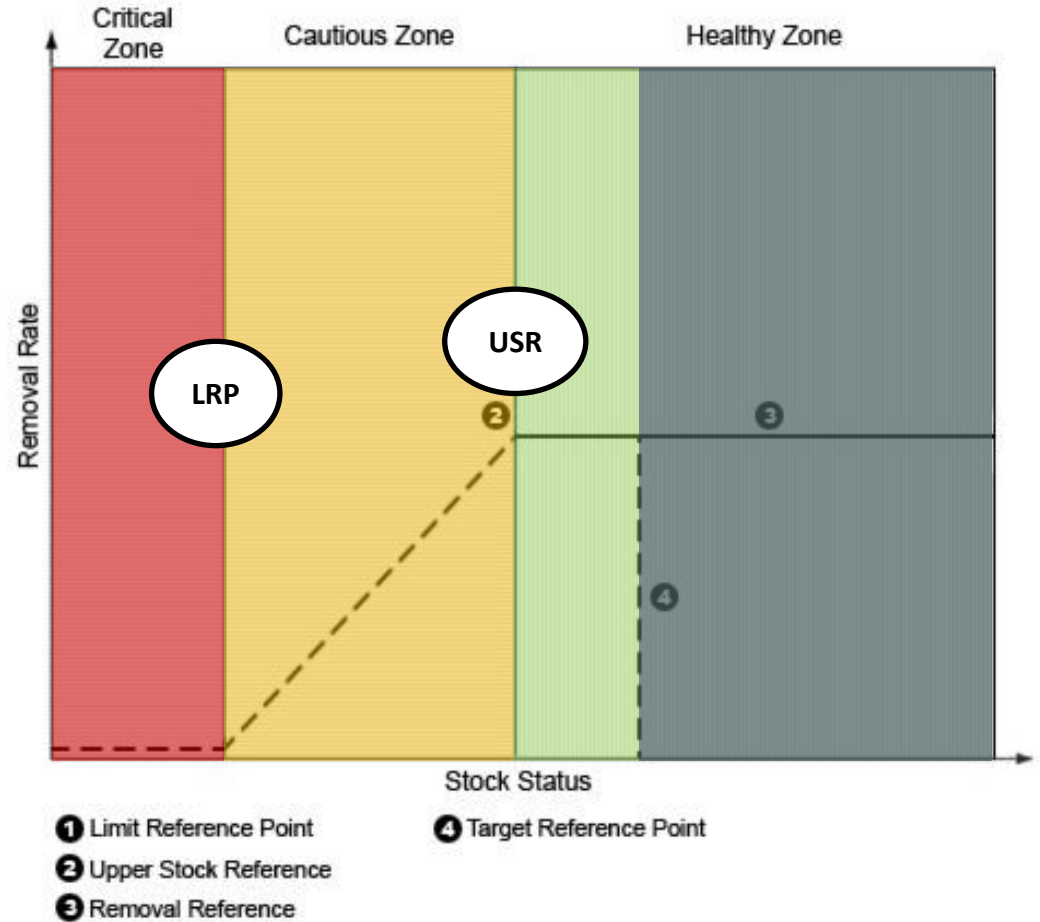
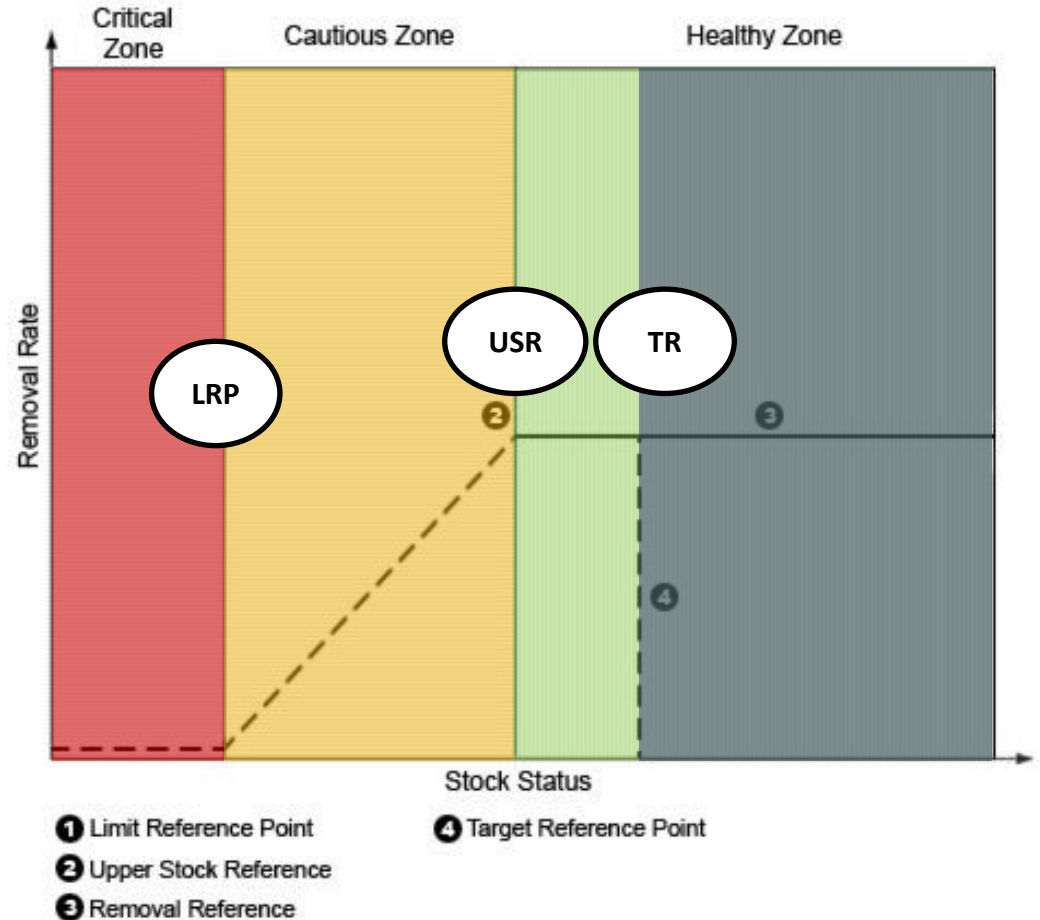- Unrelated to fishery