FRASER SOCKEYE ESCAPEMENT STRATEGY 2008

Model Overview & Summary of 2008 Planning Simulations

EXECUTIVE SUMMARY

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 2008 planning process and additional technical work that builds on the long-term strategy developed in 2007.

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.

The plan for 2008 includes some changes compared to 2007, because of revisions in the underlying simulation model and additional consideration of practical challenges:

- *Early Stuart:* The abundance forecast of 35,000 is substantially below average for this cycle line, and the strategy for this year is to maximize escapement from this low run size. 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.
- *Early Summer:* The aggregate abundance forecast of 288,000 for the eight stocks in the simulation model is about half of the average for this cycle line, with 6 of the 8 components stocks expected to return below average. The strategy for this year, 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 2008 fishing plans will be strongly influenced by in-season run-size estimates over the forecast range.
- *Summer:* The aggregate abundance forecast of 1.8 Million is about a third below the average for this cycle line, with 2 of the 4 component stocks expected to return below average. The selected strategy for this year, slightly modified 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.
- *Late:* The aggregate abundance forecast of 705,000 is just under 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, modified from 2007, 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.
- *Birkenhead:* The abundance forecast of 238,000 is near the average for this cycle line. The stock is managed passively and exposed to Summer run exploitation rates.
- *Harrison*: The abundance forecast of 47,000 equals the long-term average. The approach for 2008 is to continue managing Harrison as part of the Late run aggregate. It is not currently feasible to develop a separate escapement strategy for Harrison because production from the large 2005 escapement has not been observed and large pre-spawn mortalities in recent years add additional uncertainty to the long-term evaluation of alternative strategies.
- *Cultus:* The abundance forecast is 5,000, and the approach, as in 2007, is a fixed exploitation rate of 20%.

THIS DOCUMENT

This document is intended as an information supplement to explain the work that went into developing the escapement strategy for 2008, which is included in the 2008 *Integrated Fisheries Management Plan* (IFMP). The escapement strategy and resulting fishing plans were publicly reviewed 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 six years, explains the fundamental concepts, and outlines priorities for future developments.
- A *Summary of 2008 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 *2008 Escapement Strategy*.

The following reference materials are included:

- Concepts and terminology are summarized in Figure 1. More technical details are included in the Appendix.
- Escapement options evaluated during the planning process are detailed in Table 1
- Details of the escapement strategy for 2008 are summarized in Table 2.
- Benchmarks and past escapements are summarize in Table 3.

Related documents available from DFO are:

- 2008 Integrated Fisheries Management Plan
- Meeting notes from the 2008 planning workshop
- Final report of the Spawning Initiative.

1. INTRODUCTION

The Spawning Initiative

The *Fraser River Sockeye Spawning Initiative* (FRSSI) has been a 6-year process to develop 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 a were 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.

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.

The planning process for 2008 was streamlined, building on the progress made during the 2007 workshop series. For this year 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. After pre-season consultations, the final 2008 escapement plan was released in May.

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 became increasingly useful to DFO and participants because of their consistent structure and relatively stable attendance. Also, the format of the workshops proved 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 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 includes more detail about the population model, and how parameters are estimated for it.

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. 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 in 2007 and 2008, but these will be reviewed for consistency with WSP benchmarks as they are finalized.

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 create exactly that kind of scenario for Early Summers, which in turn affects the harvest pattern for Summers. DFO is exploring guidelines for annual adjustments to the long-term strategy, and considering the appropriate level of flexibility.

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):

- No fishing at very low run size, except for test fishing.
- 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.

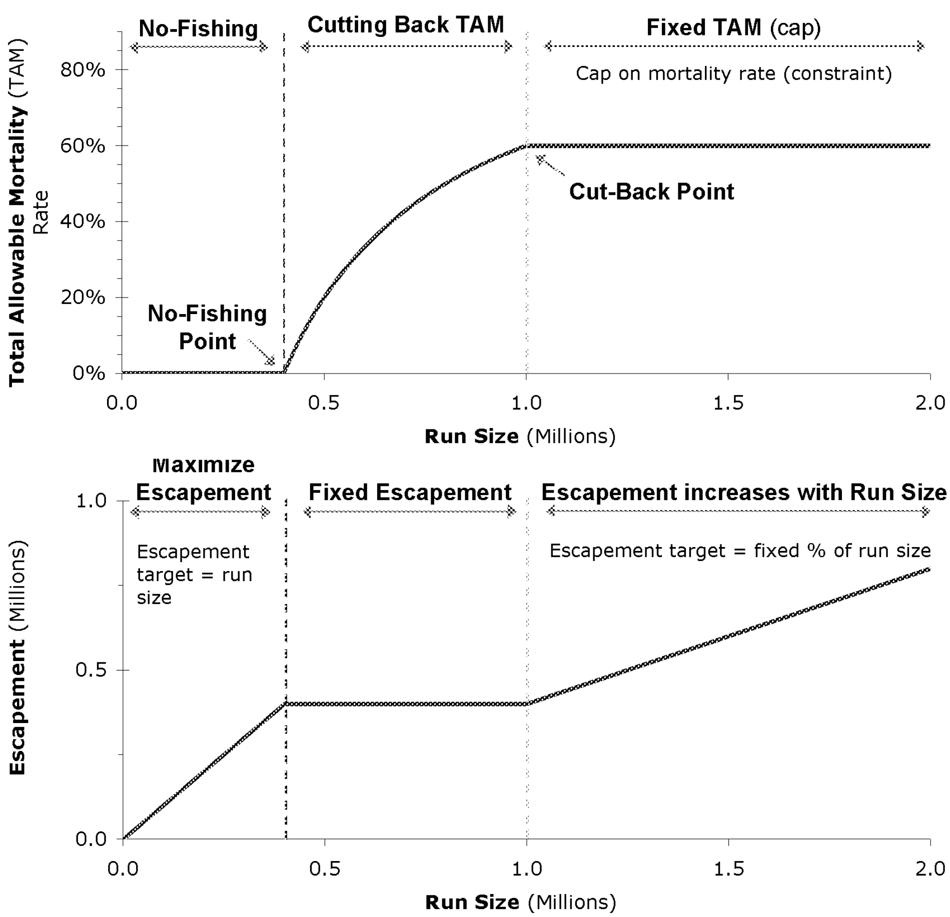

Figure 1: Illustration of Total Allowable Mortality (TAM) rule and corresponding escapement strategy.

