# A Brief History

# Of

# Fraser Sockeye Harvest Planning

# (2003 to 2013)

DRAFT / 14-Mar-2014

Prepared by the FRSSI Working Group

Note that this document incorporates updated sections from earlier FRSSI-related materials, such as annual planning memos and published reports.

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# 1. Introduction

The Fraser River Sockeye Spawning Initiative (FRSSI)

The Fraser River Sockeye Spawning Initiative has been a multi-year collaborative planning process to develop a long-term escapement strategy.

In 2003 Fisheries and Oceans Canada (DFO) committed to reviewing the rebuilding plan which had been in place since 1987, and established a collaborative planning process for incorporating new information and emerging policies.

The technical groundwork was laid through the development of a simulation model which was refined over three years and six workshops, leading up to an intensive two-year planning exercise that merged the FRSSI model into a pilot implementation of the integrated management processes envisioned under the *Wild Salmon Policy* (WSP). This combined approach was the logical next step in determining an integrated escapement and harvest strategy for Fraser River sockeye while implementing the WSP and responding to the 2002 Ministerial review of Fraser River sockeye fisheries.

Since 2006, the FRSSI simulation model has been fully integrated into the annual management cycle for Fraser River sockeye, which is bracketed by two phases of public consultation, the *post-season review* in the fall and *pre-season planning* in the spring. Annual consultations occur with First Nations and stakeholders as part of the IFMP development process.

In the Commission of Inquiry into the Decline of Sockeye in the Fraser River, Commissioner Cohen reviewed 'Escapement Target Planning' including the Fraser Sockeye Spawning Initiative model. The Commissioner noted several criticisms of the FRSSI model/process and provided the following recommendation (#26):

> The Department of Fisheries and Oceans should, by September 30, 2013, complete its planned review of the Fraser River Sockeye Spawning Initiative model and address the criticisms of the model:
>
> - Whether the maximum total allowable mortality as a function of run size should be 60 percent;
> - Whether the model could more explicitly state what values are being weighed and how they are weighed; and
> - Whether habitat considerations and large escapements could be brought into escapement planning.

The planning workshops in March 2014 are part of the work towards addressing this recommendation (e.g. Option 2 with increased TAM cap)

Key publications resulting from the FRSSI process include:

- A report describing the development process (Pestal, Ryall and Cass 2008). This memo summarizes key parts of the report.
- Two technical reports, resulting from a peer-review process through the *Canadian Science Advisory Secretariat* (CSAS), which describe the simulation model used to inform the long-term planning process (Cass, Folkes and Pestal 2004; Pestal, Huang and Cass 2011). Section 3 of this memo includes a brief overview of the model.
- Annual planning memos

The reports are available online, and links are included in the References section on page 22.

Long-term strategy vs. annual adaptation

During the annual IFMP planning process, the Department reviews possible adjustments to harvest decision rules based on feedback from consultation and expected performance of individual conservation units. Typically, a shortlist of 2 to 5 harvest rule options (with different fishery reference points) for each management group has been provided in past years for discussion during pre-season consultations. The IFMP incorporates the final harvest rule/fishery reference points selected for each management unit.

The ultimate goal of this work was to converge on a long-term strategy so that an annual process would not be needed. The collaborative nature of the FRSSI model and CSAS reviews was intended to reduce scientific disagreement. However, each year there has been additional work identified through in-season implementation, post-season reviews, and pre-season consultations.

One of the reasons is that small changes in harvest strategy, that have little effect on long-term performance and trade-offs, can have substantial implications for fisheries planning in a given year (e.g. due to overlap in run timing).

Figure 1 illustrates the linkages between long-term strategy, annual pre-season planning, and in-season fisheries management. These 3 components of the harvest planning process operate at different time scales, but are closely connected. The long-term strategy shapes annual pre-season planning, which in turn shapes in-season decision-making. However, the three components are based on different types of information. The long-term strategy is developed and revised based on larger-scale and long-term patterns in stock status and fishery performance (e.g. productivity regimes, average migration conditions). The annual pre-season plan is adjusted to adapt to the specific expectations for the year (e.g. forecast). In-season implementation then focuses on following the pre-season plan as closely as possible, given uncertain information that changes rapidly (e.g. test fishery results).

Section 4 of this memo summarizes the annual planning processes from 2006 to 2013, the resulting adaptations of the harvest rules for each year, and the rationale for those adaptations.