exploitation objectives
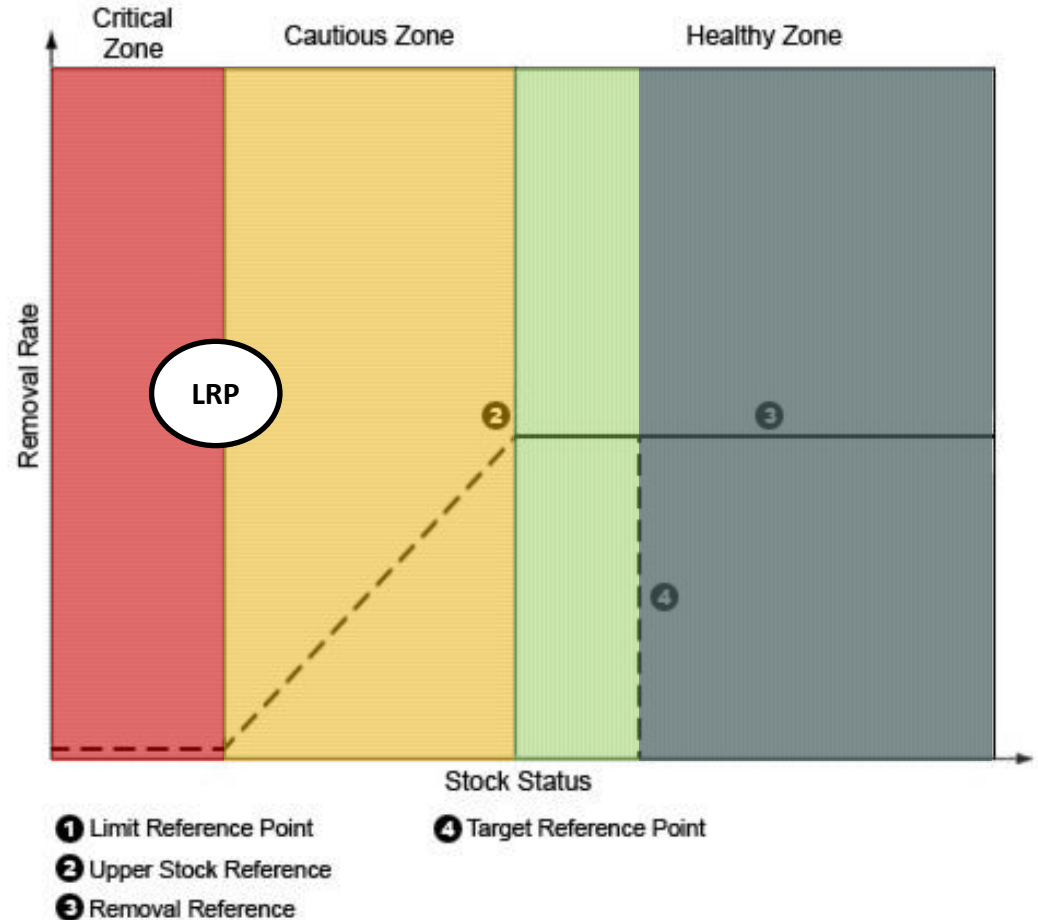
Precautionary Approach - Terminology