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 more frequently occur in the simulated trajectories. The Appendix outlines the technical details.
- *Model Structure:* The model now includes the option to specify stock-specific escapement strategies (as in Figure 1), 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.

Priorities for future model revisions

The current Spawning Initiative model has proven sufficient to evaluate 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) compared to fixed escapement strategies or fixed exploitation rate strategies. The next step is to fine tune the model and the underlying assumptions.

The following priorities were identified during the 2008 planning process:

Refine biological assumptions (correlation between stocks, correlation over time, capacity estimates, management adjustments, migration timing, population models, implementation error).

- Revise the model to run all 19 stocks concurrently, rather than one aggregate at the time, to better capture the constraints introduced by timing overlap between aggregates.
- 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 (e.g. Gates, Nadina), given their 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.

2. SUMMARY OF 2008 SIMULATION SCENARIOS

Settings and Assumptions

- The model includes 19 stocks grouped into 4 timing aggregates for management purposes.
- Each model scenario applies a specified escapement strategy to a timing aggregate 48 years into the future, starting with recent years, and tracks the performance of each individual stock within the aggregate.
- The model does not distinguish the timing and location of harvests, and does not explicitly simulate alternative fishing plans.
- Simulations start with escapement data up to 2005, and population dynamics are estimated based on spawner and recruit data up to 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. 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. For now, this calculation is applied after the fact to explore the magnitude of overlap under different combinations of escapement strategies. One of the priorities for future model revisions is to incorporate that calculation into the model.
- 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 considered separately but due to the uncertainty in the population dynamics, introduced by the large 2005 escaqpement, and the inability to identify a separate management adjustment for Harrison it was decided to continue to manage them with the other Lates.
- 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 2007 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 2008. 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 (cyclicity), which can lead to performance trends that appear counter-intuitive at first glance.
- Escapement strategies that respond to run size (Figure 1) perform better than fixed escapement strategies or fixed exploitation rate strategies.
- 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
- 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 1 and Option 2 for Early Summers is small (Figure 2), but the implications for 2008 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 Appendix includes examples and more detailed explanations of these general observations.

3. DRAFT 2008 ESCAPEMENT STRATEGY

This section outlines how a single option for 2008 was developed from the 4-5 options considered for each management group. It is important to note that while the workshop participants 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 2008 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 2009 planning process.

The escapement plan for 2008 has been modified from last year, but there are no substantial changes in strategy for the Early Stuart, Early Summer, and Summer groups. The strategy for Late run has been revised as explained below.

These escapement strategies for 2008 are identified by the bolded blue line in Figures 2-4.

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 selected for 2008 is Option 3, which has a low risk tolerance. For example, there is a less then 1 in 10 chance of not achieving the benchmark 2, averaged over 4 years (--- dashed line in Figure 2).

