FRASER SOCKEYE ESCAPEMENT STRATEGY 2007

1. INTRODUCTION

The Fraser River Sockeye Spawning Initiative (FRSSI) uses a simulation model to evaluate different management objectives and assumptions about stock dynamics in a consistent framework. This handout describes how the model works and summarizes the simulation scenarios and rationale that were used to formulate the 2007 draft escapement strategy. Additional work remains to be completed on developing a longer term escapement strategy. This spring a work plan will be developed and circulated for advice.

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), 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 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).

Escapement strategies are generally defined as a Total Allowable Mortality Rule (TAM rule) that specifies the total allowable mortality rate for a timing group 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 for each 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.

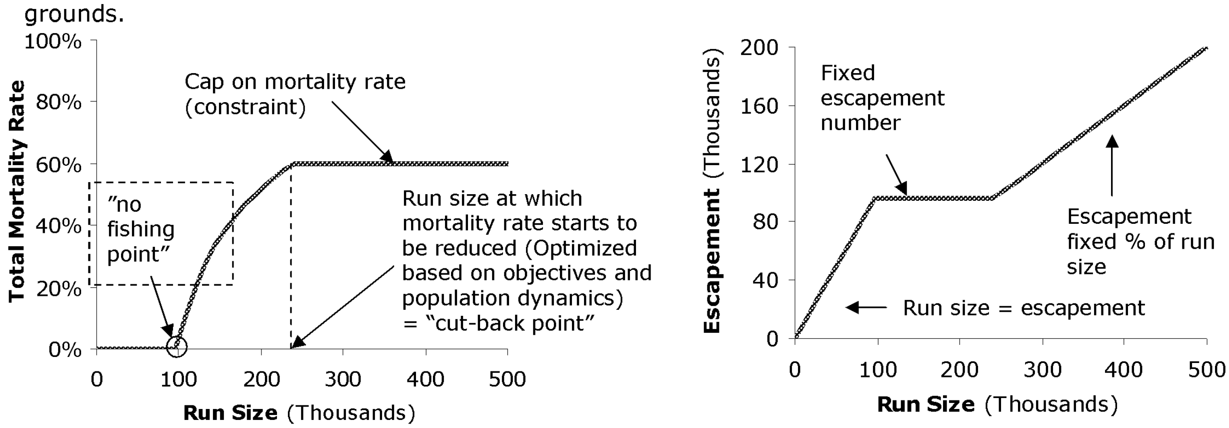

Figure 1: Illustration of Total Allowable Mortality (TAM) rule and corresponding escapement strategy.

The Working Group explored a wide range of escapement strategies (i.e. TAM rule) 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 selected 5 escapement strategies for closer evaluation during a multi-sectoral workshop on March 26/27, 2007. The feedback provided by workshop participants during a structured decision exercise was then used to assist in the formulation of the draft 2007 Fraser Sockeye Escapement plan.

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 based upon population dynamics (e.g. 20% of the escapement that maximizes run size) and past observations (e.g. smallest observed 4yr average escapement) (Appendix 1).

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 1 over 48 years). For the 2007 escapement plan the department has decided to adopt benchmark 2.

Selecting options for Workshop 3

Using several variations of these indicators to ensure robust conclusions, the Working Group selected **5 escapement strategies** for closer evaluation during Workshop 3:

1. ***Avoid low escapement(SPN):*** Reject all those escapement strategies that result in low escapement on individual stocks with higher probability than some specified risk tolerance (e.g 9 out of 10 years). If a component stock fails to meet the risk tolerance for any of the escapement strategies (e.g. highly cyclic pattern), then reject all those escapement strategies that fail to minimize the probability of low escapement for that stock. Among those strategies with sufficient probability of meeting the low escapement requirement, choose the one that maximizes long-term average catch. Low escapement indicators considered for this option compare each year's escapement and 4 year average escapement to two benchmarks that span a range of alternative definitions.
2. ***Avoid low catch (CAT):*** Reject all those escapement strategies that result in low catch from the aggregate with higher probability than some specified risk tolerance (e.g 7 out of 10 years). Among those strategies with sufficient probability of meeting the low catch requirement, choose the one that maximizes long-term average catch. Low catch benchmarks considered for this option are based on suggestions provided by participants during the 2006 workshop series.

