

FRASER SOCKEYE ESCAPEMENT STRATEGY 2009

Model Overview & Summary of 2009 Planning Simulations

EXECUTIVE SUMMARY

Fraser River Sockeye Spawning Initiative

The *Fraser River Sockeye Spawning Initiative* has been a multi-year collaborative planning process to develop a long-term escapement strategy. This information supplement summarizes the 2009 planning process and additional technical work that builds on the long-term strategy developed in 2007 and 2008.

The annual escapement 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.

Guiding principles

The main product of the Spawning Initiative is a long-term approach for setting escapement targets for Fraser sockeye, built around the following guiding principles:

- Fraser sockeye escapement is managed in 4 groups (Early Stuart, Early Summer, Summer, Late).
- Annual targets for each management group are based on escapement strategies that specify target levels of total mortality across different run sizes. Escapement strategies 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 strategies specify:
 - No fishing at very low run size, except for stock assessment.
 - 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 of 60% 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 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 reviewed in public consultation.
- Candidate escapement strategies are compared based on their performance relative to biological and socio-economic indicators.
- Biological indicators reflect the intent of the Wild Salmon Policy and the Science Advisory Report describing the minimal requirements for harvest strategies to be compliant with the Precautionary Approach. Biological indicators emphasize comparisons to stock-specific escapement benchmarks (e.g. How often does the 4-yr average escapement fall below the benchmark?).
- Stock-specific escapement benchmarks need to be robust against uncertainty in escapement 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 (Table 1). As formal benchmarks are developed for each *Conservation Unit* under the *Wild Salmon Policy*, these stock-specific benchmarks will be revised to ensure consistency (see p 8).
- Socio-economic indicators focus on stability in total harvest (e.g. How often is the realizable harvest less than 1 Million fish?).

Proposed Escapement Strategy for 2009

The plan for 2009 is based on the same long-term strategy that was publicly reviewed during the 2008 planning process, but the annual exploitation rate targets are adjusted based on expected run size and environmental conditions. Note that the 2008 plan was modified for Summer run and Late run compared to 2007, because of revisions in the underlying simulation model and additional consideration of practical challenges:

- *Early Stuart:* The abundance forecast of 255,000 (at the mid-point of the forecast range, a.k.a *50p level*) is much larger than last year's run size in the 2008 "off-cycle" year, but amounts to only about one third of the average for this "dominant" cycle line. It should be noted that returns have been closer to the lower end of the forecast range (i.e. *75p level*) in recent years. The lower end of the forecast range for 2009 is 165,000, which will be used for pre-season planning. The long-term strategy, as adopted in 2007, is to reduce total allowable mortality at run sizes below 270,000, with minimal allowable mortality at run sizes below 108,000. The implications of this long-term strategy for 2009 fishing plans will be strongly influenced by in-season run size estimates over the forecast range as well as management adjustments to account for environmental conditions during the return migration. Target exploitation rate for 2009 ranges from 33% at the mid-point of the forecast range to 0% at the lower end of the forecast range, given long-term average management adjustments for this stock.
- *Early Summer:* The aggregate abundance forecast of 443,000 for the eight stocks in the simulation model is about 40% larger than the average for this cycle line, with 7 of the 8 component stocks expected to return near or above average. The long-term strategy, as adopted in 2007, is to reduce total allowable mortality at run sizes below 300,000, with minimal allowable mortality at run sizes below 120,000. The implications of this long-term strategy for 2009 fishing plans are fairly robust to changing in-season run-size estimates over the forecast range, but will be strongly influenced by management adjustments to account for environmental conditions during the return migration. Target exploitation rate for 2009 ranges from 43% at the mid-point of the forecast range to 38% at the lower end of the forecast range, given long-term average management adjustments for this timing group.
- *Summer:* The aggregate abundance forecast of 8.68 Million is about one quarter below the average for this cycle line, with 2 of the 4 component stocks expected to return below average (Late Stuart: one quarter of cycle average, Quesnel: half of cycle average). The long-term strategy, as adapted in 2008 after a slight modification from 2007, is to reduce total allowable mortality at run sizes below 1.3 Million, with minimal allowable mortality at run sizes below 520,000. The implications of this long-term strategy for 2009 fishing plans are highly robust to changing in-season run size estimates over the forecast range. Target exploitation rate for 2009 is 57% across the forecast range to 38%, after a small management adjustment typical for this timing group.
- *Late:* The aggregate abundance forecast of 546,000 for the 5 stocks in the simulation model is just over the average for this cycle line, but this aggregate presents several unique management challenges that influence the choice of strategy (e.g. Cultus recovery planning, early migration and in-river mortality, mix of stocks). The strategy for this year, as adopted in 2008, is to reduce total allowable mortality at run sizes below 1 Million, with an exploitation rate floor of 20% at run sizes below about 500,000. This change was implemented to (1) address the strong cyclic pattern driven by Late Shuswap, historically the most abundant of the component stocks, and (2) allow consistency with the Cultus escapement strategy. The target exploitation rate for 2009 is fixed at 20%.
- *Birkenhead:* The abundance forecast of 297,000 is about one third below the average for this cycle line. The stock is managed passively and exposed to Summer run exploitation rates.
- *Cultus:* The abundance forecast is 5,000, and the strategy, as adopted in 2007, is a fixed exploitation rate of 20%.

- *Harrison*: The abundance forecast of 69,000 is about 50% larger than the long-term average. The approach for 2008 was to continue managing Harrison as part of the Late run aggregate. For 2009, four options are under consideration:
 - 1) Manage Harrison as an individual run timing group
 - 2) Manage Harrison as part of the Birkenhead run timing group
 - 3) Manage Harrison as part of Summer run timing group
 - 4) Status quo – Manage as part of Late run timing group

THIS DOCUMENT

This document is intended as an information supplement to explain the work that went into developing the draft escapement strategy for 2009, which is included in the draft *2009 Integrated Fisheries Management Plan* (IFMP). The escapement strategy and resulting fishing plans are now undergoing public review as part of the established pre-season planning consultations, particularly the annual review of the draft IFMP in March and April.

This document covers 3 topics:

- An *Introduction* that retraces the Spawning Initiative over the last seven years, explains the fundamental concepts, and outlines priorities for future developments.
- A *Summary of 2009 Simulation Scenarios* outlining assumptions and model specifications used to compare the long-term performance of alternative escapement strategies.
- A detailed description of the rationale for the draft *2009 Escapement Strategy*.

The following reference materials are included in this memo:

- Concepts and terminology are summarized in Figure 1 (p. 9). More technical details are included in the Technical Appendix (p. 26).
- Escapement options evaluated during the planning process are detailed in Table 1 (p. 21).
- Details of the escapement strategy for 2008 are summarized in Table 2 (p. 23).
- Benchmarks and past escapements are summarized in Table 3 (p. 25).

A summary report describing the Spawning Initiative is available on-line:

Pestal, Ryall, and Cass (2008) *Collaborative development of escapement strategies for Fraser River sockeye : summary report 2003-2008*. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2855.
<http://www.dfo-mpo.gc.ca/Library/334450.pdf>

Related documents available from DFO are:

- 2008 Integrated Fisheries Management Plan
- Meeting notes from the 2008 planning workshop
- 2008 Fraser Sockeye Escapement Memo
- Meeting notes from the 2009 planning workshop
- Draft 2009 Integrated Fisheries Management Plan

1. INTRODUCTION

The Spawning Initiative

Initial Development

The *Fraser River Sockeye Spawning Initiative* (FRSSI) has been a 7-year process to develop and implement new guidelines for setting annual escapement and exploitation targets for Fraser sockeye stocks. 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.

The Spawning Initiative workshops are designed to help DFO develop the annual escapement plan for Fraser sockeye by reviewing alternatives and draft materials. The workshops form a part of DFO's extensive public involvement processes, but do not constitute formal consultation with First Nations. People participate to provide advice, not as representatives.

2007 Planning Process

The 2007 planning process was a major milestone in the Spawning Initiative, with an emphasis on wrapping up the development of concepts and tools, and moving towards implementation. Accordingly, the 2007 workshops focused on trade-offs and preferences, and were organized to stimulate extensive discussion of alternative strategies and structured comparisons. Feedback received through the workshops helped shape the pre-season escapement plan for the draft IFMP in April 2007, which was reviewed in the regular advisory and consultative processes. A memo like this one, summarizing the rationale for the proposed 2007 escapement plan, was circulated to support the consultations. The final 2007 escapement plan was released in July 22, 2007.

Escapement strategies developed under the Spawning Initiative functioned well in the complex management process during the 2007 season. Management actions were responsive to changes in run size and outcomes were consistent with DFO's management priorities:

- smooth transition from a continuous decrease in escapement level to a fixed escapement
- severe reduction in total Fraser exploitation rate (to 10-15%) resulted in reasonable escapement levels being achieved despite the lowest observed return on all cycles since 1948.

However, the 2007 season only tested the upper and lower ranges of the escapement strategies, not the scenarios where commercial, recreational and full FSC fishing opportunities would have been permitted at less than 60% Total Allowable Mortality.

After the 2007 season workshop participants had an opportunity to provide written comments on the initiative and its implementation. Those who responded generally supported the intent of the process and recognized the considerable efforts and commitment by all participants. Respondents generally accepted the use of a simulation model to support a planning process and found the 2007 workshops a useful component of the pre-season planning process. However, respondents also expressed concern regarding the scope of the planning exercise and limitations of the current simulation model.

2008 Planning Process

The planning process for 2008 was streamlined, building on the progress made during the 2007 workshop series. A draft set of options was discussed at a workshop in late January, followed by a more technical review session for additional analyses, leading up to the release of the proposed escapement strategy in the draft 2008 IFMP. A memo like this one, summarizing the rationale for the proposed 2008 escapement plan, was circulated to support the consultations. After pre-season consultations, the final 2008 plan was released in May.