LRP as boundary between the critical and cautious zone

USR as boundary between the cautious and healthy zone.

Critical Zone   Cautious Zone   Healthy Zone

Removal Rate

USR

LRP

❷

❸

❹

Stock Status

❶ Limit Reference Point
❷ Upper Stock Reference
❸ Removal Reference
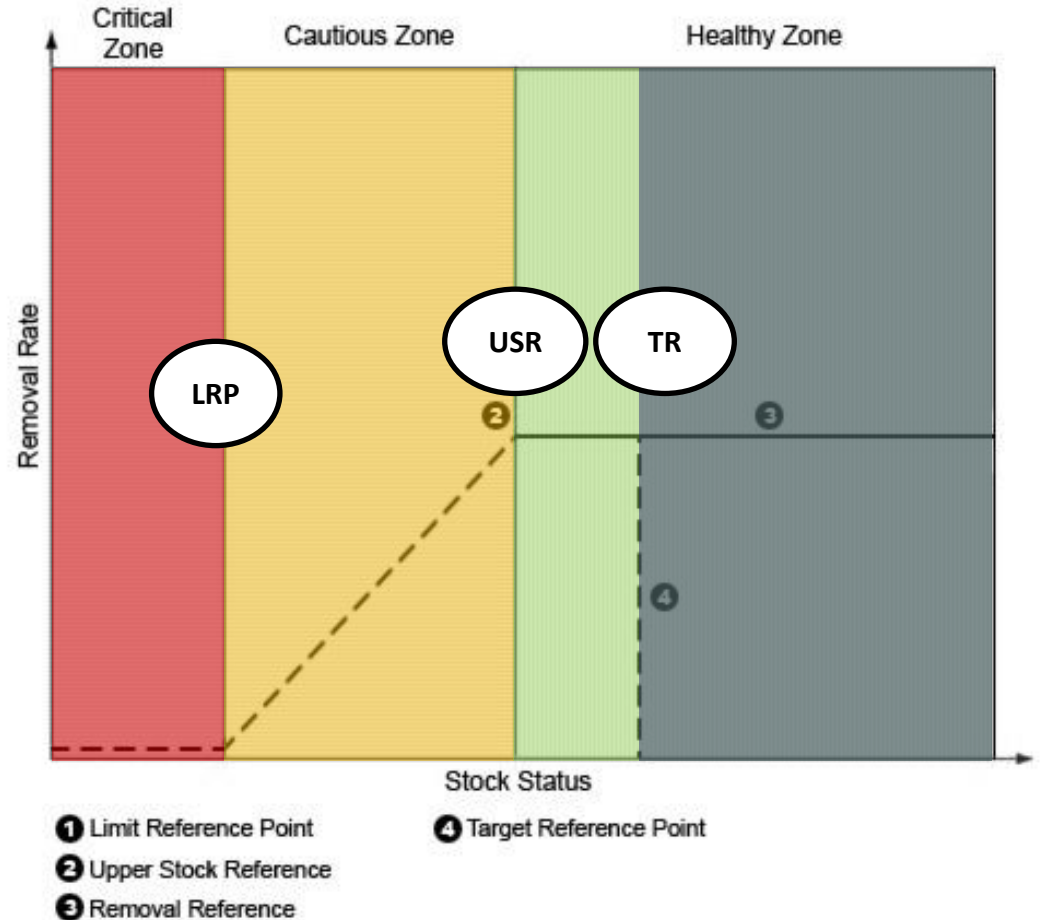
❹ Target Reference Point

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Precautionary Approach - Terminology

LRP as boundary between the critical and cautious zone

USR as boundary between the cautious and healthy zone.

TR a desirable stock status state intended to be met on average (i.e. about 50% of the time)

Critical Zone | Cautious Zone | Healthy Zone

Removal Rate

LRP   USR   TR

Stock Status

❶ Limit Reference Point
❷ Upper Stock Reference
❸ Removal Reference
❹ Target Reference Point

DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.
DFO. 2021. Science Advice for Precautionary Approach Harvest Strategies under the Fish Stocks Provisions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/004.

Canada

Precautionary Approach - Terminology

LRP as boundary between the critical and cautious zone

USR as boundary between the cautious and healthy zone.

TR a desirable stock status state intended to be met on average (i.e. about 50% of the time)

The maximum removal rate reference (RR) that would apply in the healthy zone would be the rate corresponding to the TR (<= Fmsy; fishing rate that results in maximum sustainable yield).


Critical Zone | Cautious Zone | Healthy Zone

Removal Rate

USR   TR

LRP

Stock Status

❶ Limit Reference Point   ❹ Target Reference Point
❷ Upper Stock Reference
❸ Removal Reference

DFO. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach.
DFO. 2021. Science Advice for Precautionary Approach Harvest Strategies under the Fish Stocks Provisions. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/004.

Canada

Definition of LRPs

LRP for Atlantic Salmon in DFO Gulf Region (DFO 2018b)

- Maintain production from freshwater where density-dependence is expressed
- Excludes non-stationarity productivity conditions in the ocean
- Based on an **egg-to-smolt** Beverton-Holt relationship
- LRP = egg deposition that gives 50% Rmax with probability >= 0.75
- Transferred to rivers without egg-to-smolt relationship based on habitat area