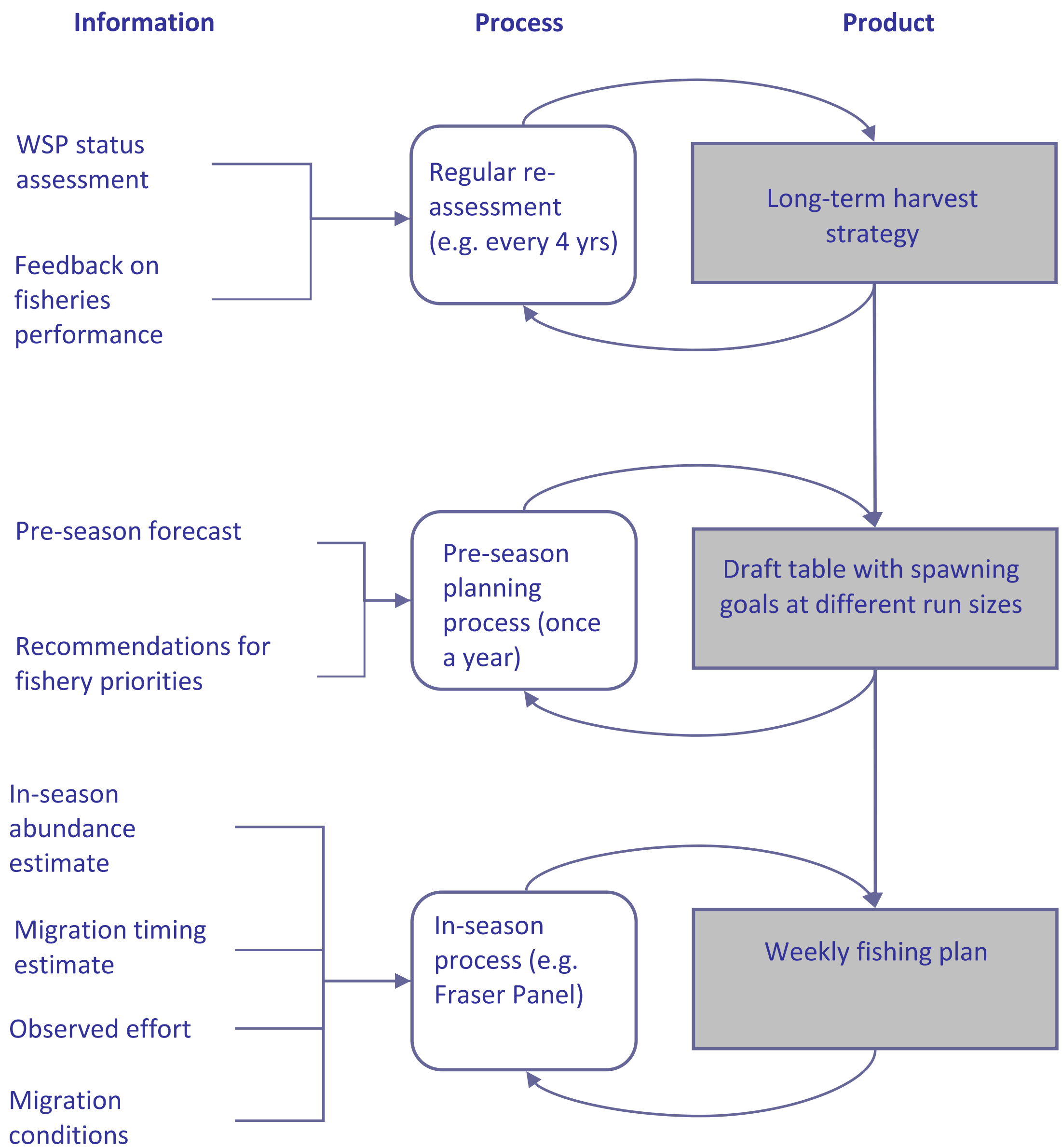


**Figure 1: From Long-term Harvest Strategy to Fishing Plan**

## 2. FRSSI Harvest Rules: Total Allowable Mortality (TAM) Rules

Basic Shape of TAM Rules

The main product of the Fraser River Spawning Initiative (FRSSI) is a long-term approach for setting annual spawning targets for Fraser sockeye, built around the following guiding principles:

- Fraser sockeye escapement is managed in 4 groups (Early Stuart, Early Summers, Summers and Lates).
- Annual targets for each management group are based on harvest rules that specify target levels of total mortality across different run sizes, called *TAM Rules*. TAM rules for each management group are designed to protect component stocks and stabilize total harvest across all sectors.
- To achieve a balance between conservation at low abundance and harvest at higher abundance, the harvest rules specify:
    - No directed harvest at very low run size with the exception of very restricted tributary fisheries (eg. Early Stuarts). However, a *Low Abundance ER* (LAER) applies across most run sizes, and specifies some low level of ER that is permitted when the management adjustment takes up most or all of the TAM. The LAER is used to plan for test fisheries, FSC, and incidental retention in fisheries targeting other Management Groups of Fraser sockeye or other species. The LAER typically ranges from 2-10%, but has been as high as 20-30% for some management groups in some years.
    - Fixed escapement and declining total allowable mortality at low run sizes (to protect the stocks and reduce process-related challenges at this critical stage (e.g. uncertain run size)
    - Fixed total allowable mortality rate at larger run sizes. This cap on mortality serves two purposes: It ensures robustness against uncertainty (e.g. estimates of productivity and capacity, changing run-size estimates) and protects stocks that are less abundant, less productive, or both. The TAM cap has been established at 60% for all management groups since 2007.

This approach is equivalent to specifying a target escapement that changes with run size. For example, if the total allowable mortality for a run size of 1 Million is 60%, then the corresponding target escapement is 400,000 and the available exploitation rate is 60% minus a management adjustment which accounts for the difference between fish counted at Mission and fish counted on the spawning grounds.

Figure 2 shows the basic shape of the TAM rules. Figure 3 illustrates some harvest control measures in addition to the basic TAM rule. Figure 4 shows how the TAM rule is used in combination with estimated abundance and estimated en-route mortality to determine a target exploitation rate.