No significant technical issues arose around implementing the 2008 escapement plan. However, concerns have been raised at various post-season meetings about the need to make additional progress on *Wild Salmon Policy* implementation. For example, 'interim lower benchmarks' (Table 3) were identified for 19 stocks in the simulation model, which covers about half of the Fraser River sockeye conservation units. There is the need to develop lower benchmarks for all Fraser River sockeye conservation units. In addition, concerns have been raised by some groups that the current process does not adequately address concerns for some stocks (e.g. Bowron) that have been identified as declining in escapement levels in recent years. Lastly, some groups have expressed that additional management aggregates need to be considered beyond the four management aggregates currently identified in this process. In the coming months departmental staff will be consulting on the current 'Spawning Initiative' to see what improvements can be made to the process to address concerns that have been identified.

2009 Planning Process

The planning process for 2009 is following the same structure as the 2008 process. A draft set of options was discussed at a workshop in late January, leading up to the release of the proposed escapement strategy in the draft 2009 IFMP in mid-March. This memo is being circulated to support the consultations. The next steps are:

- Public consultation on draft 2009 IFMP throughout March and April.
- Final IFMP scheduled for release on June, 2009
- Pre-season fishing plans developed in early June, 2009
- Intensive in-season management with weekly meetings of the *Fraser River Panel* starts in second or third week of June.

Process Summary

Over the course of the Spawning Initiative, participants have provided useful and extensive advice to DFO, and their input greatly assisted DFO in crafting an escapement strategy for consultation. Workshops have become increasingly useful to DFO and participants because of their consistent structure and relatively stable attendance. Also, the format of the workshops has proven conducive to productive discussion, because participants provided advice as knowledgeable individuals to support the development of options, and were not expected to act as decision makers or official representatives of any organization.

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 on 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 Technical Appendix (p. 26) includes more detail about the population model, and how parameters are estimated for it.

The current model has proven sufficient to evaluate long-term differences between major categories of escapement strategies for aggregates. For example, the model showed clear advantages of a strategy that responds to run size (Figure 1, p. 9) compared to fixed escapement strategies or fixed exploitation rate strategies (Technical Appendix, p. 26)

Objectives and Benchmarks

The Working Group explored a wide range of escapement strategies and compared their performance using indicators that reflect the fundamental objectives of (1) ensuring escapement and production for individual stocks and (2) accessing the catch-related benefits from the timing aggregates. These fundamental objectives have been driving the analytical work since the beginning of this initiative, but the detailed definitions have evolved over the course of several workshop series.

The notions of *low escapement* and *low catch* can be quantified in many different ways, and even the Wild Salmon Policy offers a range of potential benchmark definitions that should be explored on a case-by-case basis (see pages 17 and 18 of the policy).

For the 2007 planning process, 3 benchmarks were explored to develop an escapement strategy, listed in Table 3 (p. 25). These benchmarks are based on a combination of population dynamics (e.g. 20% of the escapement that maximizes run size) and past observations (e.g. smallest observed 4yr average escapement). Benchmarks for identifying low catch are based on feedback received during the 2006 planning workshops.

These benchmarks provide a frame of reference for the simulation output, and are used in a variety of performance indicators (e.g. probability that 4yr average escapement is less than benchmark 2 over 48 years). DFO adopted benchmark 2 for escapement planning since 2007, but these benchmarks will be reviewed for consistency with WSP benchmarks as they are finalized.

DFO is developing a toolbox for assessing the status of conservation units which differ substantially in terms of geographic extent and data availability. This toolbox will be used by DFO Area staff and partners to determine lower and upper benchmarks that delimit red, amber, and green status zones of a CU. Management actions will be determined based on a CU's biological status relative to these benchmarks: Management focuses on conservation measures for CUs in the red zone (i.e. below the lower benchmark), shifts to cautionary management in the amber zone (between the lower and upper benchmark), and emphasizes sustainable use in the green zone (i.e. above the upper benchmark).

Proposed methods for setting upper and lower CU benchmarks were presented at a technical workshop in January 2009, and will be further refined over the next year. Once the benchmark methodology is complete, DFO Area staff will begin to work with local stakeholders to identify benchmarks for CUs in each area.

Long-term Strategy vs. Annual Escapement Plan

The 2008 planning process focused on the challenges of adapting a long-term strategy to the particular circumstances of each year. Small changes in escapement strategy, that have little effect on long-term performance and trade-offs, can have substantial implications for fisheries planning in a given year. Pre-season expectations for 2008 created exactly that kind of scenario for Early Summers, which in turn affects the harvest pattern for Summers. Pre-season expectations for 2009 create a similar, but less pronounced, scenario, and DFO continues to explore guidelines for the appropriate level of flexibility and a process for annual adjustments to the long-term strategy.

Escapement Strategies

Escapement strategies in the FRSSI model are defined as a Total Allowable Mortality Rule (TAM rule) that specifies the total allowable mortality rate at different run sizes. The escapement strategies are designed around three fundamental considerations (Figure 1, below):

- No fishing at very low run size, except for test fishing. The No-Fishing point is intended to keep component *Conservation Units* out of the red zone (see p. 8) with a specified risk tolerance.
- Fixed escapement 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 to ensure robustness against uncertainty in population dynamics (e.g. capacity estimate) and in-season information.

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.

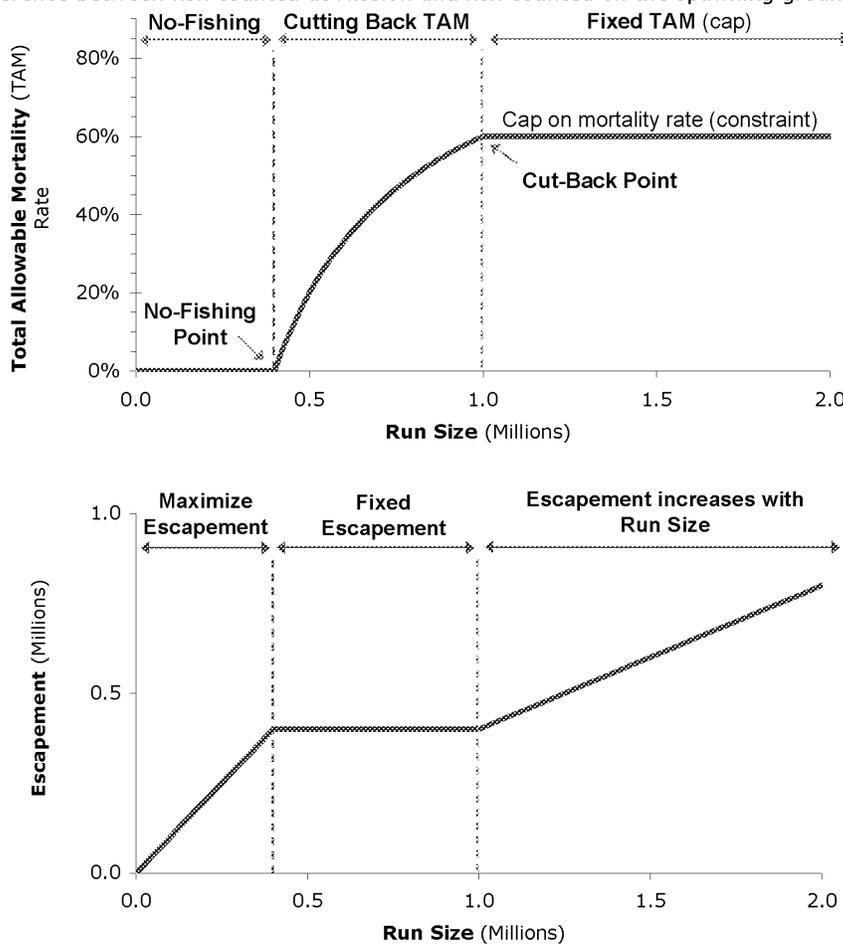


Figure 1: Illustration of Total Allowable Mortality (TAM) rule and corresponding escapement strategy.

Model revisions for 2008

A substantial amount of new technical work was completed in preparation for the 2008 planning process, in three categories:

- *Data Updates:* New escapement and recruitment data was included, and parameters for each stock's population model were updated.
- *Assumptions about the range of future outcomes:* The random variation associated with recruitment from a given escapement has been changed back to the way it was calculated up to 2006. A change was implemented for the 2007 planning process, but the technical team reverted to the original approach which results in a broader range of possible outcomes and is consistent with other DFO planning models (e.g. Cultus model by Korman and Grout, which was reviewed by PSARC in November 2007). This change has little effect on long-term average results, but some performance measures are highly sensitive. Specifically, very high and very low escapements occur more frequently in the simulated trajectories. The Technical Appendix (p. 26) outlines the details.
- *Model Structure:* The model now includes the option to specify stock-specific escapement strategies (as in Figure 1, previous page), so that the total allowable mortality for a stock would be based on its individual abundance rather than aggregate abundance. This work was identified as a priority during the 2007 planning workshops, and provides the basis for future discussion. However, much work remains to be done to refine the concepts and tools, and it is important to clearly understand the capabilities of the model: The Spawning Initiative model does not distinguish where or how that allowable mortality is accessed, but rather helps evaluate how often we would face scenarios with very different target exploitation rates for the component stocks of an aggregate. Also, management adjustments are currently available for aggregates, not individual stocks. A detailed in-season model is needed to evaluate the feasibility of different fishery arrangements and assessment frameworks.

Model revisions for 2009

The model was further updated in preparation for the 2009 planning process to address one of the long-standing questions identified by participants during previous workshops.