DFO. 2018b. Limit Reference Points for Atlantic Salmon Rivers in DFO Gulf Region. DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/015.
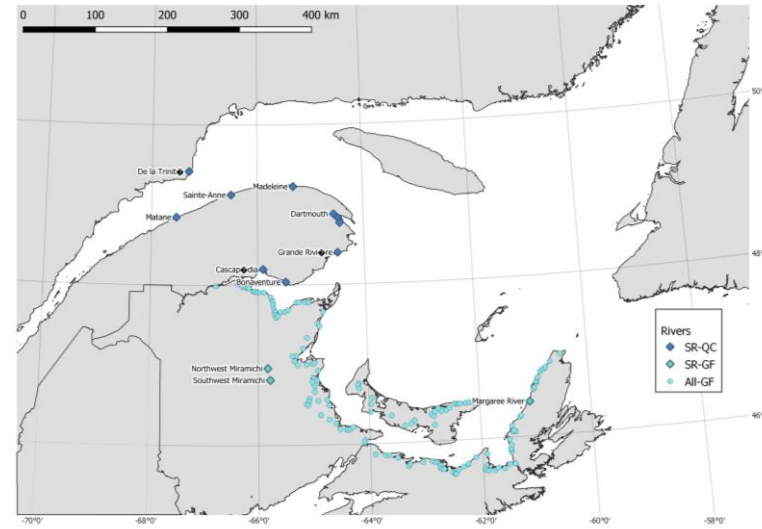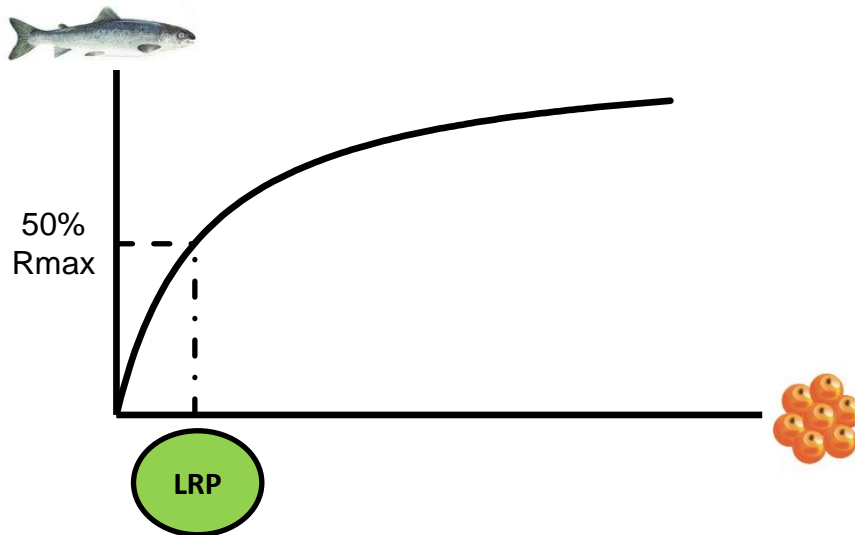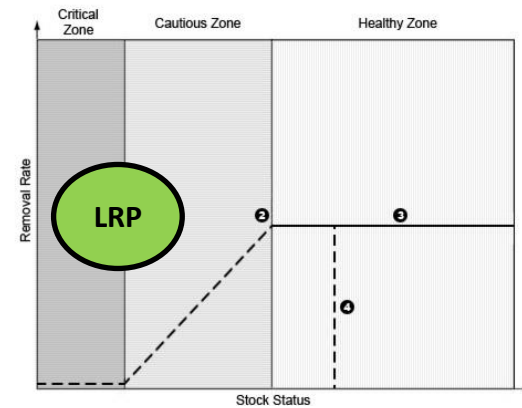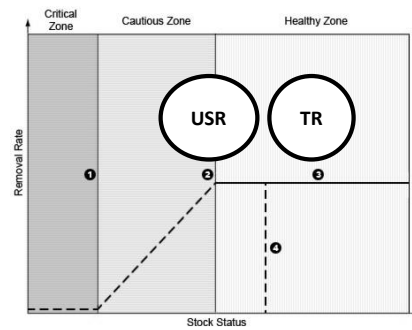
Deriving USR, TR, and RR reference points

These fisheries reference points, required when harvesting of Atlantic Salmon occurs, should be:

- Based on Maximum Sustainable Yield (MSY),

- Consider both biological aspects (from stock and recruitment relationship) and socio-economic considerations (maximizing yield), and

- Ideally, reference points and harvest decision rules would be derived using full life cycle (adult to adult) river-specific data

- Accounting for river-specific life histories, density dependent effects, quality and quantity of habitat that affects productivity, and marine survival

Canada
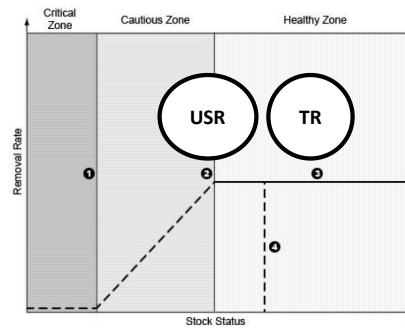
Deriving USR, TR, and RR reference points
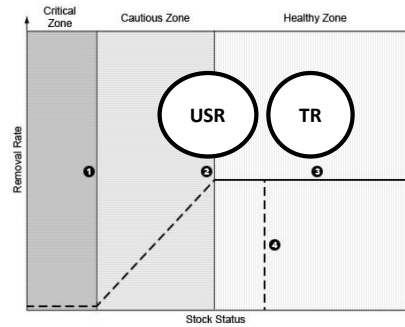

Based on adult-to-adult SR relationship

USR = 80% Recruitment at MSY (R*)

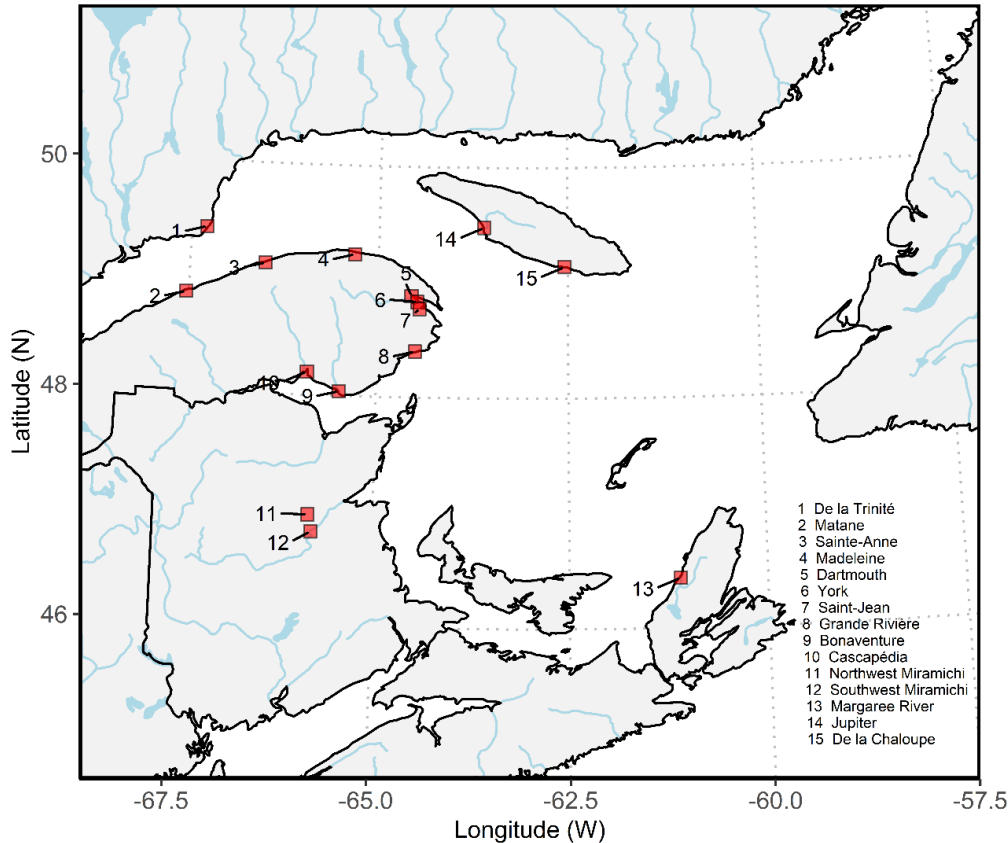TR = Recruitment at MSY (R*)

