

FRASER SOCKEYE ESCAPEMENT STRATEGY 2010

Model Overview & Summary of 2010 Planning Simulations

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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 2010 planning process and additional technical work that builds on the long-term strategy developed in 2007 and adapted each year since then.

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, and 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. Currently the model includes a 2% ER to simulate test fishing impacts. This is being reviewed to accurately reflect the current management for stocks such as Early Stuart where DFO plans to protect 90% of the migration timing which could allow for harvest impacts of up to 10%. Other stock groupings also need this review.
 - 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 simulated 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.

- Socio-economic indicators focus on stability in total harvest (e.g. how often is the realizable harvest less than 1 Million fish?).

On-going Developments

Several new developments for Fraser sockeye planning are on-going. These will not be completed in time to inform pre-season planning for 2010, but they are setting the stage for a broad review of the Spawning Initiative after 4 years of implementation. These developments include:

- *Science review of conservation benchmarks for Fraser sockeye:* A paper identifying the methodology and determining WSP biological benchmarks for Fraser River sockeye will be reviewed by the Centre for Science Advice Pacific (CSAP) in late May 2010, and will be used to support a series of collaborative multi-interest workshops.
- *Science review of the FRSSI model:* The model is currently being updated (e.g. estimating recruitment parameters) and revised to allow for more flexibility in exploring alternative scenarios (e.g. different management aggregates, alternative scenarios of future productivity). This revised model will be reviewed in late May 2010 by the Centre for Science Advice Pacific (CSAP), which replaces the Pacific *Science Advice Review Committee* (PSARC), and will be used to support a series of collaborative multi-interest workshops.
- *Fall Workshops:* A series of workshops is planned to review implementation of the Spawning Initiative and explore alternative long-term escapement strategies using the revised model and peer-reviewed conservation benchmarks. The workshops will also be broader forums on Fraser sockeye rather than focused technical discussions, with an increased emphasis on First Nations involvement.

Proposed Options for the 2010 Fraser Sockeye Escapement Strategy

This memo introduces up to 4 alternative escapement strategies for each of 4 management groups (Tables 1a and 1b, p 23-24). The same suite of options was presented in the 2009 draft *Integrated Fisheries Management Plan* (IFMP), and one option for each management group was adopted, and all the options together became the pre-season plan for 2009 after broad public consultation during the Spring of 2009.

THIS DOCUMENT

This document is intended as an information supplement to explain the work that went into developing draft options for the 2010 escapement strategy, which are included in the draft 2010 *Pacific Region Integrated Fisheries Management Plan Salmon Southern B.C.* (IFMP). These options and resulting pre-season 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 4 topics:

- An *Introduction* that retraces the Spawning Initiative over the last eight years, explains the fundamental concepts, and outlines priorities for future developments.
- A *Summary of 2010 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 *2010 Escapement Strategy*.
- A section with *Additional Considerations*, which summarizes simulations that explored the implications of (1) reduced productivity scenarios and (2) changing the minimum exploitation rate associated with each escapement strategy.

The following reference materials are included in this memo:

- Concepts and terminology are summarized in Figure 1 (p. 12). More technical details are included in the Technical Appendix (p. 26).
- Escapement options evaluated during the planning process are detailed in Table 1 (p. 23).
- Interim benchmarks and past escapements are summarized in Table 2 (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>

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1 Introduction

1.1 The Spawning Initiative

Initial Development

The *Fraser River Sockeye Spawning Initiative* (FRSSI) has been an 8-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.

2009 Planning Process

The planning process for 2009 followed 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. A draft of a memo like this was circulated to support the consultations. The next major steps were the release of the final IFMP and the development of pre-season fishing plan in June, 2009.

No significant technical issues arose around implementing the 2009 escapement plan.

Escapement plans developed under the Spawning Initiative describe a long-term strategy for the full range of possible run sizes. Pre-season discussions deal not only with the forecasted range of abundance, but also establish explicit target levels of escapement for much larger or much smaller run sizes. The importance of such contingency planning was highlighted by the drastic revision of abundance estimates during the 2009 season.

Summary of the Process so far

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 annual escapement strategy for consultation. Workshops were very 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.

However, several concerns were raised regularly throughout the process: Participants frequently emphasized the need to make additional progress on *Wild Salmon Policy* implementation. For example, 'interim lower benchmarks' (Table 2, p25) were identified for 19 stocks in the simulation model, which covers about half of the Fraser River sockeye conservation units. The section on *Objectives and Benchmarks* (p. 9) includes more detail about these interim benchmarks and how they match up against the WSP benchmark concepts. There is a 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 component stocks (e.g. Bowron) within the larger management aggregates. Also, some groups have expressed that additional management aggregates need to be considered beyond the four management aggregates currently identified in this process. Finally, concerns have been raised about participation in the planning process and the representation of different groups at the workshops. Several on-going model developments are intended to address these recurring concerns (see next section).

2010 Planning Process

The annual planning process has been restructured for 2010 due to several concurrent and overlapping processes, including a science review of the model planned for early June 2010 and a comprehensive review of Fraser sockeye currently starting up:

- *Science review of conservation benchmarks for Fraser sockeye:* A paper identifying the methodology and determining WSP biological benchmarks for Fraser River sockeye will be reviewed by the Centre for Science Advice Pacific (CSAP) in late May 2010, and will be used to support a series of collaborative multi-interest workshops.
- *Science review of the FRSSI model:* The model is currently being updated (e.g. estimating recruitment parameters) and revised to allow for more flexibility in exploring alternative scenarios (e.g. different management aggregates, alternative scenarios of future productivity). This revised model will be reviewed by the Centre for Science Advise Pacific (CSAP) in late May 2010, and will be used to support a series of collaborative multi-interest workshops.
- *Fall Workshops:* A series of workshops is planned to review implementation of the Spawning Initiative and explore alternative long-term escapement strategies using the revised model and peer-reviewed WSP benchmarks. The workshops will also be broader forums on Fraser sockeye rather than focused technical discussions, with an increased emphasis on First Nations involvement.

The emphasis of the Working Group has shifted towards technical work, such as model updates, and the workshops which are planned as a follow-up to the science review. While this approach ensures that workshop participants are presented with the latest technical information, it also creates some challenges for the annual pre-season planning process which starts in March with a suite of draft options for consultation.

To bridge the gap between these two timelines, the 2010 planning process currently has the following milestones:

- *March 9, 2010:* Science review of 2010 abundance forecasts for Fraser River sockeye.
- *March 18, 2010:* Release draft salmon management plan for 2010 which will contain a copy of this memo. We will also distribute this draft memo to support public consultation on an escapement strategy for 2010. The results included here are based on 2009 planning model, but include additional scenarios as described in Section 4 (p. 26).
- *June:* Release final salmon management plan for 2010, including the pre-season escapement strategy for Fraser sockeye.
- *May 26/27:* Science review of FRSSI model and of conservation benchmarks for Fraser River sockeye.
- *Fall:* Workshop(s) to review model revisions etc.

1.2 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. 12) compared to fixed escapement strategies or fixed exploitation rate strategies (Technical Appendix, p. 26)

1.3 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).

The methodology for calculating upper and lower CU benchmarks can be found in:

Holt, C.A., A. Cass, B. Holtby, and B. Riddell. 2009. *Indicators of Status and Benchmarks for Conservation Units in Canada's Wild Salmon Policy*. Canadian Science Advisory Secretariat Research Document 2009/058.