The model now runs all 19 stocks concurrently, rather than one aggregate at the time, to better capture the constraints introduced by timing overlap between aggregates. Timing overlap is simulated based on long-term average migration timing through Area 20 (i.e. in a mixed-stock fishing area)

Two alternative approaches for dealing with the overlap in annual implementation are included in the model:

- *Abundance:* Mixed-stock exploitation rate for each day is constrained by the smallest exploitation rate among those timing groups that contribute more than 10% of the abundance, and realizable catch in mixed-stock fisheries is calculated based on these revised exploitation rates.
- *Window:* Mixed-stock exploitation rate for each day is constrained by the smallest exploitation rate among those timing group that are present that day based on a time-window that captures 90% of each run centered around the peak. Realizable catch in mixed-stock fisheries is calculated based on these revised exploitation rates

The Technical Appendix (p. 26) illustrates how these two approaches differ in annual implementation, and summarizes the resulting differences in the long-term performance of different escapement strategies.

Note: the simulation results shown in Figures 2 to 5 are based on 10% of daily abundance, not the time window.

Priorities for future model revisions

The next step is to fine tune the model and the underlying assumptions. The following priorities were identified during the 2008 and 2009 planning processes:

- Refine biological assumptions (correlation between stocks, correlation over time, capacity estimates, management adjustments, migration timing, population models, implementation error).
- Further explore the concepts and implications of stock-specific escapement strategies.
- Compile a technical report describing the revised model structure and assumptions, once the other changes have been implemented.
- Further assess the dynamics of stocks with spawning channels (e.g. Gates, Nadina), given their counter-intuitive performance in the simulations.

Other initiatives are also developing building blocks for a long-term escapement strategy. For example, on-going work under the *Wild Salmon Policy* will establish formal benchmarks to replace the interim escapement benchmarks listed in Table 3. The section on *Objectives and Benchmarks* (p. 8) includes more detail about these interim benchmarks and how they match up against the WSP benchmark concepts.

2. SUMMARY OF 2009 SIMULATION SCENARIOS

Model Scope

The current model is set up to do the following:

- Simulate 19 stocks over 48 years and apply different long-term harvest strategies
- Apply aggregate escapement strategies, stock-specific escapement strategies, or a mixture of both
- Track aggregate and stock-specific performance measures
- Account for overlap in run timing (two options, see next page)
- Apply different levels of productivity to simulate plausible future scenarios brought about by climate change
- Apply correlation in recruitment across stocks
- Apply management adjustment (Mission vs. Up-stream)

In addition, the current model can be used to explore the alternative assumptions about the following:

- spawner-recruit model
- patterns of productivity change
- management adjustments (e.g. en-route vs. pre-spawn mortality)
- timing overlap and management strategies for dealing with it

However, the current model is not set up to address the following:

- alternative fishing plans (i.e. timing and location of harvests)
- catch sharing across sectors or areas
- annual adjustments to escapement strategy

Settings and Assumptions for 2009 Simulations

- The model includes 19 stocks grouped into 4 timing aggregates for management purposes.
- Each model scenario applies a specified escapement strategy to each of the four timing aggregates 48 years into the future, starting with recent years, and tracks the performance of each individual stock within the aggregate.
- Simulations start with escapement data up to 2005, and population dynamics are estimated based on spawner and recruit data up to brood-year 2001 (due to the time-delay to compile and analyze recruitment data from age 3, 4, and 5 returns).
- Population dynamics for all 19 stocks are simulated using the Larkin model, which explicitly estimates the level of interaction between cycle lines.
- A minimum exploitation rate of 2% for test fishing is applied every year.
- A cap of 60% total allowable mortality is applied every year for all stocks and aggregates.
- For the results presented here we assume that past observations cover the range and variability of productivity for these stocks. However, the model is set up to explore alternative assumptions about future productivity (e.g. 30% decline over 50 years).
- Overlap between timing groups is calculated based on run size, average peak timing, and average spread around the peak. Two options have been explored (p. 10) and corresponding results are presented in the next section.
- Birkenhead sockeye were not included in the assessment of Late run escapement strategies, rather, Summer run escapement strategies were applied to Birkenhead, which reflects the passively managed nature of the Birkenhead component of the Fraser sockeye run.
- Harrison sockeye were simulated as part of the Late run aggregate, but several management options for 2009 are under consideration (see p. 19).
- Cultus sockeye were considered separately based on the extensive recovery planning work completed in 2006 and 2007.
- The Working Group explored a wide range of escapement strategies and compared their performance using indicators that reflect the fundamental objectives of (1) ensuring escapement and production for individual stocks and (2) accessing catch-related benefits from the timing aggregates.
- Using several variations of these indicators to ensure robust conclusions, the Working Group re-evaluated the options put forward during the 2008 planning process.
- Workshop participants reviewed updated results (due to model revisions described earlier) and reconsidered the rationale for choosing among the options in the face of specific circumstances expected for 2009. The major planning challenges for each aggregate are briefly discussed in the remainder of this section.

General observations

- No one particular indicator is informative across all 19 stocks or 4 timing groups.
- The performance indicators reveal many complex interactions between the effect of an escapement strategy on an aggregate of stocks and the resulting performance of individual components. For example, an escapement strategy that is intended to conserve individual stocks by cutting back on TAM at large run sizes (e.g. Option 4 in Figure 3) 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 (cyclicality), which can lead to performance trends that appear counter-intuitive at first glance.

- Escapement strategies that respond to run size, as illustrated in Figure 1, perform better than either fixed escapement strategies or fixed exploitation rate strategies. The Technical Appendix (p. 26) discusses this in detail and includes results for a range of fixed exploitation rates as an illustration.
- Among the escapement 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 escapement 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 management adjustments for Early Summer account for much of this constraint over the long-term.
 - Overlap 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 (p. 26).
- Gradual changes in escapement strategy produce gradual changes in simulated performance, but may have considerable implications in a given year. For example, the difference in long-term performance between Option 2 and Option 3 for Early Summers is small (Figure 2), but the implications for 2009 TAC are considerable, particularly at the lower end of the abundance forecast (Table 1b).
- Any escapement strategy that results in substantial exploitation rates at low run sizes (e.g. Option 1 for Early Stuart, fixed 45% exploitation rate) propagates or creates a cyclic pattern in run size, harvest, and escapement.
- The long-term performance of alternative escapement strategies strongly depends on the population dynamics of individual stocks. For example, three stocks are identified as performing poorly compared to more productive stocks, across many different escapement strategies (Late Stuart, Nadina, Pitt). Under aggregate escapement strategies, these stock have a higher probability of falling below the escapement benchmark. With stock-specific escapement strategies, these stocks have consistently lower target exploitation rates.

The Technical Appendix (p. 26) includes examples and more detailed explanations of these general observations.

3. DRAFT 2009 ESCAPEMENT STRATEGY

This section outlines how the reasoning underlying the proposed approach for 2009, chosen from the 3 to 4 options considered for each management group. It is important to note that while the workshop participants during the 2008 and 2009 planning processes were not able to identify one single option that was superior to all the others their advice guided the Department's decision in crafting the draft 2009 Fraser River sockeye escapement strategy.

For all these scenarios, Benchmark 2 was used as the interim benchmark level for avoiding low escapement (Table 3). Performance of stocks relative to these interim benchmarks is evaluated based on 4-yr average escapement to reduce the influence of a single very small or very large escapement (e.g. dominant line). On-going science work under the *Wild Salmon Policy* will be used to refine these benchmarks prior to the 2011 planning process (see p. 8).

The plan for 2009 is based on the same long-term strategy that was publicly reviewed during the 2008 planning process, but the annual exploitation rate targets are adjusted based on expected run size and environmental conditions. Note that the 2008 plan was modified for Summer run and Late run compared to 2007, because of revisions in the underlying simulation model and additional consideration of practical challenges.

Note: An additional level of complexity has been introduced in the interpretation of simulation results due to the constraints imposed by overlap in run timing. The performance of alternative escapement strategies for one management aggregate is now influenced by the escapement strategy applied to the other aggregates. For example, the long-term performance of Option 1 for Summer run is influenced by the choice of strategy for Early Summers. For the simulation results presented in this section, the escapement strategies only vary for one aggregate at the time while the other aggregates are always managed based on the 2008 plan (i.e. explore the effect of changing the strategy *while keeping all else equal*).

Early Stuart

Early Stuart is modeled as a single stock with strong cycle-line interaction. Escapement strategies with high cut-back points (e.g. Option 4) tend to build up off-cycle abundances and reduce peak abundance in dominant years, so that the stock builds up to a fairly stable abundance and escapement.

Early Stuart has experienced poor returns in recent years, partly due to high en-route mortality as they migrate up the Fraser River. Many FRSSI participants and external advisors have raised the concern that this stock requires a high degree of protection. Accordingly, the escapement strategy proposed for 2009 is Option 3, which has a low risk tolerance. For example, there is a less than 1 in 10 chance of not achieving the benchmark 2, averaged over 4 years (--- dashed line in Figure 2).