RR = Removal rate at MSY (C* / R*)

LRP = spawners that give 50%Rmax with probability >= 75%
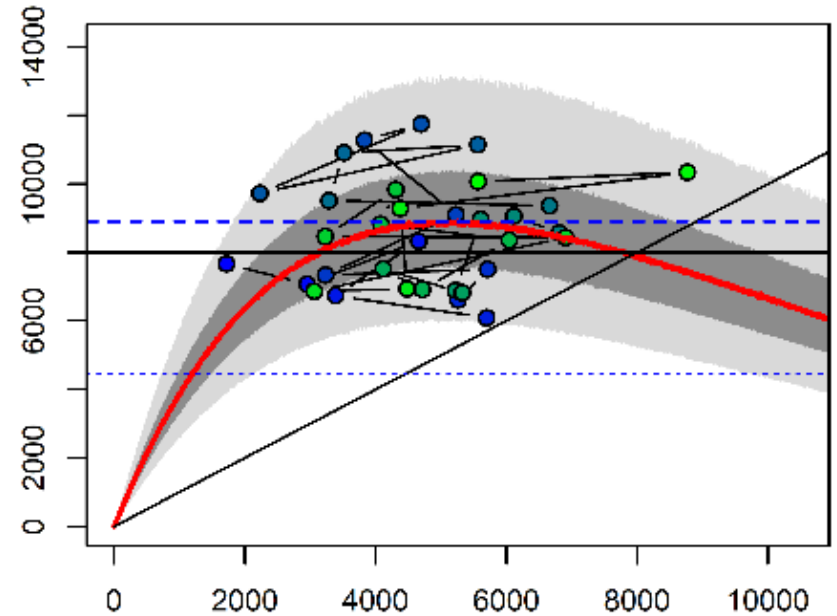
Deriving USR, TR, and RR reference points

Limited number of reconstructed and published Atlantic Salmon adult-to-adult stock recruitment time series

1 De la Trinité
2 Matane
3 Sainte-Anne
4 Madeleine
5 Dartmouth
6 York
7 Saint-Jean
8 Grande Rivière
9 Bonaventure
10 Cascapédia
11 Northwest Miramichi
12 Southwest Miramichi
13 Margaree River
14 Jupiter
15 De la Chaloupe

Data available

- 10 rivers from Quebec and 2 rivers from DFO Gulf Region

- geographically proximate with comparable life history characteristics

- egg to egg reconstructions for 1972 to 2004/2005 cohorts

Adult-to-Adult Stock Recruitment relationship

Ricker stock recruitment relationship adjusted to time-series

Classic form of the equation: $R = \alpha \cdot S \cdot e^{-\beta \cdot S}$

reparametrized using management parameters (Schnute and Kronlund, 1996):

h^*:   The equilibrium harvest rate at maximum sustainable yield, and

S^*:   The equilibrium number of spawners that allows the equilibrium catch (C^*) at maximum sustainable yield ($C^* = \frac{h^* \cdot S^*}{(1-h^*)}$)

giving

$\alpha = \frac{e^{h^*}}{1-h^*}; \quad \beta = \frac{h^*}{S^*}$

Canada

Schnute, J.T., and Kronlund, A.R. 1996. A management oriented approach to stock recruitment analysis. Can. J. Fish. Aquat. Sci. 53: 1281-1293.

Adult-to-Adult Stock Recruitment relationship

A hierarchical Ricker stock recruitment relationship was fitted to the time-series, implemented in a Bayesian Framework (JAGS + R)

A hierarchical structure over rivers (*i*) was implemented for:

