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The 2017 Fraser Sockeye Salmon (*Oncorhynchus nerka*) Integrated Biological Status Re-Assessments Under the Wild Salmon Policy Using Standardized Metrics and Expert Judgment

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The first integrated biological status re-assessment under the Wild Salmon Policy (WSP) was completed for 24 Fraser Sockeye Conservation Units (CUs) in 2017. The first status assessment was conducted in 2012 (Grant et al. 2011; Grant & Pestal 2012), and this current status re-assessment adds five years of escapement data from 2011 to 2015 and recruitment data from the 2006 to 2010 brood years.

This re-assessment identified the following integrated statuses for Fraser Sockeye CUs:

- 7 Red
- 2 Red/Amber
- 5 Amber
- 6 Amber/Green
- 3 Green
- 1 data deficient

Eleven out of 24 CUs had the same status in the 2012 and 2017 assessments: five CUs remained in the Red status zone: Bowron-ES, Cultus-L, Takla-Trembleur-EStu, Taseko-ES, and Widgeon-(River-Type); two CUs each remained in the Red/Amber status zone: Quesnel-S & Takla-Trembleur-Stuart-S, the Amber status zone: North Barriere-ES and Kamloops-ES; and the Green status zone: Chilko-S/Chilko-ES aggregate and Harrison (River-Type).

Thirteen out of 24 CUs had different statuses between the 2012 and 2017 assessments. This demonstrates the need for re-assessments at least every five years. The status for six CUs declined to Red: Harrison (U/S)-L and Seton-L; or Amber: Shuswap-ES and Lillooet-Harrison-L; or Amber/Green: Harrison (D/S)-L and Shuswap-L. The status for seven CUs improved to Amber: Nahatlach-ES; Amber/Green: Nadina-Francois-ES, Chilliwack-ES, Francois-Fraser-S, and Anderson-Seton-ES; and Green: Pitt-ES. These differences emphasize that without regular re-assessments recovery actions cannot be appropriately prioritized.

In addition to providing status designations, narratives on the factors that contributed to these statuses are provided for each CU. The combination of CU statuses, data summaries, and narratives, are recommended as inputs into the WSP's Strategy 4 on Integrated Planning. As a package, this information can guide recovery actions among the Red to Amber CUs, and also guide management actions (fisheries, salmonid enhancement, and habitat) that affect all CUs.

This status re-assessment process demonstrated that re-assessments can be conducted on a smaller scale (<9 individuals in a 1 day plenary session) than first-time WSP status assessments (~30 individuals over a 3 day plenary session in the case of Fraser Sockeye).

Similar to past status assessments, the current assessment also concludes that no single algorithm for status integration can be developed, since CUs with the same status, will not always have the same factors that drive their status designations. Instead, expert-judgement applied consistently to assess WSP status is recommended.

The current process also had recommendations for particular metrics applied. The three-generation-trend metric, relied upon by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the International Union for Conservation of Nature (IUCN) for their status evaluations, was considered less applicable to Pacific Salmon in WSP integrated status processes. New relative-abundance benchmarks, derived from the Larkin model, were included in the status assessment process for cyclic Fraser Sockeye CUs. The six cyclic CUs include Shuswap-ES, Shuswap-L, Takla-Trembleur-Early Stuart, Takla-Trembleur-Stuart-S, and Quesnel, and Chilliwack-ES. When applied in this expert-driven context, Larkin-model benchmarks are recommended for future status assessment processes for cyclic CUs.

1 INTRODUCTION

Strategy 1 of the Wild Salmon Policy (WSP) is ‘Standardized Monitoring of Wild Salmon Status’. This strategy broadly describes the identification of the fundamental unit of salmon biodiversity, the Conservation Unit (CU), and also generally identifies standardized approaches for monitoring and assessing the status of CUs. More detailed work on operationalizing Strategy 1 was subsequently published in various DFO publications (Holtby & Ciruna 2007; Holt 2009, 2010; Holt et al. 2009; Grant and MacDonald 2013; Grant and Pestal 2012; DFO 2015, 2016a).

Three biological status zones were identified in the WSP ranging from poor to healthy status: Red, Amber, to Green status zones (Figure 1; Tables 2 & 3a). Although not prescriptive for management actions, CUs in the Red status zone are expected to trigger evaluations of recovery potential, appropriate recovery activities, and management considerations that emphasize ways to protect fish and minimize extirpation risk (Table 2).

The first set of CUs to be assessed for WSP status also identified blended statuses that include Red/Amber and Amber/Green in the first status assessment processes (Table 3b; Grant & Pestal 2012; DFO 2015; DFO 2016a). These blended statuses assist with prioritization of at risk CUs, ranking conservation risk from highest in the Red, followed by Red/Amber, Amber, Amber/Green and Green status zones (Table 3b).

The assessment of WSP biological status assessments uses a variety of indicators, and one or more metrics associated with each indicator (Figure 2). The suite of indicators and metrics applied will vary depending on the CU (Grant et al. 2011; Grant & Pestal 2012; DFO 2015; DFO 2016a). These details are provided for Fraser River Sockeye CUs in previous status assessment reports (Grant et al. 2011; Grant & Pestal 2012), and new methods are detailed in the current paper where applicable.

In addition to the application of a variety of metrics to assess WSP biological status, data on trends, distribution, data quality, level of enhancement, etc. have been consolidated in standardized data summaries for each group of CUs assessed (Grant & Pestal 2012; DFO 2015; DFO 2016a). The data summary content varies between broad species groups and particular CUs, depending on nuances of the CU time series. These data summaries have been foundational to the WSP biological status integration processes, which consolidates expert opinion to determine final integrated statuses for each CU.

First time WSP biological status assessments have been conducted in larger processes including up to 30+ participants, over one to three days (Grant & Pestal 2012; DFO 2015; DFO 2016a). These have all been conducted within a Canadian Science Advisory Secretariat (CSAS) peer review process to ensure methods are adequately reviewed and accepted. The first integrated status assessment for Pacific Salmon was conducted on Fraser Sockeye CUs in 2012 (Grant & Pestal 2012).

Although there is no DFO guidance on how often CU biological statuses should be re-assessed, past WSP biological status assessments (Grant & Pestal 2012; G. Brown, DFO, pers. comm.; C. Parken, DFO, pers. comm.) have recommended that re-assessments should occur if one or more of the following apply:

- after one salmon generation (four years for Fraser Sockeye);
- when salmon productivity and/or abundance changes significantly;
- when new methods not previously peer reviewed are developed to assess WSP status.

The current re-assessment of Fraser Sockeye CU status was initiated for three reasons:

1. It has been greater than a full four year sockeye cycle since the previous assessment; specifically five years of escapement data from 2011 to 2015, and recruitment data from the 2006 to 2010 brood years, were added to the 2018 assessments.
2. In the previous WSP status assessment, Fraser Sockeye CUs had been experiencing declines in productivity and abundance (Grant et al. 2010, 2011; Peterman and Dorner 2012). For the current assessment there was a notable general improvement in productivity and abundance exhibited by most Fraser Sockeye CUs (2011 to 2015).
3. New methods were developed to estimate relative abundance benchmarks for cyclic CUs using Larkin models, which represented a gap in the previous 2012 assessment (Grant & Pestal 2012). Cyclic CUs are CUs that exhibit large differences in abundance over a four year period, which may result from density-dependent interactions between cycle lines. Cyclic CUs have typically been modeled with Larkin models (Grant et al. 2010; Pestal et al. 2012; MacDonald and Grant 2012). However, the previous WSP status assessment for Fraser Sockeye did not analytically resolve the estimation of benchmarks using the Larkin model (Grant & Pestal 2012; DFO 2012). Therefore, the current assessment develops an approach to estimate Larkin-model derived relative-abundance benchmarks for each cycle line of a cyclic CU, and assesses the status of cyclic CUs with the addition of these benchmarks.

Stream-lined approaches are recommended to re-assess CU statuses. Since salmon assessment resources are limited, effort needs to be balanced between WSP status re-assessments and first-time assessments of the remaining ~460 Pacific salmon CUs. First-time status assessments require considerable work to organize data, determine appropriate metrics and benchmarks, and develop CU-specific data summaries. In contrast, re-assessments largely add data to already established time series' and data summary frameworks. In addition, given the relatively large number of participants in past processes, re-assessments can draw on this experience in a smaller group format, and use the previous narratives and statuses as a starting point for re-assessment.

The Fraser Sockeye status re-assessment process was, therefore, comprised of a smaller group of nine individuals that included DFO and non-DFO experts. In addition to the re-assessment process, a decision was made to conduct a larger CSAS review of the assessments, because a) this is the first WSP re-assessment conducted on Pacific salmon; and b) newly-developed Larkin model-derived relative-abundance benchmarks are used for cyclic CUs, and these have not been previously reviewed. In the future, barring additional changes to the methods, re-assessments can be conducted using a smaller process, and conclusions can be published directly, without a larger CSAS review.

The objectives of the Fraser Sockeye 2017 status integration re-assessment are to:

1. Present updated (2017) integrated statuses and associated narratives (descriptions of the factors that drove the CUs status designation) for the 24 Fraser Sockeye CUs.
2. Develop an approach to estimate Larkin-model derived relative-abundance benchmarks for each cycle line of cyclic CUs (Takla-Trembleur-EStu, Takla-Trembleur-Stuart-S, Quesnel-S, Shuswap-ES, Shuswap Complex-L). Assess and present the status of cyclic CUs both with and without the addition of these benchmarks.
3. Present background material used to develop integrated status and narratives, including the uncertainty in the data and results.
4. Provide recommendations for future status re-integration processes across all species.

2 BACKGROUND

The first Wild Salmon Policy (WSP) integrated status assessments were completed on Fraser River Sockeye salmon (Fraser Sockeye) conservation units (CUs) in 2012 (Grant & Pestal 2012; DFO 2013; 2012b). These status assessments included two separate Canadian Science Advisory Secretariat (CSAS) processes. The first CSAS process compiled the relevant information and data on Fraser Sockeye CUs, determined the relevant metrics for each CU, and evaluated each individual metric by comparing the current state of the CU to the metric's benchmarks (Grant et al. 2011). The second CSAS process integrated statuses across metrics and supplemental information, presented in standardized data summaries (Grant & Pestal 2012; DFO 2013; DFO 2012).

To achieve the integrated status, the first Fraser Sockeye status integration process synthesized salmon and Fraser Sockeye expert interpretation of the data summaries over a three day workshop (Grant & Pestal 2012; DFO 2013).Through a combination of group work and plenary sessions, the 34 participants at the workshop developed integrated statuses for the 24 Fraser Sockeye CUs. In 2012, this process designated the following statuses: 7 Red, 4 Red/Amber, 4 Amber, 2 Amber/Green, and 5 Green status, as well as one CU with an undetermined status, and one CU identified as data deficient. A few CU statuses were flagged as provisional, since productivity trends were declining and their status could deteriorate in the near-future. It was recommended that provisional CUs statuses be reviewed annually.

Participants from the workshop concluded that, in addition to the integrated statuses, the narratives that accompany those statuses are a key element of the status integration process. These narratives describe participant input on what elements of the data summaries drove their interpretation of CU statuses. The Fraser Sockeye status integration process concluded that both the status of a CU, and the narrative describing the rationale underlying the status, are required inputs for WSP Strategy 4: Integrated Strategic Planning, which includes management (fisheries, salmonid enhancement and habitat) action considerations. Integrated statuses and narratives have subsequently been developed for Southern British Columbia Chinook (G. Brown, DFO, pers. comm.; DFO 2016a) and interior Fraser Coho (C. Parken, DFO, pers. comm.; DFO 2015), through similar integration processes.

Background on the Fraser Sockeye CUs (Grant et al. 2011), data and status metrics and benchmarks used (Grant et al. 2011; Grant & Pestal 2012), and data summaries and the status integration approach (Grant & Pestal 2012) are available in previous publications.

3 METHODS

Details on methods are provided in publications from the previous status assessment (Grant et al. 2011; Grant & Pestal 2012). Cases where changes were made to past methods are described in subsequent sections below.

3.1 DATA SUMMARIES

3.1.1 General Updates Across all CUs

Five years of escapement data from 2011 to 2015, and recruitment data from the 2006 to 2010 brood years, have been added to each Fraser Sockeye CU time series since the last integrated WSP status assessment (Grant & Pestal 2012). For all Fraser Sockeye CUs, this represents slightly greater than one generation (four years) of data.

Specifically, spawner data, in the form of effective female spawner abundance to use with trend metrics (total spawners for Cultus), and effective total spawner abundances for the relative-abundance metric (total spawners for Cultus), were updated to include 2011 to 2015. Effective total spawners include female plus male escapement estimates, multiplied by spawner success, which is calculated as the proportion of eggs (0%, 50%, or 100%) successfully spawned, based on spawning ground carcass surveys. Further details on the data used are presented in Grant et al. (2011) in the CU specific sections, and also in Appendix 1 of Grant et al. (2011) regarding the specific escapement sites used to evaluate trends in abundance.

Recruitment data were updated to include recruits from the 2006 to 2010 brood years; these data were provided by the Pacific Salmon Commission (PSC). Additional details on the quality of the escapement and recruitment data are presented in Ogden et al. (2015), and details for Chilko_ES in particular are presented in Akenhead et al. (2016). Escapement and recruitment data include adults only, jacks have been excluded. Identical to the previous assessment, recruitment data include 4_2 (Gilbert-Rich ageing convention) and 5_2 recruits; Harrison is unique and includes 3_1 and 4_1 recruits.

3.1.2 Specific Updates for Particular CUs

The following CU-specific changes were made to the data:

Anderson-Seton-ES: Minor updates to the recruits, provided by the PSC.

Cultus_L: In the previous Cultus status assessment, effective total spawners (ETS) were used in trend assessments. In the current report, only total spawners were used, information on female spawner success was removed from the analysis. Effective spawners are calculated as the number of spawners multiplied by female spawner success, which is the proportion of eggs (0%, 50%, or 100%) successfully spawned, based on spawning ground carcass surveys. For Cultus, there are many gaps in the spawner success time series. Further, since there have been few carcasses on the spawning grounds in recent years, given the low escapements, sample sizes of female carcasses are limited. Samples of carcasses may also be biased towards unsuccessful spawners, since fish in poor condition are often found in shallow waters near creek mouths, which are accessible to carcass surveys, while those that spawn successfully die at depth, and are inaccessible to carcass surveys. Minor updates were also made to the Cultus recruit data by the PSC

Lillooet-Harrison-L: Minor updates were made to the recruit data by the PSC.

Pitt_ES: DFO's Salmonid Enhancement Program (SEP) went through a rigorous validation process of the hatchery component of the spawner time series, and updated this. For this assessment we also decided to remove hatchery origin fish (identified by their adipose fin clip) from the spawner data, since these fish do not naturally spawn. In the past assessment we included hatchery origin fish in the spawner estimates.

Seton-L: Minor change to the recruits (specifically 1973) performed by the PSC.

Shuswap-ES: Effective total abundances, used for the relative-abundance benchmark and productivity trends, were limited to only the Seymour and McNomee populations, given the long length of these time series' (67 years) relative to the excluded population, Scotch (35 years).

Shuswap-L: Recruits were updated for a few years in the early time series by the PSC.

3.2 RICKER MODEL

3.2.1 Overview of Abundance-Based Benchmarks for Non-Cyclic CUs

Abundance-based benchmarks for non-cyclic CUs with stock-recruitment data are estimated using a Ricker model, fit to effective total spawners (total spawners for Cultus) and recruitment data. There are 13 non-cyclic CUs with stock-recruitment data: Bowron-ES, Cultus-L, Harrison (U/S)-L, Seton-L, North Barriere-ES, Kamloops-ES, Lillooet-Harrison-L, Nadina-Francois-ES, Francois-Fraser-S, Anderson-Seton-ES, Pitt-ES, Chilko-S/Chilko-ES, and Harrison River-Type.

Non-stationary models, which allow productivity to change over time, are not included in the current assessment. Recent work indicates that these models are poorly suited to the quality and abundance of data available for most salmon status assessments, leading to unstable and highly uncertain benchmark estimates (Carrie Holt, DFO, pers. comm.). When WSP benchmarks were applied in 2011, there was a great deal of concern over a large observed change in productivity that had occurred over the most recent years. Therefore, a focus of the previous analysis was to compare stationary with non-stationary models in the status assessments. This included applying Ricker models to data from only the recent time series, i.e. only data perceived to occur within the same productivity “regime” (truncated models). In recent years, as many populations have shifted from poor to more variable productivity, these types of models have become of less interest – especially since new analyses have uncovered the limitations of these models (C. Holt, DFO, pers. comm.).

3.2.2 Ricker Model Analytical Approach

Ricker Model Formulation

For each non-cyclic CU with stock-recruitment data, unique, paired lower and upper benchmarks are estimated using Bayesian methods, and are presented from the 10% to 90% probability levels (Appendix 2). These benchmarks are used to delineate the Red/Amber and Amber/Green WSP status zones (Figure 1), and are compared to the current four year (2012-2015) geometric average escapement (Grant et al. 2011).

For each year with sufficient data, a standard Ricker model (Eqn. 1) is fit in a Bayesian context, using Markov Chain Monte Carlo (MCMC) methods.

(1) $R_t = \alpha S_t e^{-\beta s_t}$,

Where S_t is the number of spawners (effective total spawners) in brood year t, and R_t is the number of adult offspring from these spawners (recruits). The parameter α (productivity) represents recruits-per-spawner at low spawner abundances, and β is the reciprocal of the number of spawners that produce maximum recruits (S_{Max}).

The Ricker equation was linearized and incorporated normally distributed process error, where τ_v represents precision of process error and is the reciprocal of variance.

(2) $\log(R_t) = \log(\alpha) + \log(S_t) - \beta S_t + \nu,\ \nu \sim normal(0,\ 1/\tau_\nu)$.

Parameters were estimated using a Bayesian approach with 500,000 MC iterations (200,000 burn-in, 300 thinning) in R interfaced with JAGS (Just Another Gibbs Sampler).

Ricker Model Alpha and Beta Priors

A weakly informative prior was used for α to ensure values greater than zero and within the bounds of generally observed productivity values for Chum Salmon (Dorner et al. 2008)

(3) $\log(\alpha) \sim normal(1,1)$.

The prior for the β parameter is applied indirectly by applying a prior on its reciprocal (S_{max}). In some cases, independently-derived estimates of Spawner capacity (S_{PR}) were available based on photosynthetic rate (PR) models and information on juvenile sockeye competitors in the lake (Grant et al. 2011). These estimates were then used as the mean of an informative lognormal prior on S_{max} (Eqn 4a). As a sensitivity analysis, uninformative priors were also applied for all non-cyclic CUs. Non-informative priors were very diffuse (CV=5) and with a mean set to the average observed number of spawners in the stock-recruit time-series (Eqn. 4b).

(4) $S_{max} \sim lognormal(\mu_S,\, \tau_S),\;\; \tau_S = 1/\log(CV^2 + 1)$

a. Informative: $\mu_S = S_{PR},\;\; CV = 0.3$
b. Uninformative: $\mu_S = mean(S_{obs}),\;\; CV = 5$

Informative β parameter priors were obtained through independent assessments of photosynthetic rate (PR) and juvenile competitors in the corresponding rearing lakes (Table 12; Grant et al. 2011). The PR models provide information on the carrying capacity of the lake-rearing environment for juvenile sockeye. Identical PR model data was used between the past (Grant et al. 2011; Grant & Pestal 2012) and current assessment. Although updated raw PR model data were available for some lakes in more recent years, such as Chilko Lake, analyses to estimate S_{max} had not been conducted at the time of this publication (D. Selbie, DFO, pers. comm.). Therefore, S_{max} estimates applied are out of date by at least a decade.

The current assessment tested more rigorously the applicability of the PR model capacity parameters for each CU (Appendix 7). Specifically, S_{max} estimates of lake-rearing capacity were compared to expert (P. Welch, DFO, pers. comm.) estimates of spawning habitat capacity, to determine if lake-rearing capacity represents a bottleneck in productivity. If spawning habitat appeared to limit capacity well before lake-rearing habitat (i.e. spawning habitat S_{max} is much lower than lake-rearing S_{max}), then the lake-rearing S_{max} was not considered appropriate. To further support these considerations, we compared the influence of the lake-rearing S_{max} prior on the posterior of S_{max}, and the resulting benchmarks. Priors that had a large effect on the posteriors were considered inappropriate (Table 12, Appendix 7). For CUs where the PR model capacity is unrealistically high, only the uninformative prior is used to estimate Ricker model relative-abundance benchmarks. In cases where the PR model capacity seemed reasonable, both informative and uninformative priors are used for comparison and are both presented in the data summaries (Table 12; Appendix 7).

Uninformative gamma priors were used for τ parameters,

(5) $\tau_v, \tau_S, \sim gamma(0.001, 0.001)$

For Ricker-based benchmarks, the lower benchmark, S_{gen}, was calculated numerically, according to the following equation (Holt et al. 2009),

(6) $S_{MSY} = S_{gen}\; \alpha\; e^{-\beta S_{gen}}$.

The upper benchmark was calculated using an approximation developed by Hilborn and Walters (1992),

(7) $0.8\, S_{MSY} = \; 0.8 \frac{\log(\alpha)}{\beta}(0.5 - 0.07\log(\alpha))$.

3.3 LARKIN MODEL

3.3.1 Abundance-Based Benchmarks for Cyclic CUs Overview

Cyclic CUs are those that exhibit persistent one large and three smaller abundance years over a four year period, which represents a single cycle of predominantly four year old Fraser Sockeye.

Status assessments for cyclic CUs published in Grant & Pestal (2012) did not consider relative-abundance benchmarks, but instead relied on short- and long-term trends, and other information presented in the data summaries. While Grant et al. (2011) presented relative-abundance benchmarks for cyclic CUs, these were not used to inform integrated status, because the methods used were only able to identify a single benchmark across all four cycle lines for each CU. This requires equal abundances across cycle lines, which negates the purpose of estimating specific benchmarks for cyclic CUs. The absence of reliable relative-abundance benchmarks for cyclic CUs increased the uncertainty of these statuses, and was recognized as a weakness in the Fraser Sockeye status assessment, particularly because cyclic stocks provide most of the production of sockeye salmon in the Fraser River. Further work to develop these benchmarks was recommended (Grant & Pestal 2012).

In the current status assessment presented in this paper, relative-abundance benchmarks are developed for cyclic CUs to inform the current integrated status assessments. The approach used here differs from that considered by Grant et al. (2011) in that annual estimates of benchmarks are derived, using observed abundances in preceding years. This approach was selected because the benchmarks met several desirable properties identified for relative-abundance-based benchmarks for cyclic CUs. This includes the following:

- they are consistent, to the extent possible, with benchmarks derived from non-cyclic CUs under the WSP
- they account for density-dependent interactions among cycle lines, which are thought to drive cyclic dynamics, for at least some CUs
- they provide a measure of uncertainty
- they can be estimated consistently over time
- they are relatively stable over time

Alternative approaches for identifying relative-abundance benchmarks for cyclic CUs were considered, but these were dismissed because they ignored cycle-line interactions (relying solely on habitat capacity, the COSEWIC small population criterion, or cycle-line specific Ricker parameters), were confounded by dominance trends that changed over time (relying on multi-dimensional optimization across cycle lines, (DFO 2006), or required information on fisheries management objectives, which falls outside the scope of WSP biological benchmarks (e.g., the approach of the Alaska Department of Fish and Game to estimate fishery reference points to optimize biological and conservation objectives for Kenai River sockeye salmon, Clark et al. (2007).

Cyclic dynamics are likely driven by a combination of stochastic environmental events and biological variables (White et al. 2014; Schmitt et al. 2016), explaining why cyclic patterns change over time. Stock-specific random fluctuations may change a population from non-cyclic to cyclic dynamics, while a similar population may remain non-cyclic due to other biological factors. In particular, Schmitt et al. (2016) suggest that cyclic patterns can be explained by stochastic models that include growth and predator-prey dynamics, specifically in nursery lakes. For Fraser River Sockeye CUs, a combination of stochastic and biological factors likely drive cyclic dynamics, and these factors likely differ among CUs, and over time. Although there are published empirical studies of mechanisms influencing cyclic population dynamics in other lake ecosystems (Kyle et al. 1988; Kyle 1996), work on biological drivers within Fraser Sockeye rearing lakes is on-going (D. Selbie, DFO, pers. comm.), and has been aided by hypotheses such as those presented by (DFO 2006) for Quesnel and Shuswap Lakes (D. Selbie, DFO, pers. comm.). Given the importance of stochastic events in creating and maintaining cyclic dominance, frequent evaluations of whether or not CUs are cyclic are warranted. Further, simulation could be used to assess the implications of applying annual Larkin benchmarks to CUs that are not cyclic, or, alternatively, applying Ricker benchmarks to CUs that are cyclic.

3.3.2 Larkin-Model Analytical Approach

The following 4 steps were used to derive benchmarks and assess status against those benchmarks.

Larkin Stock-Recruitment Models

For each CU, we estimated stock-recruit parameters for the Ricker model and seven formulations of the Larkin model: the full model (Eqn. 2) and 6 reduced forms with one or two the last three terms missing: three forms with only β_1, β_2, or β_3, (i.e., other 2 β parameters=0), and three forms with β_1 and β_2 (β_3=0), β_2 and β_3 (β_1=0), β_1 and β_3 (β_2=0).

(8) $\log\left(\frac{R_t}{S_t}\right) = \alpha - \beta_0 S_t - \beta_1 S_{t-1} - \beta_2 S_{t-2} - \beta_3 S_{t-3}$

The Larkin model reduces to the Ricker model when β_1= β_2= β_3=0. Parameters were estimated using a Bayesian approach with 60,000 MC iterations (5,000 burn-in, 100 thinning) in R interfaced with OpenBugs, using diffuse priors specified by Pestal et al. (2012). In particular,

(9) Prior(α) ~Normal (μ=0,τ=0.001) , where $\tau = \frac{1}{\sigma^2}$

(10) Prior(S_{max})~Lognormal(μ =log$_e$(max(observed S)), τ= 1), with an upper bound on S_{max} at 3×max(observed S), where S_{max}= (1/β_0)

(11) Prior(β_1, β_2, β_3)~uniform(0,100)

Model Selection

Models were selected according to Deviance Information Criterion, DIC (Spiegelhalter et al. 2002) using the approach described by Pestal et al. (2012). Briefly, models within 5 DIC units of the best-fit model (lowest DIC) were deemed equally parsimonious. When the Ricker model was within 5 DIC units of the best fit model, the CU was identified as non-cyclic (Pestal et al. 2012). All other CUs were identified as cyclic, being better explained by a form of the Larkin model. Where cyclic patterns were identified by model selection, but those patterns have dissipated recently based visual inspection of the spawner time-series, CUs were identified as non-cyclic (e.g., Anderson-Seton-ES, Chilko-S, and Francois-Fraser-S).

Annual Larkin Benchmark Estimation

To estimate annual Larkin-based benchmarks, S_{gen} and 80% of S_{MSY} were estimated for a given year but were not optimal globally because benchmark estimates depend on the series of spawner abundances in the last 3 years (t-1, t-2, t-3).. The Larkin model (Eqn. 1) collapses to the Ricker model when S_{t-1}, S_{t-2} and S_{t-3} are known and combined with the α term (see Eqn 5 below), and benchmarks can then be estimated using standard approaches (Holt et al. 2009). Analytically, the extra lag terms become a constant, which is added to the α term to produce an adjusted α' term (called a “reduced Larkin model” here):

(Eqn 5) $\log\left(\frac{R_t}{S_t}\right) = \alpha' - \beta_0 S_t$, where $\alpha' = \alpha - \beta_1 S_{t-1} - \beta_2 S_{t-2} - \beta_3 S_{t-3}$

The resulting annual variability in benchmarks is due to variability in α'(adjusted productivity) from variability in S_{t-1}, S_{t-2}, and S_{t-3} with fixed α, β_0, β_1, β_2, and β_3. Large negative deviations in α' occurs when S_{t-1}, S_{t-2}, and/or S_{t-3} are large. In these years, the model predicts low production because of strong density dependence. In contrast, α' is relatively high when S_{t-1}, S_{t-2}, and S_{t-3} are low (i.e., in a dominant year when density-dependence from other years is weak).We also compared Larkin benchmarks to those estimated using a Ricker stock-recruitment model for cyclic CUs.

3.3.3 Annual Status Assessments

The annual benchmarks capture cyclic dominance patterns, but also capture additional interannual variability in abundances ($S_{t\text{-}1}$, $S_{t\text{-}2}$, $S_{t\text{-}3}$) that may be independent of the underlying stock-recruitment relationship. To smooth out variability in annual benchmarks due to annual changes in $S_{t\text{-}1}$, $S_{t\text{-}2}$, or $S_{t\text{-}3}$, the cycle-line specific medians were calculated over the entire time-series for that cycle. Therefore, these benchmarks capture the median impact of $S_{t\text{-}1}$, $S_{t\text{-}2}$, or $S_{t\text{-}3}$, on recruitment, not the specific values that occurred in a given generation.

Statuses for each year in the most recent generation were calculated by comparing total spawner abundances in that year to the lower and upper annual Larkin benchmarks for that cycle line, for 5 percentiles in the distributions of S_{gen} and 80% of S_{MSY} (10th, 25th, 50th, 75th, and 90th) as applied to Ricker-based benchmarks for non-cyclic CUs.

In sensitivity analyses, we also assessed status against benchmarks calculated using only the most recent generation (and most recent in $S_{t\text{-}1}$, $S_{t\text{-}2}$, or $S_{t\text{-}3}$). For some cycle lines, status cannot be assessed using benchmarks calculated from the most recent generation because large in $S_{t\text{-}1}$, $S_{t\text{-}2}$, or $S_{t\text{-}3}$ values resulted in negative α' estimates. However, these gaps were inconsequential when calculating the median over multiple generations.

3.4 DATA SUMMARY UPDATES

Although the status re-assessment process can be stream-lined, there remains work required to prepare background materials for the re-assessments. This primarily involves updating the escapement and recruitment data. To facilitate this work for Fraser Sockeye, some steps have been automated, including gap filling escapement data for trend metrics, and estimating short-term and long-term trends. However, since Fraser Sockeye was the first group of CUs to undergo WSP assessment, the preparation of data summaries has not been automated, as it has been for Southern BC Chinook and Interior Fraser Coho. Currently the data summaries are produced in excel. It is recommended that data summaries be similarly automated in R statistical software to facilitate the status re-assessment process. However, a number of new diagnostic packages that were produced for the current status re-assessment process, have been automated, these include Ricker model diagnostics (Appendix 7), and the suite of cyclic CU and Larkin model diagnostics (Figure 4; Appendices 8-10).

3.5 PREPARATION OF DRAFT NARRATIVES

Using the data summaries (Appendix 2), supporting material (Appendices 3-12), and the previous Fraser Sockeye status integration narratives (see Appendix 2 in Grant & Pestal 2012), a first draft of the 2017 narratives was developed to support the individual and plenary status assessments. For some CUs, metrics and supporting material were largely identical to the previous assessment, therefore narratives and statuses from the previous assessment were replicated. These included Taseko-ES, Cultus-L, Bowron-ES, Chilko-S, Chilko-ES, North Barriere-ES, Harrison River-Type, and Kamloops-ES, and Takla-Trembleur-EStu.

Where metrics varied between the previous and current assessment, narratives were updated using the broad approach developed in the previous process (as described in Grant & Pestal 2012). These draft narratives provided the individual assessors with a foundation to conduct their own status assessments.

3.6 RE-ASSESSMENT APPROACH

A modified version of past assessments was adopted for the 2017 re-assessment. This involved a small group of individuals conducting status assessments on their own, followed by group meetings to merge narratives and statuses between individuals.

3.6.1 Individual Assessments

Nine individuals (DFO and non-DFO) participated in the initial status re-assessment process for Fraser Sockeye CUs. Individuals were selected based on their past experience in one or more of the three previous integrated status processes (Fraser Sockeye, Southern BC Chinook, or interior Fraser Coho) and their expertise in Fraser Sockeye or Pacific salmon biology and/or stock assessment. Participants included three Fraser Sockeye analytical biologists, one Fraser Sockeye operational biologist (with expertise on escapement enumeration for these CUs, and adult spawner and smolt migration), three Regional Pacific Salmon Scientists with expertise in quantitative stock assessment and freshwater ecology/biology, one fisheries management biologist, and one external participant with broad expertise in salmon and Fraser Sockeye quantitative stock assessment and fisheries management.

These assessments were not conducted 'blind', as they were in the first status assessment of Fraser Sockeye; participants were provided the names of the CUs in the data summaries. Three key reasons were identified in the first status integration process as grounds for conducting blind assessments (Grant & Pestal 2012):

1. Since assessments are meant to be standardized between CUs, larger processes (34 individuals in the case of Fraser Sockeye) required that participants focus on the information presented in data summaries to develop a systematic approach to designating integrated statuses and developing narratives.
2. 'Blind' assessments avoided side-tracks where individuals might have tapped into their detailed biological knowledge of a CU.
3. A 'blind' process avoids bias where individuals might designate a CU a better or poorer status (consciously or subconsciously) to potentially affect fisheries or other outcomes (Grant & Pestal 2012).

These reasons, however, are particularly relevant to larger groups with mixed salmon expertise and limited to no experience in status integration. Since re-assessment processes will generally require fewer participants, drawn from a small group of Pacific salmon CU-specialists with previous status integration experience, non-'blind' assessments were applied. Individuals were told to designate each CU as falling into one of five status zones (Red, Red/Amber, Amber, Amber/Green, and Green). This differs from the previous assessment, in that only three status zones were initially identified for designation (Red, Amber or Green), and blended (Red/Amber or Amber/Green) statuses were designated during plenary sessions when groups diverged and consensus on a single status zone could not be reached.

Prior to the individual assessments, participants were walked through the standard information packages during a two hour training session. This involved walking through the following:

- the data summary guide (Appendix 1);
- the 2017 data summaries for the 24 CUs (Appendix 2);
- the CU status assessment groups and order (Appendix 3);
- the guide for the stock-recruitment models used in 2017 compared to the previous assessment (Appendix 4);

- the questionnaires to be filled in by participants for the non-cyclic (Appendix 5) and cyclic CUs (Appendix 6);
- diagnostic plots: Ricker model fit to stock-recruitment data (Appendix 7);
- a number of appendices specific to the relative-abundance benchmarks for cyclic CUs estimated using the Larkin model approach:
    - diagnostic plots: Larkin model fit to stock-recruitment data (Appendix 8);
    - time series of Larkin α' parameters (Appendix 9);
    - matrices of status assessments against median benchmarks over the times-series for specific cycle lines, and alternative benchmarks derived from only the most recent generational values (Appendix 10)
    - benchmarks for the base case and sensitivity analyses (Appendix 11);
- plots for trends in cycle line plots for cyclic CUs (Appendix 12);

After the initial meeting, the participants were provided the opportunity to work with leads (S.C.H. Grant or G. Pestal) to develop their individual assessments. Individuals provided their assessments prior to an in-person plenary session. This included their individual status assessments, where each CU was designated Red, Red/Amber, Amber, Amber/Green, Green status, data deficient, or undetermined, and also their narratives, which describe the rationale for their choices.

The 24 CUs were placed into one of five groups (Appendix 3), designated with an increasing level of difficulty in the status assessments between groups:

- The first three groups were non-cyclic CUs.
    - Group (#1) included easy, non-cyclic CUs. These CUs had statuses and supporting information that were identical to the previous assessment (Grant & Pestal 2012), or statuses and supporting information that were identical across all metrics. This first group was designed to help individuals get started, and re-orient themselves to the process.
    - Group (#2) included non-cyclic CUs that required a bit more discussion, given differences in the statuses across metrics and supporting information, and differences from the previous assessment.
    - Group (#3) included a single CU that was potentially the most challenging to assess since status across metrics fell into each of the three major status zones from Red to Green.
- The final two groups were cyclic CUs. These CUs were assessed last since there were unique and more complex considerations were required.
    - Group (#4) was the first group of cyclic CUs, which were generally considered the easiest of these CUs, given that statuses were generally consistent across metrics.
    - Group (#5) were considered more challenging given differences in status designations across metrics.

Preparing the assessments took individuals up to one day to complete on their own (Appendices 5 & 6). For each CU, participants provided their status designation and identified the main drivers of the status, as well as other considerations and comments regarding their designations. Note that due to time constraints, eight individuals assessed Group 1, nine individuals assessed Groups 2 & 3, and seven individuals assessed Groups 4 & 5 (Appendix 3).

The initial statuses identified by the participants were recorded and the narrative draft was updated with the commentaries provided (Appendix 2).

3.6.2 Plenary Assessments

Two plenary sessions were conducted: one half-day in-person session and one half-day teleconference session. The first session involved nine participants and one recorder/time keeper (B.L. MacDonald). One of the nine participants (S.C.H. Grant) also chaired both plenary sessions. Although originally only a single plenary session was anticipated, a second session was scheduled to address changes to the Larkin model benchmarks and statuses that occurred immediately prior to the first plenary session. Participants felt there had not been sufficient time to review the Larkin benchmarks and statuses during the first session. The second session involved seven of the previous nine participants.

In the plenary sessions, only CUs where integrated statuses differed between the participants were discussed. Prior to the plenary, narratives were updated with all feedback from the individual participants, (Appendix 5 & 6) and individual statuses were documented (Appendix 2). To facilitate the start of each CU discussion, individual statuses were presented, and narratives were summarized. With this background, the group stepped through CU narratives that differed between participants, explained and discussed these differences, and agreed on an integrated status. If all nine participants agreed on a status designation for a CU, this was labelled a 'consensus'. If most participants agreed (>5 out of 9 or >4 out of 7), this was a labelled a 'majority view'. After discussing each CU, participants were asked whether they wanted to revise their original status designation, or retain their original. This was documented and reported in individual CU narratives (Appendix 2).

In the first plenary process non-cyclic CUs were assessed first, followed by the cyclic CUs, although these were assessed in the absence of Larkin benchmarks. In the second plenary session, the group reviewed the Larkin model approach for cyclic CU benchmarks, and then assessed the status of these CUs with the Larkin benchmarks. Cyclic CUs were, therefore, assessed both with and without Larkin benchmarks, for review in the broader CSAS process.

4 RESULTS

4.1 RICKER-BASED BENCHMARKS

4.1.1 Lake-Type CUs

Ricker model benchmarks were estimated for the 11 lake-type CUs with stock-recruitment data. Uninformative priors were used for the Ricker model α and β parameters (Appendices 2 & 7). Informative priors were also evaluated for the β parameters of 10 CUs with PR model derived estimates of lake-rearing capacity (S_{max}) (Table 11; Appendix 7). Since lake-rearing capacity may not be the limiting freshwater habitat in terms of CU production, posterior estimates were compared between those estimated with informative β priors and those with uninformative priors (Appendix 7). In cases where informative priors drove the posterior probability distribution, estimates were excluded from the data summaries (Appendix 2). Additional information from DFO's Fraser Sockeye operational stock assessment program (P. Welch) also confirmed that these S_{max} estimates were misleadingly high given the spawning ground capacity of these systems. Informative priors on the β parameter were considered appropriate for three CUs (Bowron-ES, Chilko-S/Chilko-ES, and Pitt-ES), and were used to estimate upper and lower benchmarks included in the data summaries, (Table 10; Appendix 2). PR model estimates of S_{max} for these three CUs are out of date by a decade and should be updated with recent data where available. Chilko-S/Chilko-ES, in particular, has experienced an increase in primary productivity in recent years (DFO 2016b); which could influence estimated benchmarks. Exploration of informative priors representing spawning ground capacity would be helpful in cases where this is the limiting habitat for production.

4.1.2 River-Type CUs

The only river-type CU that has stock-recruitment data that can be used to develop relative-abundance benchmarks using the Ricker model is the Harrison (River-Type) CU. This CU has exhibited a large shift in production since the 2000 brood year (Grant et al. 2010; Peterman and Dorner 2012). Prior to the 2000 brood year, Harrison sockeye escapements averaged 6,500 effective female spawners (EFS), while survival averaged 15 recruits/EFS. In recent years (post-2000), escapements have averaged 100,000 EFS, and survival has increased substantially to 26 R/EFS (Grant et al. 2010; DFO 2016b).

Since the Harrison CU is now in what appears to be a new production regime, a sensitivity analyses was conducted to assess relative-abundance benchmarks across several truncations of the stock-recruitment time series (Appendices 2 & 7). Benchmarks were estimated using four different time series subsets: full time series (1948-2010), truncated time series (1990-2010) to account for recent shifts in productivity, full time series excluding the 2005 brood year, and recent time series (1990-2010) excluding the 2005 brood year. The 2005 brood year was associated with exceptionally poor survival across CUs, suggesting that the cause of this broad response was a density-independent mechanism such as unusual environmental conditions. Since this brood year had a large escapement for the Harrison River-Type CU, the addition of this data significantly alters the shape of the Ricker model, suggesting strong density-dependence at high escapements, which may be misleading. Therefore, benchmarks were also explored without this year.

Lower benchmarks, which are particularly sensitive to changes in productivity, were lower in the more recent (post-1990 brood year) productivity period than across all data. The exclusion of the 2005 brood year increased the lower benchmarks for both time periods. In contrast, the upper benchmark was higher with only the more recent data, excluding the 2005 brood year. Statuses across the sets of benchmarks ranged from Green to Amber. Overall, given the large shift in production for this CU, relative-abundance benchmarks and statuses for this CU are particularly uncertain.

4.2 LARKIN-BASED BENCHMARKS

4.2.1 Larkin Model Fits and Model Selection

Parameter values are provided in Appendix 11. Based on DIC and expert opinion, the following CUs were identified as cyclic: Takla-Trembleur-EStu, Takla-Trembleur-Stuart-S, Quesnel, Shuswap-ES, and Shuswap-S. For these cyclic CUs, the full Larkin model was the best-fit model (Quesnel, Shuwsap-L, Shuswap-ES) or within 5 DIC units of the best-fit model (Takla-Trembleur-EStu and Stuart-S). The Ricker model was > 5 DIC units from the best-fit model for all cyclic CUs. For Takla-Trembleur-EStu and Stuart-S, the best-fit models were the Larkin model with β_1 and β_2 terms. However, the differences in benchmarks were minimal between the reduced and full versions (<=5% over the time-series), and benchmarks were more stable over time for the full compared with reduced Larkin models, so the full Larkin model was used for further analyses. Chilliwack-ES was further identified as cyclic based on expert opinion alone as time-series of recruitment were not of sufficient length to estimate Larkin-derived relative-abundance benchmarks.

4.2.2 Benchmark Estimation

In the retrospective analysis, annual estimates of the Larkin-derived relative-abundance S_{gen} and 80% of S_{MSY} were relatively stable over cycle lines and generations for some CUs (e.g., Takla-Trembleur-Stuart-S), but more variable for others (e.g., Quesnel-S) (Figure 4). In particular, when the magnitude of cyclic dominance increased or decreased over time, benchmarks tended to become more variable. Annual stock-recruitment curves for the condensed Larkin model (Eqn. 5) are provided in Appendix 8. Ricker-based benchmarks were within the range of annual variability in Larkin benchmarks for all cyclic CUs except Shuswap-L. For this CU, strong density dependence resulted in relatively low α' and S_{eq} values for the Larkin model and relatively low Larkin benchmarks compared with Ricker-based benchmarks.

Uncertainties in Larkin-derived relative-abundance benchmarks were large, and 95% confidence intervals for the upper and lower benchmarks often overlapped. For some years within a CU time series, the lower benchmark, S_{gen} was higher than the upper benchmark, 80% of S_{MSY}. In these years, the adjusted productivity, α', was low due to relatively strong density-dependence. To achieve recovery to S_{MSY} within one generation (the definition of S_{gen}), the resulting S_{gen} fell at a higher level of spawner abundance than 80% of S_{MSY}. Note, this rank reversal of lower and upper benchmarks occurs for the Ricker model as well when productivity is low, and WSP stock-recruitment based benchmarks are not recommended in these situations (Holt and Ogden 2013). Further, in years when density-dependence was extremely strong, α' was negative (Appendix 9, Figure A9.6), implying negative productivity, and resulting in undefined S_{gen} and S_{MSY} values. For example, high abundances in Shuswap-L and Shuswap-ES in 2010 were associated with strong density-dependence in the Larkin model in 2011, which predicted negative production, therefore no benchmarks could be estimated for this year (Figure 4 d and e). Annual stock-recruitment curves for the condensed Larkin model (Eqn. 5) are provided in Appendix 8, and parameter values are provided in Appendix 11.

4.2.3 Annual Status Assessments

Median benchmarks estimates for each cycle line (Figure 4, right side of each plot) were often similar (shown by overlapping labels for cycle-line specific benchmarks on those Figures). These benchmarks were used to assign statuses in the four most recent years, 2012-2015, as shown in and Appendices 1 and 10.

In sensitivity analyses, statuses were almost identical when using benchmarks calculated from the most recent generation instead of the cycle-line median. Exceptions occurred where statuses could not be estimated using the benchmarks from the current generation because of exceptionally strong density-dependence (Appendix 10, Figure A10.1e).

4.2.4 Interpretation and Assumptions

The impact of cyclic dominance on extirpation risk is uncertain. In a simulation study of Fraser River sockeye CUs, White et al. (2014) found that cyclicity and dominance were most likely to be high under conditions of low population persistence (low intrinsic productivity), high variability in survival, and narrow age structure. These associations suggest that the probability of depletion to critically low levels is higher for cyclic CUs. Further, White et al. (2014) and Schmitt et al (2016) suggest that cyclic patterns tend to occur for CUs that are well below capacity, displaying a linear stock-recruitment relationship. However, Schmitt et al. (2016) suggested that a close to linear stock–recruitment relationship does not necessarily imply a high risk of extinction, but rather indicates the presence of other factors that are limiting the population. These authors found that cyclic dynamics are more likely when good growth conditions for sockeye fry are combined with strong predator–prey interactions

The Larkin model and associated benchmarks assume that abundances are limited by delayed-density dependence. However, empirical support for delayed-density dependence is lacking for many CUs, creating uncertainties in the application of Larkin benchmarks, especially on sub-dominant and off-cycle lines. For several CUs, the Larkin model estimates upper benchmarks (80% S_{MSY}) that are relatively low in off-cycle years, due to strong-density dependence, which limits yield. Conversely, lower benchmarks, S_{gen}, are relatively high in off-cycle years, due to the low productivity, α' (Holt and Folkes 2015) that occurs under strong density dependence (e.g. Shuswap-L, Figure 4e). In dominant years, density dependence is usually very weak, due to the relatively low abundances of the preceding years (three cycle lines), and Larkin benchmarks are, therefore, theoretically similar to Ricker benchmarks for this cycle line.

As with benchmarks derived from the Ricker model, those from the Larkin model will be sensitive to errors-in-variables where spawner abundances are estimated with uncertainty resulting in biased parameter estimates (Su and Peterman 2012). Additional biases may occur for cyclic CUs due to variability in uncertainty in spawner abundances among cycle lines. Monitoring effort on off-cycle lines is relatively low compared with dominant and sub-dominant lines resulting in reduced data quality and increased uncertainty in estimates of spawners for off-cycle lines. These uncertainties and possible biases can be evaluated in simulation where underlying parameters are known and data and assessments are simulated. However, a full simulation evaluation of these and Ricker benchmarks was outside the scope of the current study.

Given the uncertainty in the underlying mechanisms driving cyclic patterns, Larkin benchmarks should not be used on their own to provide status. Our approach provides an indication of status by combining abundance based status with metrics on productivity, and short- and long-term trends. In general, no single metric captures status alone.

4.3 STATUS RE-ASSESSMENT PROCESS

4.3.1 Non-Cyclic CU Individual Status Results

Note: for the non-cyclic CU Group 1 (Appendix 3), only eight out of the nine individuals assessed status (Table 4; Appendix 2). For the remaining non-cyclic CUs in Groups 2 and 3 (Table 4; Appendix 3), all nine individuals assessed the status.

Generally there was convergence in status designations across individuals for non-cyclic CUs. Specifically, nine of the 18 non-cyclic CUs were designated the same status by each individual (Cultus-L (Red), Bowron-ES (Red), Chilko-S & Chilko-ES aggregate (Green), Chilko-ES (Data Deficient), North Barriere-ES (Amber), Harrison River (River-Type)(Green), Kamloops-ES (Amber), Pitt-ES (Green), and Lillooet-Harrison-L(Green)). In these cases, the consensus status was retained as the final integrated status (Appendix 2; Tables 4 and 5A & B). A further five of the non-cyclic CUs were designated the same status by greater than three quarters of the assessors (Harrison (D/S)-L (Amber/Green), Nahatlatch-ES (Amber), Harrison (U/S)-L (Red), Seton-L (Red) and Widgeon (River Type) (Red); for four of these CUs, only one individual provided a different status from the rest of the group. In these cases individual statuses diverged across adjacent status zones (R/A or A/G), rather than spanning the entire status zone range (R/G) (Appendix 2; Tables 4 and 5A & B).

4.3.2 Non-Cyclic CU Plenary Group Sessions: Status and Narratives

Plenary sessions focused only on CUs where complete consensus on status was not achieved. After the group discussed factors that contributed to divergent status designations, some individuals chose to change their individual status. As a result, consensus was achieved for five additional non-cyclic CUs (Taseko-ES (Red), Francois-Fraser (Red), Nahatlach (Red), Harrison (U/S)-L (Red), and Seton-L (Red)). In total, consensus was reached for 13 of the 18 non-cyclic CUs (Table 4). The remaining four non-cyclic CUs (Nadina-Francois-ES, Harrison (D/S)-L, Widgeon (river-type), and Anderson-Seton-ES) were designated with a 'majority view' , where the same status was assigned by at least three quarters of the assessors for all CUs except one (Nadina-Francois-ES), (Table 4). All participants agreed on the final status designations for all 18 non-cyclic CUs (Table 4).

Key points of the discussion were incorporated into the status narratives for each CU. There was broad agreement among the assessors regarding the comments and clarifications to be covered in the narratives. This held even for CUs where assessors did not achieve a full consensus on the integrated status. Essentially, assessor all agreed on a short-list of noteworthy pieces for each CU, but sometimes disagreed about the relative weight to be given to each aspect. Of particular note, for very small CUs there were divergent perspectives regarding the treatment of the COSEWIC criterion D1. For example, Widgeon (River-Type) has fallen below the COSEWIC Criterion D1 for small populations in recent years. Two individuals felt that since this CU has been persistent over time, despite its small size, it should be designated Amber, not Red. The majority, however, designated this CU, and other similar cases, as Red status, given their high extirpation risk and likelihood of being listed as 'endangered' by COSEWIC. These CUs were ultimately assigned statuses according to the 'majority view'.

For those CUs with stock-recruitment data, relative-abundance metrics generally drove the status designation. The COSEWIC Criterion D1 for small populations also carried weight, often downgrading statuses in cases where CU abundances fell below 1,000 fish within the most recent 12 years. Long-term productivity trends also contributed to the status designations. CUs with long-term declines in productivity were assigned poorer statuses, while long-term improvements in productivity contributed to better statuses. Recent improvements in productivity tempered poor statuses in some cases, though this metric did not have a large effect. In cases where relative-abundance metrics could not be estimated (i.e. stock-recruitment data were not available), the COSEWIC Criterion D1 for small populations drove the status designation (Appendix 2).

Long-term and short-term trends in abundance were considered during the status integration process; however, these metrics were highly dependent on the context provided by other information. Similar to the previous status assessment, there is recognition that high exploitation rates early in the time series create bias in the long-term trend metric, resulting in overly optimistic (biased high) statuses. Therefore, even in cases where this metric is consistently Green for most of the time series, this did not drive status, but was considered in the context of other information. Also similar to the previous status assessment for Fraser Sockeye, short-term trends were not given much weight in the status integration process. Since salmon species' are highly fecund and semelparous, high variability in CU productivity is common. Therefore, declining trends in salmonid abundances do not indicate the same extirpation risk, provided abundance is relatively high, as similar trends would in long-lived, low-fecundity species like Killer Whales. The short-term trend metric is also highly sensitive to extreme data points, which further reduces the relative weight of this metric in status designations, particularly in cases where this was observed.

Both trend metrics were considered in the context of their retrospective statuses over time, as presented in the data summaries. In cases where short-term trend statuses oscillate between Red and Green throughout the time series, this metric was given less weight. In contrast, if the short-term trend is consistent in recent years this metric was given more weight. Short-term and long-term trend metrics were also given more weight where they were consistent with each other, and less where these metrics diverged.

The limited role of the short-term trend metric in determining integrated statuses for Fraser Sockeye is demonstrated in Figure 5. For CUs where the short-term trend has declined and is currently in the Red status zone (< -25% rate of change), the integrated statuses range from Red to Green. Conversely, for CUs where the short-term trend has declined less than 15%, falling into the Green status zone for this metric, integrated statuses range from Red to Amber/Green.

4.3.1 Cyclic CU Individual Status Results

Note: for cyclic-CUs (Table 4; Appendix 3: Groups 4 & 5), only seven out of the nine individuals assessed status.

Generally, for cyclic CUs there was more variation in status designations across individuals. Initially, only two of the six cyclic CUs were assigned the same status by individuals regardless of whether or not the Larkin model relative-abundance benchmarks were considered (Takla-Trembleur-EStu and Chilliwack ES.

4.3.2 Cyclic CU Plenary Group Sessions: Status and Narratives

Similar to non-cyclic CUs, CUs with consistent statuses across all metrics and supporting information were designated with consensus, though only one CU had these characteristics (Takla-Trembleur-Early Stuart: Red). Plenary sessions focused on the remaining CUs where consensus was not reached across individuals. Key points of the discussion for each CU were incorporated into the status narratives. There was broad agreement among the assessors regarding the comments and clarifications to be covered in the narratives. This held even for CUs where assessors did not achieve full consensus regarding the integrated status. Essentially, assessor all agreed on a short-list of noteworthy pieces for each CU, but sometimes disagreed about the relative weight of one aspect over another. After discussing instances where individual status assignments diverged, some individuals chose to change their individual statuses, and consensus was achieved for one additional CU: Quesnel-S (Red/Amber). For three CUs, Shuswap-ES, Shuswap-L, and Takla-Trembleur-Stuart-S, two individuals changed their status designations as a result of the plenary discussions, and 'majority view' statuses could be designated (Shuswap-ES: Amber/Green; Shuswap-L: Amber/Green; Takla-Trembleur-Stuart-S: Amber).

Again, similar to non-cyclic CUs, where stock-recruitment data were available, relative-abundance metrics generally drove the status designation. Since relative-abundance metric statuses were estimated for each cycle line, the dominant cycle line had the primary influence on the status designation. For CUs where recent (past four years) weak cycle abundances fell below the COSEWIC Criterion for small populations this was noted, although this did not drive status. In one case (Late Shuswap), a declining trend on the subdominant cycle line tempered the status designation slightly, reducing status from Green to Green/Amber.

Considerations of short-term trends, long-term trends, and productivity were identical to those for non-cyclic CUs.

4.3.5 Cyclic CU statuses with and without Larkin-derived relative-abundance benchmarks

Generally, consideration of Larkin relative-abundance metrics had a moderate effect on the resulting integrated statuses (Tables 5A & B; Appendix 2). For three CUs (Takla-Trembleur-Early Stuart: Red; Shuswap-L: Amber/Green; and Takla-Trembleur-Stuart-S: Red/Amber), the integrated status did not change with this additional consideration. For two CUs (Shuswap-ES and Quesnel-S), the addition of the Larkin relative abundance metric resulted in lower statuses. For Shuswap-ES, status was downgraded from Green to Amber, while for Quesnel-S, status changed from Amber to Red/Amber. The consensus of the seven participants who assessed the status of cyclic CUs was that these metrics should be included in future assessments.

4.4 INTEGRATED STATUSES IN 2017 COMPARED TO 2012

4.4.1 CUs Ordered from Red to Green Status Zones in 2017

This re-assessment identified the following integrated statuses for Fraser Sockeye CUs: seven Red, two Red/Amber, five Amber, six Amber/Green, three Green, and one data deficient (Table 5A). There were a number of CUs that were consistently Red between the 2012 and 2017 assessments: Bowron-ES, Cultus-L, Takla-Trembleur-Early Stuart, Taseko-ES, and Widgeon-(River-Type). Widgeon-(River-Type) will remain indefinitely in the Red status zone, given its small distribution, and consequently abundance. Two CUs became Red in the current assessment: Harrison (U/S)-L and Seton-L (previously undetermined). Two CUs (Quesnel-S and Takla-Trembleur-Stuart-S) remained Red/Amber, similar to the previous assessment. The number of Green CUs decreased from five to three: Chilko-S/Chilko-ES aggregate, Harrison (River-Type), and Pitt-ES. However, the statuses of six CUs improved: Nahatlatch-ES, Nadina-Francois-ES and Francois-Fraser-S, Chilliwack-ES, Anderson-Seton, and Pitt-ES (Table 5A).

4.4.2 Degree of Change Within CUs

Conservation Units were ranked according to their change in status zone between the 2012 and 2017 assessments. A change of one full status zone between Red, Amber, or Green was assigned a value of 1 (-1 if status decreased and 1 if status increased). A change between R/A or A/G and their adjacent status zones of Red, Amber or Green was assigned a value of 0.5 (-0.5 for decreased status and +1 for increased status). These values, representing changes in status zone, were then used to rank CUs.

The largest decrease in status was one full status zone, experienced by Harrison (U/S)-L and Lillooet-Harrison-L (Table 8), while three CUs (Harrison (D/S)-L, Shuswap-ES, and Shuswap-L) exhibited a decrease of half a status zone. A number of CUs remained unchanged. Taseko-ES, Cultus-L, Bowron-ES, Widgeon (River-Type), and Takla-Trembleur-Early Stuart remained in the Red zone; Quesnel-S and Takla-Trembleur-Stuart-S remained Red/Amber; North Barriere-ES and Kamloops-ES remained Amber; and Chilko-S/Chilko-ES and Harrison (River-Type) remained Green status. Two CUs improved by half a status zone (Anderson-Seton-ES and Pitt-ES), while three CUs improved by a full status zone (Nahatlatch-ES, Francois-Fraser-S, and Chilliwack-ES) and one CU improved by 1.5 status zones (Nadina-Francois-ES). Chilko-ES remained Data Deficient and Seton-L was designated Red status in 2017, from a previously undetermined status in 2012 (Table 8).

4.4.3 CUs Ordered by Run Timing Group

For fisheries management purposes Fraser Sockeye CUs are grouped into one of four run timing groups (management units) based on the timing of their entry into the Fraser watershed as adults. The Early Stuart run (comprised of a single CU) enters the Fraser watershed first, followed by Early Summer (10 CUs), Summer (7 CUs), and Late Run (6 CUs) timing groups. Note that although there are general differences in timing between these run timing groups, there is also varying degrees of overlap between groups that vary inter-annually. Changes in status between 2012 and 2017 are compared for each of these run timing groups (Table 9).

The Early Stuart Run (Takla-Trembleur-Early Stuart) remains unchanged from the previous assessment, in the Red status zone (Table 9). For the Early Summer Run, statuses of three CUs remained the same between 2012 and 2017 (Taseko and Bowron-ES: Red; North Barriere-ES: Amber). The status of only one CU (Shuswap-ES) decreased by half a status zone to Amber. Alternatively, for most CUs in the Early Summer run timing group, statuses have improved. Nadina-Francois-ES increased by 1.5 status zones, Nahatlatch-ES, and Chilliwack-ES increased by one status zone, and Anderson-Seton-ES and Pitt-ES increased by 0.5 status zones. Most CUs in this run timing group fall into the Amber or Amber/Green status zones in 2017. In the Summer Run timing group, only one out of seven CUs changed status. Francois-Fraser-S increased from Red/Amber to Amber/Green. All other CUs in this management group remained the same: one is in the Red status zone (Widgeon (River-Type)), two CUs are in the Red/Amber status zone (Quesnel-S and Takla-Trembleur-Stuart-S), one CU is in the Amber status zone (Kamloops-ES) and two CUs are in the Green status zone (Chilko-S/Chilko-ES and Harrison-(River-Type)). In the Late Run timing group, one CU remains unchanged (Cultus-L: Red). Harrison-U/S-L decreased one full status zone to the Red zone, Lillooet-Harrison-L decreased one zone to Amber, and Harrison (D/S)-L and Shuswap-L both decreased half a status zone to Amber/Green (Table 9). Seton-L (previous unassessed) is now Red

4.4.4 CUs Ordered by Watershed

To better understand if there are spatially-based mechanisms influencing CU statuses, CUs were grouped by watershed area (Table 10), from the lower Fraser River areas up to the Upper Fraser. Watershed-scale aggregations of statuses, and changes in status, can be used for subsequent integrated planning steps. The two CUs present in the Lower Fraser have very different statuses; Widgeon is Red, and Pitt-ES is Green. However, though Widgeon and Pitt both spawn near Pitt Lake, these CUs have different life-history types (river-type vs. lake-type), and Pitt-ES rears in nearby Pitt Lake, while Widgeon sockeye migrate to the ocean after emergence. Widgeon sockeye also have a very small distribution, and consequently abundance, and therefore, will likely never have a status other than Red. Two CUs inhabit areas adjacent to the Chilliwack River in the Lower Fraser, Cultus-L and Chilliwack-ES. These CUs also have very different status (Cultus-L: Red; Chilliwack-ES: Amber/Green). In fact, Cultus has previously been listed as endangered by COSEWIC (COSEWIC 2003; Cultus Sockeye Recovery Team 2009; DFO 2010). In the near-by Harrison system, Harrison (U/S)-L, Lillooet-Harrison-L, and Harrison (D/S)-L have all decreased in status since the 2012 assessment, falling to Red, Amber and Amber/Green, respectively. Alternatively, the river-type CU in this system, Harrison (River-type), has remained Green in status since the previous assessment.

In the mid-Fraser, Anderson-Seton-ES has improved in status, from Amber to Amber/Green, and Seton-L (previously undetermined) was designated Red. In the Thompson system, North Barriere-ES and Kamloops-ES have remained Amber, and both Shuswap-ES and Shuswap-L have decreased in status by half a status zone to, respectively, Amber and Amber Green. In the Chilcotin system, Taseko-ES has remained Red, and Chilko-ES/Chilko-S has remained Green. Chilko-ES remains data deficient. Quesnel-S has remained Red/Amber.

In the upper Fraser, Francois-Fraser-S and Nadina-Francois-ES have both improved in status to Amber/Green. Takla-Trembleur-EStu and Takla-Trembleur-Stuart-S have remained, respectively, Red and Red/Amber, and Bowron-ES has remained Red.

5 DISCUSSION

This WSP integrated biological status re-assessment was completed for 24 Fraser Sockeye Conservation Units (CUs), identifying the following integrated statuses: seven Red CUs, two Red/Amber CUs, five Amber CUs, six Amber/Green CUs, three Green CUs, and one data deficient CU. There were 11 CUs that did not change in status between assessments, and 13 that did change (Table 5A). These changes emphasise the importance of re-assessing status at least every five years, to ensure appropriate allocation of resources to recover Red and Red/Amber CUs, and appropriately manage fisheries, habitat and hatchery enhancement activities.

In addition to status designations, narratives describing the factors that contributed to each status designation are provided. The combination of integrated statuses, data summaries, and narratives, are recommended as inputs into the WSP Strategy 4 on Integrated Planning. As a package, this information can guide recovery actions for Red, Red/Amber, and possibly Amber CUs, where applicable, and management actions (fisheries, salmonid enhancement, and habitat) that affect Fraser Sockeye CUs in any status zone.

This status re-assessment process demonstrates that re-assessments can be conducted on a smaller scale (<9 individuals in a 1 day plenary session) compared to first-time WSP status assessments (34 individuals over a 3 day plenary session in the case of Fraser Sockeye). Re-assessments are streamlined by the considerable amount of work conducted on data verification, synthesis, publication of background material, and the development of standardized data summaries that goes into the initial assessment and must only be updated for re-assessment. Further, previous statuses and narratives can be used as a starting point for re-assessments. Finally, assessors are selected largely from those with previous WSP status assessment experience and salmonid expertise, which accelerates the re-assessment process.

As was concluded in the previous WSP status assessment, integrating statuses across metrics and supporting information requires expert judgment. No single algorithm can be developed, since each CU has unique considerations related to data quality, metric stability over time, and time series patterns in variables such as abundance, productivity, and exploitation. These factors must be considered when interpreting individual metrics, and integrating status across metrics and supporting information.

The short-term trend metric, as one example, was never considered in isolation of supporting information, and was frequently given a low weight in status designations. This metric was also generally not given much weight in the previous status assessment for Fraser Sockeye, since short-term declines, observed for many CUs, were generally attributed to abundances returning to average after a period of high production in the mid-1990's (Grant & Pestal 2013). In some cases, this same logic was applied to particular CUs in the current assessment. There were also situations where an observed declining trend, which resulted in a Red status for this metric, was particularly sensitive to a single data point. Shuswap-L for example had a single weak cycle year with a very low abundance (12 spawners) near the end of the time series (2012). This year alone produced the Red status for the short-term trend metric; however, the data quality of this single data point was flagged as very poor by an expert on Fraser Sockeye escapement estimates. Due to the size of this system and the enumeration methods employed in this year (visual surveys), this escapement estimate could in fact range from 100 to 1,500+ fish. A sensitivity analysis across this range indicated that the short-term trend metric status could range from Red to Green depending on the true escapement. In addition to this, data treatment, prior to estimating the short-term trend metric ($\log_e$ transformation, start year for smoothing, smoothing interval), can affect the resulting status of this metric.

Retrospective evaluations of the stability of short-term trends were used to inform the weight given to this particular metric. Since anadromous salmonids are highly fecund, and spawn only once then die, changes in survival conditions can create large fluctuations in abundances over relatively short-periods of time. This is very different from long-lived species such as killer whales, or other longer-lived fish species, which require many years to recover from recruitment collapses, even when survival and productivity conditions immediately improve. For many Fraser Sockeye CUs, short-term trends are extremely variable over the time series, oscillating between Red and Green statuses. The sensitivity of the short-term trend metric to single data points and the approach taken to calculate the trend, and the variability of this metric across the time series, demonstrate that caution must be taken when interpreting this metric in the context of integrating status. This is supported by work conducted by Porszt et al. (2012), who found that long-term trend metrics, which compare current abundances to historical averages, generally reflect status more reliability than short-term trends. This research, however, also showed that no single threat indicator provides error-free estimates of status, which emphasizes the importance of applying multiple metrics and information to assess Pacific salmon status, according to expert judgement.

For non-cyclic CUs with stock-recruitment data, unique relative-abundance metrics were developed for each CU using the same approach described in the previous assessment (Grant et al. 2011; Grant & Pestal 2013). Although several publications have dealt with selection of appropriate relative-abundance benchmarks (S_{gen} and 80% S_{msy}, as the respective lower and upper benchmarks) (Holt 2009, 2010; Holt and Bradford 2011), specific analyses have not been conducted to investigate the sensitivity of these benchmarks to observation (i.e. measurement) error in stock-recruitment data. Further, for Fraser Sockeye CUs, additional error is introduced into the recruitment data by the run size adjustments (RSA) process. RSA values are based on expert judgement on en-route migration mortality of returning adult sockeye, and error in in-season hydroacoustic assessments of total returns, upstream escapement estimates, and catch assessments. For future status assessments, it is recommended that simulation studies explore the biases in stock-recruitment data, and their effect on the estimated relative-abundance benchmarks, similar to those conducted in Su and Peterman (2012).

In the current assessment of non-cyclic CUs with stock-recruitment data, informative S_{max} values, based on lake-rearing capacity, were explored in the estimation of relative-abundance benchmarks. In most cases, expert judgement determined that S_{max} values were likely too high to limit CU productivity. Instead, spawning habitat was identified as the most likely bottleneck of productivity, limiting abundances of offspring well before juveniles reach lake-rearing capacity. Informative priors were applied in three cases (Bowron-ES, Chilko-S/Chilko-ES, and Pitt-ES), where the statuses of relative-abundance benchmarks were identical using informative and uninformative priors on the β-parameter. Therefore, these informative priors were not broadly applicable to Fraser Sockeye CUs, and where they were applicable, did not influence the status for the relative-abundance metrics. Further exploration of informative lake-rearing S_{max} values is recommended. First, updated S_{max} estimates should be obtained for recent years. Although raw limnological and juvenile sockeye lake-competitor data from lake surveys were available, estimates of S_{max} were not available at the time of this publication. In some systems such as Chilko Lake, primary productivity has appeared to have increased in recent years. Updating S_{max} is important given these shifts. In addition, there are a number of CUs where S_{max} data are available for only one or two years, therefore, an investigation of the stability of these data is required.

In most cases, lake-rearing capacity does not appear to limit productivity for Fraser Sockeye CUs. Instead, habitats utilized during other life-history stages may be limiting productivity. For many this appears to occur in the freshwater spawning habitat. Recent mapping of spawning habitat use could be helpful for developing estimates of spawning habitat capacity (de Mestral Bezanson et al. 2012;de Mestral and Bradford 2014). For CUs like Chilko Lake, which have smolt data, this information on juveniles could be used to understand system capacity. The marine ecosystem may also limit CU productivity, and this was not considered in the current assessment (Ruggerone and Connors 2015; Ruggerone et al. 2016). Overall, given the limited value of informative S_{max} priors based on lake-rearing capacity, these are not recommended for future use until CU capacities are further explored in both freshwater and marine ecosystems.

Larkin-model derived relative-abundance benchmarks were included in status assessments of the five cyclic Fraser Sockeye CUs: Shuswap-ES, Shuswap-L, Takla-Trembleur-Early Stuart, Takla-Trembleur-L, and Quesnel. Larkin-model benchmarks are extensions of the existing Ricker-model benchmarks, used for non-cyclic CUs. Similarly, interpretation of statuses estimated from Larkin-model benchmarks requires expert interpretation. Further work on cyclic CUs is required to identify cases where cyclic patterns in abundance are driven by biological mechanisms versus stochastic mechanisms. Research is on-going in Fraser River sockeye lakes to resolve this (D. Selbie, DFO, pers. comm.). This additional expert knowledge, once resolved, should be used to identify cyclic CUs that are driven by biological mechanisms, where Larkin model-derived relative abundance benchmarks are most appropriate.

Extirpation risk of cyclic CUs has received considerable discussion, and many unanswered questions remain. For example, is extirpation risk higher when a CU has one very large dominant cycle that is considerably largely than its three other cycles. Essentially, does risk increase for highly cyclic CUs since production is concentrated in one year out of four. If a significant habitat perturbation coincides with a dominant cycle year, this could have serious implications for the CU as a whole, because other cycle lines are too small to contribute sufficient recruits to the dominant cycle from other age classes (three and five year olds). In contrast, non-cyclic CUs may have greater resilience to a perturbation in a single year, since each year receives contributions of different age classes from adjacent years. Another perspective, however, is that cyclic dominance may provide resilience to perturbations. For example, Shuswap-L, which exhibits large differences in abundances between the dominant (1 million EFS) and weak cycle lines (a few thousand), has experienced very stable productivity over its time series, compared to non-cyclic CUs (Appendix 2; Grant et al. 2011; Peterman & Dorner 2012).

Since there was no resolution on the fundamental question of extirpation risk for cyclic CUs, generally participants focused on the status of the dominant cycle line in terms of relative-abundance and trends. In cases where status diverged significantly between cycle lines, participants felt it was important to document this in the narratives, and for some individuals, this influenced their integrated status designation. As a result, integrated statuses for cyclic CUs should be considered with additional uncertainty. Overall, the conclusion was that Larkin-model benchmarks were helpful in the status assessment process, and they are recommended for future status assessments, provided that they are applied in a similar, expert-driven context.

Comparisons of CU statuses between the 2012 and 2017 assessments can be used, in conjunction with information described in the narratives, for subsequent integrated planning processes. This information can inform fisheries management plans for different management groups (run timing groups). Alternatively, it can inform our understanding of mechanisms driving population dynamics. Exploring different ways to group this information may help to identify mechanisms influencing population dynamics and statuses of CUs.

6 CONCLUSIONS

This paper captures the first WSP status re-assessment process, performed for Fraser Sockeye CUs. This status re-assessment builds on the considerable amount of work published in previous years (Holtby & Ciruna 2007; Holt et al. 2009; Holt 2009; Porszt 2009; Holt 2010; Grant et al. 2011; Holt & Bradford 2011; Porszt et al. 2012; Grant & Pestal 2013), and the assessment approaches that have more recently been conducted on other CU groups, including Southern BC Chinook (G. Brown, DFO, pers. comm.; DFO 2016a) and Interior Fraser Coho (C. Parken, DFO, pers. comm.; DFO 2015).

The current process demonstrated the effectiveness of performing assessments with smaller groups of individuals (< 10 individuals), and combining individual and group plenary work. Status assessments conducted by individuals were remarkably similar to one another, and where they diverged, usually represented adjacent status zones. As a result of the plenary session, final integrated statuses were identified by either consensus or 'majority-view', where greater than 50% of the participants indicated the same status. In all cases, the final integrated status was agreed upon by all individuals, with assurances that individual statuses and perspectives were documented in the narratives. The current status re-assessment process provides recommendations (see below) for the selection of individual assessors. This process also demonstrated that for these smaller-scale re-assessments, the non-'blind' approach is most efficient, since CU-specific expertise relevant to the status assessment process is provided immediately during the process. However, for first-time assessments, a 'blind' approach is recommended, as described in Grant & Pestal 2013.

The use of Larkin-derived relative-abundance benchmarks is recommended for future status re-assessment process on Fraser Sockeye cyclic CUs. Larkin model relative-abundance benchmarks provided additional information to assess the status of cyclic CUs. However, similar to other metrics, this metric must be interpreted in the context of supporting information for the CU. As has been previously identified, there are no simple algorithms that can be applied to determine an integrated status from the individual metric statuses and supporting information. Each metric status should be evaluated in the context of salmon-expert opinion on data quality, retrospective stability of the metric status over time, and patterns in abundance, productivity, and exploitation. The short-term trend metric, in particular, is flagged as requiring particular caution in interpretation, and may be more applicable to less fecund, shorter-lived species

Since different factors may drive statuses across CUs, the CU narratives and accompanying data summaries provide the context required to interpret statuses. The status, narratives, and data summaries should be used together in subsequent integrated planning processes (WSP Strategy 4) to determine where recovery strategies are required, and how management practices should be adjusted to maintain the biological diversity of Fraser Sockeye.

7 RECOMMENDATIONS

1. For future status re-assessments it is recommended that seven to ten individuals be selected representing the relevant stock assessment area, ecological experts, and those with broader cross-salmon-species expertise. It is also recommended that the group is comprised of both those with past WSP status assessment experience and individuals new to the process, in order to expand the pool of WSP status assessment experts for subsequent processes.
2. Given the smaller scale of the re-assessment process, non-'blind' CU assessments are recommended, since CU-specific expertise related to the status assessment can be

introduced immediately during individual and group discussion. For larger first-time status assessment, ‘blind’ assessments are still recommended.

3. It is recommended that information packages be distributed to individual assessors prior to the assessment. These should include the following:
    - standardized updated data summaries and a data summary guide
    - questionnaires for individuals to input their individual statuses and narratives
    - first cut of the narratives based on past narratives and status assessments
    - first cut of statuses, where data summaries are identical to the past assessment
    - any additional supporting analysis and model diagnostics, as required
4. Prior to individual assessments, assessors should be oriented to the information packages and the assessment process.
5. The consideration of any metric in the status assessment process requires expert consideration of the underlying information, for example, data quality, past abundances (e.g. short-term trends are often discounted if a CU is coming off a period of high production), and stability of retrospective metric statuses (e.g. short-term trends often change several times throughout the time series).
6. Additional sensitivity analyses are recommended for short-term trend metrics, to evaluate their sensitivity to outlying data. Although such an analysis was produced for Shuswap-L in the current assessment, it is recommended that future assessments investigate this more thoroughly.
7. Since stock-recruitment data are often highly uncertain, additional information to assist with parameter estimation is recommended. For non-cyclic CUs where Ricker models were used to estimate relative-abundance benchmarks, informative priors on the β-parameter should be further exploration. Updated S_{max} values on lake-rearing capacity should be obtained (not available at the time of this report) and explored. Estimates of spawning habitat capacity are also recommended, since this habitat appeared to limit CU productivity more so than lake-rearing capacity in a number of cases. Also, information on marine habitat capacity should also be explored, since there is recent evidence to suggest that this ecosystem might also be limiting.
8. For non-cyclic CUs, simulation modelling is recommended to explore the effect of error in stock-recruitment data (catch, escapement, and run size adjustments) on relative-abundance benchmark estimation;
9. Use of the Larkin-derived relative-abundance benchmarks is recommended for future status re-assessment processes for cyclic CUs; these metrics provided additional information to inform the integrated statuses and narratives. Similar to the previous recommendation, this metric requires expert interpretation of cycle line specific status and trend information;
10. Research and analyses empirically investigating delayed-density-dependent mechanisms in sockeye lakes are ongoing to distinguish between stochastic-drivers of cyclic dominant patterns in abundance, versus those established by in-lake biological mechanisms such as predator-prey dynamics. Results of this work will assist in determining whether or not the application of Larkin-model derived relative-abundance benchmarks is appropriate for specific CUs. These models are appropriate when cyclic dominance is driven by biological mechanisms (interactions between cycle lines);

11. The definition of individual CUs as cyclic and non-cyclic should be revisited and coordinated between the Fraser River sockeye spawning initiative (FRSSI) and the WSP status process. This involves a rigorous evaluation of the sensitivity of DIC values to prior specification, consideration of different cut-offs for DIC goodness of fit, and/or consideration of model averaging approaches where CUs are not binary (cyclic vs non-cyclic) but occur on a gradient of cyclic behaviour.
12. To facilitate future Fraser Sockeye status processes, data summaries should be converted from excel to R code; these results could be updated annually to look for shifts in status that might warrant a re-assessment;
13. Guidance on appropriate re-assessment time-lines is required. Currently there is no Departmental direction on re-assessment timelines, which is required to align the required departmental resources.
14. Further work and discussion is required to validate CUs that spawn in the same system but were designated as separate CUs due to differences in adult run timing (Chilko-S & Chilko-ES; Nadina-First Run and Nadina Second Run).
15. Additional details in Ogden et al. (2015), describing annual stock-recruitment data quality for Fraser Sockeye (including recruits/spawner estimates and the individual components, i.e. escapement, catch, and age structure), should be updated annually, and considered in status evaluations. It is important going forward that metadata be recorded in detail for each time series to support any analysis, including status evaluations.
16. It is recommended that the number of populations included in each CU be documented in the data summaries.

8 ACKNOWLEDGMENTS

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10 TABLES

Table 1: 2017 Fraser Sockeye CU list. The Nadina-Francois-ES CU has been updated after discussions with DFO's Salmonid Enhancement Branch (SEP: D. Lofthouse & D. Willis) and DFO's Fraser Sockeye Stock Assessment Program (K. Benner, T. Cone, & S. Grant).

Current	***New***	***Validation Required***	***Extirpated***
1. Anderson-Seton-ES	1. North Barriere-ES	1. Cariboo-S (extirpated?)	1. Adams-ES
2. Bowron-ES	2. Seton-L		2. Alouette-ES
3. Chilko-S	-	2. Nadina-Francois-ES (first-run & second-run: are these separate populations or extirpated CUs?)	3. Coquitlam-ES
4. Chilko-ES	-		4. Fraser-ES
5. Chilliwack-ES	-		5. Kawkawa-L
6. Cultus-L	-		6 Momich-ES
7. Francois-Fraser-S	-	3. Indian/Kruger-ES (extirpated?)	7. North-Barriere-ES
8. Harrison (D/S)-L	-		8 Seton-S
9. Harrison (U/S)-L	-	4. Middle Fraser (River-Type) (DNA required to confirm this is a unique CU)	
10. Harrison (River-Type)	-		
11. Kamloops-ES	-	5. Upper Fraser (River-Type) (DNA required to confirm this is a unique CU)	
12. Lillooet-Harrison-L	-		
13. Nadina-Francois-ES	-	-	-
14. Nahatlatch-ES	-	-	-
15. Pitt-ES	-	-	-
16. Quesnel-S	-	-	-
17. Shuswap-ES	-	-	-
18. Shuswap-L	-	-	-
19. Takla-Trembleur-EStu	-	-	-
20. Takla-Trembleur-Stuart-S	-	-	-
21 Taseko-ES	-	-	-
22. Widgeon (River Type)	-	-	-

Table 2: Guidance in the Wild Salmon Policy on assessment actions and management considerations for conservation units in the three status zones (DFO 2005: p. 17-19, 26, 32).

Status		Assessment Actions	Management Considerations
	Red	"… a detailed analytical assessment will normally be triggered to examine impacts on the CU of fishing, habitat degradation, and other human factors, and evaluate restoration potential", "… detailed stock assessments will identify the reasons for the change in status". "CUs in the Red zone … will be identified as management priorities … the protection and restoration of these CUs will be primary drivers for harvest, habitat, and enhancement planning."	"Biological considerations will be the primary driver for the management of CUs with Red status". "The presence of a CU in the Red zone will initiate immediate consideration of ways to protect the fish, increase their abundance, and reduce the potential risk of loss".
	Amber	"… a detailed analytical assessment may be required to input into Strategies 2 & 3.."	"Decisions about the conservation of CUs in the Amber zone will involve broader considerations of biological, social, and economic issues". "involves a comparison of the benefits from restoring production versus the costs arising from limitations imposed on the use of other CUs to achieve that restoration." "implies caution in the management of the CU"
	Green	" a detailed analytical assessment of its biological status will not usually be needed"	"Social and economic considerations will tend to be the primary drivers for the management of CUs in the green zone, though ecosystem or other non-consumptive values could also be considered".

Table 3a: Three zones of biological status defined in the WSP (WSP p. 17 & 18)

Status		Definition
	Red	"… established at a level of abundance high enough to ensure there is a substantial buffer between it and any level of abundance that could lead to a CU being considered at risk of extinction by COSEWIC"
	Amber	"While a CU in the Amber zone should be at low risk of loss, there will be a degree of lost production. Still, this situation may result when CUs share risk factors with other, more productive units"
	Green	"identif[ies] whether harvests are greater than the level expected to provide on an average annual basis, the maximum annual catch for a CU, given existing conditions…there would not be a high probability of losing the CU"

Table 3b: Seven status categories used for 2017 status integration process.