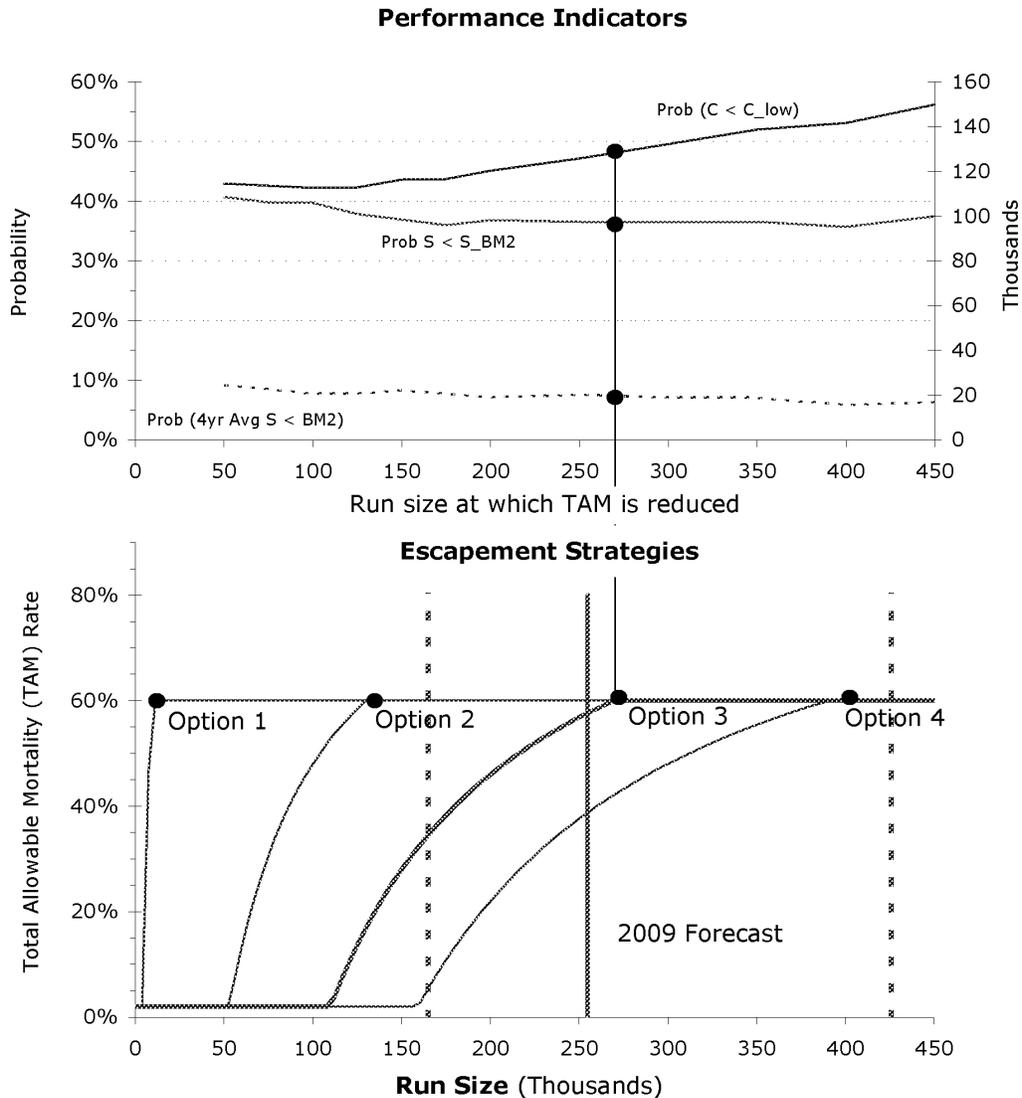


Figure 2: Sample simulation results and options for Early Stuart

Early Summer

The Early Summer aggregate is modeled as a mixture of 8 stocks, of which 3 exhibit strong cycle-line interactions and contribute the majority of the abundance (Nadina, Scotch, Seymour). For 4 of the 8 stocks considerably less data is available, with time series starting in the late 1960s (Fennel, Gates) or even in the 1980s (Scotch). This increases uncertainty in the population dynamics, and complicates interpretation of the simulation results.

Six of the eight stocks have a high probability (i.e. better than 9 out 10 years) of achieving BM 2 over the entire range of alternative escapement strategies (Bowron, Fennel, Gates, Raft, Scotch and Seymour). Nadina and Pitt don't achieve BM 2 with a similarly high probability, but show some gradual improvement as the escapement strategy shifts to a higher cut-back point (e.g. from Option 1 to Option 4). However, this marginal improvement comes at the cost of a substantial decrease in long-term average catch, as well as a substantial increase in the probability of falling below annual catch targets. Balancing these different considerations, DFO proposes Option 2 as the escapement strategy for 2009, which was also adopted last year.

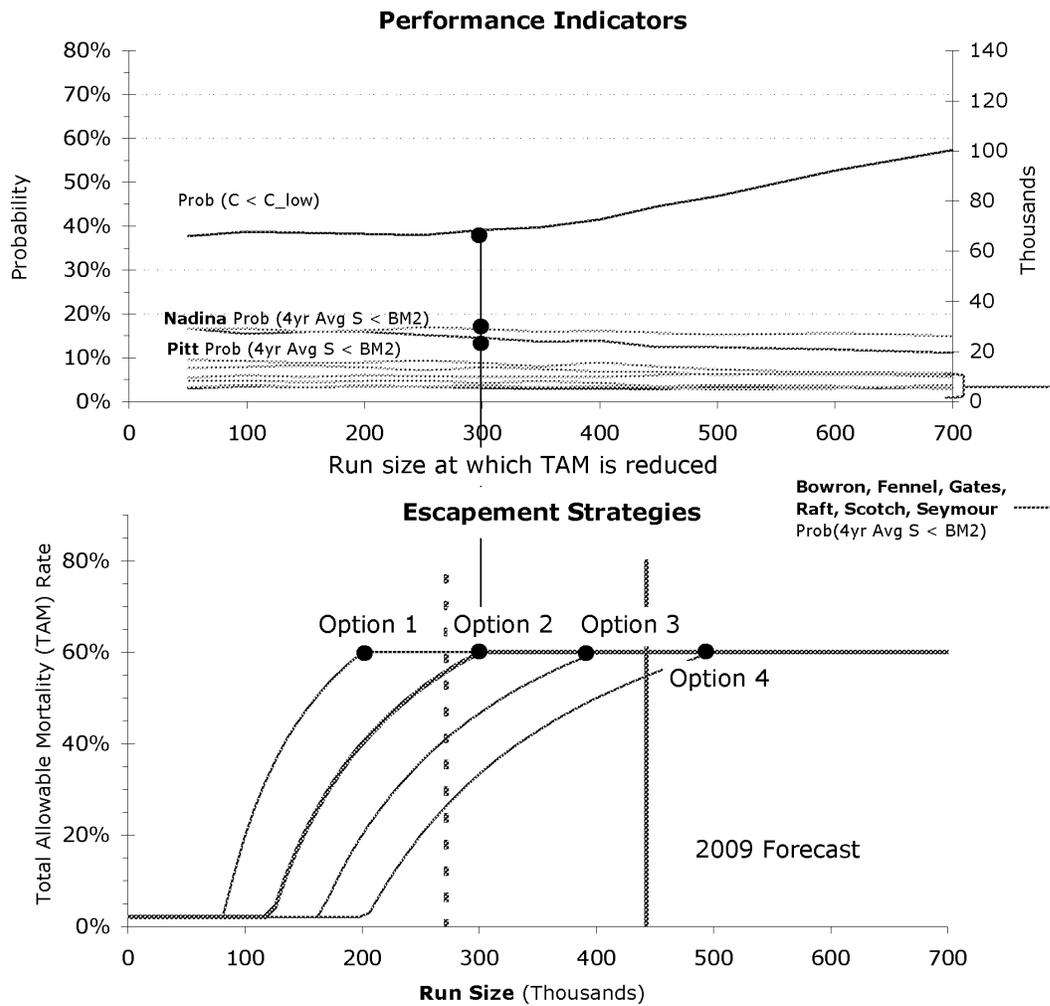


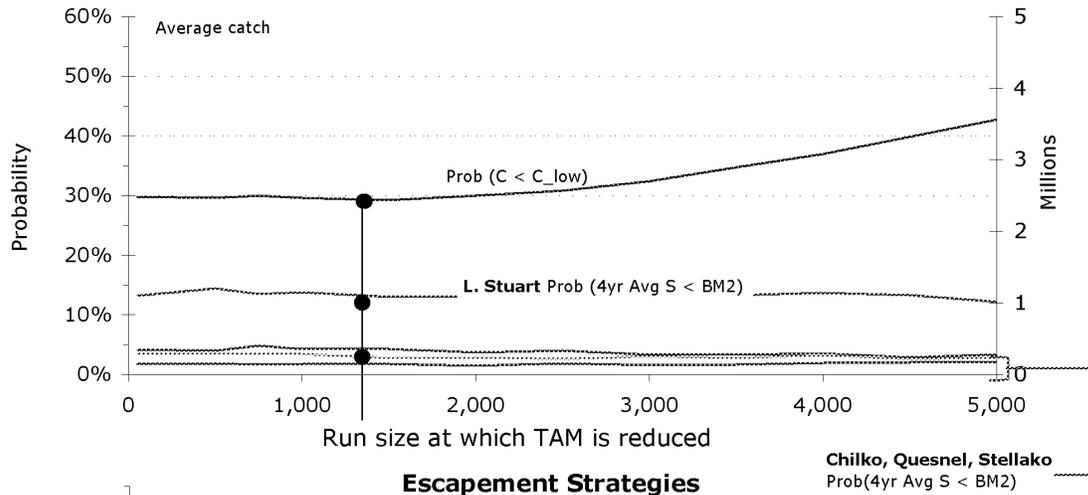
Figure 3: Sample simulation results and options for Early Summer

Summer

The Summer aggregate is modeled as mixture of 4 stocks. Late Stuart and Quesnel show strong 4 year cycles in past observations, while Stellako and Chilko show weaker cycle line interactions. Performance measures are strongly influenced by the extent to which the cyclic pattern is propagated. Birkenhead is modeled passively by applying Summer exploitation rates.