- precision (τ_i, 1/variance) of the return abundances,

- h_i^*, and

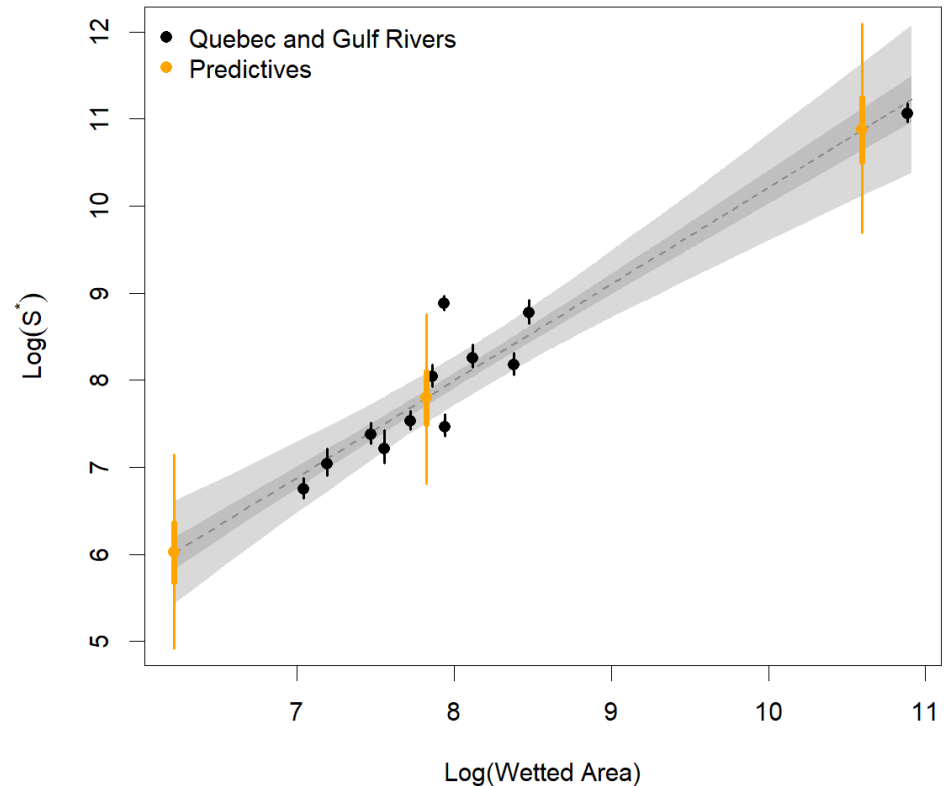- S_i^* (linked to the wetted area of each river *i* through a linear relationship in the log scale)

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Results

Hierarchical Ricker
SR fits to adult-to-adult SR data
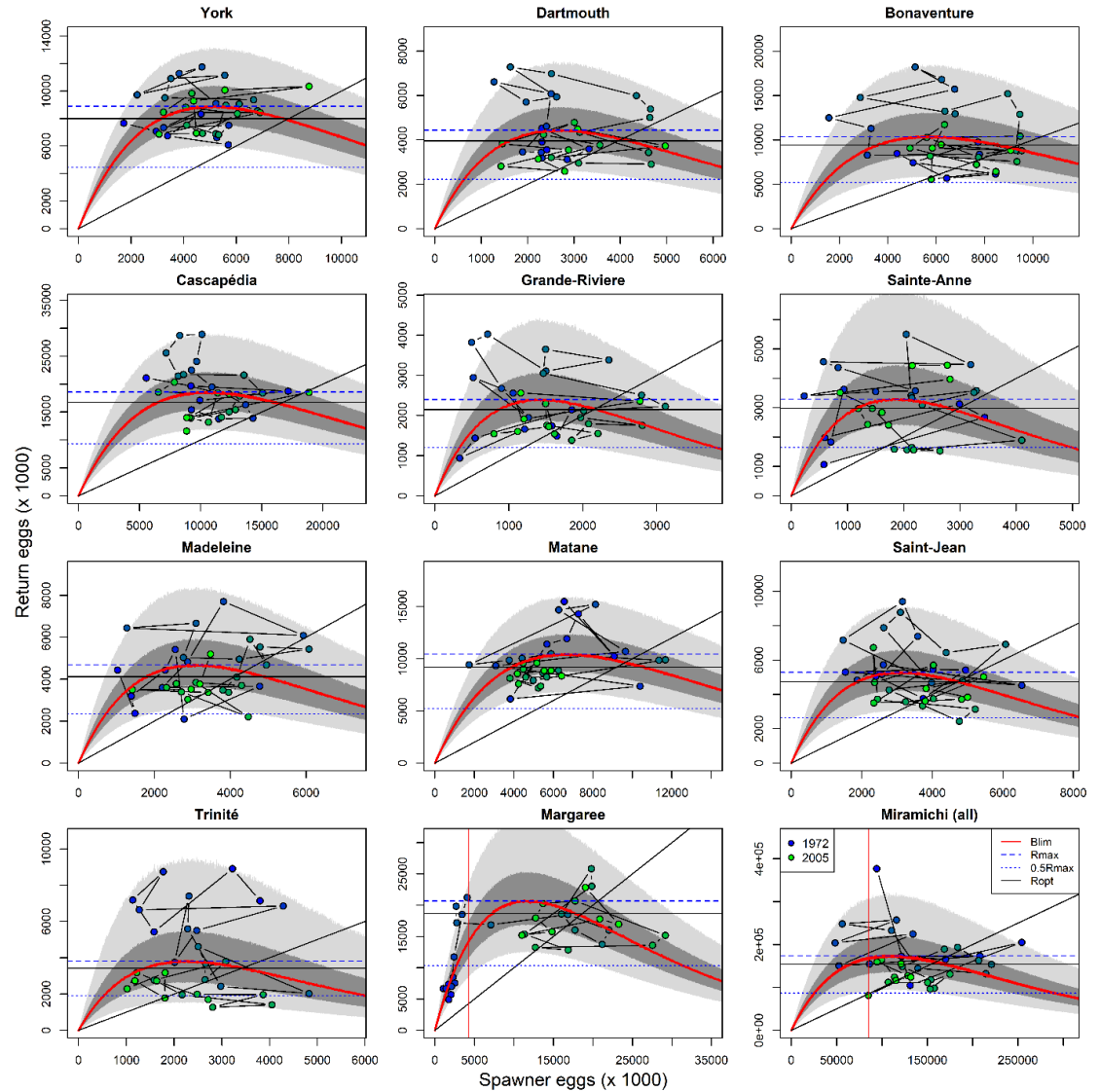
Results