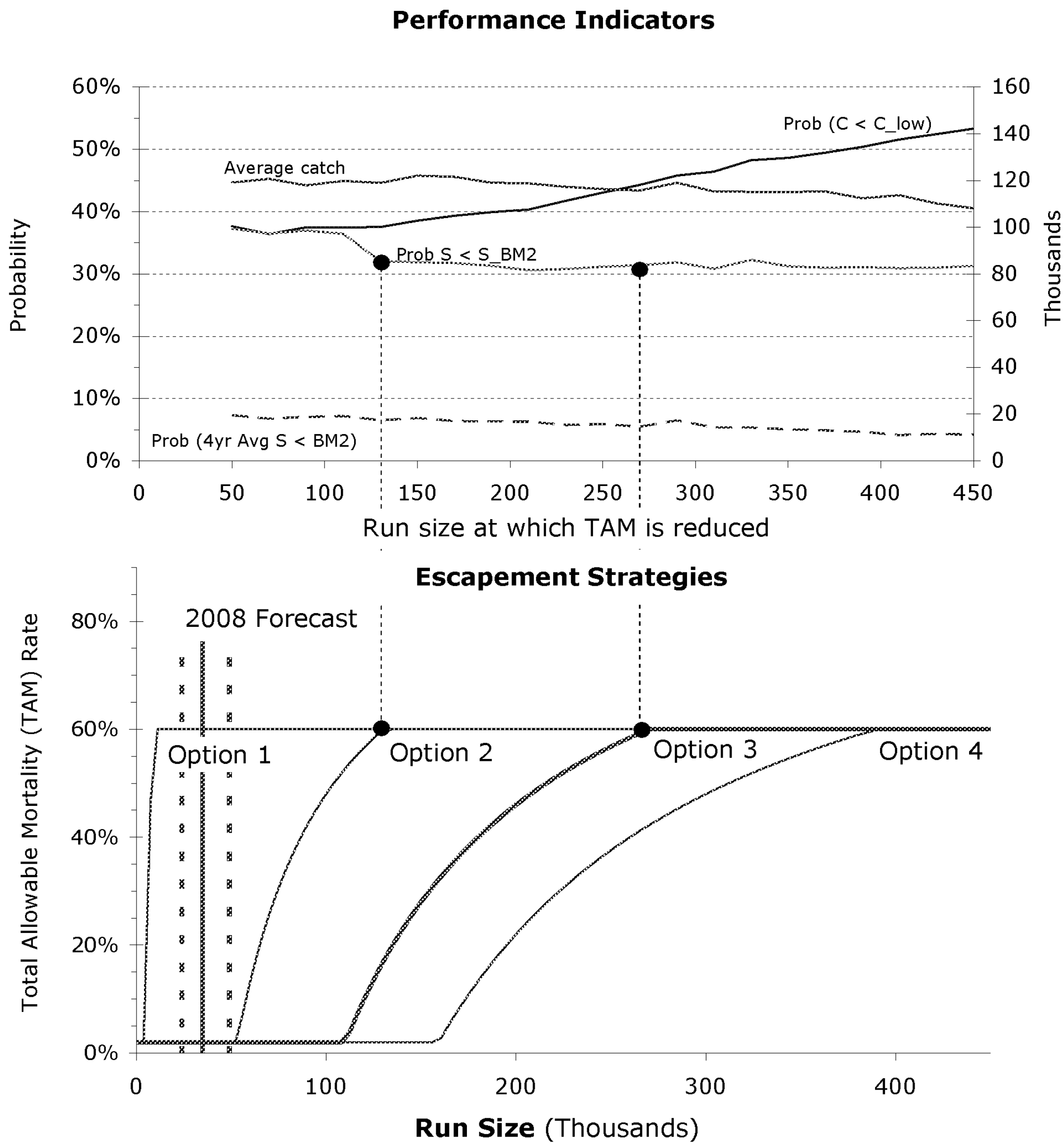

Figure 2: Sample simulation results and options for Early Stuart

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 5). 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 chose Option 2 as the long-term escapement strategy for Early Summer, which was also adopted last year. However, Table 1 shows substantial implications for 2008 fisheries planning, and DFO is working on guidelines for the degree of annual flexibility associated with this long-term strategy.

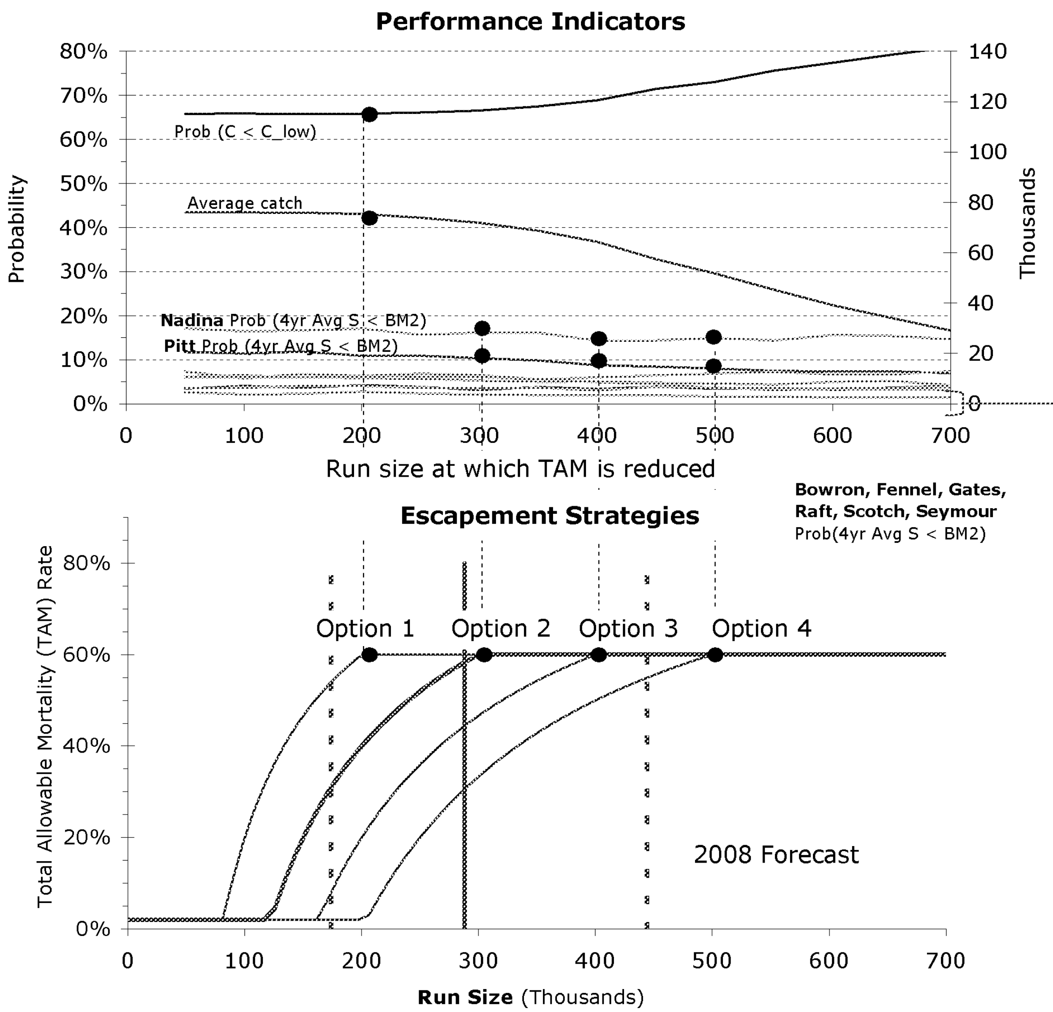

Figure 3: Sample simulation results and options for <u>Early Summer</u>

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 10 years) of achieving BM 2 over a 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 chose Option 1 as the long-term escapement strategy for the Summer aggregate, which is slightly modified from 2007 based on updated simulation results.