Three of the four stocks have a high probability (i.e. better than 9 out of 10 years) of achieving BM 2 over the entire range of alternative escapement strategies (Chilko, Quesnel and Stellako). Late Stuart doesn't achieve BM 2 with a similarly high probability, but shows some gradual improvement as the escapement strategy shifts to a higher cut-back point (e.g. from Option 1 to Option 3 and beyond). However, this marginal improvement comes at the cost of a substantial decrease in long-term average catch, as well as a substantial increase in the probability of falling below annual catch targets. Balancing these different considerations, DFO proposes Option 1 as the escapement strategy for 2009, which was also adopted last year.

Performance Indicators



Escapement Strategies

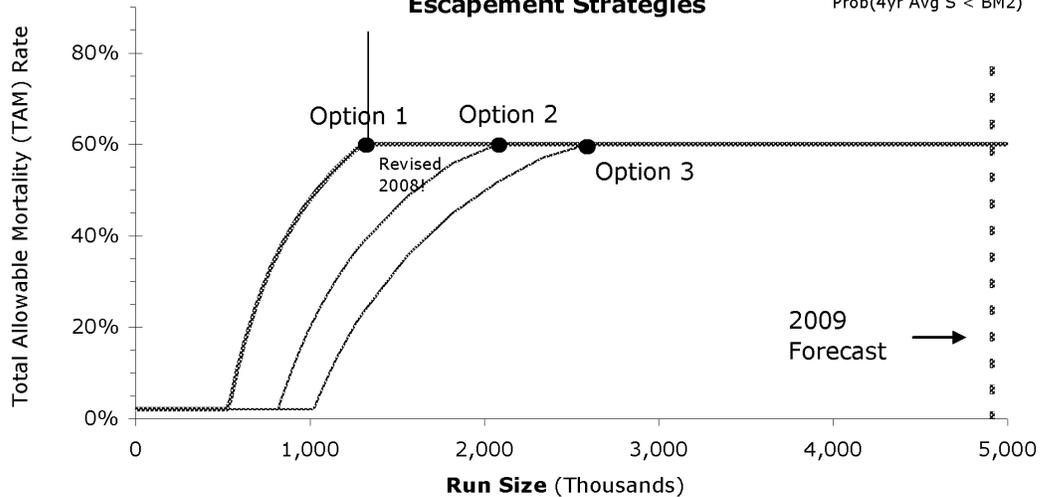


Figure 4: Sample simulation results and options for Summer

Late run

The Late run aggregate is modeled as a mixture of 5 stocks (L. Shuswap, Weaver, Portage, Harrison and Cultus), one of which exhibits strong cycle-line interactions and contributes most of the abundance (Late Shuswap). Figure 5 shows that the performance of escapement strategies is very robust across a wide range of cut-back points, because run size in most of the Late Shuswap dominant years is larger than the largest cut-back point (e.g. 2 Million) and in most of the "off" years the run size is smaller than the lowest point at which the strategy switches to the exploitation rate floor of 20% (e.g. 500,000).

DFO proposed Option 1 as the long-term escapement strategy for the Late aggregate, with a 20% floor on exploitation rate to address cyclic patterns and timing overlaps. This strategy was also adopted last year.

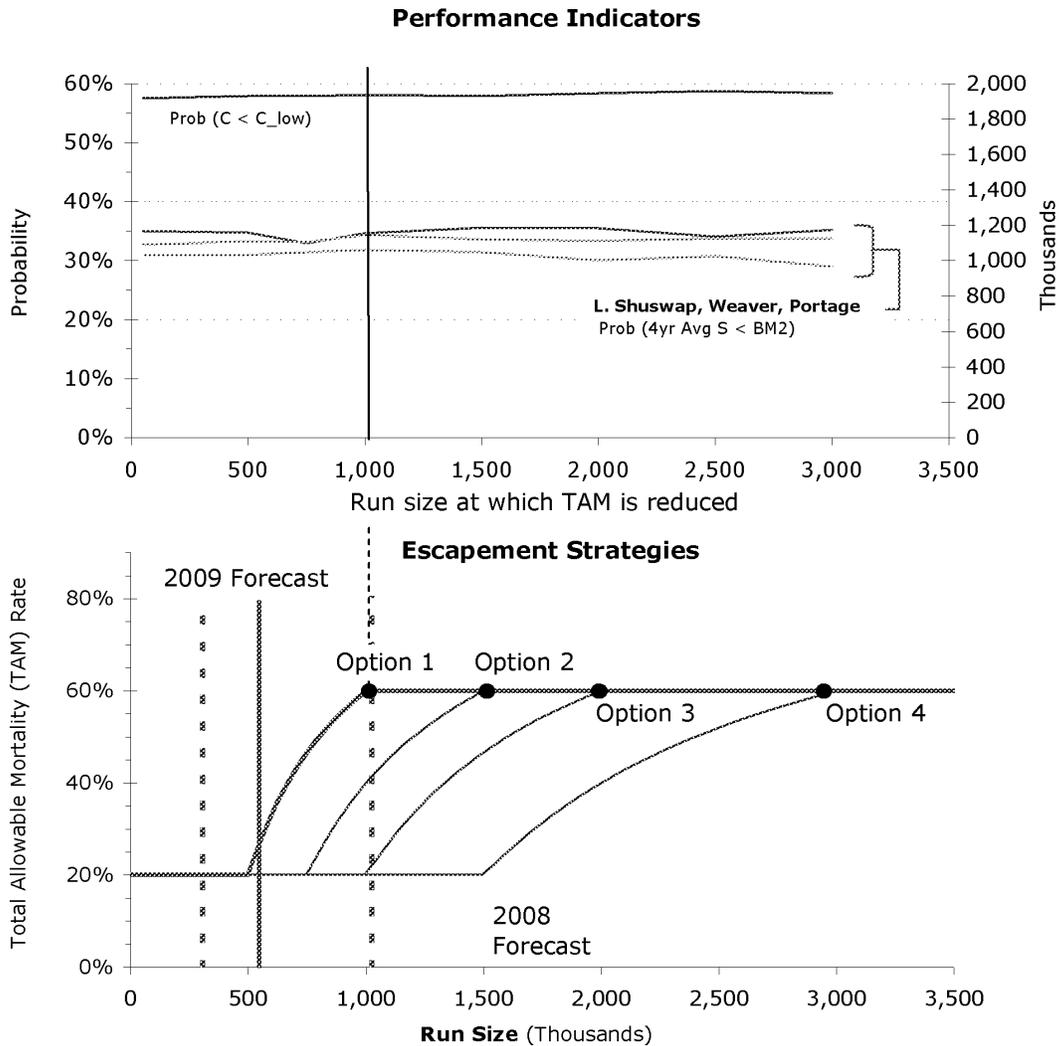


Figure 5: Sample simulation results and options for Lates (using a 20% ER floor)

The performance of escapement strategies is fairly sensitive to the chosen minimum exploitation rate, as illustrated in a detailed example in the 2008 escapement memo. The 20% exploitation rate floor was implemented in 2008 for two reasons:

- The strong cyclic pattern driven by one stock poorly reflects the dynamics of other stocks in the aggregate. The need for a modified strategy in off-cycle years was identified during the 2007 planning process, due to the timing overlap with Summer run sockeye and the associated implementation constraints on most fisheries.
- Management of the Late run aggregate benefits from consistency with the recovery strategy for Cultus Lake sockeye.

Portage, Weaver and Late Shuswap achieve the escapement benchmark roughly 7 out of 10 years under this strategy. This was considered acceptable in the context of the revised assumptions about the range of future outcomes, which increased the simulated frequency of low escapements (refer to the Technical Appendix on p. 26 for details). While this risk tolerance is not as stringent as the criteria applied to the other aggregates, it is still consistent with previous departmental risk assessments.

Harrison and Cultus were simulated as part of the Late run, but also considered separately, as described below.

Birkenhead

Birkenhead sockeye have distinct population dynamics and migration behavior. While they were managed as part of the Late run aggregate prior to 2002, they are now passively exposed to the same exploitation rate as the Summer run aggregate. In simulations, the long-term distribution of escapement is only slightly affected by the choice of escapement option for the Summer run aggregate. In fact, there is a better than 8 out of 10 chance that that escapements will exceed the benchmark *every year*.

Harrison

Harrison sockeye present a particular management challenge, and four management options have been raised for consideration:

1. treat Harrison as an individual run timing group
2. move Harrison into Birkenhead run timing group
3. move Harrison into Summer run timing group
4. status quo – leave Harrison in with Lates

The Working Group has proposed not to pursue options 2 or 3, because Harrison sockeye behave differently from Summer and Birkenhead sockeye – specifically, the historic levels of en-route mortality, pre-spawn mortality, and productivity of Harrison differ substantially from Summer run and Birkenhead sockeye.

To evaluate the option of treating Harrison as an individual run timing group, there are several key considerations that must be taken into account:

- It is difficult to interpret the large escapement in 2005, with almost 10 times more spawners than the largest previously observed escapement. This introduces large uncertainty into the population model for this stock, and makes it difficult to judge the long-term implications of alternative escapement strategies. The four year old return from the 2005 escapement will be returning in 2009.
- Simulations showed that Harrison tends to perform poorly under any of the Late run escapement options *if the population dynamics for Harrison follow the pattern of production estimated from data up to 2001, and under the same level of mortality as other Late run stocks*.

- Simulations showed that Harrison cannot sustain exploitations rates resulting from any of the Summer run escapement options *if the population dynamics for Harrison follow the pattern of production estimated from data up to 2001, and under the same level of mortality as other Late run stocks.*

To evaluate the impact of separating Harrison from the Late Run, the following must be developed:

- TAM rule for Harrison only
- TAM/fixed exploitation rate floor for Late Run without Harrison
- management adjustment models for Harrison and Late Run without Harrison
- timing models for Harrison and Late Run without Harrison

Cultus

For Cultus sockeye a separate, more detailed life history model has been developed to explore recovery options built around combinations of enhancement actions and escapement strategies. This model was used during the 2006 planning exercise, and has been directly tied in with the FRSSI model results.