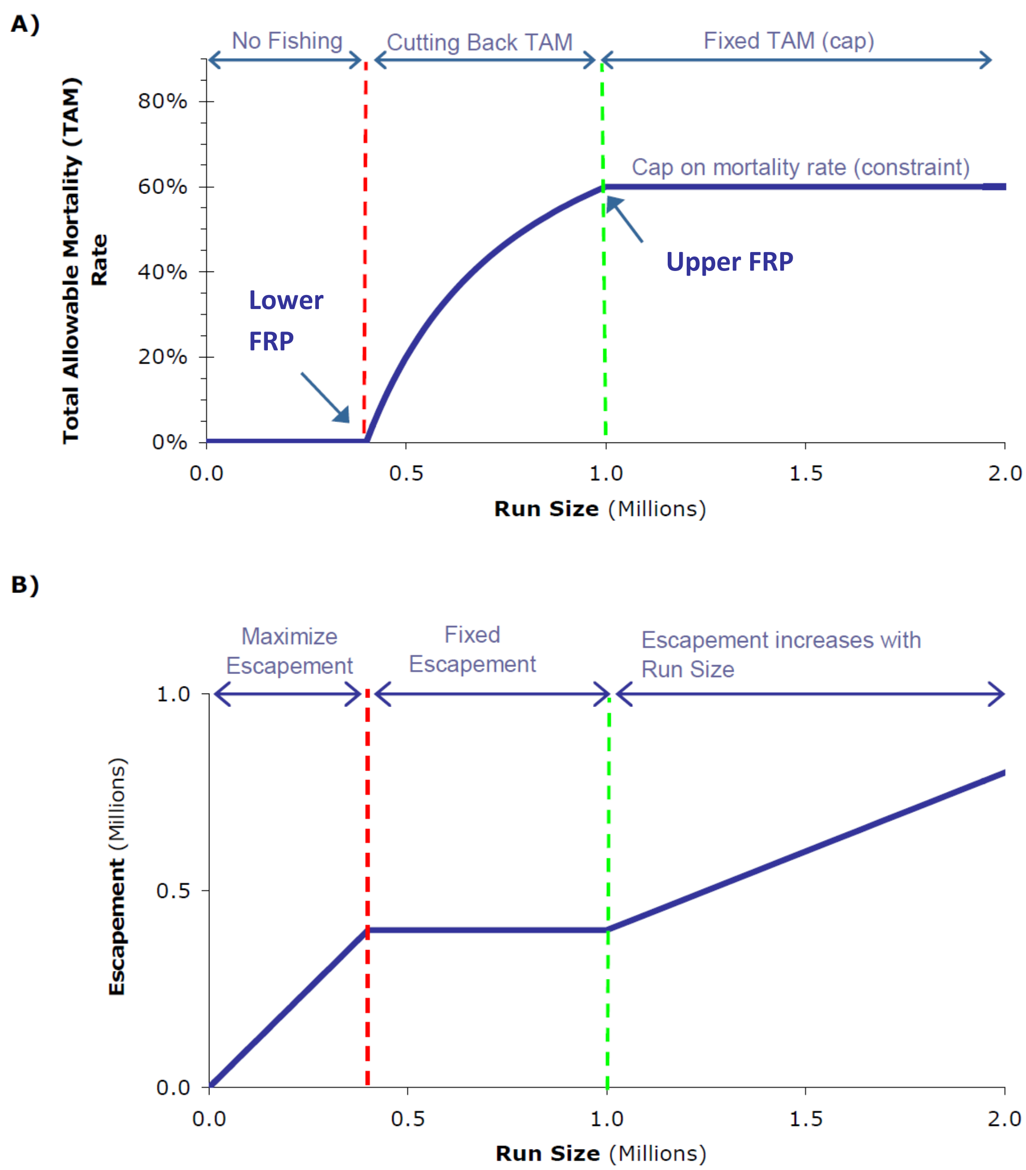


**Figure 2: Basic Shape of Total Allowable Mortality (TAM) Rule.**

For each management unit, the basic TAM rule specifies the harvest strategy for 3 different zones of abundance, delineated by a lower Fishery Reference Point (red dashed line) and an upper FRP (green dashed line) for each management unit. In this illustration, run sizes over 1 Million are managed to a total allowable mortality of 60%, including adjustments for en-route mortality. Run sizes between 1 Million and 400,000 are managed to a fixed escapement of 400,000 by gradually reducing total allowable mortality as abundance declines.

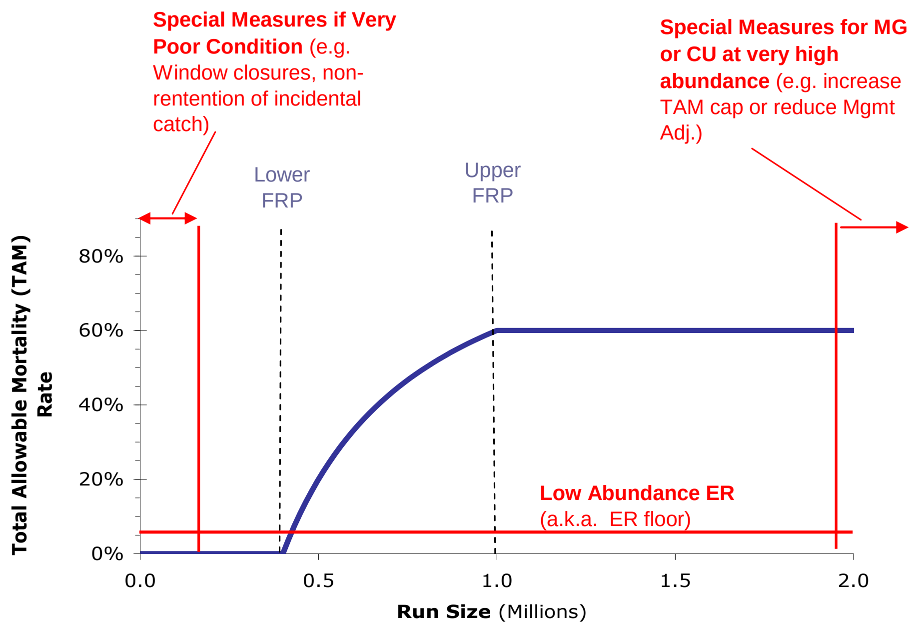


**Figure 3: Harvest Control Measures in Addition to the Basic TAM Rule**

The Low Abd ER is used to plan for test fisheries, FSC, and incidental retention in fisheries targeting other Management Groups of Fraser sockeye or other species). The LAER typically ranges from 2-10%, but has been as high as 20% for some management groups in some years. Other measures that are not captured in the shape of the TAM rule may be applied for very low and very large run sizes (window closures, ESSR fisheries)