1.4 Long-term Strategy vs. Annual Escapement Plan

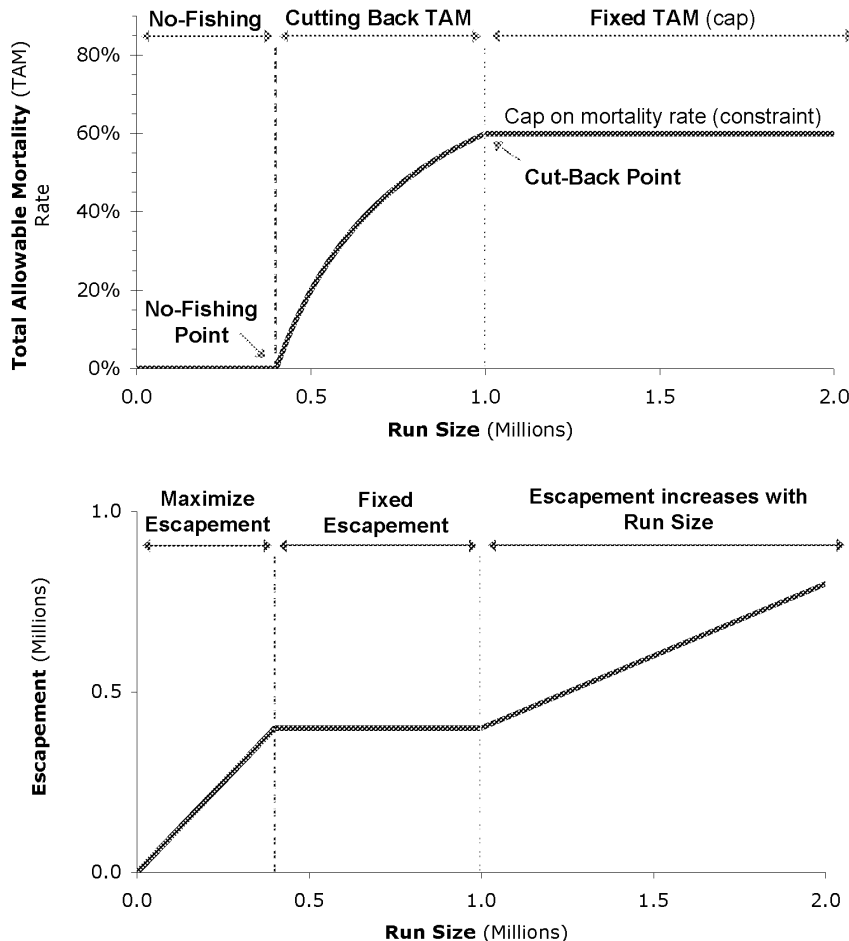
The 2008 planning process focused on the challenges of adapting a long-term strategy to the particular circumstances of each year. Small changes in escapement strategy, that have little effect on long-term performance and trade-offs, can have substantial implications for fisheries planning in a given 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 created 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. Each year, there is a need to explore guidelines in this area. The changes to the model, benchmark paper and planned workshops will form the basis for any changes over the longer term.

1.5 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.



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

1.6 History of model revisions

For 2008 Planning

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.

For 2009 Planning

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.

Note: A major model update is on-going, and will be used for pre-season planning in 2011 (p. 8)

2 SUMMARY OF 2010 SIMULATION SCENARIOS

2.1 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

2.2 Settings and Assumptions for 2010 Simulations

Given on-going model developments, the simulations for 2010 pre-season planning are based on the same settings and assumptions as for 2010 pre-season planning. Refer to p. 8 for a summary of process milestones for 2010. Also, refer to Section 4 (p 26) for additional considerations regarding reduced productivity and potential changes in escapement strategies.

The settings and assumptions used to create Figures 2 to 5 are:

- 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 2002 (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, instant and persistent decline by 75%). Section 4 of this memo (p 26) shows some exploratory analyses.
- 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. 12) and corresponding results are presented in the next section.
- For the simulations presented in this memo, Birkenhead sockeye were not included in the assessment of Late run escapement strategies, rather. Rather, Summer run escapement strategies were applied to Birkenhead, which reflects the passively managed nature of the Birkenhead component of the Fraser sockeye run. in recent years. However, the management strategy for Birkenhead will be changing in 2010 by shifting them back into the Late Run aggregate. Target exploitation rate for the Late Run aggregate tends to be smaller than for the Summer aggregate due to the generally larger environmental management adjustments, so no detrimental effects to Birkenhead are expected from this change. A more thorough evaluation will be conducted after model revisions are completed.
- Harrison sockeye were simulated as part of the Late run aggregate, but several management options for 2010 are under consideration (see p. 21).
- 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 and 2009 planning processes.

2.3 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, 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 environmental 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.
- 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 stocks 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 OPTIONS FOR THE 2010 ESCAPEMENT STRATEGY

This section outlines reasoning underlying proposed options for 2010. We have not made any changes to the suite of options in 2010 from those presented for public consultation in the spring of 2009. 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 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. 9).

The options for 2010 are based on the same suite of alternative long-term strategies that was publicly reviewed during the 2008 and 2009 planning processes, but the annual exploitation rate targets are adjusted based on expected run size and environmental conditions (i.e. management adjustments). 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.

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 2009 plan (i.e. explore the effect of changing the strategy for one aggregate *while keeping all else equal*).

Note: Section 4 of this memo explores the effect of reduced productivity on the performance of these alternative escapement strategies.

3.1 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. Extensive consultation was undertaken with First Nations and parties with an interest in the management of Fraser River sockeye. Advice received from First Nations indicated a strong interest in providing for increased escapement levels for Early Stuart sockeye in 2009 (dominant cycle year), in order to reduce harvest and enhance rebuilding. For this reason, the escapement strategy adopted for 2009 was Option 4, which has a low risk tolerance. For example, under long-term average productivity assumptions, there is a less than 1 in 10 chance of the four year running average escapement not achieving escapement benchmark 2 (--- dashed line in Figure 2).

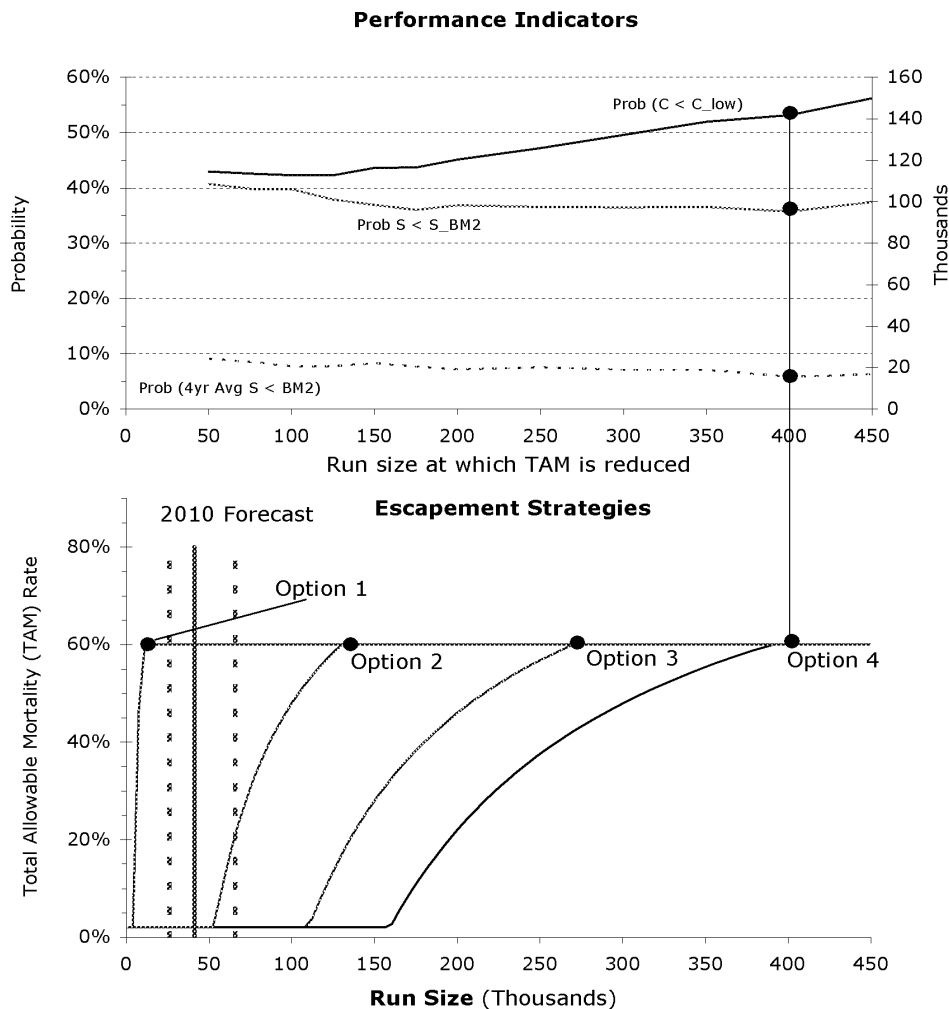


Figure 2: Sample simulation results and options for Early Stuart (Forecast lines span the lower quarter, best estimate, and upper quarter of the forecasts range)

3.2 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 of 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.