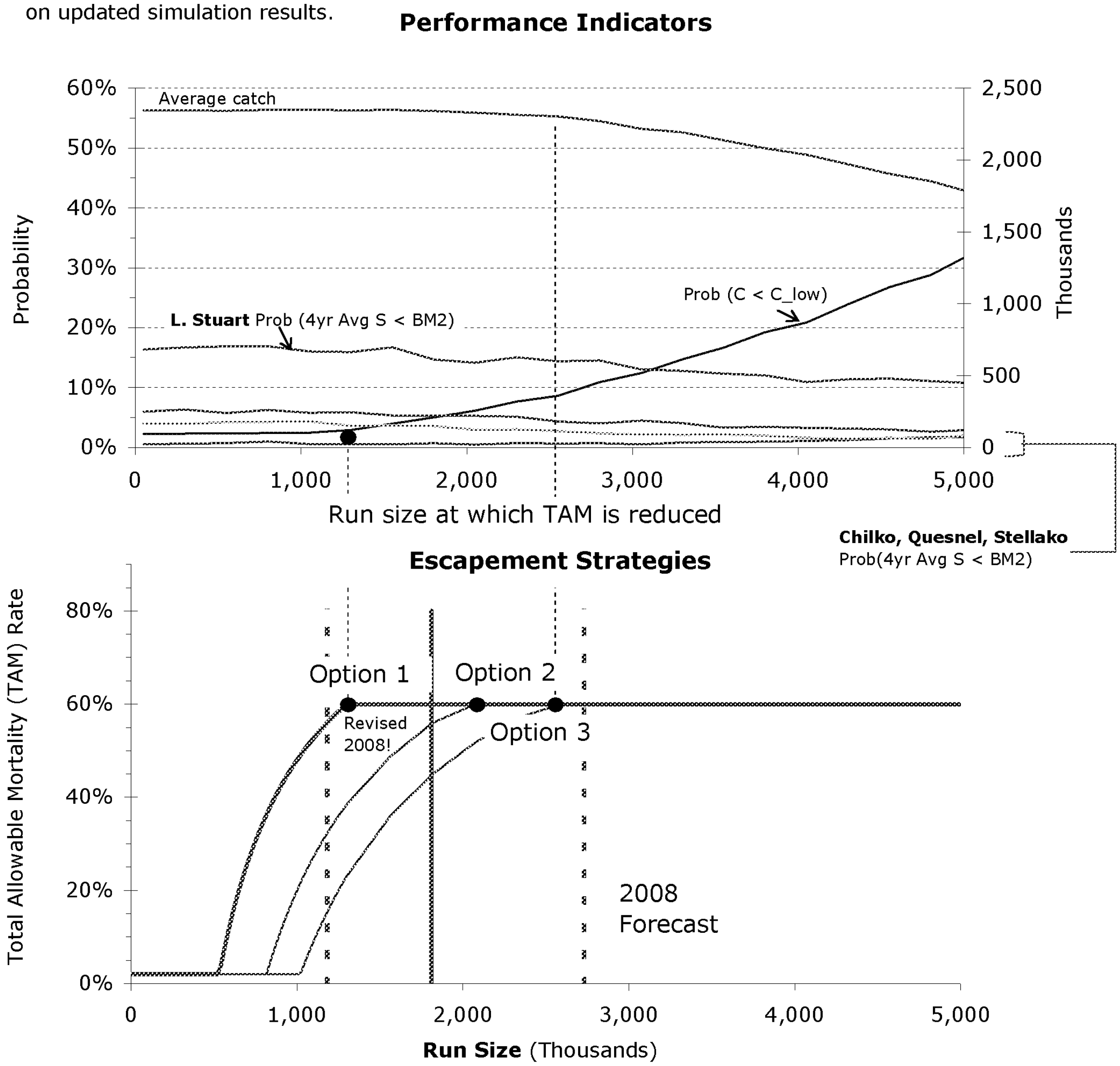

Figure 4: Sample simulation results and options for Summer

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). The performance of escapement strategies is much more sensitive to the chosen minimum exploitation rate, as shown in Figure 6.