3. ***Mix (MX):*** Reject all those escapement strategies that fail to meet either low escapement or low catch, but with increased risk tolerance. Among those strategies that remain, choose the one that maximizes long-term average catch.
4. ***Fixed 45% exploitation rate***
5. ***Avoid low escapement (Benchmark 3=SPN3):*** Same reasoning as for a*void low escapement*, but using a larger benchmark to identify low escapement.

Note: For Summers and Lates the analysis showed that there is a range of escapement strategies that meet both the requirements of *avoid low escapement* and *avoid low catch*, and the options provided for evaluation at Workshop 3 cover that range:

- ***Mix 1****:* Low end of the range that meets both constraints
- ***Mix 2****:* Mid-point of the range that meets both constraints
- ***Mix 3****:* High end of the range that meets both constraints.

Range of escapement strategies explored

	Early Stuart	**Early Summer**	**Summer**	**Late**
Run size at which TAM starts to be reduced from "cut back point" (Fig. 1)	50,000 *to* 650,000	50,000 *to* 1 Million	50,000 *to* 5 Million	50,000 *to* 3 Million
TAM ER cap ceiling (Fig. 1)	60 *or* 70%	60 *or* 70%	60 *or* 70%	60 *or* 70%

Note: TAM = Total allowable mortality, ER = Exploitation Rate

2. SUMMARY OF SIMULATION SCENARIOS

Settings and Assumptions

- Simulations start with data up to 2004.
- A minimum exploitation rate of 2% for test fishing is applied every year to each run timing aggregate.
- For the results presented here we assume that past observations cover the range and variability of productivity for these stocks. 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.
- Birkenhead sockeye were not included in the assessment of Late run escapement strategies/TAM rules, rather, Summer run escapement strategies/TAM rules were applied to Birkenhead, which reflects the passively managed nature of the Birkenhead component of the Fraser sockeye run.

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. SPN 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.
- Any escapement strategy that results in substantial exploitation rates at low run sizes (e.g. Avoid low catch, fixed 45% exploitation rate) propagates or creates a cyclic pattern in runs size, harvest, and escapement.
- The tested approach for responding to previous years' escapement, based on the degree of cycle line interaction estimated from the Larkin model, did not produce any consistent improvements in performance.

3. DRAFT 2007 ESCAPEMENT STRATEGY

This section outlines how a single option was chosen from the 4-5 options considered for each management group. It is important to note that while the 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 2007 Fraser River sockeye escapement strategy. For all these scenarios, benchmark 2 was chosen as the interim benchmark level for avoiding low escapement. It is recognized that additional work will need to be conducted in the future to better determine decision rules for identifying benchmarks. The selected escapement strategy for 2007 in Figures 2-5 are identified by the bolded blue line.

Early Stuart

- Early Stuart is modeled as a single stock with strong cycle-line interaction. Escapement strategies with large cut-back points (e.g. SPN3) 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 is a management group that has experienced poor returns in recent years partially due to high en-route mortality as they migrate up the Fraser River. Many advisors have raised the concern that this stock requires a high degree of protection. Accordingly we are proposing that the 'avoid low spawner' scenario (SPN) be adopted. This scenario has an extremely low risk tolerance (i.e. much less then 1 in 10 years) for not achieving the benchmark 2 of 50.3K averaged over 4 years. In fact by implementing the 'avoid low spawner' option there is a better than 1 in 5 chance of achieving benchmark 2 in any one year (red line in Figure 2).