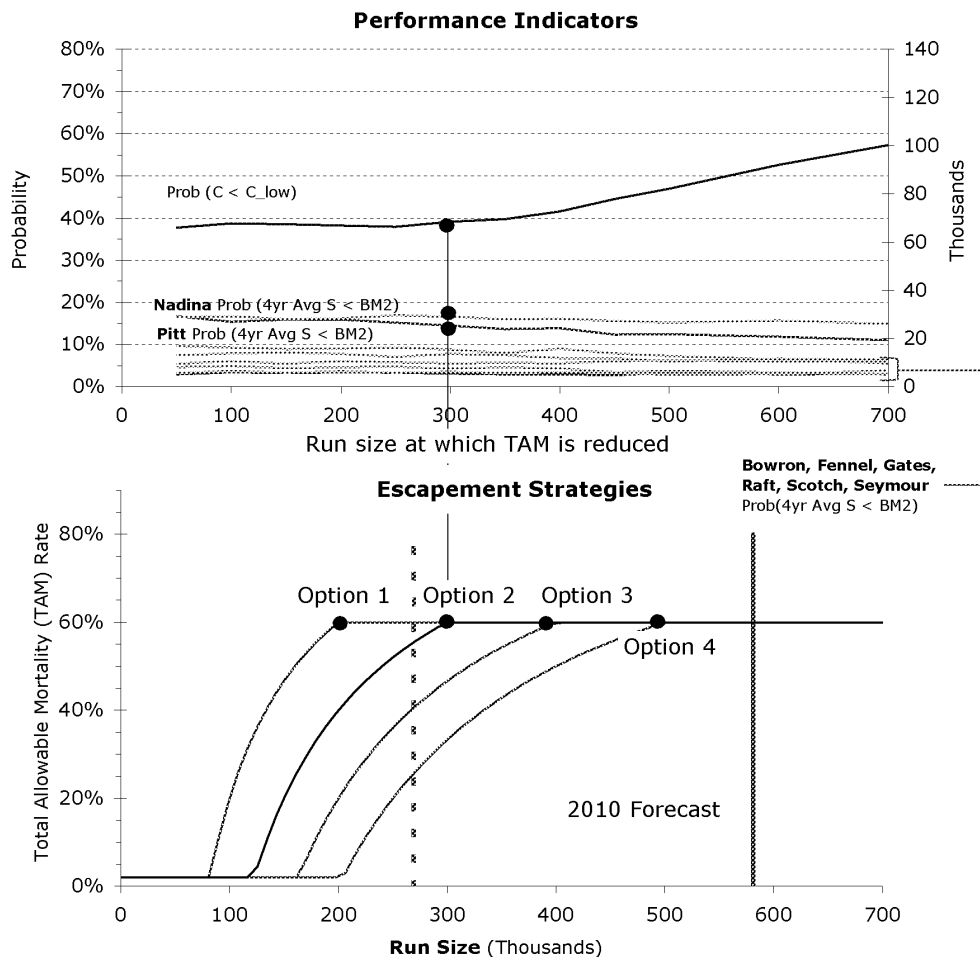


Figure 3: Sample simulation results and options for Early Summer (Forecast lines span the lower quarter, best estimate, and upper quarter of the forecasts range)

3.3 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 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.

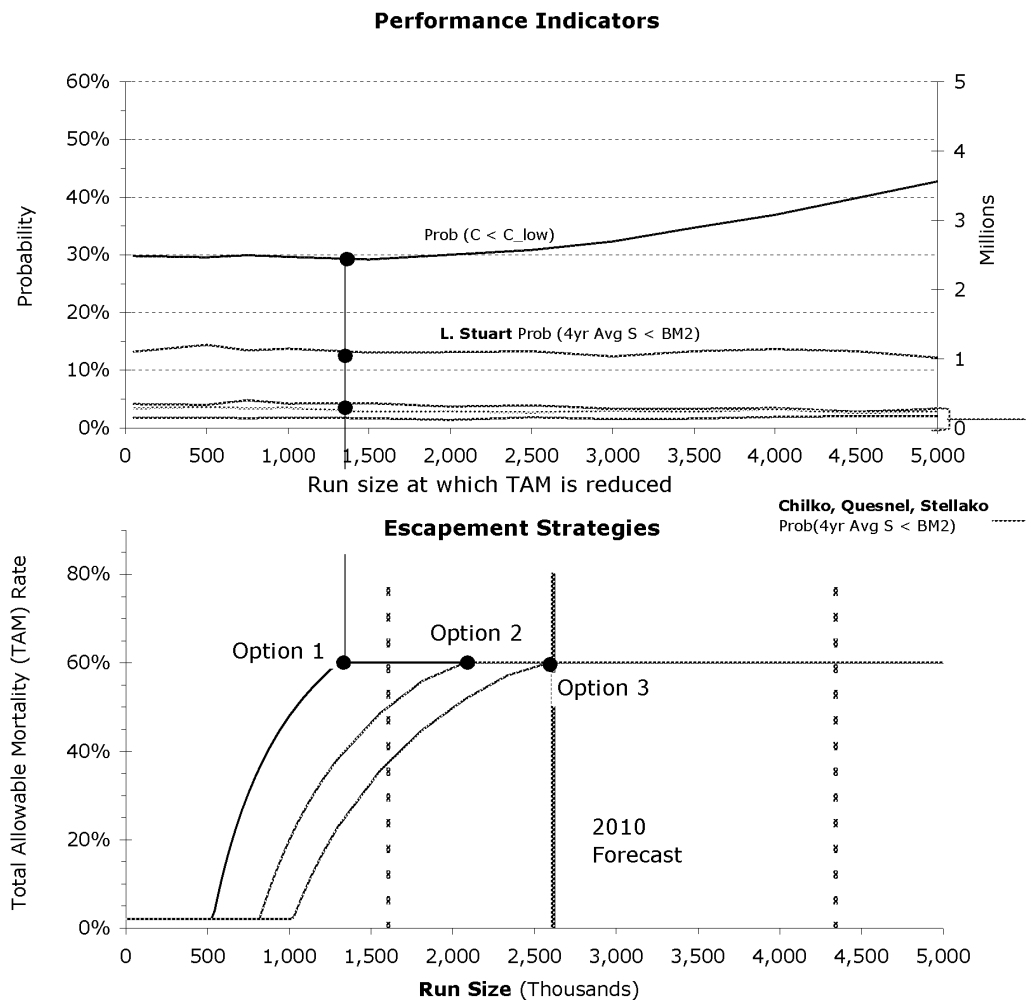


Figure 4: Sample simulation results and options for Summer (Forecast lines span the lower quarter, best estimate, and upper quarter of the forecasts range)

3.4 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. 3 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).

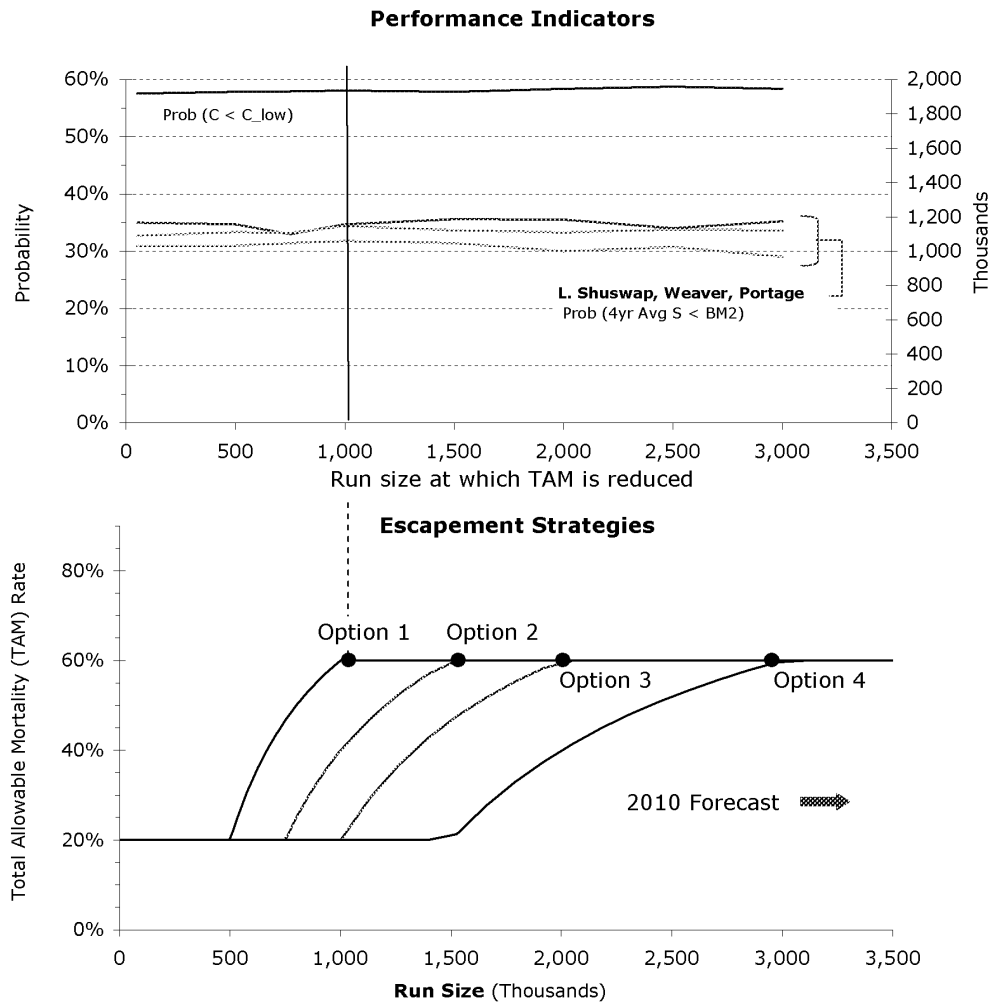


Figure 5: Sample simulation results and options for Lates (using a 20% ER floor) (Forecast lines span the lower quarter, best estimate, and upper quarter of the forecasts range)

The performance of escapement strategies for the Late Run aggregate is fairly sensitive to the chosen minimum exploitation rate, as illustrated in Section 4 of this memo. The 20% exploitation rate floor has been implemented since 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.