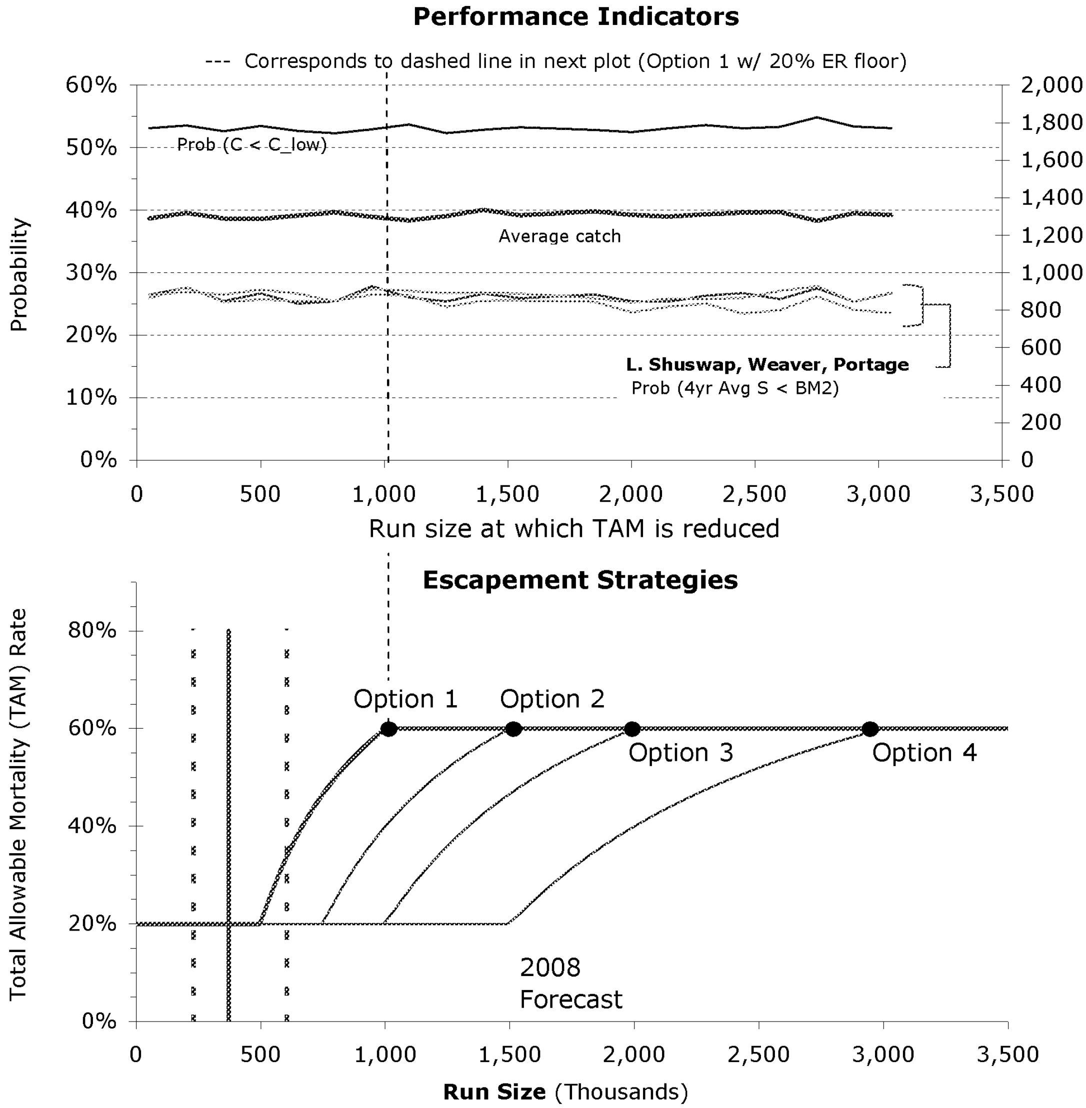

Figure 5: Sample simulation results and options for <u>Lates</u> (using a 20% ER floor)

This modification from the 2007 plan was explored 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 with a fairly high probability if the exploitation rate floor is low.

- better than 8 out of 10 years if ER floor is less than 15%.
- better than 7 out of 10 if ER floor is less than about 20%. 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.

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. The technical appendix includes a second version of Figure 6, based on the alternative assumptions. Accordingly, DFO chose 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.

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

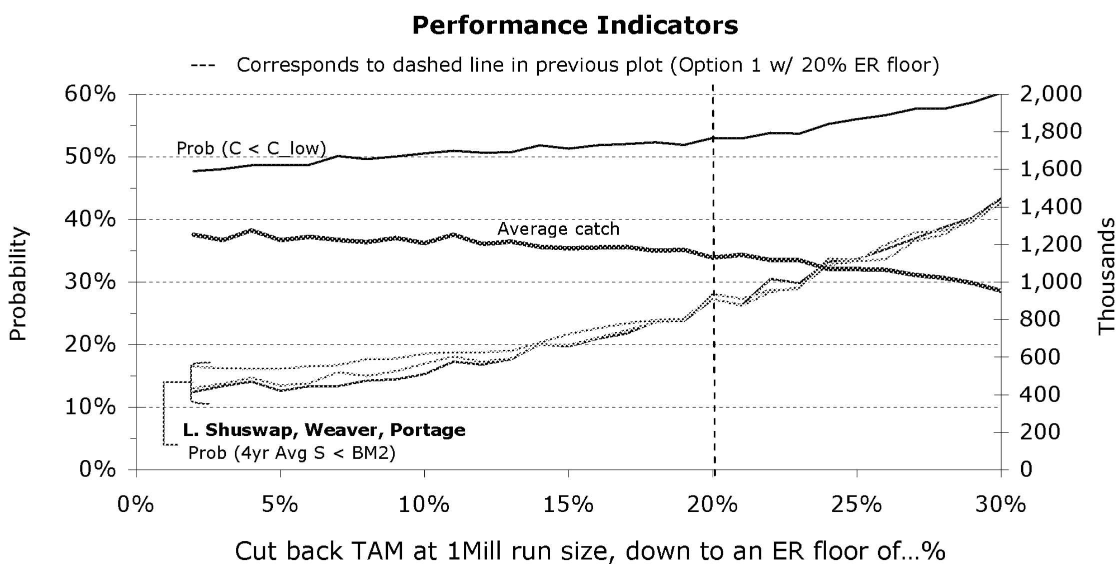

Figure 6: Effect of changing ER floor for a given TAM rule (Option1)

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 9 out of 10 chance that that escapements will exceed the benchmark *every year* (90% of escapements larger than tip of the lower whisker).

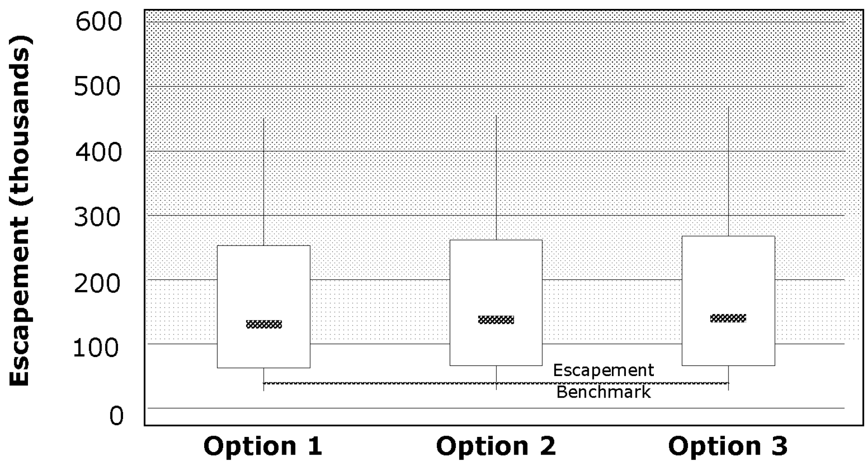

Figure 7: Response of Birkenhead escapement to alternative Summer run strategies

Harrison

Harrison sockeye present a particular management challenge, and the option of developing an individual escapement strategy for Harrison was explored during the planning workshop. However, the approach for 2008 is to continue managing Harrison as part of the Late run aggregate. Three key considerations shaped this decision:

- 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.
- 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.*

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

- a low 2008 forecast of 5,000 sockeye,
- high uncertainty in the forecast,
- unpredictable long-term responses to predator removal.