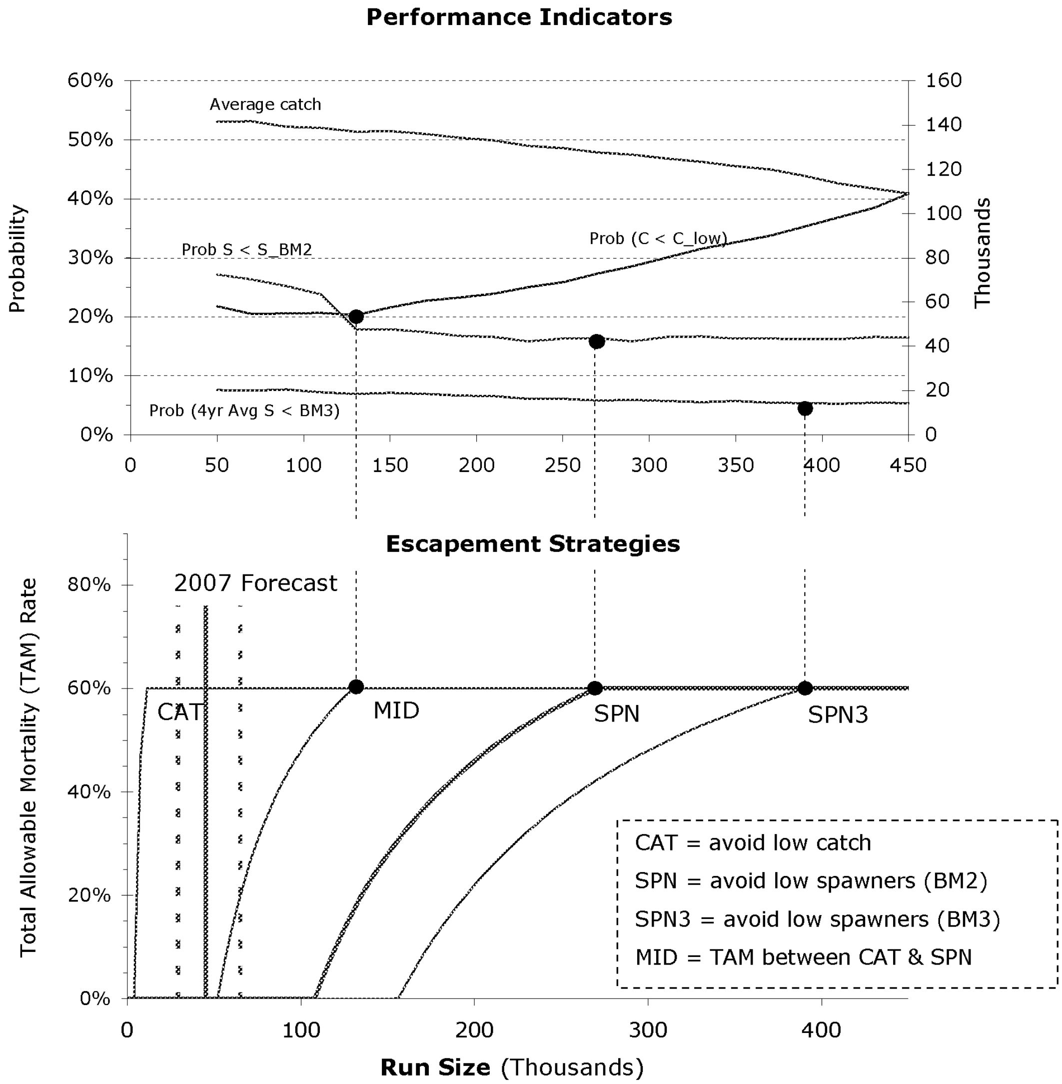

Figure 2: Sample simulation results and options for Early Stuart

Early Summer

- The Early Summer aggregate is modeled as a mixture of 8 stocks, of which 3 exhibit strong cycle-line interactions *and* contributes the majority of the abundance (Nadina, Scotch, Seymour).
- The stocks Nadina, Bowron, Fennel, Raft, Scotch and Seymour over a wide range of run sizes have a high probability (i.e. greater then 9 out 10 years) of achieving avoid low spawner benchmark 2. Pitt though never reached the 1 in 10 year benchmark of achieving benchmark 2 over the range of run sizes explored. Pitt does increase in probability though, of achieving benchmark 2 if the run size at which a fixed exploitation rate is implemented occurs at a run size of 400K. However, for a marginal increase in risk of not achieving benchmark 2, a large increase in probability of achieving the low catch benchmark is achieved. For this reason the strategy of MIX2 is proposed for 2007.