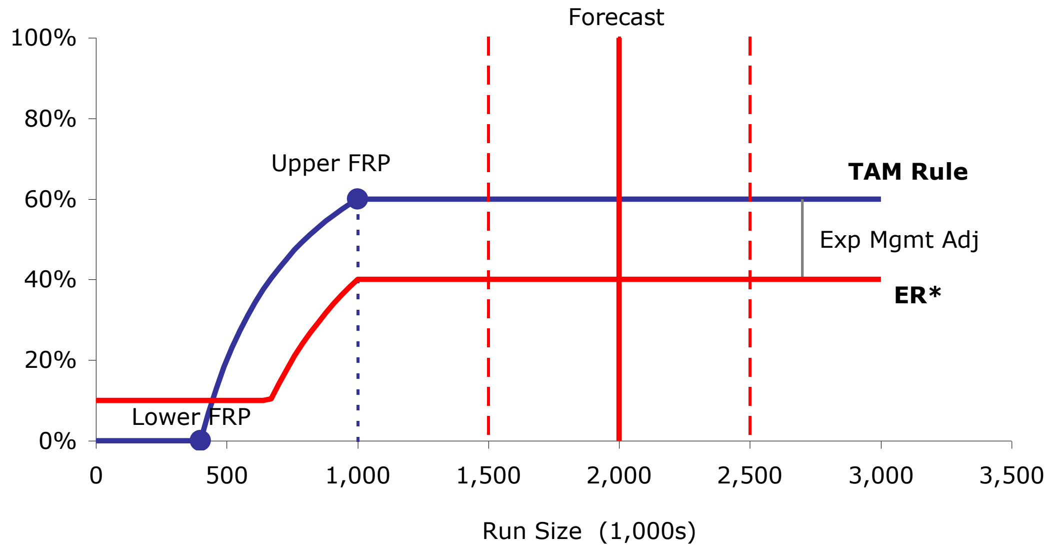


**Figure 4: From TAM Rule to Exploitation Rate**

The expected ER resulting from the TAM rule will differ due to a combination of 2 factors: the run size and the management adjustment to account for the level of en-route mortality typically associated with expected migration conditions. In this example, all of the forecast range (p25 to p75) falls into the zone of the TAM cap, resulting in a total allowable mortality of 60%, and an expected ER of 40% after accounting for the management adjustment.

General comparison of different types of harvest strategies (Fixed Spn, Fixed ER, TAM Rule)

There are 2 basic types of harvest rules: Fixed escapement and fixed exploitation rate. The FRSSI TAM rules attempt to combine the most desirable properties of both.

Table 1 summarizes previous work on the properties of these different types of harvest rules. Briefly, strategies that specify either a fixed escapement target or a fixed exploitation rate tend to perform poorly on stock aggregates with highly variable abundance and substantial differences in productivity among the component stocks. The disadvantages of these strategies are most pronounced at very large or very small run sizes.

- Fixed escapement strategies lead to high exploitation rates when aggregate run size is much larger than the aggregate escapement target. For example, a 1 Million escapement target results in a 88% exploitation rate for a run size of 8 Million. This exploitation rate for the aggregate is likely too high for less productive component stocks and may pose a high risk due to implementation uncertainty.
- Fixed exploitation rate strategies chosen based on long-term average production of a stock aggregate end up too low at large run sizes or too high at low run sizes.

Escapement strategies based on fixed exploitation rate or fixed escapement are much less robust to uncertainty and variation than TAM rules that change with run size (Figure 2).

**Table 1: Comparison of Harvest Rule Types**

| Type | Intent | Previously explored in Simulation Models? | Pros | Cons | Variations explored in FRSSI |
|---|---|---|---|---|---|
| **Fixed Escapement** | Stabilizes abundance | **YES** (e.g. 2009 Res Doc, 2006 science workshop, many papers) | Clear goal, easy to communicate, robust against uncertainty in run size and productivity | (1) All observed variability occurs in harvest (2) sensitive to uncertainty in capacity, which is high (3) leads to high ER in high abd years (especially if agg goal) (4) does not probe potential for higher capacity | Fixed Esc starting from very small to very high in intervals under different biological assumptions (for aggregates) |
| **Fixed ER** | Reduces variability in harvest (and can maximize catch if ER is set at "optimal" level) | **YES** (e.g. 2009 Res Doc, 2006 science workshop, many papers, Walters et al) | Clear goal, easy to communicate, robust against uncertainty in run size and capacity | (1) Much of observed variability occurs in escapement (2) need to set at compromise across different stock productivities (3) if set at high ER to maximize catch, then sensitive to accurate estimate of productivity (and lagging behind changes) | Fixed ER starting from very low to very high in intervals (for aggregates) under different biological assumptions |
| **TAM Rule** | Manages small runs differently from large runs (and takes into account en-route mortality) | **YES** (e.g. 2009 Res Doc, annual FRSSI memos) | Harvest level changes with abundance. Like fixed esc at small abd with clear goal and emphasis on spawning abd, but like fixed ER at large abd, probing capacity of the system (robust to uncertainty in in-season estimates as well as productivity and capacity, best of both worlds) | (1) Perception of complexity, because spawner target changes with forecast abd and allowable harvest level changes with Mgmt Adj (2) Cap on TAM set based on long-term performance, and doesn't respond to very large runs (TAM stays at cap regardless of 2,5, or 10 times larger abd, like a fixed ER rule) | Different TAM caps, cut-back points, and Low Abd ER (formerly known as ER floor), for aggregates, for individual stocks, and for a combination of agg and indiv under different biological assumptions. |

## 3. Choosing TAM Rules

Collaborative process of choosing TAM rules

The annual harvest strategy seeks a balance between long-term objectives and short-term practical considerations, and combines technical analyses with qualitative judgment. DFO releases a draft escapement plan early each year, which is then revised through consultation prior to the fishing season.

The basic approach works in 3 phases:

1. Use long-term simulations to narrow down the suite of options (FRSSI Workshops 2006-2009)
2. Choose a few options for pre-season planning (DFO WG)
3. Collaborative process to choose a specific annual TAM rule for each management group (IFMP, workshops, established consultation processes)

Considerations shaping the choice of TAM rules

- The exact shape of the escapement strategy for each management group (i.e. the run sizes at which it changes from no fishing to fixed escapement, and then to fixed mortality rate) is selected based on simulated performance and feedback from public consultation.
- Candidate escapement strategies are compared based on their simulated performance relative to biological and socio-economic indicators.
- Biological indicators reflect the intent of the Wild Salmon Policy (DFO 2005) and the Science Advisory Report describing the minimal requirements for harvest strategies to be compliant with the Precautionary Approach (DFO 2006). Biological indicators emphasize comparisons to stock-specific spawner benchmarks (e.g. How often does the 4-yr average escapement fall below the benchmark?). Stock-specific spawner benchmarks need to be robust against uncertainty in spawner data, parameter estimates (e.g. capacity), and alternative definitions. The Spawning Initiative explored a range of alternative benchmarks, using the largest and smallest value to bookend the performance measures.
- Socio-economic indicators focus on stability in total harvest (e.g. How often is the harvest less than 1 Million fish?).
- Using these stock-specific spawner benchmarks and aggregate harvest, aggregate TAM rules can then be compared based on their expected long-term performance. For example, how high should the Lower Fishery Reference Point (see Figure 2) be in order to have a good chance of keeping most of the stocks above their benchmark for most years, under a variety of different assumptions about population dynamics and future productivity? By extension, TAM rules that tend to keep stocks above the FRSSI benchmarks are intended to keep component Conservation Units out of the red zone or allow them to rebuild over time (Refer to the 2014 Planning Memo for more about CUs and their status).