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

3.5 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 have been simulated as passively exposed to the same exploitation rate as the Summer run aggregate for the last few years. 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*. Note that Birkenhead has been moved back into Late runs for the 2010 options table (Table 1). However, as the Summer run aggregate tends to have a higher exploitation rate than Late run, for the purpose of 2010 planning, we do not expect any adverse effects on Birkenhead due to this change. The revised planning model to be reviewed in May includes increased flexibility for exploring the implications of different management aggregates and the change in Birkenhead management will be explicitly modeled at that time.

3.6 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 was 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.

For 2010, a review of the exploitation rate limit for Cultus Lake sockeye is under development and will be released before the next draft of the IFMP. For Late run sockeye, abundance based TAM rules options have been developed (Section 3.4).

Table 1a. 2010 Escapement options (at mid-point of forecast range)

p50		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	2010 Forecast (p50)			41,000		0.63	fixed ER floor:		2%
									820
	Option 1	4,000	10,000	60%	16,400		10,332	35%	14,300
	Option 2	52,000	130,000	60%	41,000		25,830	0%	-
	Option 3	108,000	270,000	60%	41,000		25,830	0%	-
	Option 4	156,000	390,000	60%	41,000		25,830	0%	-
Early Summer	2010 Forecast (p50)			581,000	w/o misc	0.51	fixed ER floor:		2%
				783,000	w. misc				15,660
	Option 1	80,000	200,000						
		107,814	269,535	60%	313,200		160,484	40%	309,300
	Option 2	120,000	300,000						
		161,721	404,303	60%	313,200		160,484	40%	309,300
	Option 3	200,000	500,000						
		269,535	673,838	60%	313,200		160,484	40%	309,300
	Option 4	260,000	650,000						
		350,396	875,990	55%	350,396		179,543	32%	253,100
Summer	2010 Forecast (p50)			2,612,000		0.07	fixed ER floor:		2%
									52,240
	Option 1	520,000	1,300,000	60%	1,044,800		73,136	57%	1,494,100
	Option 2	800,000	2,000,000	60%	1,044,800		73,136	57%	1,494,100
	Option 3	1,000,000	2,500,000	60%	1,044,800		73,136	57%	1,494,100
Late (incl. BK)	2010 Forecast (p50)			7,871,000	w/o misc	0.66	fixed ER floor:		20%
				8,003,000	w. misc				1,600,600
	Option 1	400,000	1,000,000						
		406,700	1,016,800	60%	3,201,200		2,111,264	34%	2,690,500
	Option 2	600,000	1,500,000						
		610,100	1,525,200	60%	3,201,200		2,111,264	34%	2,690,500
	Option 3	800,000	2,000,000						
		813,400	2,033,500	60%	3,201,200		2,111,264	34%	2,690,500
	Option 4	1,200,000	3,000,000						
		1,220,100	3,050,300	60%	3,201,200		2,111,264	34%	2,690,500

* 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.

Notes: The fixed ER floor percentages are from the 2009 model. The 2% floor represents Test Fishing Catch and the 20% ER floor for Lates was implemented in 2008 & 2009 (see p #). Colors in the table (red/amber/green) correspond to no fishing/fixed escapement/fixed TAM portions of TAM. Options used in 2009 Escapement Plan were: Option 4 - Early Stuart, Option 2 - Early Summers, Option 1 - Summers (Summer Run TAM applied to BK), Option 1 + 20% fixed ER floor - Lates (excl. BK)

Table 1b. 2010 Escapement options (at lower quarter of forecast range)

p25		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
Label									
Early Stuart	2010 Forecast (p25)		26,000			0.63		fixed ER floor:	2%
									520
	Option 1	4,000	10,000	60%	10,400		6,552	35%	9,000
	Option 2	52,000	130,000	0%	26,000		16,380	0%	-
	Option 3	108,000	270,000	0%	26,000		16,380	0%	-
	Option 4	156,000	390,000	0%	26,000		16,380	0%	-
Early Summer	2010 Forecast (p25)		269,000			0.51		fixed ER floor:	2%
			374,000		w/o misc w. misc				7,480
	Option 1	80,000	200,000						
		111,227	278,067	60%	149,600		76,744	39%	147,700
	Option 2	120,000	300,000						
		166,840	417,100	55%	166,840		85,588	33%	121,600
	Option 3	200,000	500,000						
		278,067	695,167	26%	278,067		142,647	0%	-
	Option 4	260,000	650,000						
		361,487	903,717	3%	361,487		185,441	0%	-
Summer	2010 Forecast (p25)		1,605,000			0.07		fixed ER floor:	2%
									32,100
	Option 1	520,000	1,300,000	60%	642,000		44,940	57%	918,100
	Option 2	800,000	2,000,000	50%	800,000		56,000	47%	749,000
	Option 3	1,000,000	2,500,000	38%	1,000,000		70,000	33%	535,000
Late (incl. BK)	2010 Forecast (p25)		4,951,000			0.66		fixed ER floor:	20%
			5,023,000		w/o misc w. misc				1,004,600
	Option 1	400,000	1,000,000						
		405,800	1,014,500	60%	2,009,200		1,332,528	33%	1,681,300
	Option 2	600,000	1,500,000						
		608,700	1,521,800	60%	2,009,200		1,332,528	33%	1,681,300
	Option 3	800,000	2,000,000						
		811,600	2,029,100	60%	2,009,200		1,332,528	33%	1,681,300
	Option 4	1,200,000	3,000,000						
		1,217,500	3,043,600	60%	2,009,200		1,332,528	33%	1,681,300

* 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.

Notes: The fixed ER floor percentages are from the 2009 model. The 2% floor represents Test Fishing Catch and the 20% ER floor for Lates was implemented in 2008 & 2009 (see p #). Colors in the table (red/amber/green) correspond to no fishing/fixed escapement/fixed TAM portions of TAM. Options used in 2009 Escapement Plan were: Option 4 - Early Stuart, Option 2 - Early Summers, Option 1 - Summers (Summer Run TAM applied to BK), Option 1 + 20% fixed ER floor - Lates (excl. BK)

Table 2. Fraser River Sockeye benchmarks and escapement summary

Escapement Summary							ICE				Potential Conservation Reference Point	2007 Low Escapement BM		
(up to 2008)							x% of average for optimal 4yr escapement sequence				Smallest observed 4yr average up to 2008 (Year)	Sample benchmarks based on Expert Judgment		
ID	Stock	Smallest	Lower Quarter	Median	Upper Quarter	Largest	max(Run size)		max(log(Run size))			BM 1	BM2	BM3
							20%	40%	20%	40%				
1	E. Stuart	1,522	21,044	35,816	109,655	688,013	25,200	50,300	24,100	48,300	10,200 (1966)	10,200	50,300	100,600
4	Bowron	916	2,560	6,395	12,780	35,000	2,500	4,900	2,500	4,900	1,600 (2007)	1,600	4,900	9,800
14	Fennell	<100	1,681	5,709	9,901	32,279	1,100	2,200	1,100	2,200	500 (1970)	500	2,200	4,400
16	Gates	<100	2,582	7,181	14,838	99,836	1,700	3,500	1,100	2,300	2,400 (1972)	1,100	3,500	7,000
17	Nadina	1,723	3,666	9,547	22,952	199,381	2,900	5,700	2,000	3,900	9,600 (1978)	2,000	9,600	19,200
18	Pitt	3,560	13,412	18,673	37,747	131,481	3,400	6,800	3,400	6,800	11,200 (1985)	3,400	11,200	22,400
5	Raft	464	2,714	6,244	9,988	66,292	2,600	5,200	2,500	4,900	2,600 (1980)	2,500	5,200	10,400
15	Scotch	107	2,156	4,609	14,772	144,199	900	1,800	2,000	4,000	2,200 (1985)	900	4,000	8,000
8	Seymour	1,237	5,709	11,971	40,687	272,041	9,500	19,000	9,500	19,000	9,100 (1970)	9,100	19,000	38,000
	total	7,091	31,920	63,934	150,885	945,509	24,600	49,100	24,100	48,000	39,200	21,100	59,600	119,200
7	Chilko	17,308	120,104	305,853	544,364	1,037,737	66,400	132,900	66,400	132,900	164,500 (1967)	66,400	164,500	329,000
2	Late Stuart	15,763	42,099	87,669	138,794	373,369	39,100	78,300	39,100	78,300	37,000 (1974)	37,000	78,300	156,600
6	Quesnel	<100	392	10,222	278,061	3,510,789	77,300	154,500	41,100	82,200	7,800 (1951)	7,800	154,500	309,000
3	Stellako	<100	6,315	25,562	157,197	1,804,969	22,700	45,400	22,700	45,400	29,500 (1952)	22,700	45,400	90,800
	total	33,071	168,910	429,306	1,118,416	6,726,864	205,500	411,100	169,300	338,800	238,800	133,900	442,700	885,400
10	Birkenhead	11,905	30,656	48,916	93,480	1,044,450	19,700	39,300	19,700	39,300	23,200 (1960)	19,700	39,300	78,600
11	Cultus*	<100	1,227	9,055	16,919	47,779	3,700	7,300	3,700	7,300	1,100 (2007)	1,100	7,300	14,600
19	Harrison	313	4,239	8,259	19,717	388,605	2,000	4,100	2,000	4,100	3,600 (1990)	2,000	4,100	8,200
12	Portage	<100	1,105	3,724	9,071	31,343	100	300	600	1,200	1,300 (1971)	100	1,300	2,600
13	Weaver	2,756	25,442	42,002	59,165	294,083	8,900	17,800	8,600	17,300	19,500 (1971)	8,600	19,500	39,000
9	L. Shuswap	164	3,606	21,113	1,144,569	5,532,263	111,100	222,100	111,100	222,100	320,600 (1962)	111,100	320,600	641,200
	total	3,233	34,391	75,098	1,232,522	6,246,294	125,800	251,600	126,000	252,000	346,100	122,900	352,800	705,600