Relationship between S* and wetted area

The linear association (on the log scale) of S* to wetted area is significant (excludes 0) and coefficient encompasses 1 (median = 1.11, 95% C.I. 0.86 to 1.39), indicating a direct scaling of S* to the size of the river
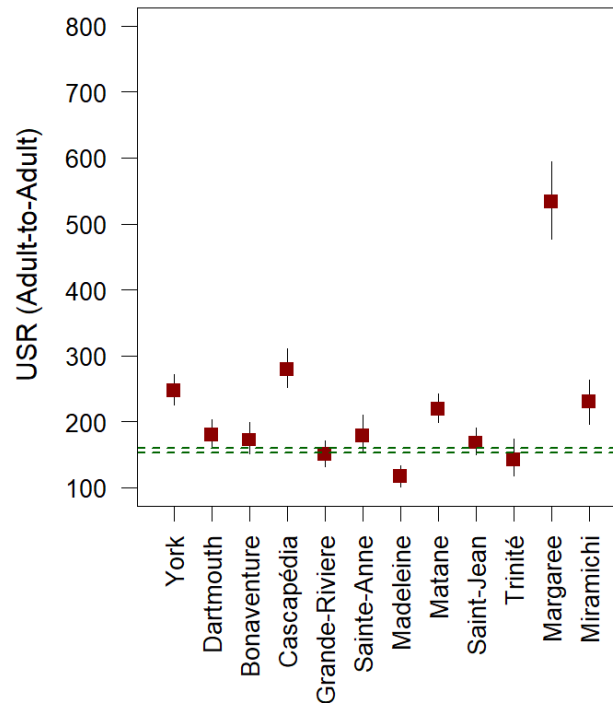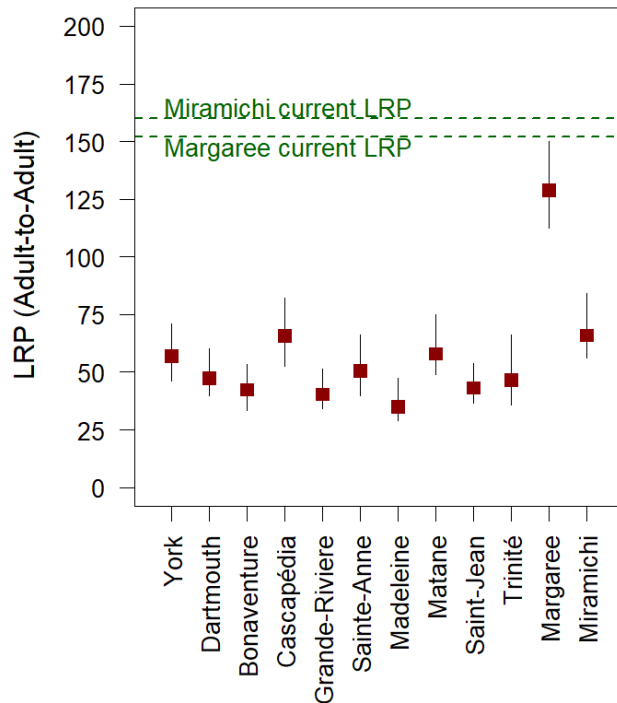
Transfer USR, TR, RR reference points – approaches

The USR and TR points could be transferred to other rivers using two approaches:

1. Transfer directly the USR and TR values in terms of eggs per unit of habitat from analyzed rivers to other rivers without stock and recruitment data

- The conservation risk of this approach: LRP reference points from adult-to-adult analyses are lower than the defined LRP based on egg to smolt data

Transfer USR, TR, RR reference points – approaches

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Transfer USR, TR, RR reference points – approaches

The USR and TR points could be transferred to other rivers using two approaches:

2. Estimate the ratios of USR and TR to LRP values of the analyzed adult to adult stock and recruitment series and calculate the USR and TR for the other rivers using that ratio and the previously defined LRP values based on the egg to smolt relationship.

- Interested in characterizing the spread between the LRP and the USR from adult-to-adult stock and recruitment data.