For each of the Late run escapement options the FRSSI model tracks the range and sequence of exploitation rates applied to Late run sockeye. The Cultus model then applies these exploitation rate trajectories to test their effect on Cultus under different enhancement scenarios. Under none of the options explored was the probability of recovery greater than 30% at current enhanced levels. If enhancement levels were significantly increased, the probability of recovery increased and the probability of extinction decreased to very low levels. However, enhancement effects for sockeye remain unproven and are costly to implement.

The 2009 plan for Cultus sockeye is a target exploitation rate of 20%, just as in 2007 and 2008. This was selected due to:

- a low 2009 forecast of 5,000 sockeye,
- high uncertainty in the forecast, and
- unpredictable long-term responses to predator removal.

Table 1a. 2008 Escapement options (at mid-point of forecast range)

| 50p | No Fishing Point / Fixed Escapement Target* | Cut-back Point* | TAM* at Run Size | Esc. Target | pMA** | Mgmt Adj. | Expl. Rate after MA | Total Allowable Catch |
|--|--|------------------------|-------------------------|--|--------------|------------------|----------------------------|------------------------------|
| Early Stuart | 2009 Forecast (50p) | | 255,000 | | 0.59 | | | |
| Option 1 | 4,000 | 10,000 | 60% | 102,000 | | 60,180 | 36% | 92,820 |
| Option 2 | 52,000 | 130,000 | 60% | 102,000 | | 60,180 | 36% | 92,820 |
| Option 3 | 108,000 | 270,000 | 58% | 108,000 | | 63,720 | 33% | 83,280 |
| Option 4 | 156,000 | 390,000 | 39% | 156,000 | | 92,040 | 3% | 6,960 |
| Early Summer | 2009 Forecast (50p) | | 443,000 | w/o misc | 0.42 | | | |
| | | | 739,000 | w. misc | | | | |
| Option 1 | 80,000 | 200,000 | | | | | | |
| | 133,454 | 333,634 | 60% | 295,600 | | 123,000 | 43% | 320,400 |
| Option 2 | 120,000 | 300,000 | | | | | | |
| | 200,181 | 500,451 | 60% | 295,600 | | 123,000 | 43% | 320,400 |
| Option 3 | 200,000 | 500,000 | | | | | | |
| | 333,634 | 834,086 | 55% | 333,634 | | 138,826 | 36% | 266,500 |
| Option 4 | 260,000 | 650,000 | | | | | | |
| | 433,725 | 1,084,312 | 41% | 433,725 | | 180,474 | 17% | 124,800 |
| Summer | 2009 Forecast (50p) | | 8,677,000 | | 0.07 | | | |
| Option 1 | 520,000 | 1,300,000 | 60% | 3,470,800 | | 242,956 | 57% | 4,963,200 |
| Option 2 | 800,000 | 2,000,000 | 60% | 3,470,800 | | 242,956 | 57% | 4,963,200 |
| Option 3 | 1,000,000 | 2,500,000 | 60% | 3,470,800 | | 242,956 | 57% | 4,963,200 |
| BK Group | 2009 Forecast (50p) | | 334,000 | (note: no MA is applied to Birkenhead type) | | | | |
| Option 1 | | | 60% | 133,600 | | | 60% | 200,400 |
| Option 2 | | | 60% | 133,600 | | | 60% | 200,400 |
| Option 3 | | | 60% | 133,600 | | | 60% | 200,400 |
| Late | 2009 Forecast (50p) | | 546,000 | w/o misc | 0.87 | | | 20% |
| | | | 573,000 | w. misc (note: Birkenhead type not included) | | | | 114,600 |
| Option 1 | 400,000 | 1,000,000 | | | | | | |
| | 419,800 | 1,049,500 | 27% | 419,800 | | 365,226 | 0% | - |
| Option 2 | 600,000 | 1,500,000 | | | | | | |
| | 629,700 | 1,574,200 | 0% | 573,000 | | 498,510 | 0% | - |
| Option 3 | 800,000 | 2,000,000 | | | | | | |
| | 839,600 | 2,098,900 | 0% | 573,000 | | 498,510 | 0% | - |
| Option 4 | 1,200,000 | 3,000,000 | | | | | | |
| | 1,259,300 | 3,148,400 | 0% | 573,000 | | 498,510 | 0% | - |
| total TAC (using proposed 2009 options) | | | | | | | | 5,681,880 |

* The escapement options in this table correspond to the options illustrated in the bottom panels of Figures 2 to 5. For example, Option 3 for Early Stuart is an escapement strategy with a cut-back point of 270,000. This describes a strategy with 60% total allowable mortality above 270,000 run size, and a fixed escapement of 108,000 below that run size. If run size falls below 108,000, the strategy prescribes no harvest except test fishing. Figure 1 explains the shape of the escapement strategies.

** pMA = expected percent management adjustment based on previously observed differences between escapement to Mission and final escapement counts.

Table 1b. 2008 Escapement options (at lower quarter of forecast range)

| 75p | | No Fishing Point / Fixed Escapement Target* | Cut-back Point* | TAM* at Run Size | Esc. Target | pMA** | Mgmt Adj. | Expl. Rate after MA | Total Allowable Catch |
|--|----------------|--|------------------------|-------------------------|--|--------------|---|----------------------------|------------------------------|
| Early Stuart | | 2009 Forecast (75p) | | 165,000 | | 0.59 | | | |
| Option 1 | 4,000 | 10,000 | 60% | 66,000 | 38,940 | 36% | 60,060 | | |
| Option 2 | 52,000 | 130,000 | 60% | 66,000 | 38,940 | 36% | 60,060 | | |
| Option 3 | 108,000 | 270,000 | 35% | 108,000 | 63,720 | 0% | - | | |
| Option 4 | 156,000 | 390,000 | 5% | 156,000 | 92,040 | 0% | - | | |
| Early Summer | | 2009 Forecast (75p) | | 272,000 | w/o misc | 0.40 | | | |
| | | | | 443,000 | w. misc | | | | |
| Option 1 | 80,000 | 200,000 | | | | | | | |
| | 130,294 | 325,735 | 60% | 177,200 | 71,400 | 44% | 194,400 | | |
| Option 2 | 120,000 | 300,000 | | | | | | | |
| | 195,441 | 488,603 | 56% | 195,441 | 78,750 | 38% | 168,800 | | |
| Option 3 | 200,000 | 500,000 | | | | | | | |
| | 325,735 | 814,338 | 26% | 325,735 | 131,250 | 0% | - | | |
| Option 4 | 260,000 | 650,000 | | | | | | | |
| | 423,456 | 1,058,640 | 4% | 423,456 | 170,625 | 0% | - | | |
| Summer | | 2009 Forecast (75p) | | 4,914,000 | | 0.07 | | | |
| Option 1 | 520,000 | 1,300,000 | 60% | 1,965,600 | 137,592 | 57% | 2,810,800 | | |
| Option 2 | 800,000 | 2,000,000 | 60% | 1,965,600 | 137,592 | 57% | 2,810,800 | | |
| Option 3 | 1,000,000 | 2,500,000 | 60% | 1,965,600 | 137,592 | 57% | 2,810,800 | | |
| BK Group | | 2009 Forecast (75p) | | 194,000 | | | (note: no MA is applied to Birkenhead type) | | |
| Option 1 | | | 60% | 77,600 | | 60% | 116,400 | | |
| Option 2 | | | 60% | 77,600 | | 60% | 116,400 | | |
| Option 3 | | | 60% | 77,600 | | 60% | 116,400 | | |
| Late | | 2009 Forecast (75p) | | 306,000 | w/o misc | 0.87 | | 20% | |
| | | | | 323,000 | w. misc (note: Birkenhead type not included) | | | 64,600 | |
| Option 1 | 400,000 | 1,000,000 | | | | | | | |
| | 422,200 | 1,055,600 | 0% | 323,000 | 281,010 | 0% | - | | |
| Option 2 | 600,000 | 1,500,000 | | | | | | | |
| | 633,300 | 1,583,300 | 0% | 323,000 | 281,010 | 0% | - | | |
| Option 3 | 800,000 | 2,000,000 | | | | | | | |
| | 844,400 | 2,111,100 | 0% | 323,000 | 281,010 | 0% | - | | |
| Option 4 | 1,200,000 | 3,000,000 | | | | | | | |
| | 1,266,700 | 3,166,700 | 0% | 323,000 | 281,010 | 0% | - | | |
| total TAC (using proposed 2009 options) | | | | | | | | 3,160,600 | |

* The escapement options in this table correspond to the options illustrated in the bottom panels of Figures 2 to 5. For example, Option 3 for Early Stuart is an escapement strategy with a cut-back point of 270,000. This describes a strategy with 60% total allowable mortality above 270,000 run size, and a fixed escapement of 108,000 below that run size. If run size falls below 108,000, the strategy prescribes no harvest except test fishing. Figure 1 explains the shape of the escapement strategies.

** pMA = expected percent management adjustment based on previously observed differences between escapement to Mission and final escapement counts.