25% of escapements were smaller than this number

Low Catch Benchmarks
Set during '06 Planning Process

Early Stuart	15,000
Early Summer	100,000
Summer	600,000
Late	300,000

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

* Note that these wild escapements need to be considered in the context of on-going enhancement activities for Cultus sockeye.

25% of escapements were smaller than this number

Low Catch Benchmarks

Set during '06 Planning Process

Early Stuart	15,000
Early Summer	100,000
Summer	600,000
Late	300,000

* Note that these wild escapements need to be considered in the context of on-going enhancement activities for Cultus sockeye.

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

4 ADDITIONAL CONSIDERATIONS

Note: Results presented here assume no overlap constraints, in order to isolate the effect of low productivity scenarios and changing ER floors on each aggregate.

4.1 Low Productivity Scenarios

The performance of alternative escapement strategies has been explored under a wide range of assumptions; including the effect of a gradual decline in average productivity by 30% over 48 years (refer to background materials listed in the Introduction). However, workshop participants also requested a further exploration of more drastic and abrupt changes in productivity. To address these requests, the following scenarios are presented in this memo:

- *No Decline*: R/S based on SR model fitted to full time series
- *Half Productivity*: R/S based on SR model fitted to full time series, then reduced by half
- *Quarter Productivity*: R/S based on SR model fitted to full time series, then reduced by 75%
- *Tenth Productivity*: R/S based on SR model fitted to full time series, then reduced by 90%

Note that these scenarios model an instant and persistent loss of productivity, not a gradual decline.

Figures 6 and 7 summarize the simulated performance of alternative escapement strategies under 4 different assumptions about future productivity. The following observations can be made:

- The performance of escapement strategies with lower cut-back points is more sensitive to productivity declines (i.e. bigger jumps in probability of low escapement on the left-hand side in Fig 7 than on the right hand side). For example, refer to the bottom left panel on Figure 7: If productivity drops by half, the probability of low escapement on Bowron quadruples for an escapement strategy that starts cutting back at 100,000, but only doubles for a strategy that starts cutting back at 500,000.
- Each stock responds differently to the combination of reduced productivity and aggregate escapement strategy. Highly productive stocks in an aggregate can even show a reduced probability of low escapement as aggregate TAM drops due to a decrease in aggregate abundance (e.g. Gates and Nadina in Fig 1 under half productivity). However, stocks that were already less productive in the past show a drastic degradation in escapement, particularly under more aggressive TAM rules.
- FRSSI escapement strategies tend to absorb the effect of reduced productivity through reduced catch (i.e. result in more years in "fixed escapement zone" or "maximize escapement zone" of the TAM rule).
- The simulated performance of Late run stocks has to be interpreted with caution. SR models for Cultus and Harrison do not adequately capture recent changes (see notes in 2009 memo). The 4yr av. escapement for Late Shuswap is strongly driven by dominant-year abundances, and the aggregate escapement strategy includes a 20% floor to address the strong cyclic pattern in abundance. In addition, the Late Shuswap and Weaver components of the Late run have not shown the same drop in productivity as the other aggregates. As these two groups are the driving populations in the Late run, we suggest that the reduced productivity scenarios may be less relevant for the Late run than other timing groups.

In conclusion, the expected performance of options proposed for Early Stuart, Early Summer and Summer is fairly robust to persistent productivity declines by up to 50% (i.e. Options to the right of biggest jumps in probability of low escapement in Fig 7).

Probability of 4yr average escapement falling below a stock-specific benchmark (Table 3)

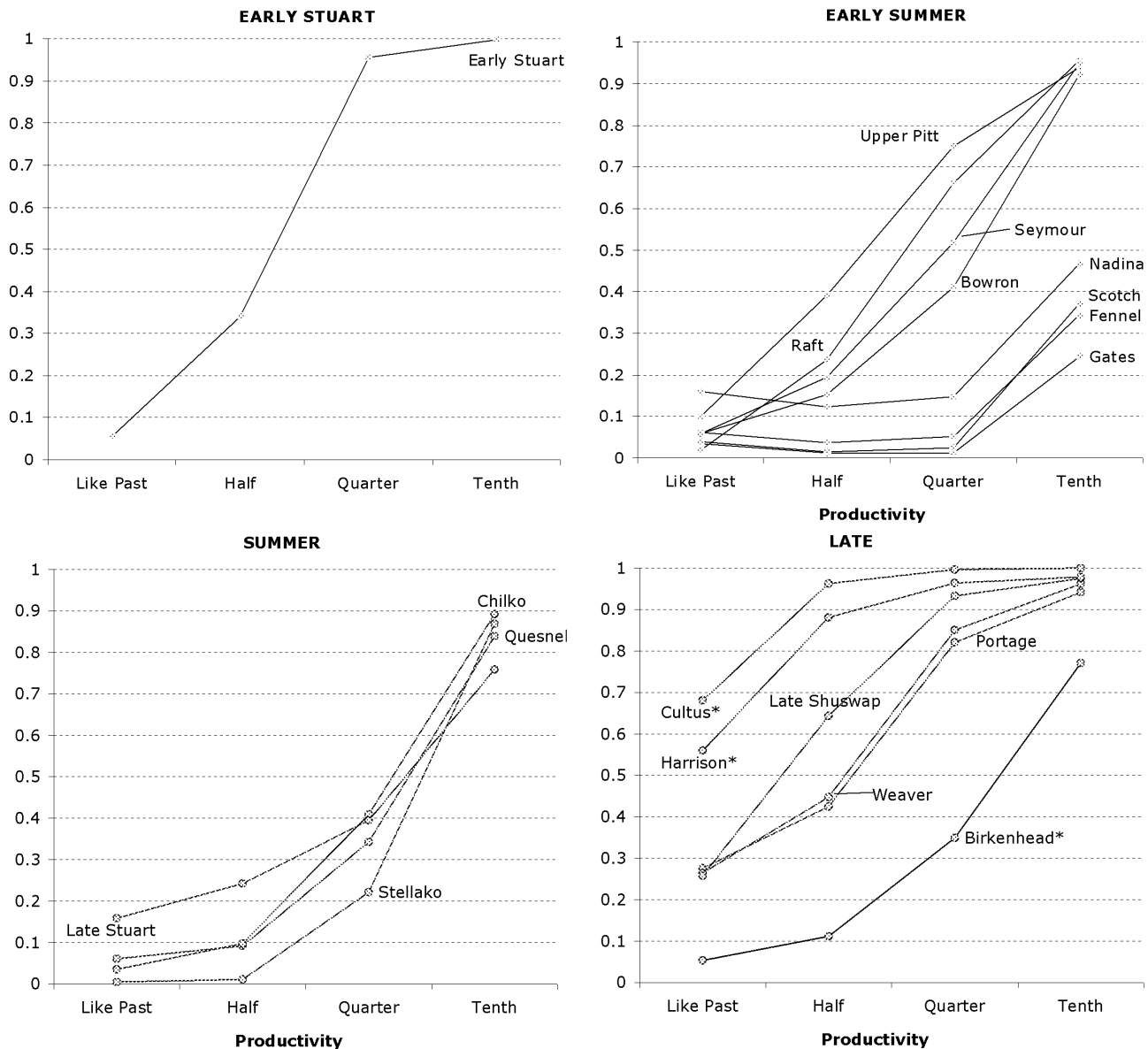


Figure 6: Performance of 2009 Escapement Strategy under 4 productivity scenarios

* Note the comments regarding Cultus and Birkenhead on p 21.