STATUS CATEGORIES	
DD	Data Deficient
UN	Undetermined
R	Red
R/A	Red/Amber
A	Amber
A/G	Amber/Green
G	Green
*	Conditional status assigned in 2012

Table 4: Summary of the 2017 integrated status designations for the 24 Fraser River Sockeye Salmon CUs. This includes the number of individuals that designated a CU in each status zone after plenary discussions, and the final 2017 integrated status based on either consensus or "majority-view" among individual assessors. These assessments incorporate relative-abundance benchmarks (Ricker-based for non-cyclic CUs; Larkin-based for cyclic CUs). Groups 1, 2, and 3 include the non-cyclic CUs. Groups 4 and 5 include the cyclic CUs. For comparison, the 2012 integrated statuses are also presented by CU; the asterisks denote CUs that have provisional statuses. The following applies to the table: R=Red (coloured red); R/A=Red/Amber (coloured orange); A=Amber (coloured yellow); A/G=Amber/Green (coloured light yellow); and G=Green (coloured Green).

2012 Status	Group	CU_ID	Cyclic	CU	Individual Assessments by 9 Fraser Sockeye Experts							2017 Status
					DD	UN	R	R/A	A	A/G	G	
R*	1	1	-	Taseko-ES	-	-	8	-	-	-	-	R
R	1	2	-	Cultus-L	-	-	8	-	-	-	-	R
R	1	3	-	Bowron-ES	-	-	8	-	-	-	-	R
G*	1	4	-	Chilko-S & Chilko-ES aggregate	-	-	-	-	-	-	8	G
DD	1	4b	-	Chilko-ES	-	-	-	-	-	-	-	DD
A	1	5	-	North Barriere-ES	-	-	-	-	8	-	-	A
G	1	6	-	Harrison River (River-Type)	-	-	-	-		-	8	G
A	1	7	-	Kamloops-ES	-	-	-	-	8	-	-	A
R/A	2	8	-	Francois-Fraser-S	-	-	-	-		9	-	A/G
R	2	9	-	Nadina-Francois-ES	-	-	-	-	4	5	-	A/G
G	2	10	-	Harrison (D/S)-L	-	-	-	-	1	7	1	A/G
R	2	11	-	Nahatlatch-ES	-	-	-	-	9	-	-	A
A	2	12	-	Harrison (U/S)-L	-	-	9	-	-	-	-	R
A/G	2	13	-	Pitt-ES	-	-	-	-	-	-	9	G
UN	2	14	-	Seton-L	-	-	9	-	-	-	-	R
R	2	15	-	Widgeon (River Type)	-	-	7	-	2	-	-	R
A	2	16	-	Anderson-Seton-ES	-	-	-	-	-	8	1	A/G
G*	3	17	-	Lillooet-Harrison-L	-	-	-	-	9	-	-	A
R	4	18	cyclic	Takla-Trembleur-EStu	-	-	7	-	-	-	-	R
A/G	4	19	cyclic	Shuswap-ES	-	-	-	-	4	3	-	A
R/A	4	20	cyclic	Quesnel-S	-	-	-	7	-	-	-	R/A
G	5	21	cyclic	Shuswap Complex-L	-	-	-		2	5	-	A/G
R/A	5	22	cyclic	Takla-Trembleur-Stuart-S	-	-	2	5	-	-	-	R/A
R/A	5	23	cyclic	Chilliwack-ES	-	-	-	-	-	7	-	A/G

Table 5A: The 2017 Integrated status designations for the 24 Fraser River Sockeye Salmon CUs, ranked from poor (Red zone) to healthy (Green zone) status based on the current 2017 assessment. Cyclic CU statuses are determined including relative-abundance benchmarks estimated using the Larkin model.For each CU, more commonly used stock names are presented. Cyclic CUs are identified. An astericks (*) indicates provisional status designations; R/A: Red/Amber; A/G: Amber/Green; DD: data deficient; Undet: undetermined. The previous assessment's integrated statuses are also listed in the 2012 column (Grant & Pestal 2012).

2017		2012		Conservation Unit	Cyclic	Stock
R		R		Bowron-ES	-	Bowron
R		R		Cultus-L	-	Cultus
R		R		Takla-Trembleur-EStu	cyclic	Early Stuart
R		R*		Taseko-ES	-	Miscellaneous Early Summers
R		R		Widgeon – River*	-	Miscellaneous Lates
R		A		Harrison (U/S)-L	-	Weaver
R		UD		Seton-L	-	Portage
R	A	R	A	Quesnel-S	cyclic	Quesnel
R	A	R	A	Takla-Trembleur-Stuart-S	cyclic	Late Stuart
A		A		North Barriere-ES	-	Fennel & Miscellaneous Early Summ
A		A		Kamloops-ES	-	Raft & Miscellaneous Early Summ
A		A	G	Shuswap-ES	cyclic	Scotch, Seymour, Mis.Early Summ
A		G*		Lillooet-Harrison-L	-	Birkenhead
A	G	R		Nadina-Francois-ES	-	Nadina
A	G	R	A	Chilliwack-ES	cyclic	Miscellaneous Early Summers
A	G	R	A	Francois-Fraser-S	-	Stellako
A	G	A		Anderson-Seton-ES	-	Gates
A	G	G		Harrison (D/S)-L	-	Miscellaneous Lates
A	G	G		Shuswap Complex-L	cyclic	Late Shuswap
G		A	G	Pitt-ES	-	Pitt
G		G*		Chilko-S & Chilko-ES agg.	-	Chilko
G		G		Harrison River – River Type	-	Harrison
DD		DD		Chilko-ES	-	Chilko

Table 5B: The 2017 integrated status designations for the 24 Fraser River Sockeye Salmon CUs, ranked in same order as Table 5A for comparison. CU statuses are determined without relative-abundance benchmarks estimated using the Larkin model.For each CU, more commonly used stock names are presented. Cyclic CUs are identified. Astericks (*) indicate provisional status designations; R/A: Red/Amber; A/G: Amber/Green; DD: data deficient; Undet: undetermined. The previous assessment's integrated statuses are also listed in the 2012 column (Grant & Pestal 2012).

2017	2012	Conservation Unit	Cyclic	Stock
R	R	Bowron-ES	-	Bowron
R	R	Cultus-L	-	Cultus
R	R	Takla-Trembleur-EStu	cyclic	Early Stuart
R	R*	Taseko-ES	-	Miscellaneous Early Summers
R	R	Widgeon – River	-	Miscellaneous Lates
R	A	Harrison (U/S)-L	-	Weaver
R	UD	Seton-L	-	Portage
R A	R A	Quesnel-S	cyclic	Quesnel
R A	R A	Takla-Trembleur-Stuart-S	cyclic	Late Stuart
A	R	Nahatlatch-ES	-	Miscellaneous Early Summers
A	A	North Barriere-ES	-	Fennel & Miscellaneous Early Summ
A	A	Kamloops-ES	-	Raft & Miscellaneous Early Summ
G	A G	Shuswap-ES	cyclic	Scotch, Seymour, Mis.Early Summ
A	G*	Lillooet-Harrison-L	-	Birkenhead
A G	R	Nadina-Francois-ES	-	Nadina
A G	R A	Chilliwack-ES	cyclic	Miscellaneous Early Summers
A G	R A	Francois-Fraser-S	-	Stellako
A G	A	Anderson-Seton-ES	-	Gates
A G	G	Harrison (D/S)-L	-	Miscellaneous Lates
A G	G	Shuswap Complex-L	cyclic	Late Shuswap
G	A G	Pitt-ES	-	Pitt
G	G*	Chilko-S & Chilko-ES agg.	-	Chilko
G	G	Harrison River – River Type	-	Harrison
DD	DD	Chilko-ES	-	Chilko

Table 6: The 2017 Integrated status narratives for the 24 Fraser River Sockeye Salmon CUs, based on status rank presented in Table 4. Rel Abd: relative abundance metric; LT: long-term trend; ST: short-term trend; Abs Abd: absolute abundance; prod: productivity trends; prod incr: productivity increase; repl.: replacement;

2017 Status	Conservation Unit	Status Narrative (Key Drivers)
R	Bowron-ES	All metrics RED
R	Cultus-L	Rel Abd RED, LT trend Red, 9 of 12 yrs <1,000
R	Takla-Trembleur-EStu	All metrics RED, declining prod
R	Taseko-ES	LT and ST trends RED, no rec est, so no Rel Abd BM
R	Widgeon – River	Abs abd low, 3 of last 4 < 1,000
R	Harrison (U/S)-L	All metrics RED, 2 of last 4 yrs <1,000
R	Seton-L	Rel Abd RED, 2 of last 4 yrs < 1,000, LT & ST RED
R A	Quesnel-S	Rel Abd R/A mix (p-levels, cycles), ST RED, prod slight
R A	Takla-Trembleur-Stuart-S	Rel Abd R/A mix (p-levels, cycles), ST RED, prod below
A	Nahatlatch-ES	Abs Abd (median 2000, 1 of last 4 <1000), LT and ST
A	North Barriere-ES	Rel Abd AMBER (but LBM ~ 1,000), LT GREEN, ST RED
A	Shuswap-ES	Rel Abd AMBER on dom line, LT & ST GREEN, prod incr
A	Kamloops-ES	Rel Abd AMBER (high unc), LT GREEN, ST RED aft peak)
A	Lillooet-Harrison-L	Rel Abd AMBER, LT GREEN, ST RED, low prod, no
A G	Nadina-Francois-ES	Rel Abd AMBER at 50p, RED above, LT & ST GREEN,
A G	Chilliwack-ES	Rel Abd is AMBER, ST and LT trend GREEN, no yrs <1,000
A G	Francois-Fraser-S	Rel Abd is A/G mix, LT trend GREEN, ST trend AMBER
A G	Anderson-Seton-ES	ST and LT trend GREEN, no years in past 4<1,000; Red Abd mixed AMBER/GREEN, improved prod
A G	Harrison (D/S)-L	LT trend GREEN, ST trend RED coming off peak, no Rel Abd
A G	Shuswap Complex-L	Rel Abd GREEN and Abs Abd large for dom cycle, stable prod; declining trends on sub dom. cyc decreased status to A/G
G	Pitt-ES	Rel Abd GREEN, LT GREEN (ST Red did not influence status)
G	Chilko-S & Chilko-ES agg.	All metrics GREEN; no years < 1,000; prod improved
G	Harrison River – River Type	Rel Abd GREEN at 50p, ST and LT trend green
DD	Chilko-ES	No independent data available (small part of Chilko

Table 7: The 2017 Integrated statuses for the 24 Fraser River Sockeye Salmon CUs, organized by the amount of change between assessments. CUs were given a numerical score that corresponds to their integrated status: 0=R (Red), 0.5=R/A (Red/Amber), 1=A (Amber), 1.5=A/G (Amber/Green) and 2=G (Green). Differences between the 2017 score and the 2012 score are ranked from most negative to most positive.

	Status		Score			
Conservation Unit	**2012**	**2017**	**2012**	**2017**	**Diff**	**Change**
Harrison (U/S)-L	A	R	1	0	-1	decline
Lillooet-Harrison-L	G	A	2	1	-1	decline
Harrison (D/S)-L	G	A G	2	1.5	-0.5	decline
Shuswap-ES	A G	A	1.5	1	-0.5	decline
Shuswap Complex-L	G	A G	2	1.5	-0.5	decline
Taseko-ES	R	R	0	0	0	no change
Cultus-L	R	R	0	0	0	no change
Bowron-ES	R	R	0	0	0	no change
Widgeon (River Type)	R	R	0	0	0	no change
Takla-Trembleur-EStu	R	R	0	0	0	no change
Quesnel-S	R A	R A	0.5	0.5	0	no change
Takla-Trembleur-Stuart-S	R A	R A	0.5	0.5	0	no change
North Barriere-ES	A	A	1	1	0	no change
Kamloops-ES	A	A	1	1	0	no change
Chilko-S/Chilko-ES agg.	G	G	2	2	0	no change
Harrison River (River-Type)	G	G	2	2	0	no change
Anderson-Seton-ES	A	A G	1	1.5	0.5	improved
Pitt-ES	A G	G	1.5	2	0.5	improved
Nahatlatch-ES	R	A	0	1	1	improved
Francois-Fraser-S	R A	A G	0.5	1.5	1	improved
Chilliwack-ES	R A	A G	0.5	1.5	1	improved
Nadina-Francois-ES	R	A G	0	1.5	1.5	improved
Chilko-ES	DD	DD	Na	Na	Na	Na
Seton-L	UNDET	R	Na	Na	Na	Na

Table 8: The 2017 Integrated statuses for the 24 Fraser River Sockeye Salmon CUs, organized by the run timing group currently used for fisheries management. CUs were given a numerical score that corresponds to their integrated status: 0=R (Red), 0.5=R/A (Red/Amber), 1=A (Amber), 1.5=A/G (Amber/Green) and 2=G (Green). The difference between the 2017 score and the 2012 score are ranked from most negative to most positive.

	Status		Score				
Conservation Unit	**2012**	**2017**	**2012**	**2017**	**Diff**	**MGMT GROUP**	**Change**
Takla-Trembleur-EStu	R	R	0	0	0	Early Stuart	still Red
Taseko-ES	R	R	0	0	0	E Summ	still Red
Bowron-ES	R	R	0	0	0	E Summ	still Red
North Barriere-ES	A	A	1	1	0	E Summ	still Amber
Shuswap-ES	A G	A	1.5	1	-0.5	E Summ	decline
Nahatlatch-ES	R	A	0	1	1	E Summ	improved
Anderson-Seton-ES	A	A G	1	1.5	0.5	E Summ	improved
Chilliwack-ES	R A	A G	0.5	1.5	1	E Summ	improved
Nadina-Francois-ES	R	A G	0	1.5	1.5	E Summ	improved
Pitt-ES	A G	G	1.5	2	0.5	E Summ	improved
Chilko-ES	DD	DD	Na	Na	Na	E Summ	still DD
Widgeon (River Type)	R	R	0	0	0	Summer	still Red
Quesnel-S	R A	R A	0.5	0.5	0	Summer	still R/A
Takla-Trembleur-Stuart-S	R A	R A	0.5	0.5	0	Summer	still R/A
Kamloops-ES	A	A	1	1	0	E Summ	still Amber
Francois-Fraser-S	R A	A G	0.5	1.5	1	Summer	improved
Chilko-S & Chilko-ES agg.	G	G	2	2	0	Summer	still Green
Harrison River (River-Type)	G	G	2	2	0	Summer	still Green
Harrison (U/S)-L	A	R	1	0	-1	Late	declined
Cultus-L	R	R	0	0	0	Late	still Red
Seton-L	UNDET	R	Na	0	Na	Late	declined
Lillooet-Harrison-L	G	A	2	1	-1	Late	declined
Harrison (D/S)-L	G	A G	2	1.5	-0.5	Late	declined
Shuswap Complex-L	G	A G	2	1.5	-0.5	Late	declined

Table 9: The 2017 Integrated statuses for the 24 Fraser River Sockeye Salmon CUs, organized by Area. CUs were given a numerical score that corresponds to their integrated status: 0=R (Red), 0.5=R/A (Red/Amber), 1=A (Amber), 1.5=A/G (Amber/Green) and 2=G (Green). The difference between the 2017 score and the 2012 score are ranked from most negative to most positive.

	Status		Score				
Conservation Unit	2012	2017	2012	2017	Diff	AREA	Change
Widgeon (River Type)	R	R	0	0	0	1. L.Fraser-Pitt	still Red
Pitt-ES	A G	G	1.5	2	0.5	1. L.Fraser-Pitt	improved
Cultus-L	R	R	0	0	0	2. L.Fraser-Chllwck	still Red
Chilliwack-ES	R A	A G	0.5	1.5	1	2. L.Fraser-Chllwck	improved
Harrison (U/S)-L	A	R	1	0	-1	3. L.Fraser-Harr	declined
Lillooet-Harrison-L	G	A	2	1	-1	3. L.Fraser-Harr	declined
Harrison (D/S)-L	G	A G	2	1.5	-0.5	3. L.Fraser-Harr	declined
Harrison River (River-Type)	G	G	2	2	0	3. L.Fraser-Harr	still G
Nahatlatch-ES	R	A	0	1	1	4. M.-Fraser-Nah.	improved
Anderson-Seton-ES	A	A G	1	1.5	0.5	5. M.-Fraser S/A	improved
Seton-L	UNDET	R	Na	Na	Na	5. M.-Fraser S/A	now Red
North Barriere-ES	A	A	1	1	0	6. Thompson-North	still A
Kamloops-ES	A	A	1	1	0	6. Thompson-North	still A
Shuswap-ES	A G	A	1.5	1	-0.5	6. Thompson-North	decline
Shuswap Complex-L	G	A G	2	1.5	-0.5	6. Thompson-North	decline
Taseko-ES	R	R	0	0	0	7. M.-Fraser-Chilko	still Red
Chilko-S/Chilko-ES agg.	G	G	2	2	0	7. M.-Fraser-Chilko	still G
Chilko-ES	DD	DD	Na	Na	Na	7. M.-Fraser-Chilko	still DD
Quesnel-S	R A	R A	0.5	0.5	0	8. U. Fraser-Quesnel	still R/A
Francois-Fraser-S	R A	A G	0.5	1.5	1	9. U. Fraser-Nechako	improved
Nadina-Francois-ES	R	A G	0	1.5	1.5	9. U. Fraser-Nechako	improved
Takla-Trembleur-EStu	R	R	0	0	0	10. U. Fraser-Stuart	still Red
Takla-Trembleur-Stuart-S	R A	R A	0.5	0.5	0	10. U. Fraser-Stuart	still R/A
Bowron-ES	R	R	0	0	0	11. U. Fraser	still Red

Table 10: Smax values estimated using photosynthetic rate (PR) models (where available) are presented for non-cyclic CUs with recruitment data, and Chilliwack-ES. These values are estimated for each CU's respective juvenile rearing lake (as indicated by the CU's name or noted in column 1). PR model Smax values for recent years are not available at the time of this publication. Average Smax values from these surveys were used as informative β parameter priors for the estimation of relative-abundance benchmarks using the Ricker model (see equation 1, 2, 4a & b).

Conservation Unit (CU)	Years	S_{max}	S_{max} Average (β prior average)	Used for Ricker BM
Anderson-Seton	2000	311,954	286,000	No
	2001	332,410	-	-
	2002	290,394	-	-
	2003	209,392	-	-
Bowron-ES	2004	40,883	41,000	Yes
Cultus-L	2001	89,627	85,000	-
	2002	99,985	-	-
	2009	66,695	-	-
Chilko-ES/Chilko-S (unfertilized years only)	1985	423,507	483,000	Yes
	1986	332,477	-	-
	1989	321,171	-	-
	1994	540,470	-	-
	1995	529,576	-	-
	2009	751,788	-	-
Chilliwack-ES	2001	55,721	41,000	Yes
	2002	34,352	-	-
	2009	32,583	-	-
Francois-Fraser-S (used Fraser Lake only)	1992	745,232	600,000	No
	1994	461,681	-	-
Harrison (U/S)-L	1999	587,670	811,000	No
	2000	1,034,002	-	-
Kamloops-ES	2007	444,642	445,000	No
Lillooet-Harrison-L (used Lillooet Lake only)	2000	164,486	164,000	No
Nadina-Francois-ES	1992	1,671,118	1,350,000	No
	1993	1,030,938	-	-
Pitt-ES	1989	115,306	115,000	Yes
Seton-L	2000	177,150	188,000	No
	2001	235,079	-	
	2002	168,560	-	-
	2003	172,559	-	-

11 FIGURES

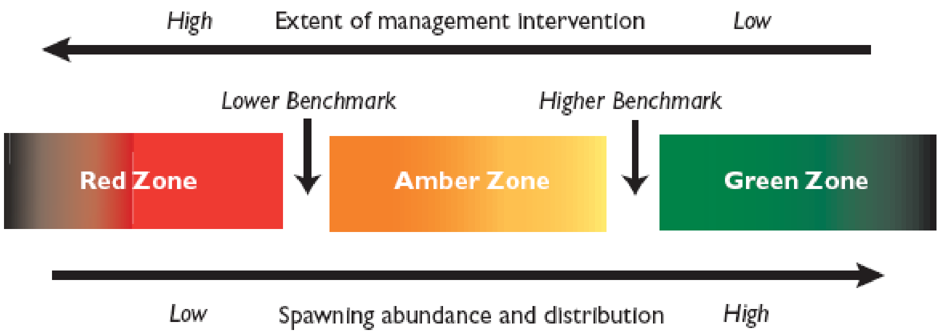


Figure 1. Wild Salmon Policy status zones (Red, Amber, and Green) delineated by lower and upper benchmarks. Increasing spawner abundance is inversely related to the extent of management intervention. Reprinted from Fisheries and Oceans Canada (2005).

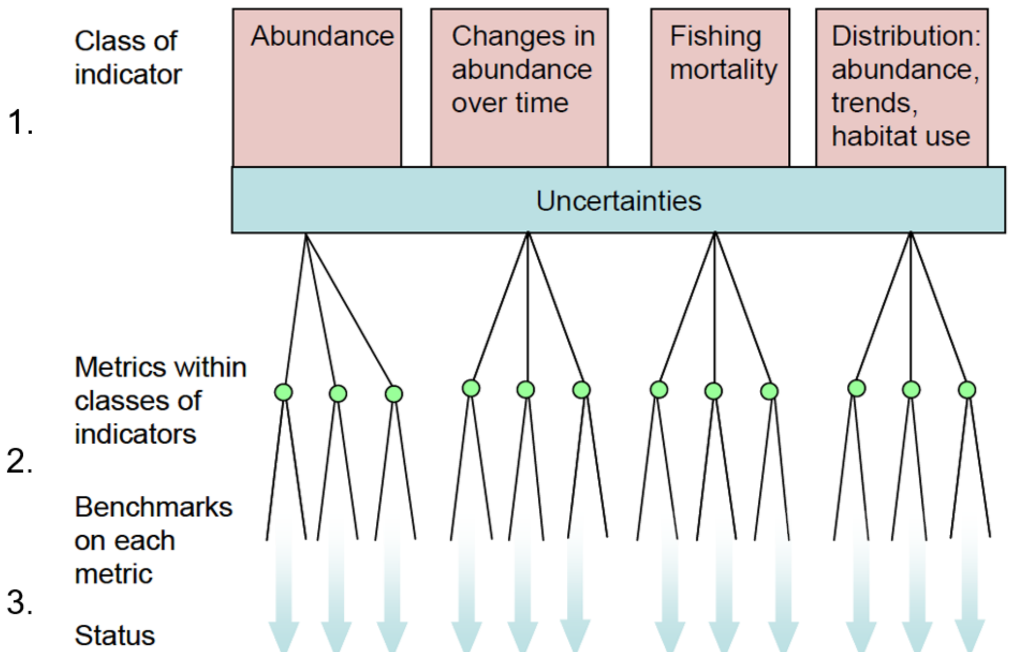


Figure 2. Hierarchy for the assessment of biological status of WSP CUs including 1) four classes of indicators, 2) quantifiable metrics within each indicator class, and 3) benchmarks on each metric. Reprinted from Holt et al. (2009)

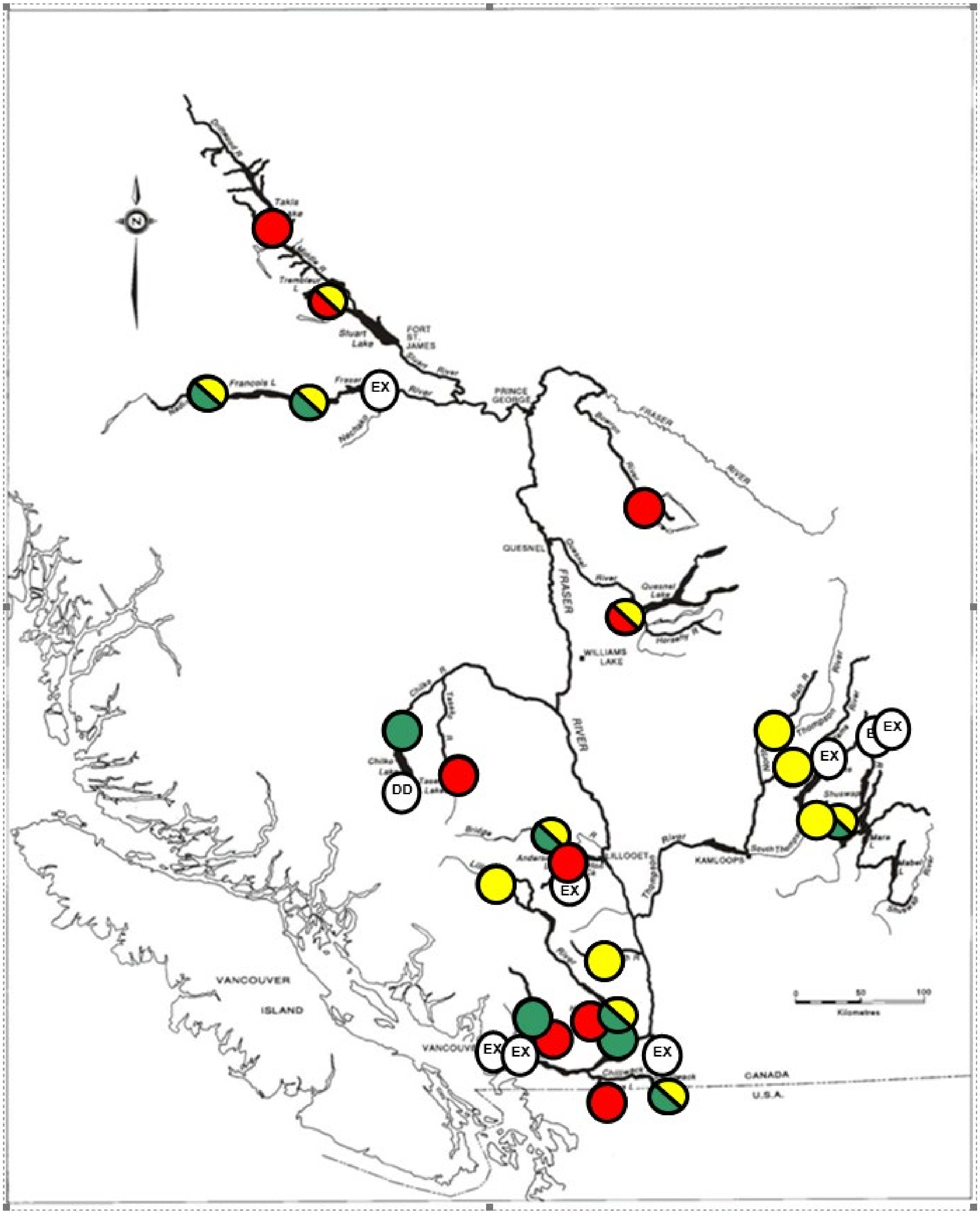


Figure 3. Map of the spawning distribution (darkened black lines) of Fraser River Sockeye CUs in south-western British Columbia with the 2017 integrated statuses indicated for each CU (see preceding table 4). There is one data deficient CU (DD) (Chilko-ES), as well as the 8 extirpated CUs (EX), indicated on the map.

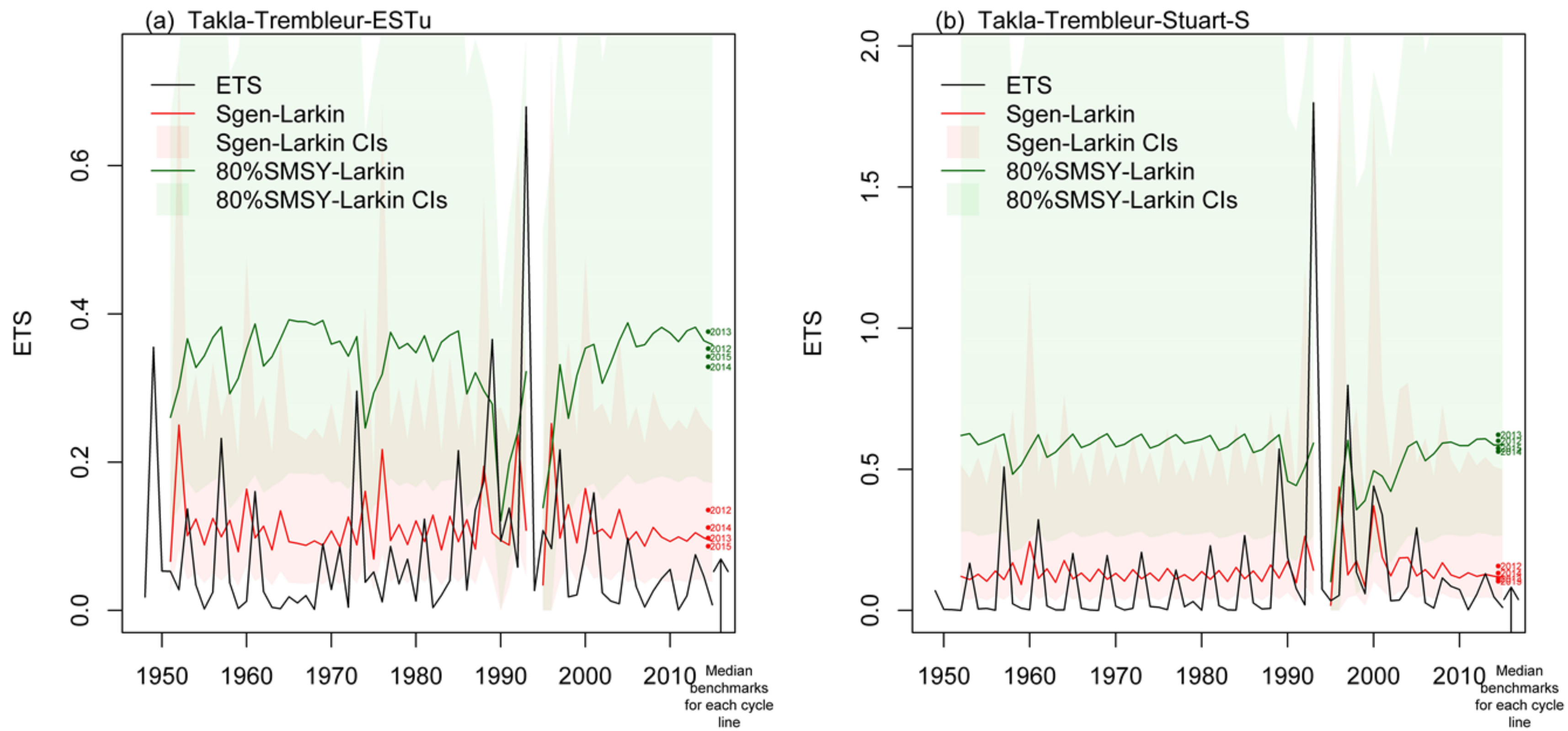


Figure 4. Time-series of annual Larkin benchmarks, Sgen (red line) and 80% of SMSY (green line) with 95% confidence intervals (CIs, red and green bands, respectively) for each cyclic CU (a) Takla-Trebmleur-EStu, (b) Takla-Trembleur-Stuart-S, (c) Quesnel-S, (d) Shuswap-ES, and (e) Shuwsap-L. Ricker lower and upper benchmarks based are shown with hollow red and green dots, respectively, on the left side of each plot (with 95% confidence intervals) For some CUs and years, the upper bound of the CIs for 80% SMSY extends beyond the y-limit of the plot. The areas of overlap between the CIs of the upper and lower benchmarks are coloured brown. Effective total spawner abundances are shown with the black line. The median benchmark values over the time-series for each cycle line are shown on the right side of the plot, labelled by the last year in the time-series (red for Sgen and green for 80% SMSY). Where the labels overlap, the benchmarks were almost indistinguishable.

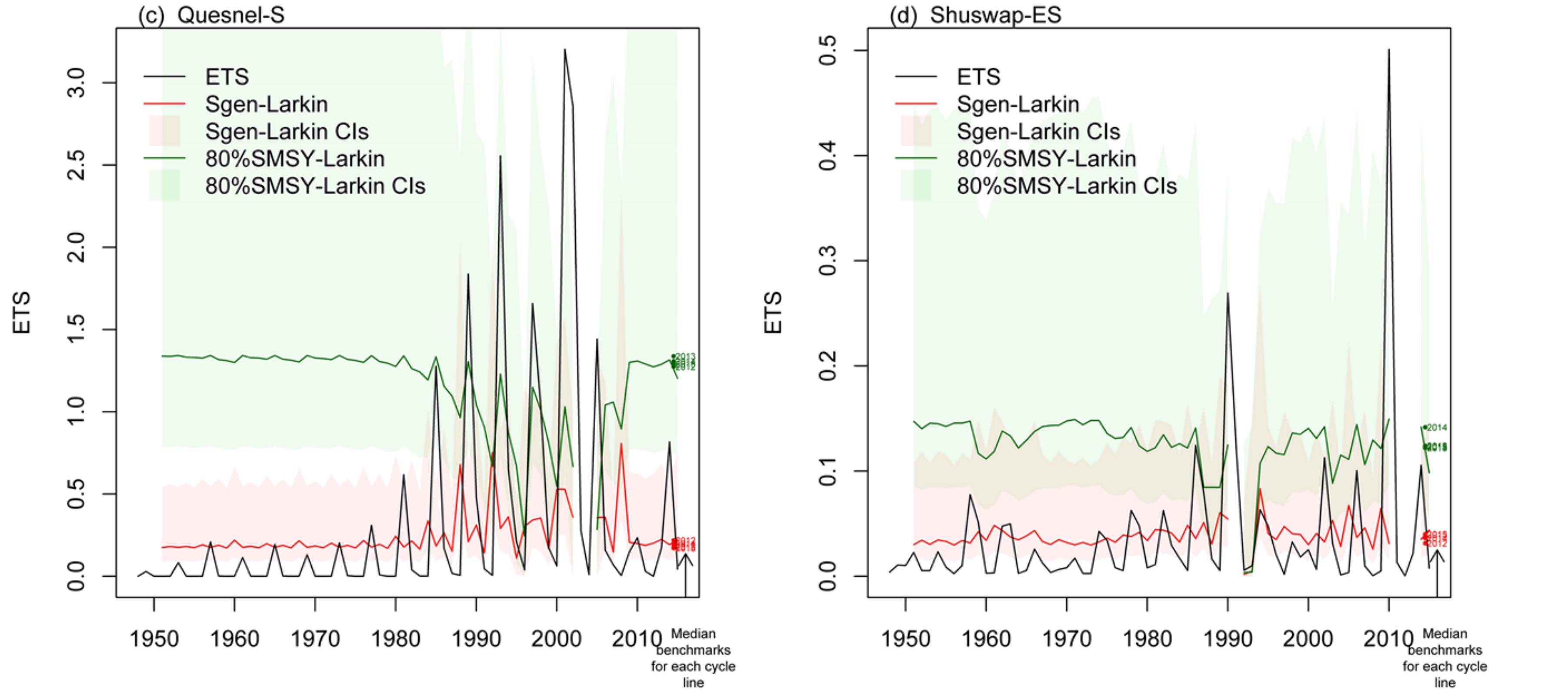


Figure 4 continued

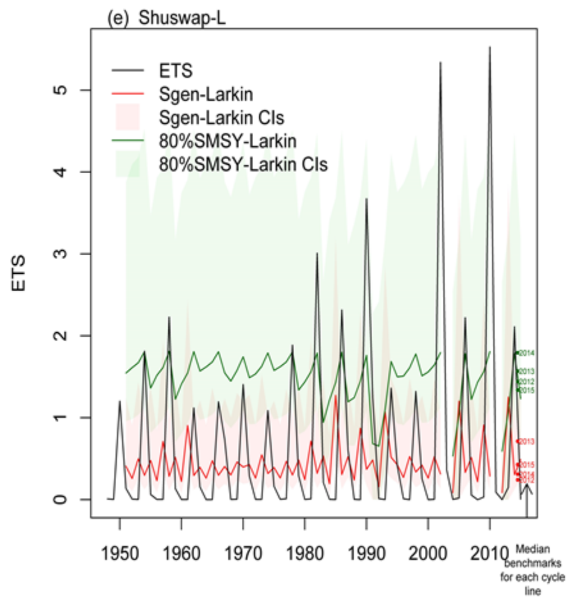


Figure 4 continued

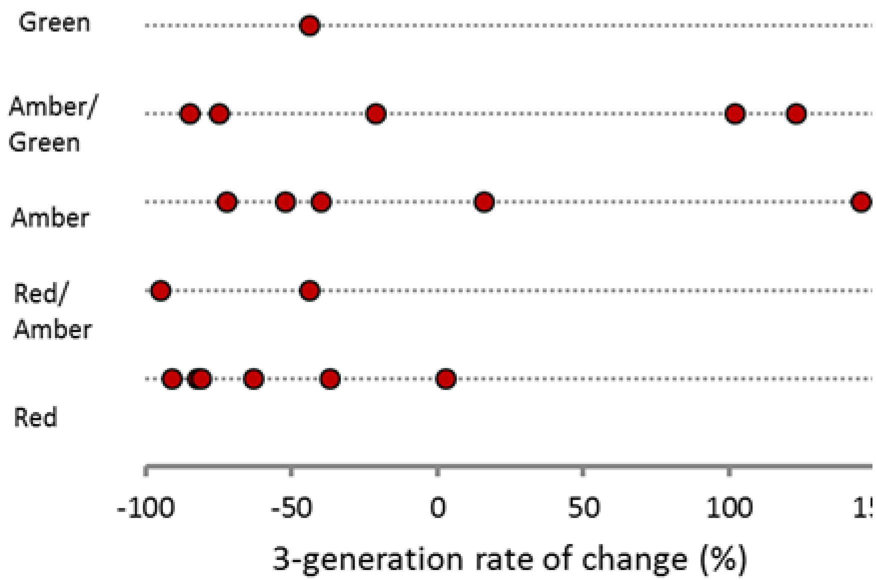


Figure 5. A Fraser Sockeye CU's three generation rate of change (percent) compared to their final integrated status (presented in Appendix 2).

APPENDIX 1: GUIDE TO 2017 DATA SUMMARIES

Participants received a data summary for each CU to support their assessments. This guide explains the key pieces of information presented in these data summaries.

Purpose of Data Summaries

- Standardized summary of available data by CU; all data have been updated from Grant et al. (2011) to include escapement data up to 2015 and recruitment data up to 2011.
- Emphasis on status metrics in Grant et al (2011), with additional information provided.
- Data summaries were modified based on feedback by workshop participants, and those revised summaries are appended in Appendix 2.

Overview

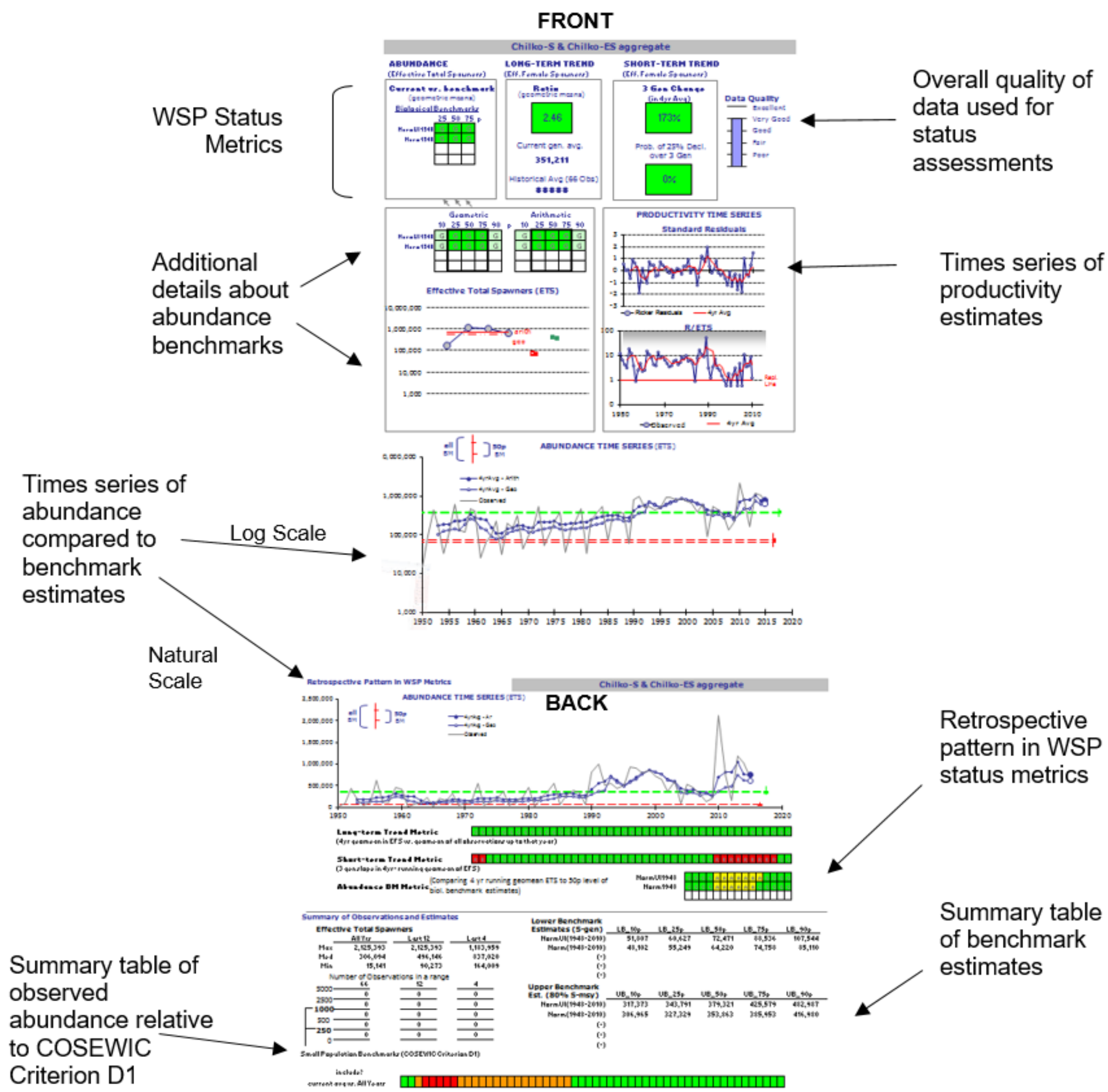


Figure A1-1. Overall guide to the first page of data summaries.

Section 1: Comparison to Abundance Benchmark

Key Point: This metric compares the average abundance of the most recent generation to estimates of the lower benchmark (S_{gen}) and upper benchmark (80% S_{MSY}) for each CU. WSP status is Red if the last generation abundance is below the lower benchmark, Green if it is above the upper benchmark, and Amber if it is between the lower and upper benchmarks.

Key Challenge: How to integrate uncertainty in benchmarks (and resulting status assessments) for each CU that includes 1) across alternative population dynamic models (rows in benchmark tables); and 2) across probability levels that reflect uncertainty in the model fit to the data (columns in benchmark tables).

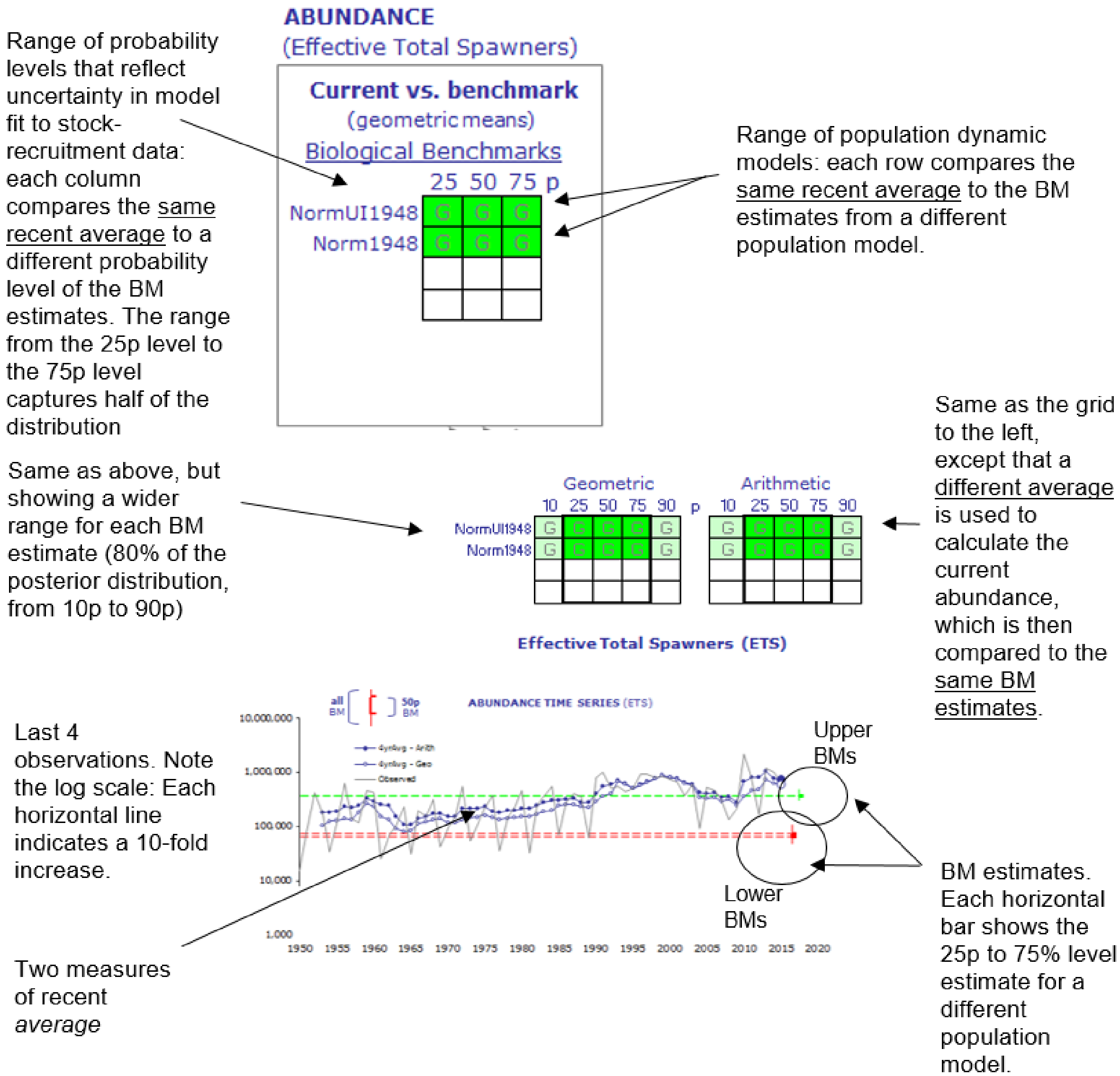


Figure A1-2. Detailed guide to the first page of data summaries.

Section 2: Trend Metrics

Key Point: These metrics assess recent trends in abundance over the last three generations (up to 2010) and long-term trends (current generation average abundance relative to the long-term average)

Key Challenge: Interpreting <u>both</u> metrics together.

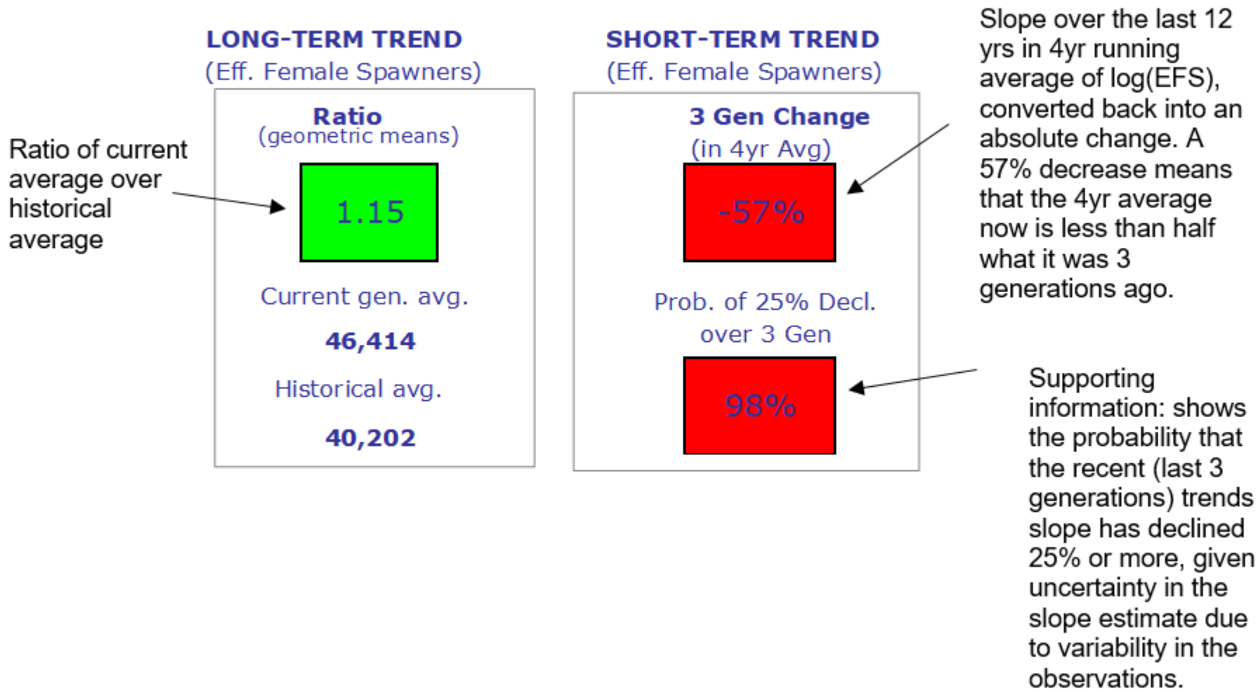


Figure A1-3. Detailed guide to long-term and short-term trend metric on first page of data summaries.

Section 3: Escapement Data Quality

Overall quality of data used in status evaluations.

This is a global score for all years in a time series. For highly cyclic CUs like Late Shuswap, the data quality score will be for the highest proportion of the total abundance over four years. On dominant cycles, high precision (high quality) escapement estimates are generated. For weak cycles, low precisions (fair) escapement estimates are generated.

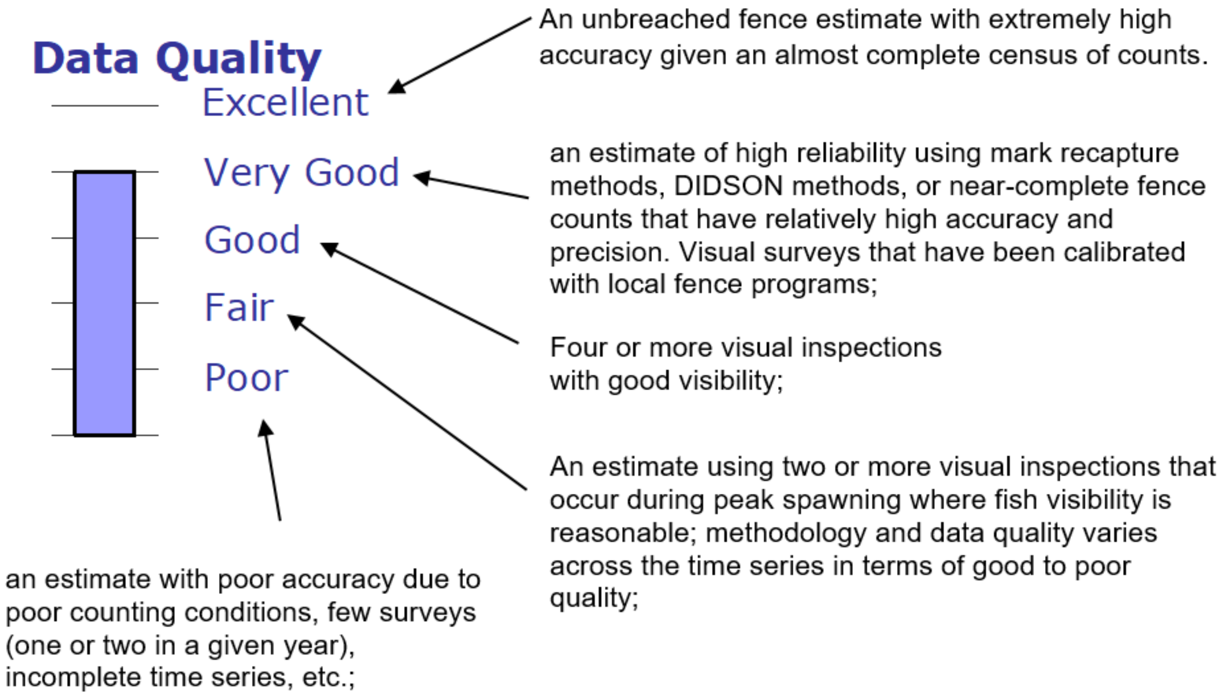


Figure A1-4. Guide to data quality

Section 4: Productivity patterns

Key Point: Observed productivity (recruits / spawner) can show pronounced trends over time.

Key Challenge: Should this information be considered in the evaluation of status, and if so, how?

The points show standardized Ricker or Larkin model residuals (Ricker for non-cyclic CUs; Larkin is used for cyclic CUs). Years with positive deviations had higher than average productivity. The red line is the running 4yr average of the residuals, which starts on the second year of the data set

Points show the raw estimates of productivity over time, and the red line shows a running 4yr average. Note the log scale, such that each horizontal line marks a 10-fold increase. If R/ETS is less than 1, the population failed to replace itself in that generation. R/ETS larger than about 20 are probably due to biased estimates.

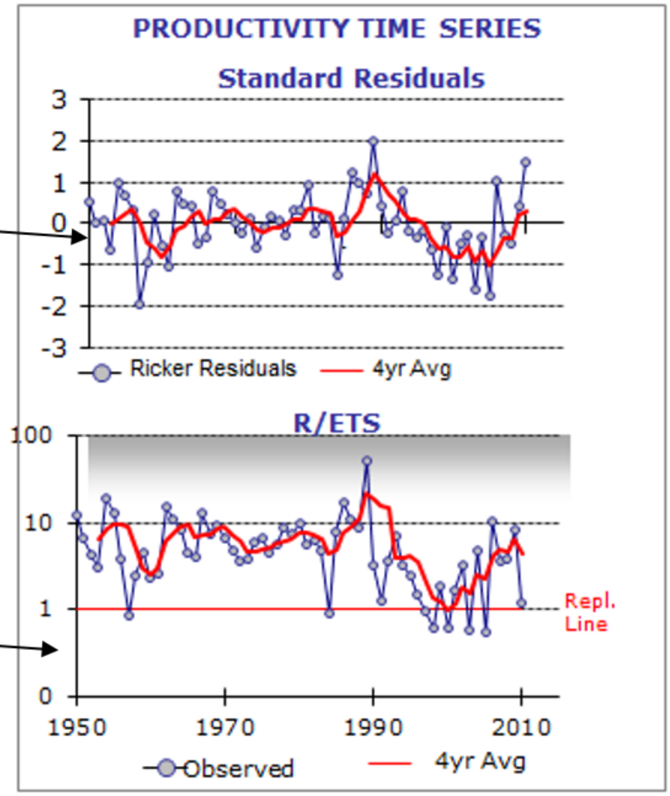


Figure A1-5. Guide to a CU's productivity trends in first page of the data summaries. Top figure is standard Ricker residuals (blue lines and dots) with smoothed four year running average (red line). Bottom figure is recruits-per-effective total spawner (R/ETS) (blue line and dots) with smoothed four year running average (red line); replacement line where one recruit=one spawner is indicated (Repl. Line). Note that not all CUs have productivity data, so this figure will not be available for each CU.

Section 5: Times Series of Abundance Compared to Benchmarks

Key Point: Show pattern in abundance over time compared to <u>current</u> estimates of abundance benchmarks.

Key Challenge: Considering uncertainty in BM estimates (i.e. across population models and probability levels). Another challenge is considering how BM estimates may change, especially with models that incorporate time-varying productivity.

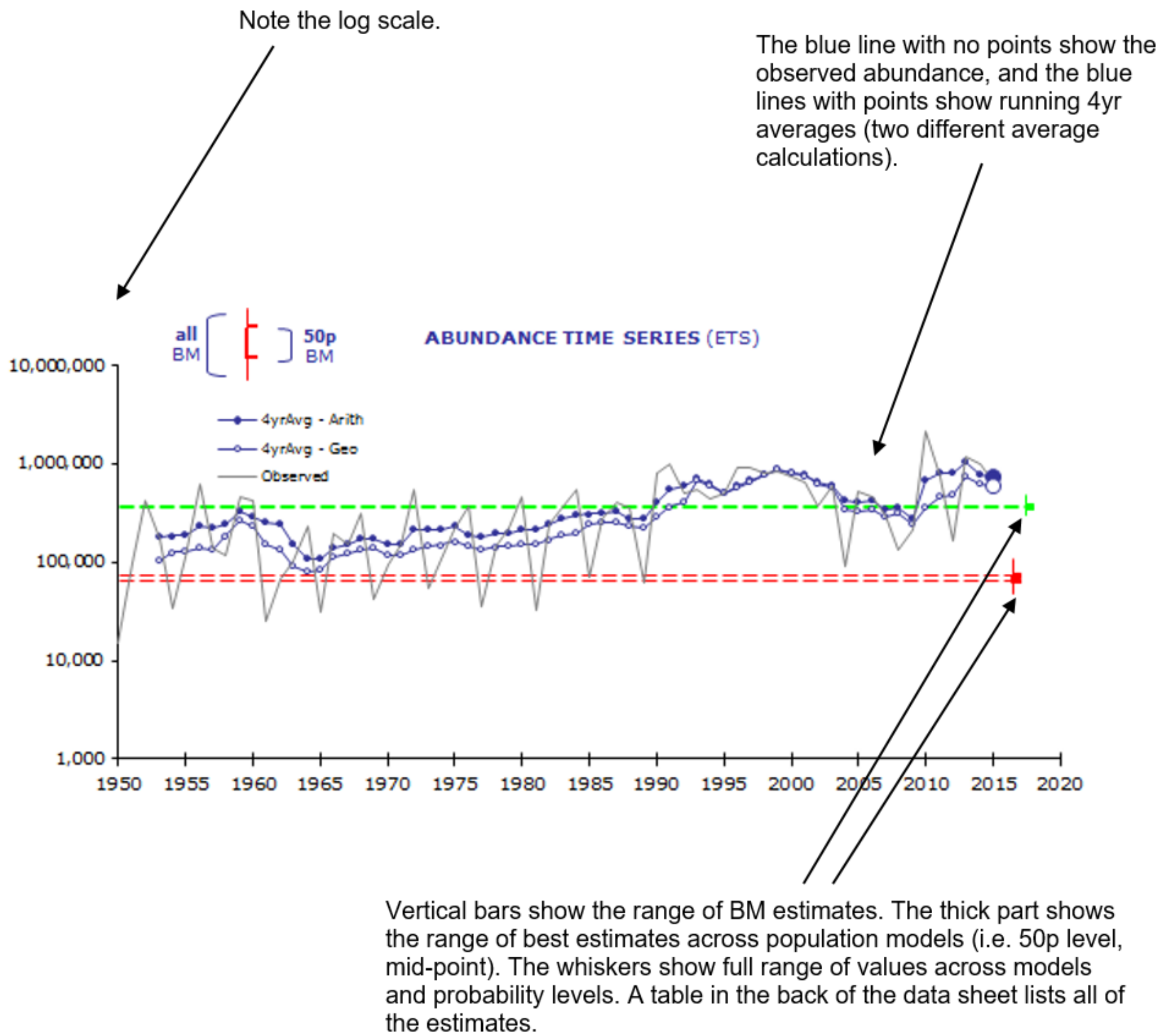
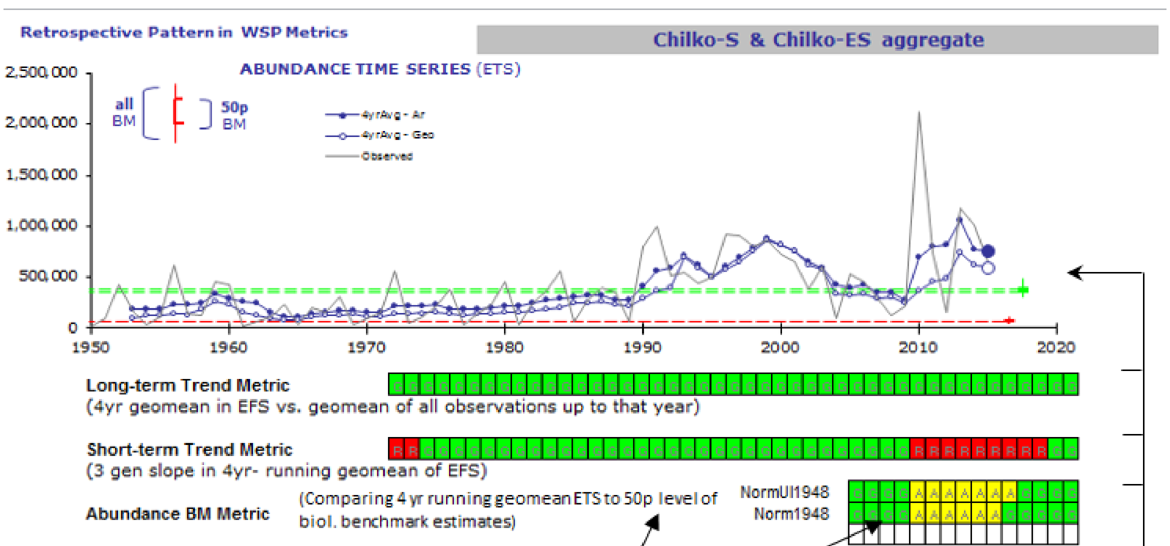


Figure A1-6. Guide to log abundance trends on second page of data summaries.

Section 6: Retrospective Pattern in Status Metrics

Key Point: All 3 metrics are designed to describe current status, but they differ in their sensitivity to changing observations through time.

Same as the previous time series plot, just on a natural scale rather than a log scale. This emphasizes the pattern in large abundances.



Status over the time series using data up to each end year on the time series axis

Lines up with time series above

Median (50% p-level) benchmarks were not re-estimated across years; only the last generation abundance was re-estimated up to each end year on the time series axis, and compared to current benchmarks.

Last column corresponds to values shown on top of front page (50p levels for abundance BM metric).

Figure A1-7. Guide to retrospective trends in abundance and abundance metrics on the second page of the data summaries.

Section 7: Summary Tables

Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	2,125,393	2,125,393	1,183,959
Med	306,094	496,146	837,020
Min	15,141	90,273	164,009

Number of Observations in a range

5000	66	12	4
2500	0	0	0
1000	0	0	0
500	0	0	0
250	0	0	0
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2010)	51,807	60,627	72,471	88,536	107,544
Norm(1948-2010)	48,102	55,249	64,220	74,758	85,110
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2010)	317,373	343,791	379,321	425,579	482,987
Norm(1948-2010)	306,965	327,329	353,863	385,953	416,980
(-)					
(-)					
(-)					

COSEWIC D Criteria (for reference):

<1,000 mature individuals: 'threatened'

<250 mature individuals: 'endangered'

Benchmarks across model form (rows) and probability levels (columns)

Figure A1-8. Guide to COSEWIC criteria in the context of a CUs abundances in the last four, twelve and entire time series. The number of observations falling above 1,000, or 250, individuals. Guide to lower and upper benchmarks estimated for a CU using one or more model forms. Length of time series used is included in brackets. Benchmarks are presented at 10% (10p), 25% (25p), 50% (50 p), 75% (75 p), and 90% (90p) probability levels for lower benchmark (LB) and upper benchmark (UB).

APPENDIX 2: 2017 INTEGRATED STATUS NARRATIVES AND DATA SUMMARIES FOR THE 24 FRASER SOCKEYE CUS

OVERVIEW

Status narratives are presented in Appendix 2 (with the CU name identified) in alphabetical order. For each CU the following information is presented:

- Background: this section contains relevant background extracted from Grant et al. (2011) and recent information to assist specifically with the status integration process; it does not contain a synthesis of all biological and assessment information provided in previous reports (Grant et al. 2011; Grant & Pestal 2013);
- Benchmark Analysis (Abundance Metrics): this section provides the general background on whether relative-abundance benchmarks were estimated for a CU, and if they were estimated, the general description of approach;
- Summary of final integrated status:

2017 Status	2012 Status
A/G	A

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A/G	G	A/G	G	A/G	A/G	G	G	A/G
After Plenary	A/G	A/G	A/G	A/G	A/G	A/G	G	A/G	A/G
Change?		Y		Y				Y	
Num Changes	3								

Figure A2-1. First row are the integrated status for each CU in 2017 (recent year) and 2012 (first year). The second row compares the integrated statuses for the CU by each individual before the plenary session, and the third row is after the plenary session.

  - This includes the 9 participants individual integrated status in the 1st row; participants are identified by number not name to retain anonymity;
  - The 2nd row contain each individual's integrated status following the plenary sessions; individual statuses have changed in some cases as a result of the plenary discussion;
  - The 3rd row identifies with the letter Y (for Yes) if an individual changed their integrated status after the plenary;
  - The 4th row box indicates the number of individuals that changed their status following the plenary; summarizing the number of yes's (Y) in the 3rd row.

- Status Commentary: provides a synthesis of the narratives that influenced the integrated status assessment rolled up from individual written narratives and plenary discussions; for cyclic CUs, narratives for statuses bot with or without Larkin relative-abundance benchmarks are included.
- Points of Discussion: additional points of discussion brought up either in individual written narratives or plenary discussions;

Standardized Data Summaries: standardized data summary packages (see Appendix 1 for Data Summary guide) used to inform these status assessments; where available, exploitation, recruits, and spawner time series are provided;

ANDERSON-SETON-ES (I.E. GATES) (AMBER/GREEN)

Background: Forest harvesting and other human activities were believed to have deteriorated habitat quality prior to the 1960's, as a result, a channel was constructed between 1967-1968 to compensate for this loss to production; the channel accounts for a high proportion of this CU's production. Both Gates Creek and the Channel are included in the escapement time series for status evaluations. Note: similar to Seton-L, these fish must migrate through a hydroelectric facility, which can challenge migration (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series for Anderson-Seton-ES includes the brood years 1950-2010. Although historically this CU exhibited cyclic dominance (dominant cycle line: 1956), this has not occurred for the past two decades (post-2000). Therefore, a Ricker model was used to estimate benchmarks for this CU's relative-abundance metric. The S_{max} derived from the PR model exceeded the spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Anderson-Seton-ES	**A/G**	**A**

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A/G	G	A/G	G	A/G	A/G	G	G	A/G
After Plenary	A/G	A/G	A/G	A/G	A/G	A/G	G	A/G	A/G
Change?		Y		Y				Y	
Num Changes	3								

Figure A2-2. First row presents final integrated statuses for Anderson-Seton-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber/Green integrated status was driven by the Green short-term and long-term trend statuses and the fact that no years out of the past four fell below the COSEWIC Criterion for small populations (1,000); the general declining productivity pattern for this CU contributed to lowering the status to Amber/Green, although there have been improvements in productivity since the 2012 status assessment;
- the Amber/Green status was also influenced by the mixed Amber/Green relative-abundance metric (i.e. at probability levels below 75% this metric was Amber and at probability levels above the 50% probability level this metric was Green);
- in the retrospective evaluation, the short-term trend has been Green for the past 6 years and the long-term trend has been Green for most of the time series;
- the current status (Amber/Green) of this CU has improved since the previous assessment (Amber); in the previous assessment, one metric indicated a Red status, whereas, in the current assessment no metrics indicate a Red status;

Points of Discussion

- the relative-abundance-based Ricker benchmarks were flagged by some participants; there was some concern with the Ricker model's estimation of carrying capacity and, as a result, a few individuals placed less weight on this metric for this CU;

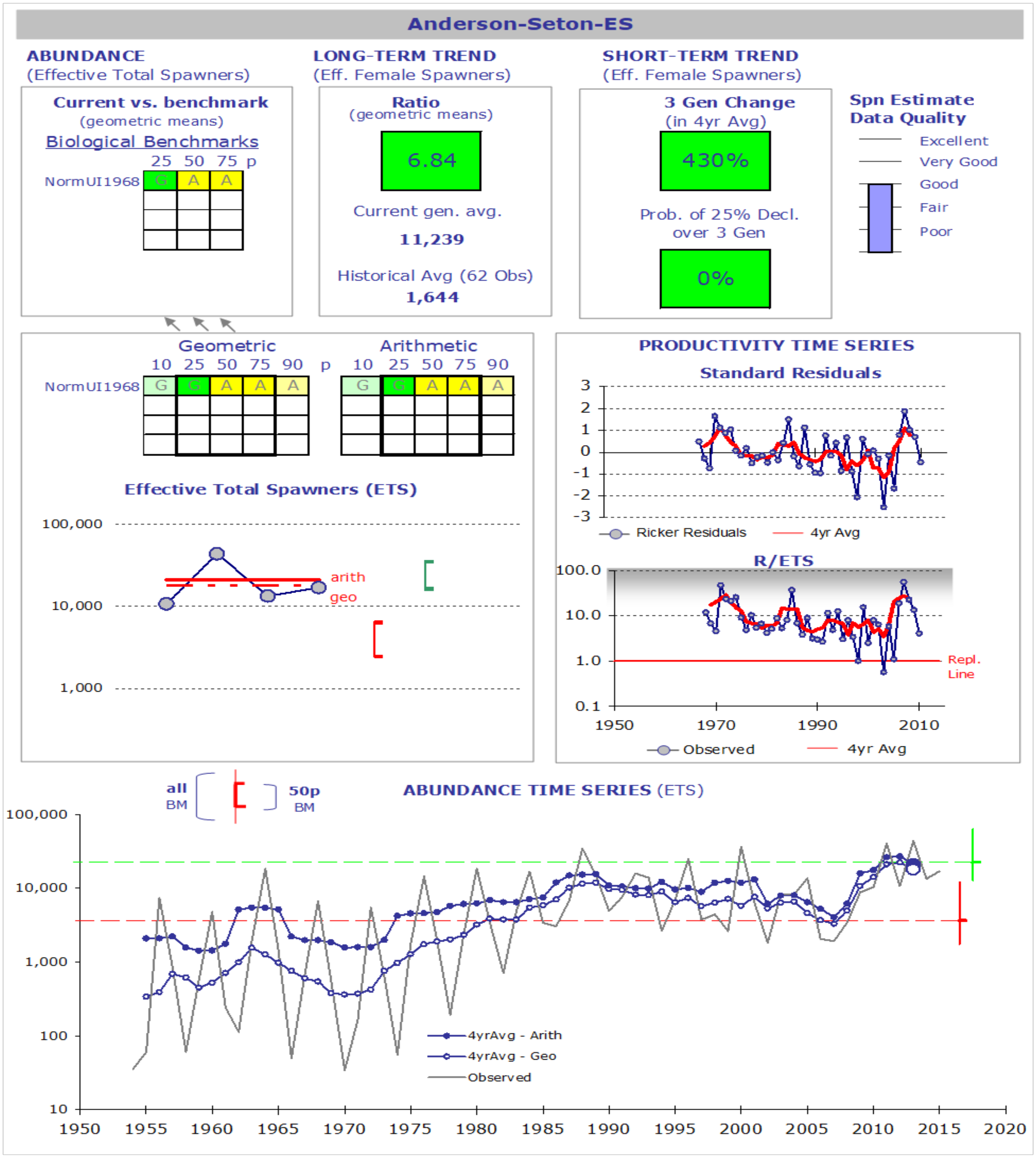


Figure A2-3. Anderson-Seton-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1

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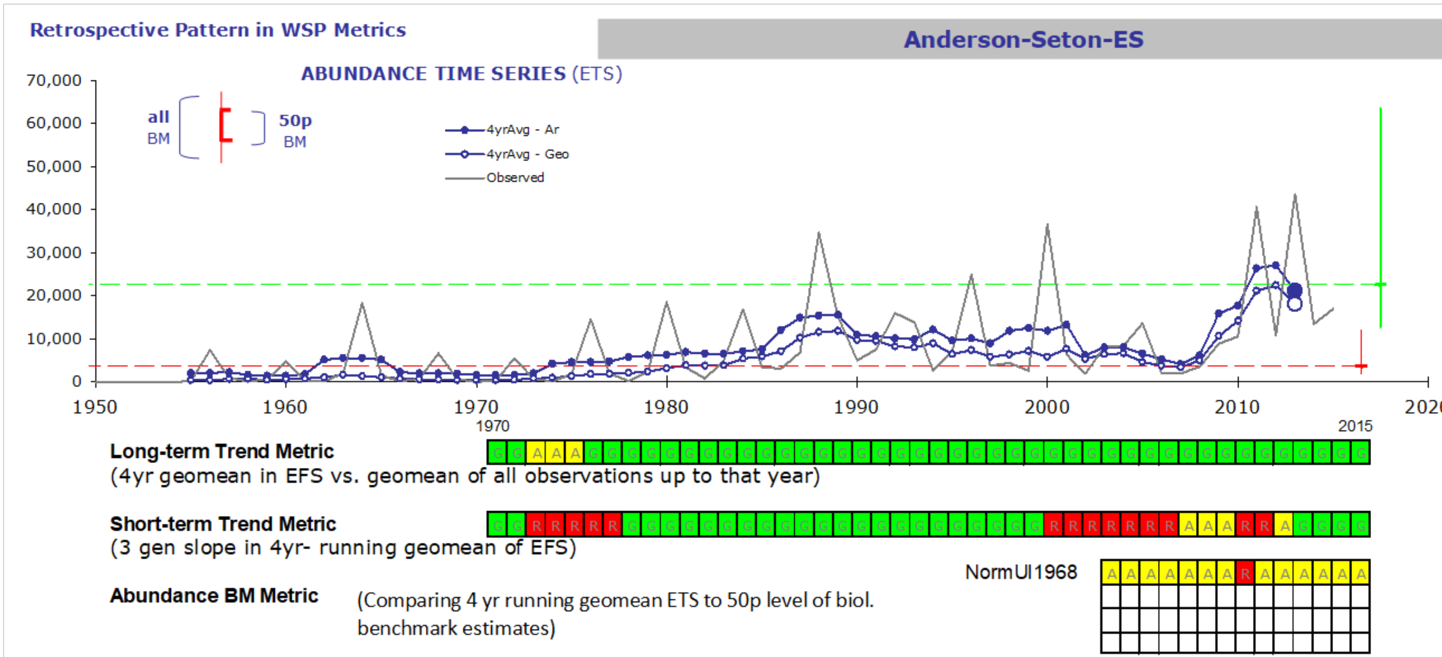


Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	43,654	43,654	43,654
Med	4,087	10,601	15,161
Min	34	1,932	10,714

Number of Observations in a range

	All Yrs	Last 12	Last 4
>5000	27	9	4
2500–5000	11	1	0
1000–2500	8	2	0
500–1000	6	0	0
250–500	0	0	0
0–250	10	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1968-2010)	1,747	2,440	3,662	6,292	12,222
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1968-2010)	12,802	16,200	22,534	34,607	63,588
(-)					
(-)					
(-)					
(-)					

Figure A2-4. Anderson-Seton-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

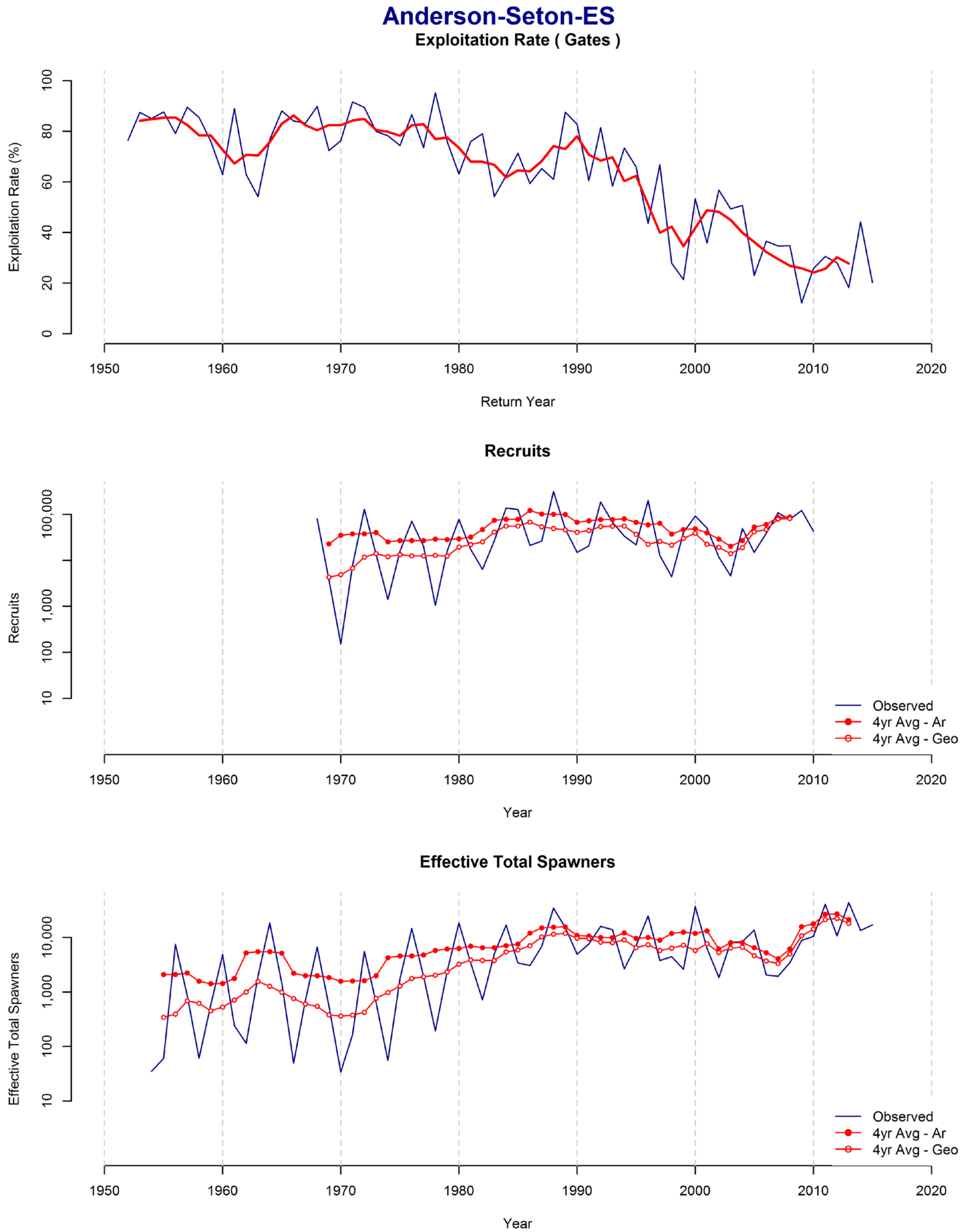


Figure A2-5. Anderson-Seton-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

BOWRON-ES (RED) Background: This CU's expansion after Hells Gate landslide is attributed to remnant Bowron Sockeye (see Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series for Bowron-ES includes the brood years 1950-2010. Although historically this CU exhibited cyclic dominance (dominant cycle line: 1955), this has not occurred for several decades now. Therefore, a Ricker model was used to estimate benchmarks for this CU's relative-abundance metric. The S_{max} derived from the PR model seemed reasonable when compared to the spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, a Ricker model was applied with both an informative and uninformative prior on the beta parameter. Both priors resulted in Red statuses for the relative-abundance metric across all probability levels.