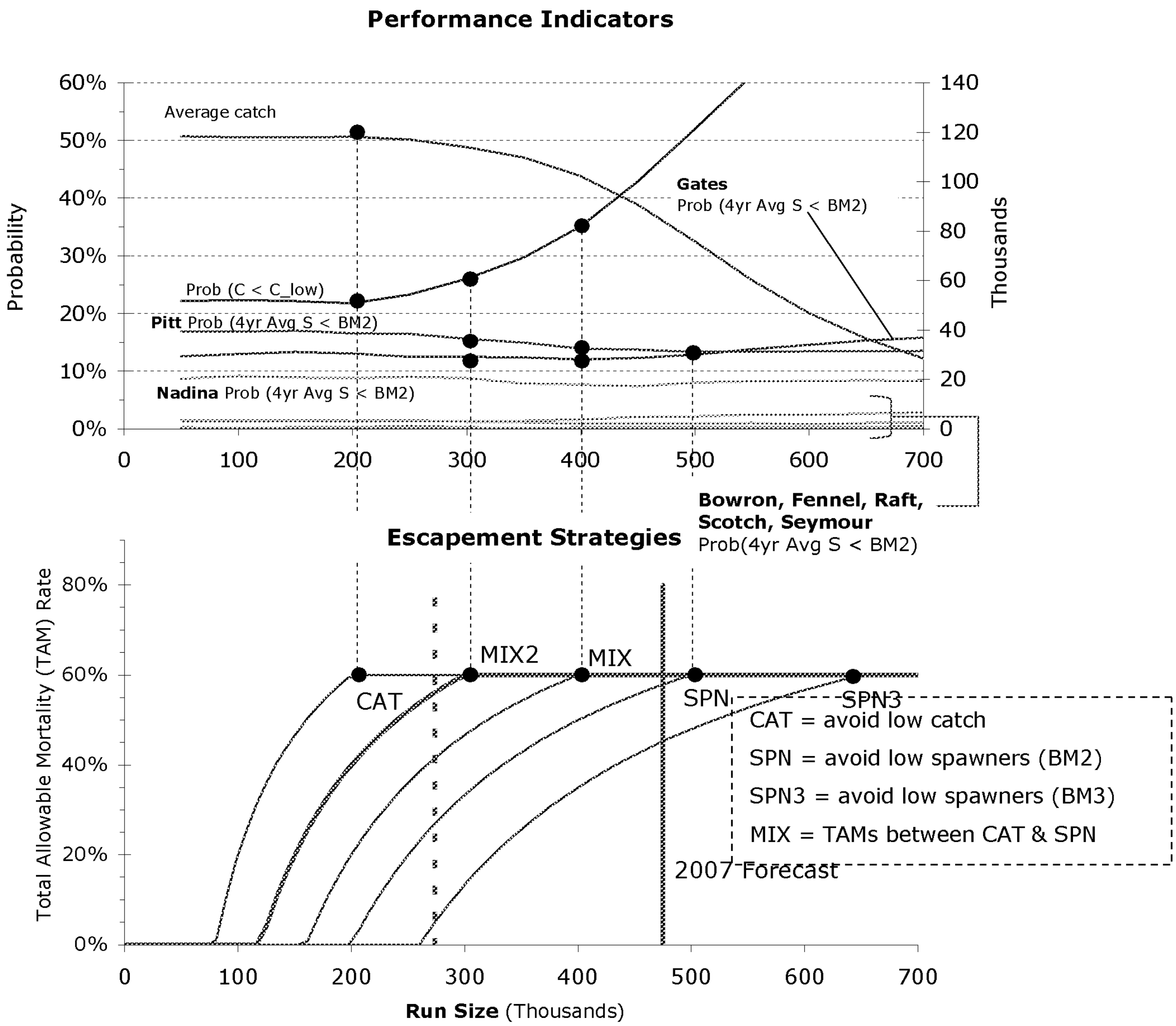

Figure 3: Sample simulation results and options for Early Summer

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 2-year patterns (high-low-high-low) in the escapement sequence that should maximize run size. Performance measures are strongly influenced by the extent to which the cyclic pattern is propagated. Birkenhead is modeled passively by applying Summer exploitation rates.
- In reviewing the performance of Chilko, Quesnel and Stellako over the range of run sizes explored we observe that these 3 stocks all have a large probability of achieving benchmark 2 (i.e. much greater then 9 of 10 years) over a four year average. Late Stuart while being consistently better than 9 of 10 years in achieving benchmark 2 does show some reduction in risk as the run size at which fixed exploitation is implemented (i.e., the *cut-back point* shown in Figure 1) increases. Concurrently, as the *cut-back point* increases, average catch starts to decrease. It isn't until the *cut-back point* goes above 1.5 million that the average catch starts to decrease. For this reason the escapement strategy of MIX1 in Figure 4 was selected for the 2007 escapement strategy.