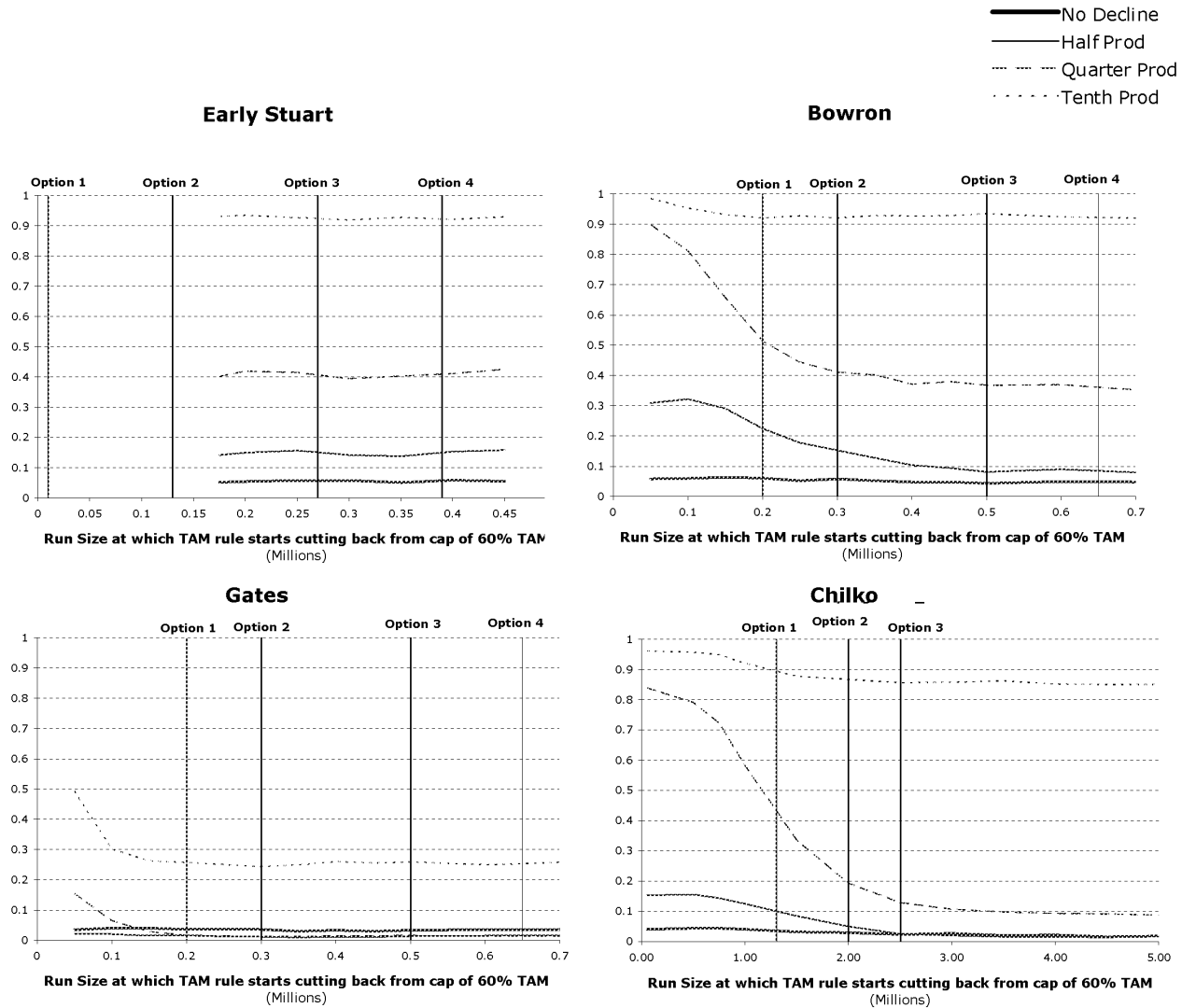


Figure 7: Probability of 4yr average escapement < BM 2* for a range of escapement strategies under 4 alternative productivity assumptions.

* see Table 3

4.2 Effect of Changing the Exploitation Rate floor

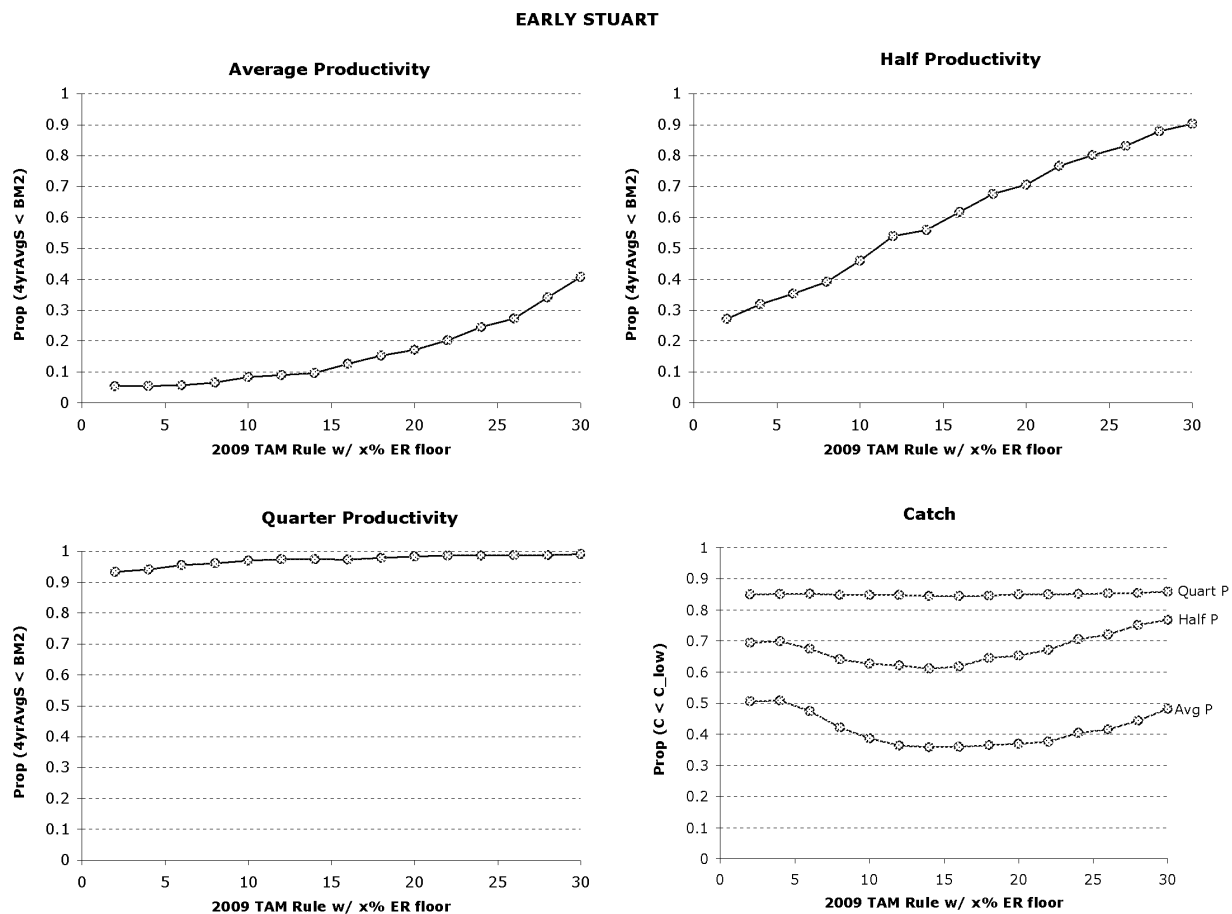


Figure 8: Probability of low escapement and low catch under 3 alternative assumptions about future productivity – EARLY STUART