Bowron-ES	R	R

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R	R	R	R		R
After Plenary	R	R	R	R	R	R	R		R
Change?									
Num Changes	0								

Figure A2-6. First row presents final integrated statuses for Bowron-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by consistently Red statuses for almost all probability levels and model forms of the relative-abundance metric benchmarks, and across all trends in abundance metrics. In addition, this CU has exhibited very low recent absolute abundances: one year in the last four was below the COSEWIC Criterion for small populations (1,000). Note that thi9s low abundance year was assessed with visual surveys, and is therefore very uncertain;
- for the past decade, all metrics (long-term trends, short-term trends, and relative-abundance metrics) have been Red in status;
- productivity has been systematically decreasing for this CU, although there have been some slight improvements in the past seven years;
- the current status (Red) of this CU has not changed since the previous assessment;

Points of Discussion

- There has been a recent improvement in productivity; this needs to be tracked as it could lead to improvements in this CU's status;
- Note: the low abundance of 30 fish in 2012 drives the Red short-term trend metric; since this escapement is estimated visually it is associated with a lot of uncertainty. In a sensitivity analysis, the escapement was doubled to 60, changing the short-term trend metric status to Amber. When the escapement is increased to 80 fish, the status changes to Green;

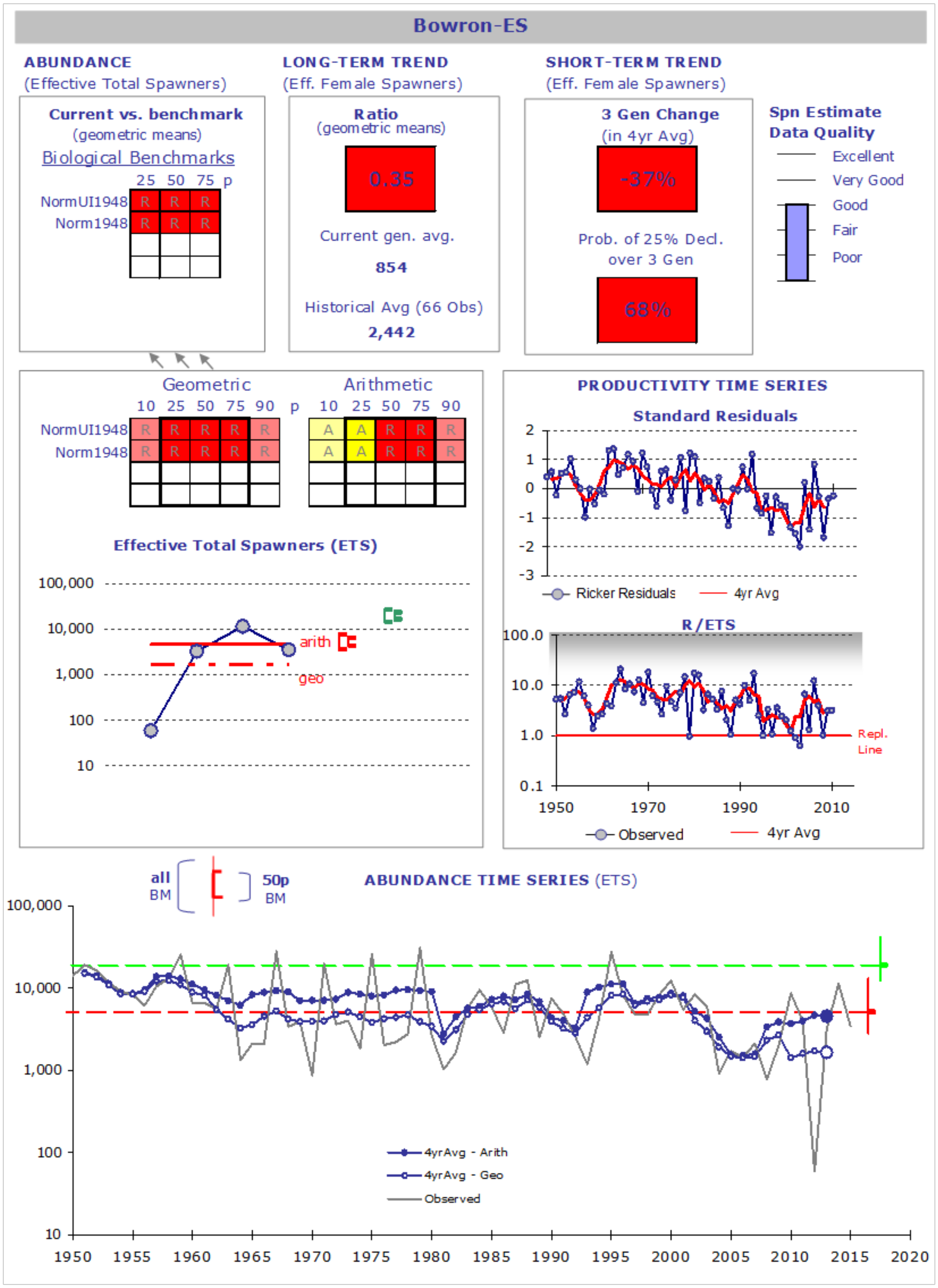
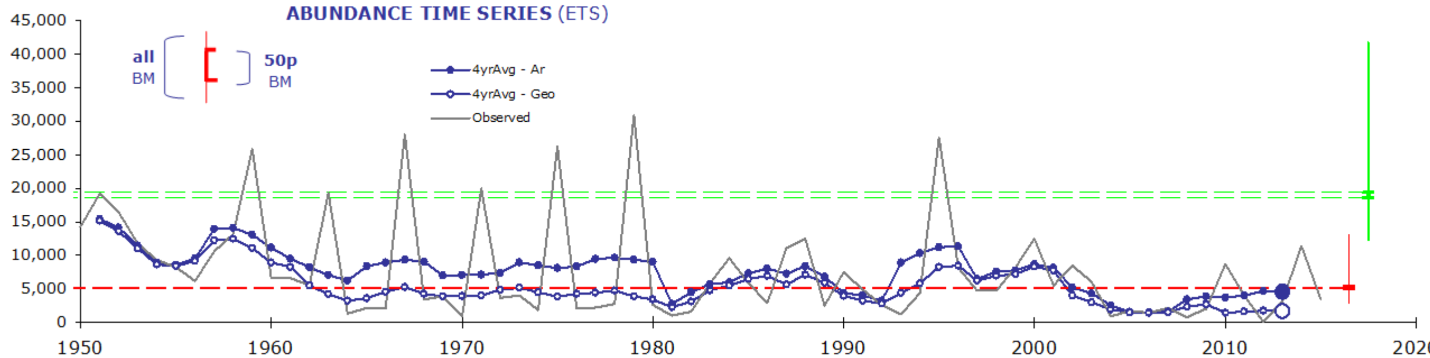


Figure A2-7. Bowron-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Bowron-ES



1970 … 2015

Long-term Trend Metric
(4yr geomean in EFS vs. geomean of all observations up to that year)

A A A A A A A A A A A A A A A A A G G G G G G G A A A G G G G G G G G G A R R R R R R R R R

Short-term Trend Metric
(3 gen slope in 4yr- running geomean of EFS)

R R R R R G G G G G G G G R R R A G G G G G G G G R R R A G G G G G G G R R R R R R R R R R

Abundance BM Metric (Comparing 4 yr running geomean ETS to 50p level of biol. benchmark estimates)

NormUI1948	A	A	R	R	R	R	R	R	R	R	R	R	R	R
Norm1948	A	A	R	R	R	R	R	R	R	R	R	R	R	R

Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	30,898	11,413	11,413
Med	5,212	2,075	3,343
Min	59	59	59

Number of Observations in a range

Range	All Yrs	Last 12	Last 4
> 5000	33	2	1
2500–5000	16	3	2
1000–2500	13	4	0
500–**1000**	3	2	0
250–500	0	0	0
0–**250**	1	1	1

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2010)	2,800	3,621	5,047	7,658	13,185
Norm(1948-2010)	3,619	4,314	5,249	6,491	7,856
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2010)	12,285	14,604	18,580	26,557	41,680
Norm(1948-2010)	14,610	16,489	19,369	22,903	26,966
(-)					
(-)					
(-)					

Figure A2-8. .Bowron -ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

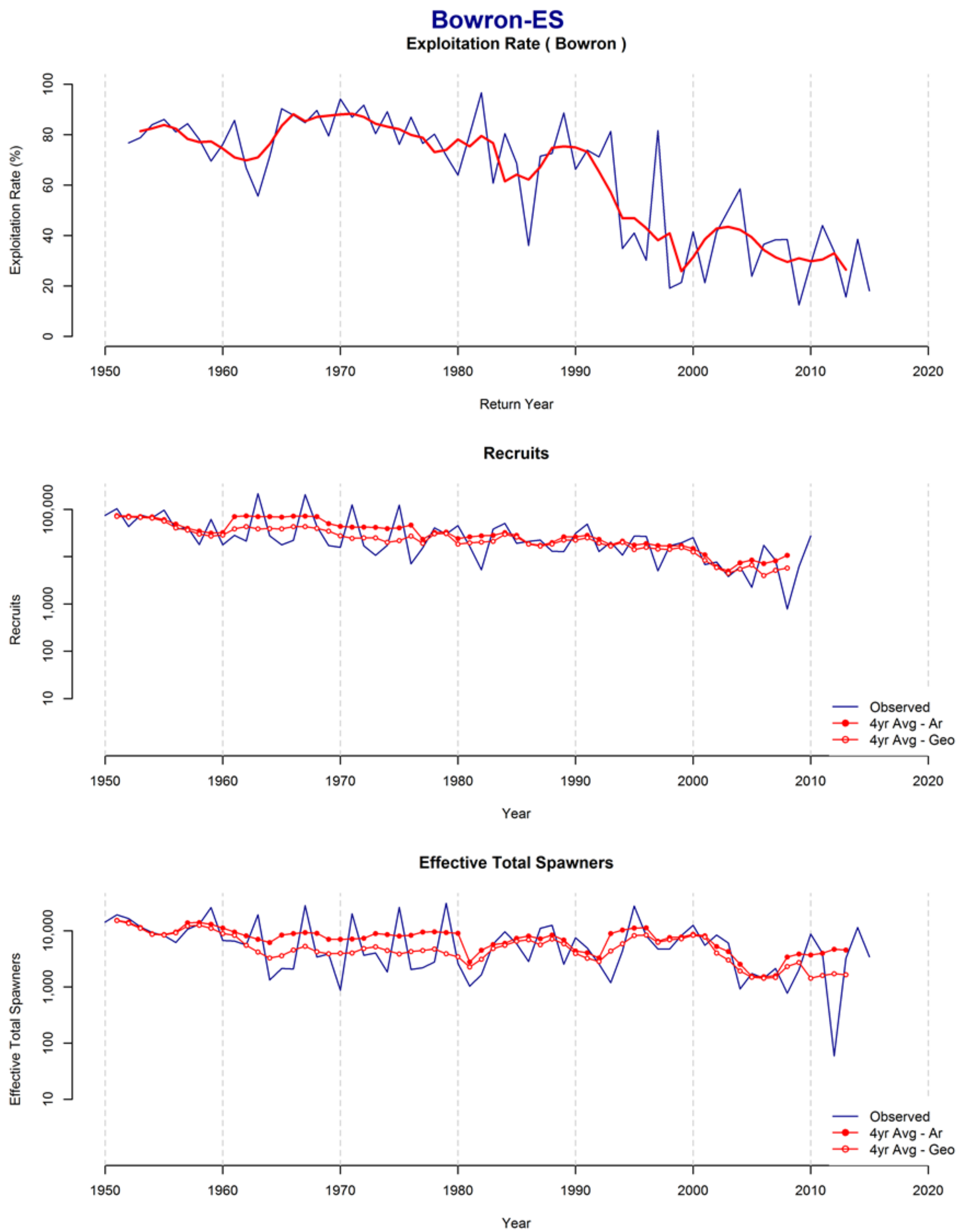


Figure A2-9. Bowron-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

CHILKO-ES/CHILKO-S (I.E. CHILKO) (GREEN)

Background: This CU was one of the least impacted by the Hells Gate landslide compared to other upper Fraser Sockeye populations. Chilko Lake was fertilized in 1988 and 1990-1993. In addition, a small artificial side channel was operated from 1988 to 2004 on Chilko River, to enhance the productive capacity of Chilko; although spawning habitat did not appear to be limiting to Sockeye at that time. See Akenhead et al. (2016) for an evaluation of the effect of these activities on the stock-recruitment time series for Chilko. Although this CU is distinct from the Chilko-ES CU (different run timing and spawning locations in the Chilko watershed), data for these two CUs currently have not been disaggregated. Since the Chilko-ES abundance comprises less than 10% of the combined Chilko-S & Chilko-ES aggregate, status information for the aggregate is assumed to represent this larger Chilko-S CU (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series for Chilko-ES/Chilko-S includes the brood years 1950-2010. This CU has not exhibited cyclic dominance historically. Therefore, a Ricker model was used to estimate benchmarks for this CU's relative-abundance metric. The S_{max} derived from the PR model (excluding fertilized years) seemed reasonable when compared to the spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). However, there has been a notable increase in primary production observed in this system in recent years, which is not captured in the available S_{max} data (D. Selbie, DFO, pers. comm.). Therefore, a Ricker model was applied with both informative and uninformative priors on the beta parameter.

	2017 Status	2012 Status
Chilko-S & Chilko-ES aggregate	G	G*

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	G	G	G	G	G	G		G
After Plenary	G	G	G	G	G	G	G		G
Change?									
Num Changes	0								

Figure A2-10. First row presents final integrated statuses for Chilko-ES/Chilko-S in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Green integrated status was driven by consistently Green relative-abundance metric statuses across all benchmark probability levels and model forms; high data quality was noted for this CU; no years on the time series fall below the COSEWIC Criterion for small populations (1,000); the long-term trend metric is also Green;
- productivity and short-term trends (Green) have improved; in the previous assessment both these trends were declining and were flagged as a risk to deteriorating status had they continued; the long-term trend metric was also Green;
- based on retrospective analysis, the relative-abundance metric has been Green for five years; the long-term trend has been Green for a number of decades, and the short-term trend has been Green for the last three years;
- the current status (Green) of this CU has not changed since the previous assessment;

Points of Discussion

- although not included in the data summary, marine survival has been close to average since the 2006 brood year, although it dropped in the 2011 brood year.

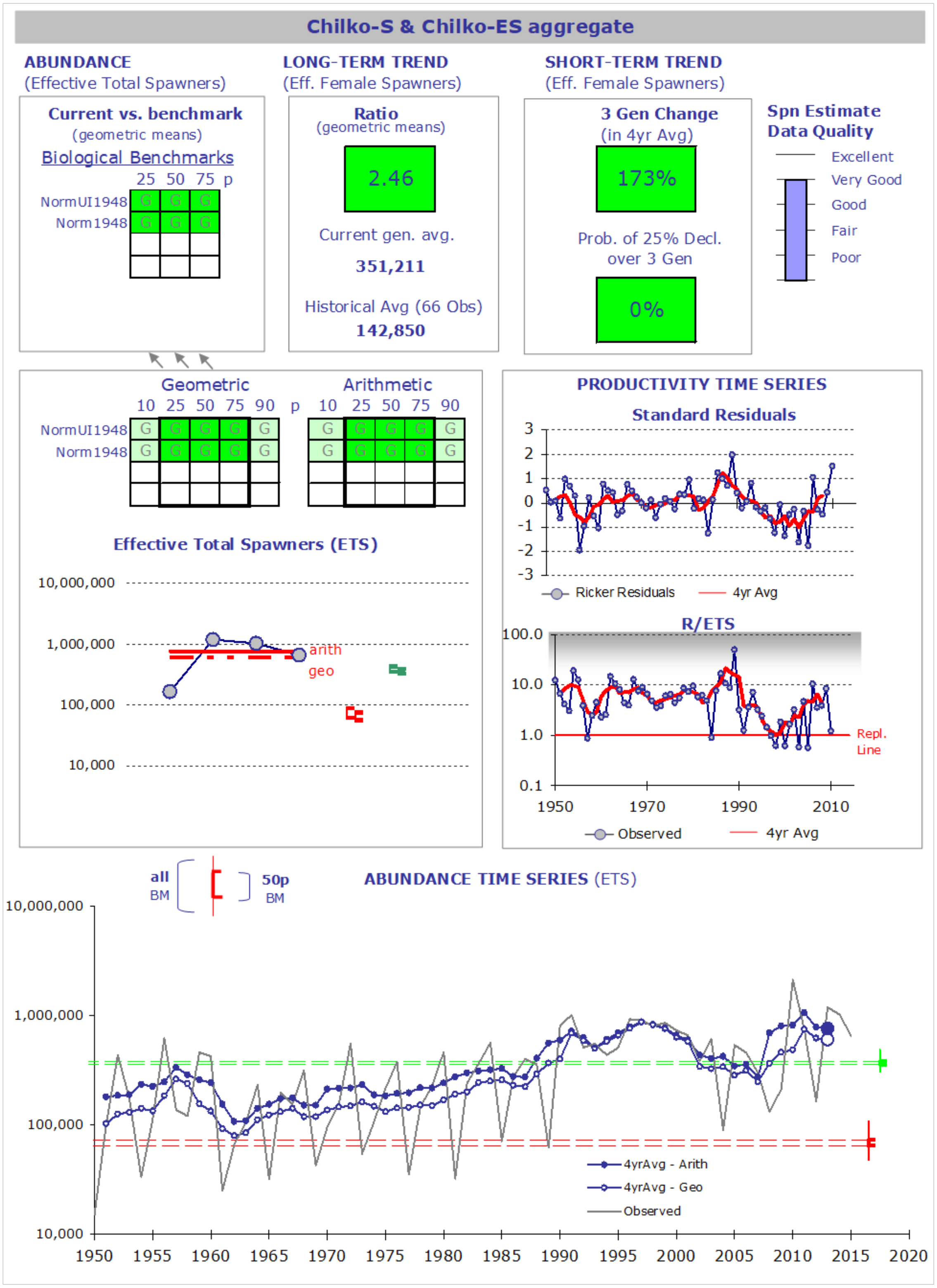
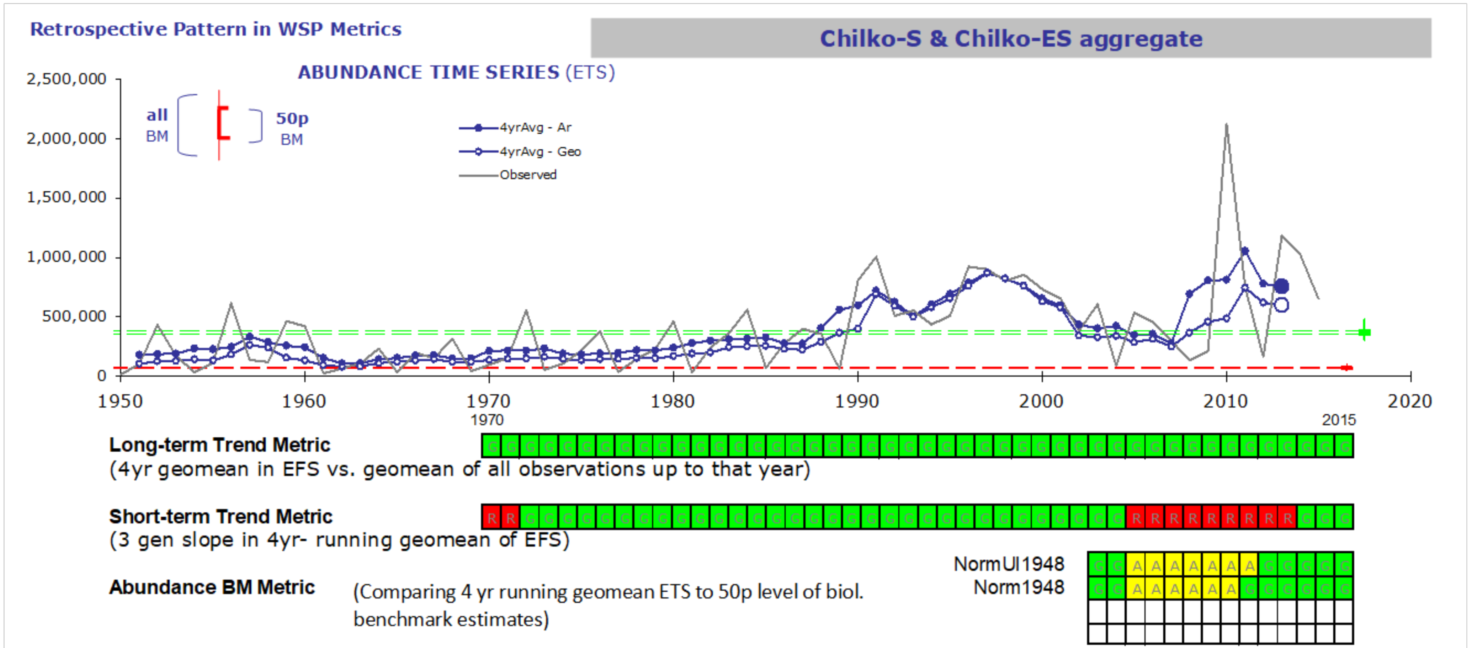


Figure A2-11. Anderson-Seton-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	2,125,393	2,125,393	1,183,959
Med	306,094	496,146	837,020
Min	15,141	90,273	164,009

Number of Observations in a range

	All Yrs	Last 12	Last 4
	66	12	4
5000	0	0	0
2500	0	0	0
1000	0	0	0
500	0	0	0
250	0	0	0
0			

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2010)	51,807	60,627	72,471	88,536	107,544
Norm(1948-2010)	48,102	55,249	64,220	74,758	85,110
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2010)	317,373	343,791	379,321	425,579	482,987
Norm(1948-2010)	306,965	327,329	353,863	385,953	416,980
(-)					
(-)					
(-)					

Figure A2-12. Chilko-S & Chilko-ES aggregrate data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

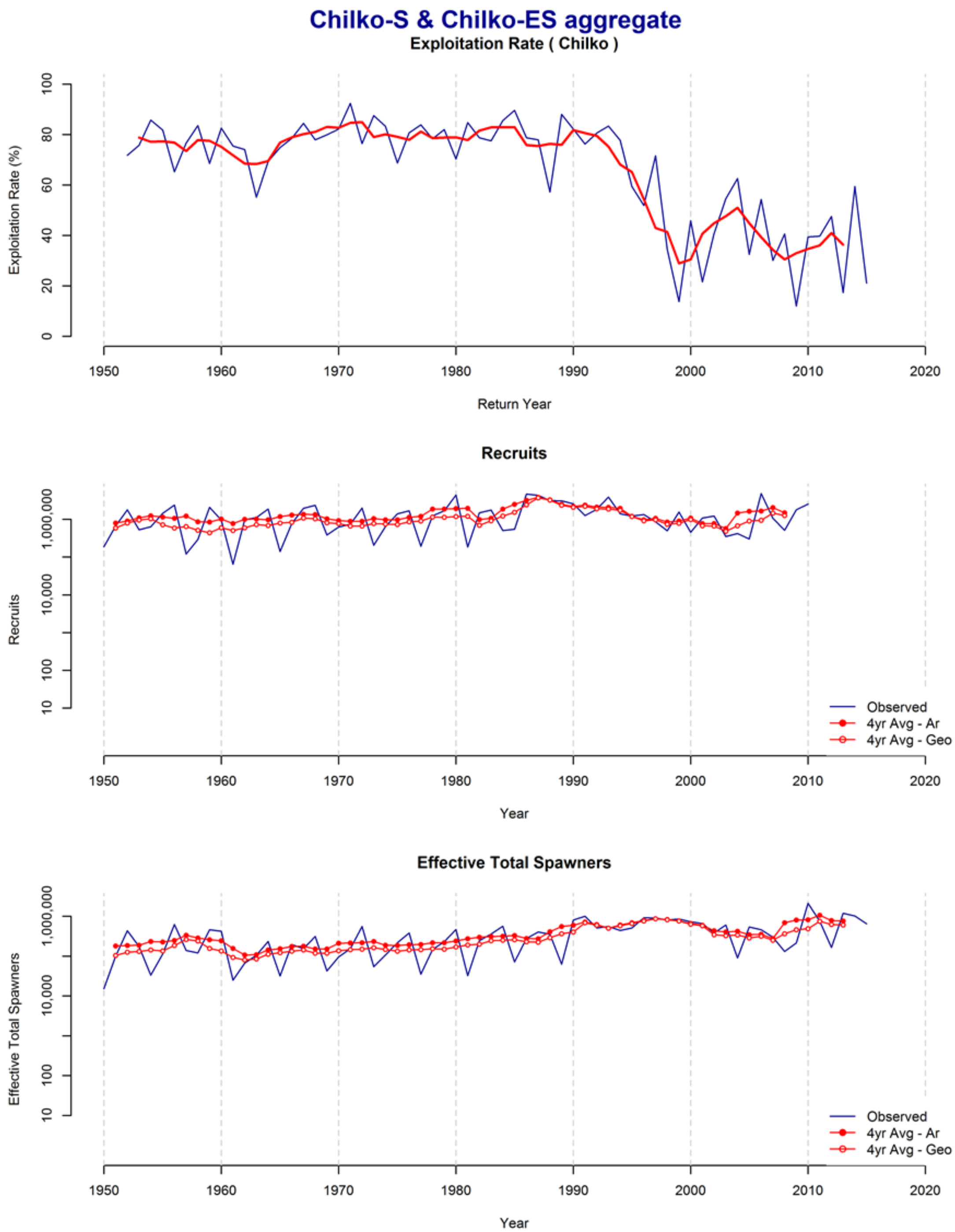


Figure A2-13. Chilko-S & Chilko-ES aggregate data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

CHILKO-ES (I.E. CHILKO) (DATA DEFICIENT)

Background: Although this CU is distinct from the Chilko-S CU (different run timing and spawning locations in the Chilko watershed), the data for this CU currently has not been disaggregated from the larger Chilko-S CU. The Chilko-ES abundance comprises less than 10% of the combined Chilko-S & Chilko-ES aggregate (see Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): Recruitment data are not available for this CU.

	2017 Status	2012 Status
Chilko-ES	DD	DD

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	DD	DD	DD	DD	DD	DD	DD		DD
After Plenary	DD	DD	DD	DD	DD	DD	DD		DD
Change?									
Num Changes	0								

Figure A2-14. First row presents final integrated statuses for Chiko-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- similar to the previous assessment (Grant & Pestal 2013), the integrated status could not be evaluated for this CU given the lack of available independent data;

Points of Discussion

- participants in the previous assessment recommended that an escapement index and proxy exploitation rate for Chilko-ES be developed to provide information for subsequent status evaluations, however, this has not been completed to date;
- there are historic tagging data that suggest that there is overlap in the spawning distribution of the Chilko-ES and Chilko-S CUs (K. Benner, DFO, pers. comm.); more work is required to verify that the early summer timed component is a unique CU;

CHILLIWACK-ES (I.E. MISCELLANEOUS EARLY SUMMER) (AMBER/GREEN)

Background: Complete escapement assessments of this CU did not begin until 2001; prior to this year, the Upper Chilliwack River (Dolly Varden Creek) was not assessed in its entirety. Therefore, for consistency, this time series only includes 2001 to present. The lake component of the escapement estimates are considered fair in quality. Higher precision sonar methods have been applied in recent years to improve these estimates.

Benchmark Analysis (Abundance Metrics): The short stock-recruitment time series (2001-2010) available for this CU was not considered sufficient in length to estimate stock-recruitment benchmarks with a Larkin or Ricker model. Therefore, although this CU exhibits a cyclic pattern in its escapement time series, these two models could not be evaluated for suitability. Instead, as in the previous assessment, S_{max} estimates from a PR model were used to develop relative abundance benchmarks (Table 11; Grant et al. 2011; Grant & Pestal 2013).

	2017 Status		2012 Status
Chilliwack-ES	**A/G**	Cap BM	**R/A**

With Capacity Benchmarks									
Participant									
Individual Assessments	A/G	G	A	G	A/G		G		A/G
After Plenary	A/G	A/G	A/G	A/G	A/G		A/G		A/G
Change?		Y	Y	Y			Y		
Num Changes	4								

Figure A2-15. First row presents final integrated statuses for Chilliwack-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- this CU's Amber/Green integrated status was driven by the relative-abundance metric Amber status; the relative-abundance metric has been Amber for the past four years and was Red prior to that;
- no years in the time series fell below the COSEWIC Criterion for small populations (1,000)'
- the Green short-term trend and long-term trend statuses contributed to the integrated status; the short-term trend has been Green for the past 3 years and the long-term trend has been Green across the assessed time series;
- the short-time series was flagged, and this contributed to the down-weighting of the Green statuses on other metrics;
- the current status (Amber/Green) of this CU has improved slightly since the previous assessment (Amber);

Points of Discussion

- additional work has been conducted on the PR model estimates of carrying capacity for Chilliwack Lake in recent years; analyses to estimate S_{max} and apply this to status evaluation is recommended for this CU;
- if this CU is cyclic, further consideration of how to interpret the current relative-abundance metric based on capacity is required, since this could vary by cycle line;

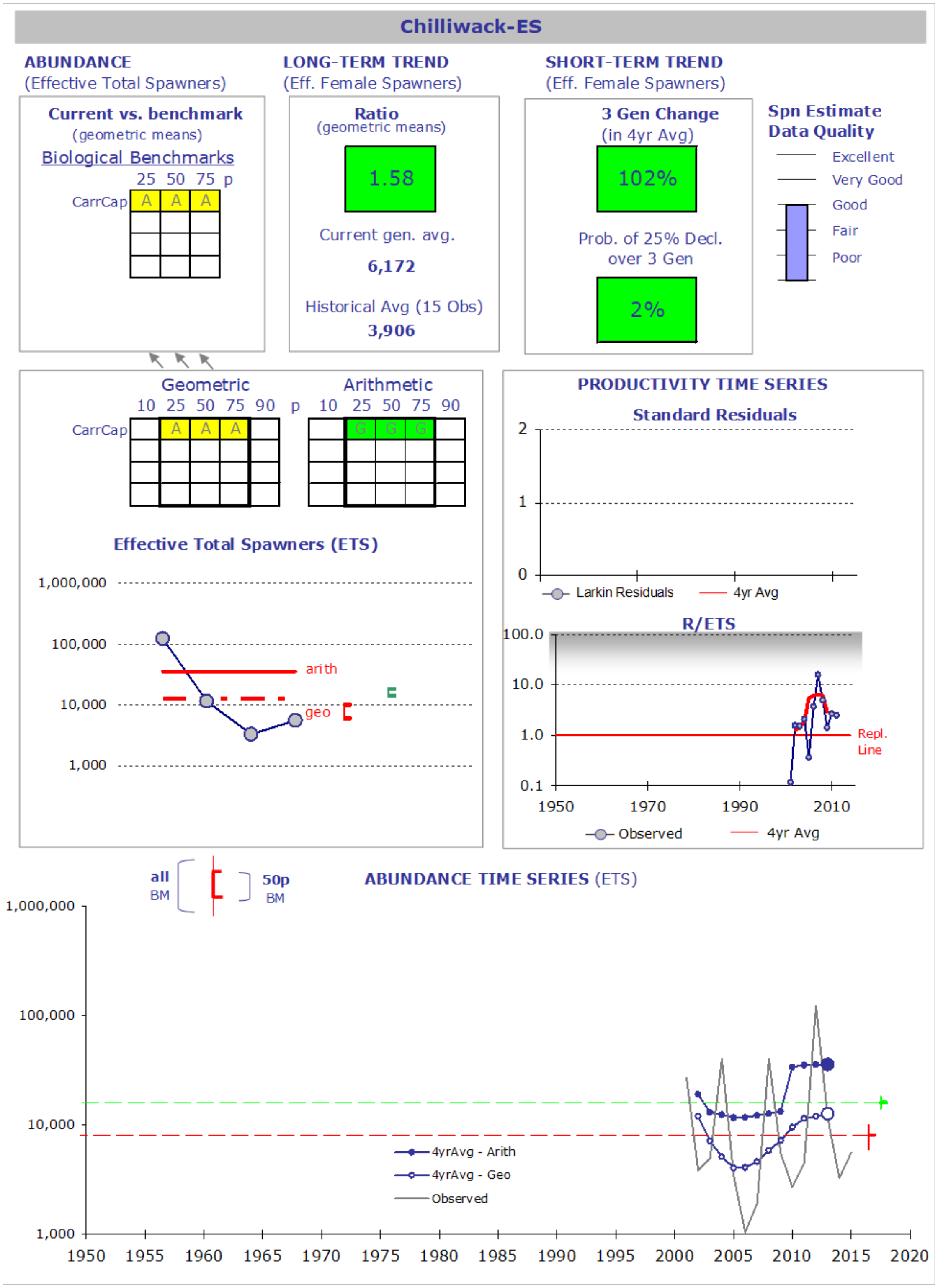
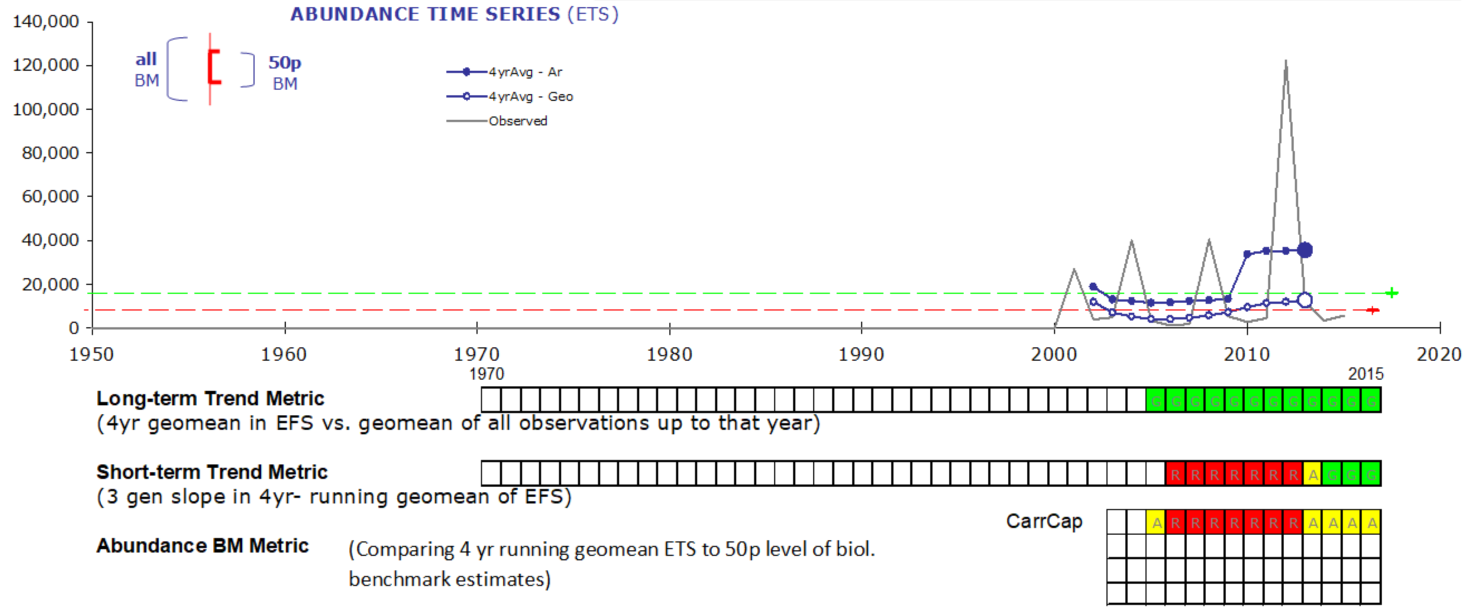


Figure A2-16. Chilliwack-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Chilliwack-ES



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	122,073	122,073	122,073
Med	4,920	4,979	8,526
Min	1,046	1,046	3,268

Number of Observations in a range

	All Yrs	Last 12	Last 4
>5000	7	6	3
5000	6	4	1
2500	2	2	0
1000	0	0	0
500	0	0	0
250	0	0	0
0			

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
CarrCap(-)		6,000	8,000	10,000	
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
CarrCap(-)		14,000	16,000	18,000	
(-)					
(-)					
(-)					
(-)					

Figure A2-17. Chilliwack-ES data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

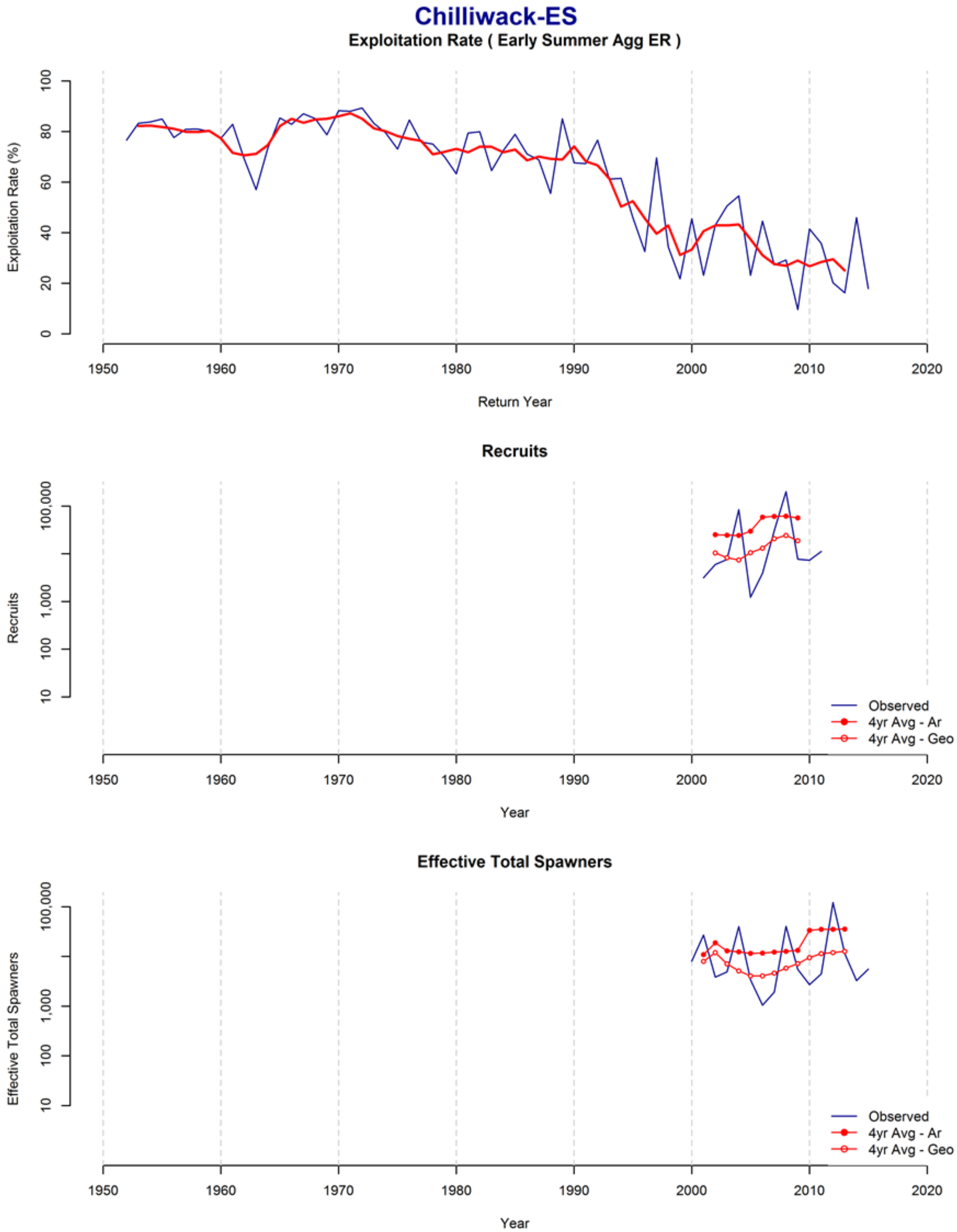


Figure A2-18. Chilliwack-ES data summaries page 3 : exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

CULTUS-L (RED)

Background: This CU was listed as 'endangered' by COSEWIC in 2003 (COSEWIC 2003). A Cultus Conservation Team has coordinated multiple initiatives focused on the recovery of this CU since this designation. For conservation purposes, this CU has been hatchery enhanced since 2000; all hatchery fish are marked with an adipose-fin-clip. Cultus Sockeye are enumerated at the counting fence located in Sweltzer Creek, along with unmarked fish. For this status assessment, hatchery marked fish are removed from the escapement time series. Adipose-clip failure occurs at a low rate in marked fish, which may result in some fish identified as 'wild' actually being hatchery fish. In addition, offspring from naturally spawning hatchery-origin parents remain in the escapement time series for the status assessment, since these fish have no external marks for identification at the enumeration fence. These offspring from hatchery-origin parents are not considered 'wild', as defined by the WSP. Note that while both a captive brood stock (CBS) and hatchery program were operated for a number of years starting in the 2000 brood year, the CBS program was terminated recently (see Grant et al. 2011). This has considerably reduced the number of smolts produced by this system.

Since Cultus Sockeye migrate through the enumeration fence months prior to spawning, their secondary sexual characteristics have generally not developed. Therefore, sex identification at the fence is poor. In recent years, validation of sex ratios from carcass surveys has been a challenge given the low escapements, and therefore, limited access to carcasses. The limited access to carcasses also creates challenges in estimating unbiased spawner success for females. As a result, total spawner abundances are used to evaluate escapement trends and for stock-recruitment relationships.

Benchmark Analysis (Abundance Metrics): The full stock-recruit time series for Cultus-L includes data from 1948-2000. The time series does not extend beyond the year 2000 because hatchery introductions confound the stock-recruitment relationship. Although historically this CU exhibited cyclic dominance (dominant cycle line: 1955), this has not occurred for several decades. Therefore, a Ricker model was used to estimate relative abundance benchmarks for this CU. The S_{max} estimate derived from the PR model exceeds the spawning capacity of this system, based on expert opinion of the capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Cultus-L	R	R

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R	R	R	R		R
After Plenary	R	R	R	R	R	R	R		R
Change?									
Num Changes	0								

Figure A2-19. First row presents final integrated statuses for Cultus-L in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by consistently Red statuses for all probability levels of the relative-abundance metric benchmarks, and for the long-term trend in abundance; in addition, three of the last four years and nine of the last 12 years EFS fell below the COSEWIC Criterion for small populations (1,000);

- productivity decreased for this CU in years preceding the 2000 brood year, before hatchery intervention; productivity data after 2000 could not be compared since these values are confounded by hatchery intervention;
- although the short-term trend metric is Green, the slightly increasing abundance is being supported by hatchery intervention (second generation hatchery enhanced fish that are unmarked); therefore, this metric is not given much weight; it is unclear whether this CU would currently be sustainable in the absence of hatchery intervention;
- the retrospective analysis indicates that the long-term, short-term and relative-abundance metrics have been Red for almost two decades (the short-term trend metric has only turned Green in the last year);
- the current status (Red) of this CU has not changed since the previous assessment;

Points of Discussion

- since this assessment was unable to remove offspring from naturally spawning hatchery-origin parents, the abundances of 'wild' spawners used to assess status are biased high. The inability to estimate spawner success, which could be low, also contributes to a positive bias in the escapement time series;
- further work is recommended to determine whether genetics can be used to identify offspring of hatchery-origin parents, so these "non-wild" fish may be eliminated from the escapement time series;
- there are concerns regarding high exploitation in recent years on this CU, given that it co-migrates with considerably more abundant CUs;

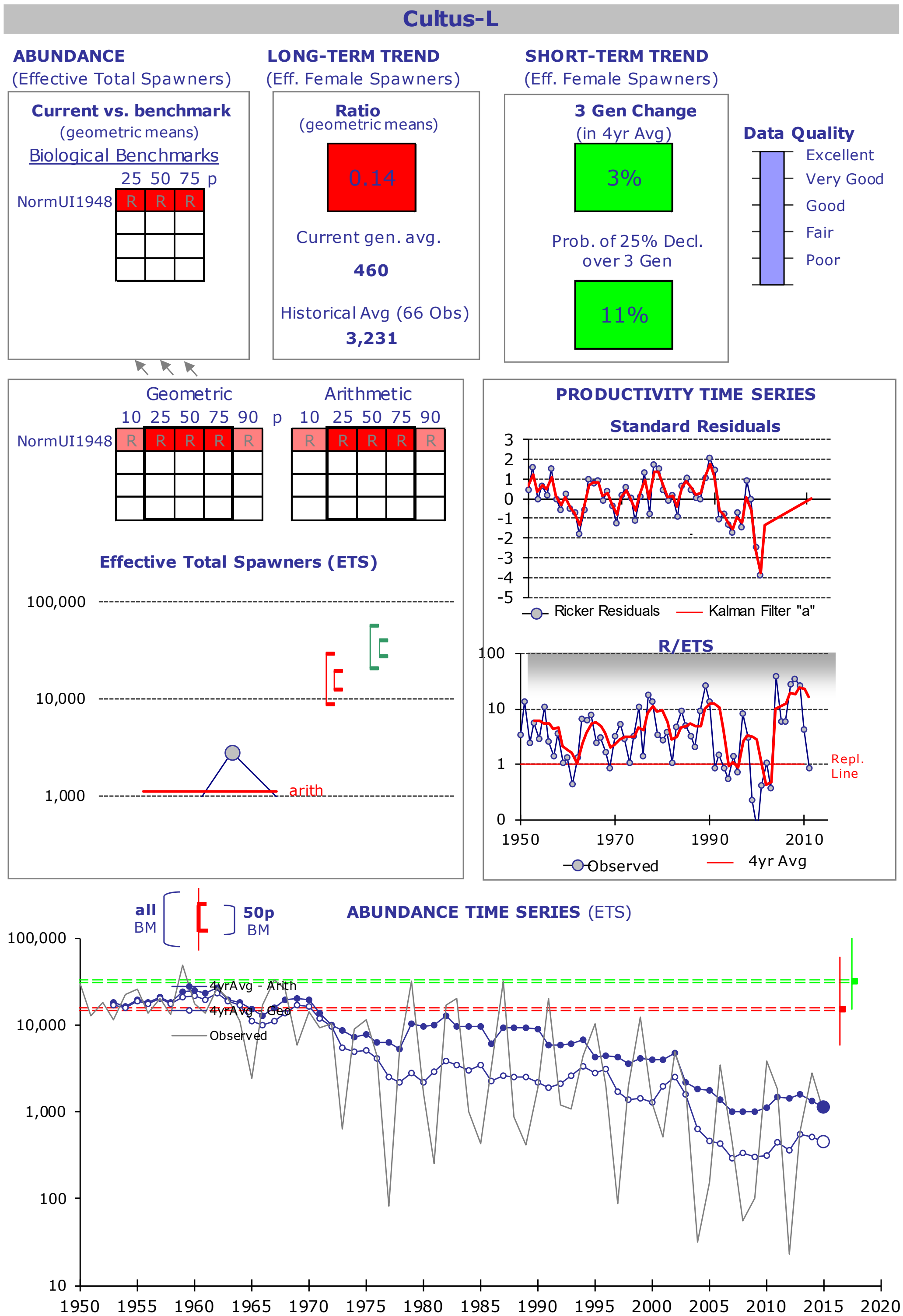
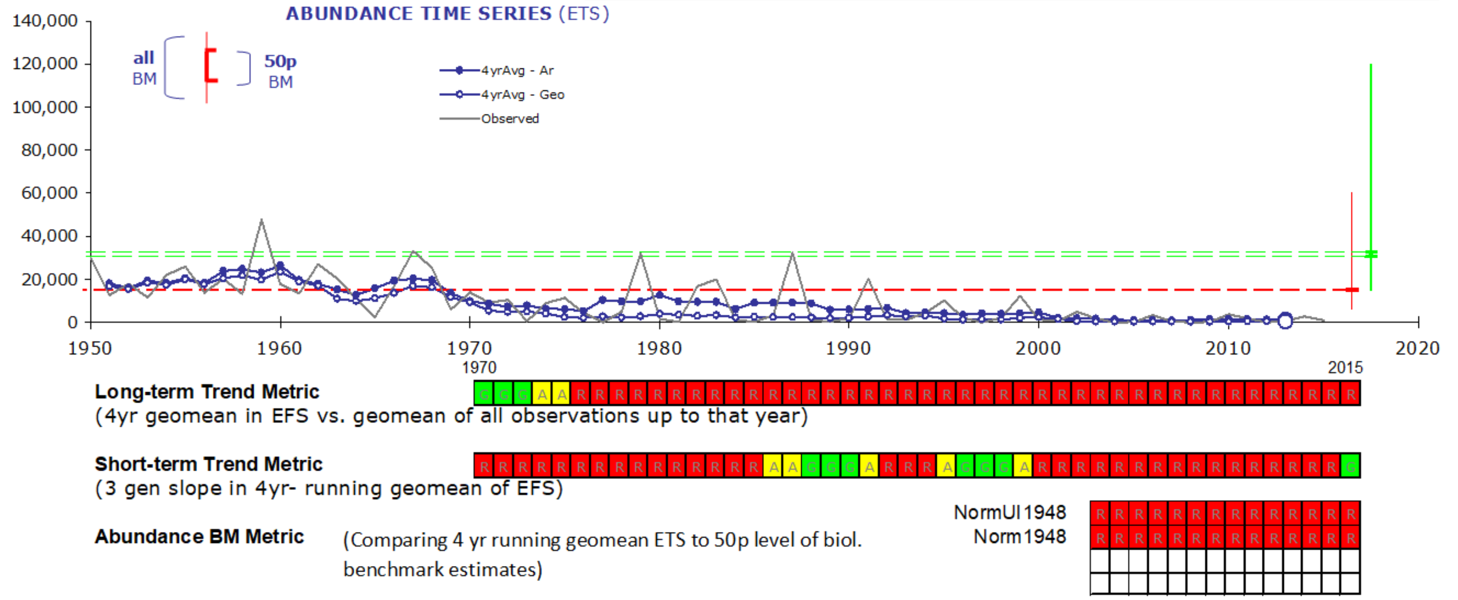


Figure A2-20. Cultus-L data summaries page 1 -first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Cultus-L



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	47,779	3,815	2,812
Med	4,654	519	778
Min	23	23	23

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	32	0	0
2500	7	3	1
1000	10	1	0
500	6	2	2
250	4	1	0
0	7	5	1

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2000)	5,900	8,734	14,634	28,842	60,753
Norm(1948-2000)	10,391	12,502	15,454	19,030	23,107
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2000)	15,239	20,314	30,642	56,583	119,753
Norm(1948-2000)	22,855	27,103	32,556	39,406	47,309
(-)					
(-)					
(-)					

Figure A2-21. Cultus-L data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

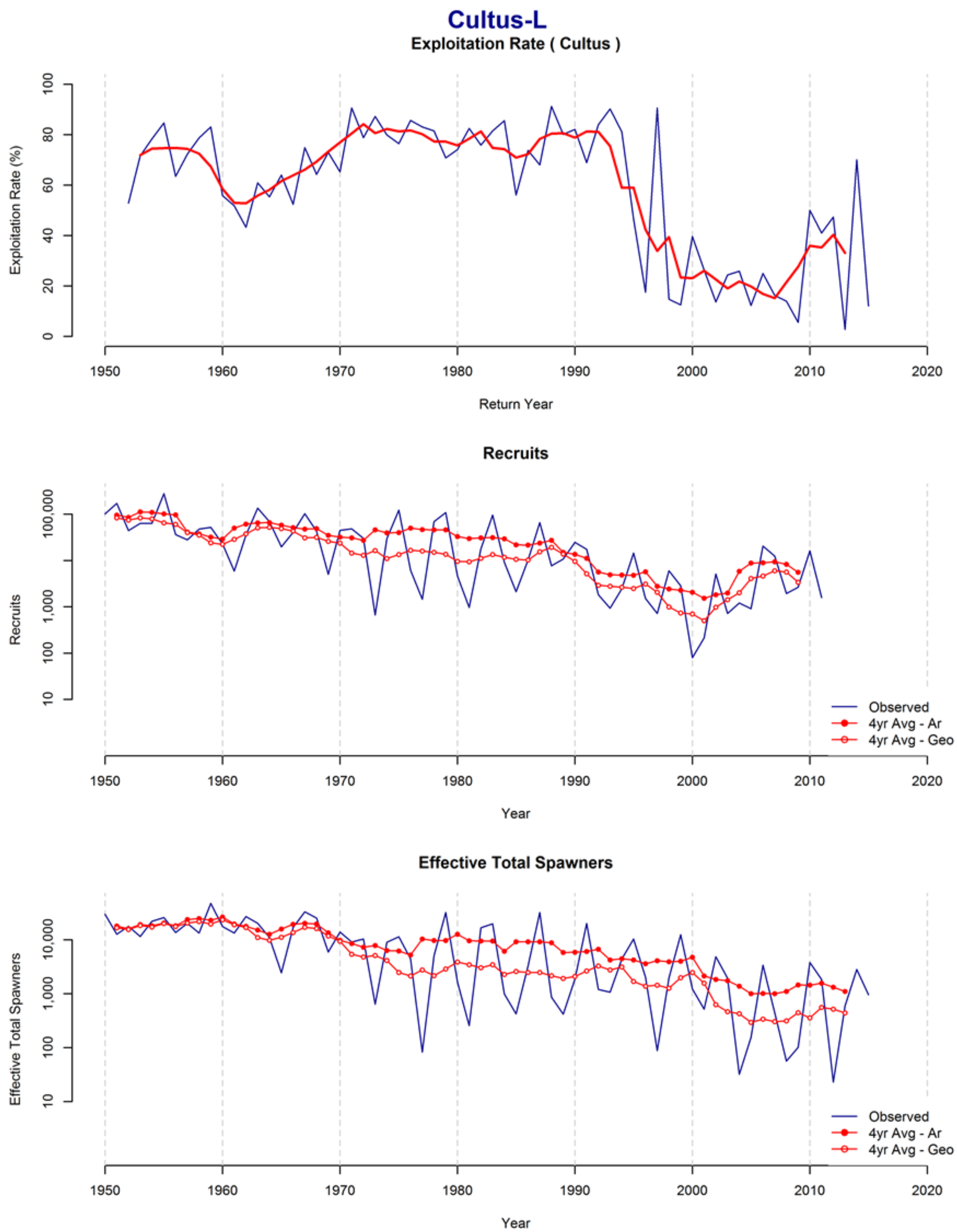


Figure A2-22. Cultus-L data summaries page 3 : exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

FRANCOIS-FRASER-S (I.E. STELLAKO) (AMBER/GREEN)

Background: This CU rebuilt after the 1913 Hells Gate landslide and a subsequent period (1964- 1968) of log driving that impacted spawning habitat (see Grant et al. 2011 for details).

Benchmark Analysis (Abundance Metrics): The stock-recruitment time series for Francois-Fraser-S includes brood years 1950-2010. This CU has not exhibited cyclic dominance historically. The S_{max} derived from the PR model exceeded spawning capacity of this system, based on expert opinion of the capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Francois-Fraser-S	**A/G**	**R/A**

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A/G	G	G	G	A/G	A/G	A/G	A/G	A/G
After Plenary	A/G	A/G	A/G	A/G	A/G	A/G	A/G	A/G	A/G
Change?		Y	Y	Y					
Num Changes	3								

Figure A2-23. First row presents final integrated statuses for Francois-Fraser-S in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- this CU's Amber/Green status was driven by the mixed Amber/Green status of the relative-abundance metric; at or below the 50% probability level this metric was Green, and above was Amber; this metric also only turned Green in the recent generation;
- the long-term trend metric was Green for the entire assessed time series; absolute abundances are high for this CU, with no years in the time series falling below the COSEWIC Criterion for small populations (1,000);
- although the short-term trend metric was Amber (this has improved since the previous assessment, which was Red), it is very sensitive to the 2009 data point (it would be Green if this value were doubled); this trend was previously Red, as it was driven by high production in the 2000's;
- productivity for this CU has started to increase in the last generation; however, this trend needs to be monitored to ensure it continues, since productivity remains below average; one recent year falls below replacement;
- the status (Amber/Green) of this CU has improved since the previous assessment (Red/Amber);

Points of Discussion

- this CU has fluctuated around S_{msy} for the past 30 years under exploitation and appears sustainable; this does not suggest that when the population dips into the yellow zone there is anything to be concerned about;

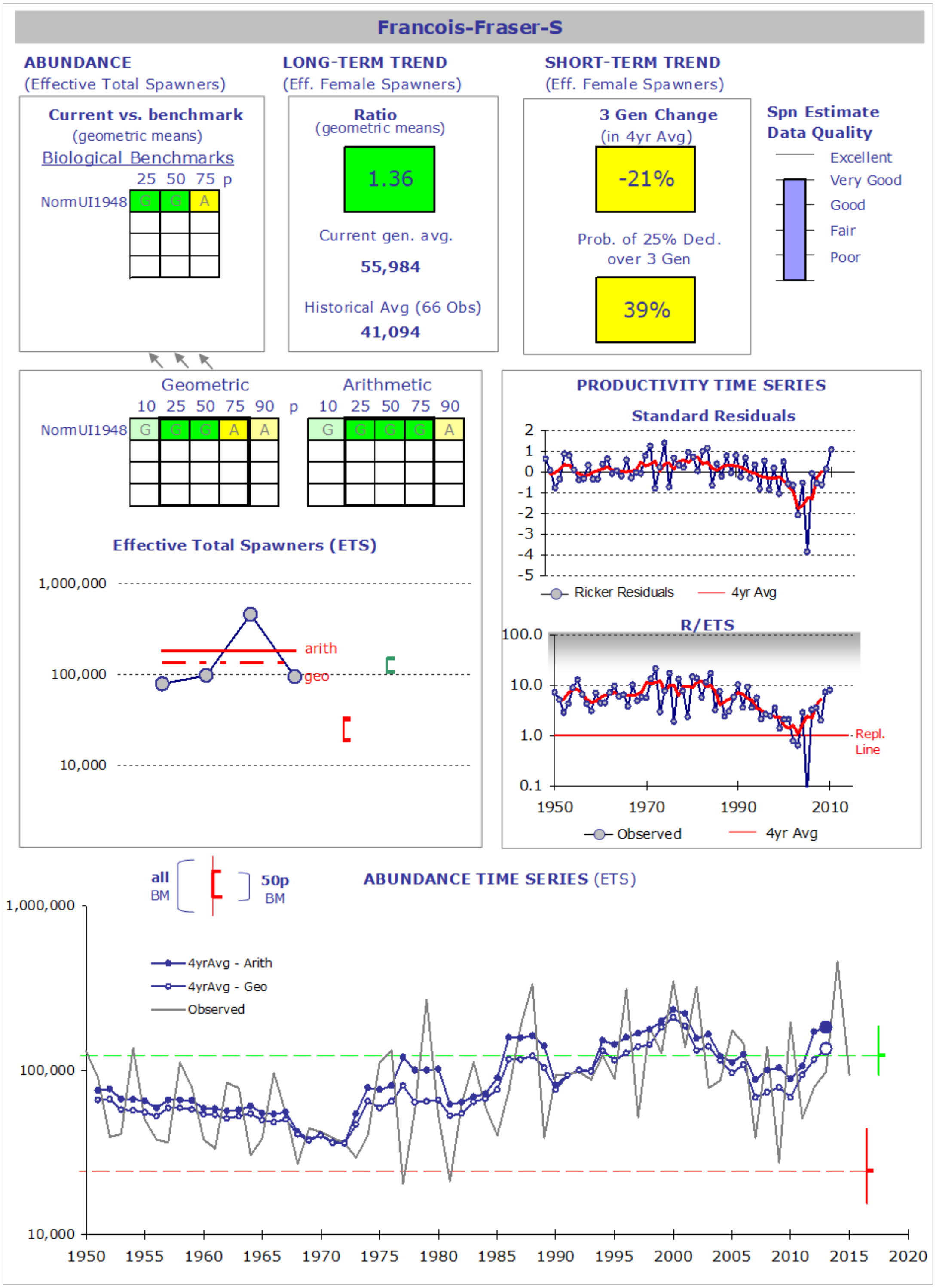
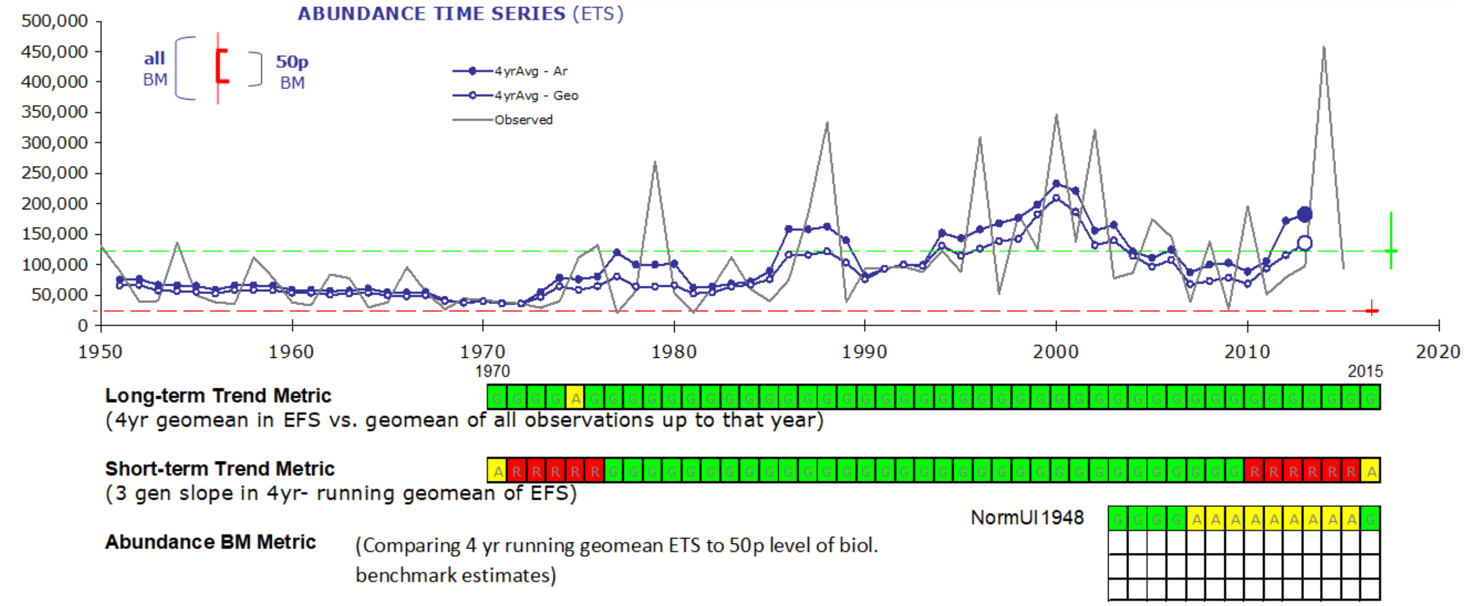


Figure A2-24. Francois- Fraser-S data summaries page 1 -first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Francois-Fraser-S



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	458,072	458,072	458,072
Med	78,591	95,954	95,954
Min	20,348	27,431	78,932

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	66	12	4
2500	0	0	0
1000	0	0	0
500	0	0	0
250	0	0	0
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2010)	15,446	18,912	24,256	32,336	43,943
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2010)	93,559	105,599	122,612	149,591	184,864
(-)					
(-)					
(-)					
(-)					

Figure A2-25. Francois- Fraser-S data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

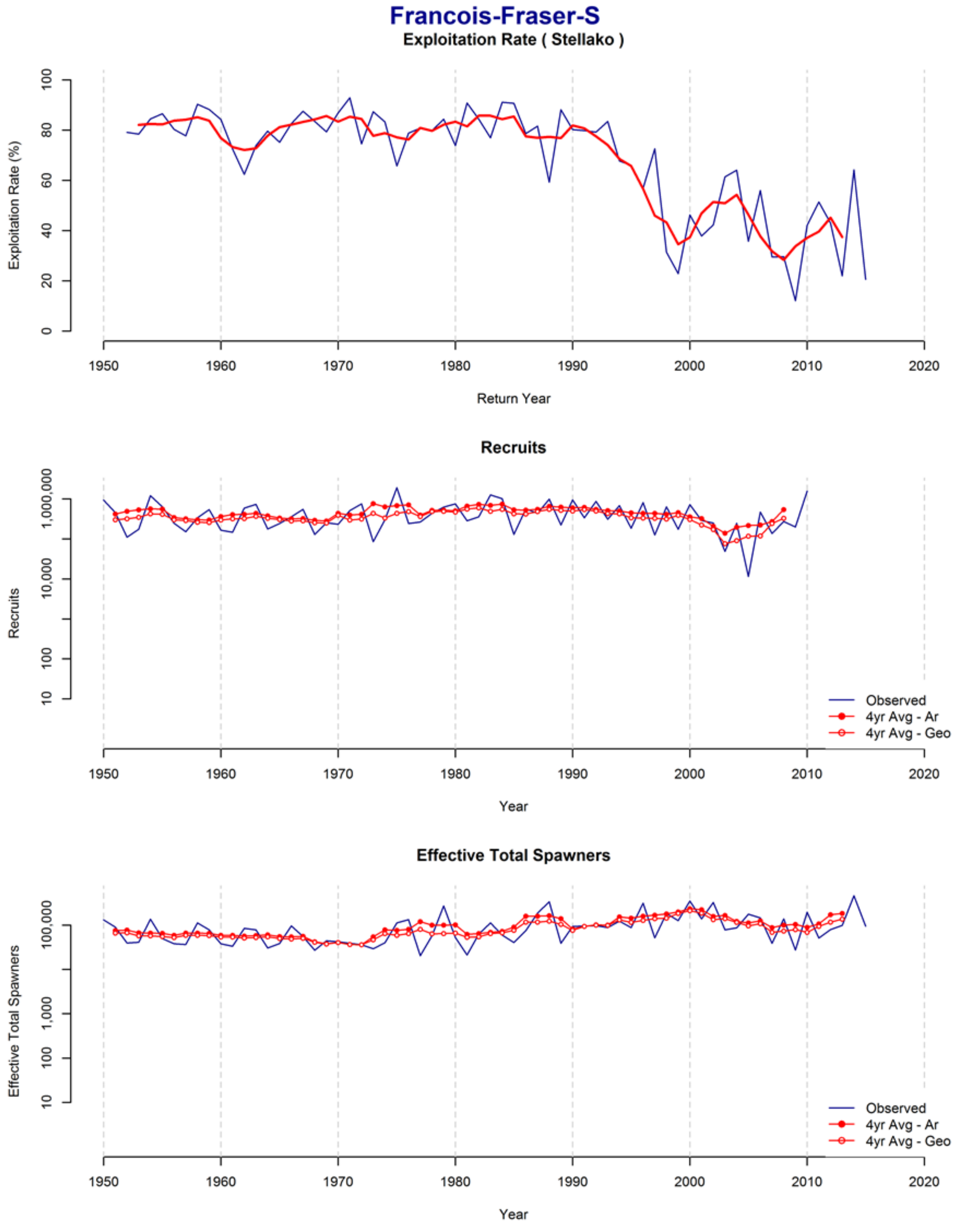


Figure A2-26. Francois- Fraser-S data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

HARRISON (D/S)-L (I.E. MISCELLANEOUS LATE) (AMBER/GREEN)

Background: This CU is comprised of several separate stream populations that migrate downstream to rear in Harrison Lake during their freshwater fry stage; only a single population (Big Silver Creek) is used for status assessments as it has been consistently assessed and has a relatively long time series of escapement data (Grant et al. 2011). Since only one population is consistently assessed escapement estimates are biased low.

Benchmark Analysis (Abundance Metrics): Recruitment data are not available for this CU.

	2017 Status	2012 Status
Harrison (D/S)-L	A/G	G

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A/G	A/G	A/G	A/G	A/G	A/G	G	A	A/G
After Plenary	A/G	A/G	A/G	A/G	A/G	A/G	G	A	A/G
Change?									
Num Changes	0								

Figure A2-27. First row presents final integrated statuses for Harrison (D/S)-L in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber/Green integrated status was driven by the Green long-term trend metric; the long-term trend metric has been Green for almost the entire assessed time series; further, this CU is in a period of high abundances relative to the historic time series;
- the short-term trend metric was not given as high a weight as this CU was declining from a period of high abundances (this metric has been declining for the past four years); however, this metric did contribute to pulling down the status of this CU from Green; in addition, there was one year in the past four that fell at the COSEWIC Criterion for small populations (1,000); overall the abundance of this CU is relatively small; however, since not all populations are included in the escapement data, this time series is biased low; the current status (Amber/Green) of this CU has declined from the previous assessment (Green);

Points of Discussion

- in the previous assessment it was recommended that the declining trend be monitored; although the short-term trend metric remains Red, the abundance has been stable at a relatively high abundance in the last few years;
- for many years this stream was managed at a low level of abundance that would likely be considered Red if benchmarks were available; the current level of abundance (under reduced harvest) likely represents a stable situation for the current productivity regime;

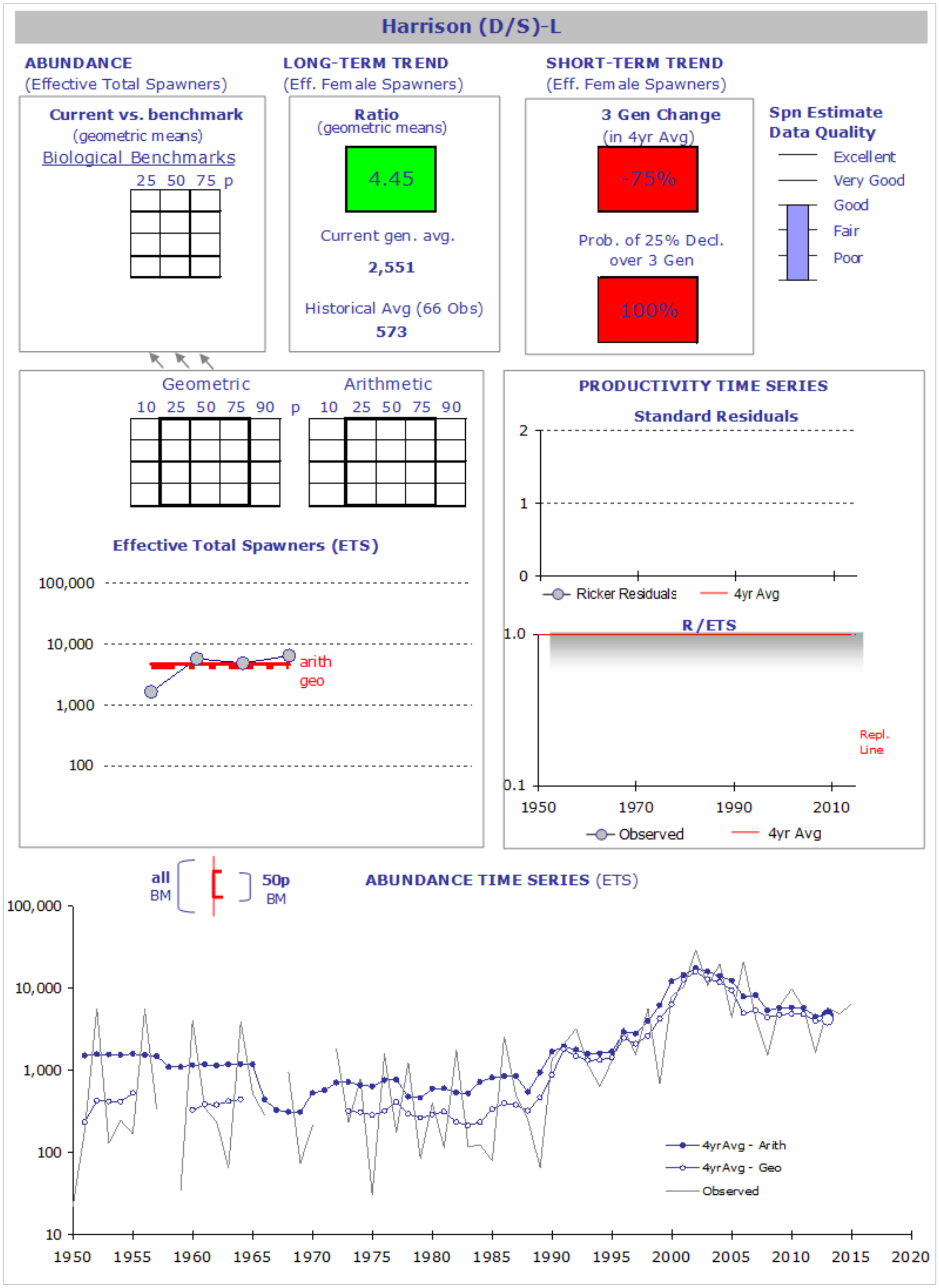
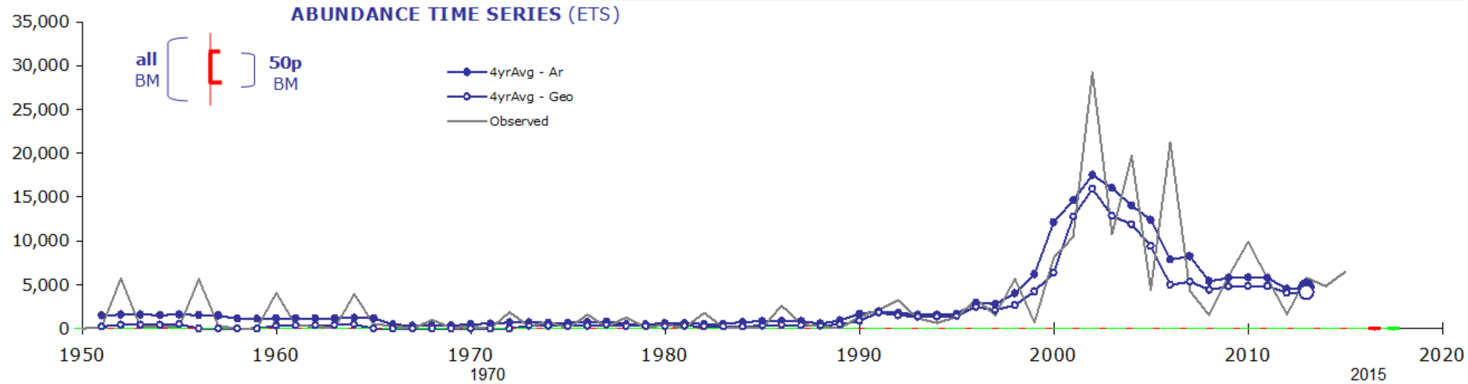


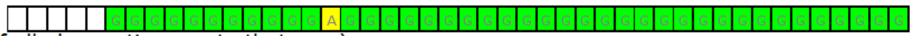
Figure A2-28. Harrison (D/S)-L data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

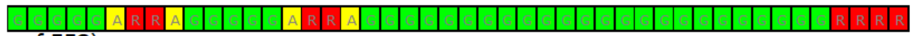
Harrison (D/S)-L



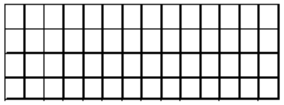
Long-term Trend Metric
(4yr geomean in EFS vs. geomean of all observations up to that year)



Short-term Trend Metric
(3 gen slope in 4yr- running geomean of EFS)



Abundance BM Metric (Comparing 4 yr running geomean ETS to 50p level of biol. benchmark estimates)



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	29,213	21,253	6,483
Med	1,064	5,763	5,331
Min	0	1,531	1,650

Number of Observations in a range

	All Yrs	Last 12	Last 4
> 5000	14	7	2
2500–5000	8	3	1
1000–2500	11	2	1
500–1000	5	0	0
250–500	5	0	0
0–250	20	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Figure A2-29. Harrison (D/S)-L data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

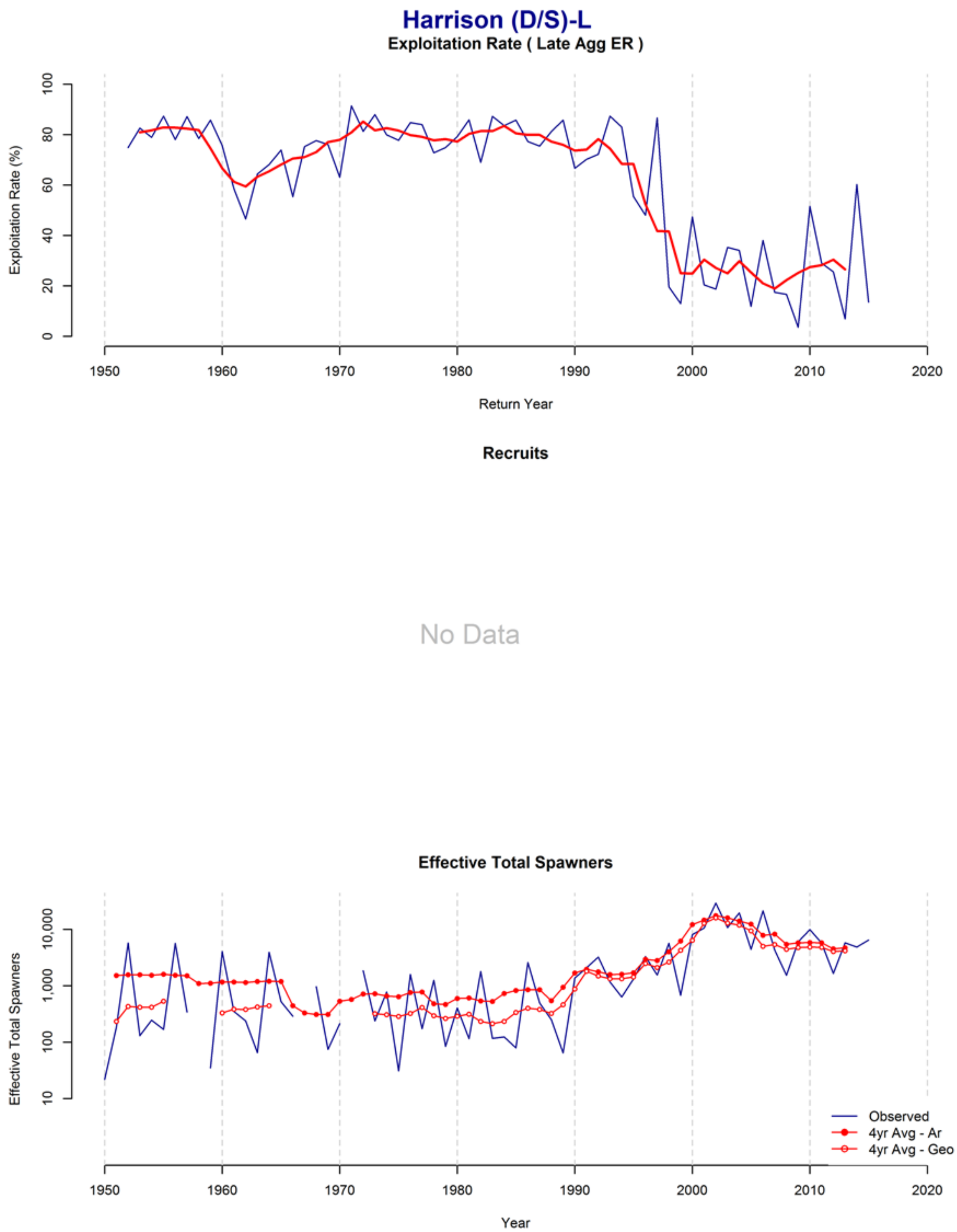


Figure A2-30. Harrison (D/S)-L data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

HARRISON RIVER (RIVER TYPE) (I.E. HARRISON) (GREEN)

Background: This is a river-type CU (migrates to the ocean shortly after gravel emergence). This CU has exhibited unique population dynamics relative to other CUs. It increased in abundance and productivity in the 1990's up to 2005, when most other CUs declined. This CU also has a unique age structure (Harrison-River Type are three and four year old Sockeye) compared to all other CUs (most are four and five year olds) (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): Since this CU does not rear in lakes, no independent estimates of S_{max}, based on lake rearing capacity are applied to the stock-recruitment model. Therefore only a Ricker model with an uninformative prior on S_{max} was used. However, a sensitivity analysis was conducted, which involved fitting the stock-recruitment model to variations of the stock-recruitment data set to estimate relative-abundance benchmarks (Appendix 7). Benchmarks estimated from the Ricker model fit to four different time series were compared: full time series (1948-2010), truncated time series (1990-2010) to account for recent shifts in productivity, and each of these time series excluding the 2005 brood year. In the 2005 brood year, all CU's including the Harrison River-Type CU experienced exceptionally low productivity, which suggests the cause of this broad response was a density-independent mechanism, such as unusual ocean conditions. Since this is one of the years when escapement started to increase for the Harrison River-Type CU, this data point highly influences the Ricker model fit under the assumption of a strong density-dependent response to the exceptional escapement. Therefore, benchmarks were also explored without this year. Benchmarks were particularly uncertain for this CU.

	2017 Status	2012 Status
Harrison River (River-Type)	G	G

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	G	G	G	G	G	G		G
After Plenary	G	G	G	G	G	G	G		G
Change?									
Num Changes	0								

Figure A2-31. First row presents final integrated statuses for Harrison River-River Type in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Green integrated status was driven by a Green status for the relative-abundance metric at the 50% probability level for the full and truncated time series, and also by the Green status for the long-term and short-term trend metrics. Productivity has also increased over the past decade, and the average absolute abundance in the last generation has been an order of magnitude higher than the time series average; both the short-term trend and long-term trend have been Green for almost 2 decades; the relative-abundance metric has also been Green for the past 5 years;
- although there were some Amber statuses for the relative-abundance metric at high probability levels, and for model forms that excluded the 2005 brood year, this did not influence the overall Green status determination, given the uncertainty in the relative-abundance benchmarks due to non-stationarity of the estimated Ricker model parameters;
- the current status (Green) of this CU has not changed since the previous assessment;

Points of Discussion

- estimating relative-abundance benchmarks is a challenge for this CU, given the non-stationarity in the alpha parameter (systematic increases in productivity);
- During the period in the post-1990's when productivity decreased for most CUs, this CU increased, and therefore, would have benefited from lower exploitation on other CUs.