The FRSSI Model – A quick overview

The FRSSI simulation model uses spawner-recruitment relationships to incorporate stock specific productivity for each of the 19 stocks to evaluate the implications of alternative harvest rules (and corresponding fishery reference points) and outcomes such as the probability of stocks falling below specified lower abundance benchmarks. The modelling framework developed is consistent with the biological principles outlined in the WSP. For example, the 19 stocks included in the simulation model closely match up with conservation units and harvest rules are evaluated based on the performance of individual stocks, not management groups. The lack of spawner-recruit data for some CUs presents an on-going challenge for the operational aspects of the Wild Salmon Policy, but is much less of an issue for Fraser Sockeye than for other areas or species. For more information about the model, refer to the Technical Reports listed on page 22. The rest of this section highlights some aspects of the model.

**Important Update**: The FRSSI process used 19 stocks in the model up until the 2013 planning process. However, Harrison is no longer one of the modelled stocks due to drastic changes in population dynamics since the 2005 return year. Some recent spawner abundances have been 20 times larger than the largest observed since the 1950s, and it is not possible to fit meaningful spawner-recruit relationships to the data at this time. In the near future, once return data is available for these recent brood years with large abundance, SR models will be re-evaluated.

Simulating the life cycle and harvest of Fraser sockeye

The FRSSI model was developed to improve our understanding of the complex interaction between the population dynamics of individual stocks and escapement strategies that, due to practical constraints of in-season management, are applied to groups of stocks. The model currently includes 19 stocks (i.e. production units delineated based on spawning site and timing).

The stocks within each timing group are modeled individually, based on the historical relationship between spawning escapement (i.e. number of adults in the brood year) and recruitment (i.e. number of 4 and 5 year old adults produced from that brood year). The model approximates the full life cycle of these sockeye populations using the most consistent data available, but does not capture the dynamics of each individual life stage (e.g. egg-to-fry survival, juvenile migration). The latest FRSSI Res Doc (Pestal, Huang, and Cass 2011) includes more detail about the population model, and how parameters are estimated for it.

Strengths and Limitations of the FRSSI Model

The FRSSI model, as well as the planning process it supports, focuses on long-term strategies and does not attempt to capture all of the operational complexities of in-season management. The model assumes that one strategy is going to be adopted and applied for 48 years, which is not likely in practice. However, previous versions of this model have proven sufficient to explore and illustrate the long-term differences between major categories of escapement strategies applied to the 4 management groups of Fraser sockeye (see summary in Table 1).

The particular choices made in the initial scoping of the FRSSI model were shaped by the existing decision process for Fraser sockeye. Revisions and extensions over the years mirrored the progression of debate among participants at various levels of the process (Steering Committee, Working Group, Workshops, annual review of draft IFMP, Fraser Panel)

Discussions around annual model revisions helped with highlighting alternative hypotheses and brought practical considerations into the analytical work. For example, the TAM rule was adapted to specify a fixed escapement in the middle range (bottom panel of Figure 2), rather than a linear reduction in allowable mortality rate (top panel of Figure 2).

The main strength of the FRSSI model is that it allows us to consistently evaluate the expected long-term-performance of alternative harvest strategies under different explicitly-stated assumptions about the biology of Fraser sockeye (e.g. population dynamics, future productivity).

The main limitation of the model is that it cannot offer any information regarding the many nuanced operational decisions specific to each year’s circumstances.

As an illustration:

- We can use the model to show that changing the TAM cap from 60% to 70% has little effect on the probability of "low spawners" (i.e. below the FRSSI benchmark) over 48 yrs for most of the 19 stocks under long-term average productivity. However, under a "half productivity" scenario many stocks show a marked increase in Prob(low spawners) as the TAM cap increases from 60% to 70%. In particular, these are stocks with lower productivity than the other stocks in their management group.
- However, the long-term simulations can only offer general guidance regarding the risks and benefits of choosing a TAM cap of 60% or 70% for the Summer Run in 2014 given the forecasted abundance of all component stocks, expected migration conditions, and assumptions about the productivity of this year's brood for each component stock.
- There are many more specific measures that can be taken to adapt the overall strategy, and these measures are not currently part of the model (e.g. fishing locations, window closures, gear restrictions, ESSR).

TAM Rules and population cycles

Spawner-recruit dynamics for Fraser sockeye have been intensively studied, but as yet there is no agreement on whether populations are intrinsically cyclic or not, and whether harvesting could initiate cycles or is a perpetuating mechanism. To address this uncertainty, changes to past management approaches were incorporated into the FRSSI model as follows:

- Harvest strategies for a given year are based on a total mortality rate (which includes fishery exploitation and management adjustments to account for en-route losses), not on a fixed escapement target. Estimates of spawning capacity are highly uncertain for some stocks, and harvest strategies based on total mortality rates should be more robust to this uncertainty.
- Escapement strategies respond to run size, but do not change for different cycle years. Under the 1987 Rebuilding Plan (previous approach), a different interim escapement goal was identified for each cycle line. Under the FRSSI approach, off-cycle years in cyclic stocks are simply treated as an instance of low abundance, with the total mortality rate based on the shape of the escapement strategy. In other words, we deal with years of low abundance by lowering the exploitation rate (down to the Low Abd ER set for each management group).