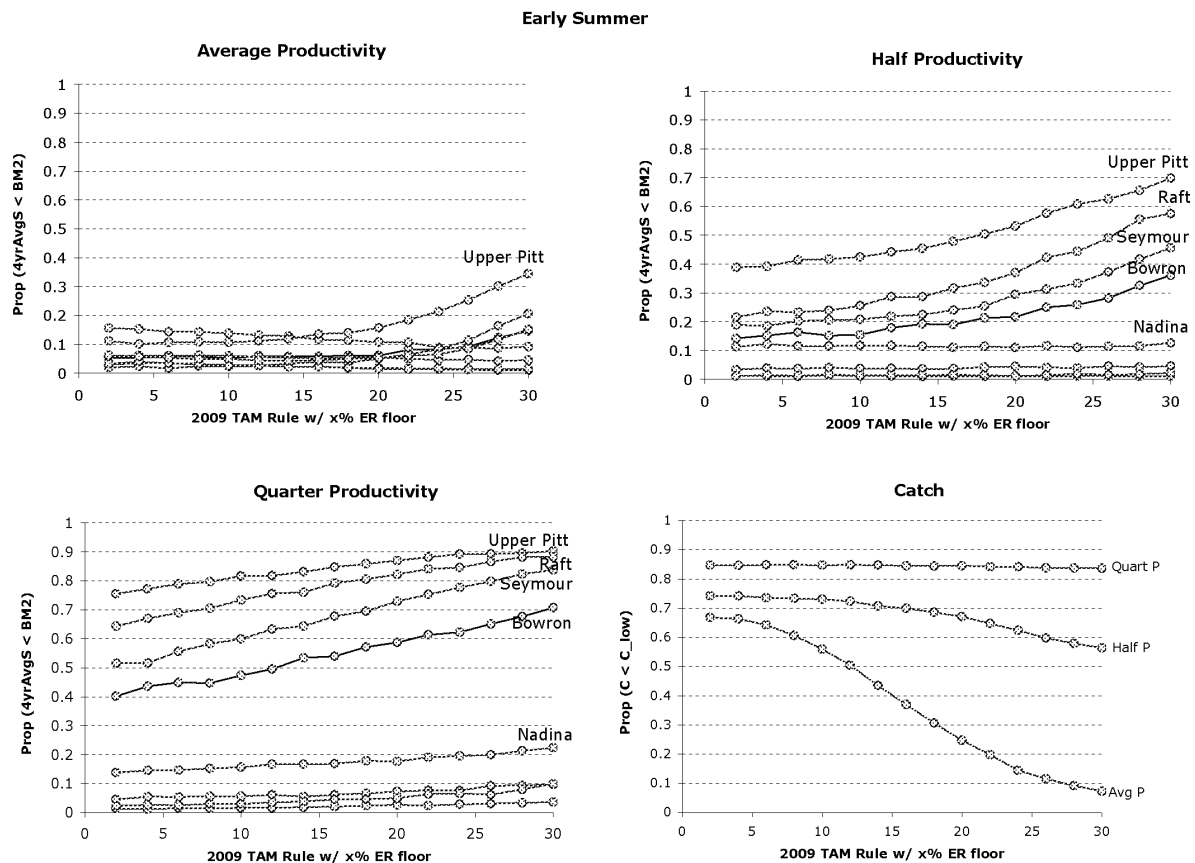


Figure 9: Probability of low escapement and low catch under 3 alternative assumptions about future productivity – EARLY SUMMER

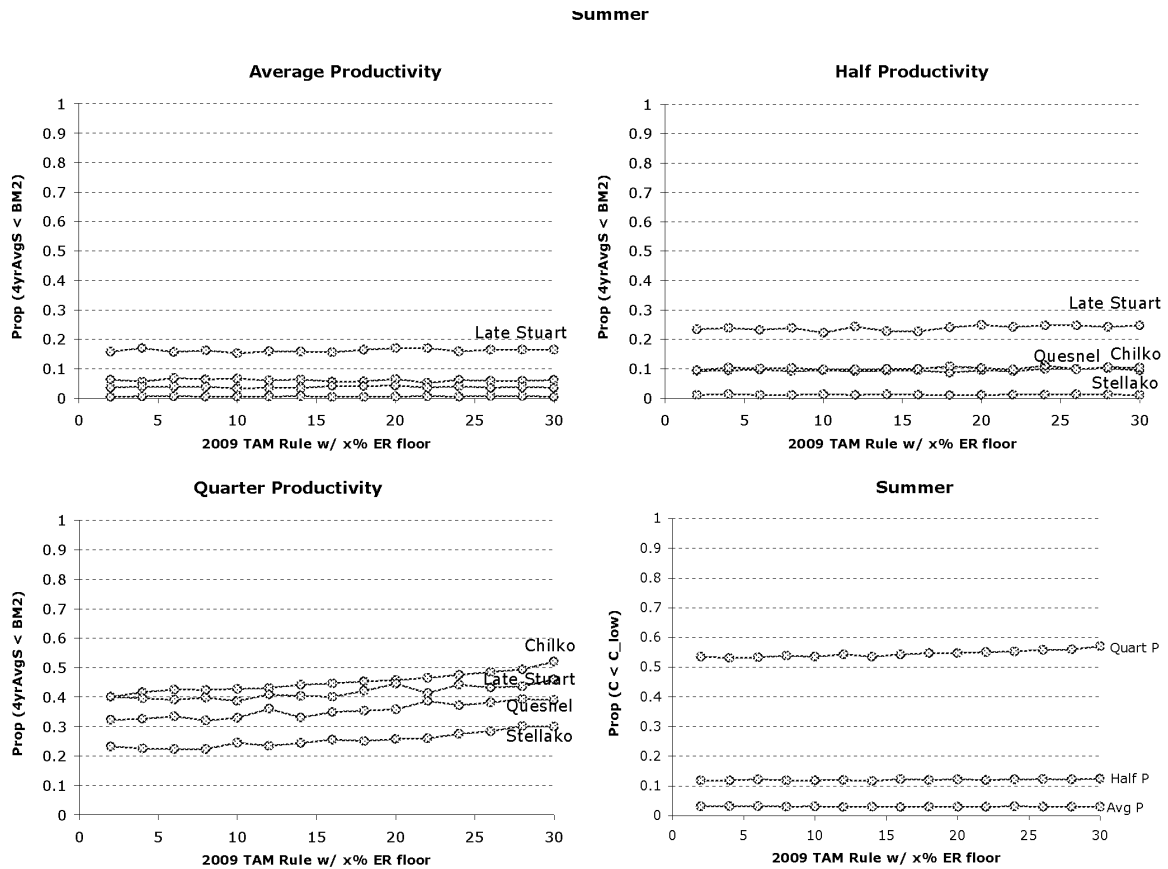


Figure 10: Probability of low escapement and low catch under 3 alternative assumptions about future productivity – SUMMER

LATE

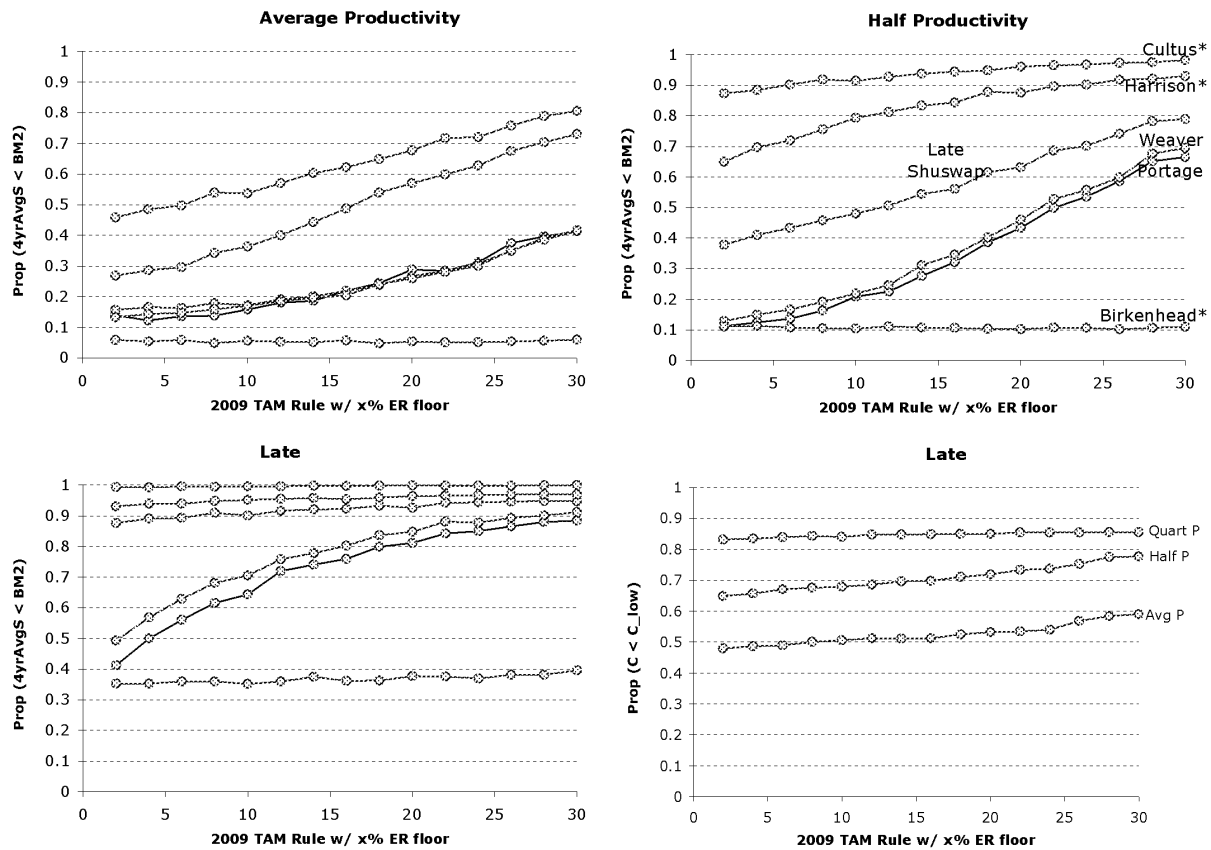


Figure 11: Probability of low escapement and low catch under 3 alternative assumptions about future productivity – LATE

5 TECHNICAL APPENDIX

5.1 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 year's earlier on recruitment from this year's 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).