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

	Label	Cut-back Point*	No Fishing Point / Fixed Escapement Target*	TAM* at Run Size	Esc. Target	pMA**	Mgmt Adj.	Expl. Rate after MA	Total Allowable Catch
Early Stuart		**2008 Forecast** (50p)		**35,000**		**0.69**			
	Option 1	10,000	4,000	60%	14,000		9,660	32%	11,340
	Option 2	130,000	52,000	0%	35,000		24,150	0%	-
	Option 3	**270,000**	**108,000**	**0%**	**35,000**		**24,150**	**0%**	**-**
	Option 4	390,000	156,000	0%	35,000		24,150	0%	-
Early Summer		**2008 Forecast** (50p)		**288,000**	w/o misc	**0.41**			
				349,000	w. misc				
	Option 1	200,000	80,000						
		242,400	*97,000*	*60%*	*139,600*		*56,840*	*44%*	*152,600*
	Option 2	**300,000**	**120,000**						
		363,500	***145,400***	***58%***	***145,400***		***59,202***	***41%***	***144,400***
	Option 3	500,000	200,000						
		605,900	*242,400*	*31%*	*242,400*		*98,696*	*2%*	*7,900*
	Option 4	650,000	260,000						
		787,700	*315,100*	*10%*	*315,100*		*128,297*	*0%*	*-*
Summer		**2008 Forecast** (50p)		**1,810,000**		**0.05**			
	Opt 1_08	**1,300,000**	**520,000**	**60%**	**724,000**		**36,200**	**58%**	**1,049,800**
	Opt 1_07	1,500,000	600,000	60%	724,000		36,200	58%	1,049,800
	Option 2	2,000,000	800,000	56%	800,000		40,000	54%	970,000
	Option 3	2,500,000	1,000,000	45%	1,000,000		50,000	42%	760,000
BK Group		**2008 Forecast** (50p)		**331,000**		(note: no MA is applied to Birkenhead type)			
	Opt 1_08			**60%**	**132,400**			**60%**	**198,600**
	Opt 1_07			60%	132,400			60%	198,600
	Option 2			56%	146,300			56%	184,700
	Option 3			45%	182,900			45%	148,100
Late		**2008 Forecast** (50p)		372,000	w/o misc	**4.26**			
	TO BE DETERMINED			**374,000**	w. misc (note: Birkenhead type not included)				
	Note: if 2007 TAM rules are applied to 2008 forecasts, TAM = 0% at both 50p and 75p run sizes								
	Alternate management options used in the past include managing to a low fixed exploitation rate(e.g. 15%)								
	The proposed approach for 2008 is a 20% floor on exploitation rate.								

* 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)

	Label	Cut-back Point*	No Fishing Point / Fixed Escapement Target*	TAM* at Run Size	Esc. Target	pMA**	Mgmt Adj.	Expl. Rate after MA	Total Allowable Catch
Early Stuart			**2008 Forecast** (75p)	**24,000**		**0.69**			
	Option 1	10,000	4,000	60%	9,600		6,624	32%	7,776
	Option 2	130,000	52,000	0%	24,000		16,560	0%	-
	Option 3	**270,000**	**108,000**	**0%**	**24,000**		**16,560**	**0%**	**-**
	Option 4	390,000	156,000	0%	24,000		16,560	0%	-
Early Summer			**2008 Forecast** (75p)	**174,000**	w/o misc	**0.39**			
				205,000	w. misc				
	Option 1	200,000	80,000						
		242,400	*97,000*	*53%*	*97,000*		*38,024*	*34%*	*70,000*
	Option 2	**300,000**	**120,000**						
		353,400	***141,400***	***31%***	***141,400***		***55,429***	***4%***	***8,200***
	Option 3	500,000	200,000						
		605,900	*242,400*	*0%*	*205,000*		*80,360*	*0%*	*-*
	Option 4	650,000	260,000						
		787,700	*315,100*	*0%*	*205,000*		*80,360*	*0%*	*-*
Summer			**2008 Forecast** (75p)	**1,182,000**		**0.05**			
	Opt 1_08	**1,300,000**	**520,000**	**56%**	**520,000**		**26,000**	**54%**	**636,000**
	Opt 1_07	1,500,000	600,000	49%	600,000		30,000	47%	552,000
	Option 2	2,000,000	800,000	32%	800,000		40,000	29%	342,000
	Option 3	2,500,000	1,000,000	15%	1,000,000		50,000	11%	132,000
BK Group			**2008 Forecast** (75p)	**200,000**		(note: no MA is applied to Birkenhead type)			
	Opt 1_08			**56%**	**88,000**			**56%**	**112,000**
	Opt 1_07			49%	101,500			49%	98,500
	Option 2			32%	135,400			32%	64,600
	Option 3			15%	169,200			15%	30,800
Late			**2008 Forecast** (75p)	231,000	w/o misc	**4.26**			
	TO BE DETERMINED			**232,000**	w. misc (note: Birkenhead type not included)				
	Note: if 2007 TAM rules are applied to 2008 forecasts, TAM = 0% at both 50p and 75p run sizes								
	Alternate management options used in the past include managing to a low fixed exploitation rate(e.g. 15%)								
	The proposed approach for 2008 is a 20% floor on exploitation rate.								