Table 2a. Draft 2009 Fraser River sockeye escapement plan (In 1000s of fish; at mid-point of forecast range)

To be included once 2009 IFMP is finalized

\\svbcvanfp01\Cohen-Comm\Network Drives\Regional Salmon Drive\Salmon Consultations\Salmon IHPC\IHPC May 6-7th 2009\strategy_2009frasersockeyeescapement.pdf

Table 2b. Draft 2009 Fraser River sockeye escapement plan (In 1000s of fish; at lower quarter of forecast range)

To be included once 2009 IFMP is finalized

Table 3. Fraser River Sockeye benchmarks and escapement summary

| ID | Stock | Escapement Summary * (up to 2004) | | | Production BM % of average for optimal 4yr escapement sequence | | | Potential Conservation Reference Point Smallest observed 4yr average | 2007 Low Escapement BM Sample benchmarks based on Expert Judgment | | | | | |
|----|-------------|--------------------------------------|---------|---------|--|-----------|----------------------|---|---|---------|---------|---------|---------|---------|
| | | Smallest | 75p | Median | 25p | Largest | max(Run size) 20% | | max(log(Run size)) 20% | 48% | BM 1 | BM 2 | BM 3 | |
| 1 | E. Stuart | 1,500 | 21,500 | 42,400 | 121,500 | 668,000 | 25,300 | 50,300 | 24,100 | 48,300 | 10,300 | 10,200 | 50,300 | 100,600 |
| 4 | Rowlen | 800 | 3,000 | 6,600 | 13,200 | 35,000 | 2,500 | 4,900 | 2,500 | 4,900 | 3,000 | 2,500 | 4,900 | 9,800 |
| 14 | Fennell | <100 | 1,400 | 5,700 | 9,100 | 32,300 | 1,100 | 2,000 | 1,100 | 2,200 | 500 | 500 | 2,200 | 4,400 |
| 16 | Gates | <100 | 2,000 | 4,800 | 10,700 | 86,300 | 1,700 | 3,500 | 1,100 | 2,300 | 1,500 | 1,100 | 3,500 | 7,000 |
| 17 | Nadima | 1,000 | 2,400 | 6,300 | 17,000 | 173,800 | 2,900 | 5,700 | 3,000 | 3,900 | 5,800 | 2,000 | 5,900 | 11,600 |
| 18 | Pitt | 3,600 | 12,900 | 18,300 | 37,300 | 131,500 | 3,400 | 6,800 | 3,400 | 6,800 | 11,200 | 3,400 | 11,200 | 22,400 |
| 5 | Raft | 500 | 2,600 | 6,200 | 8,900 | 56,300 | 2,600 | 5,200 | 2,500 | 4,900 | 2,600 | 2,500 | 5,200 | 10,400 |
| 15 | Scotch | 100 | 2,200 | 4,400 | 13,600 | 101,300 | 900 | 1,800 | 2,000 | 4,000 | 2,200 | 900 | 4,000 | 8,000 |
| 8 | Seymour | 1,300 | 5,700 | 12,700 | 42,600 | 272,000 | 9,500 | 19,000 | 9,500 | 19,000 | 9,100 | 9,100 | 19,000 | 38,000 |
| | total | 7,300 | 32,200 | 65,000 | 152,400 | 898,500 | 24,600 | 49,100 | 24,100 | 48,000 | 35,900 | 22,000 | 55,800 | 111,600 |
| 7 | Chilko | 17,300 | 112,200 | 247,300 | 542,300 | 1,037,700 | 66,400 | 132,900 | 66,400 | 132,900 | 184,500 | 66,400 | 164,500 | 329,000 |
| 2 | Late Stuart | <100 | 5,800 | 23,600 | 189,100 | 1,353,800 | 39,100 | 78,300 | 39,100 | 78,300 | 29,500 | 29,500 | 78,300 | 156,600 |
| 6 | Quesnel | <100 | 300 | 9,200 | 267,700 | 3,062,200 | 77,300 | 154,500 | 41,100 | 82,200 | 7,800 | 7,800 | 154,500 | 309,000 |
| 3 | Stellako | 15,800 | 42,100 | 83,000 | 138,100 | 371,600 | 22,700 | 45,400 | 22,700 | 45,400 | 37,000 | 22,700 | 45,400 | 90,800 |
| | total | 33,100 | 160,400 | 365,100 | 1,137,200 | 5,835,300 | 205,500 | 411,100 | 169,300 | 339,300 | 239,800 | 126,400 | 482,700 | 885,400 |
| 10 | Birkenhead | 11,900 | 30,900 | 49,000 | 78,300 | 335,600 | 19,700 | 39,300 | 19,700 | 39,300 | 23,200 | 19,700 | 39,300 | 78,600 |
| 11 | Cultus | 100 | 1,700 | 9,700 | 17,500 | 47,800 | 3,700 | 7,300 | 3,700 | 7,300 | 1,800 | 1,800 | 7,300 | 14,600 |
| 19 | Harrison | 300 | 3,900 | 6,200 | 17,200 | 388,600 | 2,000 | 4,100 | 2,000 | 4,100 | 3,600 | 2,000 | 4,100 | 8,200 |
| 12 | Portage | <100 | 1,100 | 3,700 | 8,700 | 31,300 | 100 | 300 | 600 | 1,200 | 1,300 | 100 | 1,300 | 2,600 |
| 13 | Weaver | 3,200 | 16,800 | 35,900 | 45,700 | 267,300 | 8,900 | 17,800 | 8,900 | 17,800 | 14,500 | 8,900 | 17,800 | 35,600 |
| 9 | L. Shuswap | 500 | 3,600 | 17,000 | 1,061,300 | 5,216,800 | 111,100 | 222,100 | 111,100 | 222,100 | 330,500 | 111,100 | 320,500 | 641,000 |
| | total | 4,300 | 27,100 | 74,500 | 1,150,400 | 5,951,800 | 125,900 | 251,600 | 126,000 | 252,000 | 341,700 | 123,600 | 351,000 | 702,000 |

25% of escapements were smaller than this number

BM1: Smallest value among the alternative definitions (grey shaded)
 BM2: Largest value among the alternative definitions
 BM3: Double BM2

2007 Extirpation Benchmarks: 200,500,1000

2006 Low Catch Benchmarks
 Set during '06 Planning Process

| | | | | | |
|--------------|---------|--------------|------|------|---|
| Early Stuart | 15,000 | Early Stuart | 1 | +0% | NA |
| Early Summer | 100,000 | Early Summer | 1.21 | +21% | Misc. Early Summers |
| Summer | 600,000 | Summer | 1.18 | +18% | Birkenhead, Birkenhead-type lates (misc. non-Shuswap) |
| Late | 300,000 | Late | 1 | +0% | misc. Shuswap |

* in total effective spawners

Expansion Factors

| | |
|------------------------------|---|
| Based on 2008 Forecast (50p) | Scale up run size for TAM rule to include |
| 1 | +0% |
| 1.21 | +21% |
| 1.18 | +18% |
| 1 | +0% |

TECHNICAL APPENDIX

Estimating Population Parameters

The Spawning Initiative uses the Larkin model to simulate the recruitment produced from different levels of spawning escapement. The Larkin model has two main parameters: productivity at low run size and long-term capacity. In addition, the Larkin model also includes three interaction parameters that capture the effect of escapement 1,2, and 3 years earlier on recruitment from this years escapement. Stocks that are highly cyclic (e.g. Quesnel) have stronger interaction terms. Parameters for each stock are estimated based on available spawner and recruit (SR) data, but the availability and quality of SR data differs between stocks. Four important estimation issues arise:

- Most data are from a period with heavy fishing, so that we have a good picture of how much exploitation the stocks can handle and still recover, given survival conditions at the time (i.e. well defined productivity parameter). However, we don't have much information about very abundant conditions, resulting in a poor picture of how large the runs could get, and a poor estimate of population size that maximize long-term catch (i.e. highly uncertain capacity parameter).
- Available time series capture past dynamics for abundant stocks, but recent environmental changes such as warmer rivers and unfavorable ocean conditions introduce additional sources of uncertainty.
- Shorter time series of SR data result in larger uncertainty (Weaver, Fennel, Scotch, Gates, Nadina)
- Uncertain response at/above largest observed escapements (1982 Weaver, 1990 Seymour, 2000 Raft & Nadina, 2005 Harrison).

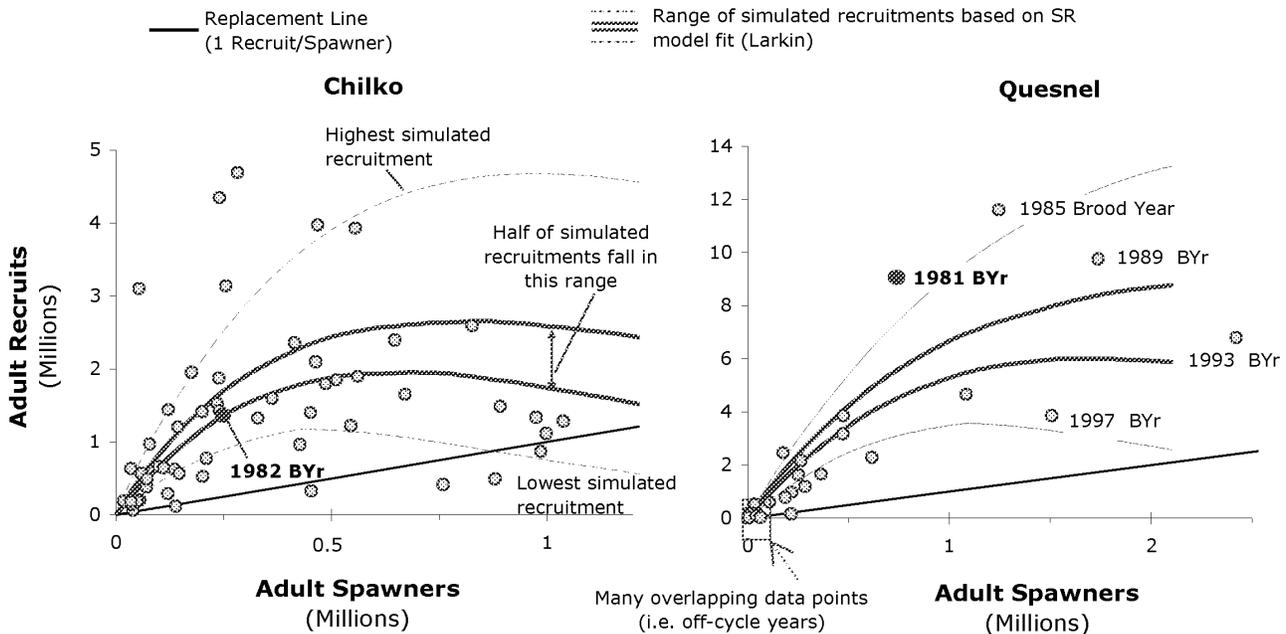


Figure A1: Relationship between spawning abundance and recruitment for 2 Fraser sockeye stocks.