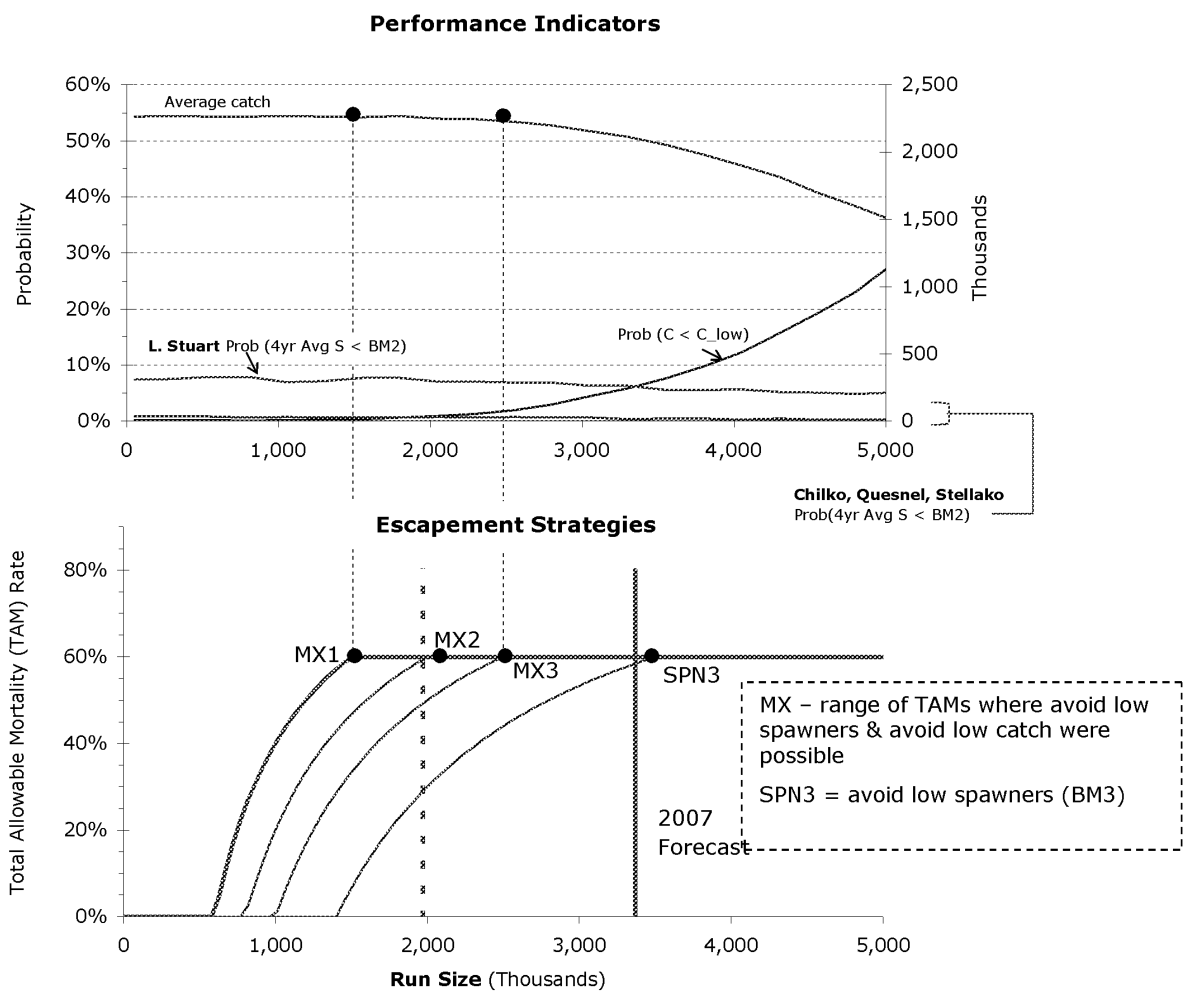

Figure 4: Sample simulation results and options for <u>Summer</u>

Late

- The Late run aggregate is modeled as a mixture of 5 stocks, of which 1 exhibits strong cycle-line interactions *and* contributes most of the abundance (Late Shuswap). The performance of escapement strategies is very robust across a wide range of escapement strategies, because run size in most of the Late Shuswap dominant years is larger than the *cut-back point* (e.g. 2 Million) and in most of the "off" years,the run size is smaller than the *no-fishing point* (e.g. 500,000). Additional work will be done in 2007/08 to explore options for low abundance years.
- In reviewing the performance of Portage, L. Shuswap and Weaver over the range of run sizes explored we observe that these 3 stocks all have a high probability of achieving benchmark 2 (i.e. greater then 9 of 10 years) over a four year average. Harrison though never does achieve a low risk (i.e. better than 9 out of ten years) of achieving benchmark 2. Concurrently, as the *cut-back point* increases, average catch starts to decrease and the probability that the catch will be less than C_low starts to increase rapidly at *cut-back points* greater 1 million. For this reason the escapement strategy of MX1 in Figure 5 was selected for the 2007 escapement strategy.