* 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 2008 Fraser River sockeye escapement plan (In 1000s of fish; at mid-point of forecast range)

Stock Group	Run Size Estimate of forecasted stocks	Run Size Reference Points		Total Mortality Rate Guidelines	Total Allowable Mortality at Run Size	Escapement Target at Run Size	Management Adjustment (a)		Exploitation Rate after MA	Cycle year adult escapement estimates 1988	1992	1996	2000	2004
Early Stuart	35	-	108	0%	0%	35	69%	24	0%	180	66	88	90	9
		108	270	0 - 60%										
		270		60%										
Early Summer		-	145	0%						218	102	363	574	157
	349	145	364	0 - 60%	58%	145	41%	59	41%					
		364		60%										
Summer		-	520	0%						745	635	1,412	1,650	272
		520	1,300	0 - 60%										
	1,810	1,300		60%	60%	724	5%	36	58%					
				0%						167	186	56	14	38
Birkenhead and Birkenhead-type Lates (b)				0 - 60%										
	331			60%	60%	132			60%					
true-Late	374	-	503	20%	20%	299			20%	61	80	143	25	54
(excl. Birk. Type)		503	1,005	20 - 60%										
		1,005		60%										
Cultus	5								20%	1	1	2	1	0
Sockeye Totals	2,899 *Est. Return*					1,336		120		1,371	1,070	2,064	2,354	529

a) Management adjustments (MAs) are added to the escapement targets to correct for the actual differences between Mission and upstream abundance estimates over all years. This approach makes no prior assumption about environmental conditions because we don't yet know whether conditions will be favourable or unfavourable in 2008. We expect that the MAs will be revised to take into account an environmental conditions during the inseason management period.

b) Birkenhead type Lates include returns in the miscellaneous non-Shuswap component of the forecast returning to natal spawning areas in the Harrison-Lillooet systems (excluding Harrison and Weaver).

Table 2b. Draft 2008 Fraser River sockeye escapement plan (In 1000s of fish; at lower quarter of forecast range)

Stock Group	Run Size Estimate of forecasted stocks	Run Size Reference Points		Total Mortality Rate Guidelines	Total Allowable Mortality at Run Size	Escapement Target at Run Size	Management Adjustment (a)		Exploitation Rate after MA	Cycle year adult escapement estimates 1988	1992	1996	2000	2004
Early Stuart	24	- 108 270	108 270	0% 0 - 60% 60%	0%	24	69%	17	0%	180	66	88	90	9
Early Summer	205	- 141 353	141 353	0% 0 - 60% 60%	31%	141	39%	55	4%	218	102	363	574	157
Summer	1,182	- 520 1,300	520 1,300	0% 0 - 60% 60%	56%	520	5%	26	54%	745	635	1,412	1,650	272
Birkenhead and Birkenhead-type Lates (b)	200			0% 0 - 60% 60%	56%	88			56%	167	186	56	14	38
true-Late (excl. Birk. Type)	232	- 502 1,004	502 1,004	20% 20 - 60% 60%	20%	186			20%	61	80	143	25	54
Cultus	3								20%	1	1	2	1	0
Sockeye Totals	1,843 *Est. Return*					959		98		1,371	1,070	2,064	2,354	529

a) Management adjustments (MAs) are added to the escapement targets to correct for the actual differences between Mission and upstream abundance estimates over all years. This approach makes no prior assumption about environmental conditions because we don't yet know whether conditions will be favourable or unfavourable in 2008. We expect that the MAs will be revised to take into account an environmental conditions during the inseason management period.

b) Birkenhead type Lates include returns in the miscellaneous non-Shuswap component of the forecast returning to natal spawning areas in the Harrison-Lillooet systems (excluding Harrison and Weaver).

Table 3. Fraser River Sockeye benchmarks and escapement summary

ID	Stock	Escapement Summary (up to 2004): Smallest	75p	Median	25p	Largest	Production BM (x% of average for optimal 4yr escapement sequence): max(Run size) 20%	max(Run size) 40%	max(log(Run size)) 20%	max(log(Run size)) 40%	Potential Conservation Reference Point: Smallest observed 4yr average	2007 Low Escapement BM (Sample benchmarks based on Expert Judgment): BM 1	BM2	BM3
1	**E. Stuart**	1,500	21,500	42,400	121,500	688,000	25,200	50,300	24,100	48,300	10,200	10,200	50,300	100,600
4	**Bowron**	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	2,200	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	**Nadina**	1,000	2,400	6,300	17,000	173,800	2,900	5,700	2,000	3,900	5,800	2,000	5,800	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	66,300	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	164,500	66,400	164,500	329,000
2	**Late Stuart**	<100	5,800	23,600	189,100	1,363,800	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	363,100	1,137,200	5,835,300	205,500	411,100	169,300	338,800	238,800	126,400	442,700	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	8,200	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	8,600	17,300	14,500	8,600	17,800	35,600
9	**L. Shuswap**	600	3,600	17,000	1,061,300	5,216,800	111,100	222,100	111,100	222,100	320,500	111,100	320,500	641,000
	total	4,200	27,100	74,500	1,150,400	5,951,800	125,800	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 Summer	100,000
Summer	600,000
Late	300,000

Expansion Factors

	Based on 2008 Forecast (50p)		Scale up run size for TAM rule to include
Early Stuart	1	+0%	NA
Early Summer	1.21	+21%	Misc Early Summers
Summer	1.18	+18%	Birkenhead, Birkenhead-type lates (misc. non-Shuswap)
Late	1	+0%	misc. Shuswap

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 unfavourable 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).