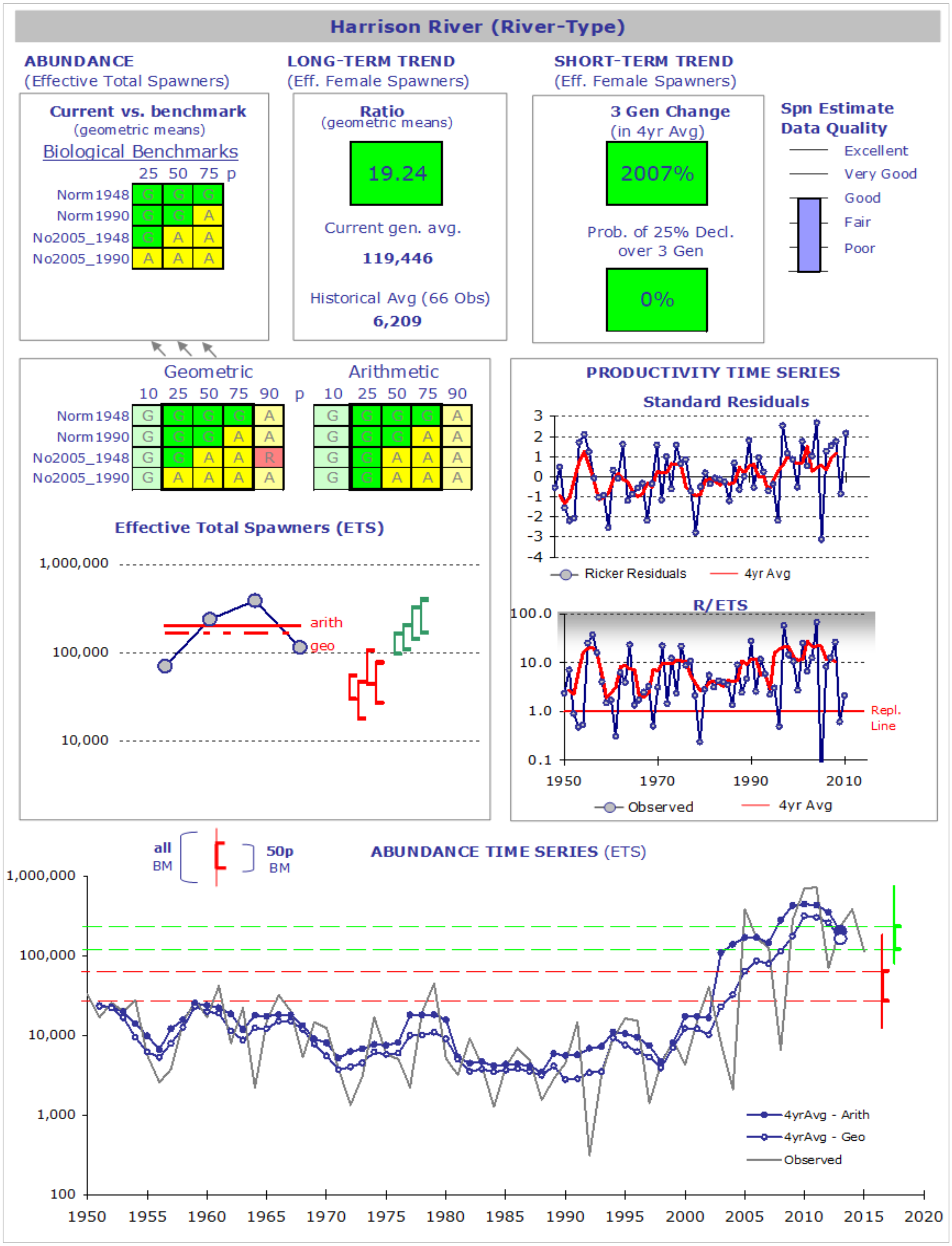
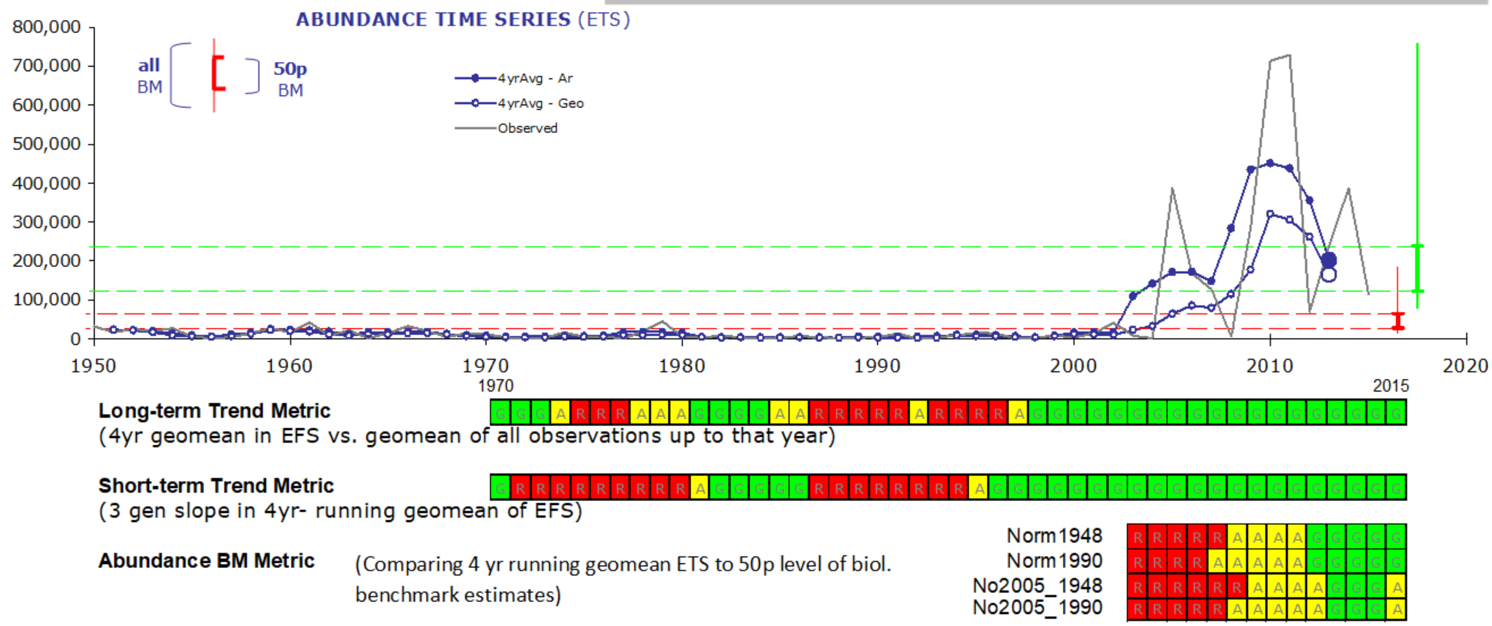


Figure A2-32. Harrison River (River-Type) data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Harrison River (River-Type)



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	729,064	729,064	386,746
Med	10,933	203,637	176,987
Min	313	2,106	70,273

Number of Observations in a range

	All Yrs	Last 12	Last 4
> 5000	45	11	4
5000	13	0	0
2500	7	1	0
1000	0	0	0
500	1	0	0
250	0	0	0
0			

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Norm(1948-2010)	23,864	29,665	38,928	55,035	83,033
Norm(1990-2010)	12,577	17,873	27,185	46,303	84,624
No2005_(1948-2010)	33,368	44,095	64,878	106,233	185,230
No2005_(1990-2010)	18,654	26,836	41,544	77,302	153,616
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Norm(1948-2010)	80,812	96,663	122,165	164,011	241,678
Norm(1990-2010)	88,657	108,559	140,706	205,415	348,012
No2005_(1948-2010)	112,472	142,444	203,047	323,929	548,490
No2005_(1990-2010)	130,157	166,961	237,451	396,547	757,801
(-)					

Small Population Benchmarks (COSEWIC Criterion D1)

Figure A2-33. Harrison River (River-Type) data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

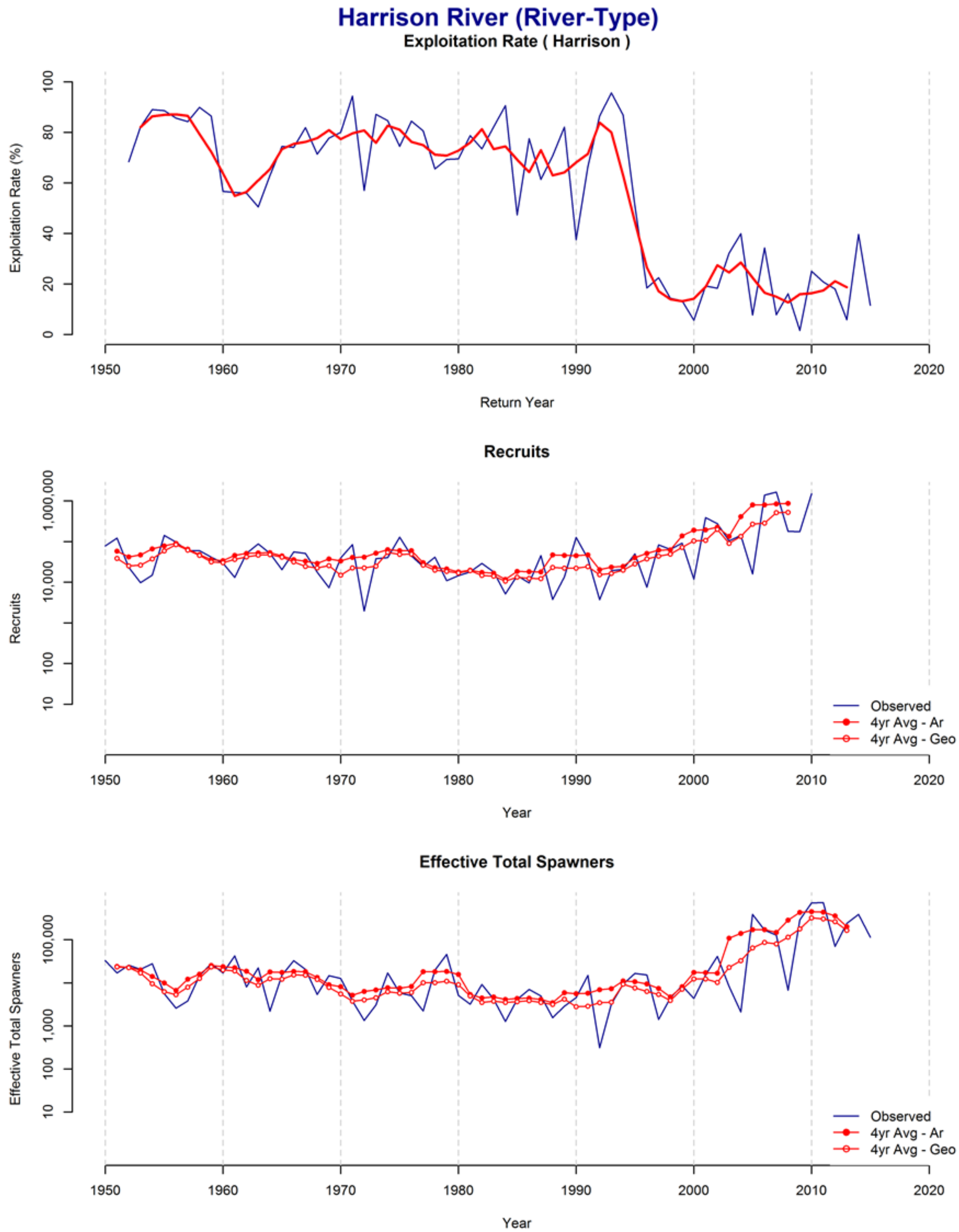


Figure A2- 34. Anderson-Seton-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

HARRISON (U/S)-L (I.E. WEAVER) (RED)

Background: A channel started operations in 1965 to re-build production from the Weaver stock, and subsequently allow for increased harvest opportunities on the Late Run CUs. The channel was also constructed to protect this CU from periodic flooding events; sockeye are preferentially diverted by channel operators into the channel rather than the creek in this system. Channel freshwater production is higher than the adjacent creek (Weaver Creek) (Grant et al. 2011). One of the biggest landslides in Canada (Meager Creek) occurred on this system in 2010. This landslide created a large sediment plume at the north end of Lillooet Lake. This sediment plume moved south into Harrison Lake over the next year, where juveniles from this CU rear. Both Lillooet-Harrison-L and Harrison (U/S)-L CUs exhibited poor survival in the years following this landslide.

Benchmark Analysis (Abundance Metrics): The Harrison (U/S)-L stock-recruitment time series only includes years after the construction of the Weaver spawning channel (brood years 1966-2010), to ensure consistency in the spawning area throughout the time series. This CU has not exhibited cyclic dominance historically. Therefore, a Ricker model was used to estimate benchmarks for this CU's relative-abundance metric. The S_{max} derived from the PR model exceeded the spawning capacity of this system, based on expert opinion of the spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Harrison (U/S)-L	R	A

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R/A	R	R	R	R	R
After Plenary	R	R	R	R	R	R	R	R	R
Change?				Y					
Num Changes	1								

Figure A2-35. First row presents final integrated statuses for Harrison (U/S)-L in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by the Red status on every status metric, including the relative-abundance metrics across all probability levels; abundance has declined over several generations and the short-term trend metric was Red; in addition, two out of the recent four years have fallen at or below the COSEWIC Criterion for small populations (1,000); productivity has been variable, but has declined in recent years;
- the short-term trend metric has been Red for the past 7 years; the long-term trend metric changed from Amber to Red in the current assessment year;
- the current status (Red) of this CU has declined since the previous assessment (Amber);

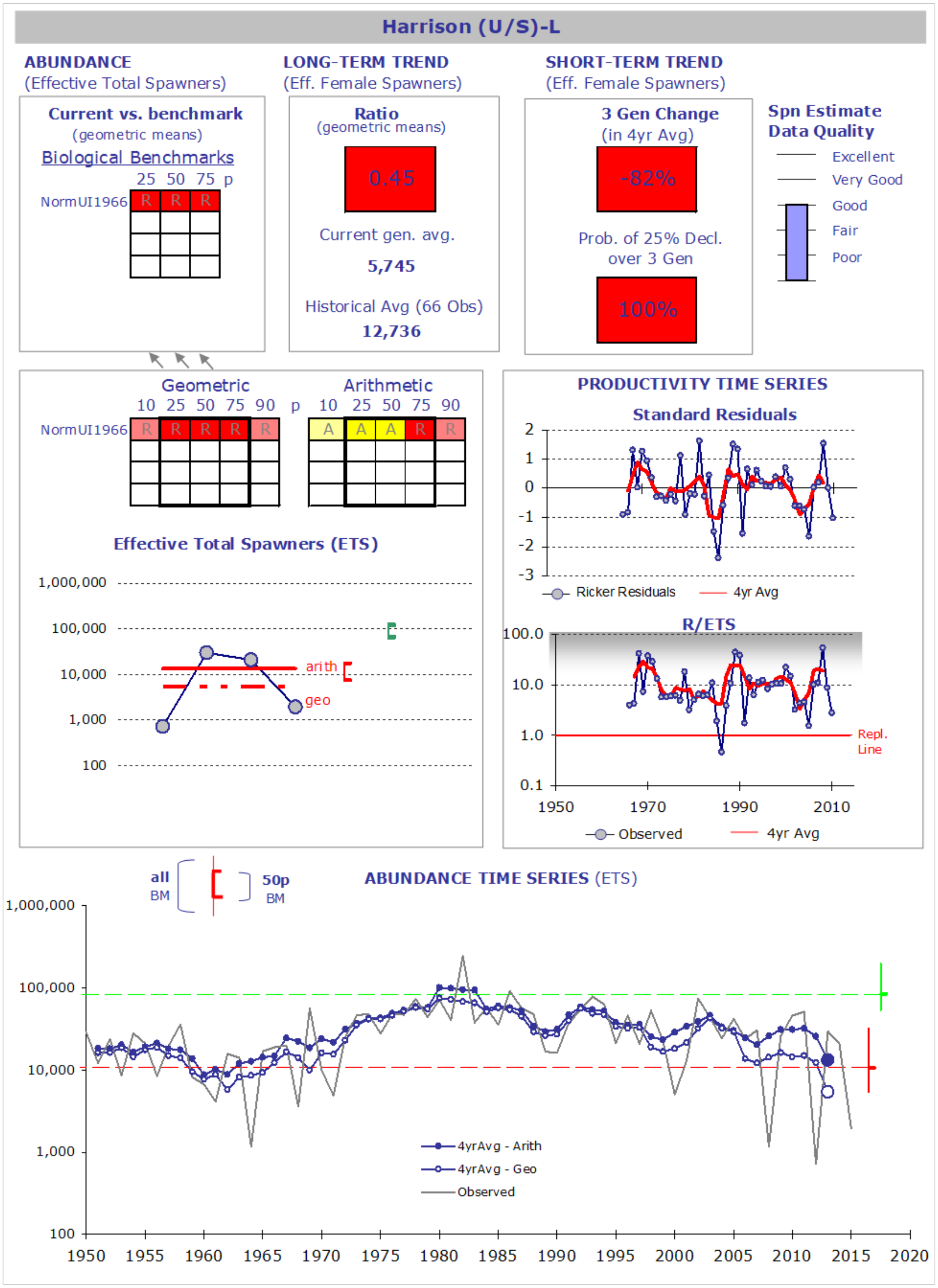
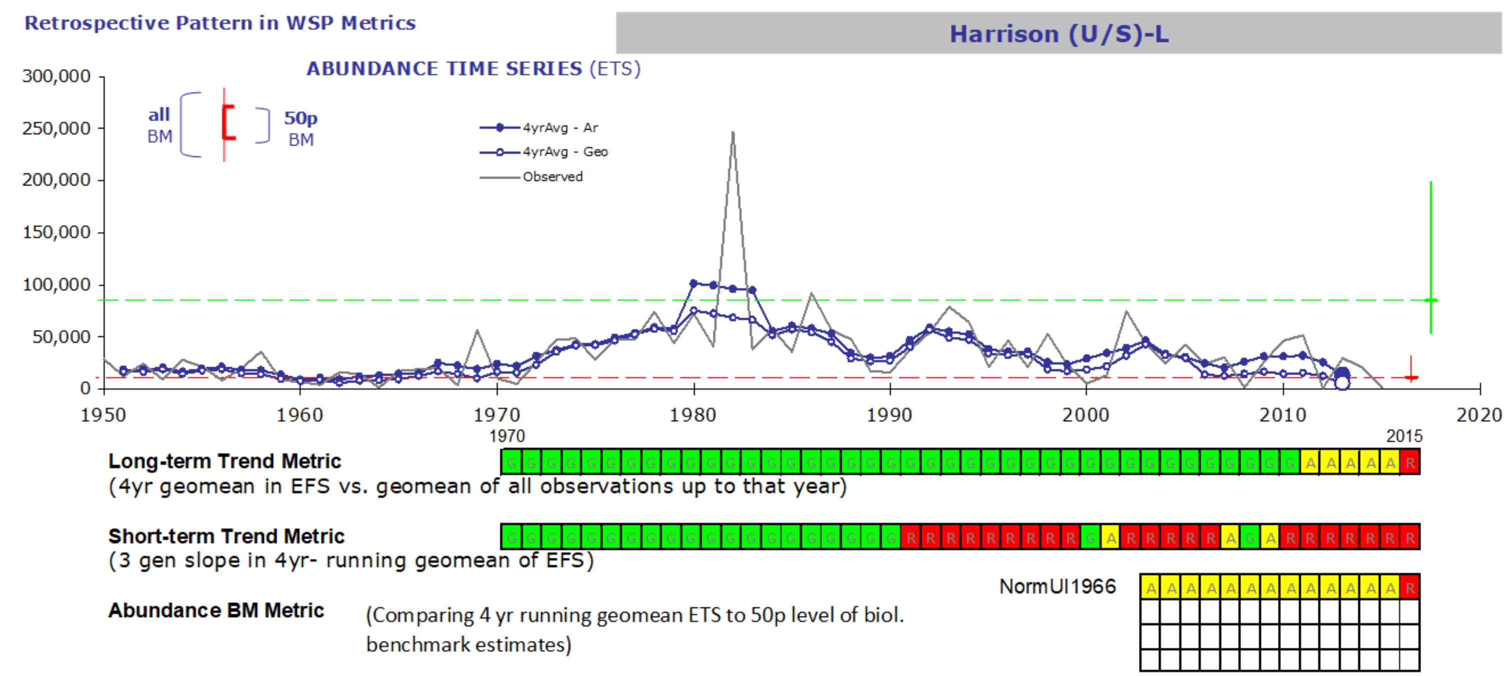


Figure A2-36. Harrison (U/S)-L data summaries page 1 -first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	247,021	51,609	29,720
Med	26,898	25,202	11,438
Min	719	719	719

Number of Observations in a range

	All Yrs	Last 12	Last 4
(above 5000)	59	9	2
5000	3	0	0
2500	3	2	1
1000	1	1	1
500	0	0	0
250	0	0	0
0			

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1966-2010)	5,475	7,428	10,731	17,145	32,353
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1966-2010)	53,638	65,056	84,597	120,230	198,497
(-)					
(-)					
(-)					
(-)					

Figure A2-37. Harrison (U/S)-L data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

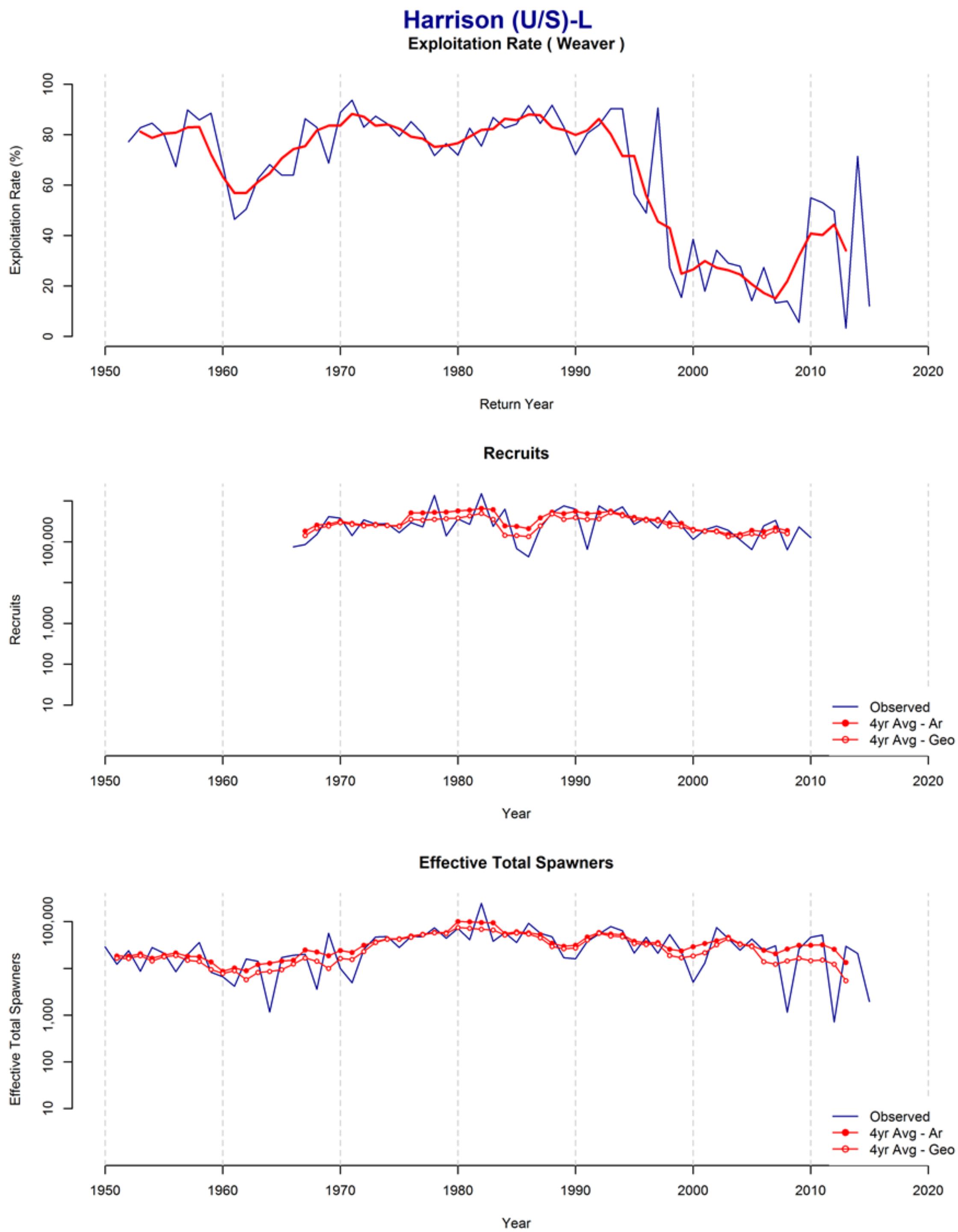


Figure A2-38. Harrison (U/S)-L data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

KAMLOOPS-ES (I.E. RAFT) (AMBER)

Background: Raft is the only consistently assessed population in this CU, therefore, only this population was used to assess status for this CU (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The stock-recruitment time series for Kamloops-ES includes the brood years 1950-2010. Since this CU is not currently considered cyclic, a Ricker model was used to estimate the relative-abundance benchmarks. The S_{max} derived from the PR model exceeded the spawning capacity of this system, based on expert opinion of the spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Kamloops-ES	A	A

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A	A	A	A	A	A	A		A
After Plenary	A	A	A	A	A	A	A		A
Change?									
Num Changes	0								

Figure A2-39. First row presents final integrated statuses for Kamloops-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber integrated status was driven by the Amber Status of the relative-abundance metric across most probability levels; although, these benchmarks are associated with high uncertainty (wide probability distribution);
- productivity declined from the 2000 to 2005 brood years, and subsequently has started to improve in the last five brood years; the short-term trend metric remains Red and the decline is greater than that observed in the previous assessment (2012: -31%; 2016: -40%), although this CU is coming off a period of high production in the mid-1990's, as indicated in the previous assessment; in the last four years abundance has started to improve;
- similar to the previous assessment, the long-term trend metric is Green; this metric provides additional support for an Amber integrated status; there are no years that fall below the COSEWIC Criterion for small populations (1,000) in the last 12 years; also, since not all populations are included in the escapement data, the data for this CU are biased low;
- Based on the retrospective evaluation, the short-term trend metric has been Red for the past 6 years, and the long-term trend metric has been Green for the past 20 years;
- the current status (Amber) of this CU has not changed since the previous assessment;

Points of Discussion

- NA

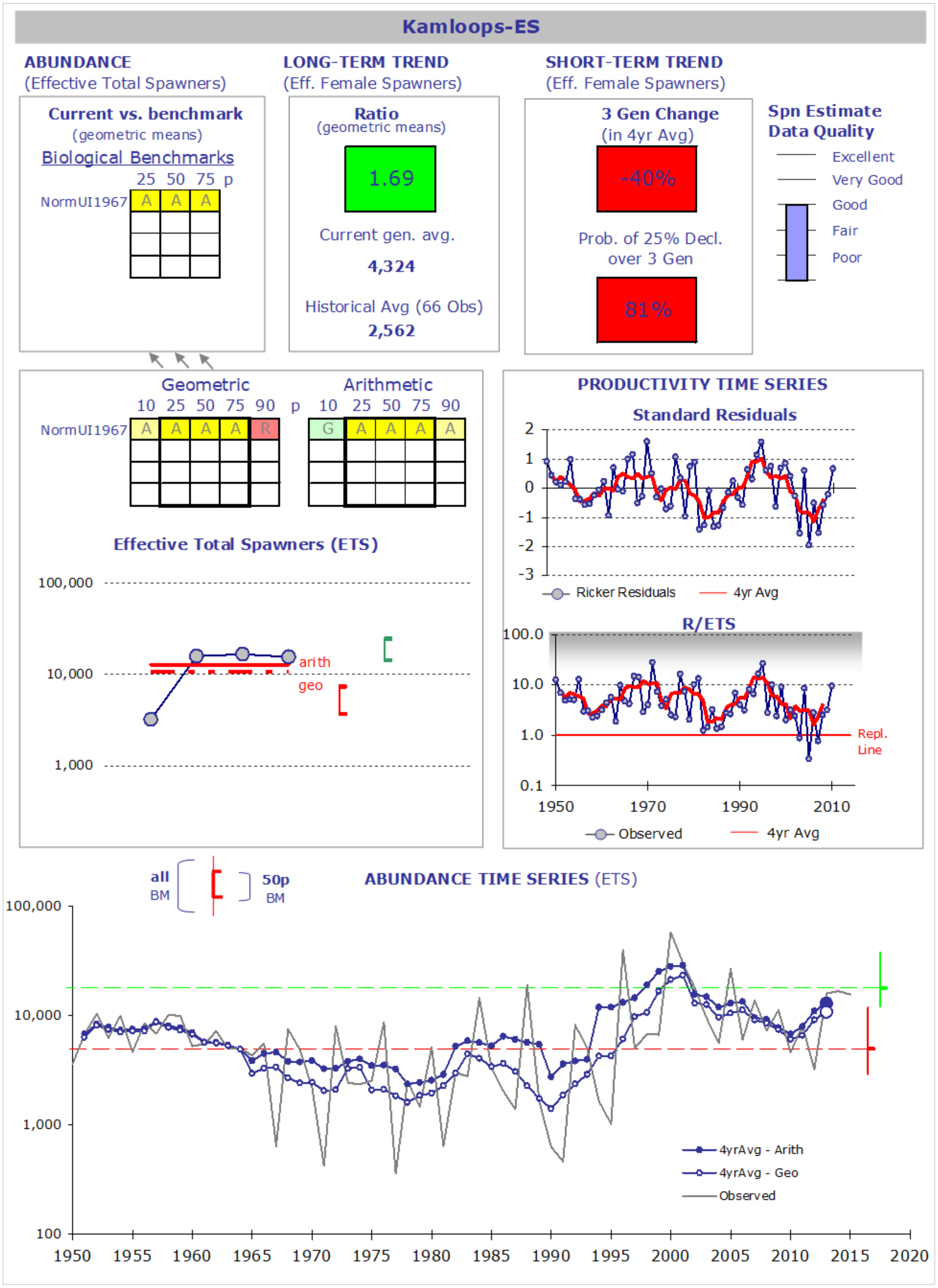
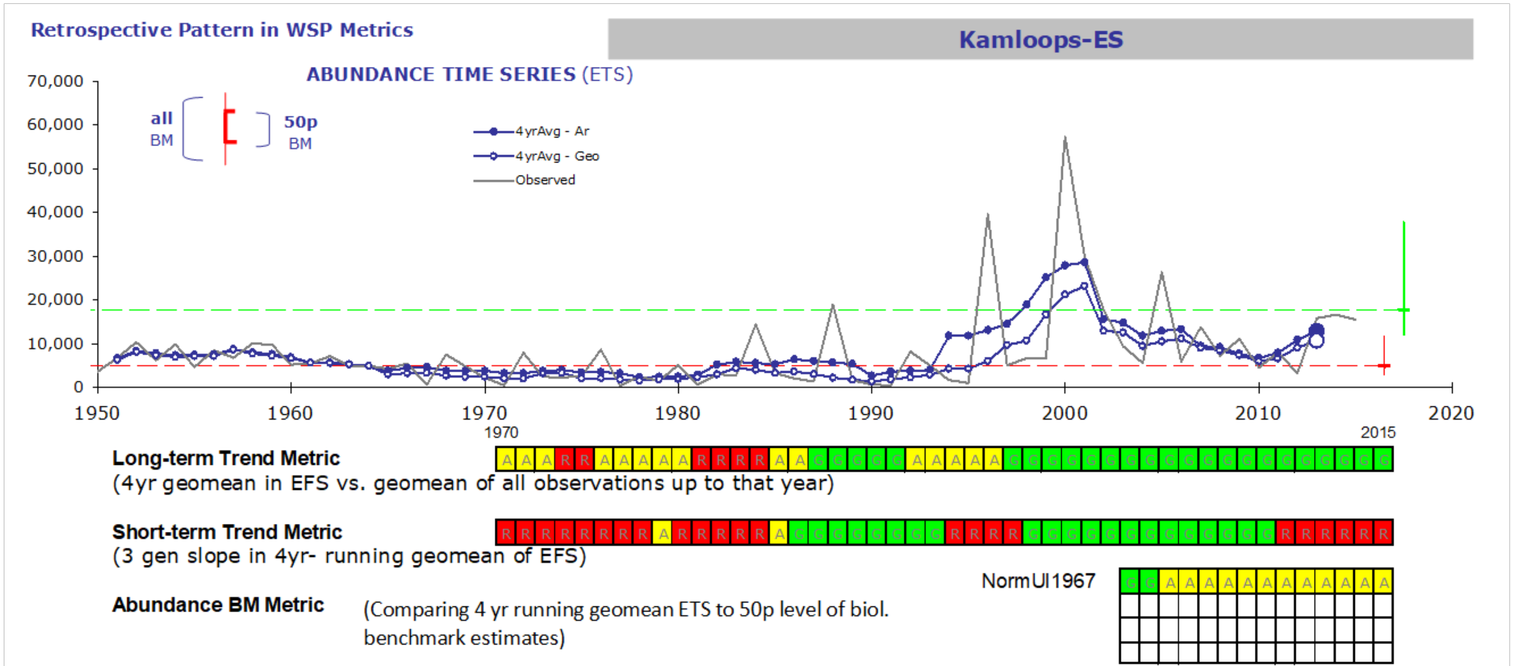


Figure A2-40. Kamloops-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	57,396	26,400	16,651
Med	5,485	9,578	15,712
Min	360	3,218	3,218

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	38	10	3
2500	12	2	1
1000	10	0	0
500	3	0	0
250	3	0	0
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1967-2010)	2,894	3,681	4,958	7,344	11,903
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1967-2010)	12,002	14,227	17,838	24,545	37,829
(-)					
(-)					
(-)					
(-)					

Figure A2-41. Kamloops-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

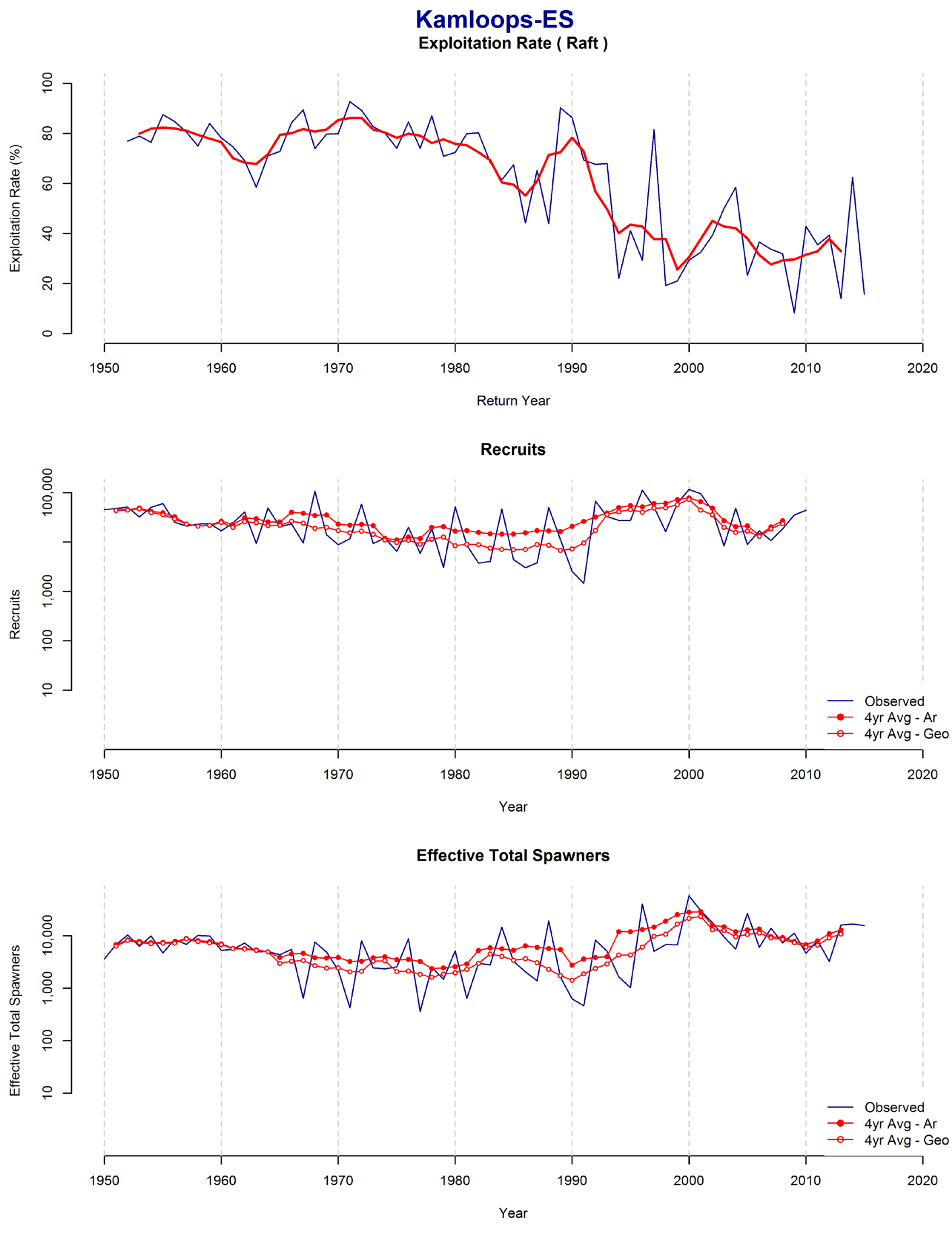


Figure A2-42. Kamloops-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

LILLOOET-HARRISON-L (I.E. BIRKENHEAD) (AMBER)

Background: Only the Birkenhead River is included in the abundance time series for this CU, since it has been consistently assessed and has a relatively long and complete time series (Grant et al. 2011). One of the biggest landslides in Canada (Meager Creek) occurred on this system in 2010. This landslide created a large sediment plume at the north end of Lillooet Lake, where fry from this CU first enter the lake from the spawning habitat in Birkenhead River. This sediment plume moved south into Harrison Lake over the next year. Both Lillooet-Harrison-L and Harrison (U/S)-L CUs exhibited poor survival in the years following this landslide.

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series for Lillooet-Harrison-L includes the brood years 1950-2010. Since this CU is not currently considered cyclic, a Ricker model was used to estimate the relative abundance benchmarks. The S_{max} derived from the PR model seemed reasonable when compared to the spawning capacity of this system, based on expert opinion of the spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, a Ricker model was applied with both an informative and an uninformative prior on the beta parameter. Both priors resulted in Amber statuses for the relative-abundance metric across all probability levels.

	2017 Status	2012 Status
Lillooet-Harrison-L	A	G*

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A	A	A	A	A	A	A	A	A
After Plenary	A	A	A	A	A	A	A	A	A
Change?									
Num Changes	0								

Figure A2-43. First row presents final integrated statuses for Lilloet-Harrison-L in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber integrated status was driven by the Amber relative-abundance status across all model forms and probability levels; in the previous assessment the relative-abundance metric status was not given much weight: there was concern that the high productivity years in the time series were biased estimates influencing benchmark estimates; the current assessment provides additional diagnostics to validate their use;
- a low productivity trend has persisted in this CU, with a few recent years falling below the replacement line; this contributed to the Amber status;
- similar to the past assessment, the absolute abundance for this CU was well above the COSEWIC Criterion for small populations (1,000) for the entire time series; also, since not all populations are included in the escapement data, these data are biased low;
- the long-term trend is Green (this metric has been Green for the entire time series) and the short-term trend is Red (this metric has been Red for the past 5 years); neither of these metrics held much weight in the integration process; given the short-term declines in abundance and the recent declines in productivity, the status of this CU should be monitored.
- the current status (Amber) of this CU has declined since the previous assessment (Green);

Points of Discussion

- there was interest in the most recent data available for this CU, which was not included in this assessment, and whether this CU is improving following the landslide;

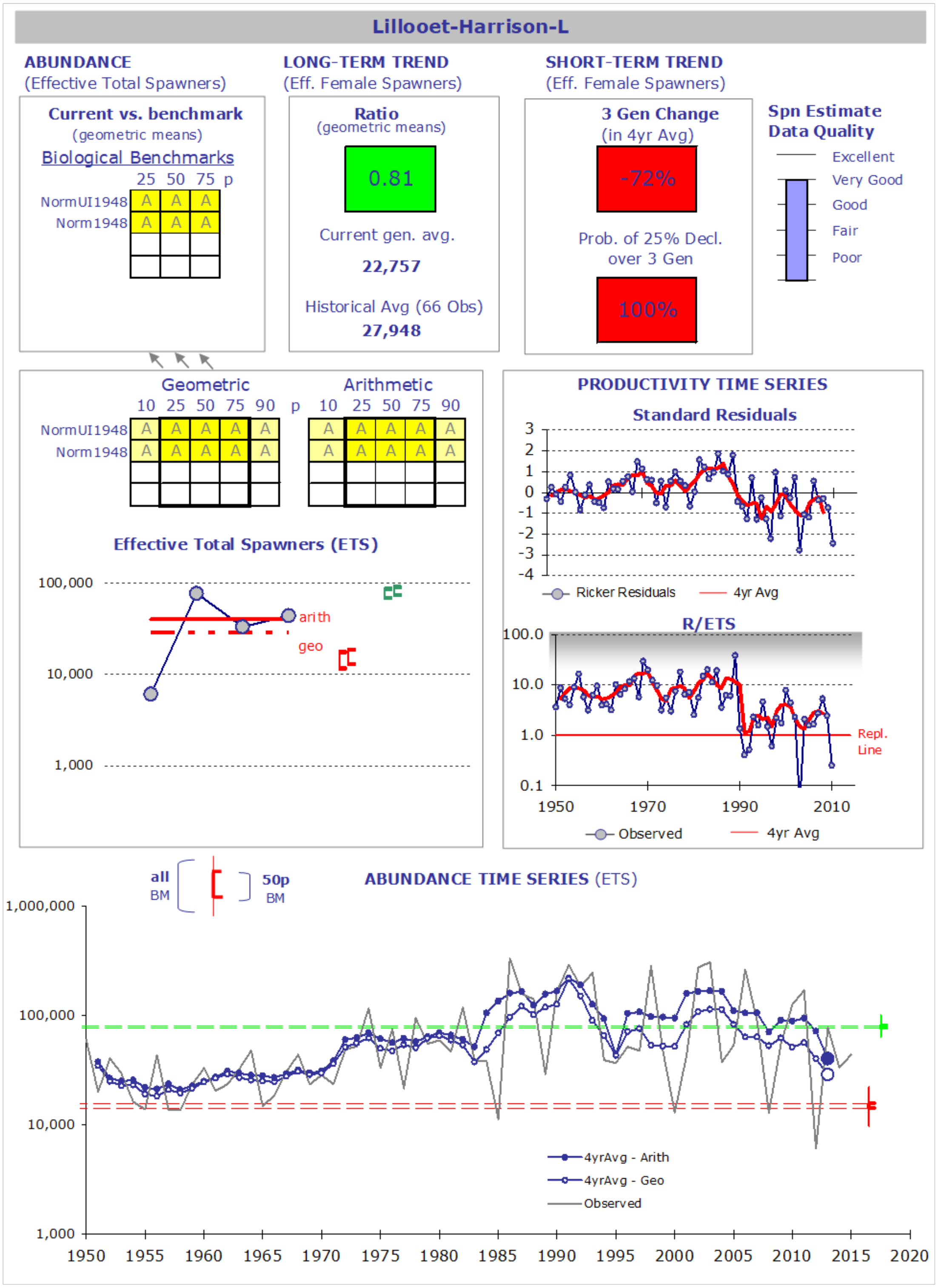
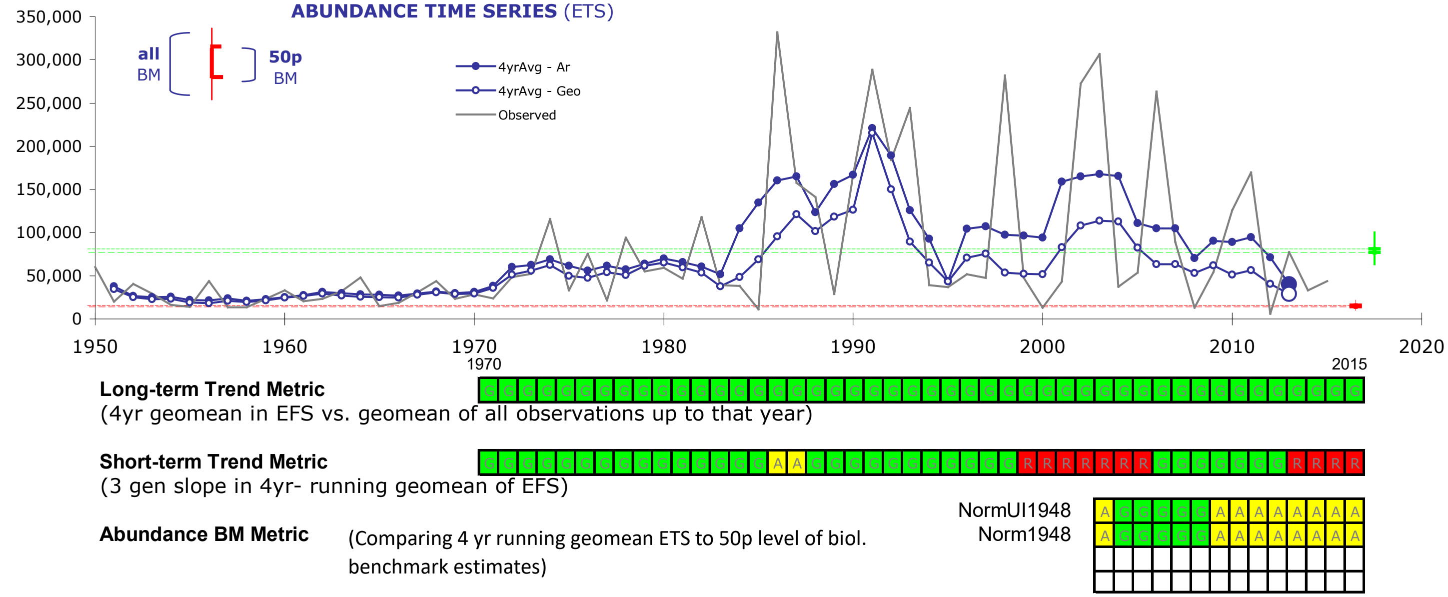


Figure A2-44. Lillooet-Harrison-L data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Lillooet-Harrison-L



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	331,737	263,475	77,218
Med	43,806	53,646	38,650
Min	6,085	6,085	6,085

Number of Observations in a range

	All Yrs	Last 12	Last 4
	66	12	4
5000	0	0	0
2500	0	0	0
1000	0	0	0
500	0	0	0
250	0	0	0
0			

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1948-2010)	9,765	11,554	14,178	17,618	21,783
Norm(1948-2010)	11,083	13,070	15,685	18,702	22,134
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1948-2010)	63,207	68,976	76,930	86,797	99,625
Norm(1948-2010)	67,621	73,428	81,023	90,379	100,285
(-)					
(-)					
(-)					

Figure A2-45. Lillooet-Harrison-L data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

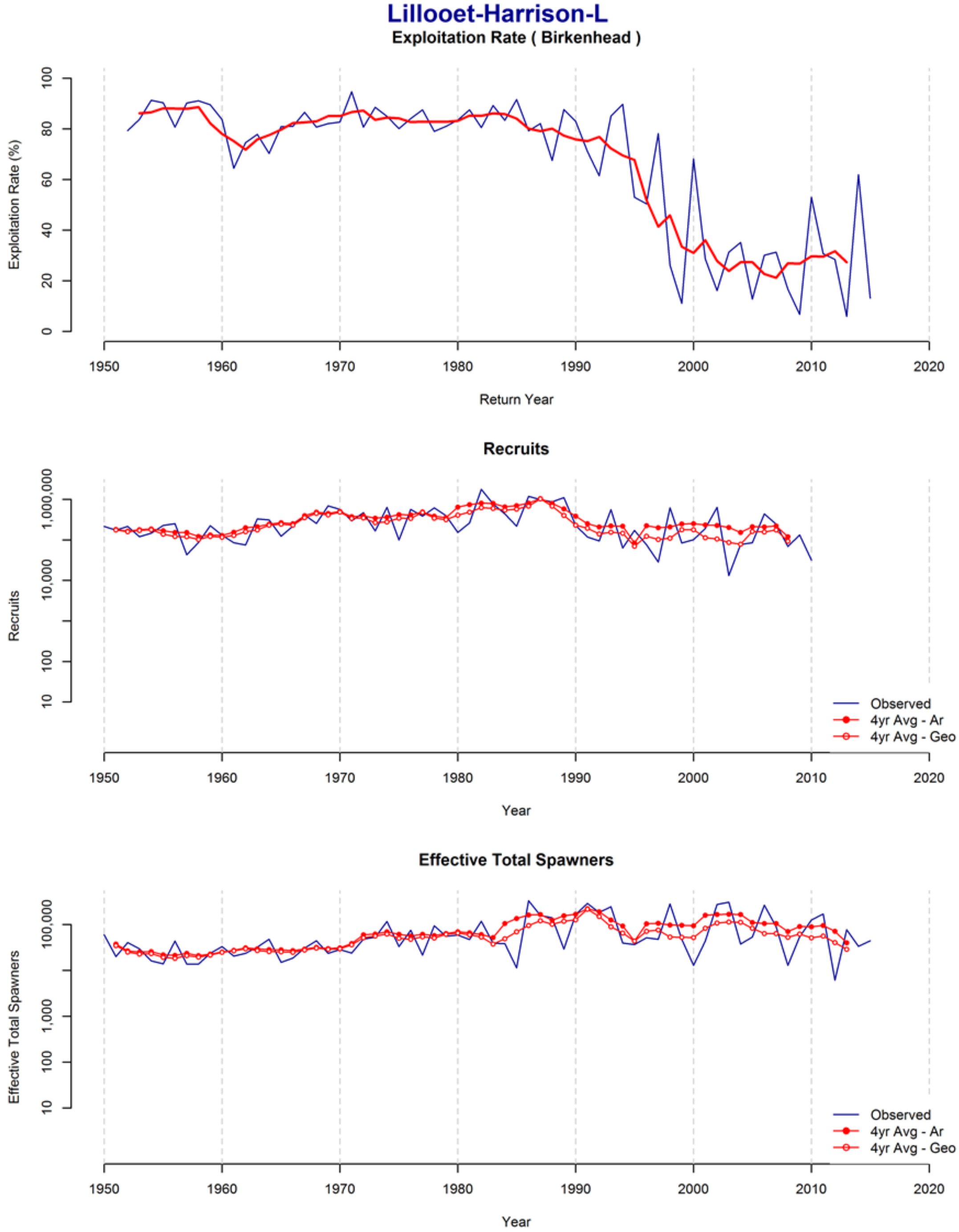


Figure A2-46. Lillooet-Harrison-L data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

NADINA-FRANCOIS-ES (I.E. NADINA) (AMBER/GREEN*)*

Following the 2011 and 2012 Fraser Sockeye status work, background information related to the Nadina-Francois-ES CU was reviewed (Grant et al. 2011; Grant & Pestal 2013). This review included DFO staff from the Salmonid Enhancement Program (SEP: D. Willis & D. Lofthouse) and from Fraser River Stock Assessment Program (StA: K. Benner, T. Cone, & S. Grant). The original status reports provided background on two adult run timing components of this CU, early (first-run) and late (second-run) populations. Given the unique run timing and spawning locations of these two populations, they were each identified as independent CUs (Grant et al. 2011). The 2011 and 2012 CSAS Fraser Sockeye WSP reports indicated that the first- and second-run components were merged into a mixed CU, given the original migration and spawning behavior of these two components and their interaction with the existing spawning channel located at the outlet of Nadina Lake. The previous reports also indicated that the original first- and second-run components, considered separate CUs, required more assessment to validate their extirpation. Efforts to determine whether or not the first- and second-run CUs are extirpated are ongoing.

Historically, the first-run adults entering the Nadina River would migrate in two weeks earlier than the second-run, and spawn about three weeks earlier than the second-run (peak spawning occurred late-August). IPSFC reports indicate that a portion of the early-run adults travelled up to the falls in the uppermost reaches of the river, just below the outlet of Nadina Lake, and would then drop back downstream to spawn (Figures A2.1 and A2.2). It is unclear what percentage of first-run Nadina Sockeye exhibited this behavior, though historical or current tagging work may help resolve this. Records indicate that spawning of the first-run sockeye occurred largely downstream of the mouth of Tagetochlain (a.k.a. Popple/Poplar) Creek (~6.5 to 21 km upstream of François Lake). The lower boundary of spawning for the first-run was reported at Seymour flats (6.5 km upstream of Francois Lake). The upper distribution could occur up to 40 km upstream of Francois Lake (Figures A2.1 and A2.2).

The later-run-timing component (second-run) spawned in mid-September. The majority of this run would spawn in the uppermost reaches of the river immediately downstream of Nadina Lake. It is this later run-timing component that was specifically targeted for enhancement by the channel that commenced operation in 1973, located adjacent to the main spawning grounds for the second-run CU (Rosberg et al, 1986).

Historically, there was one dominant cycle for the first and second-run, which occurred on the 1957 cycle year. For the first-run, the first three dominant cycle years on record (1949, 1953, and 1957) had an average EFS abundance of 12,000, while the average EFS for the second-run was 6,700. Subsequently, a number of factors appear to have contributed to a decline of the first-run CU, including the deterioration of spawning habitat quality and quantity. A few years of high pre-spawn mortality, particularly for the first-run CU, were reported in the escapement records on the dominant 1961 and 1965 cycle years. Productivity (ratios of female offspring in 1961 and 1965 vs. female parents in 1957 and 1961) was higher for the second-run compared to the first run in the 1957 (1.4 vs. 1.8) and 1964 (0.1 vs. 0.6) brood years. Lower productivity, attributed to pre-spawn mortality, reduced abundances of the first-run CU in these years.

Habitat loss was also reported in the lower Nadina River where first-run sockeye spawned. Loss of habitat was caused by log driving on Nadina River, which began in 1966. Logs were driven down the lower river, resulting in scouring of the river substrate. Although timing of the drives was conducted to minimize scouring of redds after spawning, the annual succession of drives in this river, and consequent log jams, created an unstable channel in lower Nadina River, which affected the quality of spawning habitat. During this period, the first-run sockeye stopped using this historic spawning ground. Although log driving was discontinued in 1968, early Nadina River sockeye no longer used the damaged lower spawning grounds (1969 first-run EFS: 4,000;

second-run EFS: 15,000). During this period the first-run abundances remained low relative to the second-run.

Further declines of the first-run coincided with the construction of the spawning channel on the Nadina River in 1973. The channel was installed to increase fry production from the second-run, and was installed near the spawning grounds of that population, below the falls at the outlet of Nadina Lake. It was felt that the rearing potential of Francois Lake was higher than current spawner abundances provided for, and the second-run was chosen for expansion. From 1974 to 1990, spawner abundances of the first-run further declined to particularly low abundances (1950-1972 average: 1,800 EFS; 1973-1988 average: 300). Meanwhile, escapements of the second-run (second-run plus channel estimates) increased following the construction of the channel (1973-2015) (average EFS: 23,000).

The 2011 Fraser Sockeye WSP report indicated that the first-run CU was potentially extirpated by channel operations, which prevented their access to Nadina Lake upstream, and also trapped first-run fish in the channel, resulting in mixing with the second-run. The potential extirpation of the first-run was suggested by the absence of escapements for this run in the post-1990 time series. However, it is unclear whether the post-1990 gap in the time series of first-run sockeye estimates is attributed to rolling up of the first and second run estimates, or whether the lack of observations of this run post-1990s was due to the discontinuation of assessments in the lower river, where the first-run sockeye spawned. Therefore, currently, we cannot confirm the extirpation of this first-run. A 2016 tagging study was conducted to validate whether or not the first-run CU still exists, through assessments of spawning timing and distribution within the Nadina River. Preliminary results from the 2016 study suggest that first-run spawners still exist. In addition, the tagging data indicate that there is much more mixing between the first- and second-run components than originally thought, suggesting that the first-run and second-run populations may not be as distinct from each other as previously believed, and could be considered a single CU. Presumably if there is sufficient spawning overlap between the first- and second-run populations, then these are not unique CUs. Additional tagging work is planned in upcoming years to confirm this. Some DNA sampling is also recommended to assist with verification.

<u>Benchmark Analysis (Abundance Metrics)</u>: The Nadina-Francois-ES stock-recruitment time series only includes years after the construction of the Nadina spawning channel (brood years 1973-2010), to ensure consistency in the spawning area throughout the time series. This CU is not considered cyclic. Therefore, a Ricker model was used to estimate relative abundance benchmarks for this CU. The S_{max} derived from the PR model exceeded spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Nadina-Francois-ES	**A/G**	**R**

Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Individual Assessments	A	A	A	G	R/A	A	G	A	A
After Plenary	A/G	A/G	A/G	A/G	A	A	A/G	A	A
Change?	Y	Y	Y	Y	Y		Y		
Num Changes	6								

Figure A2-47. First row presents final integrated statuses for Nadina/Francois-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber/Green status was driven by the relative-abundance metric, which was Amber at the 50% probability level and below, and Red at higher probability levels; this metric was Red for the most recent 12 years, and turned Amber in the current assessment year; although the productivity for this CU has been increasing in recent years, one year in the last four was below replacement;
- Green long-term trend and short-term trend metrics combined with increasing productivity in the past decade, tempered the Red high probability level relative-abundance statuses; improvement in the short-term trend metric is attributed to the stabilization of abundances in recent years, with no extremely large or small escapements occurring as observed earlier in the time series; this metric has been Green for the past two years;
- the status (Amber/Green) of this CU has improved since the previous assessment (Red);

Points of Discussion

- in the previous assessment there were comments regarding the stock-recruitment time series used for relative abundance benchmarks, specifically regarding low contrast in the time series, potentially due to channel operations; participants felt that the S_{max} was too high and its use should be reviewed, as was investigated in this assessment resulting in this prior not being used; regardless, a number of individuals felt as though the relative abundance benchmarks are high given the historic stock-recruitment time series.

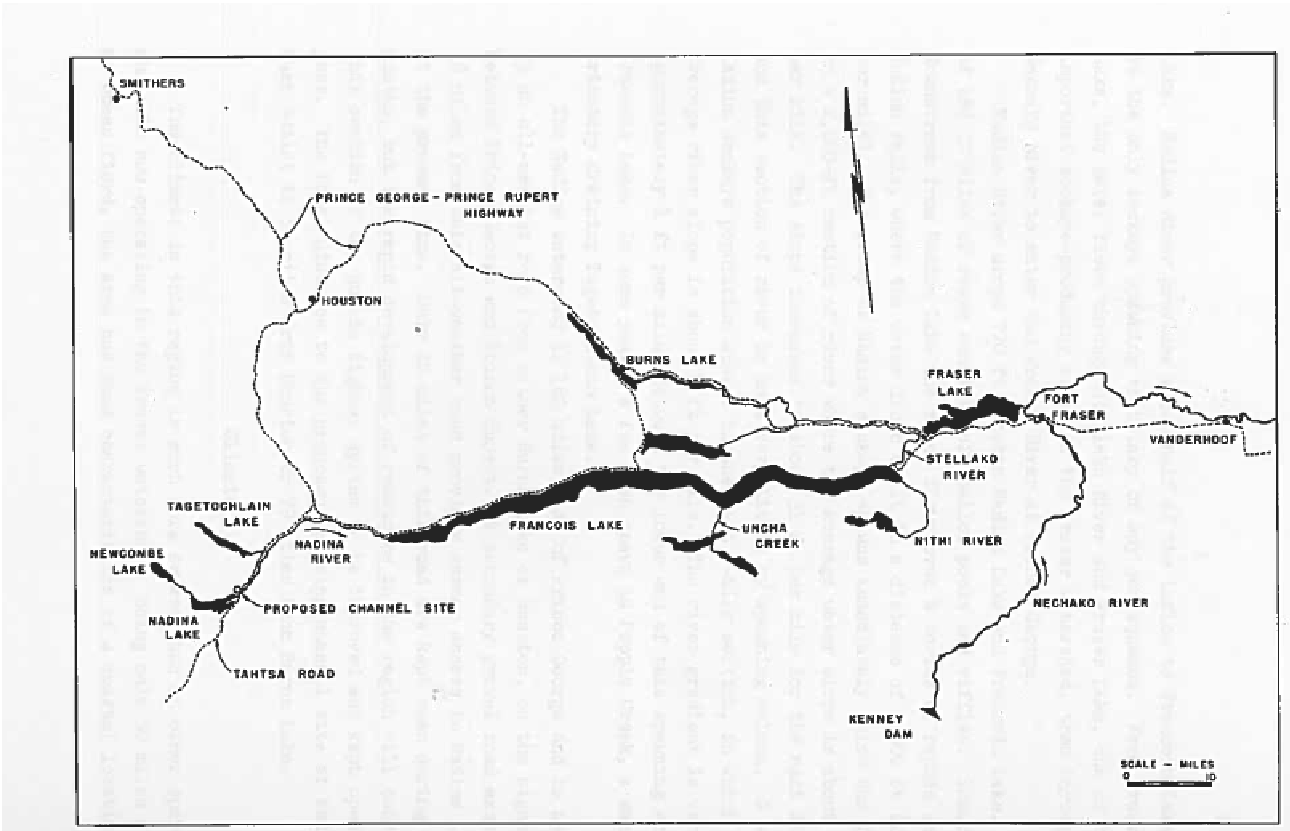


Figure A2-48 The Nechako system, including Fraser, Francois, and Nadina Lakes.

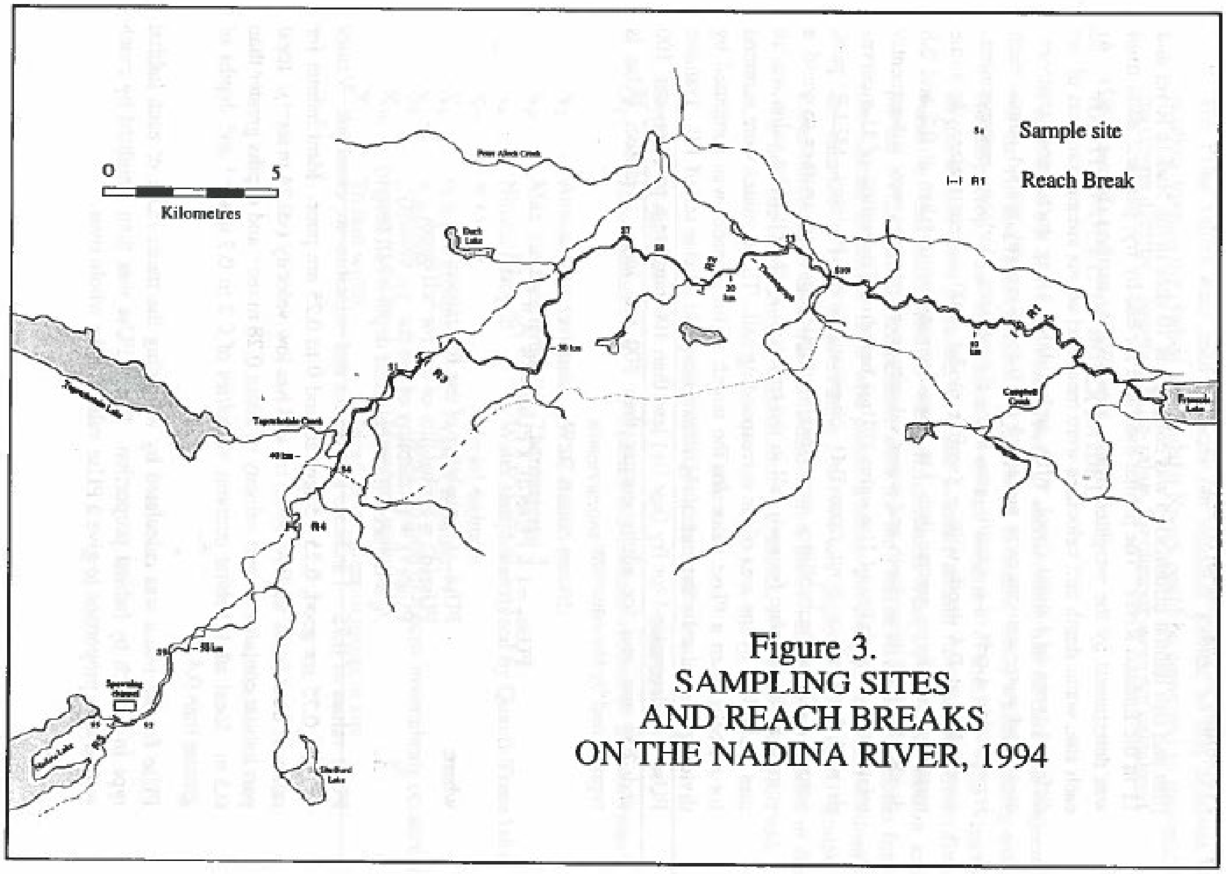


Figure A2-49 The Nadina River between Nadina Lake (left side of map) and Francois Lake (right side of map).The spawning channel is located at the outlet of Nadina Lake, as indicated on the map.

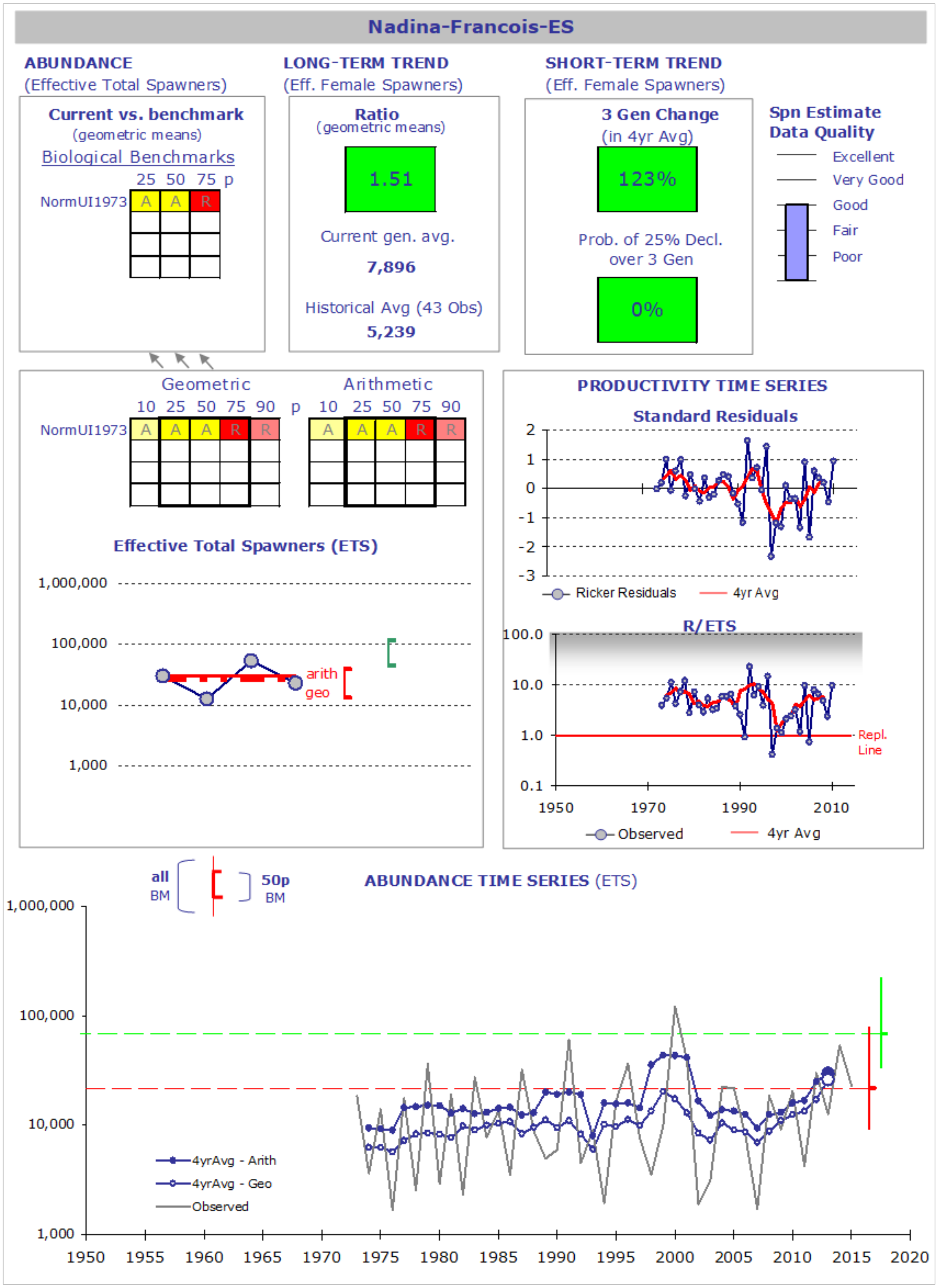
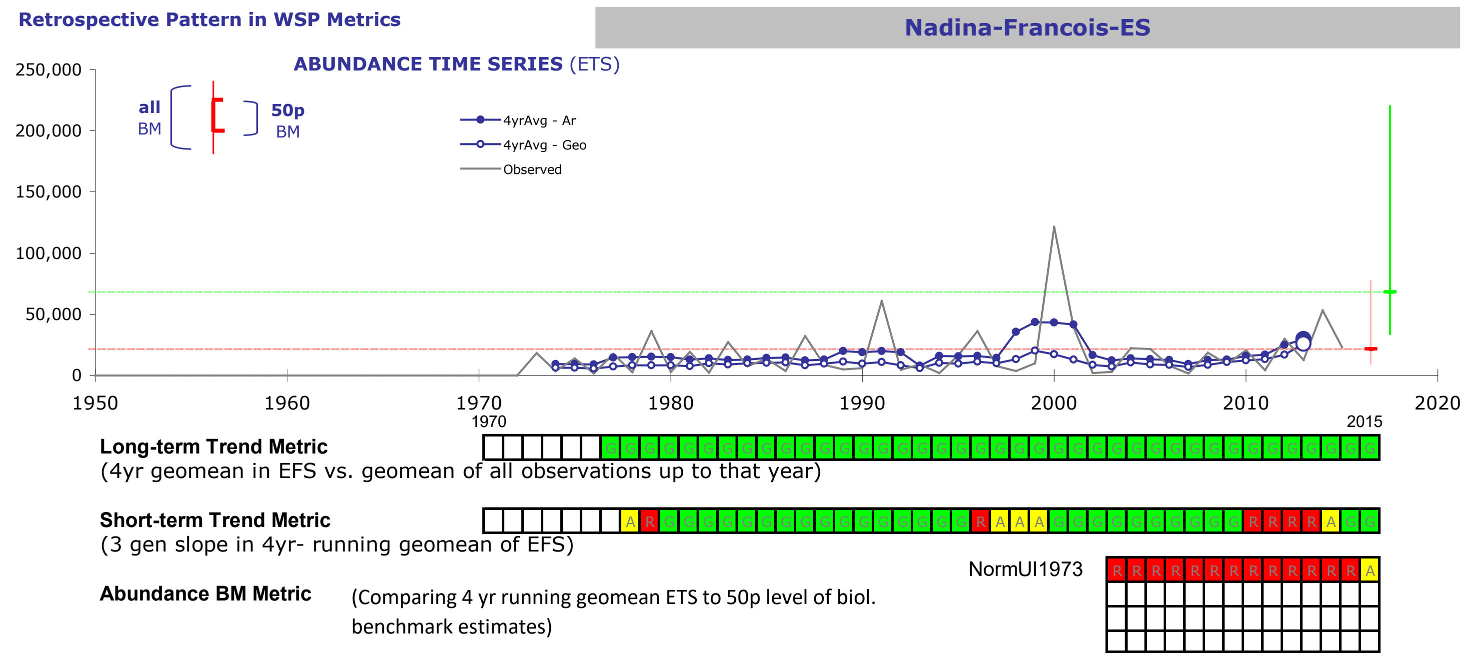


Figure A2-50. Nadina-Francois-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	121,490	53,348	53,348
Med	10,021	19,523	26,464
Min	1,685	1,722	12,655

Number of Observations in a range

	All Yrs	Last 12	Last 4
> 5000	29	10	4
2500–5000	9	1	0
1000–2500	5	1	0
500–**1000**	0	0	0
250–500	0	0	0
0–**250**	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1973-2010)	9,391	13,227	21,694	38,954	77,505
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1973-2010)	33,966	44,880	68,273	115,809	220,053
(-)					
(-)					
(-)					
(-)					

Figure A2-51. Nadina-Francois-ES -ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

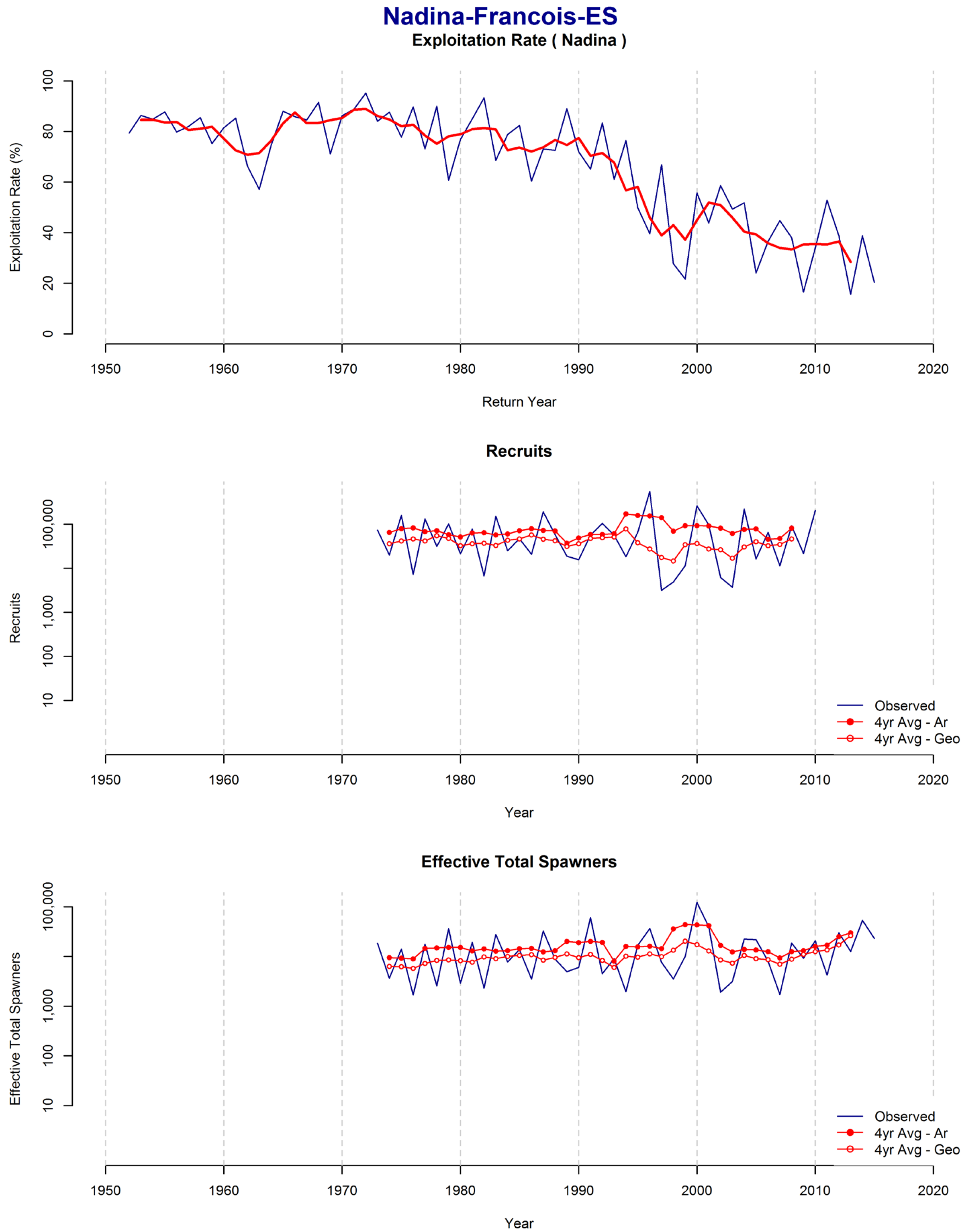


Figure A2-52. Nadina-Francois-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

NAHATLATCH-ES (I.E. MISCELLANEOUS EARLY SUMMER) (AMBER)

Background: This CU occurs in a relatively remote system located in a protected BC park. As a result, there are no known transplants or major human activities associated with this CU (Grant et al. 2011). This CU includes the Nahatlach Lake and River populations, since the lake is an index of abundance only, escapements for this CU are biased low

Benchmark Analysis (Abundance Metrics): Recruitment data are not available for this CU.

	2017 Status	2012 Status
Nahatlatch-ES	A	R

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A	A	A	A/G	A	A	A	A	A
After Plenary	A	A	A	A	A	A	A	A	A
Change?				Y					
Num Changes	1								

Figure A2-53. First row presents final integrated statuses for Nahatlatch-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the absolute abundance of this CU drives the overall status of Amber (median abundances are 2,000 EFS); one recent year falls under the COSEWIC Criterion for small populations (1,000);
- the short-term trend metric changed to Green in the current assessment; retrospective analysis indicates that this metric was Amber in the previous year and Red for the 8 years prior to that; the long-term trend metric is also Green; currently this CU has a Green status on most metrics other than absolute abundance;
- the current status (Amber) of this CU has improved since the previous assessment (Red);

Points of Discussion

- absolute abundances in this CU are small (although biased low-see background above), therefore, changes in the metrics of this CU should be evaluated frequently to ensure there are no factors that could be managed to improve the state of the CU;
- status of this CU has declined despite reductions in exploitation overall;

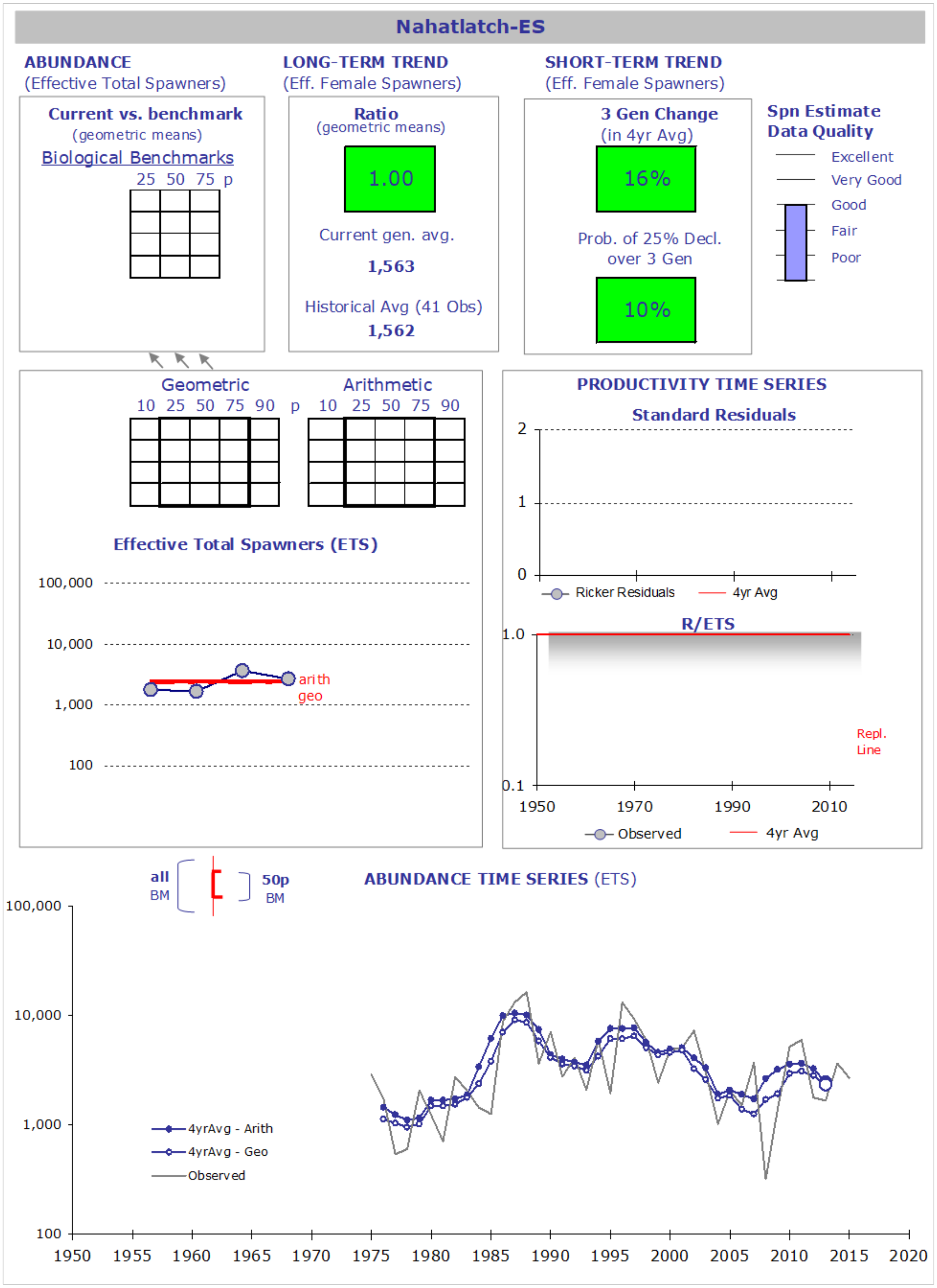
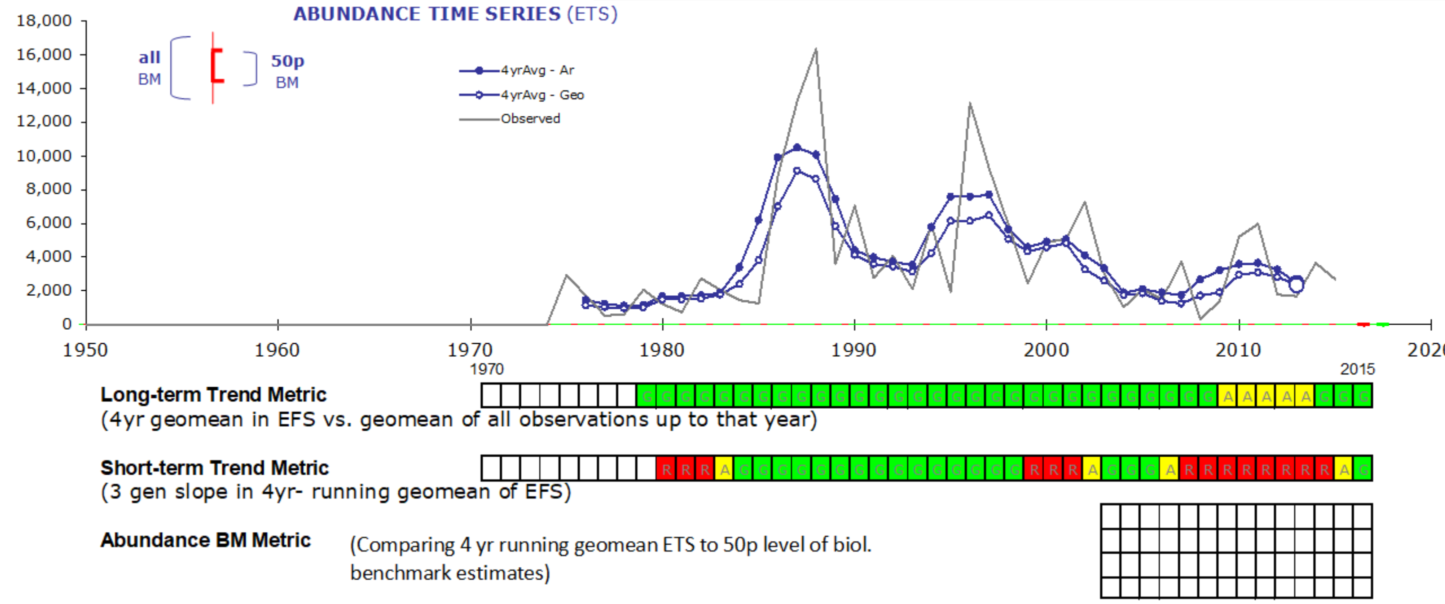


Figure A2-54. Nahatlatch-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Nahatlatch-ES



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	16,349	5,957	3,635
Med	2,734	1,915	2,234
Min	318	318	1,672

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	12	2	0
2500	10	3	2
1000	15	6	2
500	3	0	0
250	1	1	0
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Figure A2-55. Nahatlatch-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

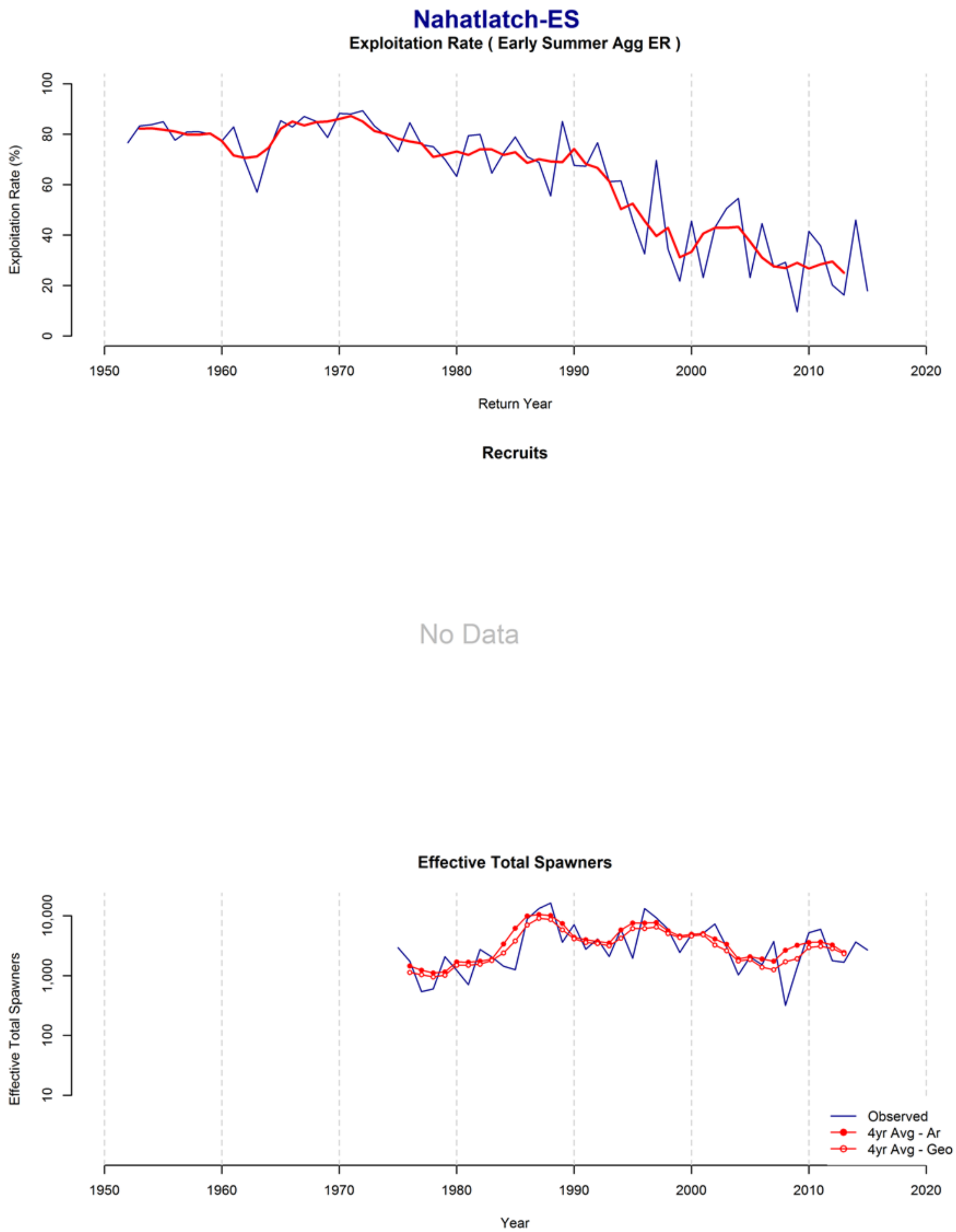


Figure A2-56. Nahatlatch-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

NORTH BARRIERE-ES DE NOVO (I.E. UPPER BARRIERE/FENNELL) (AMBER)

Background: The original North Barriere-ES CU was extirpated by the construction of a downstream dam. With the combination of dam removal and hatchery transplants, this population was re-established (Grant et al. 2011). Only data post-1970, after this CU started to re-build, was used in the status evaluation

Benchmark Analysis (Abundance Metrics): This CU has not exhibited cyclic dominance historically. Therefore, a Ricker model was used to estimate relative abundance benchmarks for this CU. No independent estimates of S_{max} (based on photosynthetic rate models) were available for this CU (Appendix 7). Abundance benchmarks were therefore fit using an uninformative lognormal prior on Smax .