General Observations from FRSSI simulations

- No one particular performance indicator is informative across all 19 stocks or 4 management groups.
- The performance indicators reveal many complex interactions between the effect of a harvest strategy on an aggregate of stocks and the resulting performance of individual components. For example, a strategy that is intended to conserve individual stocks by cutting back on TAM at large run sizes may lead to quick increases in aggregate abundance, which in turn increases the average exploitation rate, and therefore slightly increases the probability of falling below the low escapement benchmark for some smaller component stock. Similarly, escapement strategies affect the degree of variability in escapement, both in any given year (uncertainty) and in four year patterns (cyclicity), which can lead to performance trends that appear counter-intuitive at first glance.
- Harvest strategies that respond to run size tend to perform better than either fixed escapement strategies or fixed exploitation rate strategies (see page 10 and Table 1 for a quick overview and the Technical Reports listed on page 22 for more detail). The main thing to note is that fixed escapement policies can perform really well *if you know what the optimal spawner abundance is*. If there is high uncertainty and large discrepancies depending on the method used, then a policy that probes different spawner levels

tends to perform better, and is more adaptive, in the long run. This is one of the main conclusions of the 2006 workshop on population dynamics (DFO 2006b). Similarly, a Fixed ER strategy can do really well, *if you know the productivity of major component stocks and focus you evaluation on catch-related performance measures.*,

- Among the harvest strategies explored for each of the aggregates, long-term performance is more sensitive to assumptions about population structure (e.g. degree of interaction between cycle lines) and the mix of populations in an aggregate than to changes in harvest strategy.
- The run timing overlap between management groupings has a pronounced effect on the long-term performance of different escapement strategies. Generally:
  - Exploitation rates for the Summer run aggregate are severely constrained by lower target exploitation rates for Early Summers and Late.
  - The large environmental management adjustments for Early Summer account for much of this constraint over the long-term.
  - Timing overlap of the management groups results in a substantial reduction in total catch over the long-term, but has a much smaller effect on performance measures intended to capture conservation objectives (e.g. probability of low escapement).
  - The simulated strategy for dealing with overlap has a strong effect on the level of catch reduction observed over the long term.
- Gradual changes in harvest strategy produce gradual changes in simulated long-term performance, but may have considerable implications in a given year.
- Any harvest strategy that results in substantial exploitation rates at low run sizes tends to propagate or create cyclic pattern in run size, harvest, and escapement.
- The long-term performance of alternative harvest strategies strongly depends on the population dynamics of individual stocks. Under aggregate harvest strategies, stocks with lower productivity will have a higher probability of falling below the stock-specific spawner benchmark. With stock-specific escapement strategies, these stocks have consistently lower target exploitation rates.

<u>Key Results from FRSSI simulations</u>

This section summarizes some of the results presented in the FRSSI model Research Document (Pestal, Huang, and Cass 2011), with an emphasis on the effect of changing TAM caps.

- The long-term performance of TAM rules is fairly robust over a wide range of scenarios, but not optimal for any one set of assumptions and performance measures. For example, if productivity and capacity of a stock are well known and stable over time, then a fixed ER strategy can maximize average annual catch. However, in a situation where the harvest strategy is applied to a group of stocks, each with uncertain and variable population dynamics, then a policy that reduces the harvest rate in low-abundance years will have a lower probability of bad things happening to any of the component stocks (i.e. very low spawner abundances).
- Given the basic shape of TAM rules with a cap and a gradual reduction below the Upper FRP (Figure 2), long-term performance is fairly robust to variations in the specific choices of Upper FRP, Lower FRP, cap on TAM, and Low Abd ER. In general, long-term performance is more sensitive to the choice of TAM cap and Low Abd ER than to the choice of Upper FRP (i.e. how much you harvest from large aggregate runs, and how low you cut back to on low abundances makes more of a difference than where exactly you start cutting back. Most years will either be large or small, not exactly in the middle, and those years in the middle range will be managed to a fixed spawner target anyway, as per Figure 2).

- With average productivity, the effect of varying the TAM cap from 40% to 90%, was found to be (Res Doc Fig 34):
    - Prob(Low Spawners) showed little to no change up to about 70-80% for all of the 19 stocks under average productivity , with a steep increase for higher caps
    - Prob(Low Catch) decreases steadily as TAM cap increases
    - Median catch gradually increases as TAM increases, peaks at a TAM cap of 85-90%, and then drops sharply (following the same pattern as for fixed ER policies in Res Doc Fig 30)
- The same general patterns hold under a "half-productivity" scenario, but are shifted to a lower cap (Res Doc Fig 39):
    - Most stocks show pronounced increase in Prob(Low Spawners) for caps larger than about 60-70%
    - Prob(Low Catch) now shows u-shape for 3 of the 4 management groups, which is most pronounced for the Summer group with a clear minimum around a TAM cap of 70%-80%
    - Median catch now shows a clear dome shape, most pronounced for the Summer group, peaking at a TAM cap of about 70-75%

# 4. Brief Review of FRSSI Implementation 2006-2013

Annual Planning Process

The current form of TAM rules (Figure 2) has been used annually for each management group of Fraser Sockeye since 2007. 2006 was a pilot year and total allowable mortality (TAM) rules were in a precursor form to the form used since 2007.

The specific details of the TAM rule were adapted annually to account for each year's particular constellation of aggregate forecast, stocks-specific forecasts, and expected en-route mortality. Table 2 summarizes the annual FRSSI planning processes since 2006. For a general overview of how the long-term plan interacts with the annual implementation process, refer to Chapter 1 of this document.