The red curves show how expected recruitment changes for different spawning abundances *in a given brood year*, but the shape of the red curves changes depending on the spawning abundance *in the three previous years*. Recruitment curves shown are for two highly productive brood years: the dominant Quesnel cycle in 1981, and the 1982 brood year for Chilko. A stock must produce at least 1 recruit per spawner to maintain a stable abundance in the absence of fishing and in-river mortality (i.e. replace parent abundance).

Comparison to fixed escapement strategies and fixed exploitation rate strategies

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.
- 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 1, p. 9).

Figure A2 shows the effect of increasing fixed exploitation rate from 5% to 60%. Most stocks show a drastic increase in the probability of low escapements somewhere between 25% for low productivity stocks and 45% for more productive stocks. Highly productive stocks like Chilko and Stellako can sustain fixed 60% exploitation rates over the 48year period of the simulation without significant increase in the probability of low escapement.

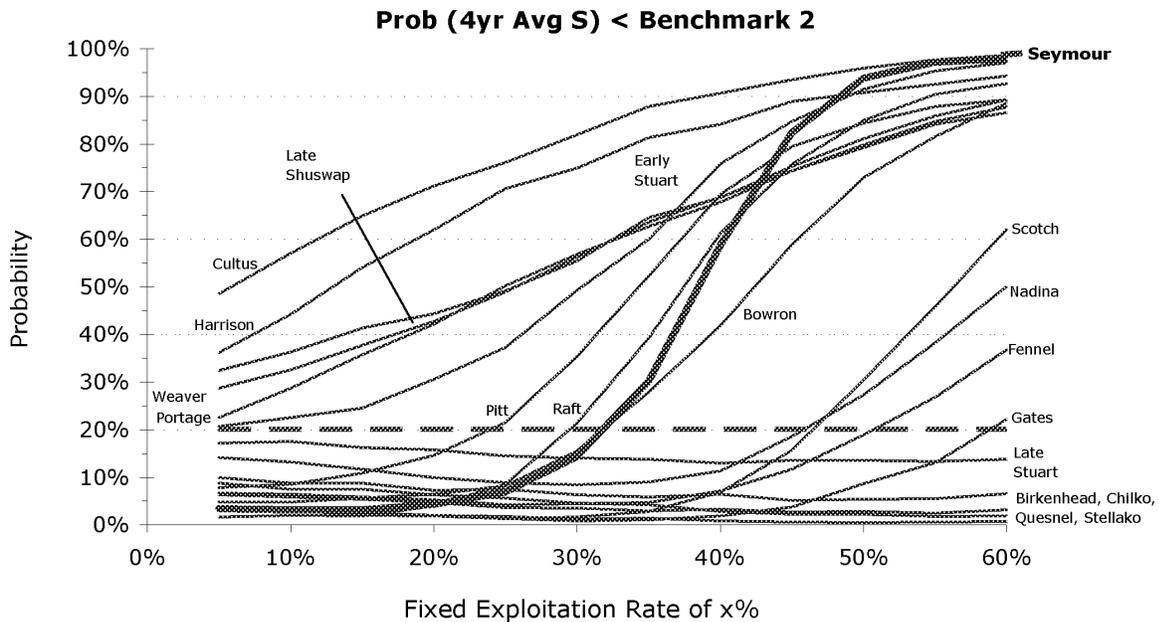


Figure A2: Applying a fixed exploitation rate to 19 stocks of Fraser sockeye.

Effect of overlap in run timing

The approach for dealing with overlap has substantial implications for the long-term performance of alternative escapement strategies:

- If overlap is managed based on 10% of daily abundance, then there is a short period around the peak during which the Summer run aggregate can be harvested based on it's own abundance and corresponding target exploitation rate. However, this slightly increases the long-term average exploitation rate on Early Summers and Lates, because the tail-ends of their migration end up being harvested at Summer run exploitation rates. Summer run catch is reduced compared to the "No Overlap" scenario.
- If overlap is managed based on a window around the peak of each aggregate, then there is not single day during which the Summer run exploitation rate can be applied. Substantial amounts of potential catch are shifted to spawning escapement. However, there is no increase in long-term exploitation rates for Early Summers and Lates.

Figure A3 and Table A1 illustrate the differences using the 2009 run size forecast.

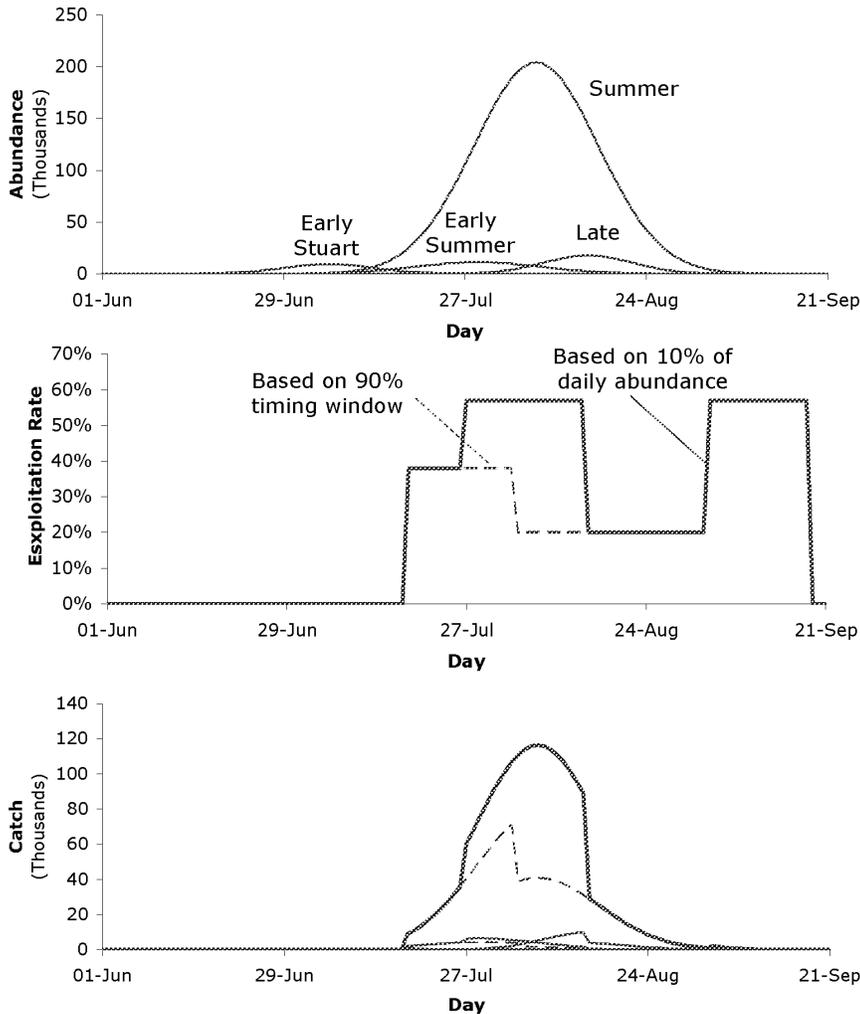


Figure A3: Two assumptions about harvest constraints due to overlap in run timing applied to 2009 expectations (75p)

| | Run | Target ER | Constraint based on 10 % Abundance | | Constraint based on 90% Time Window | |
|--------------|-----------|--------------|--|-------|---|-------|
| | | | Catch | ER | Catch | ER |
| Early Stuart | 165,000 | 0% | 3,352 | 2.0% | 3,291 | 2.0% |
| Early Summer | 272,000 | 38% | 118,294 | 43.5% | 77,578 | 28.5% |
| Summer | 4,914,000 | 57% | 2,273,045 | 46.3% | 1,273,881 | 25.9% |
| Late | 306,000 | 20% | 114,811 | 37.5% | 64,235 | 21.0% |

Table A1: Target harvest vs. realized harvest for the two scenarios in Figure A3.

Assumptions about the plausible range of future outcomes

Over the course of the Spawning Initiative, the Working Group explored two alternative approaches to simulating random variation in future recruitment:

Transformed: normal (0,1) random deviation $\ast(\sigma^2)/2$

Untransformed: normal (0,1) random deviation $\ast \sigma$

Average results are fairly robust to these two alternative settings, but the distribution of outcomes changes: Untransformed residuals produce a much broader range of possible outcomes, and transformed residuals result in fewer very low or very high years.

At first glance this appears to be a purely technical consideration, but the implications for model results are drastic. In particular, fewer years with low outcomes translate into a much lower probability of falling below the stock-specific escapement benchmarks, which indicates less risk for a given escapement strategy. A wider range of outcomes produces more contrast in performance across different escapement strategies (i.e. steeper gradient in the performance indicators from left to right). The 2008 Escapement Memo includes a detailed illustration.

There is no clear-cut choice between these options, but the Working Group chose to use the untransformed residuals for 2009 planning simulations to remain consistent with other models used for Pacific Salmon, such as the Cultus model.