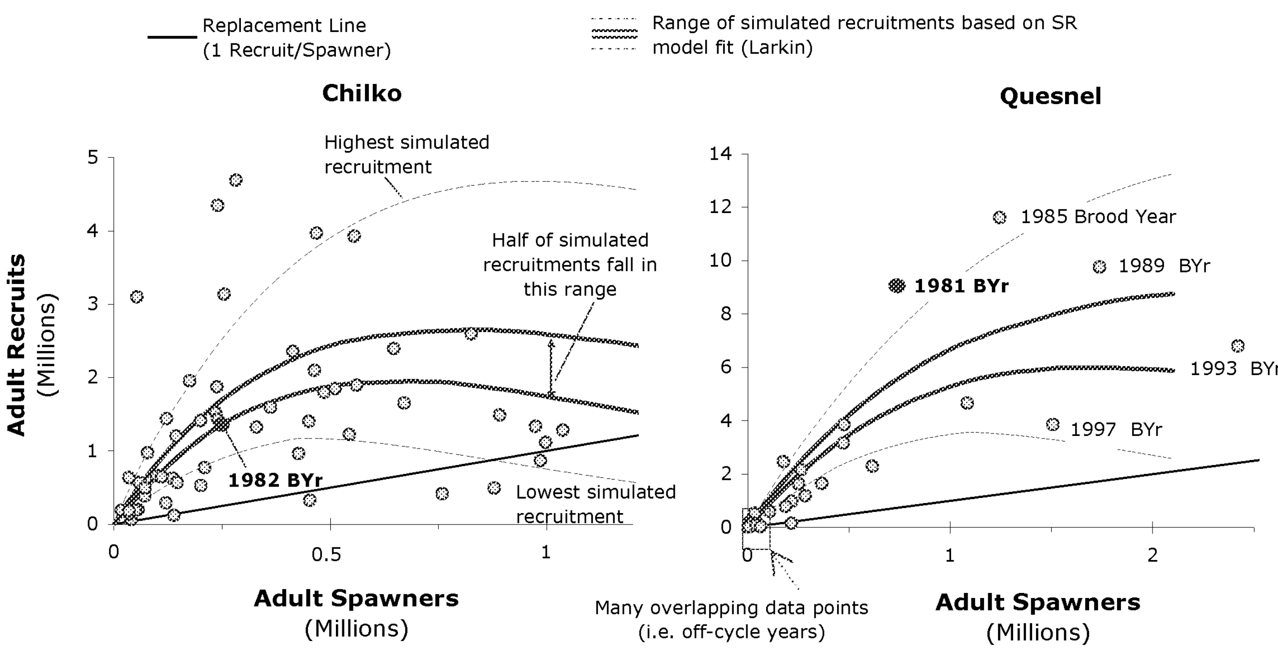

Figure A1: Relationship between spawning abundance and recruitment for 2 Fraser sockeye stocks. The red curves show how expected recruitment changes for different spawning abundances *in a given brood year*, but the shape of the red curves changes depending on the spawning abundance *in the three previous 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).

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 *(σ^2)/2

Untransformed: normal (0,1) random deviation * σ

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, as illustrated by comparing Figure A.2 below and Figure 6 on page 13. In particular, fewer years with low outcomes translate into in a much lower probability of falling below the stock-specific escapement benchmarks, which indicates less risk for a given escapement strategy. Also note that 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. For example, with transformed residuals, the difference between a 5% ER floor and a 25% ER floor is about a 5% higher probability of Late Shuswap, Weaver, or Portage falling below their individual escapement benchmarks (Figure A.2). For untransformed residuals the same comparison shows about 20% higher probability.

There is no clear-cut choice between these options, but the Working Group chose to use the untransformed residuals for 2008 planning simulations to remain consistent with other models used for Pacific Salmon, such as the Cultus model.

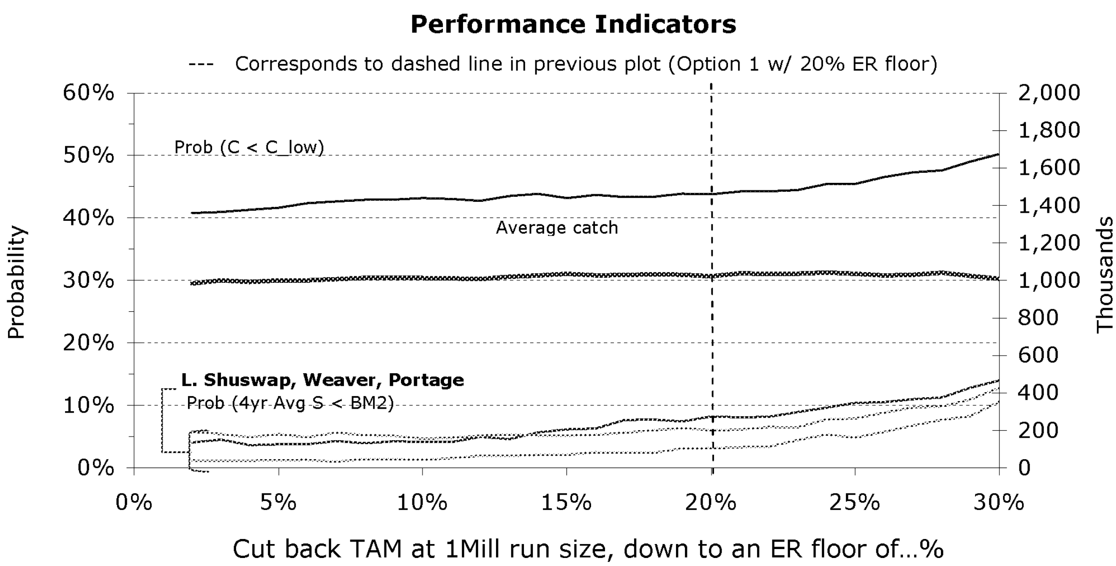

Figure A2: Effect of changing ER floor for a given TAM rule (Option1) with alternative assumption about plausible range of future outcomes. (compare to Figure 6)