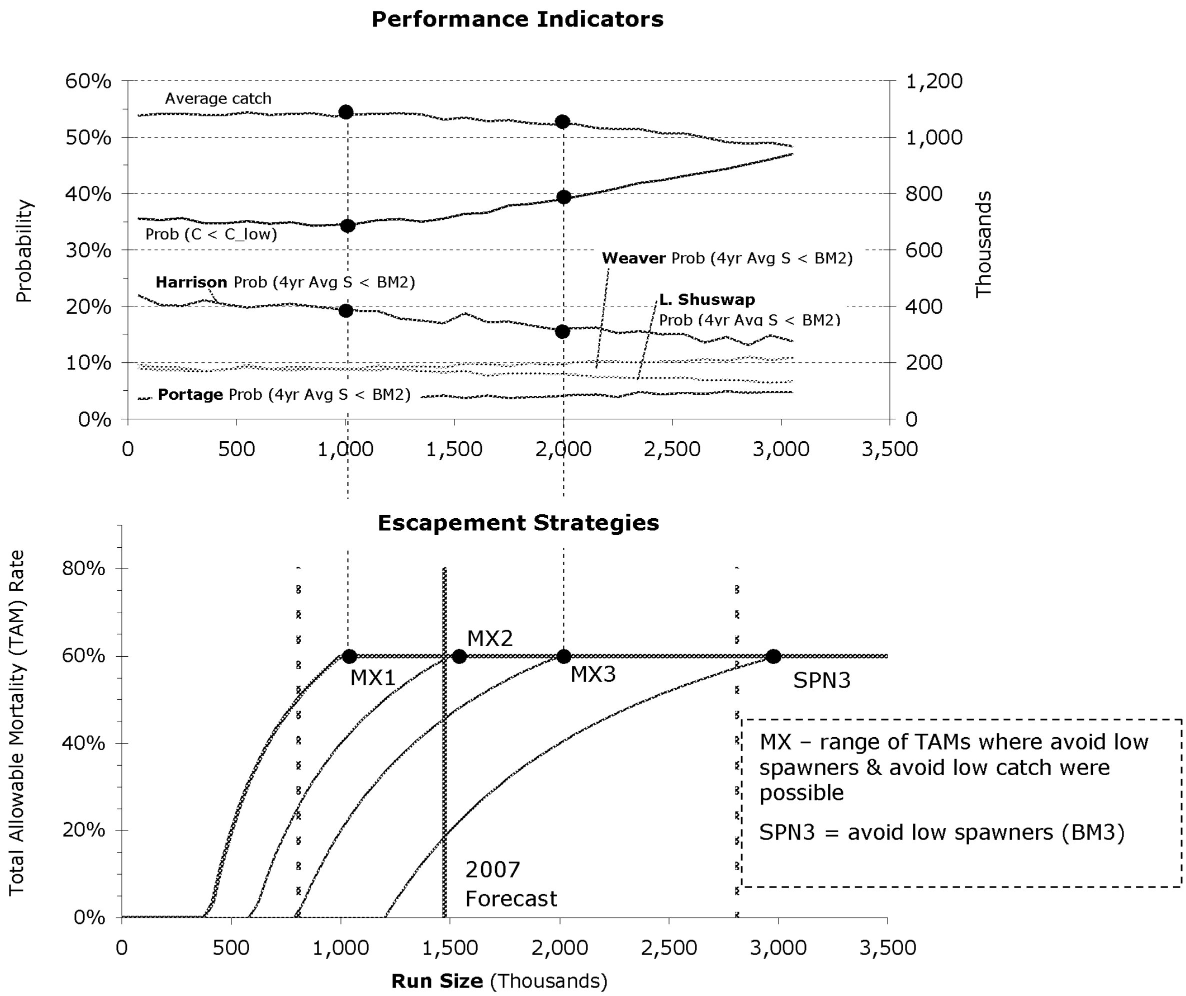

Figure 5: Sample simulation results and options for Lates

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 this year it is directly tied in with the FRSSI model results.
- For each of the late run escapement strategies (e.g. MX3, SPN3) 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 extinction less than 25% at current enhanced levels. If enhancement levels were significantly increased the probability of extinction decreased to low levels. However, enhancement effects for sockeye remain unproven and are costly to implement.
- The proposed 2007 IFMP for Cultus sockeye is for a return to a target exploitation rate of 10-12%. This is proposed due to:
    - a lower 2007 forecast of 4,000 sockeye compared to 2006,
    - high uncertainty in the forecast and a potentially lower 2007 return compared to the forecast abundance related to climate change impacts,
    - unexplained and a potentially new mortality agent causing high pre-spawning mortality in 2006 in the range of 30-90% that will reduce the reproductive potential of the last relatively abundance brood year in the 4-year abundance cycle, and
    - unpredictable long-term responses to predator and milfoil removal.

Summary