Transfer USR, TR, RR reference points – approaches

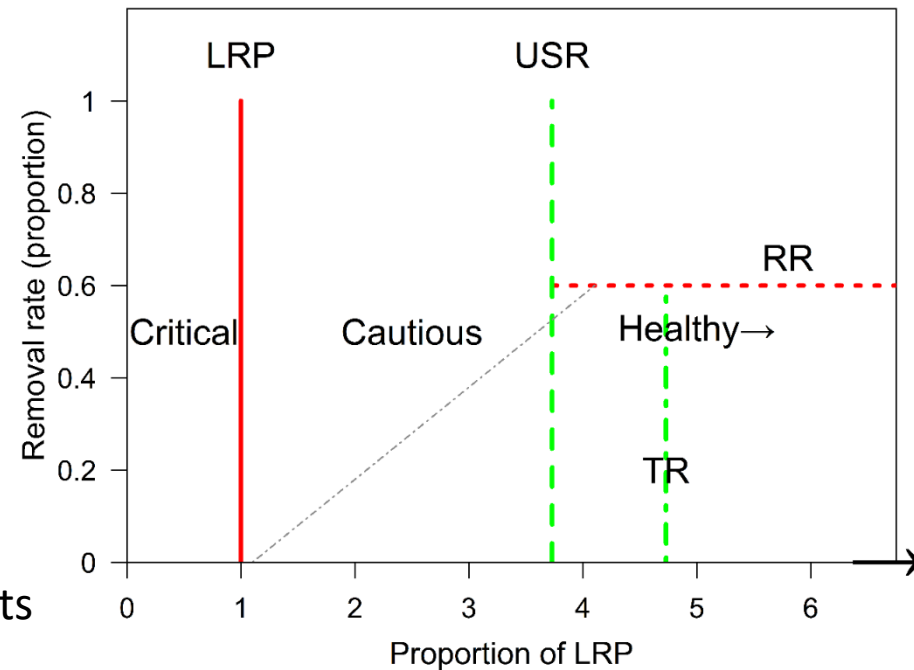Ratios of USR and TR to LRP for 12 rivers with adult-to-adult SR time series
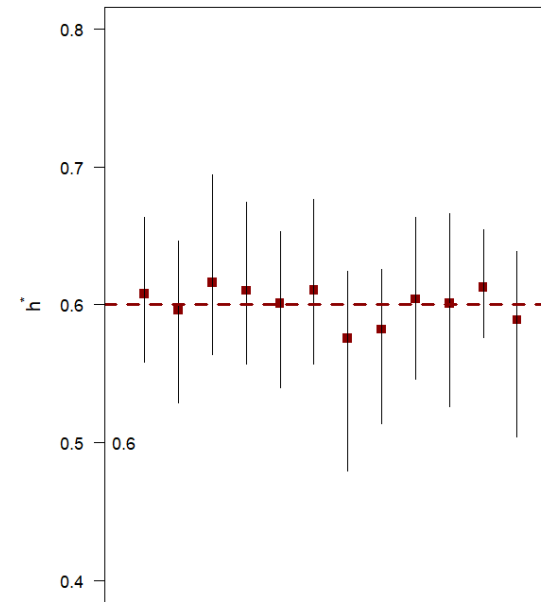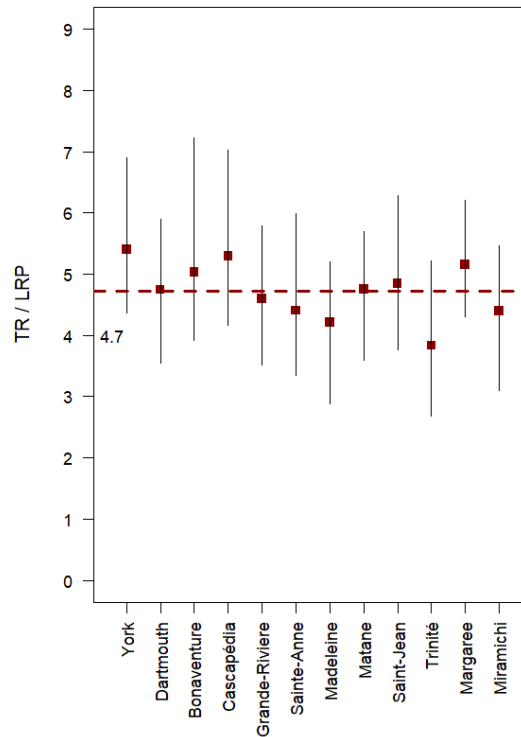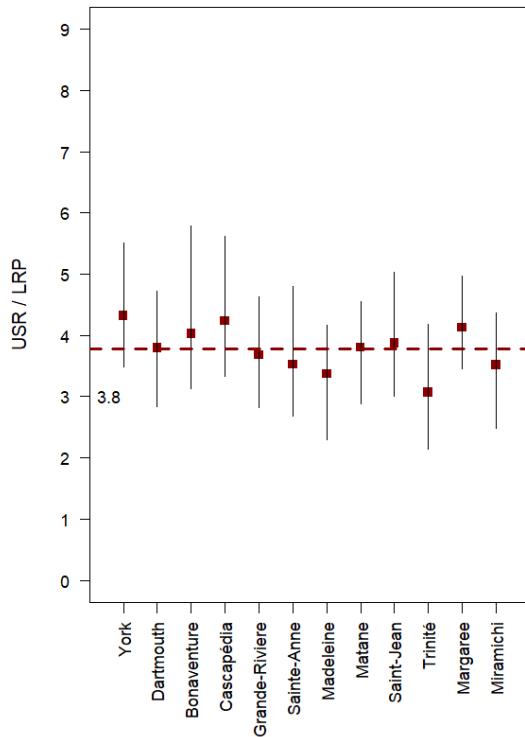
- URS/LRP: mean = 3.78, range = 3.07 to 4.32 (factor of 1.4)

- TR/LRP: mean = 4.73, range = 3.84 to 5.41 (factor of 1.4)

- RR: mean = 0.60, range = 0.58 to 0.62 (factor of 1.07)

Conclusions

- Ratios quantify the spread between the LRP and the USR (3.8) or TR (4.7) obtained from adult-to-adult stock and recruitment data which are then applied to the defined LRP based on the freshwater stage.

- The ratio approach is used because:

    - LRPs are defined using the life stage and dynamics restricted to the freshwater phase of the anadromous life cycle, the phase where density dependent compensatory survival is expressed (DFO 2015)

    - USR and TR references are intended to identify desired states of abundance of the anadromous components with associated fisheries benefits

    - This spread should provide ample time for a management response to reduce exploitation rate when stock abundance declines and take action to move the stock toward the healthy zone (PA policy, DFO 2009)

Questions

Sources of uncertainty

- Substantial evidence of directional change in the North Atlantic Ocean conditions that have affected anadromous Atlantic Salmon abundance (primarily survival)

- The estimated parameters of the stock and recruitment dynamics depend upon the time series considered

- Calculated ratios are also affected by non-stationarity conditions

  - Low marine productivity conditions noted for the salmon stocks after 1990.

  - Using the longer time series beginning in 1970s results in inclusion of higher productivity conditions to estimate the reference points (gives higher mean values)

- Lower productivity conditions of recent decades are considered reversible

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