	2017 Status	2012 Status
North Barriere-ES	A	A

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A	A	A	A	A	A	A		A
After Plenary	A	A	A	A	A	A	A		A
Change?									
Num Changes	0								

Figure A2-57. First row presents final integrated statuses for North Barriere-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Amber integrated status was driven by the consistent Amber relative-abundance statuses across probability levels; however, similar to the last assessment, the lower benchmarks were flagged as being low (ranged from 600 to 1,400) relative to the COSEWIC Criterion for small populations (1,000); this CU is comprised of a single small population, which contributes to Amber status;
- Recent productivity appears stable but low, with a number of years falling below the replacement line;
- the short-term trend metric was Red; this CU has been exhibiting a declining trend for a number of cycles;
- the Green long-term trend status alone was not sufficient to increase this CU's status from Amber; the retrospective evaluation indicates that the long-term trend status has been Green for most of the assessed time series, likely due to the building of this population following the dam removal in the early time series; unlike the previous assessment, there were no years in the past four that fell below the COSEWIC Criterion for small populations (1,000);
- the current status (Amber) of this CU has not changed since the previous assessment;

Points of Discussion

- data issues were flagged prior to 1980, where recruit-to-spawner ratios were greater than 20 to 1; it was suspected that issues with the data are linked to recruitment estimates, since very few fish were estimated in the fisheries, due to the low abundances in this early period; due to concern over the S/R time series, given the small size of this CU, less weight given to the productivity trends;
- in the previous assessment there was discussion regarding the relative importance of the WSP relative-abundance benchmark estimated for this CU compared to the COSEWIC Criterion for small populations (1,000).

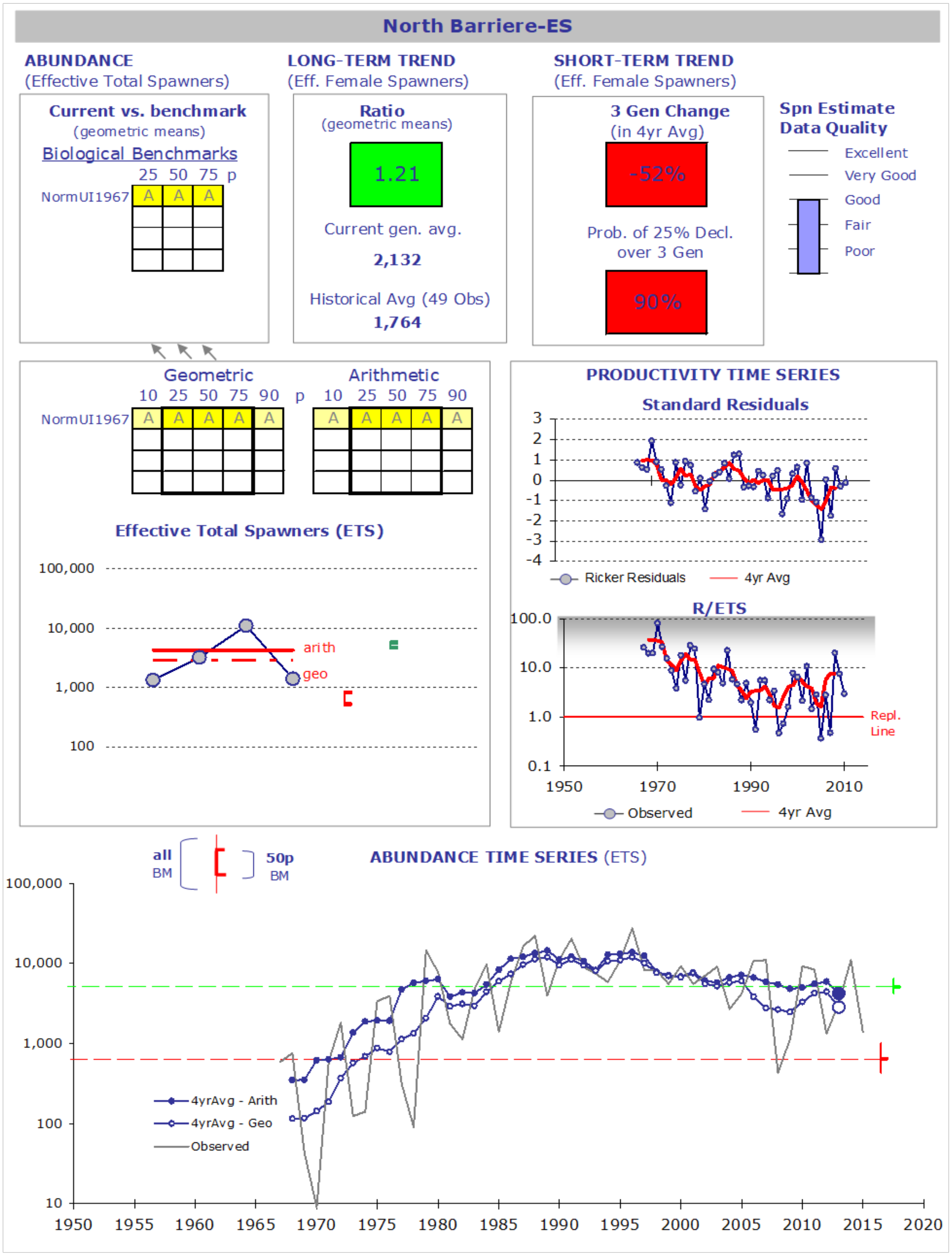
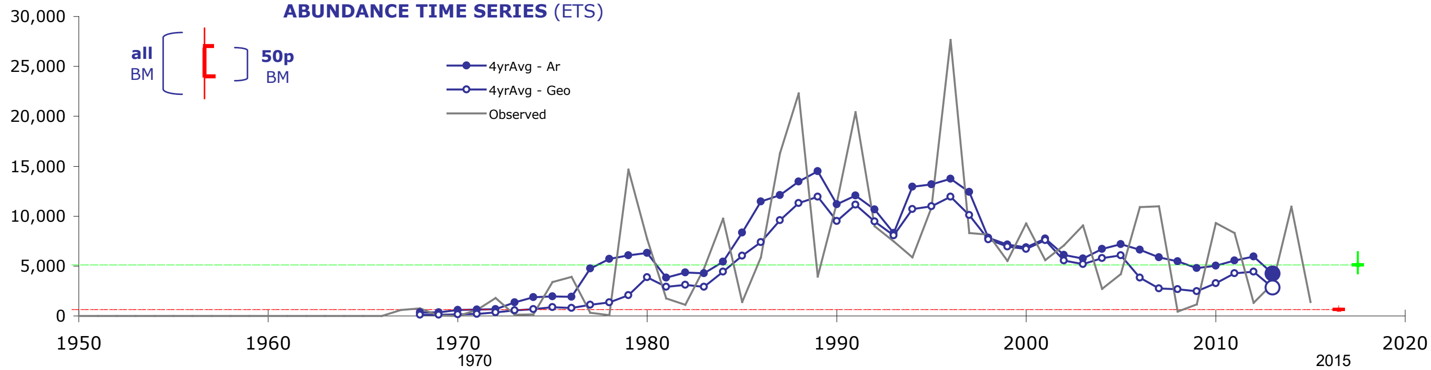


Figure A2-58. North Barriere-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

North Barriere-ES

ABUNDANCE TIME SERIES (ETS)

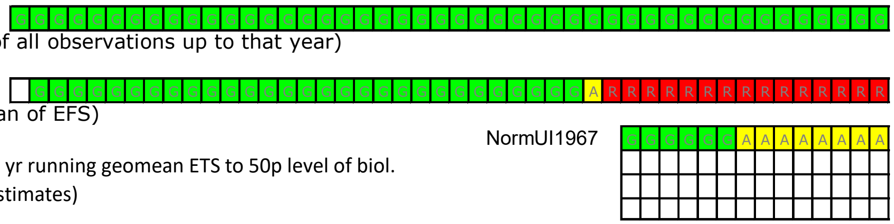


Long-term Trend Metric
(4yr geomean in EFS vs. geomean of all observations up to that year)

Short-term Trend Metric
(3 gen slope in 4yr- running geomean of EFS)

Abundance BM Metric (Comparing 4 yr running geomean ETS to 50p level of biol. benchmark estimates)

NormUI1967



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	27,628	10,991	10,957
Med	5,531	3,709	2,304
Min	9	431	1,331

Number of Observations in a range

Range	All Yrs	Last 12	Last 4
above 5000	25	5	1
2500–5000	7	3	1
1000–2500	7	3	2
500–**1000**	3	0	0
250–500	2	1	0
0–**250**	5	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1967-2010)	427	518	640	820	1,019
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1967-2010)	4,260	4,615	5,097	5,723	6,403
(-)					
(-)					
(-)					
(-)					

Figure A2-59. North Barriere-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

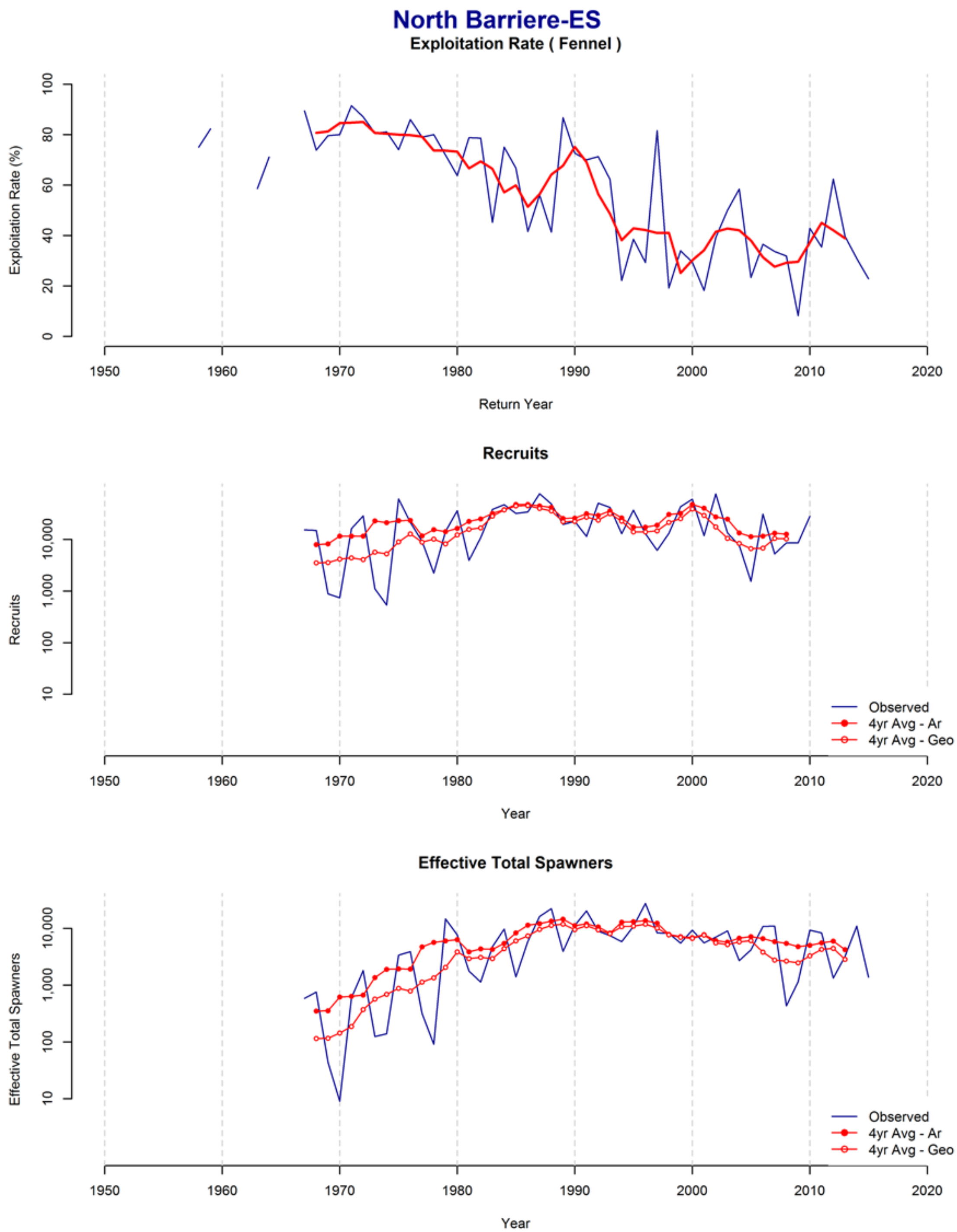


Figure A2-60. North Barriere-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

PITT-ES (GREEN)

<u>Background:</u> This CU is supplemented with hatchery produced fry releases (Pitt Sockeye origin). Since these hatchery-origin sockeye are not externally marked, it is unclear how this supplementation influences the stock-recruitment time series (Grant et al. 2011).

<u>Benchmark Analysis (Abundance Metrics):</u> The full stock-recruitment time series for Pitt-ES includes the brood years 1950-2010. This CU has not exhibited cyclic dominance historically. Therefore, a Ricker model was used to estimate relative abundance benchmarks for this CU. The Pitt escapement and recruitment time series includes fish removed from the spawning population for Pitt River hatchery enhancement. The S_{max} derived from the PR model seemed reasonable when compared to the spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, a Ricker model was applied with both an informative and uninformative prior on the beta parameter. Both priors resulted in Red statuses for the relative-abundance metric across all probability levels.

	2017 Status	2012 Status
Pitt-ES	G	A/G

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	G	G	G	G	G	G	G	G
After Plenary	G	G	G	G	G	G	G	G	G
Change?									
Num Changes	0								

Figure A2-61. First row presents final integrated statuses for Pitt-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

<u>Status Commentary</u>

- the Green integrated status was driven by the consistently Green status for the relative-abundance metric across all probability levels; this metric has been Green for the entire assessed time series; the long-term trend metric was also Green, and has been Green for almost two decades; recent productivity is increasing (in the previous assessment productivity was decreasing) and recent abundances are starting to increase;
- only the short-term trend was Red, which indicates that this CU should be monitored to ensure that the very recent trend of increasing abundances continues, however, this metric alone was not sufficient to reduce the status of this CU; the short-term trend metric has been Red for the past 7 years and there have been periods of Red and Green statuses throughout the time series; no values in the past 12 years, fall below the COSEWIC Criterion for small populations (1,000). Absolute abundances are relatively large for this CU and the minimum ETS in the last four years was 30,000;
- the hatchery influence should introduce a positive bias to the productivity and abundance time series;
- the current status (Green) of this CU has improved since the previous assessment (Amber/Green);

<u>Points of Discussion</u>

- hatchery released fry otoliths are thermally marked by SEP; the ratios of marked to unmarked returning adults was not provided at the time of this assessment; why this CU is enhanced remains a question.

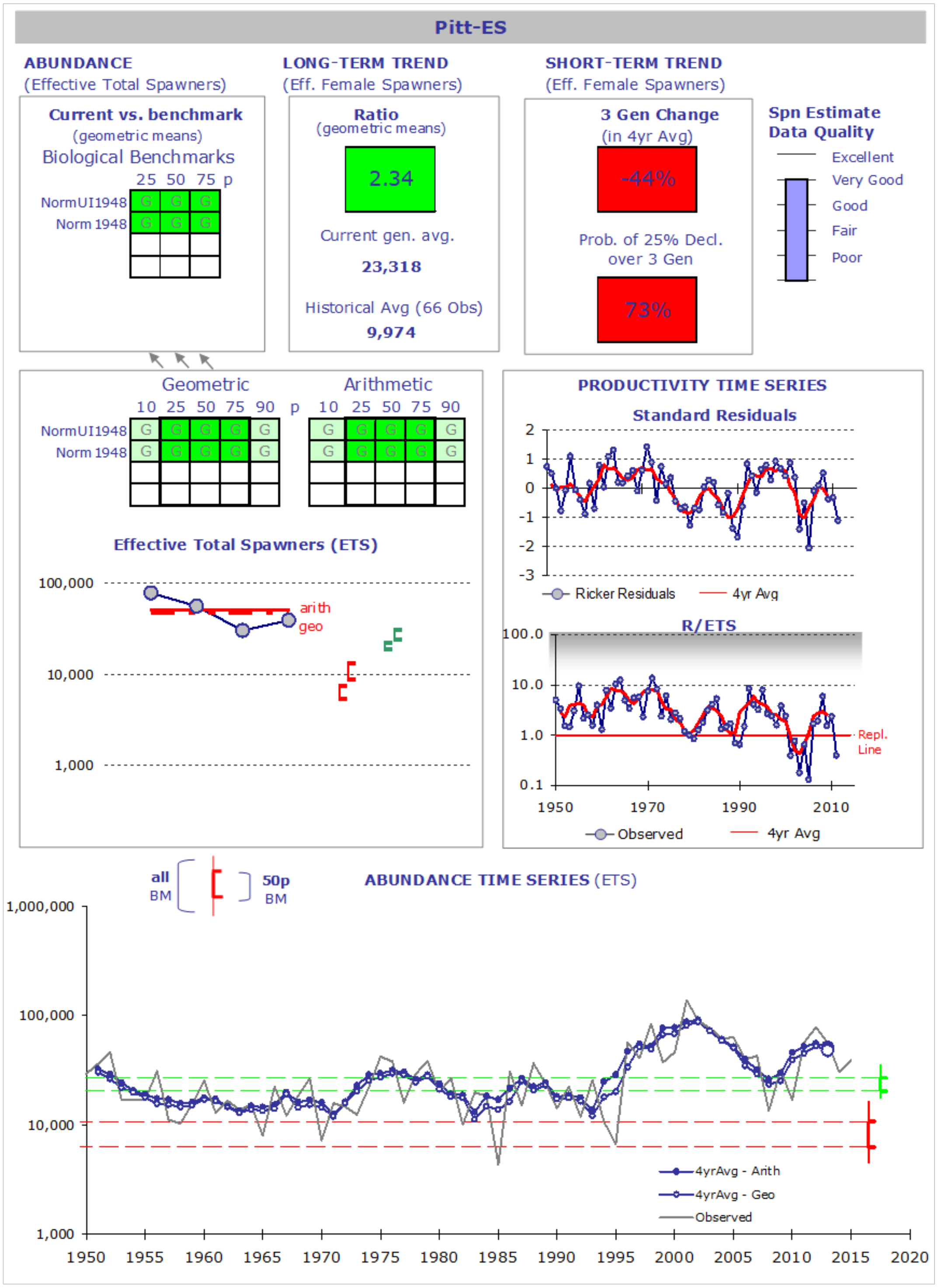
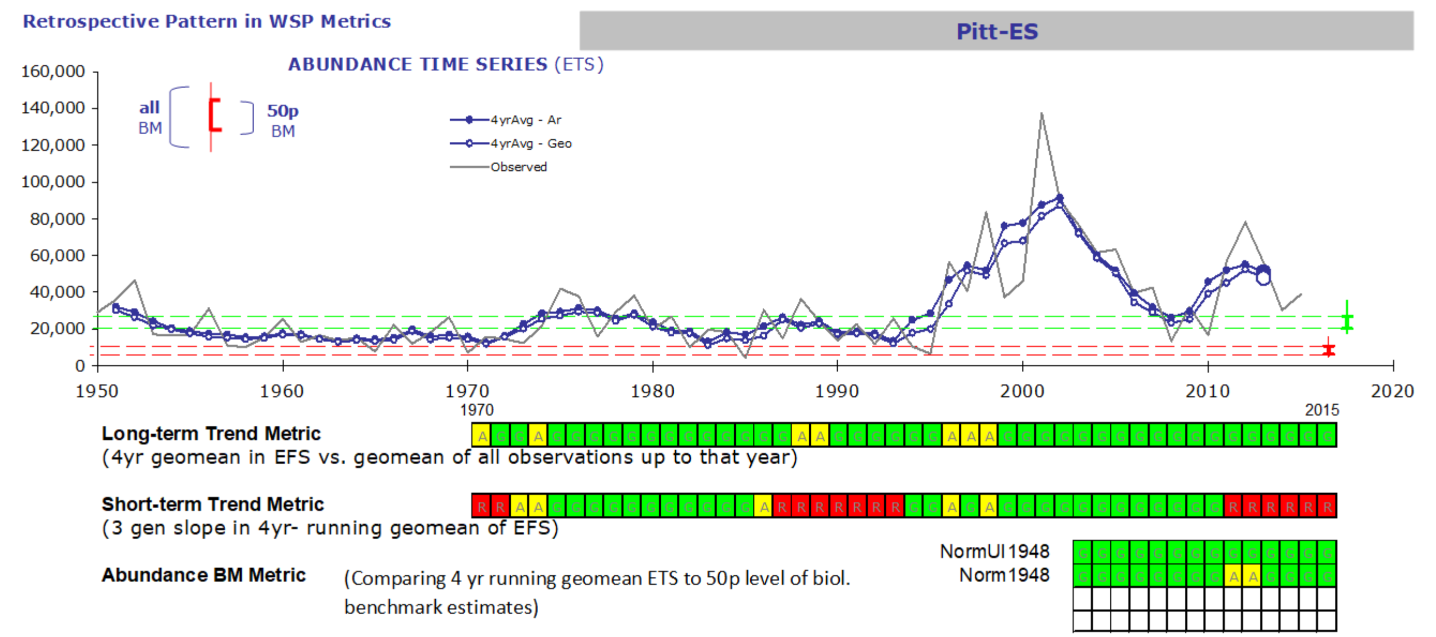


Figure A2-62. Pitt-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	137,313	78,089	78,089
Med	23,245	41,060	47,548
Min	4,336	13,445	30,293

Number of Observations in a range

	65	12	4
5000	1	0	0
2500	0	0	0
1000	0	0	0
500	0	0	0
250	0	0	0
0			

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Norm UI(1948-2011)	4,586	5,308	6,240	7,482	9,001
Norm(1948-2011)	7,450	8,788	10,627	13,108	16,112
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Norm UI(1948-2011)	17,583	18,800	20,333	22,264	24,504
Norm(1948-2011)	21,990	23,957	26,845	30,710	35,263
(-)					
(-)					
(-)					

Figure A2-63. Pitt-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

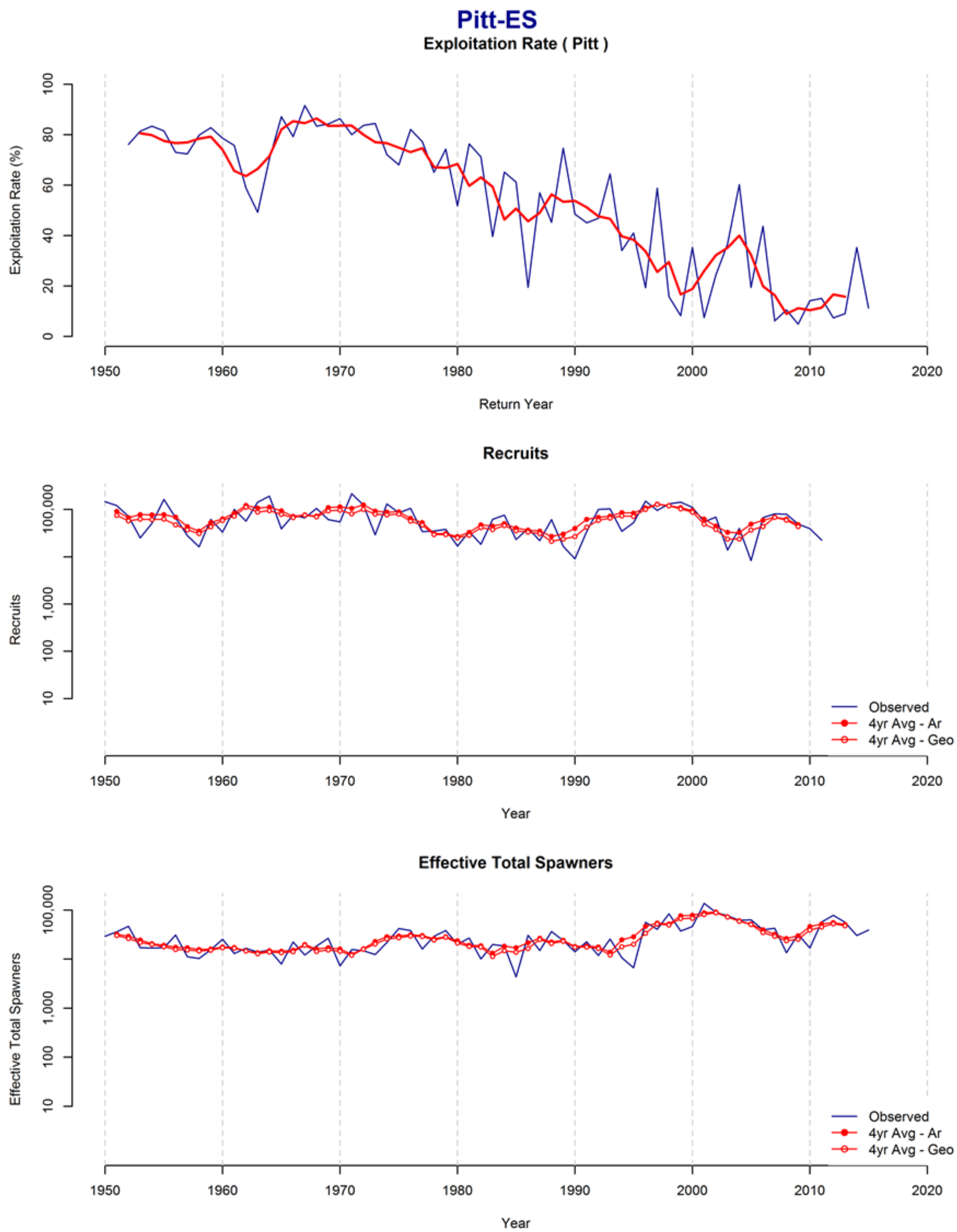


Figure A2-64. Pitt-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

QUESNEL-S (CYCLIC) (RED/AMBER-LARKIN; AMBER-NO LARKIN)

Background: This CU was likely the largest of all summer run timed populations prior to the late-1880's. Subsequently, this CU declined due to dam construction at the outlet of Quesnel Lake, placer mining impacts on spawning habitat, and the Hells Gate landslide. After barriers to fish migration were eliminated, this CU started to re-build notably in the 1980's (see Grant et al. 2011 for further details). In 2010, the Mount Polley mine breach occurred on the west side of the Quesnel Lake system, which dumped mine tailings into the lake. Research is on-going to determine if there are any short- or long-term impacts on this CU.

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series available for Quesnel-S includes the brood years 1950-2010. This CU is currently considered cyclic, though there may be shifts in the dominant cycle year recently. Larkin-based benchmarks are presented for each cycle line (one dominant, one sub-dominant, and two low) and are compared to the most recent ETS from each respective cycle line.

Quesnel-S

	2017 Status		2012 Status
Larkin	R/A		R/A
no Larkin	A		

No Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A	A	A	R/A	A		A		A
After Plenary	A	A	A	A	A		A		A
Change?				Y					
Num Changes	1								

With Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R/A	R/A	R/A	R	R/A		A		R/A
After Plenary	R/A	R/A	R/A	R/A	R/A		R/A		R/A
Change?				Y			Y		
Num Changes	2								

Figure A2-65. First row presents final integrated statuses for Quesnel-S in 2017 with and without Larkin model benchmarks included in decision and 2012, where no Larkin model methods were used. The second and third row presents this CU's integrated status by individual participant before and after the plenary session excluding consideration of Larkin benchmarks. The forth row is the number of changes. The third and fourth row present this CU's integrated status by individual participant before and after the plenary session including consideration of Larkin benchmarks. The final row is the number of changes indicated.

Status Commentary (with Larkin)

- mixed statuses for the relative-abundance metric contributed to the Red/Amber integrated status; status for this metric was Red on the dominant cycle at probability levels below 50%, and Amber above; statuses were Amber on the subdominant cycle and Red on the two weak cycles; it appears that the dominant cycle might be shifting, with the new dominant cycle emerging on the previously subdominant cycle;
- the Red component of the Red/Amber integrated status for this CU is driven by declines in productivity in the recent decade, and the Red short-term trend status; abundance was relatively low from 2006 to 2013 and one year in the last four falls below the COSEWIC Criterion for small populations (1,000);
- some positive signals in the status include the slight increase in the R/ETS time series in recent years, though the Larkin model residuals do not indicate a similar increase; and the Green status of the long-term trend metric (which has been Green for the entire time series);
- the current status (Red/Amber) of this CU has not changed since the previous assessment;

Status Commentary (without Larkin)

- the Amber integrated status is driven by declines in productivity in the recent decade, and the Red short-term trend status; abundance was relatively low from 2006 to 2013, and one year in the last four falls below the COSEWIC Criterion for small populations (1,000); positive signals in status include the slight increase in the R/ETS time series in recent years, though the Larkin model residuals do not indicate a similar increase; and the Green status of the long-term trend metric (which has been Green for the entire time series);
- declines in abundance have not occurred on all cycles: although the dominant 2013 cycle has decreased in very recent years, along with one weak cycle, the subdominant 2014 cycle and weak 2015 cycle have both increased and remained high in recent years;
- Retrospective results indicate that the short-term trend metric has been Red for a decade; there has been one year in the last four that falls below the COSEWIC Criterion for small populations (1,000).
- the current status (Amber) of this CU has improved since the previous assessment;

Points of Discussion

- two very large successive escapements in 2001 and 2002 altered lake productivity; since the collapse, a new “dominant” cycle has emerged from the previous subdominant cycle. This seems to create problems for the labelling of the lines and the Larkin model. A few individuals did not weigh the relative-abundance metric high when they assessed the status.
- Lots of discussion on cycle patterns changing over time, and whether the Larkin benchmarks may become less reliable in these cases;

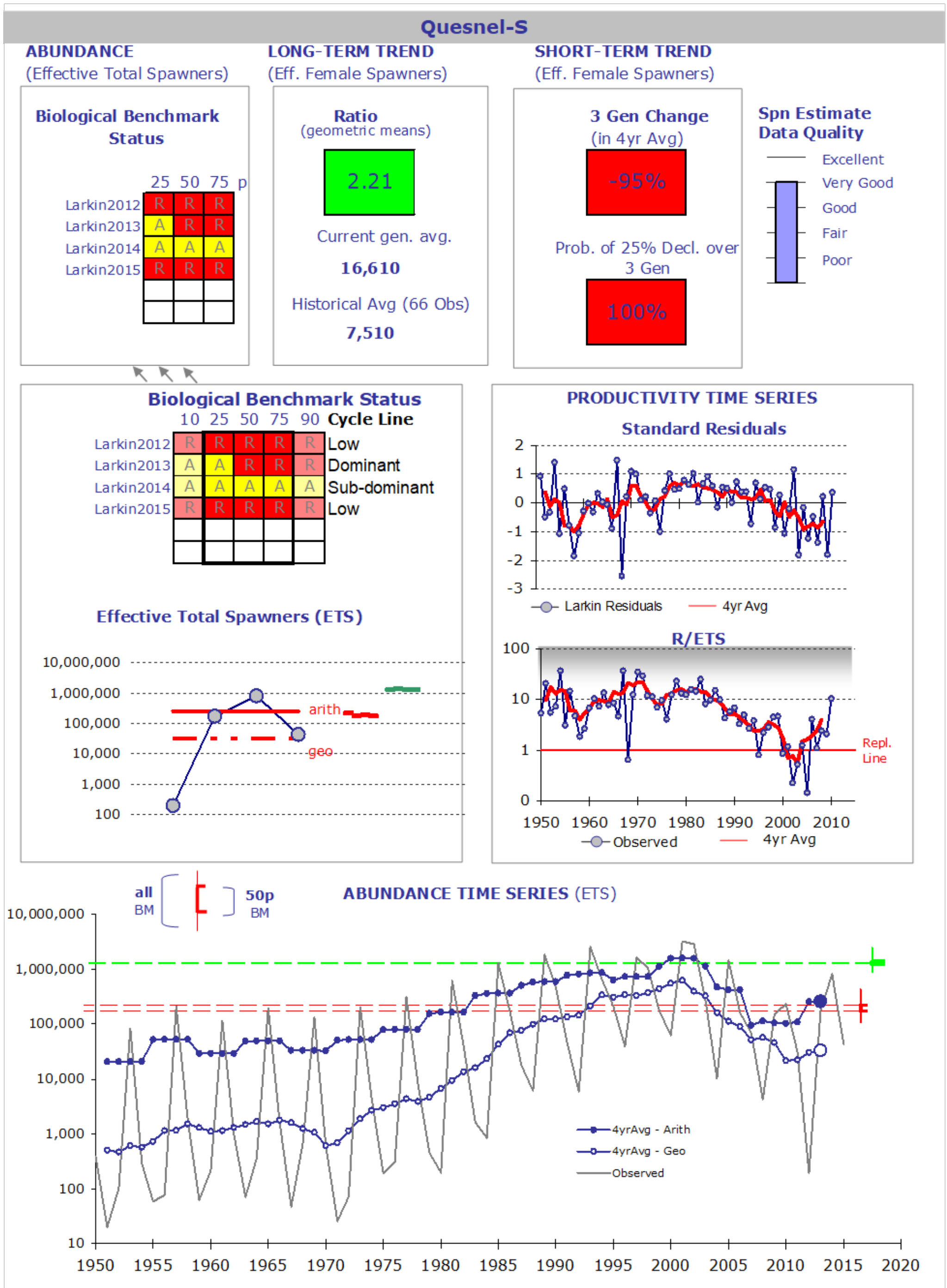
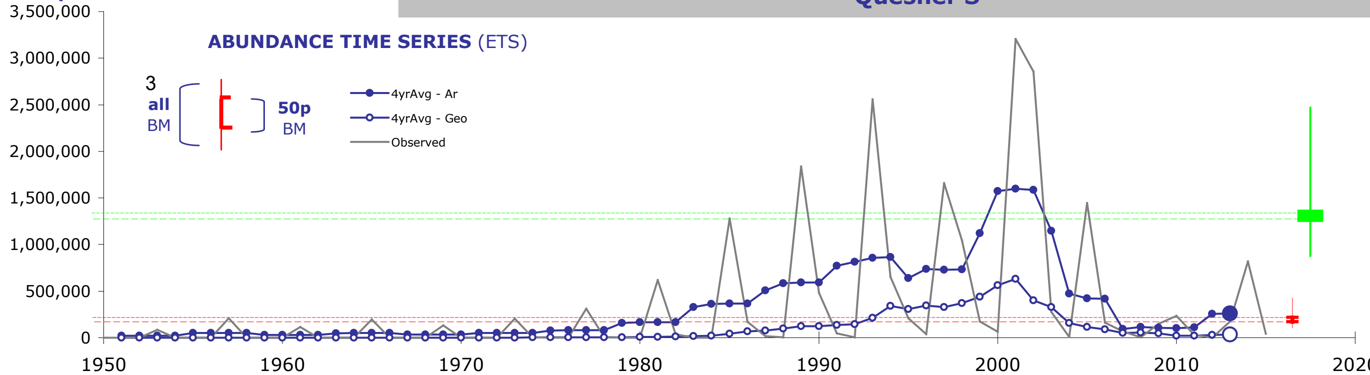


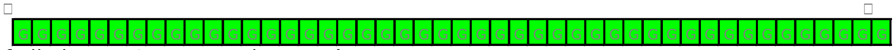
Figure A2-66. Quesnel-S data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

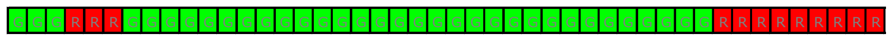
Quesnel-S



Long-term Trend Metric
(4yr geomean in EFS vs. geomean of all observations up to that year)

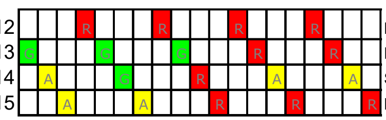


Short-term Trend Metric
(3 gen slope in 4yr- running geomean of EFS)



Abundance BM Metric (compares that year's ETS to Larkin, or geomean ETS to percentile or biological benchmark 50p level)

Larkin2012
Larkin2013
Larkin2014
Larkin2015



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	3,205,043	1,443,290	817,922
Med	35,094	109,009	108,148
Min	20	198	198

Number of Observations in a range

5000	39	10	3
2500	2	1	0
1000	3	0	0
500	4	0	0
250	5	0	0
0	13	1	1

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S_{gen})

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Larkin(2012)	137,943	168,503	218,849	301,303	428,416
Larkin(2013)	111,879	136,942	180,491	250,005	356,422
Larkin(2014)	122,828	151,674	197,467	274,762	393,295
Larkin(2015)	108,218	132,480	172,260	238,726	341,368

Upper Benchmark Est. (80% S_{MSY})

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Larkin(2012)	876,714	1,023,759	1,274,566	1,688,626	2,336,125
Larkin(2013)	917,580	1,071,124	1,337,891	1,772,895	2,466,672
Larkin(2014)	901,383	1,051,708	1,307,742	1,728,165	2,392,470
Larkin(2015)	886,184	1,037,337	1,291,038	1,712,144	2,367,459

Figure A2-67. Quesnel-S data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1

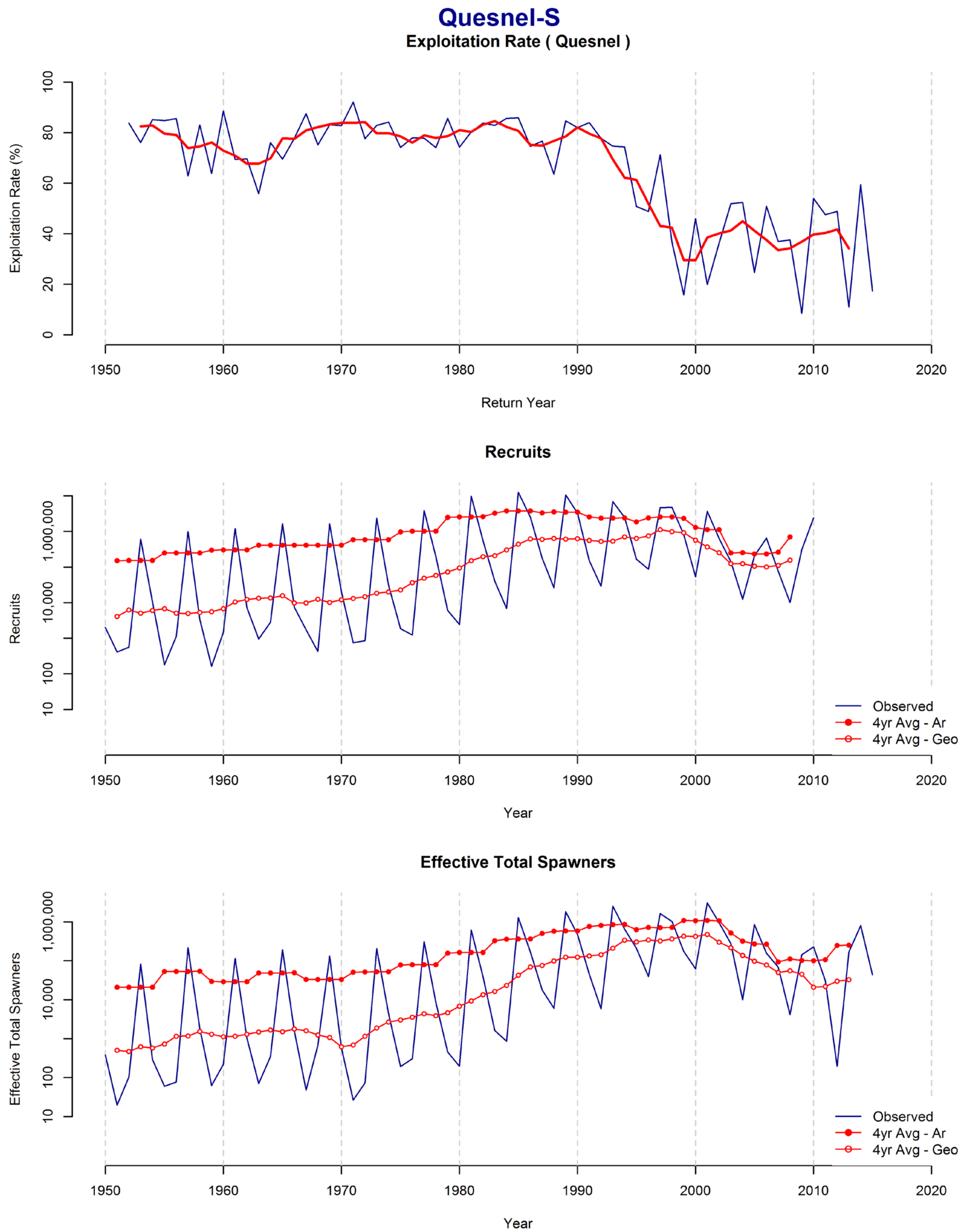


Figure A2-68. Quesnel- S data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

SETON-L (DE NOVO) (I.E. PORTAGE) (RED)

Background: The original CU was extirpated by poor hatchery husbandry techniques and the Hells Gate landslide. Subsequently hatchery transplants were used initially to re-build this population (hatchery supplementation does not occur currently). This population re-established and is labelled *de novo* due to its hatchery origins. Note: these fish must migrate through a hydroelectric facility, which can represent challenges to migration (detailed in Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series for Seton-L includes the brood years 1965-2010. This CU is not considered cyclic. Therefore, a Ricker model was used to estimate relative-abundance benchmarks for this CU. The S_{max} derived from the PR model exceeded spawning capacity of this system, based on expert opinion of spawning habitat capacity and a sensitivity analysis of the impact of informative Bayesian priors on posteriors and estimated biological benchmarks (Table 11; Appendix 7). Therefore, only a Ricker model with an uninformative prior on the beta parameter was applied.

	2017 Status	2012 Status
Seton-L	**R**	**UNDET**

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	UNDET	R	R	R	R	R
After Plenary	R	R	R	R	R	R	R	R	R
Change?				Y					
Num Changes	1								

Figure A2-69. First row presents final integrated statuses for Seton-L in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by the relative-abundance-metric status, which was Red across all probability levels, and the consistency of Red statuses across all metrics (long-term and short-term trends); in addition, two years out of the past four have fallen below the COSEWIC Criterion for small populations (1,000); productivity has also been low in recent cycles, with a few years falling below replacement;
- the retrospective evaluation indicates that all metric statuses have been Red for a number of years: the relative-abundance status has been Red for the past seven years; the short-term trend status has been Red for the past 15 years; and the long-term trend status has been Red for the past 5 years;
- the current status (Red) of this CU has changed since the previous assessment (undetermined); in the previous assessment, status could not be assessed because all metrics and information indicated different statues;

Points of Discussion

- there is uncertainty in the escapement estimates, given the small abundances; however, the overall conclusions will not be affected even if they are underestimates;
- this CU exhibited cyclic patterns historically, but has not in recent years;

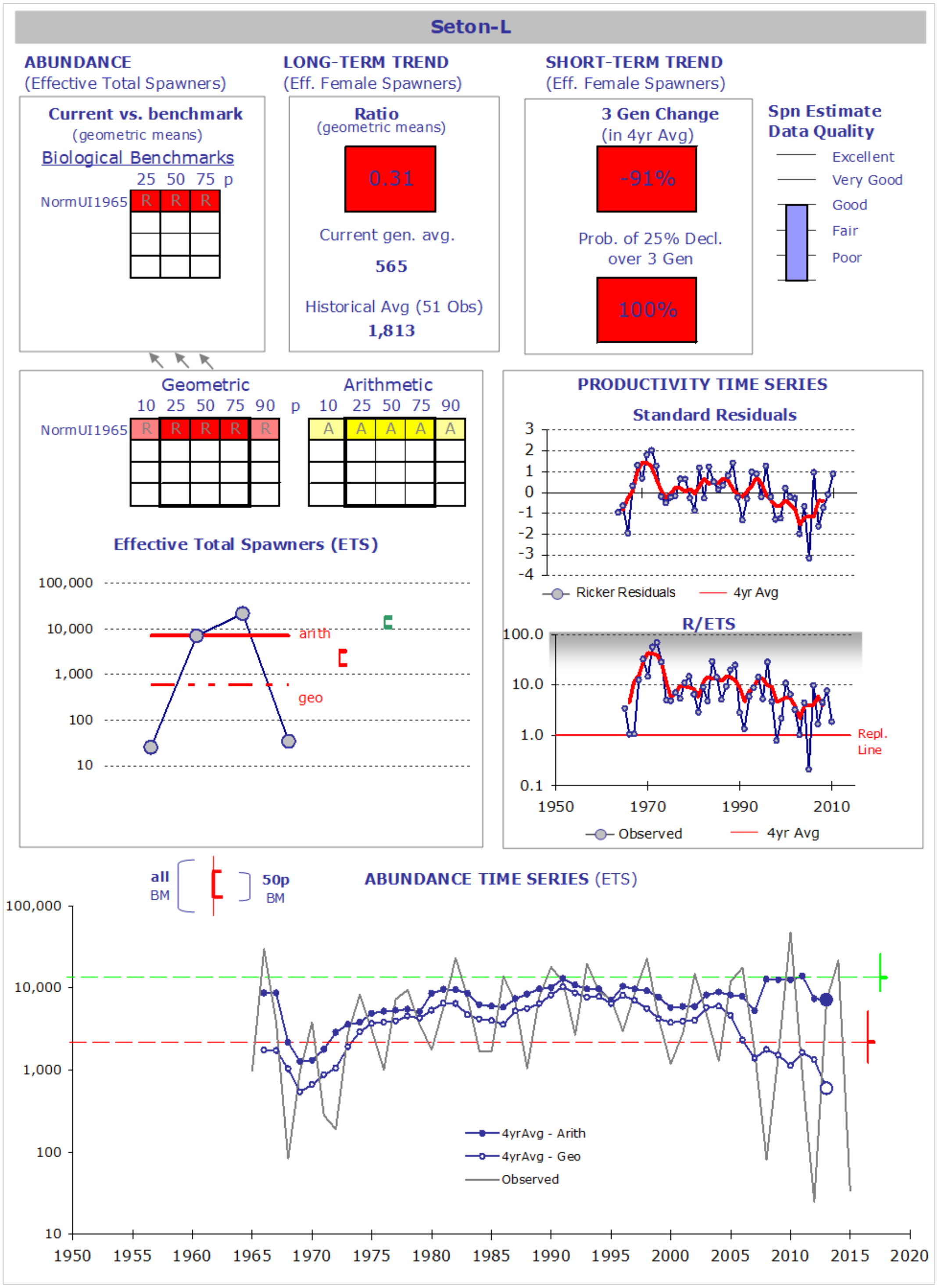
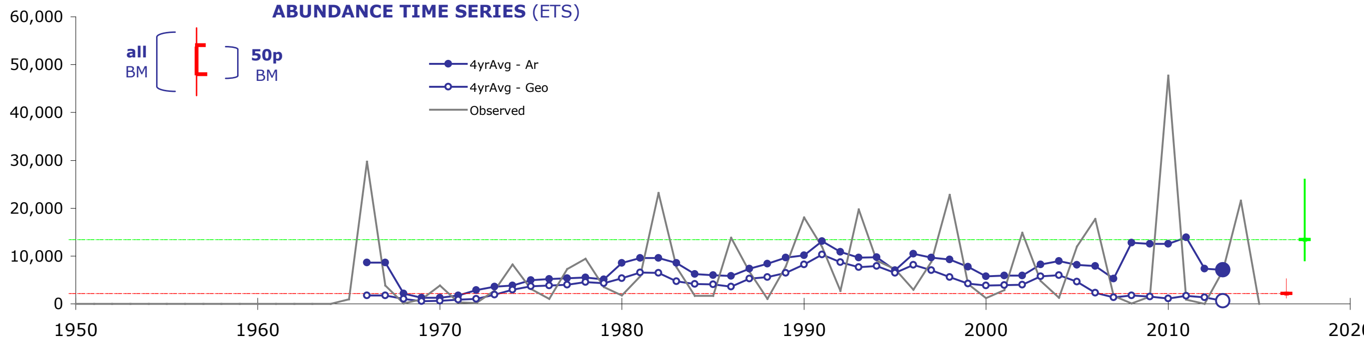


Figure A2-70. Seton-L data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.

Retrospective Pattern in WSP Metrics

Seton-L



Long-term Trend Metric
(4yr geomean in EFS vs. geomean of all observations up to that year)

Short-term Trend Metric
(3 gen slope in 4yr- running geomean of EFS)

Abundance BM Metric (Comparing 4 yr running geomean ETS to 50p level of biol. benchmark estimates)

NormUI1965

Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	47,722	47,722	21,582
Med	3,857	1,622	3,494
Min	25	25	25

Number of Observations in a range

	All Yrs	Last 12	Last 4
>5000	23	5	2
2500–5000	10	0	0
1000–2500	9	3	0
500–1000	3	1	0
250–500	1	0	0
0–250	5	3	2

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
NormUI(1965-2010)	1,224	1,585	2,193	3,225	5,294
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
NormUI(1965-2010)	9,108	10,760	13,453	17,697	25,948
(-)					
(-)					
(-)					
(-)					

Figure A2-71. Anderson-Seton-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

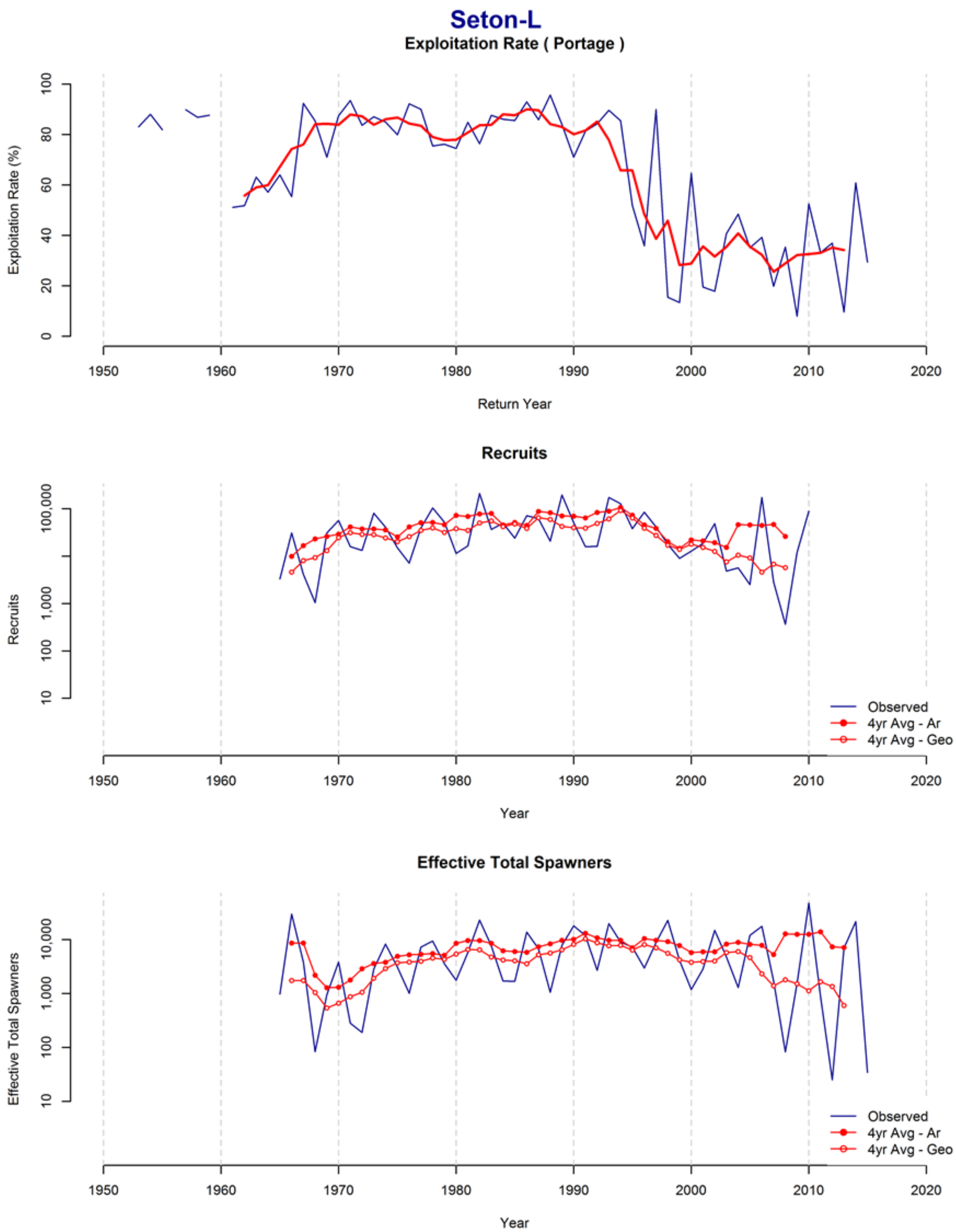


Figure A2-72. Seton-L data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

SHUSWAP-ES (CYCLIC) (I.E. SCOTCH & SEYMOUR) (AMBER-LARKIN OR GREEN-NO LARKIN)

Background: Scotch Creek was enhanced on the cycle line coinciding with the dominant Adams River cycle using Seymour Creek as a donor stock; as a result the Scotch Creek population started to build in the 1980's. Seymour is frequently used as a hatchery donor population for other CUs (Grant et al. 2011). Scotch, Seymour and McNomee are used for the escapement trends metrics, and only Seymour is used for the stock-recruitment analysis.

Benchmark Analysis (Abundance Metrics): This CU is considered cyclic. Therefore, a Larkin model was used to estimate relative-abundance benchmarks for this CU. Only data from Seymour River in considered for the relative-abundance metric. The full stock-recruitment time series available for Shuswap-ES includes the brood years 1950-2010. Cyclic Larkin-based benchmarks are presented for each cycle line (one dominant, one sub-dominant, and two low) and are compared to the most recent ETS abundance from each respective cycle line.

Shuswap-ES

	2017 Status		2012 Status
	A	Larkin	A/G
	G	no Larkin	

No Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	A	G	G	R/A		G		G
After Plenary	G	A/G	G	G	A/G		G		G
Change?		Y			Y				
Num Changes	2								

With Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	A/G	A	A	A/G	R		G		A
After Plenary	A/G	A	A	A/G	A		A/G		A
Change?					Y		Y		
Num Changes	2								

Figure A2-73. First row presents final integrated statuses for Shuswap-ES in 2017 with and without Larkin model benchmarks included in decision and 2012, where no Larkin model methods were used. The second and third row presents this CU's integrated status by individual participant before and after the plenary session excluding consideration of Larkin benchmarks. The forth row is the number of changes. The third and fourth row present this CU's integrated status by individual participant before and after the plenary session including consideration of Larkin benchmarks. The final row is the number of changes indicated.

Status Commentary (With Larkin)

- the integrated Amber status is driven by the Amber status of the relative-abundance metric on the dominant cycle line; although the three other cycles are Red, they did not drive the integrated status of this CU.
- the consistently Green statuses across the long-term trend and short-term trend metrics, and a decade-long increase in productivity did not pull up the Amber status;
- the long-term trend status has been Green for most of the assessed time series, the short-term trend status has been Green for five years; on the dominant cycle, status has been Green for the relative-abundance metric for four cycles; the following trends in abundance occur by cycle line: the 2014 dominant cycle has increased, the 2015 subdominant cycle has decreased, the 2012 weak cycle has decreased, and the 2013 weak cycle increased in the last year of the time series.

- one off-cycle year abundance in the last four has fallen at 1,000, which is the COSEWIC Criterion for small populations; however, this alone was not sufficient to reduce the status of this CU from Amber;

Status Commentary (Without Larkin)

- in the absence of Larkin benchmarks for this cyclic CU, consistently Green statuses across the long-term trend and short-term trend metrics and a decade-long increase in productivity drove the Green integrated status;
- Based on the retrospective evaluation of the trend metric, the long-term trend metric has been Green for most of the assessed time series, the short-term trend metric has been Green for five years; on the dominant cycle the relative-abundance metric status has been Green for four cycles;
- one off-cycle year abundance in the last four has fallen at 1,000, which is the COSEWIC Criterion for small population; however, this alone was not sufficient to reduce the status of this CU from Green;

Points of Discussion

- One weak cycle line has a low abundance; so need to consider this, however, this cycle alone does not drive status;

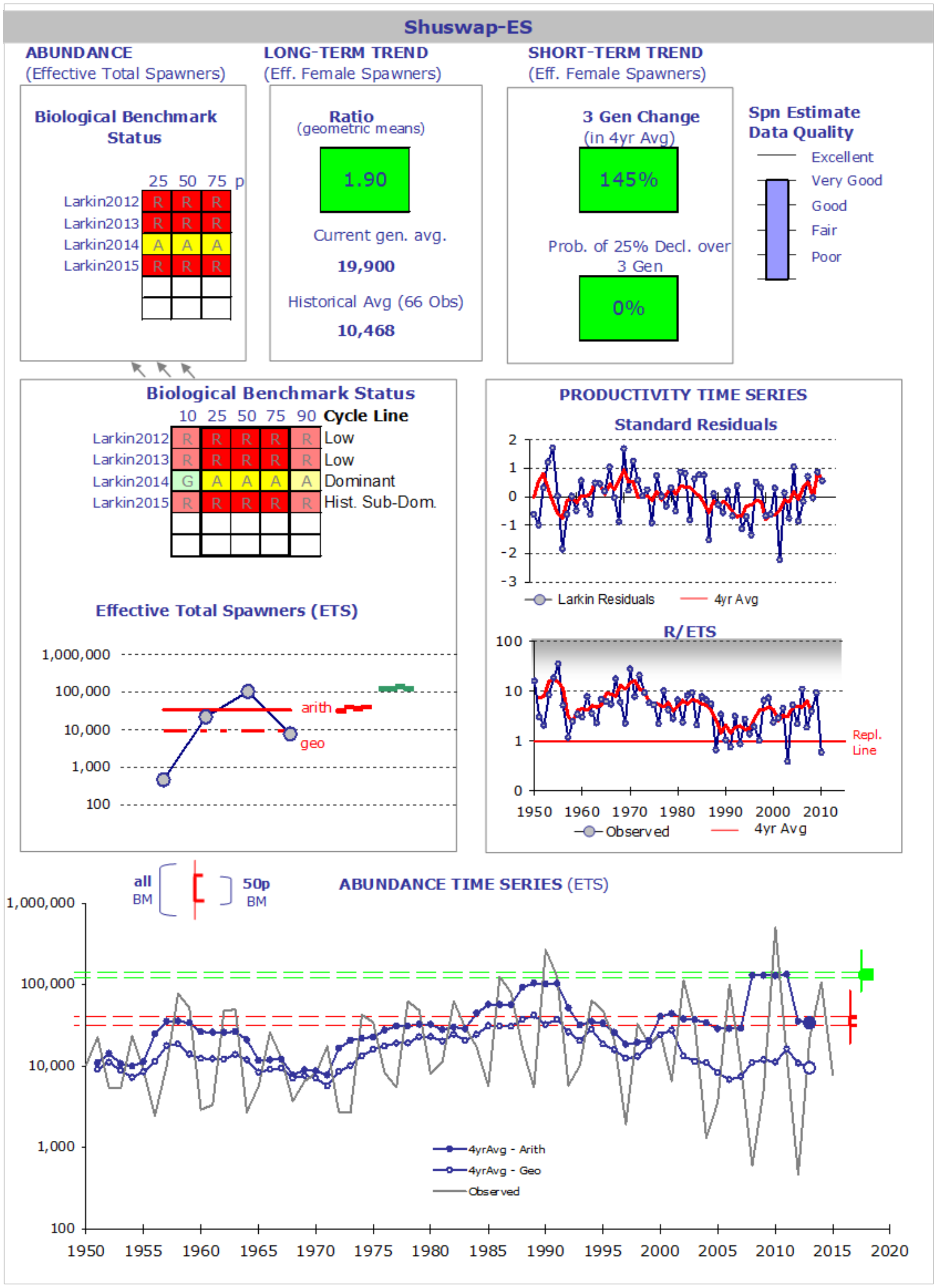
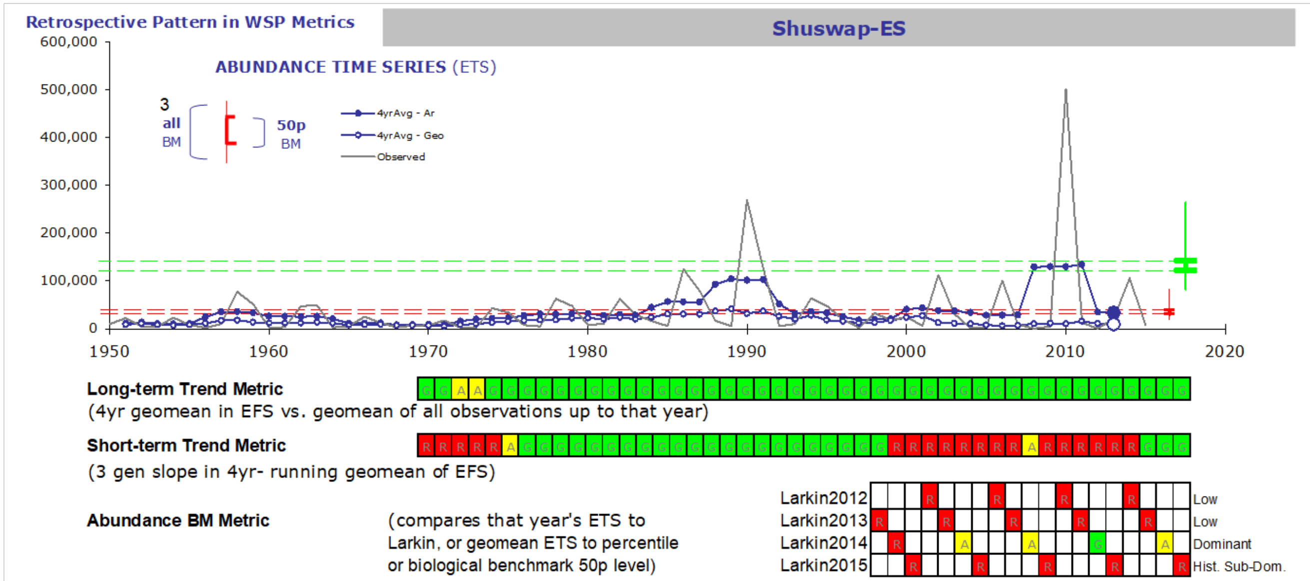


Figure A2-74. Shuswap-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	501,183	501,183	105,619
Med	12,803	8,749	14,765
Min	464	464	464

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	54	8	3
2500	7	1	0
1000	3	1	0
500	1	1	0
250	1	1	1
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S_{gen})

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Larkin(2012)	18,801	23,471	31,445	44,841	66,105
Larkin(2013)	25,199	30,755	40,035	55,456	84,371
Larkin(2014)	22,616	27,679	36,380	50,521	73,780
Larkin(2015)	24,607	30,273	39,741	55,223	80,918

Upper Benchmark Est. (80% S_{MSY})

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Larkin(2012)	83,888	99,405	124,072	165,836	233,304
Larkin(2013)	82,721	97,783	122,124	163,614	227,548
Larkin(2014)	95,945	113,368	141,746	189,257	264,455
Larkin(2015)	84,627	99,200	123,428	163,448	227,681

Figure A2-75. Shuswap-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

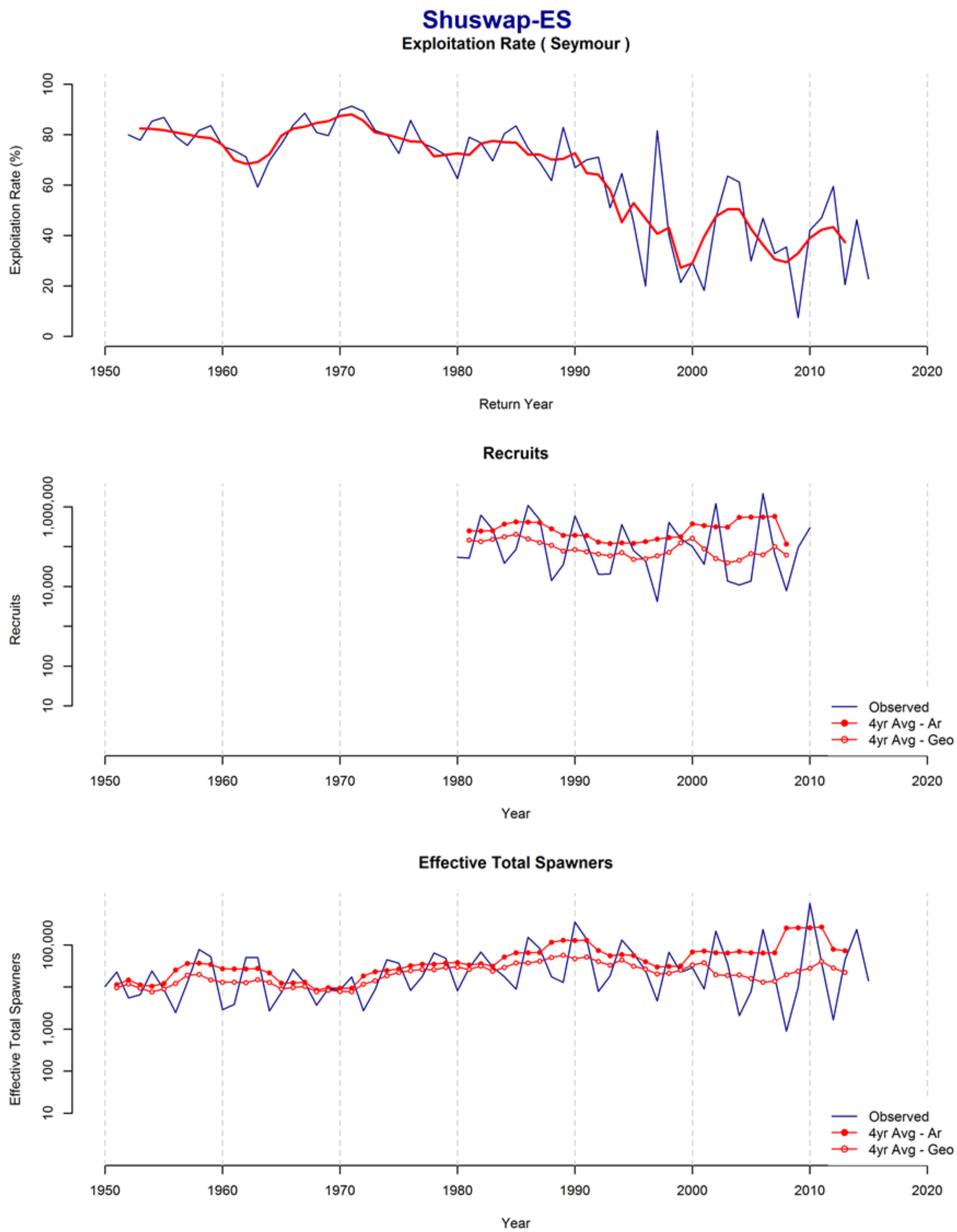


Figure A2-76. Shuswap-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

SHUSWAP COMPLEX-L (I.E. LATE SHUSWAP) (CYCLIC) (AMBER/GREEN)

Background: This CU comprises a large proportion of the total Fraser Sockeye return abundance during its dominant cycle years; in contrast the subdominant and weak cycles of this CU have relatively small abundances (see Grant et al. 2011 for further details). Note that the weak cycles are not estimated with the same level of precision as the dominant cycle. The dominant cycle is estimated with a combination of mark-recapture, DIDSON, and visual methods, whereas the weak cycles are estimated with visual methods.

Benchmark Analysis (Abundance Metrics): This CU is considered cyclic. Therefore, a Larkin model was used to estimate relative-abundance benchmarks for this CU. The full stock-recruitment time series available for Shuswap-L includes the brood years 1950-2010. Cyclic Larkin-based benchmarks are presented for each cycle line (one dominant, one sub-dominant, and two low) and are compared to the most recent ETS abundances from each respective cycle line.

Shuswap Complex-L

	2017 Status		2012 Status
	A/G	Larkin	**G**
	A/G	no Larkin	

No Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	A	G	A/G	A/G		A/G		A/G
After Plenary	A/G	A	A/G	A/G	A/G		A/G		A/G
Change?	Y		Y						
Num Changes	2								

With Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	G	A	G	A/G	A		A/G		A/G
After Plenary	A/G	A	A/G	A/G	A		A/G		A/G
Change?	Y		Y						
Num Changes	2								

Figure A2-77. First row presents final integrated statuses for Shuswap Complex-L in 2017 with and without Larkin model benchmarks included in decision and 2012, where no Larkin model methods were used. The second and third row presents this CU's integrated status by individual participant before and after the plenary session excluding consideration of Larkin benchmarks. The forth row is the number of changes. The third and fourth row present this CU's integrated status by individual participant before and after the plenary session including consideration of Larkin benchmarks. The final row is the number of changes indicated.

Status Commentary (With Larkin)

- the Amber/Green integrated status was driven by the Green status of the dominant cycle relative-abundance; the large number of spawners on the dominant cycle year for this CU (dominant cycle abundance in the last generation was 2.1 million) also contributed to this status; in addition, relative to other CUs, productivity for Shuswap-L has been stable since the beginning of the time series, and has increased in very recent years; the low abundances of the other cycle-lines, and declining trends observed for the subdominant cycle, down-weighted this CU's status to Amber/Green;
- The dominant 2014 cycle has remained relatively stable, while the subdominant cycle has decreased in abundance, although there are issues with poor data quality at these low spawner abundances; the 2012 weak cycle has decreased and, conversely, the 2013 weak

cycle has increased, though trends on the weak cycles had little influence on the overall status designation;

- though the short-term trend status is Red, this is driven by the subdominant (which are largely five year old fish from the dominant cycle) and the first (and smallest) weak cycle; the dominant cycle has not exhibited a declining trend, and in fact had exceptional returns in the last two cycle years (2010 and 2014). Since the weak cycle is not enumerated with high precision methods (visual methods applied), a sensitivity analysis of the potential error in the recent weak cycle estimate indicates that the trend metric status could range from Red to Green, depending on the true value;
- similarly, the long-term trend of 0.46 is Red status, but falls right on the edge of an Amber status (lower benchmark is 0.5); if the most recent weak cycle abundance were actually greater than 100 (which is within the range of error for this data point), this metric status would change to Green;

Status Commentary (Without Larkin)

- the Amber/Green integrated status was driven by the large number of spawners on the dominant cycle year for this CU (the dominant cycle abundance in the last generation was 2.1 million); in addition, relative to other CUs, productivity for Shuswap-L has been stable since the beginning of the time series, and has increased in very recent years; the low abundances of the other cycle-lines, and declining trends observed for the subdominant cycle down-weighted this CU's status to Amber/Green;
- all other comments in the previous commentary (with Larkin) apply here;

Points of Discussion

- Last assessment there was debate regarding the implications of highly cyclic abundance patterns regarding risk of extirpation; if there is one high-abundance dominant cycle that is consistently stable in terms of productivity and trends, and three small cycles, does this uneven distribution of abundance, with most of the genetic information and biomass concentrated in a single dominant year (out of four), increase a CUs risk of extirpation; this CU is one that has not exhibited any systematic trends in productivity, and has exhibited very stable abundances throughout the time series, therefore, does cyclic dominance improve the resilience of a CU;
- ultimately a deeper understanding of the weaker cycle lines needs to be considered with regards to risk (i.e. the rescue effect of non-four-year-old fish, both from a demographic and genetic perspective;

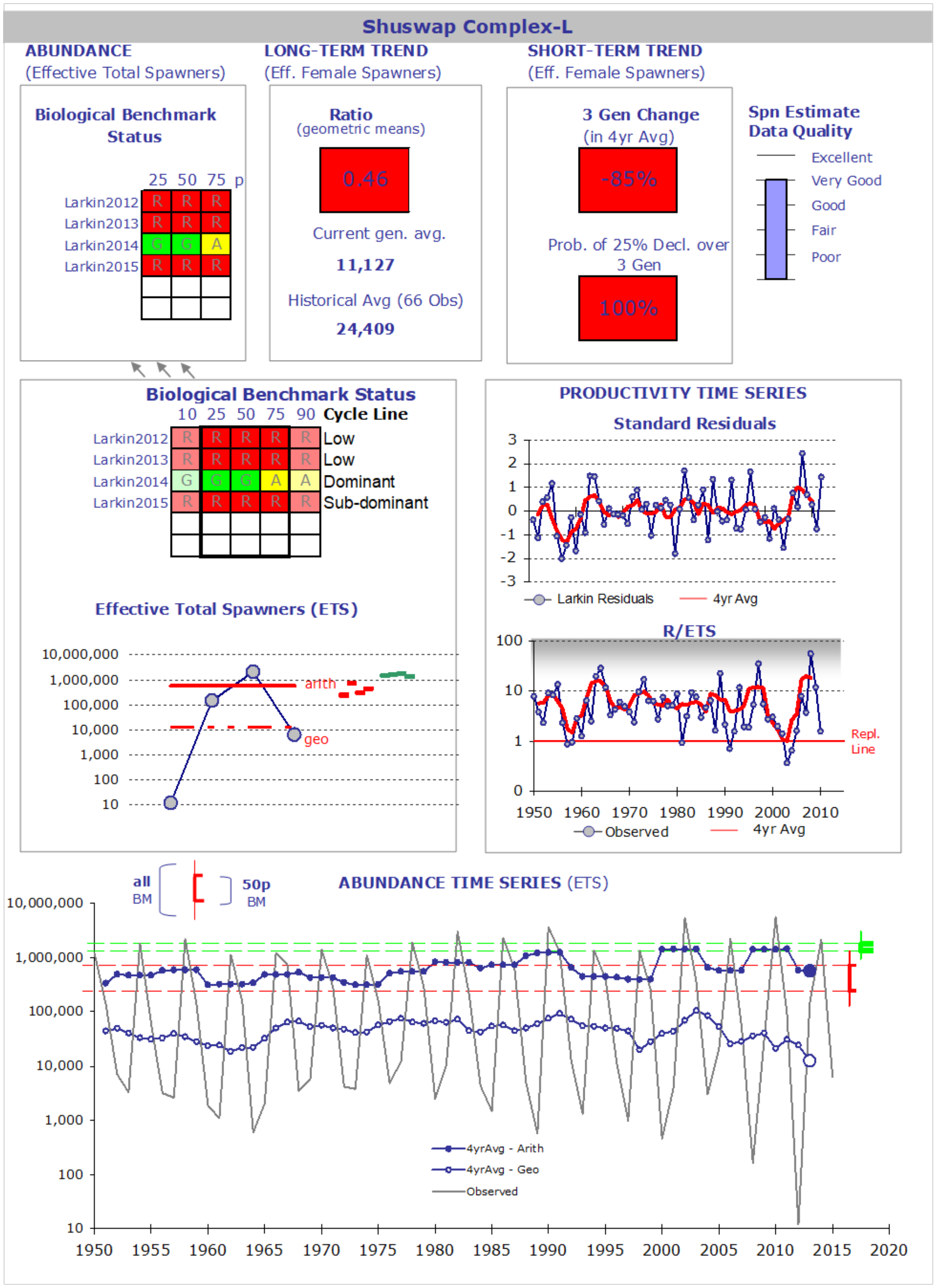
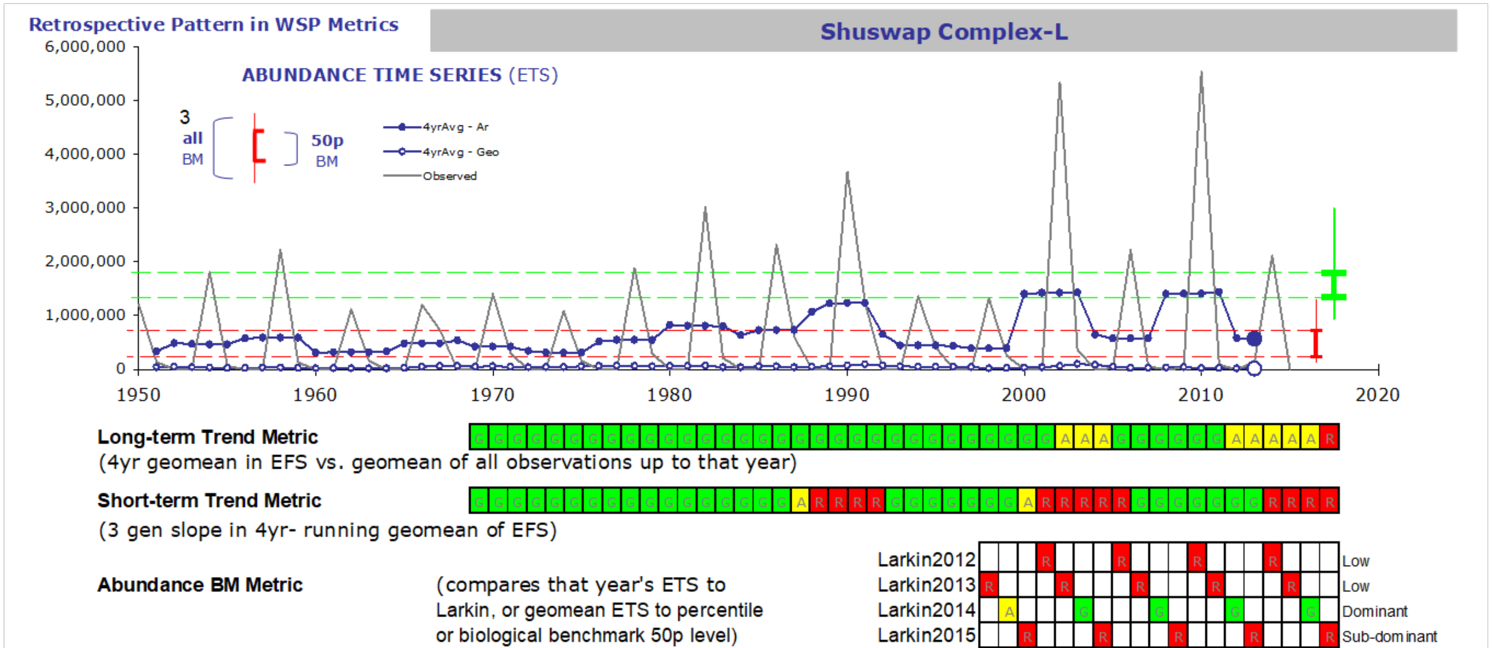


Figure A2-78. Shuswap Complex-L data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	5,528,630	5,528,630	2,112,414
Med	60,097	44,399	77,576
Min	12	12	12

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	44	9	3
2500	10	1	0
1000	6	0	0
500	3	0	0
250	1	0	0
0	2	2	1

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S_{gen})

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Larkin(2012)	129,975	171,552	242,156	352,426	513,321
Larkin(2013)	404,910	549,650	713,769	965,431	1,307,870
Larkin(2014)	177,273	228,848	310,783	434,875	620,666
Larkin(2015)	261,533	329,206	429,435	587,067	816,652

Upper Benchmark Est. (80% S_{MSY})

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Larkin(2012)	999,078	1,176,840	1,442,603	1,844,565	2,452,726
Larkin(2013)	1,102,058	1,287,899	1,569,783	2,004,865	2,660,435
Larkin(2014)	1,283,649	1,478,301	1,794,869	2,277,522	2,986,004
Larkin(2015)	943,076	1,097,622	1,338,164	1,707,545	2,242,135

Figure A2-79. Shuswap Complex-L data summaries page 2 -row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

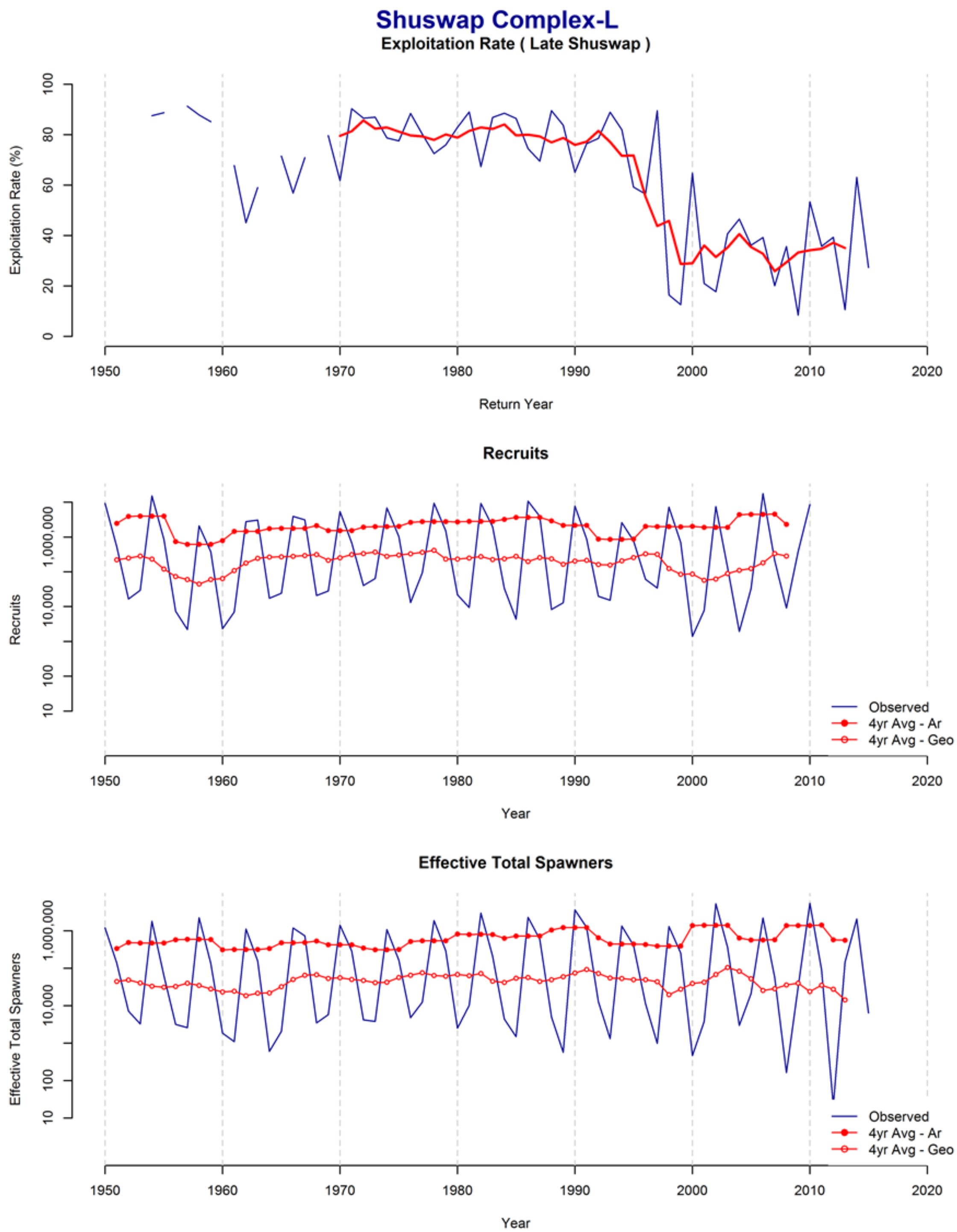


Figure A2-80. Shuswap Complex-L data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

TAKLA-TREMBLEUR-ESTU (CYCLIC) (I.E. EARLY STUART) (RED)

Background: Abundances of this CU were particularly low from 1962-1968, peaked in the 1990s, and have subsequently decreased. Declining abundances are largely attributed to this CU's long migration route (longest upstream migration of all Fraser Sockeye CUs), their spring upstream migration timing, and increases in water temperatures in the Fraser during their upstream migration (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series available for Takla-Trembleur-Early Stuart includes the brood years 1950-2010. This CU is considered cyclic. Therefore, a Larkin model was used to estimate relative-abundance benchmarks for this CU. Cyclic Larkin-based benchmarks are presented for each cycle line (one dominant and three weak cycles) and are compared to the most recent ETS abundance from each respective cycle line.