Table 1 provides an over all summary of the 2007draft escapement strategy. You'll note that Table 1 assumes a level of required management adjustment. Management adjustments are added to the escapement target to correct for the actual difference between the estimated number of fish passing by the Mission hydro-acoustic facility and estimated upstream abundance. Table 1 assumes no prior assumption regarding environmental conditions. The management adjustment will be estimated in-season.

Table 1. Draft 2007 Fraser River sockeye escapement plan

Stock Group **total run size**	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 1987	1991	1995	1999	2003
Early Stuart	45	-	108	0%	0%	45	69%	31	0%	148	141	123	25	13
		108	270	0 - 60%										
		270		60%										
Early Summer		-	120	0%						200	270	160	105	193
690		120	300	0 - 60%										
	475	300		60%	60%	276	48%	131	41%					
Summer		-	600	0%						659	1,257	918	1,281	1,003
		600	1,500	0 - 60%										
	3,369	1,500		60%	60%	1,348	2%	27	59%					
Birkenhead and				0%						165	294	40	49	310
Birkenhead-type				0 - 60%										
Lates (b)	613			60%	60%	245			60%					
true-Late		-	400	0%						724	1,345	499	406	458
(excl. Birk. Type)		400	1,000	0 - 60%										
1530	*1,475*	1,000		60%	60%	612	94%	575	22%					
Cultus	*4*								10%-12%	32	20	10	12	2
Sockeye Totals	6,247 *Est. Return*					2,526		765		1,928	3,326	1,749	1,878	1,980

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 2007. 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).