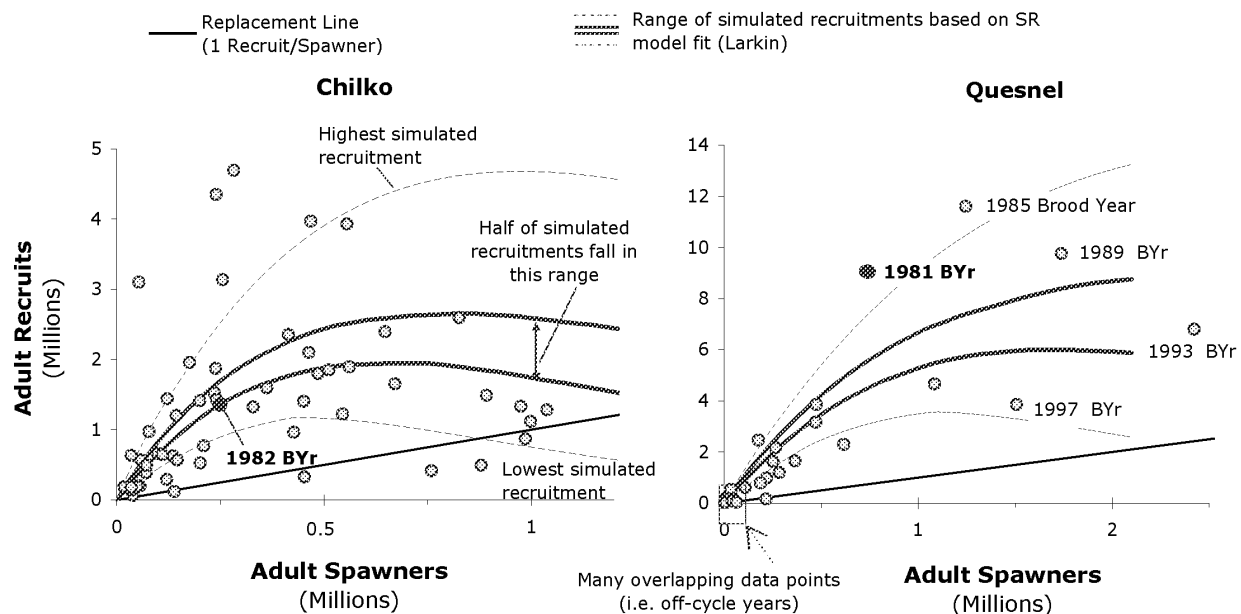


Figure A1: Relationship between spawning abundance and recruitment for 2 Fraser sockeye stocks.

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).

5.2 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 an 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. 12).

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.

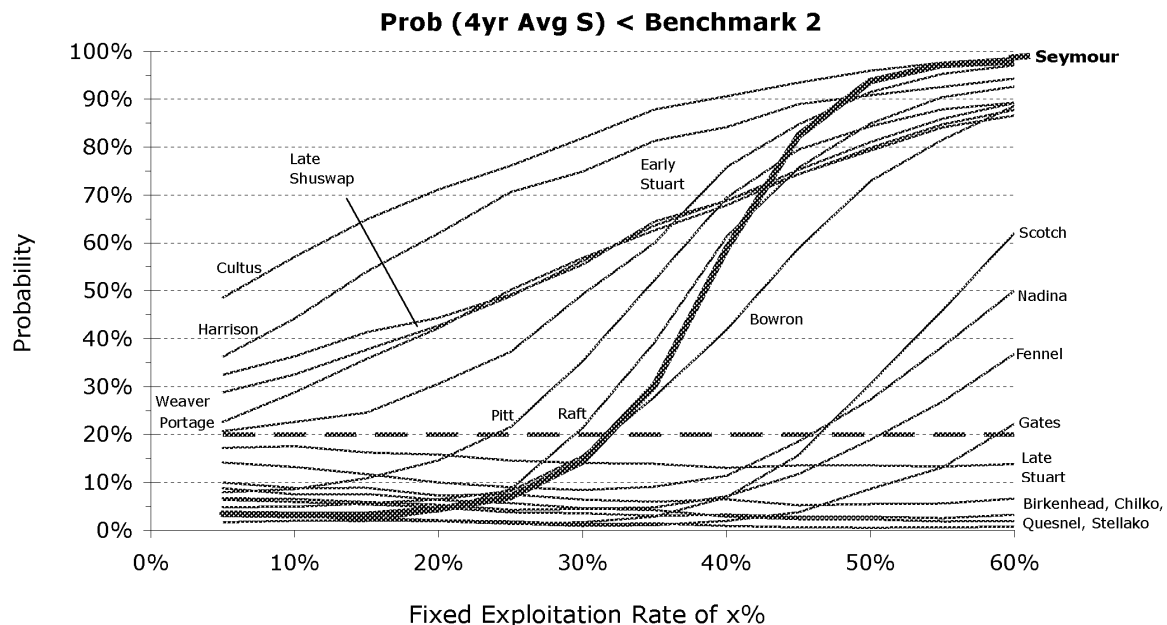


Figure A2: Applying a fixed exploitation rate to 19 stocks of Fraser sockeye.

5.3 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 its 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 no 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.

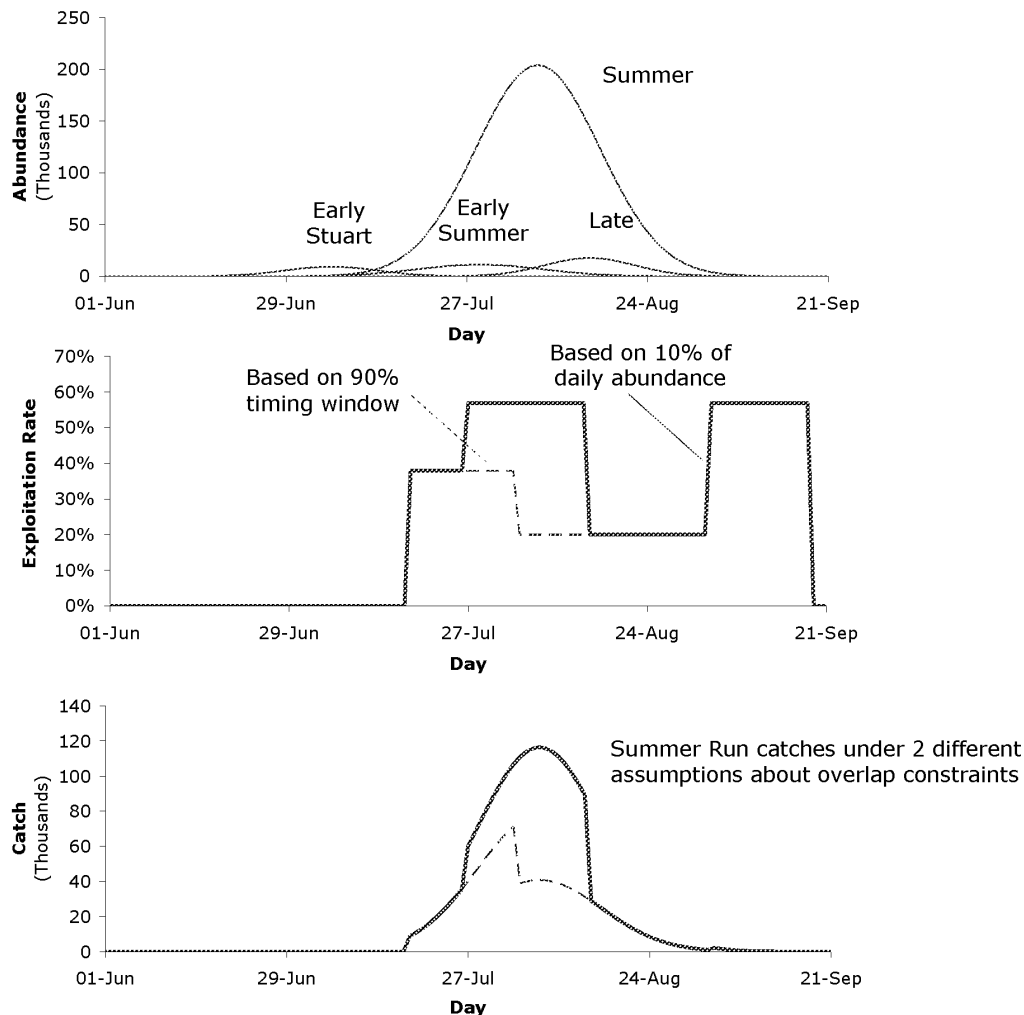


Figure A3: Two assumptions about harvest constraints due to overlap in run timing applied to 2009 expectations (75p)

	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.