	2017 Status	2012 Status
Takla-Trembleur-EStu	R	R
	R	

No Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R	R		R		R
After Plenary	R	R	R	R	R		R		R
Change?									
Num Changes	0								

With Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R	R		R		R
After Plenary	R	R	R	R	R		R		R
Change?									
Num Changes	0								

Figure A2-81. First row presents final integrated statuses Takla-Trembleur-EStu in 2017 with and without Larkin model benchmarks included in decision and 2012, where no Larkin model methods were used. The second and third row presents this CU's integrated status by individual participant before and after the plenary session excluding consideration of Larkin benchmarks. The forth row is the number of changes. The third and fourth row present this CU's integrated status by individual participant before and after the plenary session including consideration of Larkin benchmarks. The final row is the number of changes indicated.

Status Commentary (With Larkin)

- the Red integrated status was driven by the consistent Red statuses across all metrics, and also the generally declining productivity trend; this includes the relative-abundance metric, which was Red status across all cycle lines and probability levels using the Larkin model; relative abundance statuses have been Red on all cycles for almost 5 cycles;
- the short-term trend in abundance was Red in status and the decline was steep (46% decrease); declines have occurred for three out of the four cycle-lines (only the 2014 subdominant cycle has remained relatively high and stable in the recent decade); escapement did not fall below the COSEWIC Criteria D1 in the last four years, however, it did once in the last 12 years; the long-term trend status has turned Red (in the previous assessment this metric status was Amber) (Grant & Pestal 2013); the short-term trend status has been Red for 2 decades; the long-term trend status has been Red for 6 years;

- productivity has remained relatively low, which contributes to the Red status; although there has been a very slight increase in the past five years, this was not sufficient to improve the Red status for this CU;
- the current status (Red) of this CU has not changed since the previous assessment;

Status Commentary (Without Larkin)

- the Red integrated status was driven by the consistent Red status across all metrics, and also the generally declining productivity trend;
- the short-term trend in abundance status was Red and the decline was steep (46% decrease); declines have occurred for three out of the four cycles (only the 2014 subdominant cycle-line has remained relatively high and stable in the recent decade); escapement did not fall below the COSEWIC Criteria D1 in the last four years, however, it did once in the last 12 years; the long-term trend status has turned Red (in the previous assessment this metric was Amber) (Grant & Pestal 2013); the short-term trend status has been Red for 2 decades; the long-term trend status has been Red for 4 years;
- productivity has remained relatively low, which contributes to the Red status; although there has been a very slight increase in the past five years, this was not sufficient to improve the Red status for this CU;
- the current status (Red) of this CU has not changed since the previous assessment;

Points of Discussion

- NA

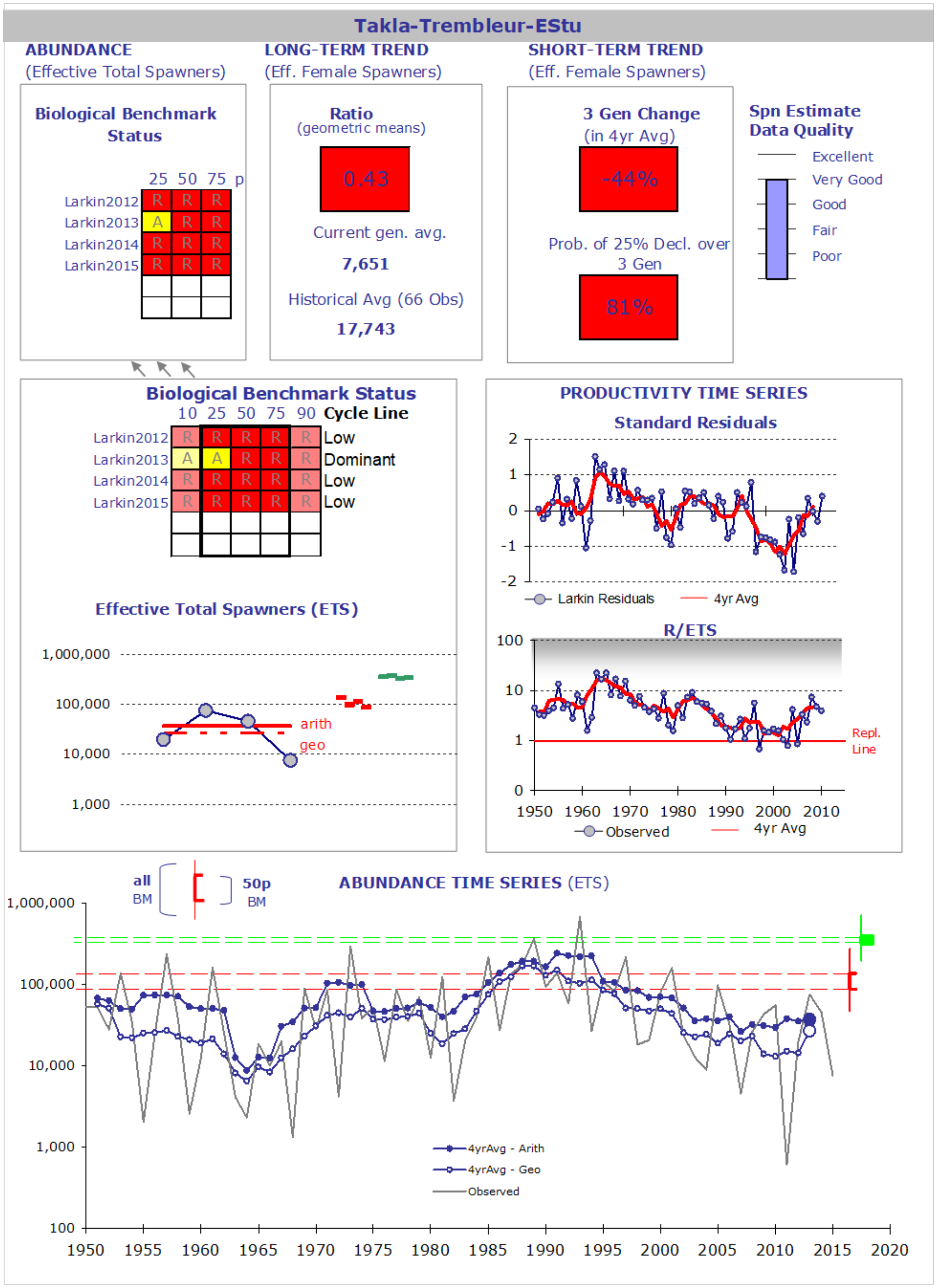
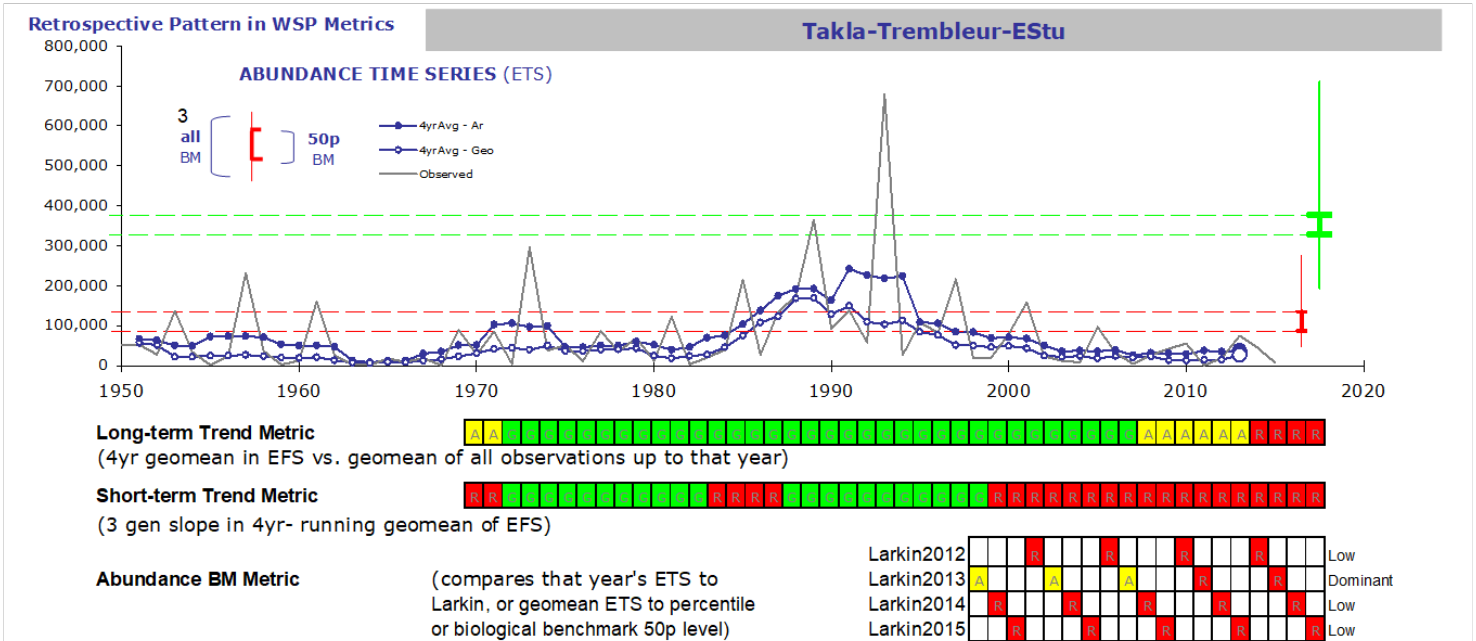


Figure A2-82. Takla-Trembleur-EStu data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	679,396	97,771	75,310
Med	36,533	29,139	32,802
Min	617	617	7,570

Number of Observations in a range

	All Yrs	Last 12	Last 4
5000	57	10	4
2500	5	1	0
1000	3	0	0
500	1	1	0
250	0	0	0
0	0	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S_{gen})

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Larkin(2012)	72,010	94,063	135,409	201,428	276,368
Larkin(2013)	53,246	68,704	97,682	143,933	199,513
Larkin(2014)	61,576	79,287	111,753	163,199	223,839
Larkin(2015)	47,071	61,132	86,738	127,757	177,521

Upper Benchmark Est. (80% S_{MSY})

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Larkin(2012)	208,112	260,441	353,292	495,657	666,170
Larkin(2013)	222,946	279,579	376,174	533,942	711,337
Larkin(2014)	193,821	243,653	328,617	463,277	618,448
Larkin(2015)	204,744	255,427	342,479	483,775	644,239

Figure A2-83. Takla-Trembleur-EStu data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

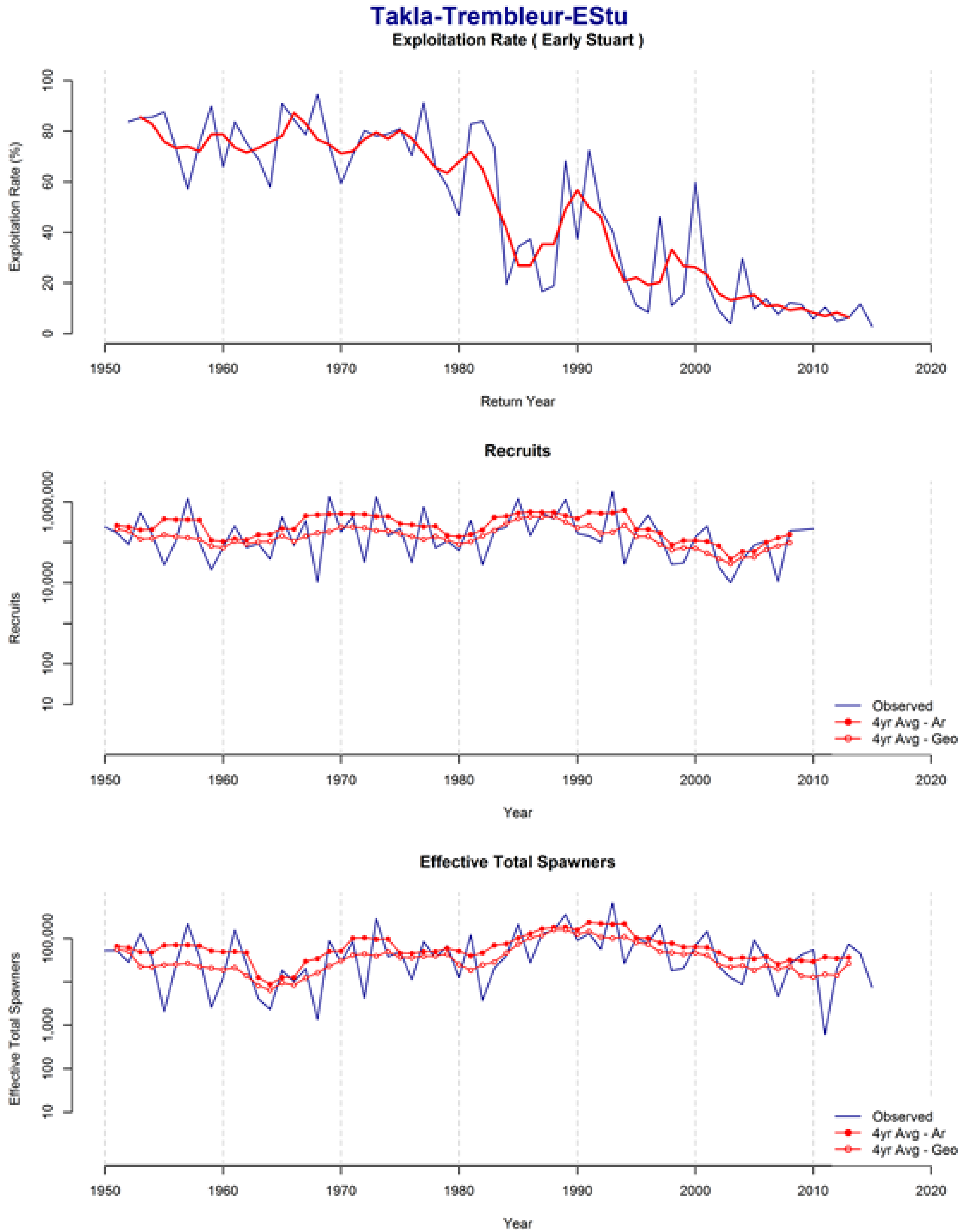


Figure A2-84. Takla-Trembleur-EStu data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

TAKLA-TREMBLEUR-STUART-S (CYCLIC) (I.E. LATE STUART) (RED/AMBER)

Background: Historically human activities impacted spawning habitat in this CU. Specifically, log driving in Tachie River, starting in the 1960's had unknown impacts on the available spawning habitat (see Grant et al. 2011 for further details). Habitat in Middle River was also degraded by forestry activities and railroad construction, though habitat has subsequently improved in this system. Note that visual estimates in this system are highly uncertain (large dark tannic system). The loss of high precision estimates on the off-cycles in recent years has increased uncertainty in the escapement time series for these smaller abundance years.

Benchmark Analysis (Abundance Metrics): The full stock-recruitment time series available for Takla-Trembleur-Stuart-S includes the brood years 1953-2010. This CU is considered cyclic. Therefore, a Larkin model was used to estimate relative-abundance benchmarks for this CU. Cyclic Larkin-based benchmarks are presented for each cycle line (one dominant and three weak cycles) and are compared to the most recent ETS abundance from each respective cycle line.

Takla-Trembleur-Stuart-S

	2017 Status		2012 Status
	R/A	Larkin	R/A
	R/A	no Larkin	

No Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R/A	R/A	A	R		R/A		R/A
After Plenary	R/A	R/A	R/A	R/A	R		R/A		R/A
Change?	Y			Y					
Num Changes	2								

With Larkin Benchmarks

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R/A	R/A	R/A	R		R/A		R
After Plenary	R/A	R/A	R/A	R/A	R		R/A		R
Change?	Y								
Num Changes	1								

Figure A2-85. First row presents final integrated statuses Takla-Trembleur-Stuart-S in 2017 with and without Larkin model benchmarks included in decision and 2012, where no Larkin model methods were used. The second and third row presents this CU's integrated status by individual participant before and after the plenary session excluding consideration of Larkin benchmarks. The forth row is the number of changes. The third and fourth row present this CU's integrated status by individual participant before and after the plenary session including consideration of Larkin benchmarks. The final row is the number of changes indicated.

Status Commentary (With Larkin)

- the Red/Amber integrated status was driven by the mixed Red/Amber relative-abundance statuses, particularly on the dominant cycle line; these were Red for the three weak cycles, Amber for the dominant cycle at probability levels greater than 25%, and Red below 25%;
- the short-term trend status is Red and productivity has declined and remained low for the past 15 years (three of these years exhibited below replacement productivity); this CU has continued to decline in abundance since the previous assessment; the dominant cycle line and one weak cycle line have decreased in abundance, and the subdominant and second weak cycle lines have respectively, remained stable and increased;
- the short-term trend status has been Red for the past 15 years; currently, no abundances in the past 12 years fell below COSEWIC Criterion D1 for small populations (1,000); further, the long-term trend status is Green and has been Green for most of the time series;

however, this metric alone was not sufficient to bump up the integrated status from Red/Amber;

Status Commentary (Without Larkin)

- the Red/Amber integrated status was driven by the Red short-term trend status and declines in productivity, which has remained low for the past 15 years (for three of these years productivity fell below replacement); this CU has continued to decline in abundance since the previous assessment; the dominant cycle line and one weak cycle line have decreased in abundance, and the subdominant and second weak cycle line have respectively, remained stable and increased; however, in the absence of relative-abundance statuses, the Green long-term trend status was enough to improve the integrated status to Red/Amber; retrospective results on the long-term trend metric indicate that this CU has been Green in status for most of the time series;
- the short-term trend status has been Red for the past 15 years; no years in the past 12 fell below COSEWIC Criterion D1 for small populations (1,000);

Points of Discussion

- similar to Quesnel, this CU may be experiencing some re-arrangement in its dominant and weak cycles.

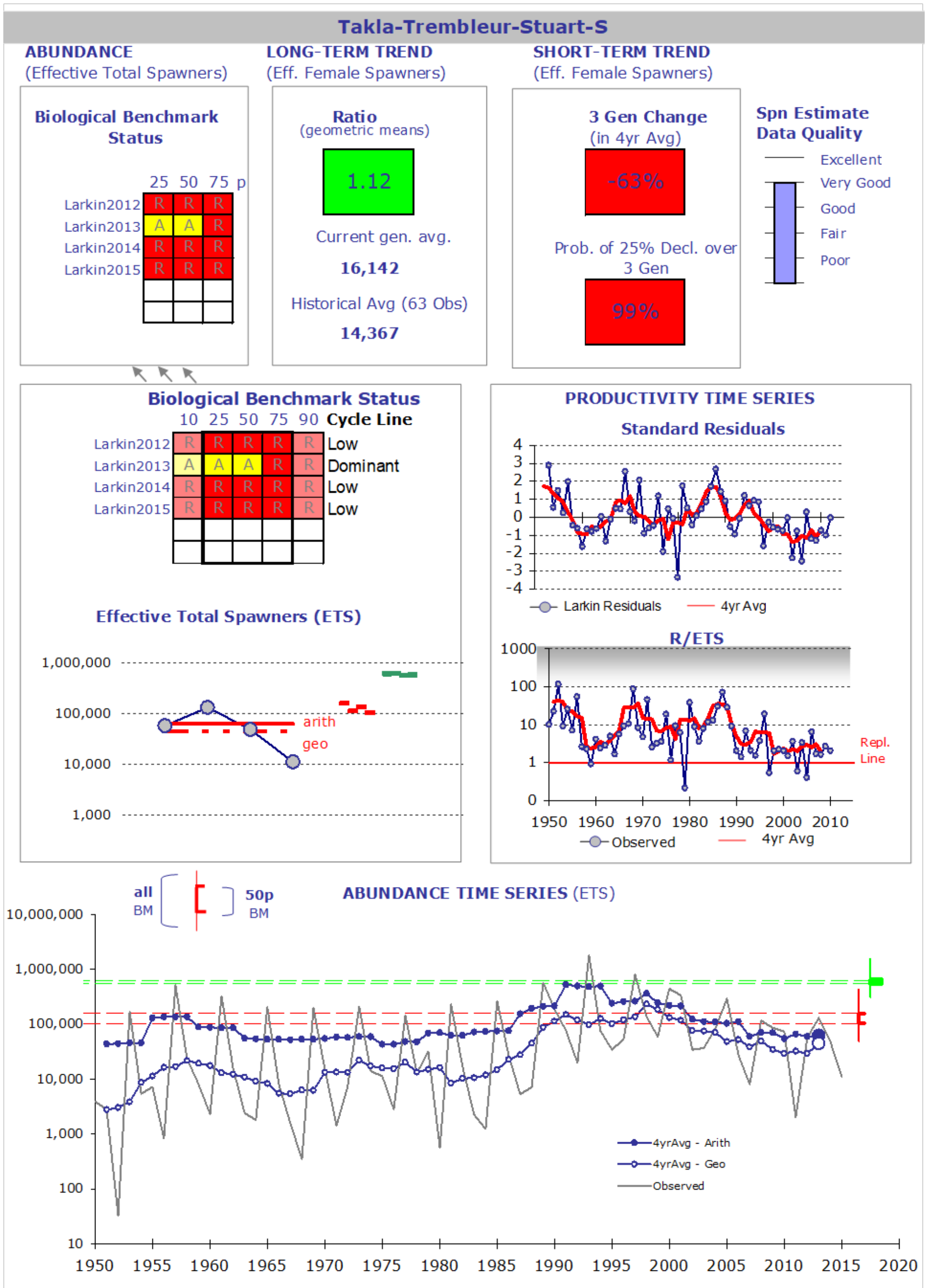
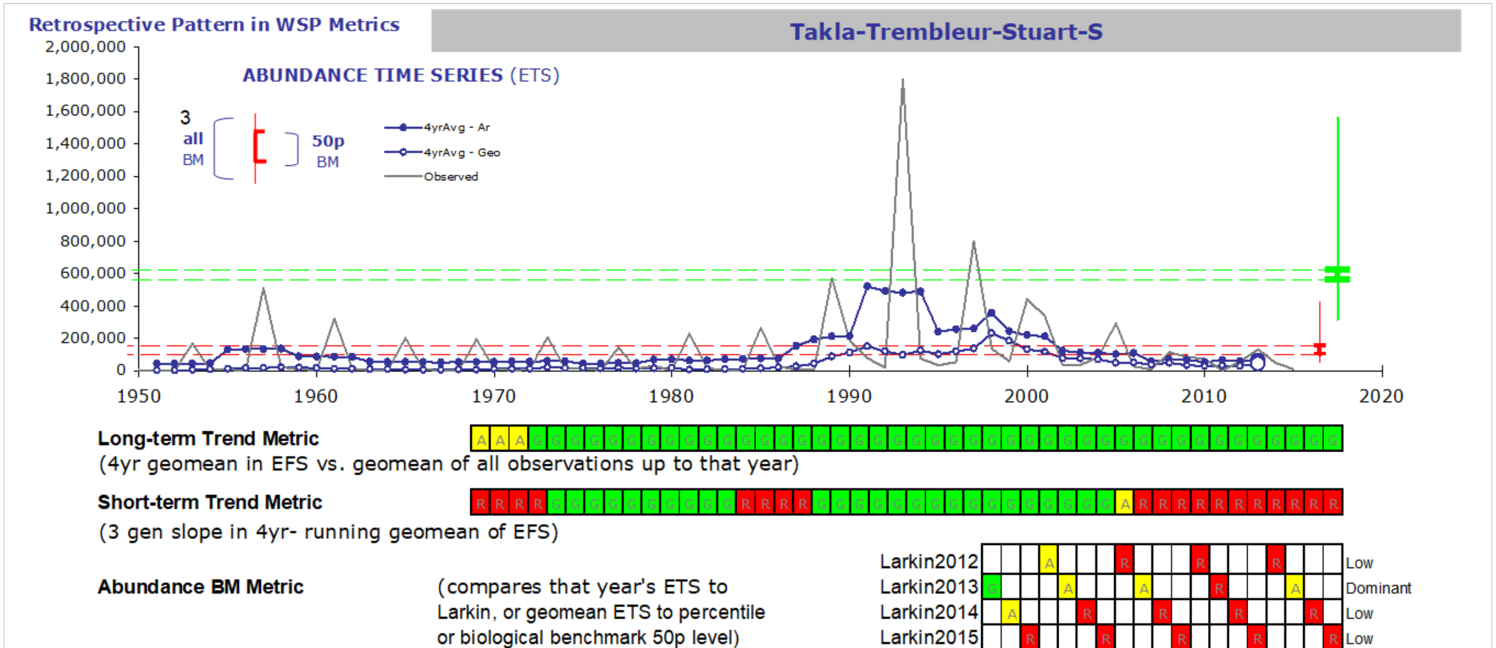


Figure A2-86. Takla-Trembleur-Stuart-S data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric and productivity time series observed (blue line) and smoothed four year running average (red line); forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	1,799,060	292,637	130,493
Med	26,954	65,354	52,547
Min	33	2,026	10,950

Number of Observations in a range

5000	51	11	4
2500	3	0	0
1000	8	1	0
500	2	0	0
250	1	0	0
0	1	0	0

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S_{gen})

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
Larkin(2012)	76,753	105,076	157,103	264,703	429,442
Larkin(2013)	54,346	74,035	112,600	190,452	315,547
Larkin(2014)	65,129	88,580	132,547	219,935	364,172
Larkin(2015)	49,555	67,889	103,286	173,764	288,735

Upper Benchmark Est. (80% S_{MSY})

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
Larkin(2012)	335,200	426,708	600,900	943,394	1,498,272
Larkin(2013)	348,211	442,868	622,626	983,780	1,563,538
Larkin(2014)	315,045	401,409	563,123	881,305	1,407,487
Larkin(2015)	322,084	408,245	574,972	899,929	1,439,561

Figure A2-87. Takla-Trembleur-Stuart-S data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

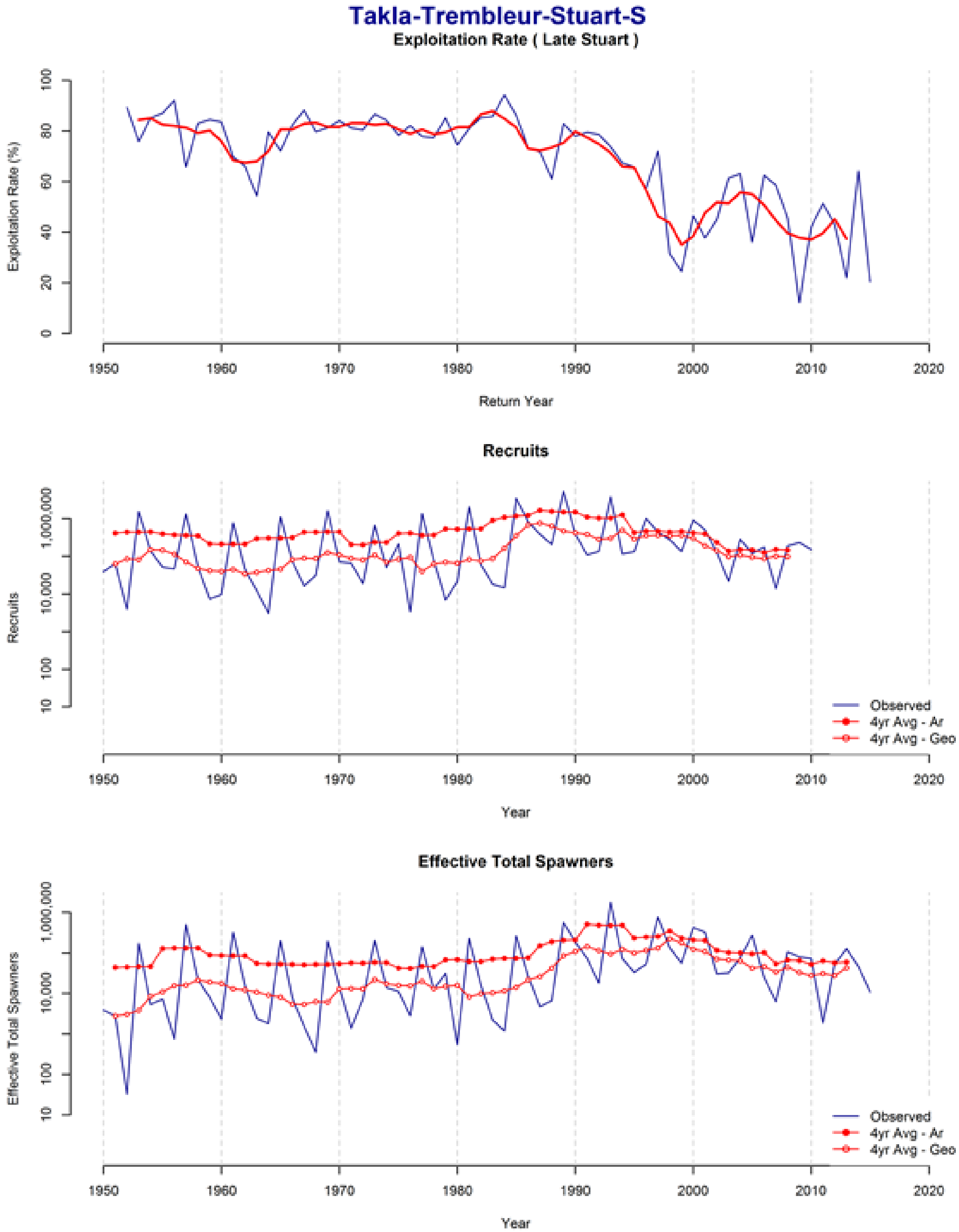


Figure A2-88. Takla-Trembleur-Stuart-S data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

TASEKO-ES (RED) (I.E. MISCELLANEOUS EARLY SUMMER) (RED)

Background: This CU resides in a glacially influenced lake. Since escapement estimates are based on visual surveys of carcasses in the lake, expanded by survey effort, these escapements are likely biased low and represent an index of spawning abundances only (see Grant et al. 2011). Identical assessment methods have been applied throughout the time series. There has been a significant increase in grizzly bear activity in this area since hunting regulations were changed in 1996; therefore data quality in these years should be considered poor. Escapement estimates are dependent on the availability of carcasses. Grizzly bear abundance has a large effect on the probability of recovering carcasses during assessment surveys. Therefore escapement estimates may be further biased low in recent years. Although escapements are indices of abundance only, true escapements to this system are very low, as confirmed by sonar feasibility work conducted by the Upper Fraser Fishing Conservation Alliance and the Tsilhqot'in National Government since 2012. This work confirms that recent abundances are likely at/near the COSEWIC Criterion for small populations (1,000).

Benchmark Analysis (Abundance Metrics): Recruitment data are not available for this CU, therefore, relative-abundance metrics could not be assessed.

	2017 Status	2012 Status
Taseko-ES	R	R*

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	DD	R	R	R		R
After Plenary	R	R	R	R	R	R	R		R
Change?				Y					
Num Changes	1								

Figure A2-89. First row presents final integrated statuses for Taseko-ES in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by consistently Red statuses for all trends in abundance metrics (short-term and long-term); this CU does not have recruitment data, therefore, relative-abundance metric status could not be estimated; since abundance data for this CU are an index only, recent abundances could not directly be compared to COSEWIC Criterion D1, although sonar methods have confirmed that abundances are low and close to this Criterion;
- Based on the retrospective analysis, the short-term trend has had a Red status for the past 8 years, and the long-term trend has had a Red status for the past 9 years;
- the current status (Red) of this CU has not changed since the previous assessment;

Points of Discussion

- NA

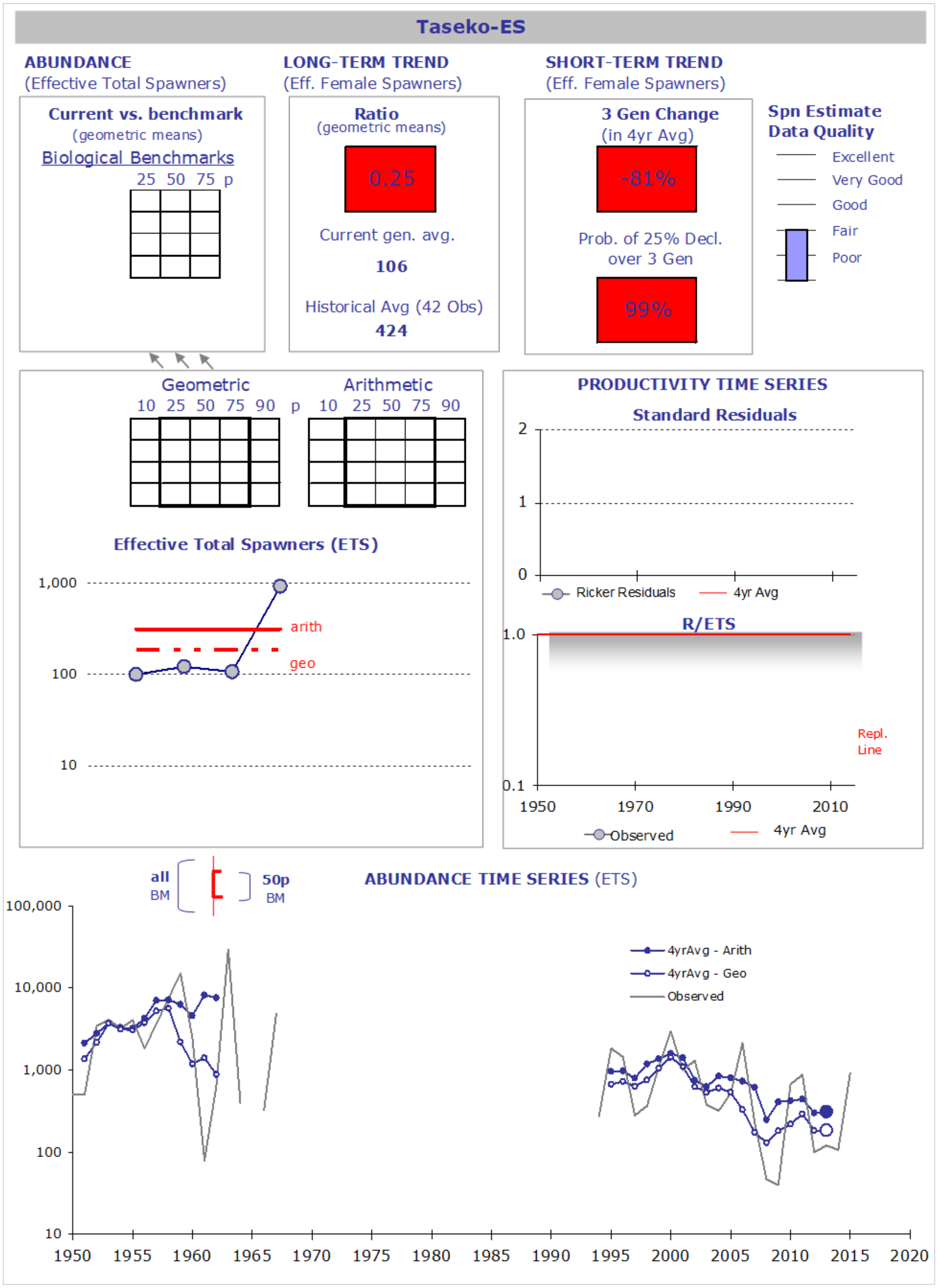
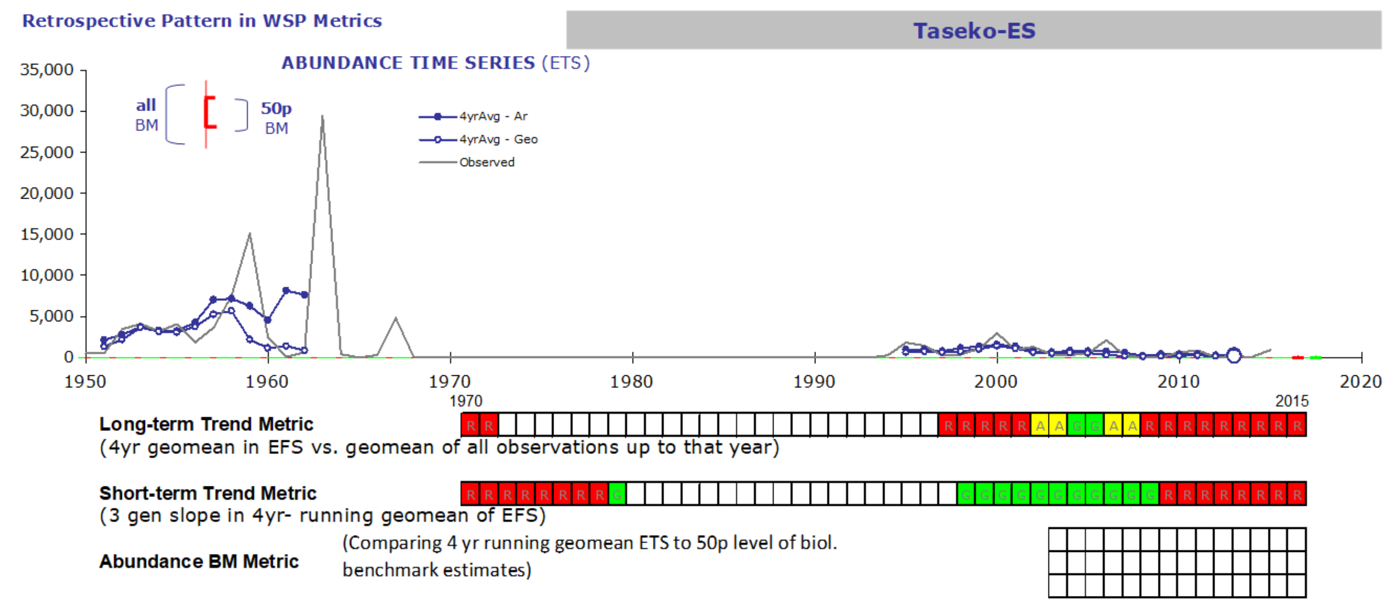


Figure A2-90. Taseko-ES data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric; forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	29,388	2,140	918
Med	875	277	114
Min	40	40	100

Number of Observations in a range

Range	All Yrs	Last 12	Last 4
> 5000	3	0	0
2500–5000	8	0	0
1000–2500	6	1	0
500–**1000**	6	4	1
250–500	9	1	0
0–**250**	7	6	3

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Figure A2-91. Taseko-ES data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

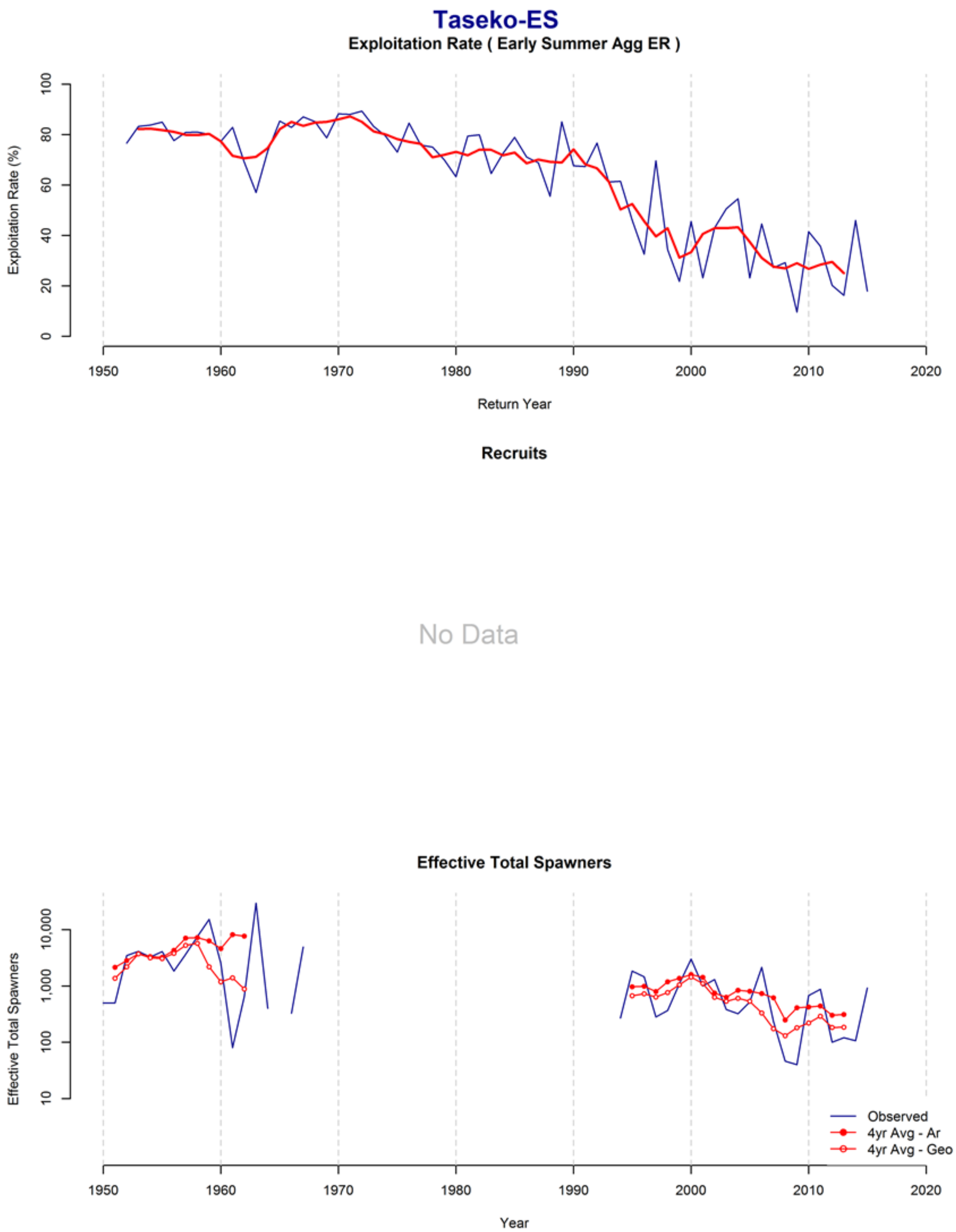


Figure A2-92. Taseko-ES data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

WIDGEON (RIVER TYPE) (I.E. MISCELLANEOUS LATE) (RED)

Background: This CU is a naturally small population, which occupies a small geographic area. This CU is a river-type CU (migrate to the ocean after gravel emergence) that is adapted to the tidal conditions of Widgeon Slough. It is considered a very unique Fraser Sockeye population (Grant et al. 2011).

Benchmark Analysis (Abundance Metrics): There are no recruitment data available for this CU, therefore, no relative-abundance benchmarks could be estimated.

	2017 Status	2012 Status
Widgeon (River Type)	R	R

Participant	1	2	3	4	5	6	7	8	9
Individual Assessments	R	R	R	R	R/A	R	R	G	R
After Plenary	R	R	R	A	R	R	R	A	R
Change?				Y	Y			Y	
Num Changes	3								

Figure A2-93. First row presents final integrated statuses for Widgeon (River Type) in 2017 and 2012. The second and third row presents this CU's integrated status by individual participant before and after the plenary session with number of changes indicated.

Status Commentary

- the Red integrated status was driven by this CU's low absolute abundance, with abundances in three of the past four years falling below the COSEWIC Criterion for small populations (1,000). The minimum ETS in the past four years is 100, and the median is 400;
- unlike the past assessment, the long-term trend metric status was Green (last assessment this metric was Red); however, given the low absolute abundance of this CU, this metric did not change the status from Red; similar to the previous assessment, the short term trend status is Green; however, abundances have declined in the most recent two years and should be monitored;
- the short-term trend status has been Green for 10 years, and the long-term trend status has been Green for 4 years;
- the current status (Red) of this CU has not changed since the previous assessment;

Points of Discussion

- identical to the last assessment, regardless of short-term trends, this CU is triggering the COSEWIC Criterion for small populations (1,000); this CU is naturally quite small given its limited spawning habitat, therefore, it is likely that this CU will always have a poor status designation, which cannot be altered by human intervention;
- the restricted area of spawning increases the risk of extirpation;
- recent abundances have returned to historic levels after a period of very low abundances in the 1990's and 2000's; should abundances above 1,000 be considered Amber given the sustained long time series of abundances in this range under the influence of exploitation; Red may be warranted if the suite of risks is extended beyond fishing (habitat/uniqueness etc.).

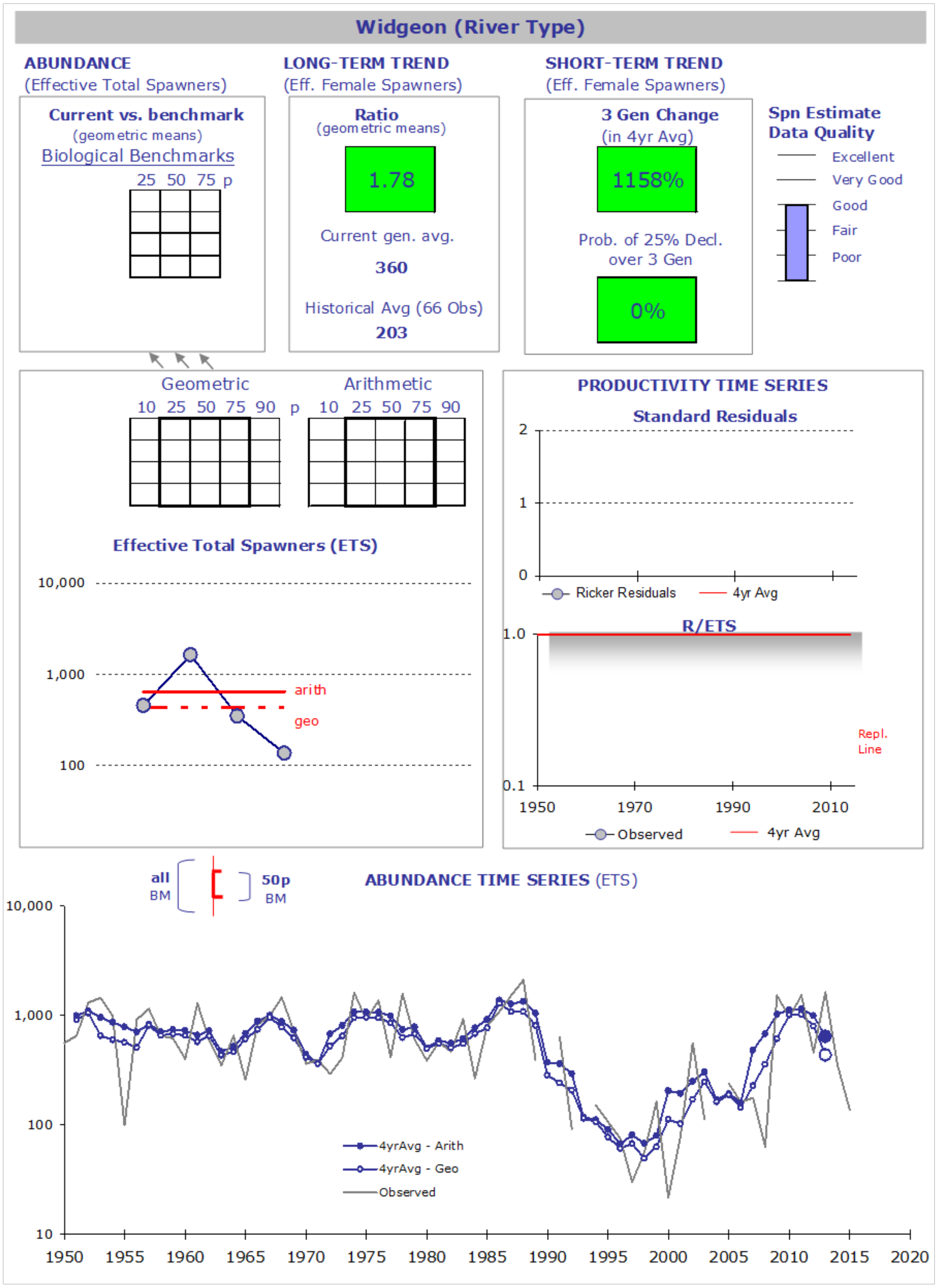
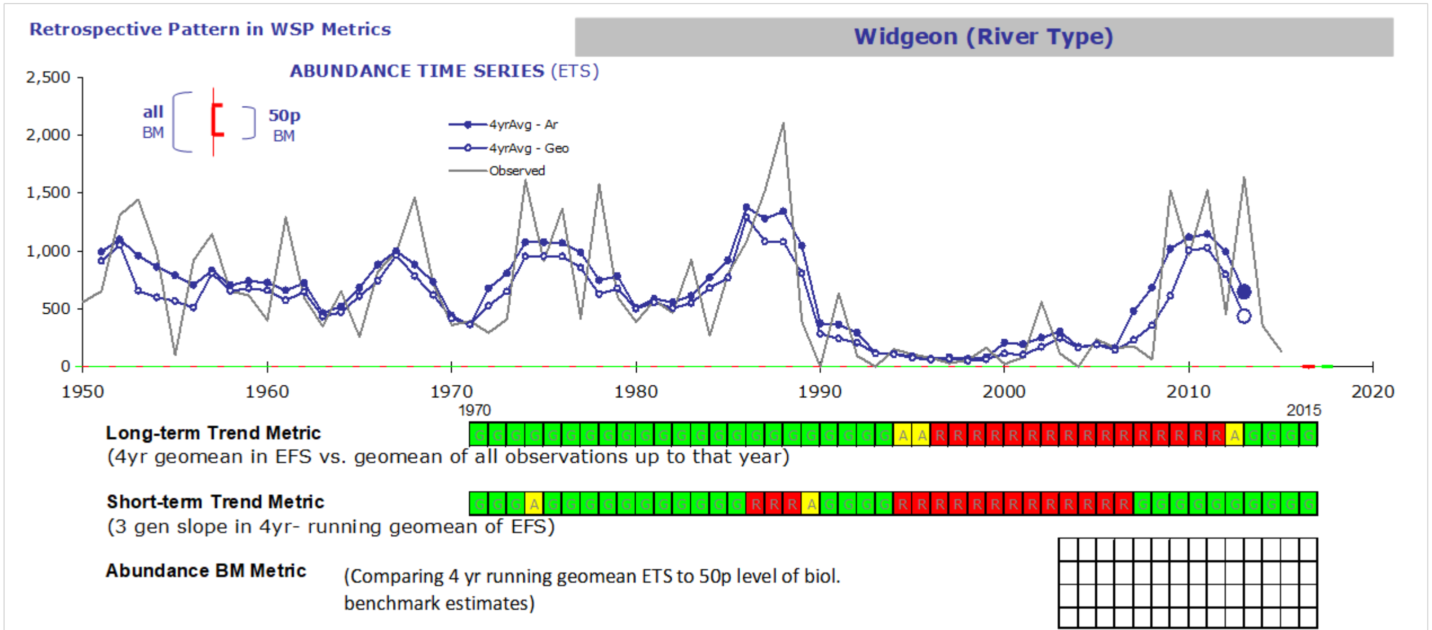


Figure A2-94. Widgeon (River Type) data summaries page 1-first row: WSP metric statuses and data quality; second & third rows: statuses across probability and model forms for the relative-abundance metric; forth row: effective total spawner time series on a log scale annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines). Detailed background can be found in Appendix 1.



Summary of Observations and Estimates

Effective Total Spawners

	All Yrs	Last 12	Last 4
Max	2,109	1,636	1,636
Med	560	350	403
Min	22	63	137

Number of Observations in a range

Range	All Yrs	Last 12	Last 4
>5000	0	0	0
2500–5000	0	0	0
1000–2500	14	3	1
500–1000	19	1	0
250–500	14	2	2
0–250	16	5	1

Small Population Benchmarks (COSEWIC Criterion D1)

Lower Benchmark Estimates (S-gen)

	LB_10p	LB_25p	LB_50p	LB_75p	LB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Upper Benchmark Est. (80% S-msy)

	UB_10p	UB_25p	UB_50p	UB_75p	UB_90p
(-)					
(-)					
(-)					
(-)					
(-)					

Figure A2-95. Widgeon (River Type) data summaries page 2-row 1: Effective total spawner time series annual observations (black line) and smoothed arithmetic mean (solid filled blue circles and lines) and smoothed geometric mean (unfilled blue circles and lines); rows 2,3, & 4: retrospective status for the long-term trends, short-term trends and abundance metrics; rows 5+: summary of observations and estimates, and estimated benchmarks for abundance metric across probability levels and model forms. Details background can be found in Appendix 1.

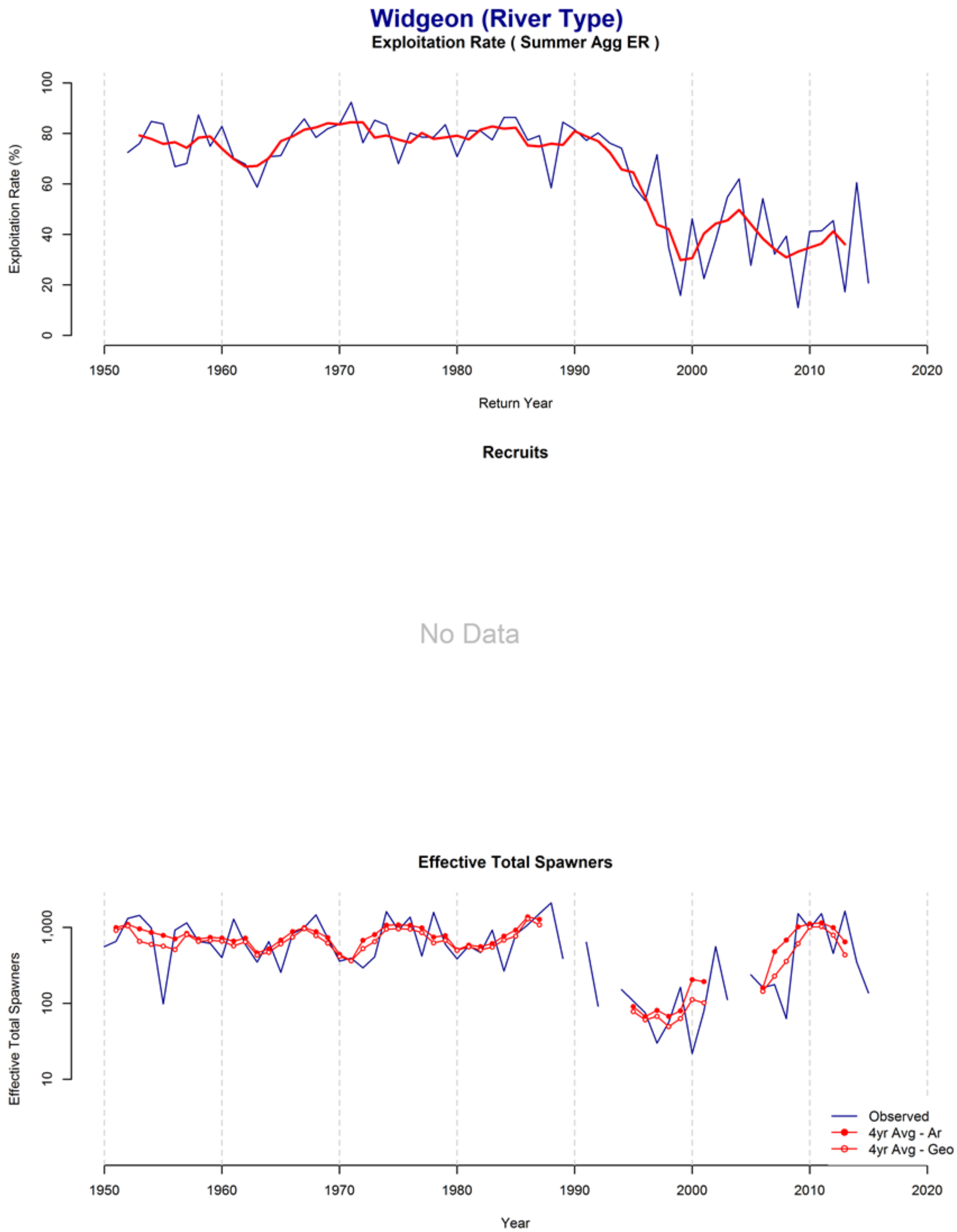


Figure A2-96. Widgeon (River Type) data summaries page 3: exploitation rate, recruits, and effective total spawners. Blue solid line are annual observations, red filled circle with solid red line is a smoothed four year running arithmetic average of the time series, and red circle unfilled with solid red line is a smoothed four year running geometric average of the time series.

APPENDIX 3: FRASER SOCKEYE CU GROUPINGS FOR THE 2017 STATUS INTEGRATION RE-ASSESSMENT PROCESS

Table 3-1. Fraser Sockeye CU Groupings for the 2017 Status Integration re-assessment process. The CUs were organized into groups of increasing order of complexity for status assessments, starting with less complex non-cyclic CUs (either all metrics and supporting information clearly indicated the same status, or statues were identical to the previous assessment) to the most complex cyclic CUs (statuses were not consistent across metrics and/or diverged from the previous assessment and included the additional complexity of considerations of cyclic patterns of abundance characterized by high and low abundance years, over a four year period).

GROUP 1 **CUs That are the Same as 2011**	Group 2 **CUs Requiring Some Discussion**	Group 3 **CUs Requiring More Discussion**	Group 4 **Easy Cyclic CUs**	Group 5 **More Discussion Cyclic CUS**
Taseko-ES (all metrics Red)	**Francois-Fraser-ES** (improvements)	**Lillooet-Harrison-L**	**Takla-Trembleur-ESTU** all metrics Red	**Shuswap-L** (weak cycle causing decline trend to be Red)
Cultus-L (short-term trend Green)	**Chilliwack-ES** (more metrics)	-	**Shuswap-ES** (all metrics Green)	**Takla-Trembleur-S** (changes)
Bowron-ES (all metrics Red)	**Nadina-Francois-ES** (improvements)	-	**Quesnel-S** (all metrics Red)	**Chilliwack-ES**
Chilko-S (all metrics Green)	**Harrison (D/S)-L** (recent decline)	-	-	-
Chilko-ES (data deficient)	**Nahatlatch-ES** (all metrics Green)	-	-	-
North Barriere-ES (identical)	**Harrison (U/S)-L** (all metrics Red)	-	-	-
Harrison River-Type (identical)	**Pitt-ES** (identical)	-	-	-
Kamloops-ES (identical)	**Seton-L** (all metrics Red)	-	-	-
-	**Widgeon River Type** Mixed signals	-	-	-
-	**Anderson-Seton-ES** (all metrics Green)	-	-	-

APPENDIX 4: OVERVIEW OF STOCK-RECRUITMENT MODELS USED FOR RELATIVE-ABUNDANCE BENCHMARKS

Table 4-1. Overview of stock-recruitment models used for relative-abundance benchmarks.

2017 Label	2011 Label	Currently Used For	Description	Comments
CarrCap	**CarrCap**	Chilliwack-ES	Uses 20% and 40% of spawners at maximum juvenile production (S_{max}) estimated from freshwater production studies (Jeremy Hume and Lucas Pon's data from the 2011 report); although stock-recruitment data exist for this CU the time series is too short to reliably produce BMS from this information	Used since Grant et al. (2011) and Grant et al. (2012);
COSEWIC	**N/A**	Cycles of cyclic CUs where Larkin BMs could not be estimated	Uses a lower benchmark of 1,000 to coincide with COSEWIC criteria benchmark for small population size; this only shows where an annual ETS for a cycle falls below this value; there is no colour when annual estimate > 1,000 ETS.	New to this process with the inclusion of Larkin BMs for cyclic CUs for cycles where these could not be estimated
Larkin	**Lark**	Cycles of cyclic CUs where Larkin BMs could be estimated	Based on methods developed by Holt; BMs are unique to a cycle and cycle year; the BMs are estimated using the Larkin model and the brood year ETS and the three previous year's ETS observed	Using same Larkin model to fit SR, but using the resulting parameters differently to estimates BMs.
Norm	**Rick**	Applied to non-cyclic CUs where testing indicated the **informative prior was considered applicable**	Applies an informative prior on the carrying capacity parameter of a Ricker model based on spawners at maximum juvenile production (S_{max}) estimated from freshwater production studies (Jeremy Hume and Lucas Pon's data from the 2011 report); these were applied to CUs after examination of priors, posteriors,	Applied to all non-cyclic CUs in the 2011 and 2012 reports; was applied only after testing and expert opinion in the current assessment; is only presented in the table when it was considered applicable;

2017 Label	2011 Label	Currently Used For	Description	Comments
			and based on expert knowledge of these systems from the DFO Sockeye operational program of K.Benner;	Note: the start year is indicated in this label (e.g. Norm1967 SR time series begins in 1967)
NormUI	**N/A**	Applied to all non-cyclic CUs with stock-recruitment data	No informative prior applied to the capacity parameter of the Ricker model	See considerations in previous one Note: the start year is in this label (e.g. Norm1967 SR starts in 1967)
N/A	**RBLark**	None	Recursive Bayes – Larkin	Not applied in the current assessment because productivity improved after the last Fraser Sockeye status assessment; in the past assessment CUs experienced decade long declining productivity trend
N/A	**RBRick**	None	Recursive Bayes – Ricker	Same as RBLark
N/A	**SmLark**	None	Smoothed Larkin	Same as RBLark
N/A	**SmRick**	None	Smoothed Ricker	Same as RBLark
No 2005_1948	**N/A**	Harrison	Sensitivity analysis of the Harrison BM and statuses excluding the 2005 brood year when all CUs had poor survival including Harrison; this data point was assumed to be the result of density-independent factors, and was removed to test this; 1948 indicates that the full stock-recruitment time series was used	This sensitivity analysis was not conducted in the previous assessment
No 2005_1948	**N/A**	Harrison	Sensitivity analysis of the Harrison BM and statuses excluding the 2005 brood year when all CUs had poor survival including Harrison; this data point was assumed to be the result of density-independent factors and was removed to	Only a component of this sensitivity analysis was conducted in the previous assessment to test the effect of post-1990 data only on the BM and statuses

2017 Label	2011 Label	Currently Used For	Description	Comments
			test this; 1990 indicates that the post-1990 stock-recruitment time series was used to eliminate the period	

APPENDIX 5: QUESTIONNAIRE FOR NON-CYCLIC CUS

CU NAME: ____________________________

Question 1: What are the main drivers for the status this CU?
Question 2: What are some other considerations for the status this CU?
Question 3: What is the overall WSP status of this CU?
Question 4: Any other comments or points of discussion related to this CU.
Question 5: Any comments on the draft status narrative? (additions?, clarifications?, corrections?)

APPENDIX 6: QUESTIONNAIRE FOR CUS

CU NAME: ____________________________

Question 1: What are the main drivers for the status this CU?
Question 2: What are some other considerations for the status this CU?
Question 3a: What is the overall WSP status of this CU – **WITHOUT** CONSIDERING LARKIN-BASED BENCHMARKS?
Question 3b: What is the overall WSP status of this CU – **WITH** CONSIDERING LARKIN-BASED BENCHMARKS?
Question 4: Any other comments or points of discussion related to this CU.
Question 5: Any comments on the draft status narrative? (additions?, clarifications?, corrections?)

APPENDIX 7: DIAGNOSTIC PLOTS FOR NON-CYCLIC RICKER MODEL S_{MAX} AND BENCHMARKS ESTIMATE WITH AND WITHOUT INFORMATIVE PRIORS ON RICKER MODEL.

Figures are presented for CUs with both stock-recruitment data and independently-derived estimates of S_{max} from photosynthetic rate (PR) models. The year of the lake survey used to assess S_{max} using the PR model are indicated above the black filled circle. There may be one or more years where these S_{max} values were estimated for a CU. There are a few CUs such as Chilko-S and Shuswap-L that have more recent PR model derived Smax values, but these data are not yet available. For reference, the maximum estimated escapements are presented for each CU, to compare with PR model-derived S_{max} values. A sensitivity analysis is presented for Harrison (river-type) across variations in the time series used. Informative (red line) and uninformative (blue line) prior (solid line) and posterior (dashed line) distributions are presented.

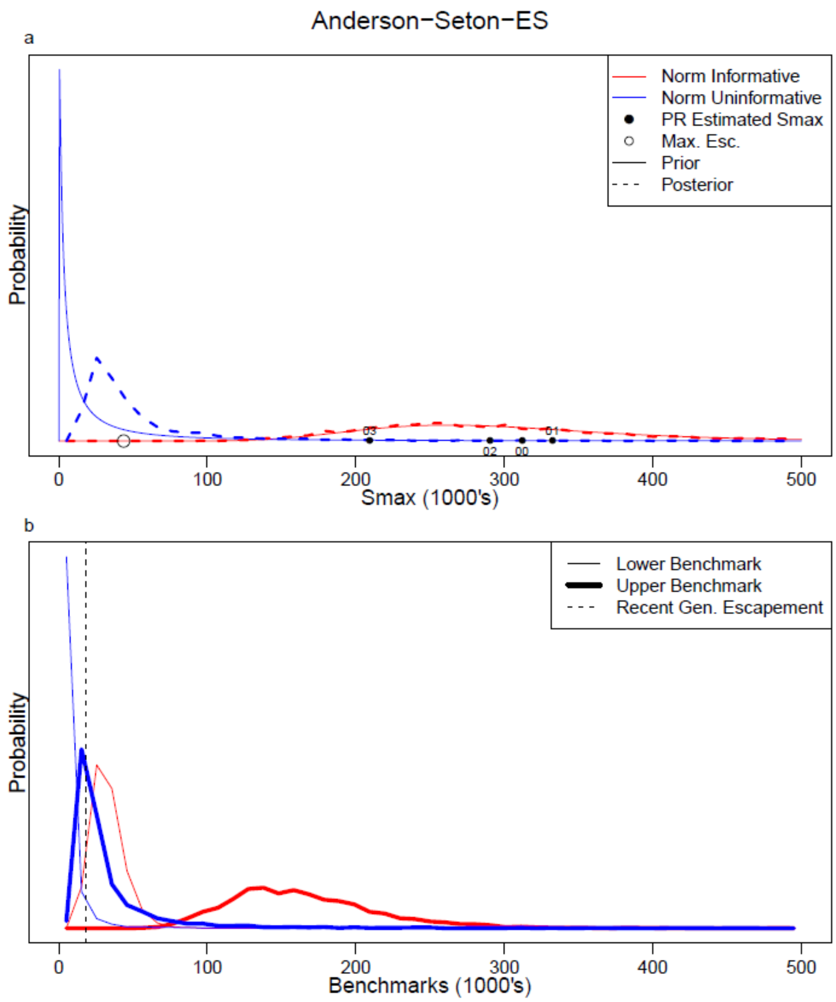


Figure A7-1: A. Anderson-Seton-ES prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

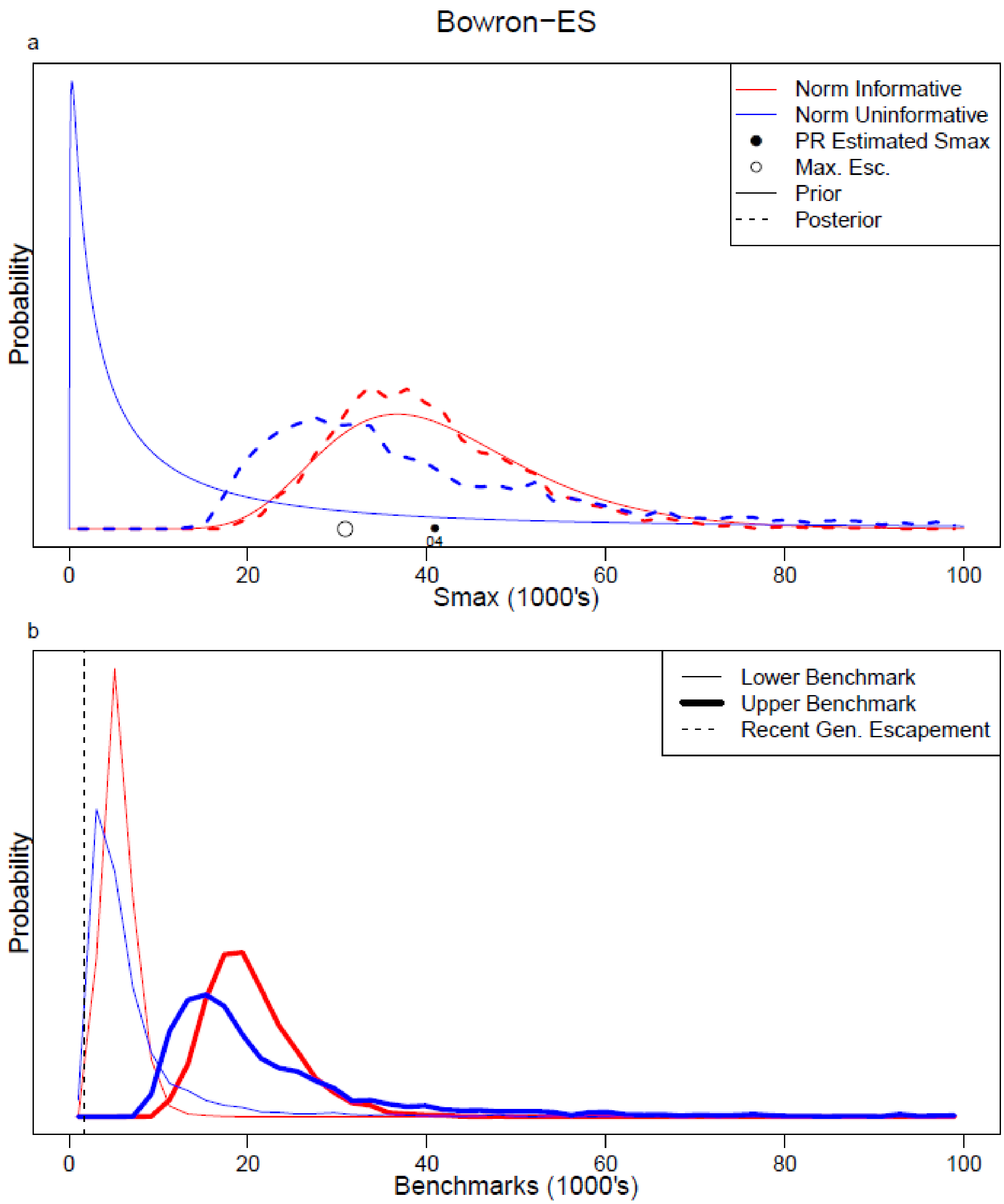


Figure A7-2: A. Bowron-ES prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

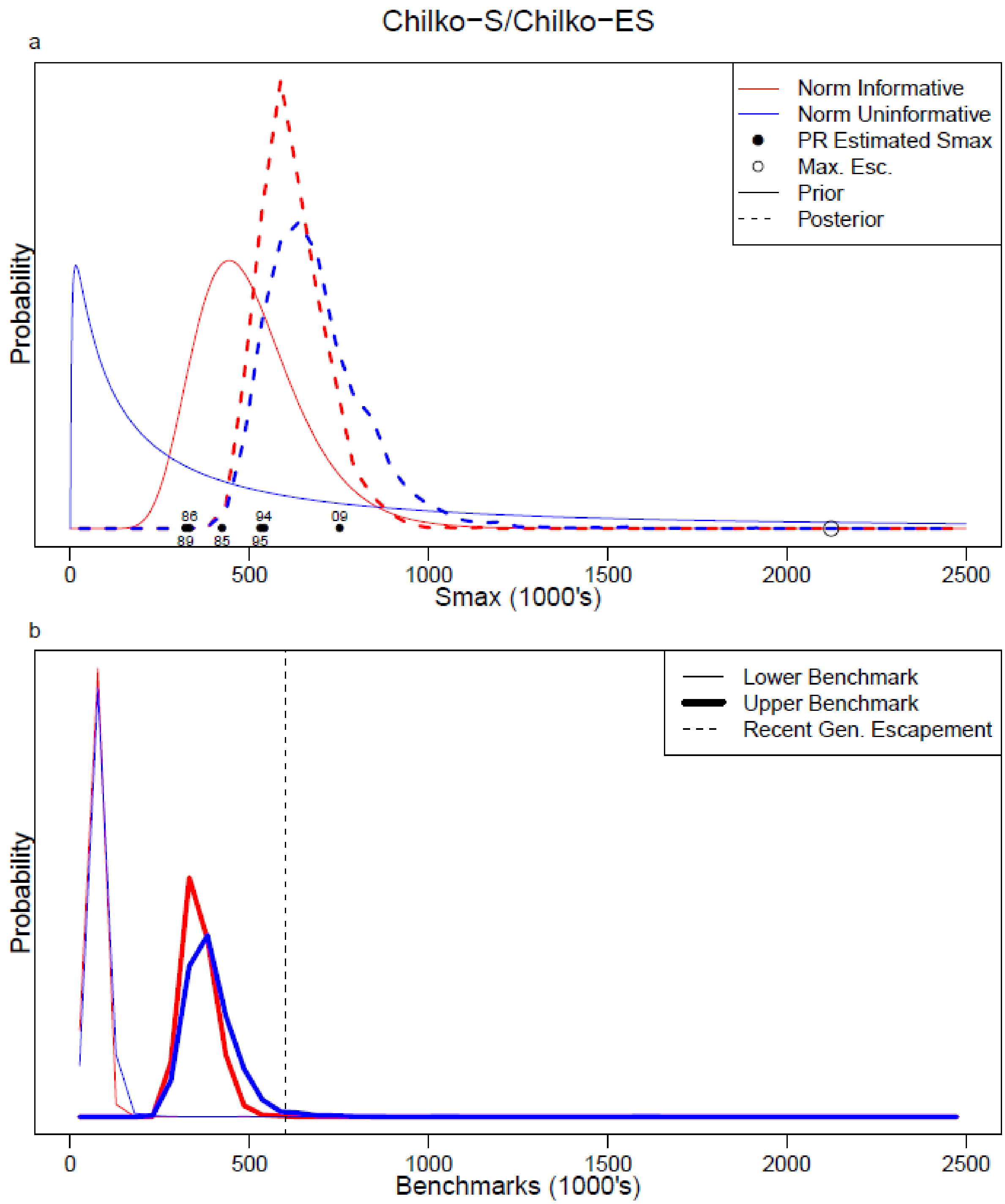


Figure A7-3: A. Chilko-S/Chilko-ES prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model; red) or with an uninformative prior (blue), which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

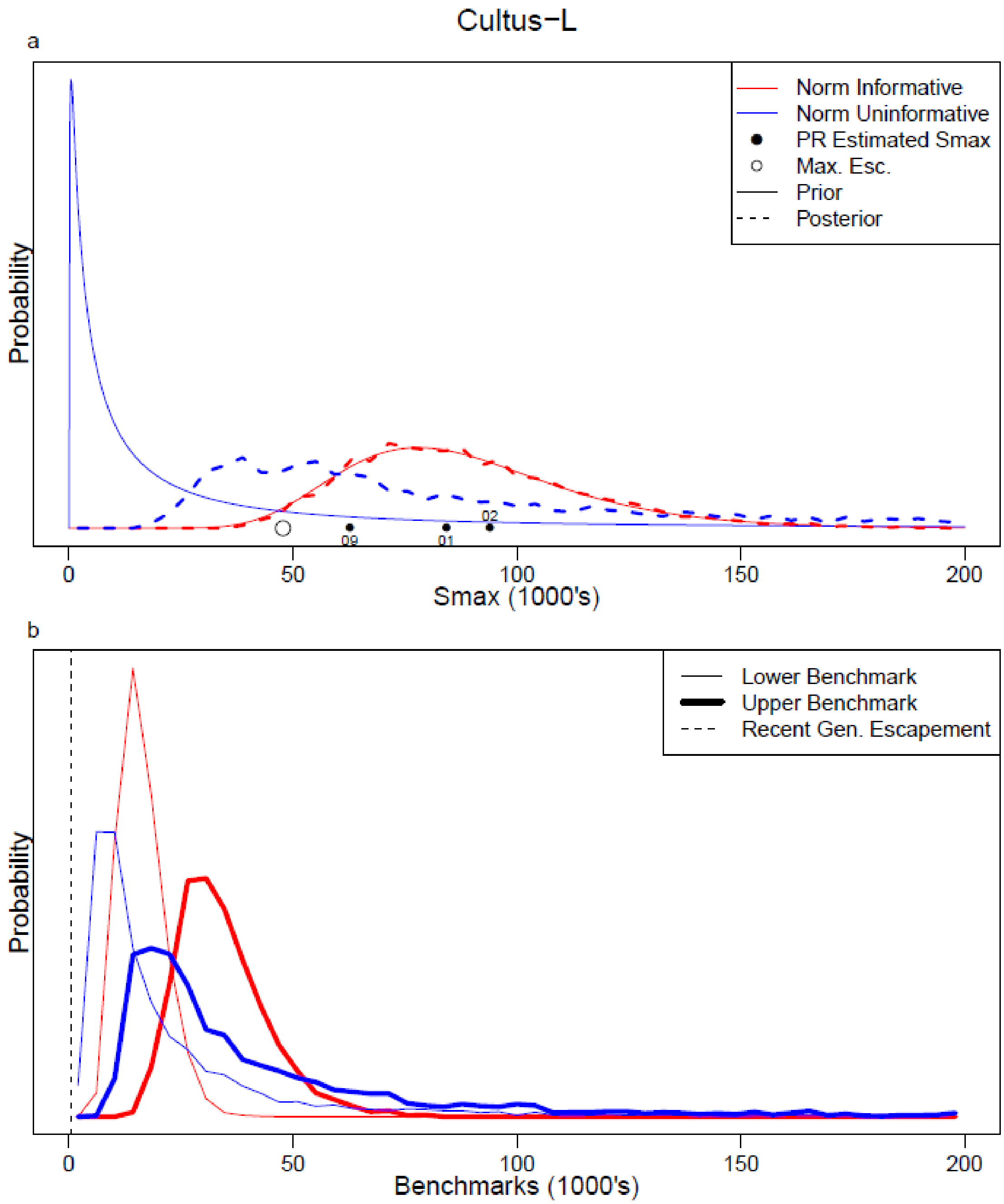


Figure A7-4: A. Cultus-L prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

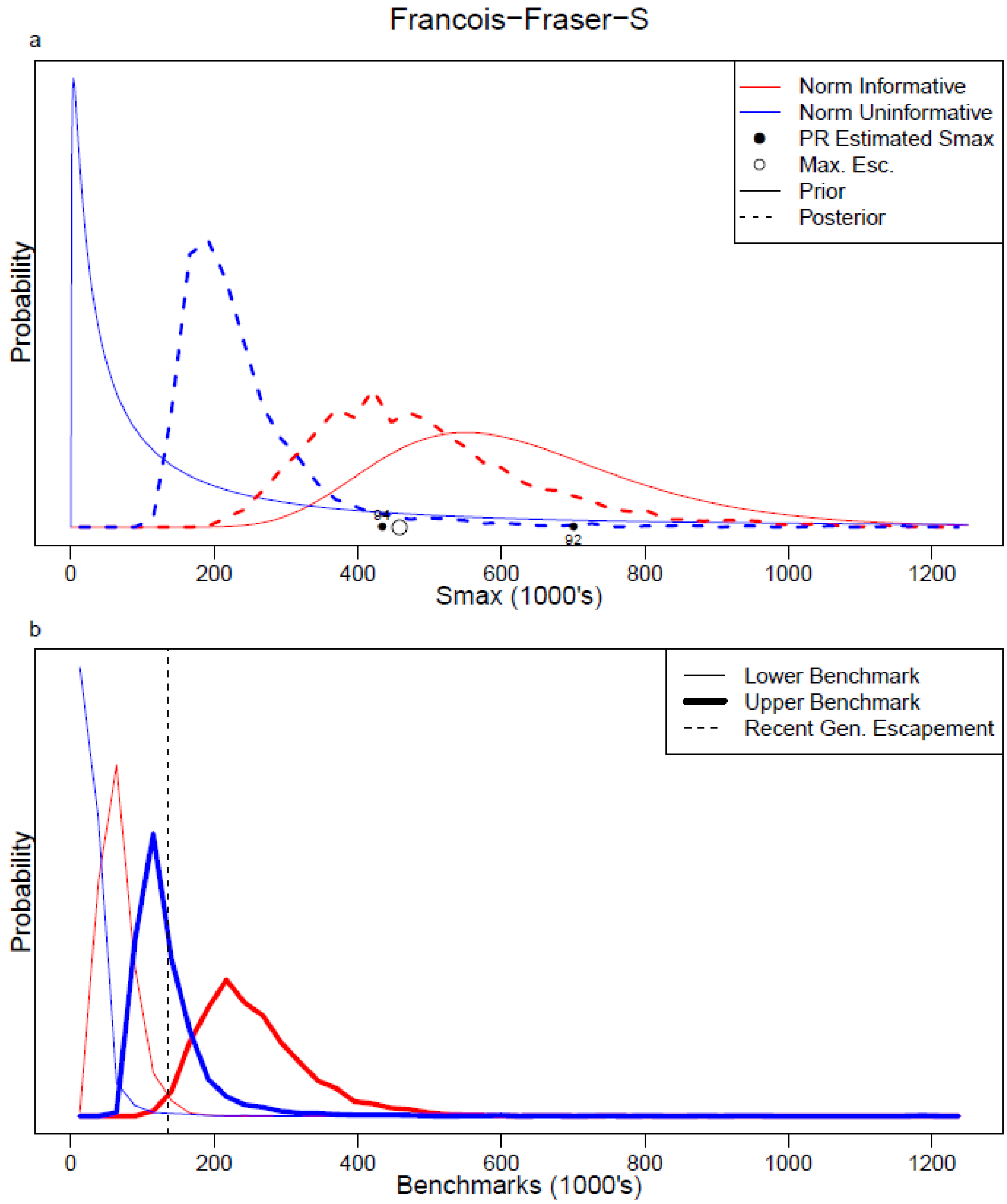


Figure A7-5: A. Francois-Fraser-S prior and posterior distributions for Smax (top) for model forms with either an informative prior (based on Smax estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on Smax. b. Resulting posterior distributions for abundance benchmarks (lower: Sgen, upper: 80% S_{MSY}).