Rationale for Annual Adaptations of TAM Rules

Table 3 shows how the Upper and Lower Fishery Reference Points were modified annually. The cap on TAM was established early in the FRSSI process and has remained at 60% throughout. The Low Abd ER has been specified since 2010. It is 10% for Early Stuart. Early Summer, and Summers, and 20-30% for Lates

Briefly, the annual adaptation was shaped by the following considerations:

- **2007**: First year for the current form of the Fraser sockeye harvest decision rules. Fishery Reference Points were chosen based on an intensive series of multi-sectoral workshops over 2 years.
- **2008**: The Department proposed a slight reduction to the Summer run reference points as most populations had a high probability of remaining above BM2 and higher reference points resulted in a decline in potential harvest with only small incremental improvement in probabilities of exceeding BM2 for individual stocks.
- **2009**: Based on consultations, there was support for increasing the Early Stuart reference point to reduce exploitation rates and increase the probability of higher spawner abundances.
- **2010**: Approximately 80% of the forecast returns in 2010 were anticipated to be produced from just 2 dominant stocks: Chilko Lake (Summer run) and Late Shuswap (dominant year returns to Late run stocks, including Adams River). Weaker returns were forecast for several stocks in the Early Stuart, Early Summer and Summer run management units, especially populations returning to the middle and upper Fraser areas. Given concerns raised by some First Nations and stakeholders about the potential for high exploitation rates if returns were in the lower quartile of the forecast, higher fishery reference points were set for Early Summer, Summer and Late management units that would result in lower exploitation rates if these low returns materialized.
- **2011**: Fishery reference points similar to previous years
- **2012**: Early Stuart reference point reduced as expected spawner abundance was expected to exceed the brood year and this would allow earlier initiation of First Nations fisheries. Fishery reference points adjusted to account for re-alignment of stocks in each management unit. Raft and North Thompson (previously in Early Summer) and Harrison (previously in Late) included with Summer run to reflect current run timing patterns. As a result, upper fishery reference points were adjusted for Early Summer (-50,000), Summer (+300,000) and Late (-250,000).
- **2013**: Early Stuart reference point was increased based on feedback from many First Nations in consultations and concern the lower reference point of 52K was not sufficiently above WSP lower benchmarks. Summer run reference points increased to provide for additional stock rebuilding if returns were at the lower quartile of the forecast; outcomes would have been the same as previous reference points if returns were above the forecast mid-point.

**Table 2: Overview of FRSSI Planning Process 2006 to 2013**

| Planning For | Process Highlights | Key Questions Considered | Outcomes / Conclusions |
|---|---|---|---|
| **2013** | WG development of draft Principles and Guidelines document | Documenting all aspects of harvest planning (i.e. annual adaptations, implementation challenges etc) | Draft P&G Doc with suggested description of strategy for different abundance zones |
| **2012** | Multi-sector workshop in early Feb 2012. | (1) Should we change TAM caps? (2) Should we manage Raft & Harrison with Summer group? (3) Should we adjust TAM rule for observed recent productivity? | (1) No change implemented because need different questions (2) Raft & Harrison now managed with Summers (3) No change b/c had no plausible long-term productivity forecast (and then saw return to avg) |
| **2011** | FRSSI 101 Workshop in July | Focus on communication | Priorities for 2012 Planning |
| **2010** | CSAS review of updated FRSSI Model | Model revisions and extensions: 19 stocks at same time, faster sims, pre-spawn mortality option, depensation option, ability to do productivity scenarios, ability to do different mgmt groupings | Res Doc describing the modeling methodology was accepted and published (Pestal, Huang and Cass 2011). |
| **2009** | 1 Multi-Sector Planning Workshop in late January | (1) Alternative TAM rules (cap, cut-back points) (2) constraints due to overlap in run timing | (1) 2009 Escapement Memo, (2) no change, because would need a detailed in-season model to address this fully |
| **2008** | 1 Multi-Sector Planning Workshop in late January followed by a technical review session | (1) Alternative TAM rules (cap, cut-back points) (2) Stock-specific TAM rules | (1) 2008 Escapement Memo with options, Manuscript Report (Pestal, Ryall, and Cass 2008) (2) stock-spec rules => no change because challenges with choosing 19 individual rules and implementing resulting approach |
| **2007** | 3 Multi-Sector Planning Workshops (Jan -March) | Wrap up development of concepts and tools, and shift to a focus on exploring trade-offs and preferences (Structured Decision Making) | 2007 Escapement Memo with options, First year of management based on revised FRSSI TAM rules (no bump!) |
| **2006** | 3 Multi-Sector Planning Workshops (Jan -March), Science workshop on sockeye population dynamics (plus a preparatory WS in Dec 2005) | Planning priorities and alternative harvest rules, pilot for testing WSP integrated planning process | First year of management based on FRSSI TAM rules // science WS => Larkin model, mgmt based on mortality rates |

**Table 3: Summary of Fraser Sockeye Fishery Reference Points 2007-2013**

| Management Unit | Early Stuart | | Early Summer[a] | | Summer[a] | | Late[a] | | *Cultus Sockeye*[b] |
|---|---|---|---|---|---|---|---|---|---|
| FRP | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Exploitation rate limit |
| **2007** | 108,000 | 270,000 | 120,000 | 300,000 | 600,000 | 1,500,000 | 400,000 | 1,000,000 | 20% |
| **2008** | 108,000 | 270,000 | 120,000 | 300,000 | 520,000 | 1,300,000 | 400,000 | 1,000,000 | 20% |
| **2009** | 156,000 | 390,000 | 120,000 | 300,000 | 520,000 | 1,300,000 | 400,000 | 1,000,000 | 20% |
| **2010** | 156,000 | 390,000 | 200,000 | 500,000 | 1,000,000 | 2,500,000 | 1,200,000 | 3,000,000 | 20%[c] |
| **2011** | 108,000 | 270,000 | 120,000 | 300,000 | 520,000 | 1,300,000 | 400,000 | 1,000,000 | 20%[c] |
| **2012** | 52,000 | 130,000 | 100,000 | 250,000 | 640,000 | 1,600,000 | 300,000 | 750,000 | 20%[c] |
| **2013** | 108,000 | 270,000 | 100,000 | 250,000 | 1,250,000 | 3,125,000 | 300,000 | 750,000 | 20%[c] |

Notes:

a) For Early Summers, Summers, and Lates, the fishery reference points are scaled up annually to account for the expected contribution of unforecasted miscellaneous stocks in the MU.

b) A separate management objective is identified for Cultus Lake sockeye in the salmon IFMP and includes an exploitation rate constraint that limits harvest of Late run sockeye.

c) Beginning in 2010, the maximum allowable exploitation rate for Cultus sockeye was permitted to increase above 20% if conditions were expected to permit continued rebuilding of the population based on inseason information on returns of Late run sockeye and potential numbers of effective spawners.