Appendix 1. Fraser River sockeye benchmarks

ID	Stock	Escapement Summary (up to 2004)				Production BM x% of average for optimal 4yr escapement sequence				Potential Conservation Reference Point	2007 Low Escapement BM Sample benchmarks based on Expert Judgment		
						max(Run size)		max(log(Run size))		Smallest observed 4yr average			
		Smallest	75p	Median	25p	20%	40%	20%	40%		BM 1	BM2	BM3
1	**E. Stuart**	1,500	21,000	39,500	122,900	25,200	50,300	24,100	48,300	10,200	10,200	50,300	100,600
4	**Bowron**	800	3,100	6,800	13,300	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	1,100	2,200	1,100	2,200	500	500	2,200	4,400
16	**Gates**	<100	2,000	4,700	8,400	1,700	3,500	1,100	2,300	1,500	1,100	3,500	7,000
17	**Nadina**	1,000	2,400	5,900	14,300	2,900	5,700	2,000	3,900	5,800	2,000	5,800	11,600
18	**Pitt**	3,600	12,700	18,000	36,500	3,400	6,800	3,400	6,800	11,200	3,400	11,200	22,400
5	**Raft**	500	2,600	6,100	8,700	2,600	5,200	2,500	4,900	2,600	2,500	5,200	10,400
15	**Scotch**	100	2,200	4,600	14,800	900	1,800	2,000	4,000	2,200	900	4,000	8,000
8	**Seymour**	1,300	5,700	13,400	44,600	9,500	19,000	9,500	19,000	9,100	9,100	19,000	38,000
	total	7,300	32,100	65,200	149,700	24,600	49,100	24,100	48,000	35,900	22,000	55,800	111,600
7	**Chilko**	17,300	109,600	239,900	544,400	66,400	132,900	66,400	132,900	164,500	66,400	164,500	329,000
2	**Late Stuart**	<100	5,700	21,600	157,100	39,100	78,300	39,100	78,300	29,500	29,500	78,300	156,600
6	**Quesnel**	<100	300	8,500	263,000	77,300	154,500	41,100	82,200	7,800	7,800	154,500	309,000
3	**Stellako**	15,800	42,100	79,300	138,000	22,700	45,400	22,700	45,400	37,000	22,700	45,400	90,800
	total	33,100	157,700	349,300	1,102,500	205,500	411,100	169,300	338,800	238,800	126,400	442,700	885,400
10	**Birkenhead**	11,900	30,700	48,900	78,600	19,700	39,300	19,700	39,300	23,200	19,700	39,300	78,600
11	**Cultus**	100	1,900	10,300	17,600	3,700	7,300	3,700	7,300	1,900	1,900	7,300	14,600
19	**Harrison**	300	3,800	8,200	17,100	2,000	4,100	2,000	4,100	3,600	2,000	4,100	8,200
12	**Portage**	<100	1,100	3,600	8,200	100	300	600	1,200	1,300	100	1,300	2,600
13	**Weaver**	3,200	16,700	34,700	45,400	8,900	17,800	8,600	17,300	14,500	8,600	17,800	35,600
9	**L. Shuswap**	600	3,600	12,800	1,133,400	111,100	222,100	111,100	222,100	320,500	111,100	320,500	641,000
	total	4,200	27,100	69,600	1,221,700	125,800	251,600	126,000	252,000	341,800	123,700	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 DRAFT 2007 Forecast		Scale up run size for TAM rule to include
Early Stuart	1	+0%	NA
Early Summer	1.44	+44%	Misc Early Summers
Summer	1.19	+19%	Birkenhead, Birkenhead-type lates (misc. non-Shuswap)
Late	1.04	+4%	misc. Shuswap