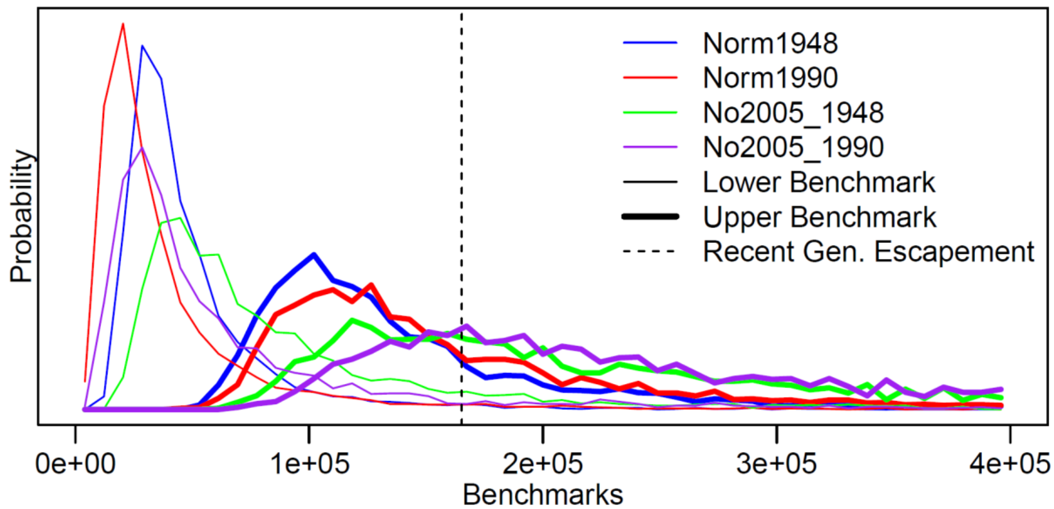


Figure A7-6: Harrison (River-Type) posterior distributions for relative-abundance benchmarks for different data sets (lower: S_{gen}, upper: 80% S_{MSY}). Data sets include: 1) Norm1948 (data set includes: 1948-2010); 2) Norm1990 (data set includes: 1990-2010); 3) No2005_1948 (data set includes: 1948-2004 and 2006-2010); 4) No2005_1990 (data set includes: 1990-2004, 2006-2010). Norm indicates the Ricker model as described in the methods is applied.

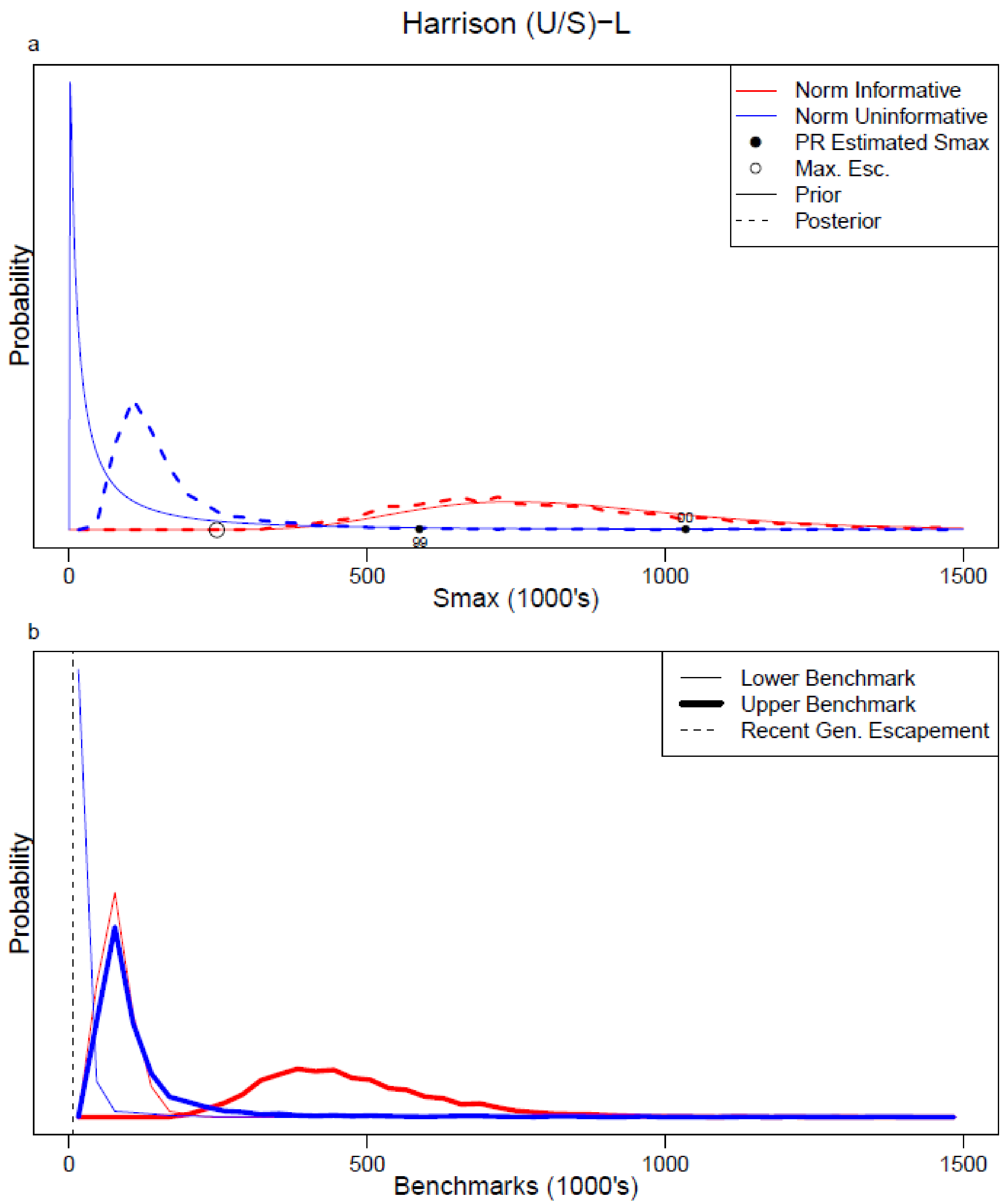


Figure A7-7: A. Harrison (U/S)-L prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

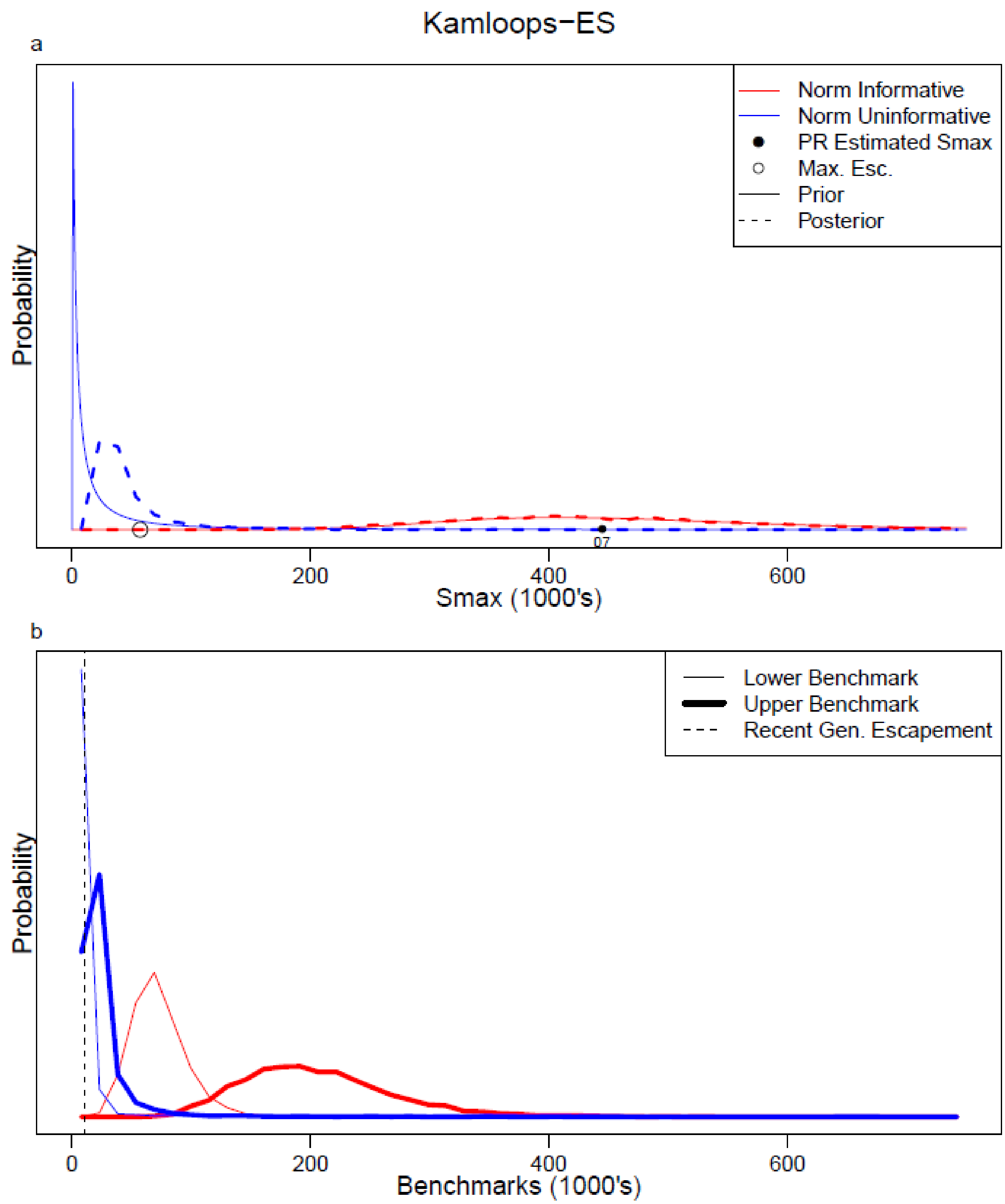


Figure A7-8: A. Kamloops-ES prior and posterior distributions for Smax (top) for model forms with either an informative prior (based on Smax estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on Smax. B. Resulting posterior distributions for abundance benchmarks (lower: Sgen, upper: 80% S_{MSY}).

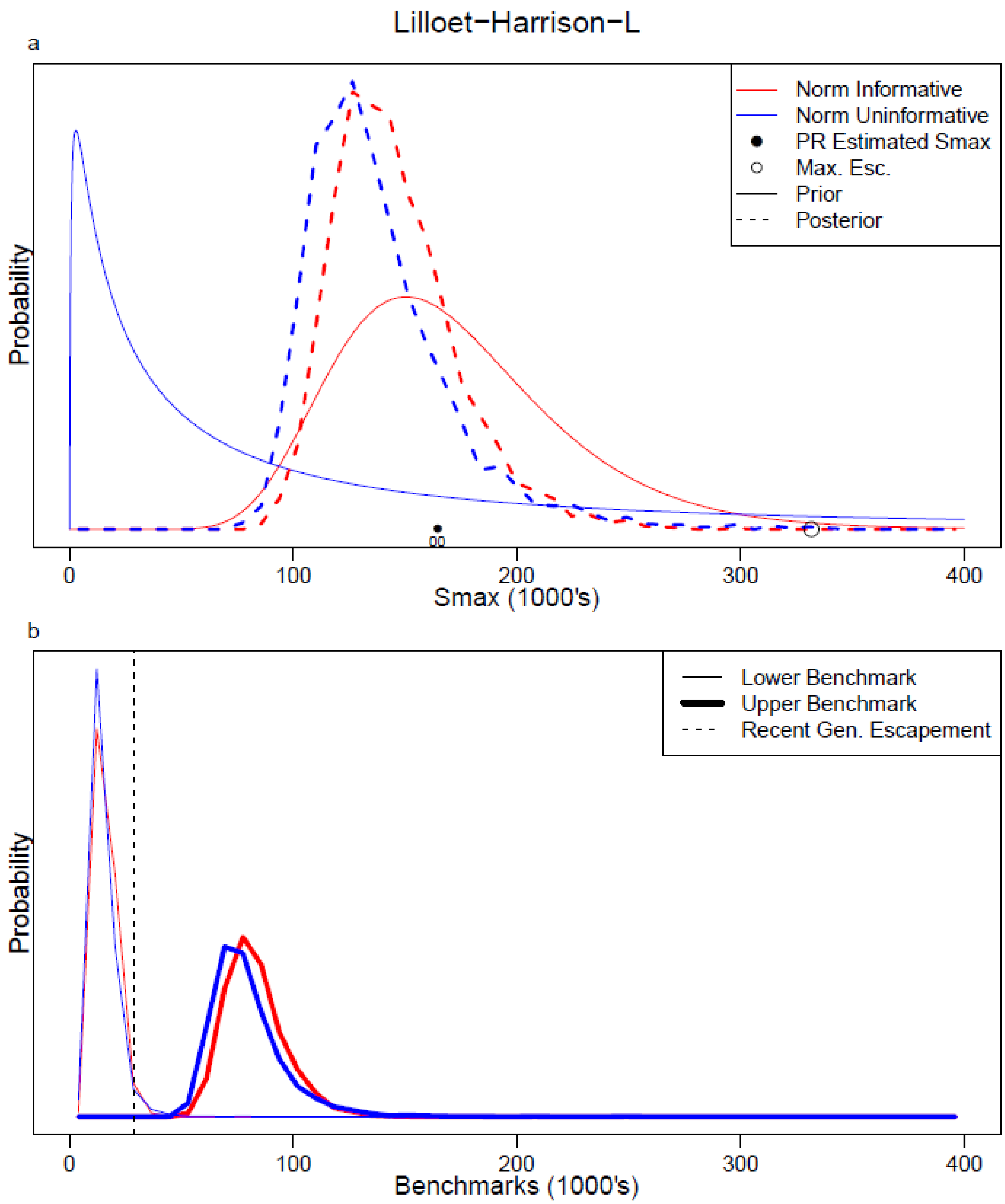


Figure A7-9 A. Lillooet-Harrison-L prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

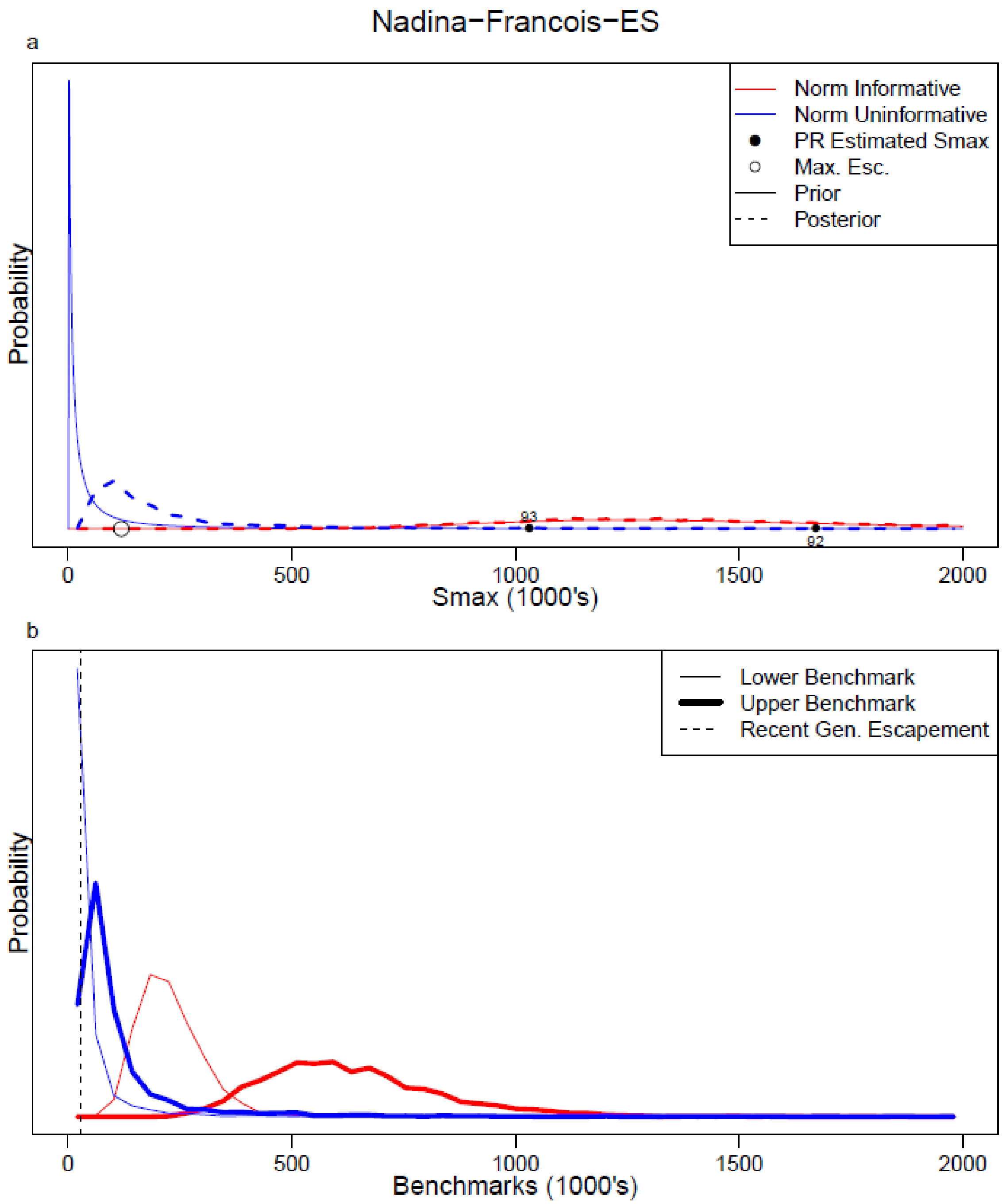


Figure A7-10: A. Nadina-Francois-ES prior and posterior distributions for Smax (top) for model forms with either an informative prior (based on Smax estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on Smax. B. Resulting posterior distributions for abundance benchmarks (lower: Sgen, upper: 80% SMSY).

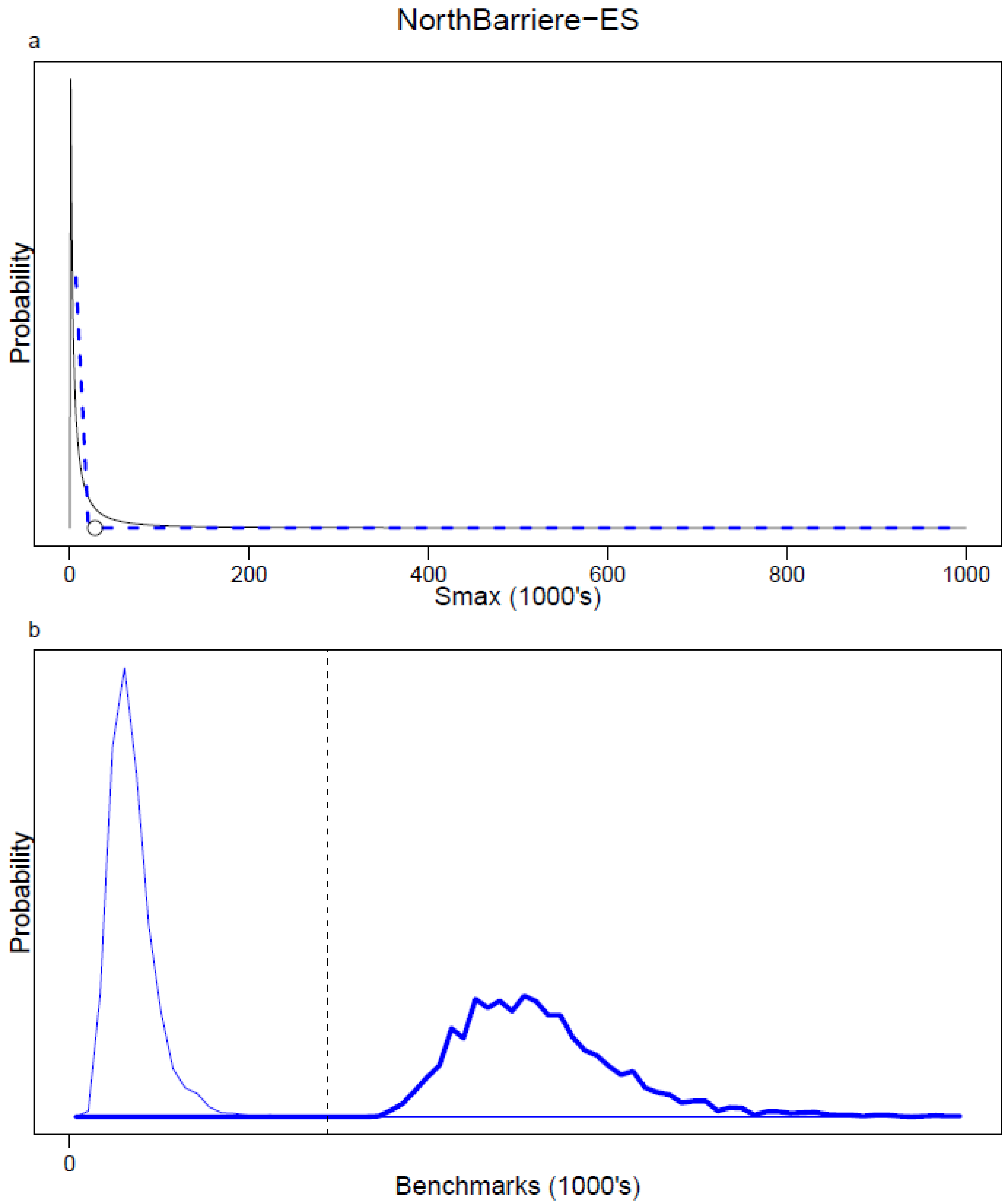


Figure A7-11: A. North Barriere prior and posterior distributions for S_{max} (top) for model forms with an uninformative prior, which does not use any prior information on S_{max} (not available for this CU). b. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

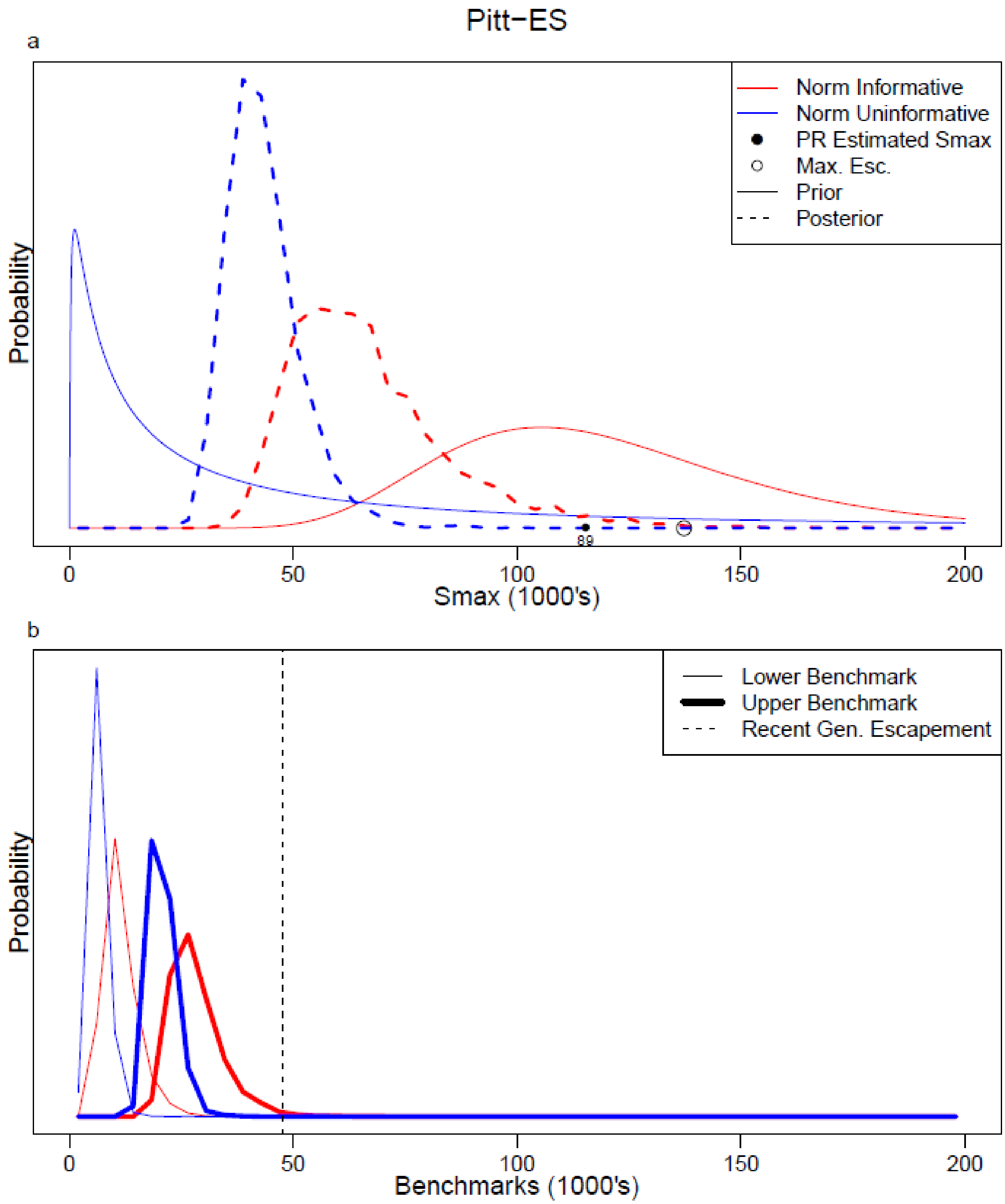


Figure A7-12 A. Pitt-ES prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

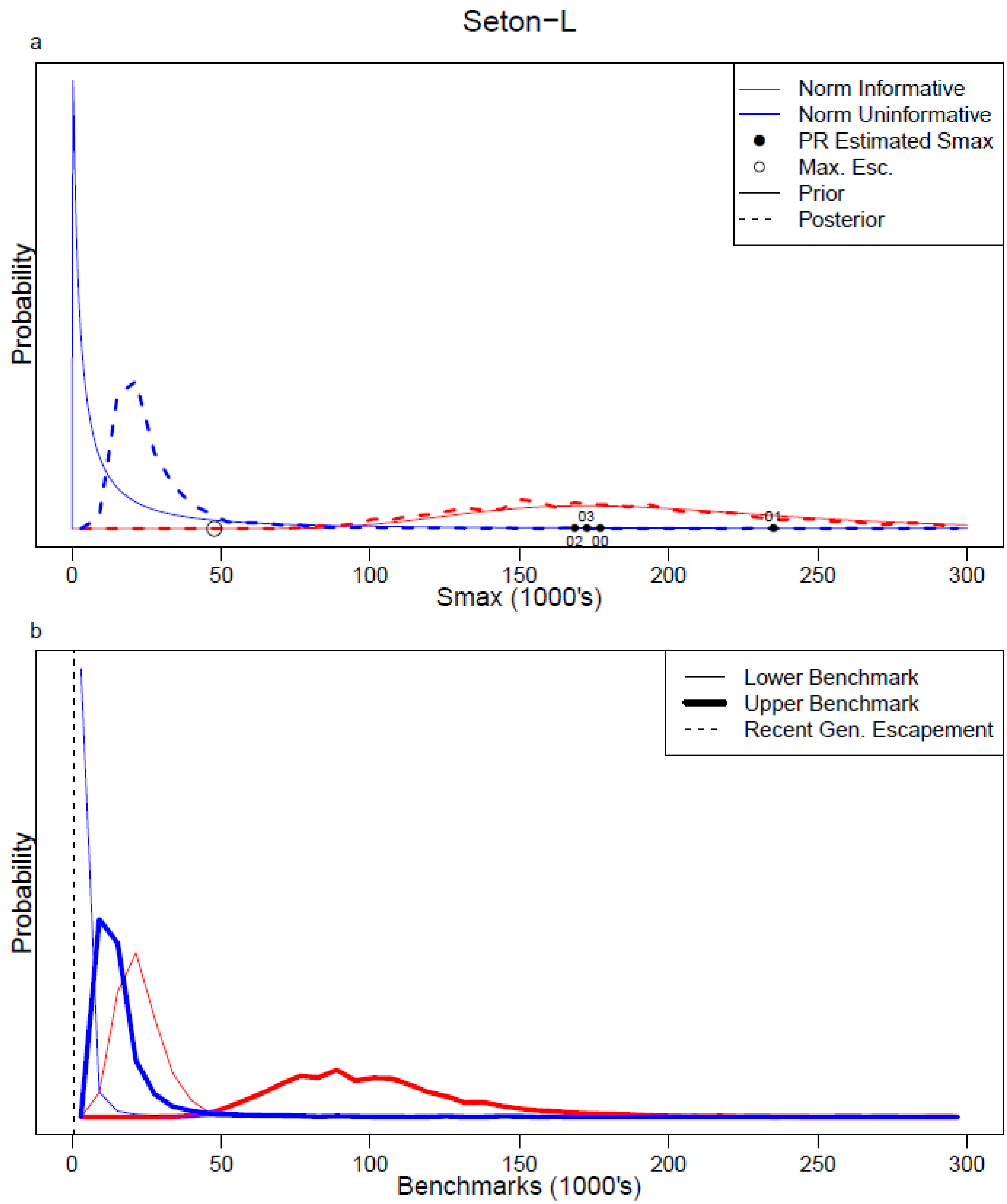


Figure A7-13: A. Seton-L prior and posterior distributions for S_{max} (top) for model forms with either an informative prior (based on S_{max} estimated from a photosynthetic rate model) or with an uninformative prior, which does not use any prior information on S_{max}. B. Resulting posterior distributions for abundance benchmarks (lower: S_{gen}, upper: 80% S_{MSY}).

APPENDIX 8: DIAGNOSTIC PLOTS FOR CYCLIC CUS: LARKIN MODELS BY CYCLE RELATIVE TO STOCK-RECRUITMENT DATA AND ESTIMATED BENCHMARKS

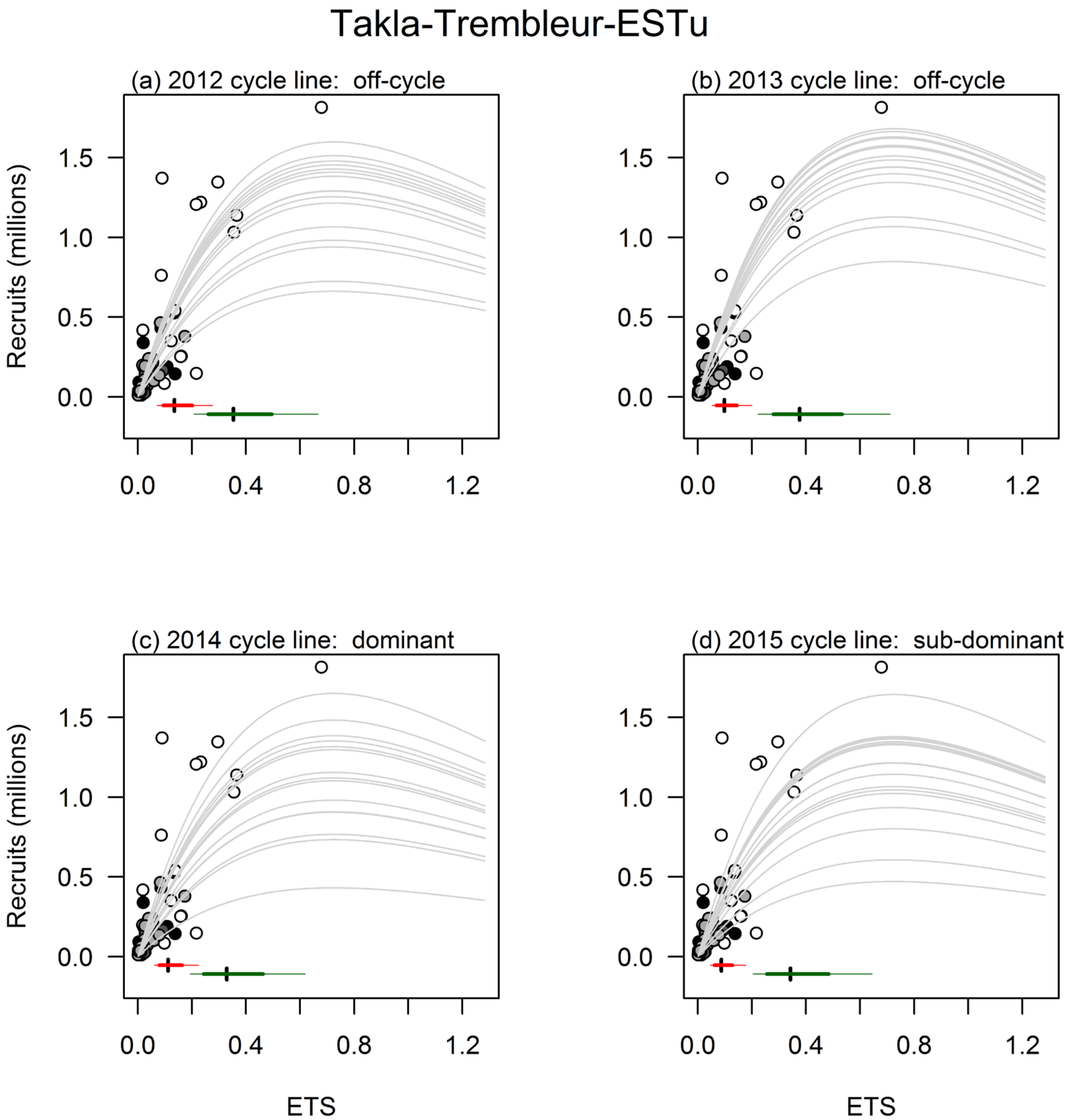


Figure A8-1. Stock-recruitment relationships by cycle line for 2012-2015 (a-d) for Takla-Trembleur-EStu (black curve). ETS is effective total spawners (millions). Data points for all cycle lines are shown for each plot because the stock-recruitment (Larkin) curves are based on the entire time-series. Recruitment abundances for the dominant cycle line are shaded white, sub-dominant cycle line are shaded light grey, the 1st off-cycle line are shagged dark grey, and 2nd off-cycle line are shade black. Grey lines depict reduced Larkin curves for all generations in the time series for a given cycle line, labeled at the top of the panel. The horizontal lines below each panel show the median and distribution (10th-90th probabilities, thin lines, and 25th-75th probabilities, thick lines) for S_{gen} (green) and 80% of S_{MSY} (red).

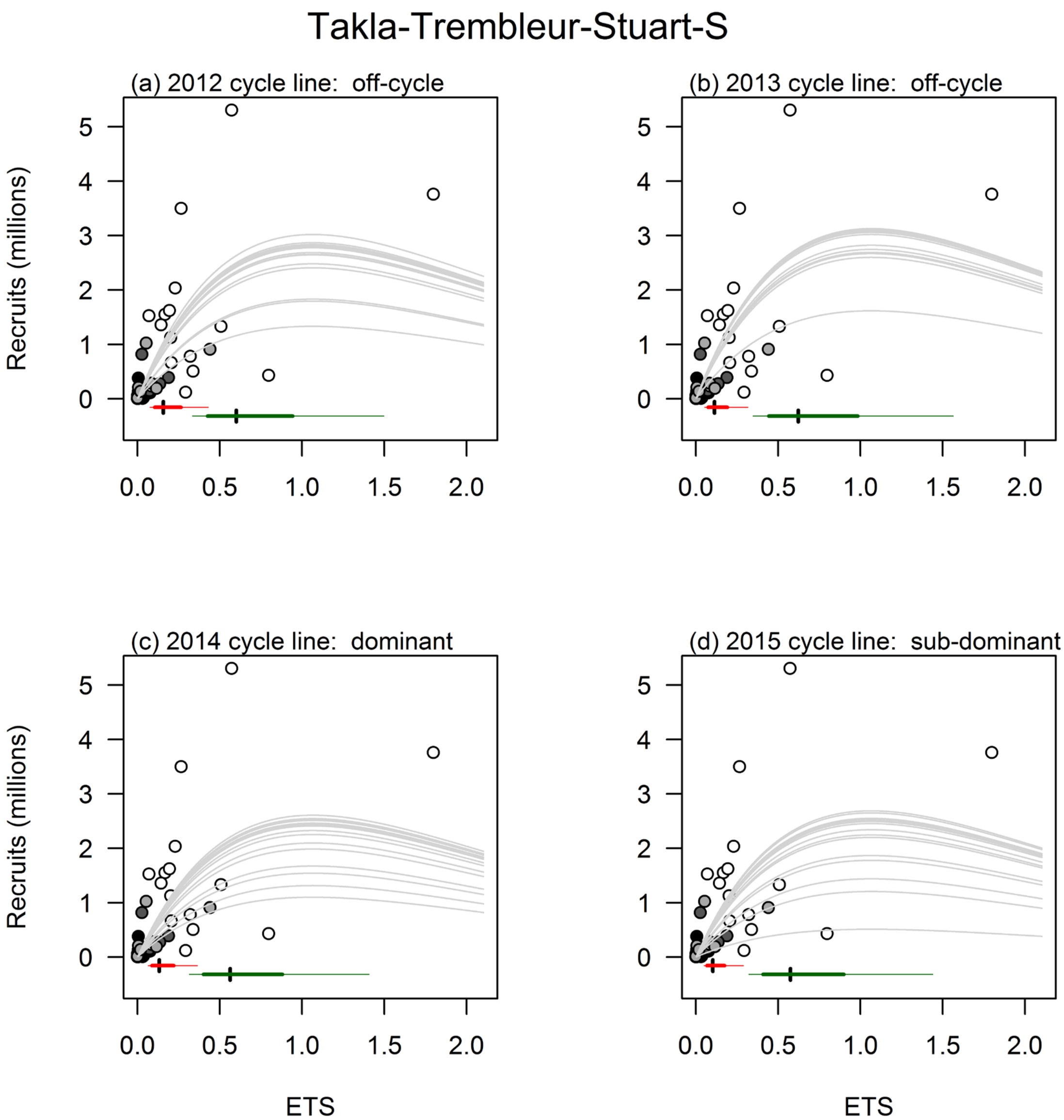


Figure A8-2. Stock-recruitment relationships for Takla-Trembleur-Stuart-S. Points, curves, and lines are described in the caption to Figure A8.1.

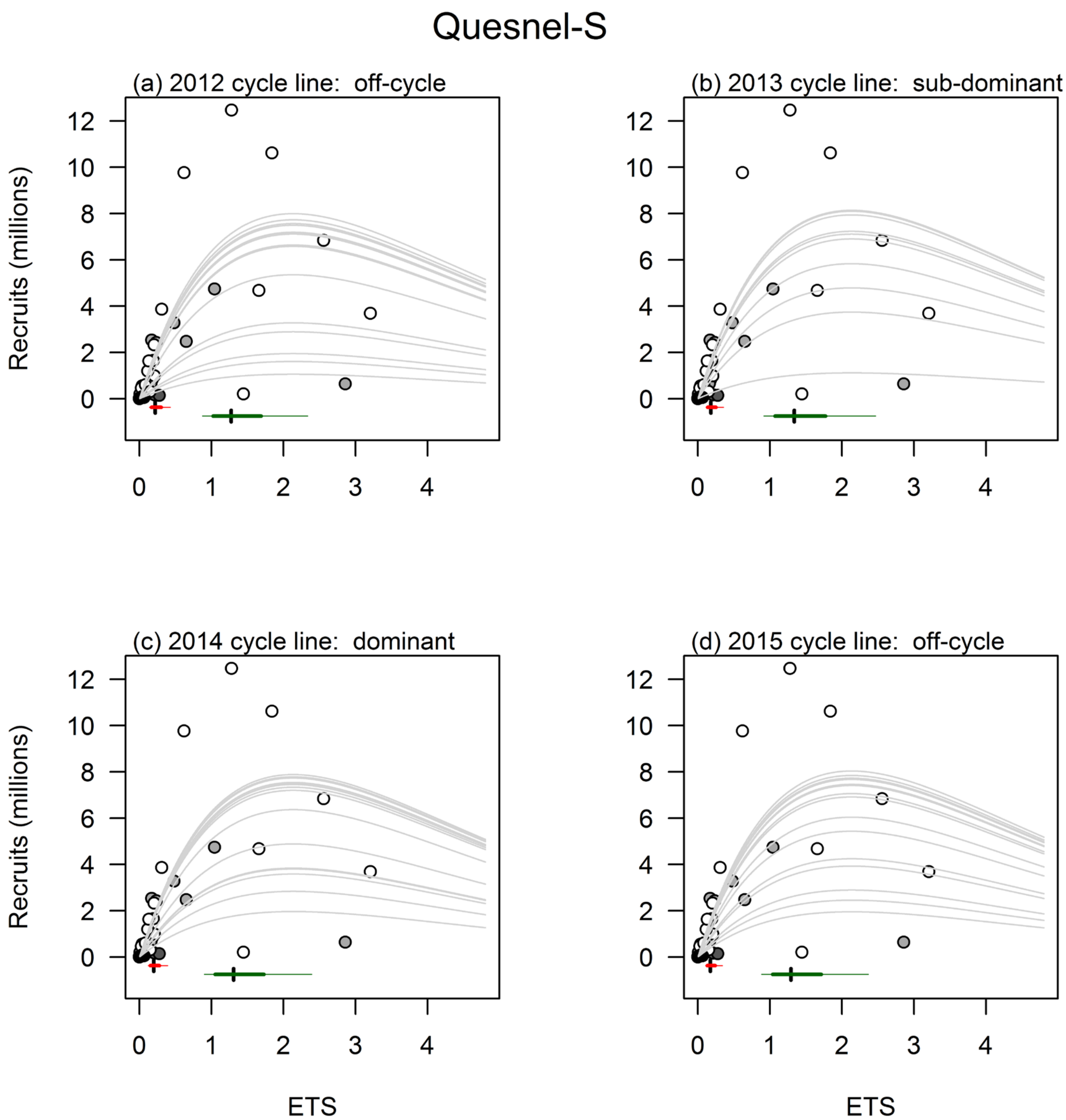


Figure A8-3. Stock-recruitment relationships for Quesnel-S. Points, curves, and lines are described in the caption to Figure A8.1.

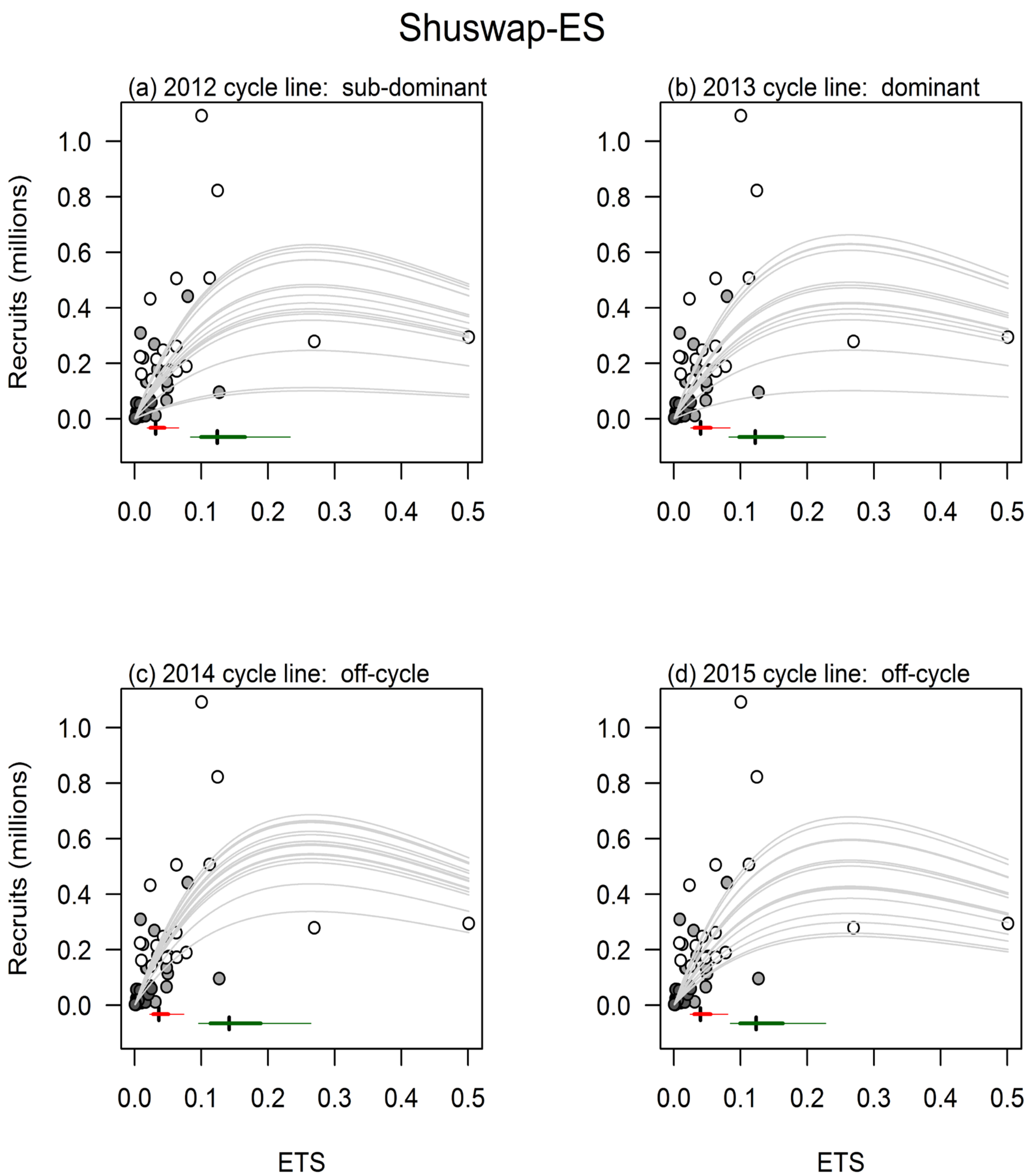


Figure A8-4. Stock-recruitment relationships for Shuswap-ES. Points, curves, and lines are described in the caption to Figure A8.1.

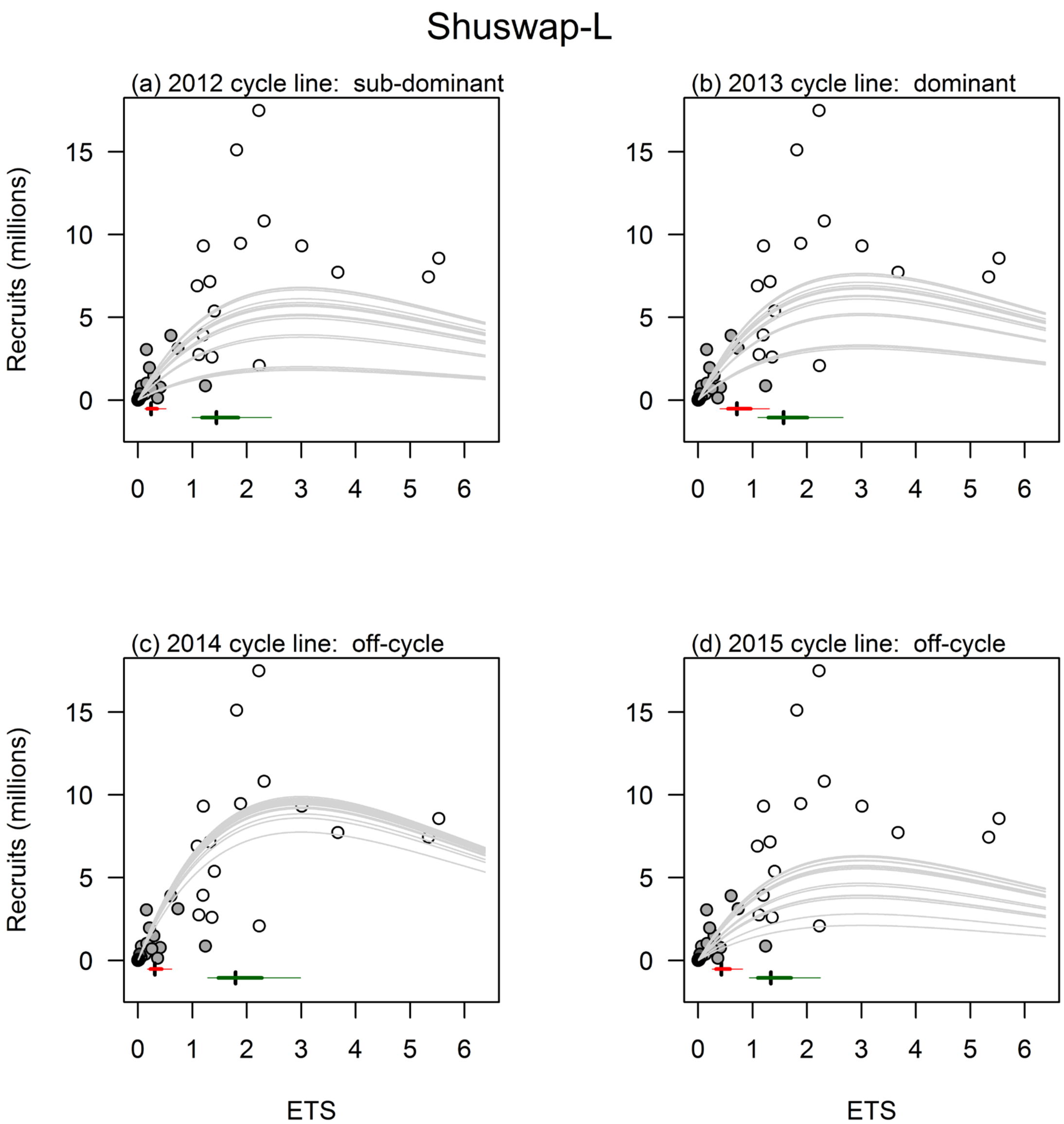


Figure A8-5. Stock-recruitment relationships for Shuswap-L. Points, curves, and lines are described in the caption to Figure A8.1.

APPENDIX 9: DIAGNOSTIC PLOTS FOR CYCLIC CUS: TIME SERIES OF ALPHA PARAMETERS FROM THE LAKRIN MODEL WITH 95% CONFIDENCE INTERVALS FOR EACH CYCLIC CU

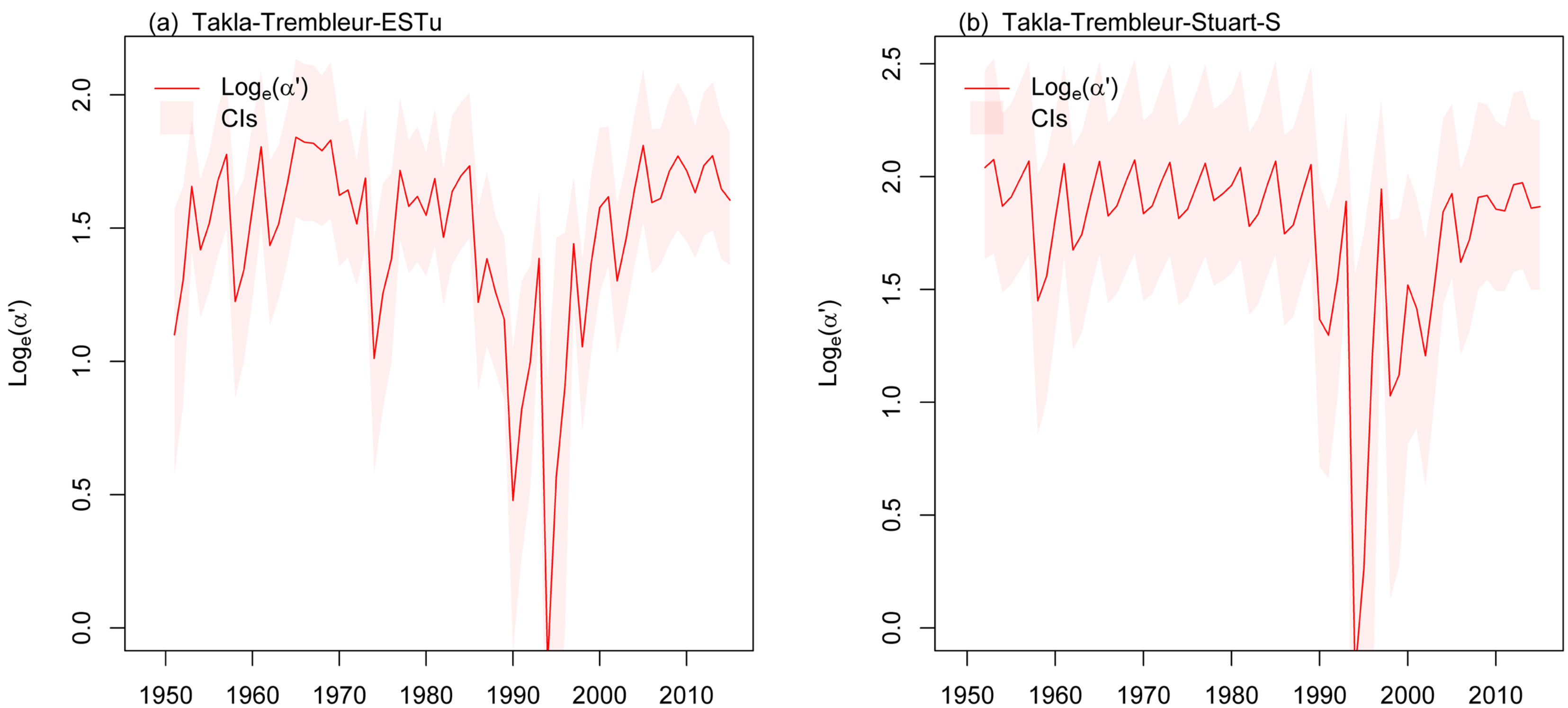


Figure A9. Time-series of annual α' parameters from the Larkin model with 95% confidence intervals for each cyclic CU (a) Takla-Trembleur-EStu, (b) Takla-Trembleur-Stuart-S, (c) Quesnel-S, (d) Shuswap-ES, and (e) Shuswap-L.

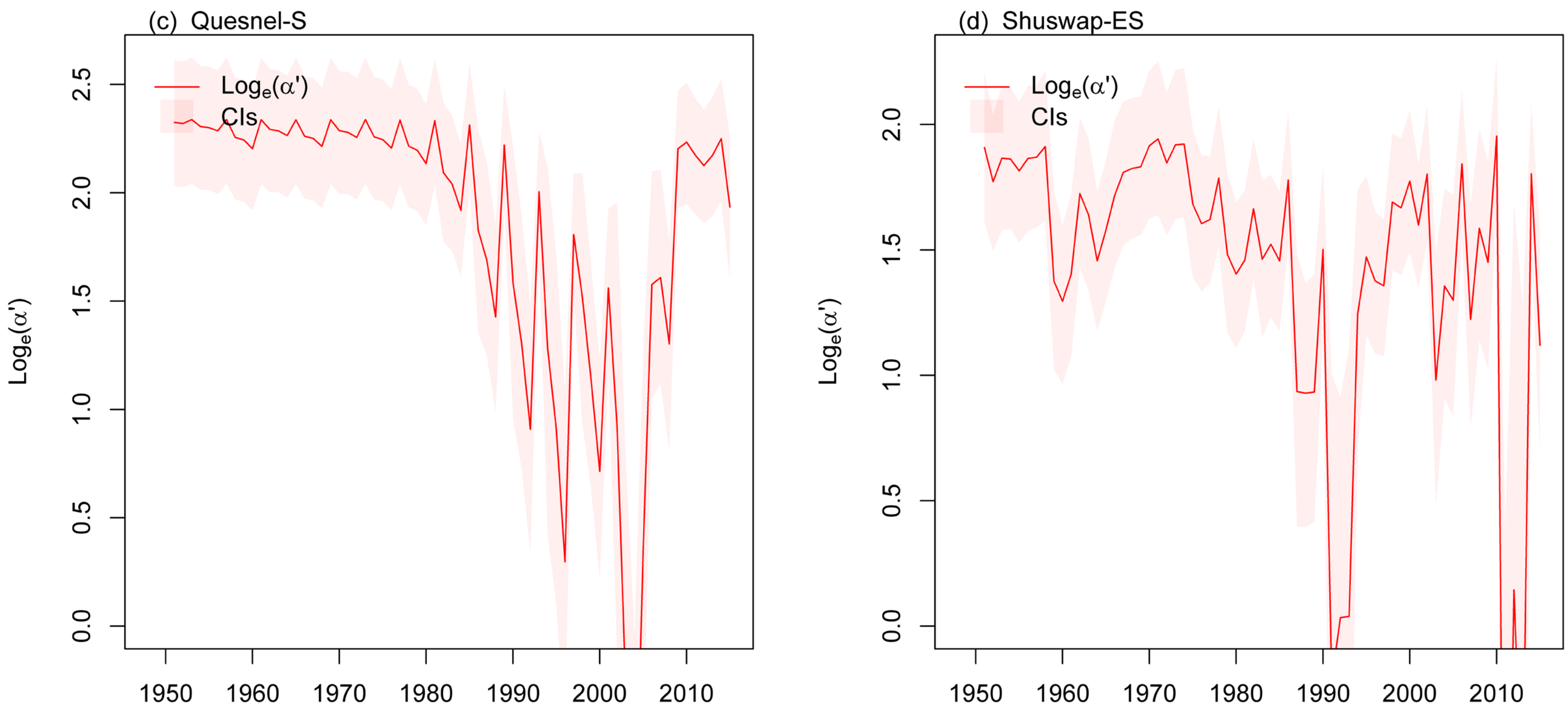


Figure A9 Continued.

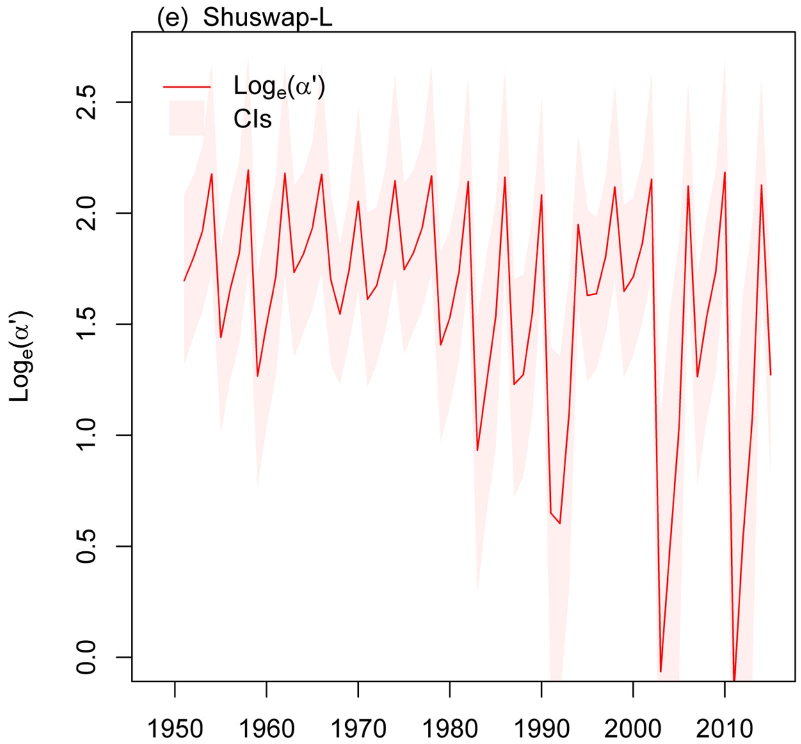


Figure A9 Continued.

APPENDIX 10: DIAGNOSTIC PLOTS FOR CYCLIC CUS: STATUSES PRESENTED FOR LARKIN-DERIVED RELATIVE ABUNDANCE BENCHMARKS ESTIMATED FOR EACH YEAR IN THE CURRENT GENERATION, AND THE MEDIAN OF ALL BENCHMARKS ESTIMATED OVER THE ENTIRE TIME SERIES.

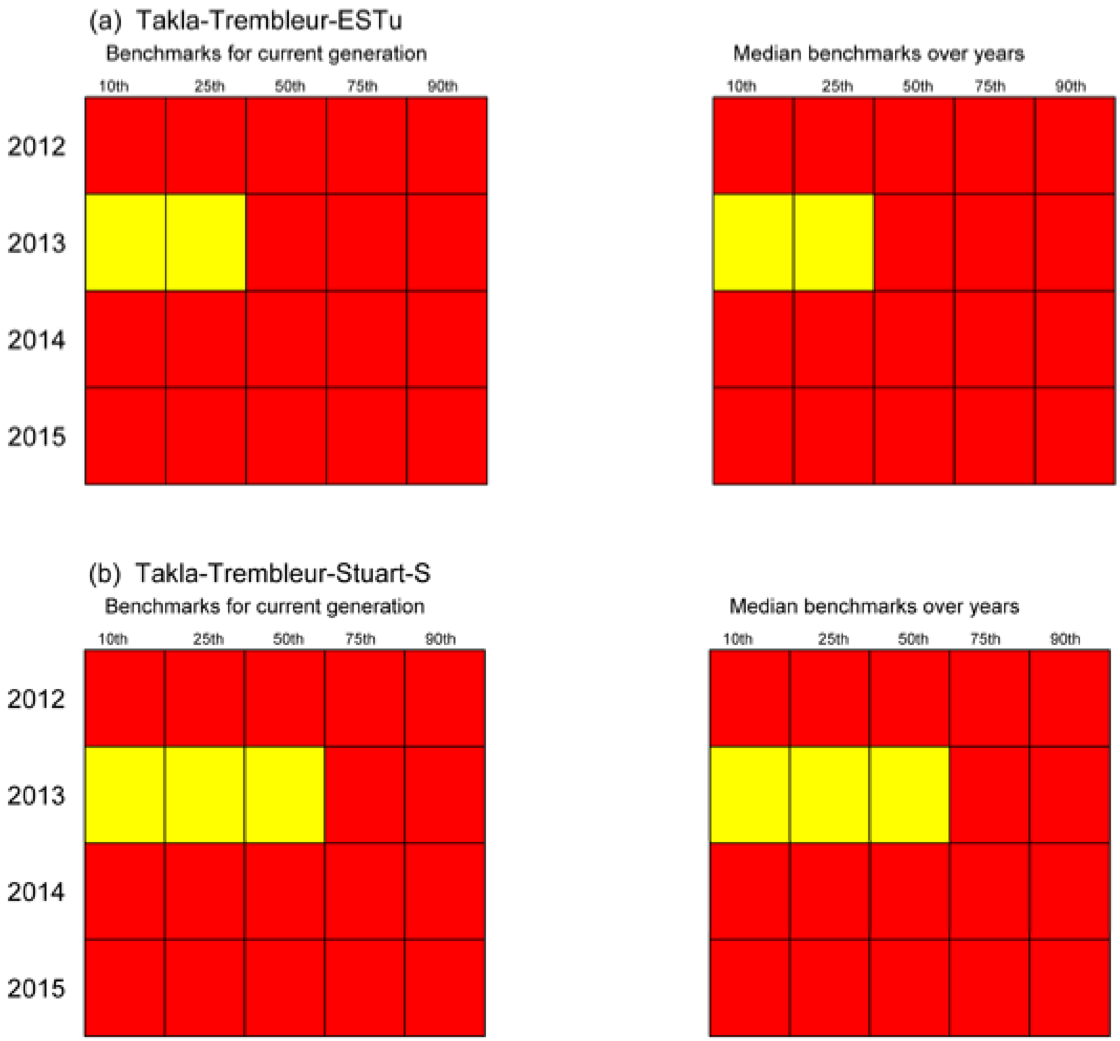
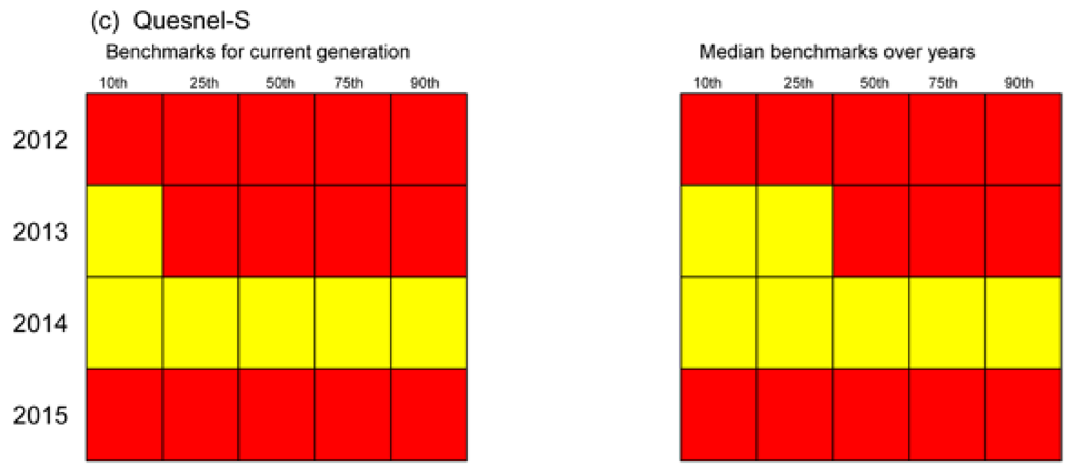


Figure A10-1. Status assessments of spawner abundances in the current generation (2012-2015) against cycle-line specific benchmarks for the most recent generation (left panels), and against benchmarks calculated as the cycle-line specific median over the time-series (right panels), for each cyclic CU (a) Takla-Trembleur-EStu, (b) Takla-Trembleur-Stuart-S, (c) Quesnel-S, (d) Shuswap-ES, and (e) Shuswap-L.



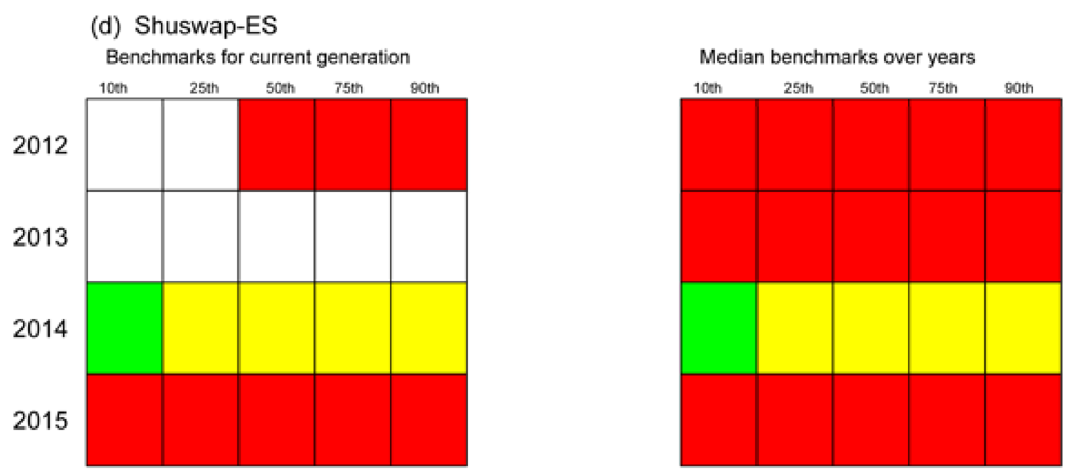


Figure A10-1 Continued.

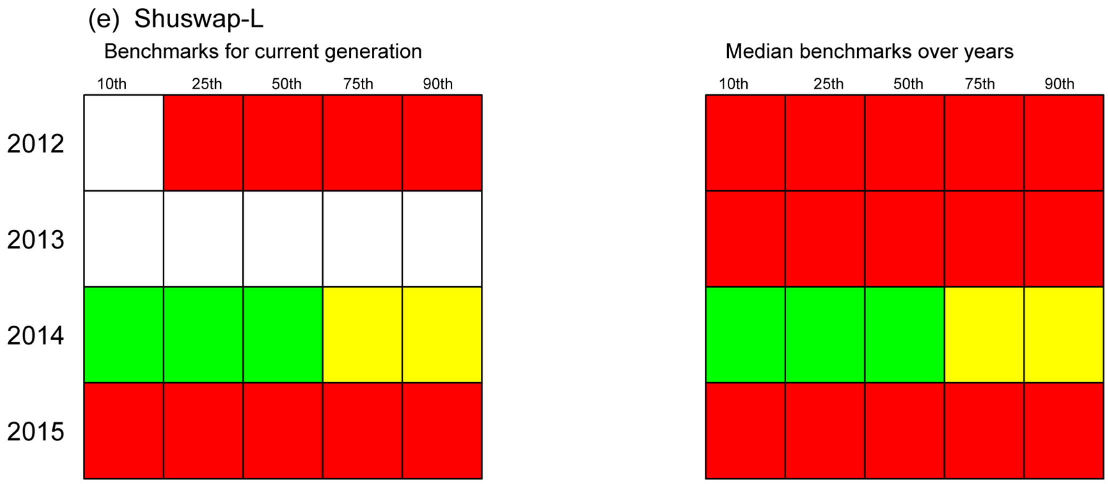


Figure A10-1 Continued.