Observed outcomes are due to a combination of harvest strategy, productivity, and en-route mortality

Despite a period of very poor overall survival for Fraser sockeye that resulted in the lowest historical returns per spawner in 2009, the Department's management approach based on the FRSSI initiative has substantially reduced overall Fraser sockeye exploitation rates which has resulted in a corresponding increase in the proportion of the run destined for the spawning areas (potential spawners). The realized proportion of spawners showed additional fluctuations due to uncertain and highly variable en-route mortality. Spawner abundance and resulting returns would likely have been much lower for many of the Fraser River sockeye salmon stocks if historic exploitation rates had been maintained in the face of reduced productivity during the last 10-15 years.

Figure 5 shows that as productivity decline, and increasing proportion of the returning Sockeye was set aside for potential contribution to spawning (and therefore to future abundance).

The FRSSI process was initiated after a period of declining productivity led to calls for a review of the 1987 Rebuilding Strategy, and the associated strict rebuilding trajectory. Productivity continued to decline during the initial implementation phase of the FRSSI TAM rules, and hit the lowest point since the 1950s in the 2009 return year. Beginning in 2010, returns of Fraser River sockeye began a reversal of the downward trend in productivity that culminated in the historic low returns per spawner in 2009 (1.6 million return from brood escapement of 3.3 million equalled 0.5 recruits per spawner). Returns in the last 4 years are back to levels more similar to long-term averages.

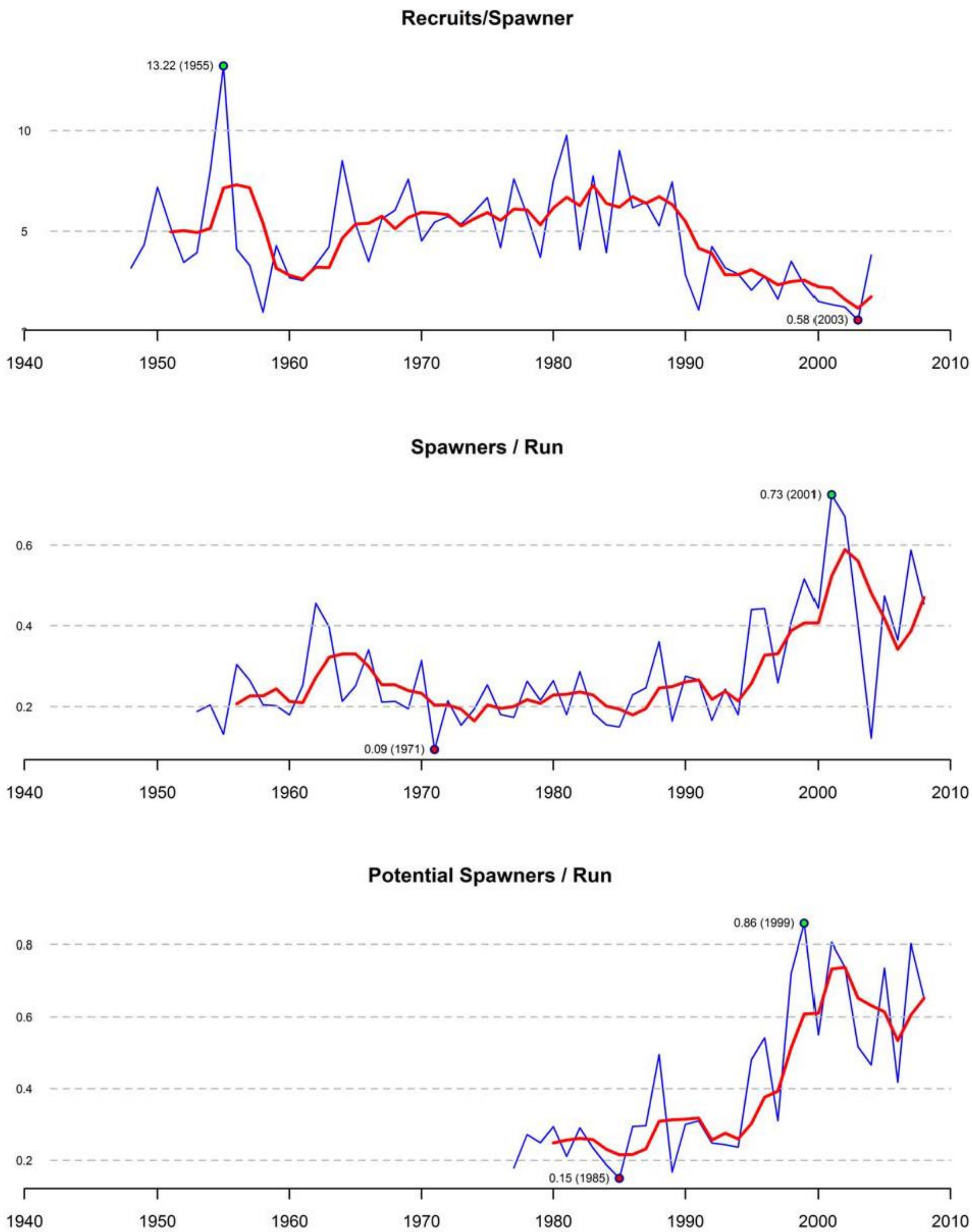


**Figure 5: Aggregate patterns in productivity and harvest**

Total include all data available for a year, with more stocks included in the later part of the time series Trend line (in red) show 4yr running averages. Potential spawning escapement is reconstructed, based on estimated in-river mortality. Note that the R/S pattern does not separate out density effects (i.e. SR fits). An updated version of this figure will be included in the final version of this document.

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