APPENDIX 11: LARKIN PARAMETER VALUES FOR ALL CUS

Table A 11-1. Larkin parameter values for all CUs. Asterisk denotes those identified as cyclic

CU	$\log_e(\alpha)$			β_0			β_1			β_2			β_3			σ		
	Median	LCL	UCL	Median	LCL	UCL	Median	LCL	UCL	Median	LCL	UCL	Median	LCL	UCL	Median	LCL	UCL
Takla-Trembleur-ESTu*	1.88	1.57	2.19	1.38	0.55	3.06	2.61	0.90	4.29	1.74	0.29	3.43	0.93	0.06	2.43	0.75	0.63	0.92
Takla-Trembleur-Stuart-S*	2.08	1.66	2.53	0.94	0.24	2.15	1.25	0.19	2.47	0.95	0.08	2.12	0.40	0.02	1.40	1.29	1.08	1.57
Francois-Fraser-S	2.69	2.33	3.06	3.60	1.43	5.81	1.47	0.11	3.64	0.93	0.05	2.85	6.06	3.77	8.23	0.68	0.57	0.83
Bowron-ES	1.94	1.58	2.36	31.60	12.72	58.88	7.80	0.36	29.55	9.67	0.48	34.06	5.64	0.20	24.10	0.87	0.73	1.06
Kamloops-ES	1.92	1.63	2.26	22.75	7.57	44.12	5.96	0.26	22.87	17.86	2.05	39.87	12.16	0.81	32.36	0.81	0.68	0.99
Quesnel-S*	2.34	2.04	2.62	0.47	0.16	0.80	0.40	0.07	0.74	0.46	0.11	0.81	0.65	0.30	0.99	0.87	0.73	1.05
Chilko-S/Chilko-ES	2.38	2.03	2.74	1.04	0.44	1.63	1.03	0.24	1.88	0.40	0.02	1.10	0.18	0.01	0.68	0.74	0.62	0.90
Shuswap-ES*	2.05	1.72	2.40	3.78	1.19	6.74	8.05	3.12	13.01	3.51	0.32	8.32	5.52	1.13	10.44	0.81	0.67	0.98
Shuswap-L*	2.21	1.75	2.73	0.33	0.13	0.57	0.43	0.17	0.70	0.29	0.06	0.55	0.20	0.02	0.46	0.94	0.78	1.15
Lilloet-Harrison-L	2.39	2.00	2.82	6.32	3.06	9.46	3.05	0.46	6.11	0.91	0.04	3.27	1.22	0.06	3.83	0.98	0.82	1.19
Cultus-L	1.54	1.10	2.09	15.13	7.43	38.42	8.34	0.37	30.85	8.15	0.31	30.90	6.17	0.20	26.74	1.21	0.99	1.51
Seton-L	2.90	2.30	3.56	47.45	12.24	85.53	53.96	8.51	95.05	17.10	0.73	56.74	16.74	0.84	56.94	1.07	0.86	1.36
Harrison (U/S)-L	2.82	2.32	3.39	6.36	1.76	13.90	2.96	0.16	9.21	1.60	0.07	6.60	4.88	0.36	11.94	0.92	0.74	1.18
NorthBarriere-ES	2.74	2.23	3.28	92.51	38.25	144.50	31.32	2.05	78.29	25.93	1.84	69.74	26.12	1.56	71.98	0.95	0.76	1.21
Anderson-Seton-ES	3.00	2.46	3.60	36.60	10.80	68.34	20.70	1.79	52.47	35.96	6.82	67.29	38.31	8.22	70.30	0.87	0.70	1.12
Nadina-Francois-ES	1.95	1.51	2.49	9.07	3.13	21.15	5.39	0.30	17.14	7.53	0.50	20.77	9.29	0.79	22.81	0.89	0.71	1.17
Pitt-ES	1.82	1.48	2.16	13.34	4.37	22.87	4.46	0.23	13.49	10.78	1.90	20.55	3.31	0.15	11.40	0.74	0.62	0.90
Harrison River-Type	1.61	1.23	2.02	2.14	0.55	5.49	0.92	0.04	4.08	1.24	0.04	5.41	1.44	0.06	5.93	1.46	1.22	1.79

APPENDIX 12: REFERENCE PLOTS – SPAWNER TIME SERIES BY CYCLE LINE

OVERVIEW

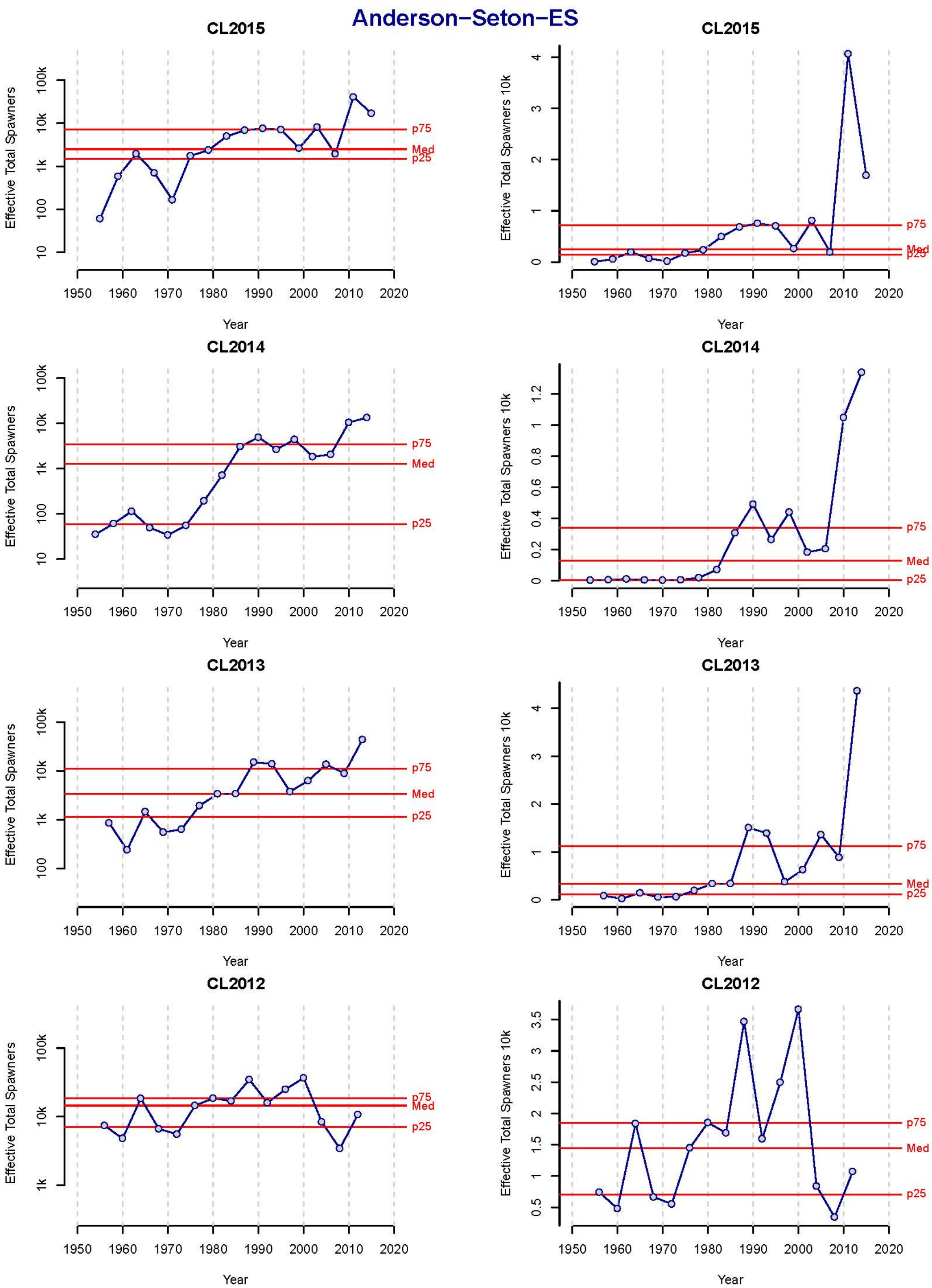


Figure A 12-1. Reference plots of spawner time series by cycle line for Anderson-Seton-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

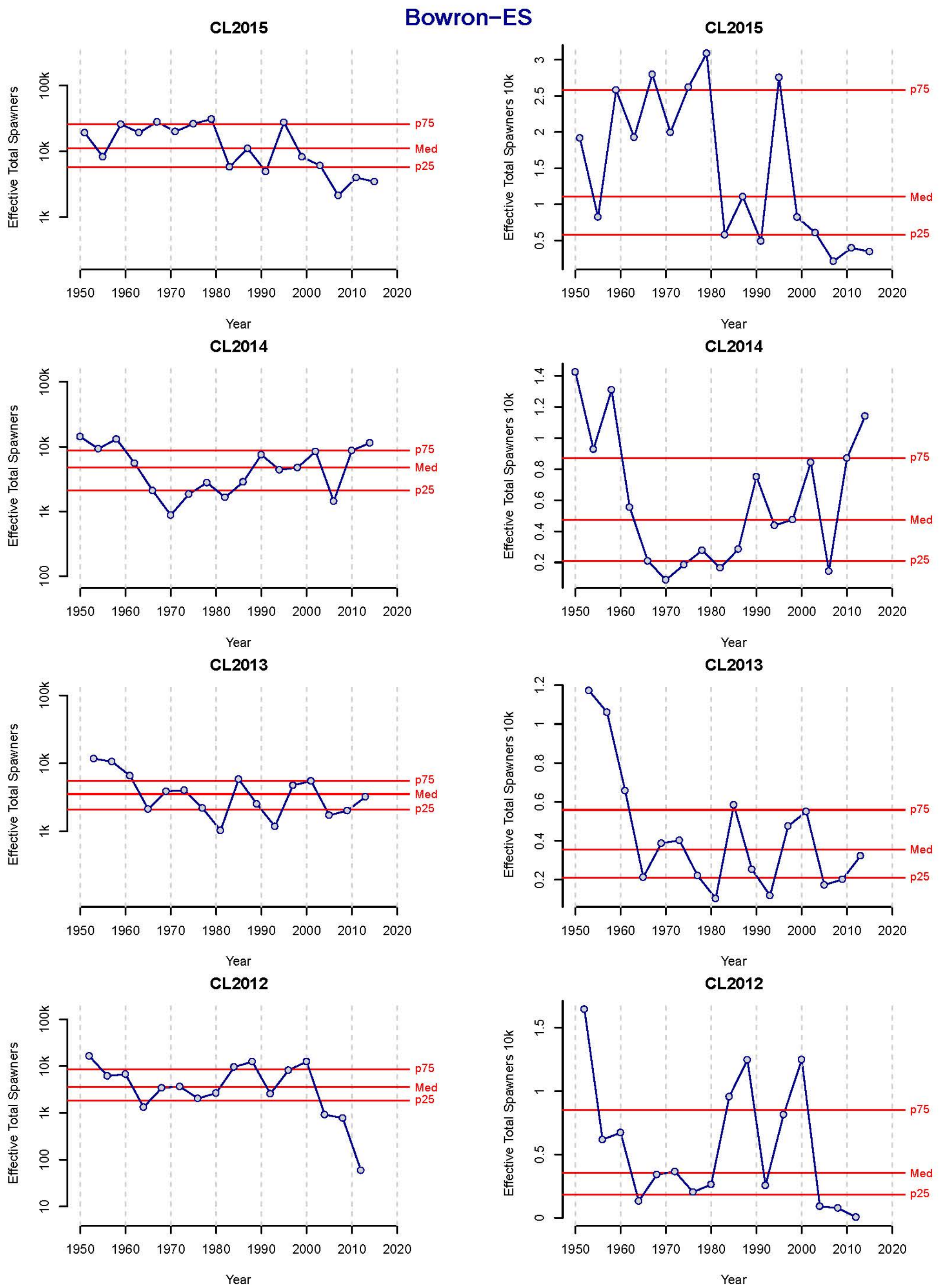


Figure A 12-2. Reference plots of spawner time series by cycle line for Bowron-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

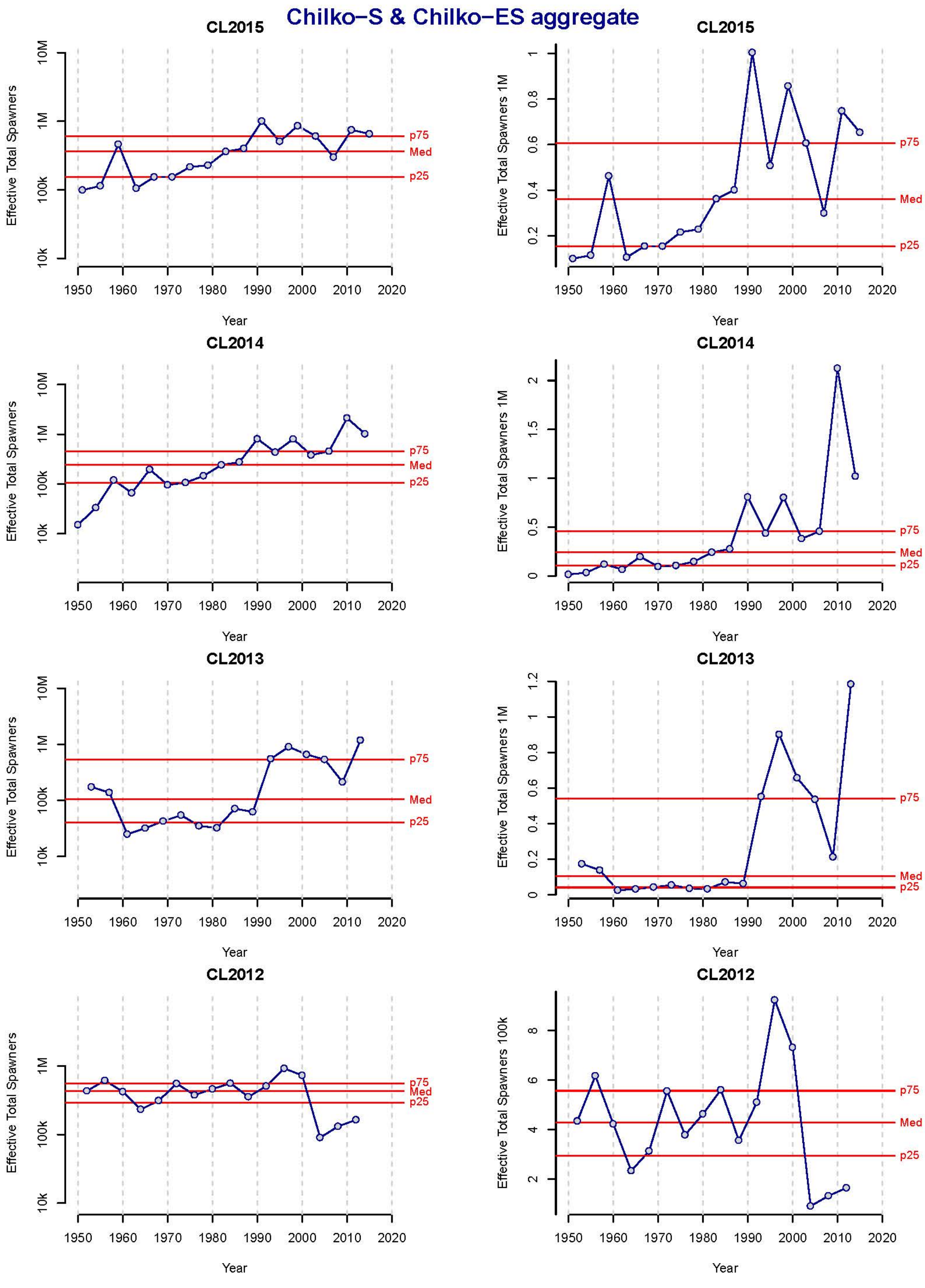


Figure A 12-3. Reference plots of spawner time series by cycle line for Chilko-S & ES- aggregate. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

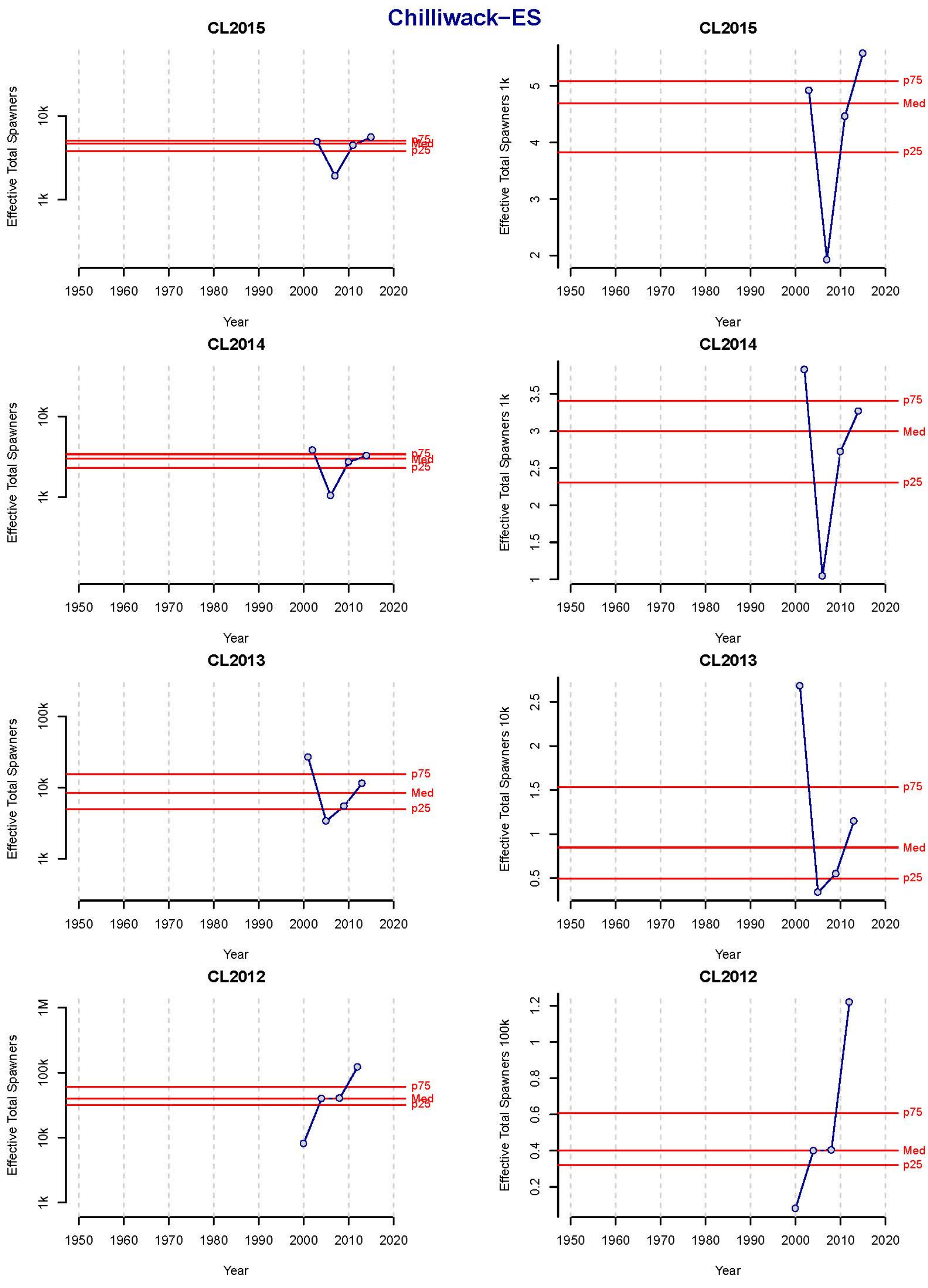


Figure A 12-4. Reference plots of spawner time series by cycle line for Chlliwack- ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

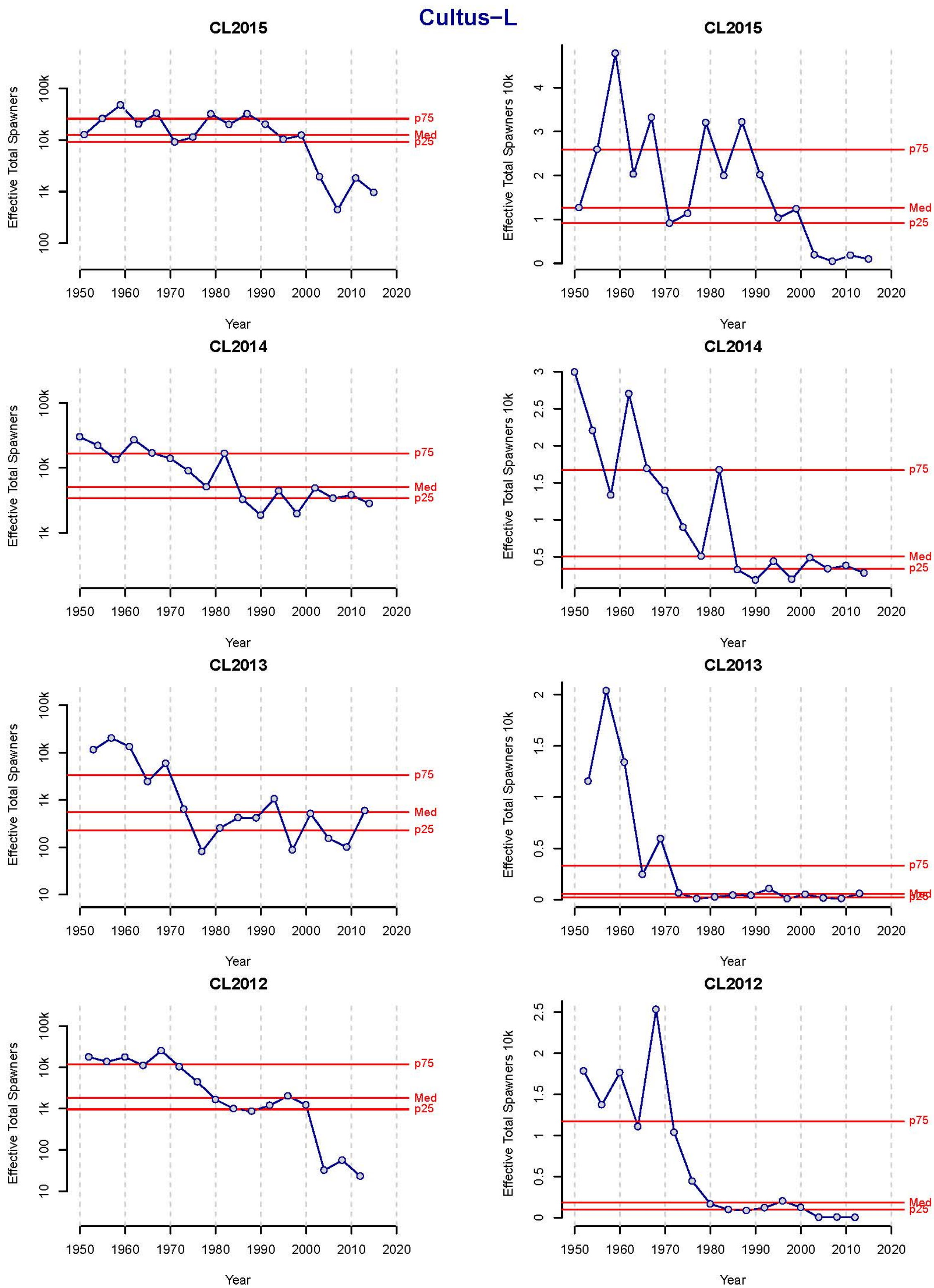


Figure A 12-5. Reference plots of spawner time series by cycle line for Cultus-L. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

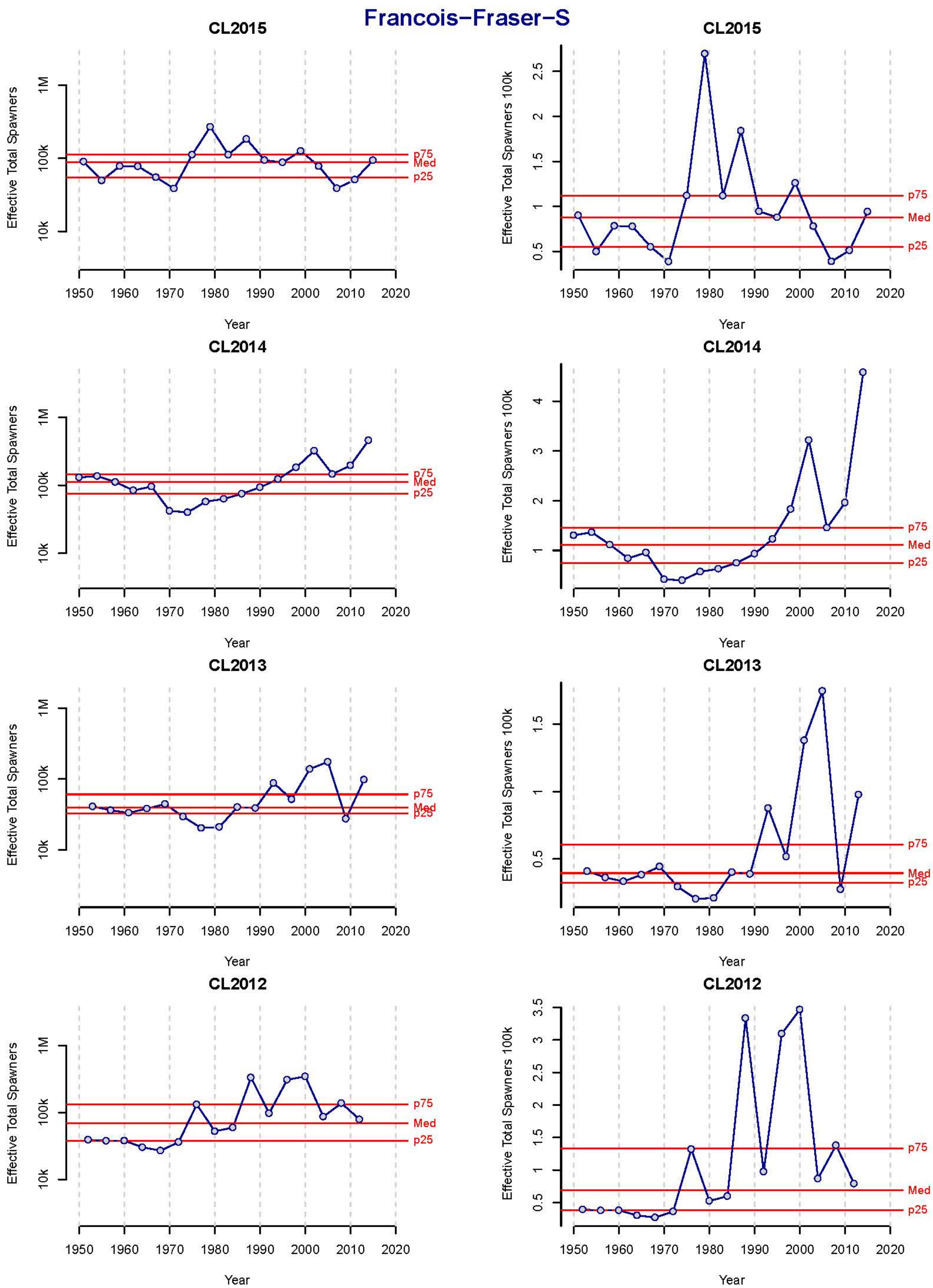


Figure A 12-6. Reference plots of spawner time series by cycle line for Francois- Fraser- S. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

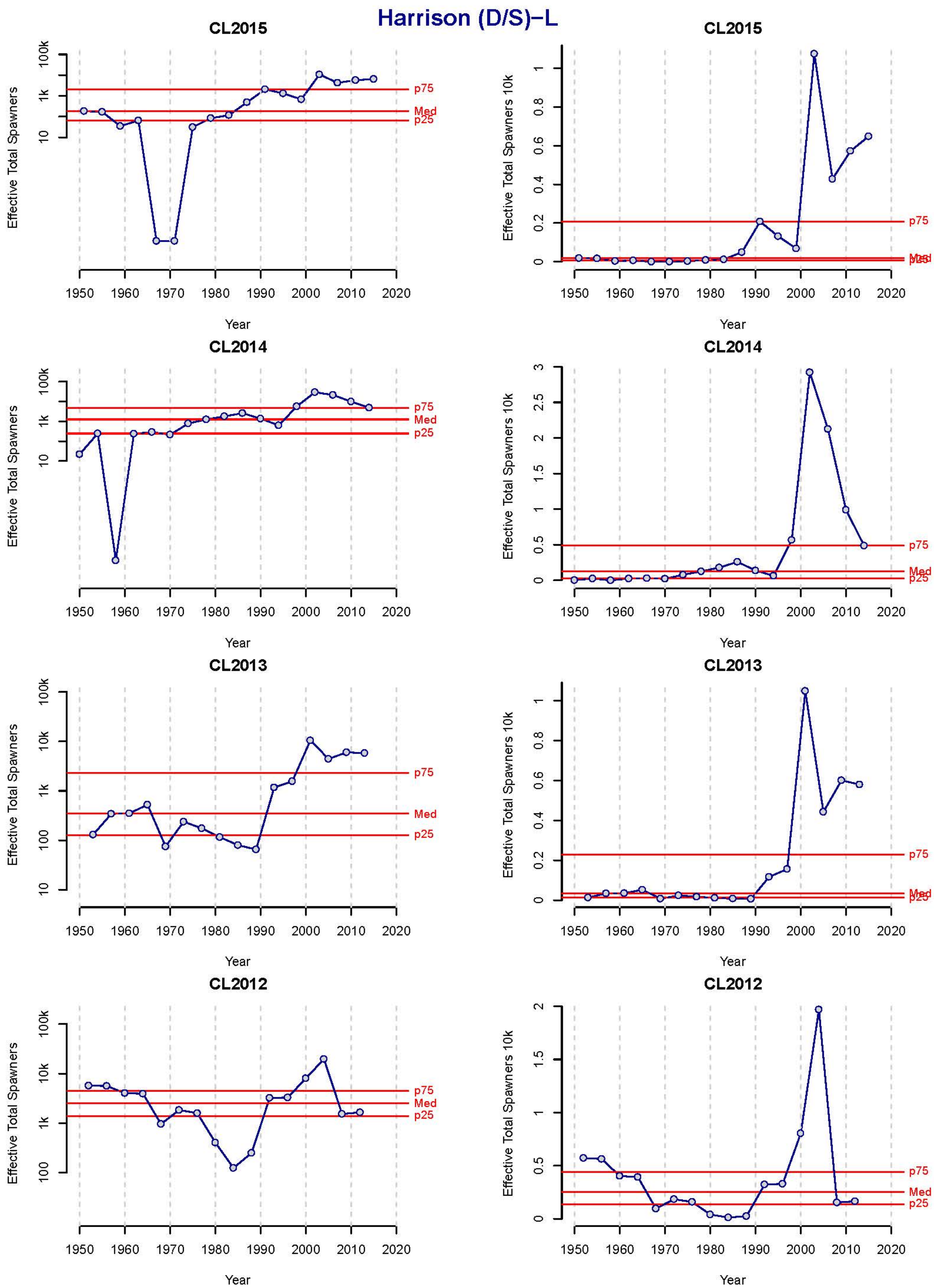


Figure A 12-7. Reference plots of spawner time series by cycle line for Harrison (D/S)-L. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

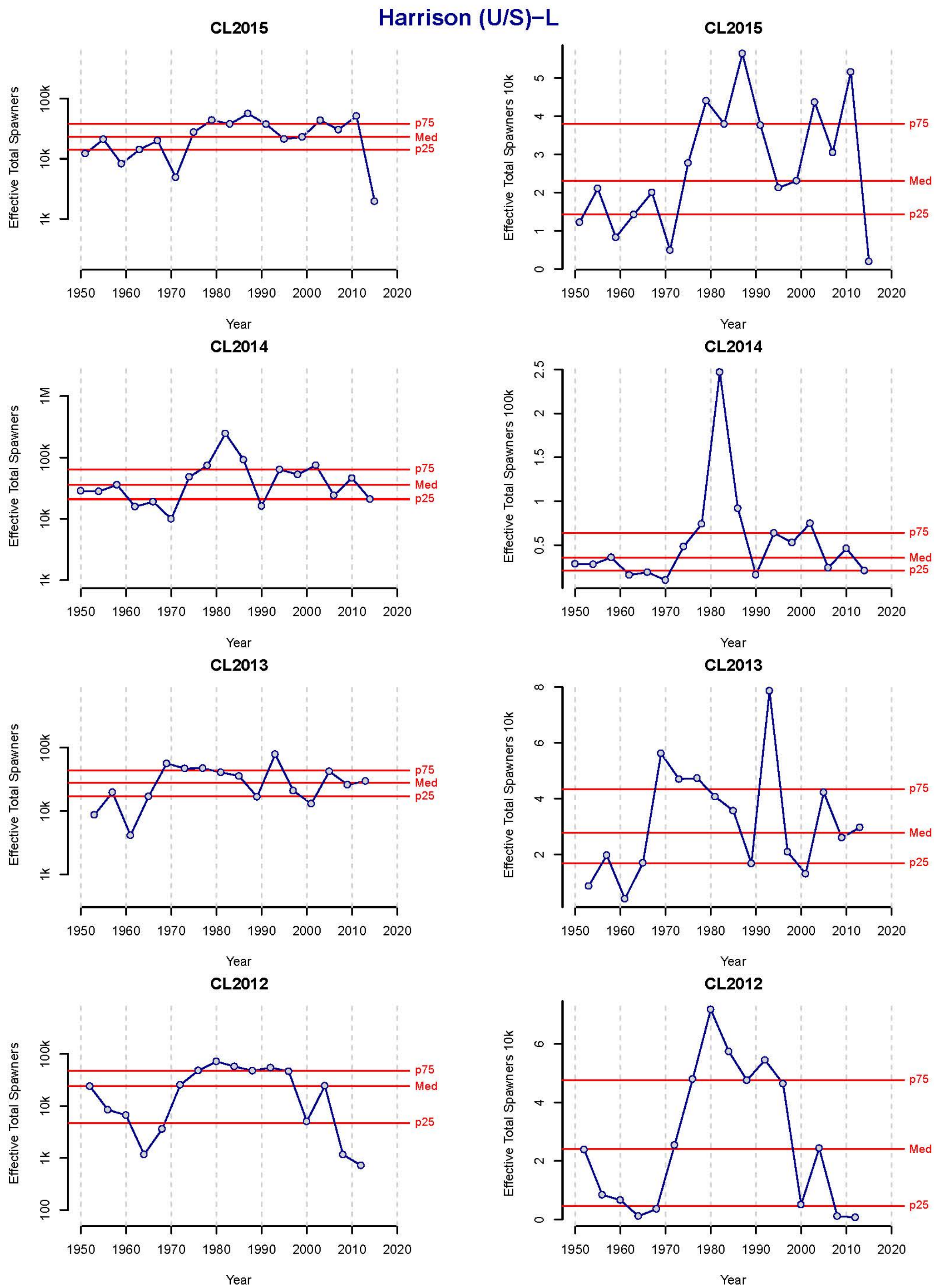


Figure A 12-8. Reference plots of spawner time series by cycle line for Harrison (U/S) L. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

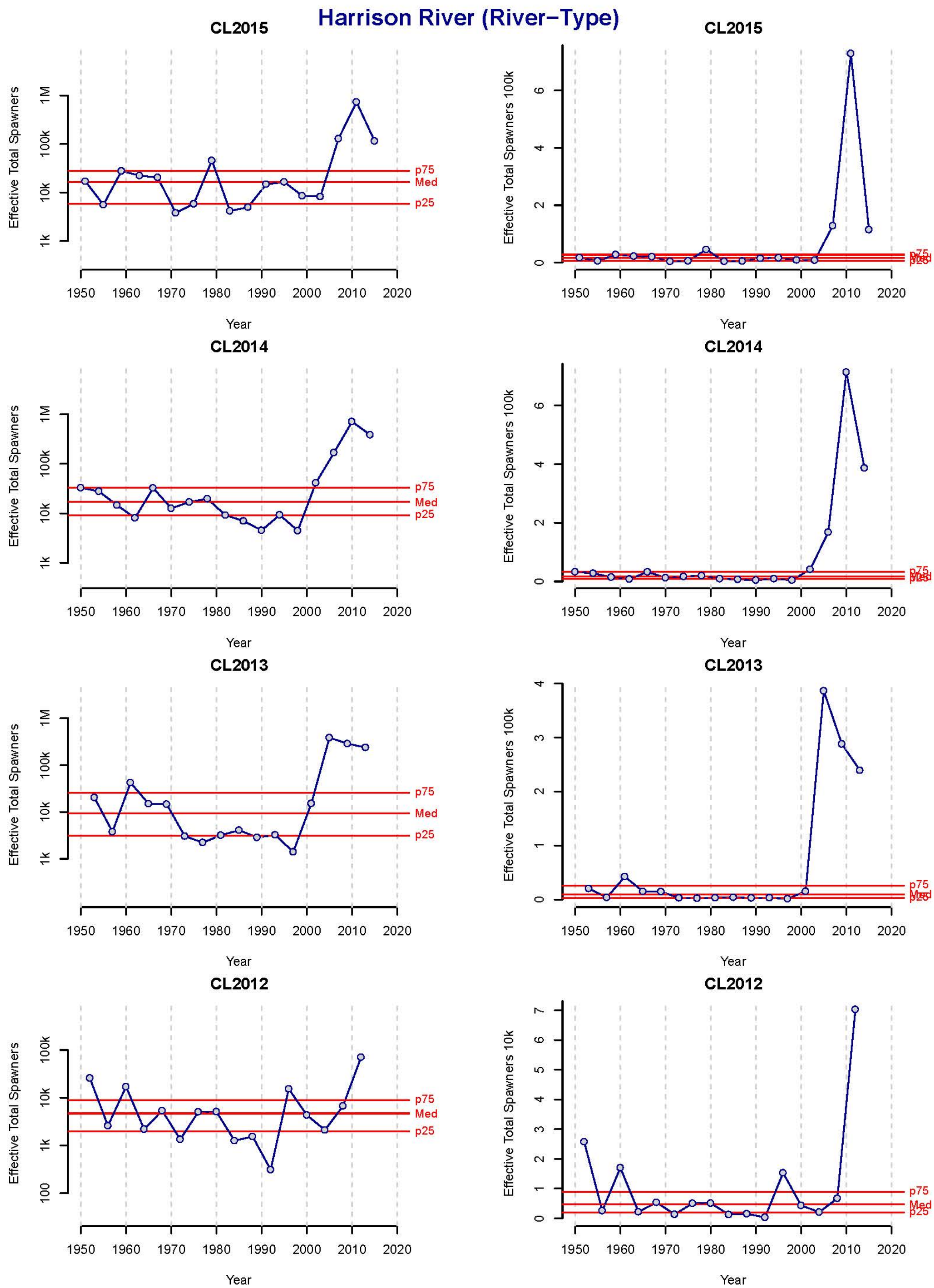


Figure A 12-9. Reference plots of spawner time series by cycle line for Harrison River (River-Type). These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

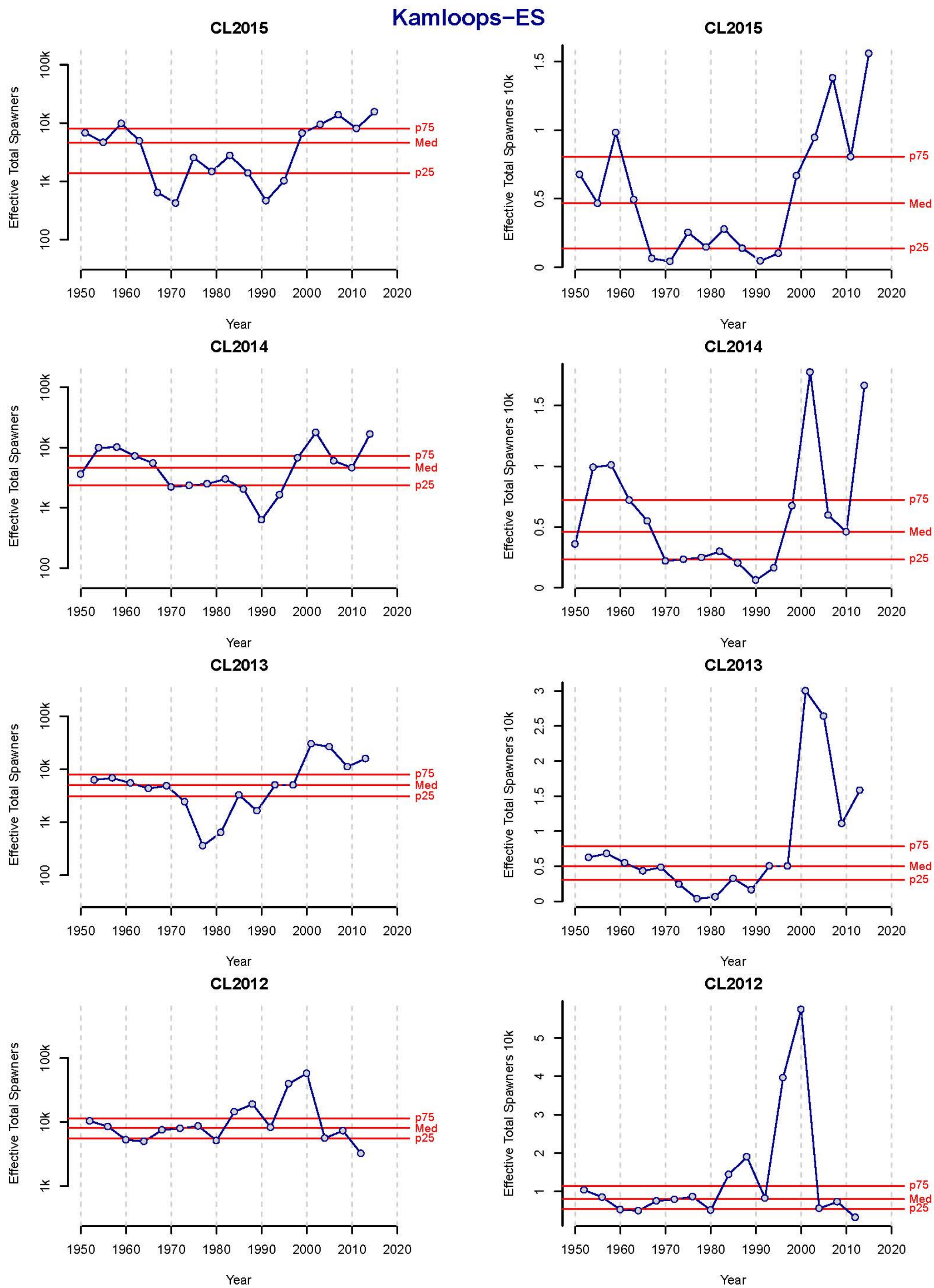


Figure A 12-10. Reference plots of spawner time series by cycle line for Kamloops-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

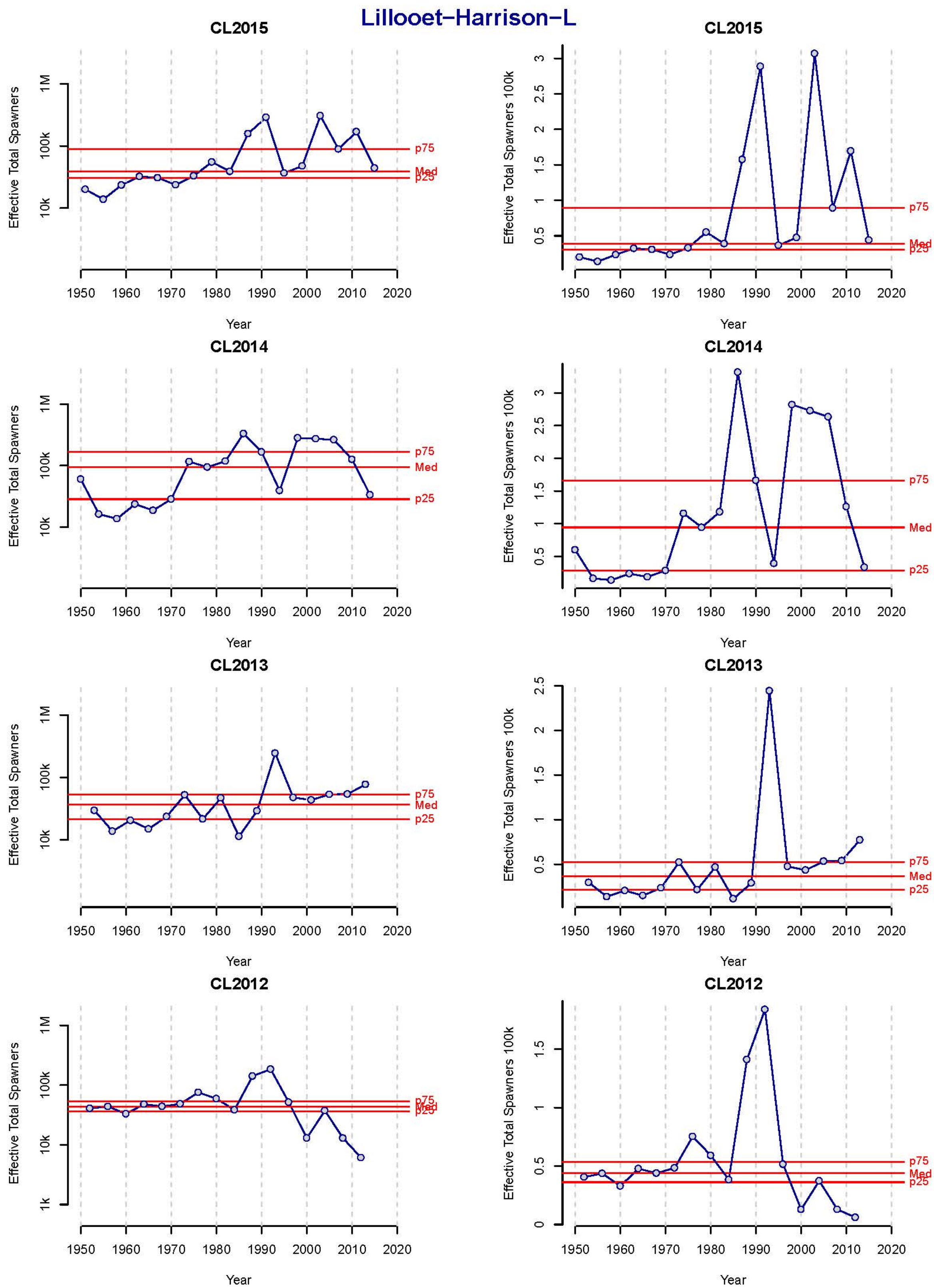


Figure A 12-11. Reference plots of spawner time series by cycle line for Lillooet-Harrison-L These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

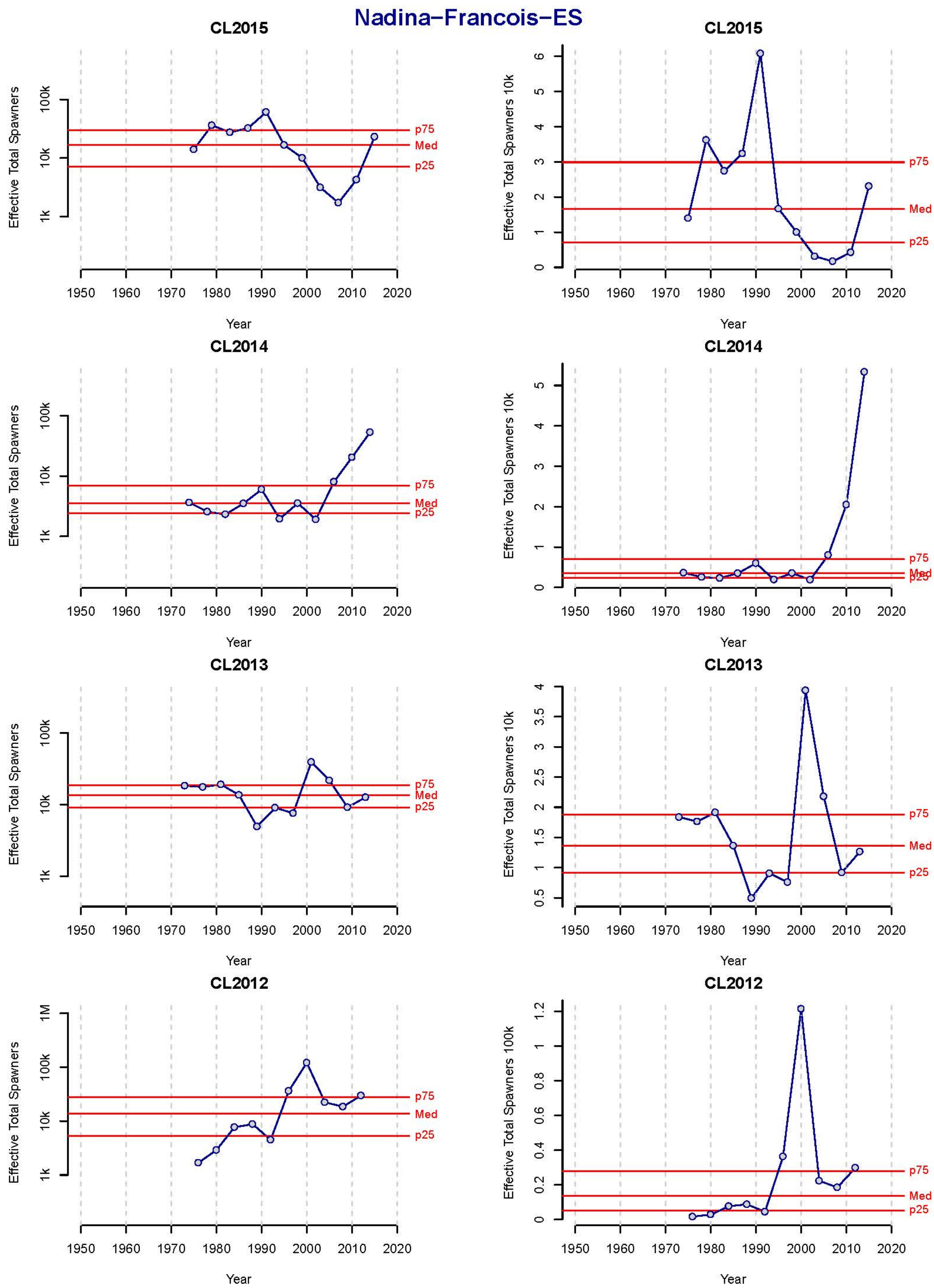


Figure A 12-12. Reference plots of spawner time series by cycle line for Nadia-Francois-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

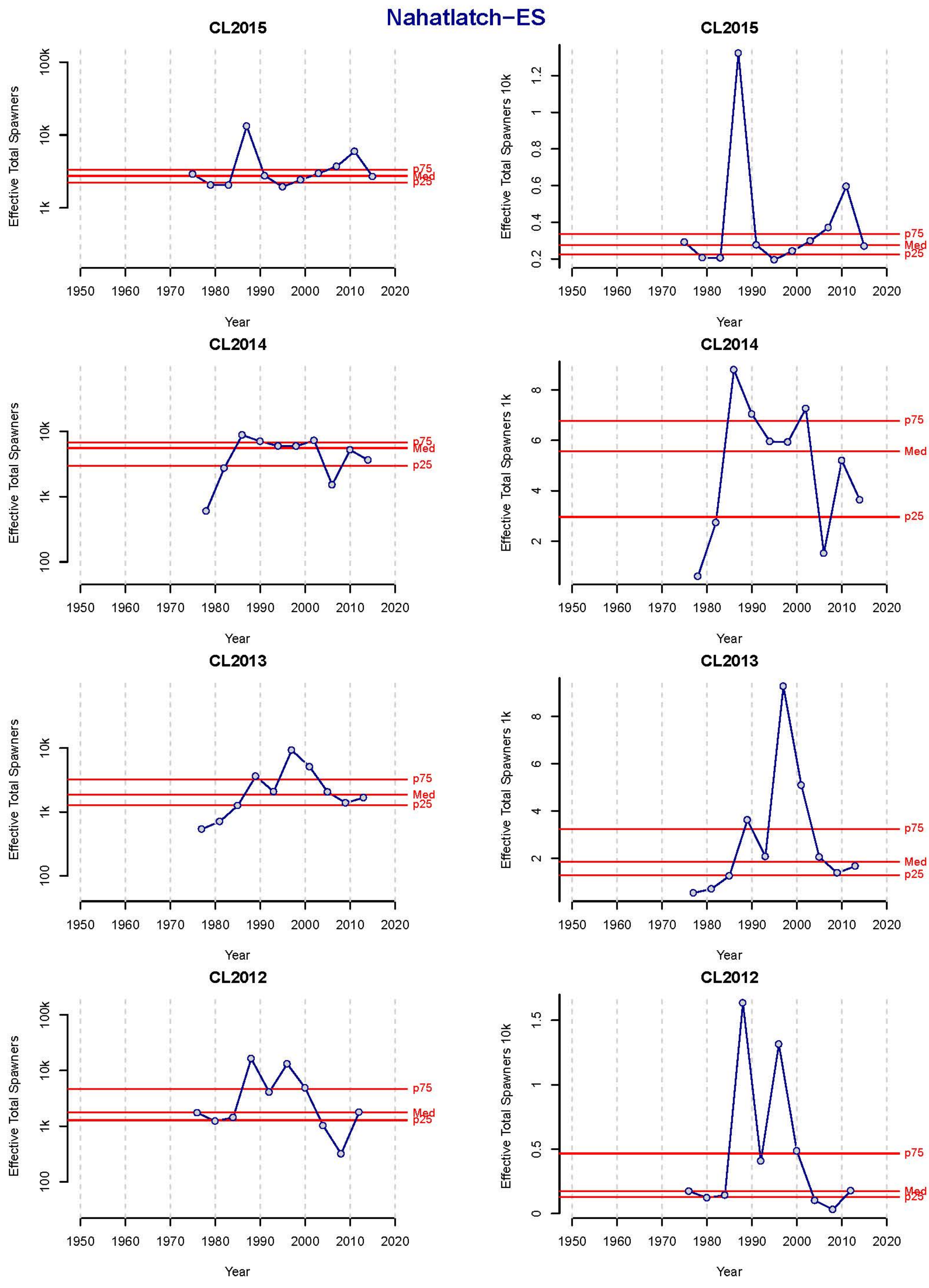


Figure A 12-13. Reference plots of spawner time series by cycle line for Nahatlatch-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

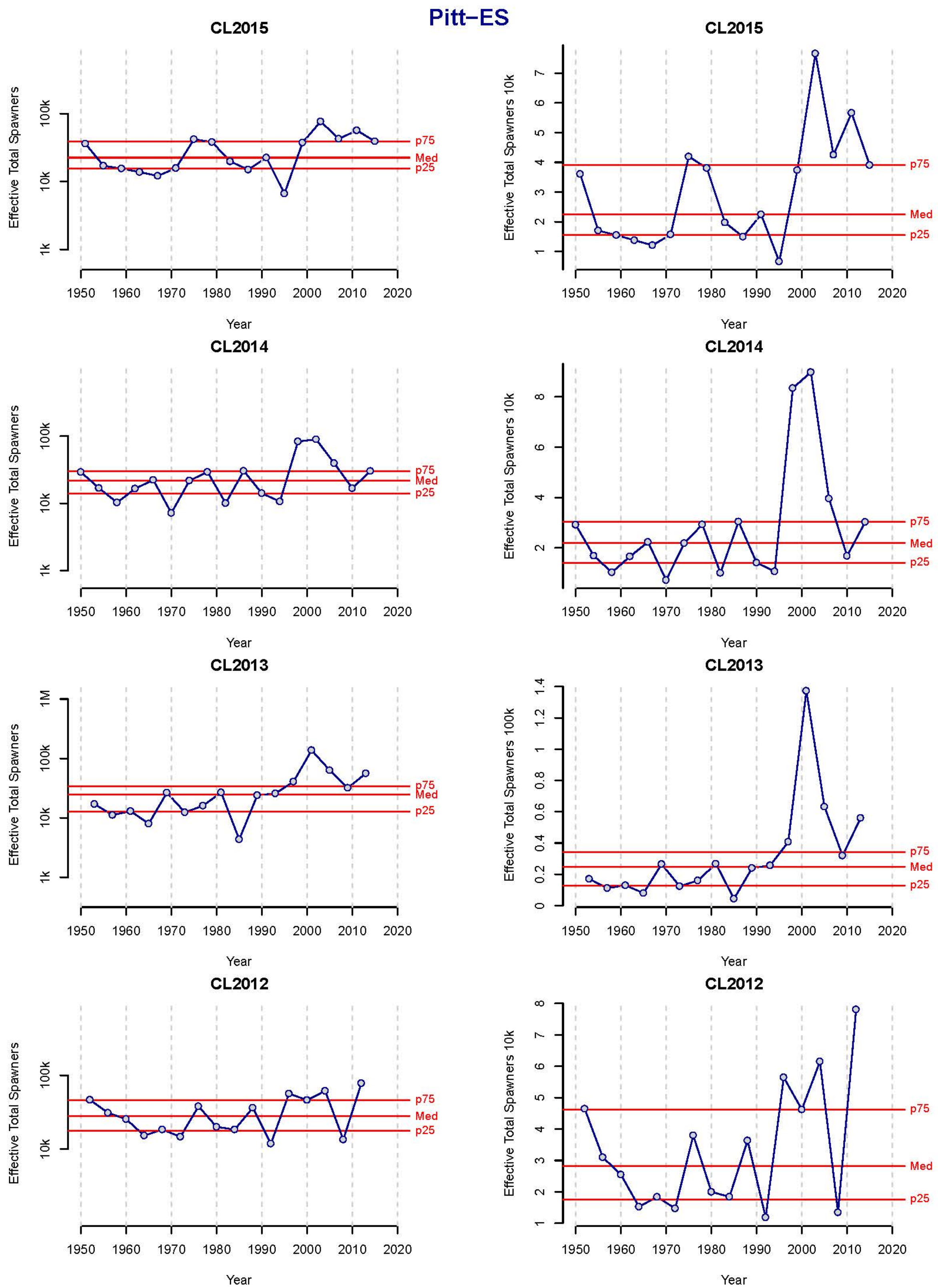


Figure A 12-14. Reference plots of spawner time series by cycle line for Pitt-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

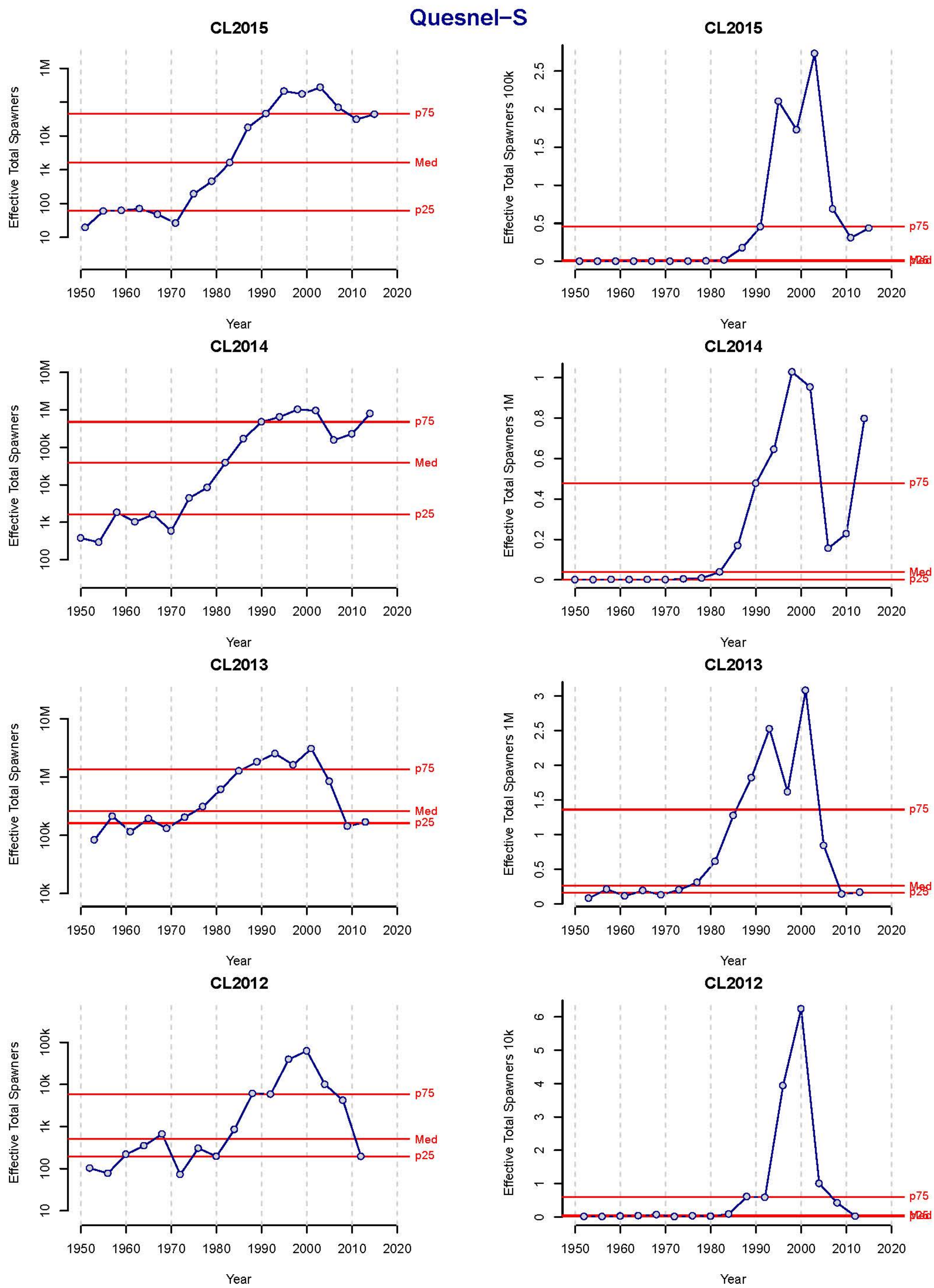


Figure A 12-15. Reference plots of spawner time series by cycle line for Quesnel-S. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

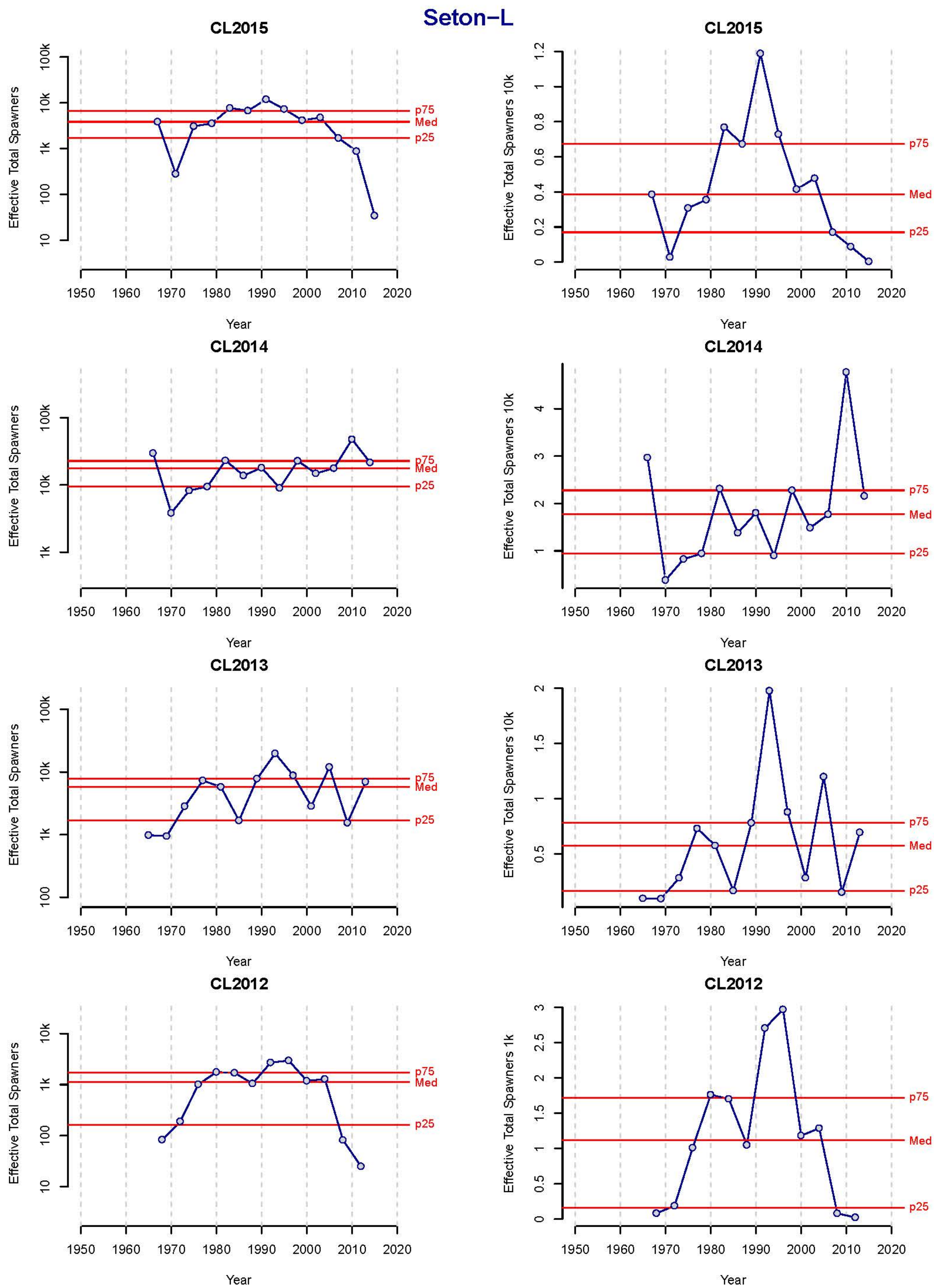


Figure A 12-16. Reference plots of spawner time series by cycle line for Seton-L. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

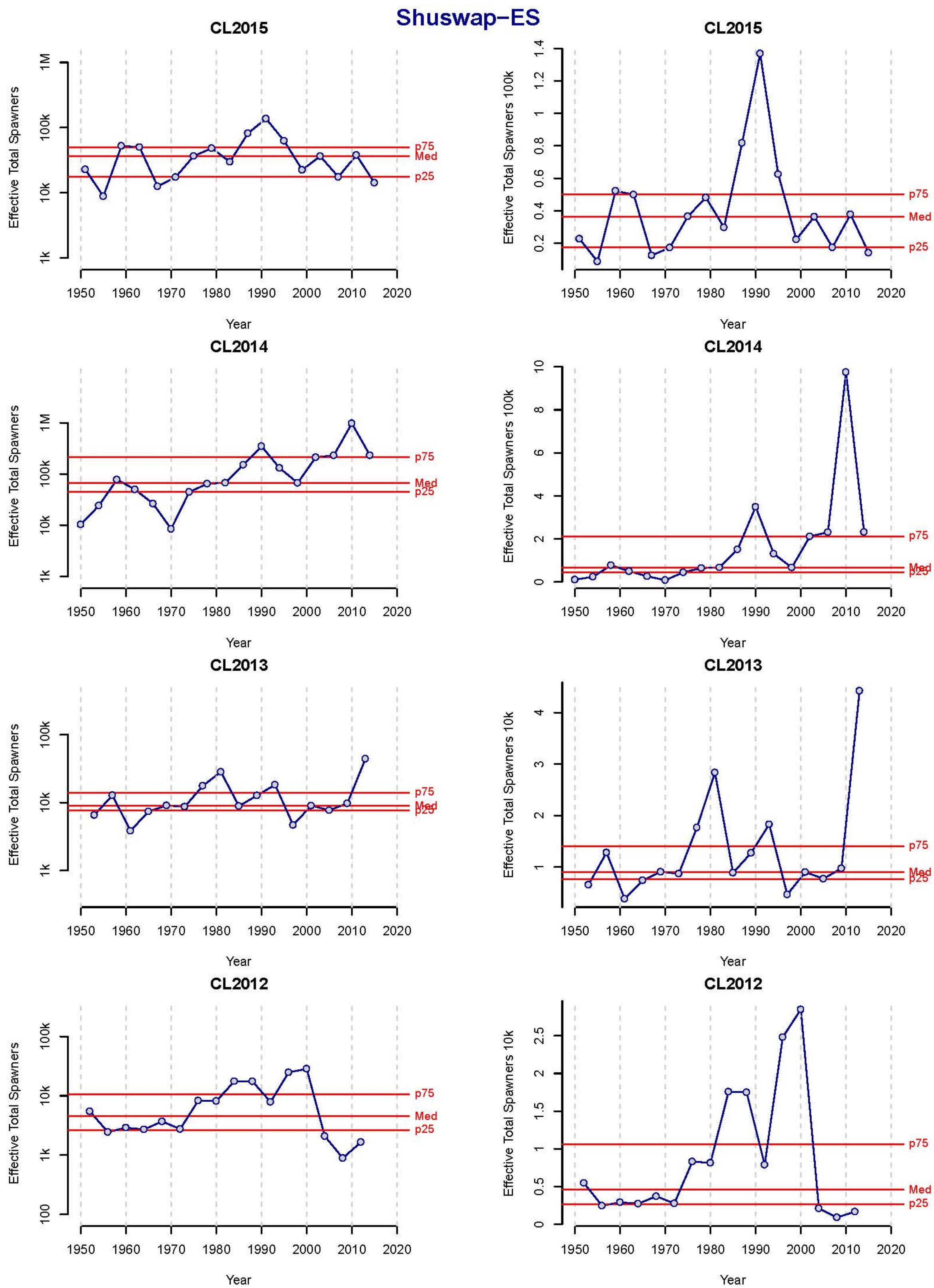


Figure A 12-17. Reference plots of spawner time series by cycle line for Shuswap- ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

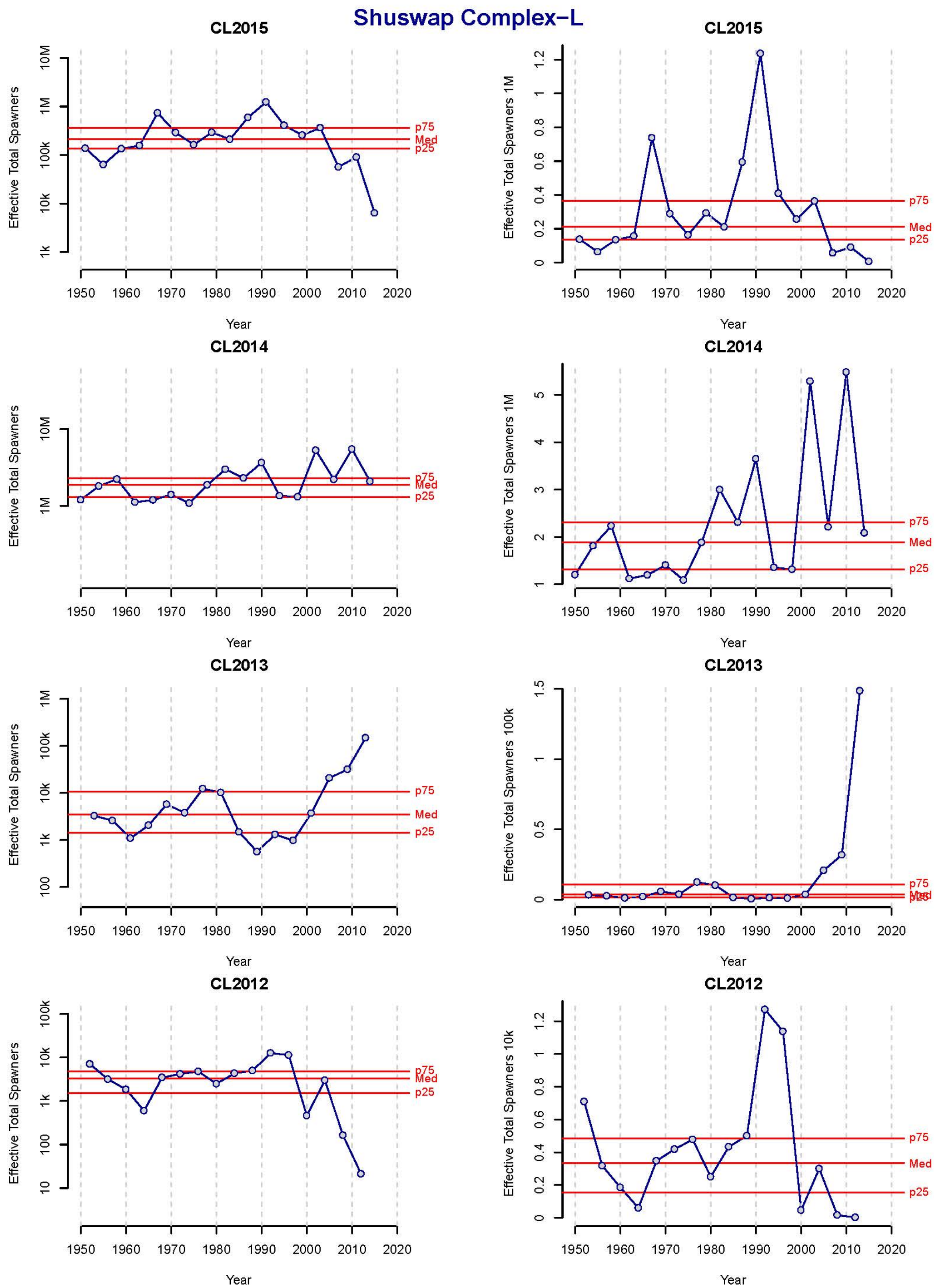


Figure A 12-18. Reference plots of spawner time series by cycle line for Shuswap Complex- L. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

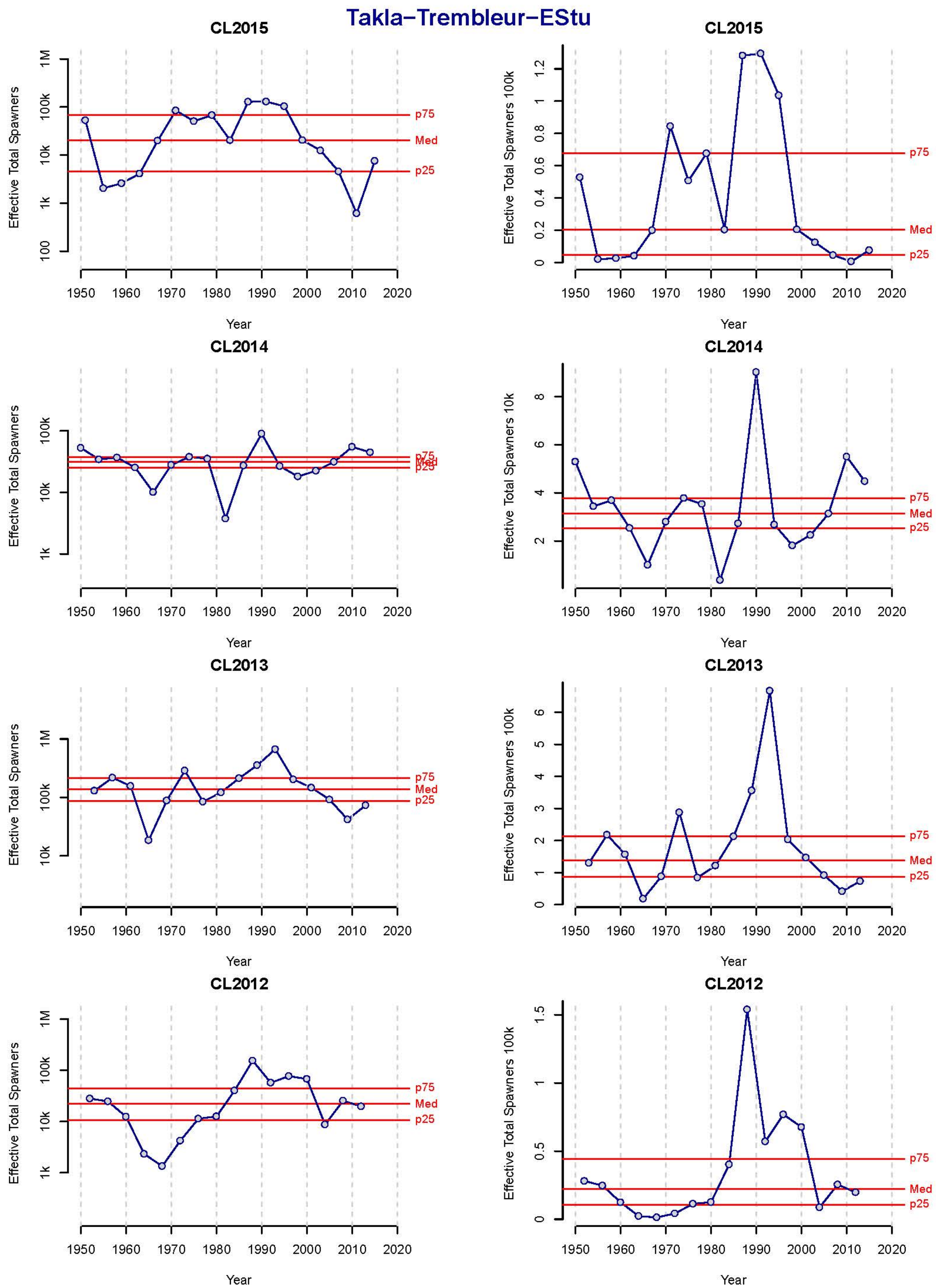


Figure A 12-19. Reference plots of spawner time series by cycle line for Takla- Trembleur-EStu. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

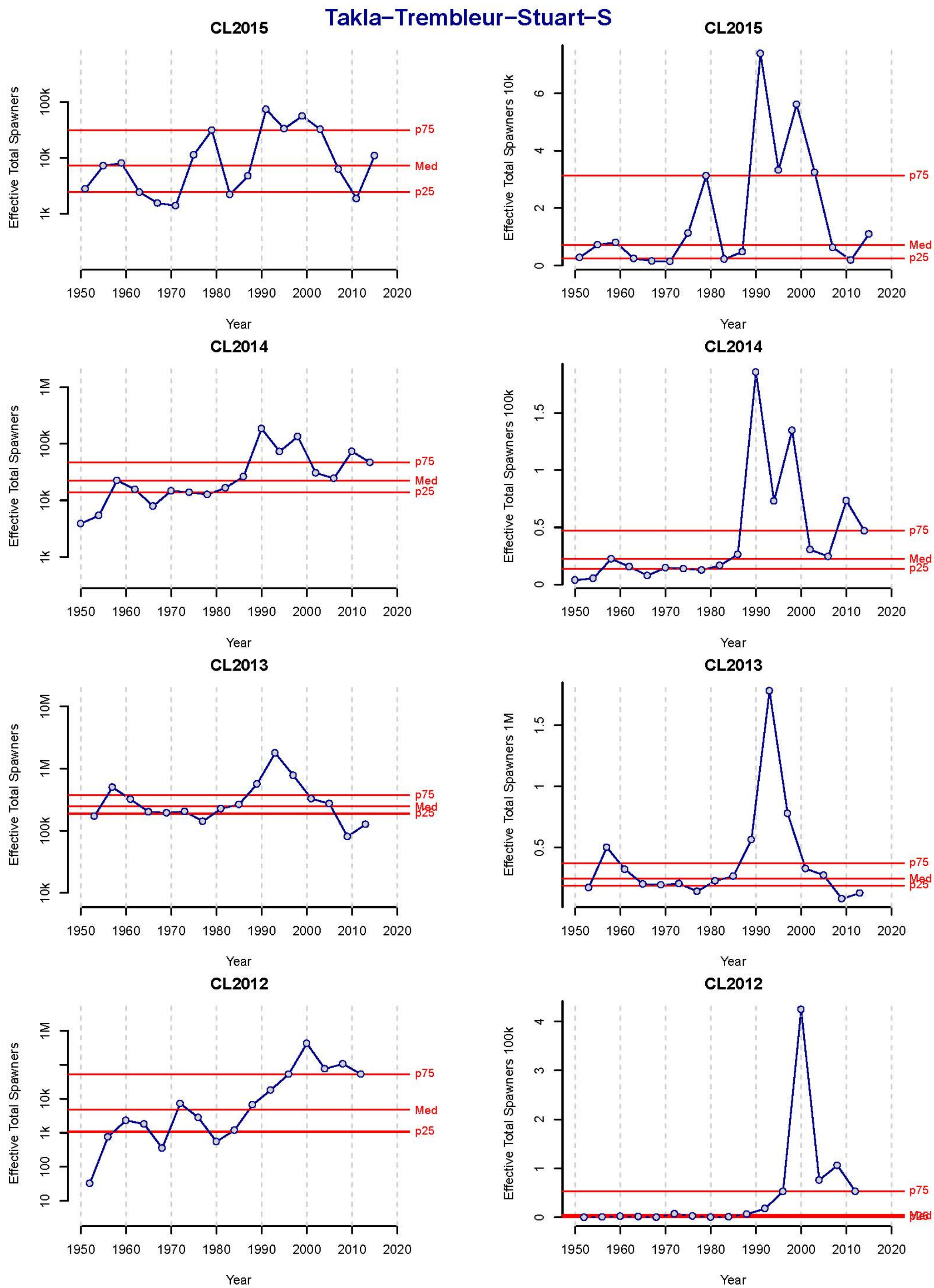


Figure A 12-20. Reference plots of spawner time series by cycle line for Takla- Trembleur- Stuart- S. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

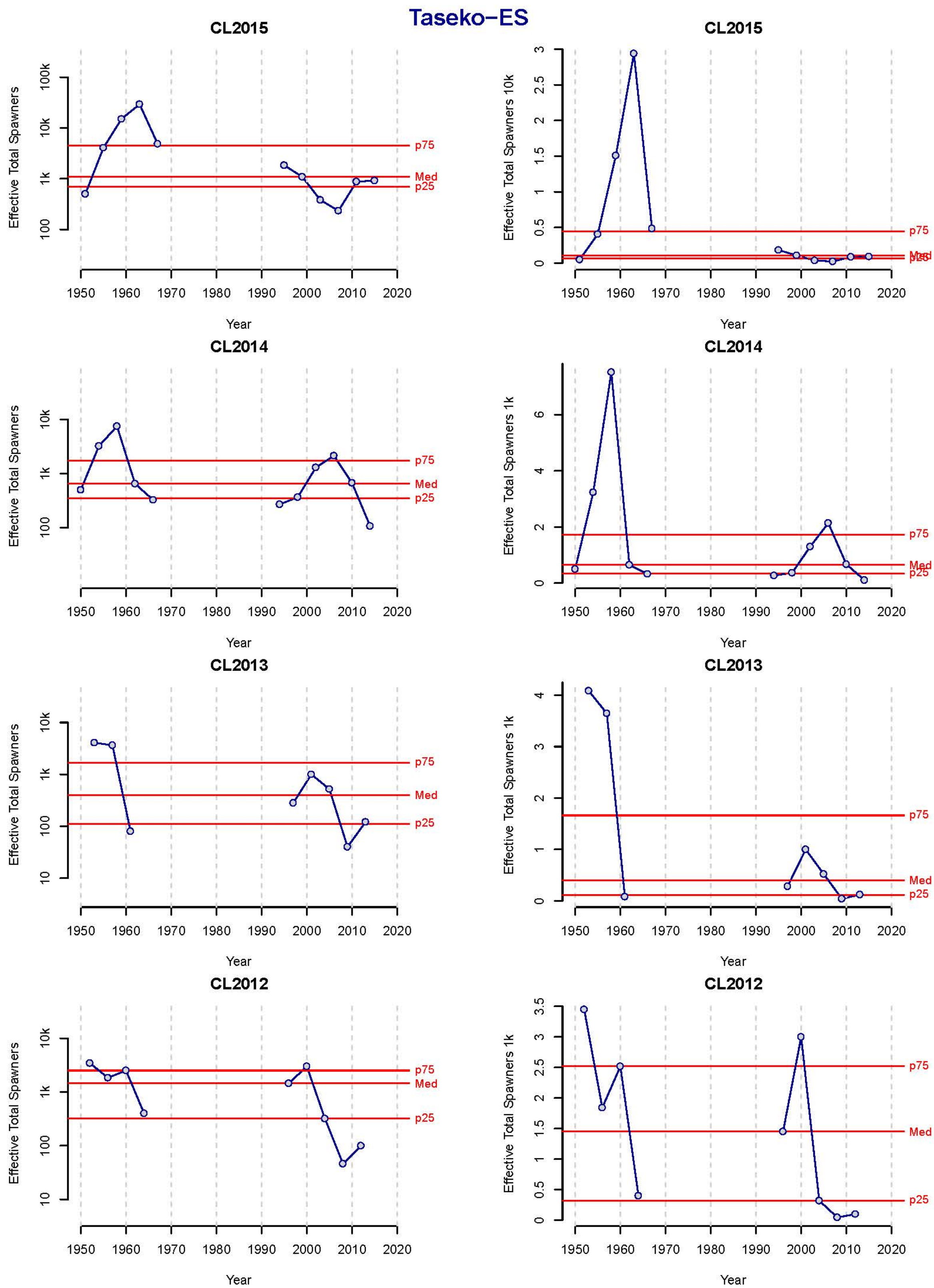


Figure A 12-21. Reference plots of spawner time series by cycle line for Taseko-ES. These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).

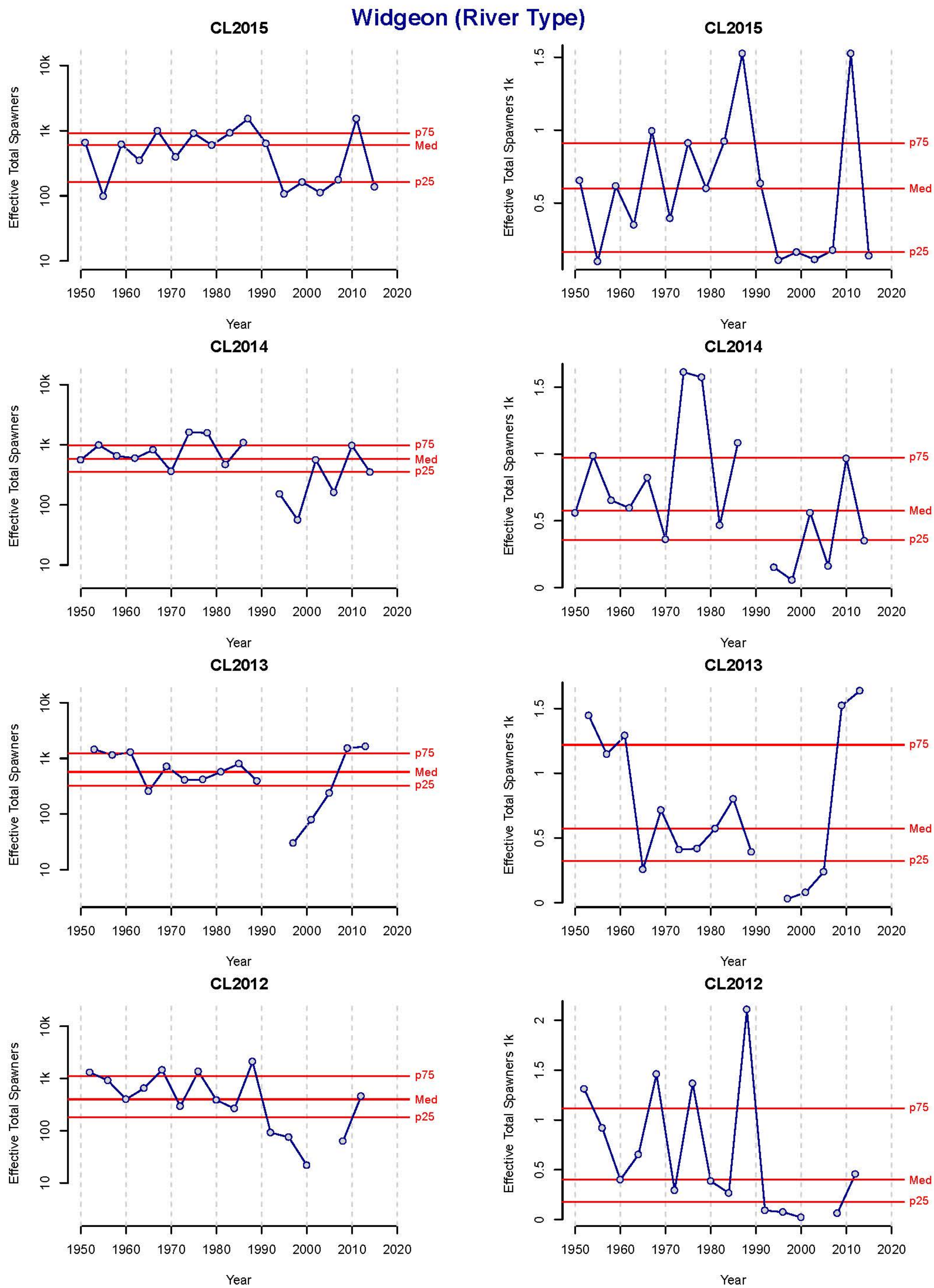


Figure A 12-22. Reference plots of spawner time series by cycle line for Widgeon (River Type). These are plots for effective total spawners split by cycle line (for each CU, 4 panels on a page) on log-scale; this includes the median , lower quartile (p25) and upper quartile (p75).