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Evaluation of interim harvest strategies for sablefish (*Anoplopoma fimbria*) in British Columbia, Canada for 2008/09

Évaluation des stratégies intérimaires de capture de la morue charbonnière (*Anoplopoma fimbria*) en Colombie-Britannique, au Canada, pour 2008-2009

S.P. Cox[2]
A.R. Kronlund[1]

[1] Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

[2] Canadian Sablefish Association
406-535 Howe Street
Vancouver, BC V6C 2Z4

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Abstract

This paper applies a management strategy evaluation (MSE) approach toward identifying an *interim* management procedure for setting sablefish (*Anoplopoma fimbria*) quotas in 2008/2009 and beyond. We employ the MSE methodology developed by Cox et al. (2008) to evaluate the likely performance of data-based and model-based management procedures under four simulation scenarios for sablefish stock dynamics. Conservation, catch variability, and catch performance are compared to four management objectives that were developed through consultations with industry stakeholders and managers. Our simulations indicate that 70-80% of the management procedures examined would likely fail to meet specified conservation objectives under some scenarios for sablefish population dynamics. These failures occurred despite the fact that most procedures rebuild the sablefish stock over 40 years. The remaining "admissible" management procedures show the capability to improve stock status within 3-7 years with 90% certainty even under the most pessimistic scenario for stock productivity and current status. TAC levels for 2008 under these admissible procedures range from 1,500 to 2,700 tonnes; however, most will decrease TACs by up to 50% between 2009 and 2014 if the current stock decline continues. The simulated time required to maintain the spawning stock above 2007 levels with 90% certainty ranged from 4 to 7 years when the 2008 TACs were combined with the highest performing data-based management procedure. Advice in this paper is subject to several limitations based on our current representation of sablefish population dynamics in the operating model scenarios. High discard rates in all fisheries are of greatest concern at the moment because (*i*) our operating model estimates of stock status would be optimistic and (*ii*) failing to account for discard mortality in future projections means that actual recovery rates will be slower.

Résumé

Dans ce document, on applique une approche d'évaluation de stratégie de gestion (ESG) en vue d'établir une procédure de gestion *intérimaire* pour déterminer les quotas de pêche de la morue charbonnière pour 2008-2009 et par la suite. Nous utilisons la méthodologie ESG mise au point par Cox et al. (2008) afin d'évaluer le rendement probable des procédures de gestion reposant sur les données et les modèles, avec quatre scénarios de simulation pour la dynamique des stocks de morue charbonnière. La conservation, la variabilité de la capture et le rendement de la capture sont comparés à quatre objectifs de gestion qui ont été mis au point suivant des consultations avec les parties intéressées de l'industrie et les gestionnaires. Nos simulations indiquent que 70 à 80 p. 100 des procédures de gestion étudiées échoueraient probablement à satisfaire aux objectifs précisés en matière de conservation pour certains scénarios de la dynamique des populations de morue charbonnière. On a eu ces échecs malgré le fait que la plupart des procédures reconstituent les stocks sur une période de 40 ans. Le reste des procédures de gestion « admissibles » indiquent qu'il est possible d'améliorer l'état des stocks dans un délai de 3 à 7 ans avec 90 p. 100 de certitude, même avec le scénario le plus pessimiste quant à la productivité des stocks et la situation actuelle. Selon ces procédures admissibles, les niveaux TAC pour 2008 varient entre 1 500 et 2 700 tonnes; toutefois, la plupart diminueront les TAC d'un taux pouvant aller jusqu'à 50 p. 100 entre 2009 et 2014 si la baisse actuelle des stocks se poursuit. Selon la simulation, le temps nécessaire pour maintenir le stock reproducteur supérieur aux niveaux de 2007 avec 90 p. 100 de certitude variait entre 4 et 7 ans lorsque les TAC étaient combinés avec la procédure de gestion reposant sur les données procurant le meilleur rendement. Les avis donnés dans ce document font l'objet de plusieurs limitations selon notre représentation actuelle de la dynamique des populations de morue charbonnière pour les scénarios de modèle d'exploitation. Le taux élevé de rejet pour toutes les activités de pêche est actuellement des plus préoccupants, car (*i*) selon notre modèle d'exploitation, les estimations de l'état des stocks seraient optimistes et (*ii*) si l'on ne tient pas compte du taux de mortalité dans les projections futures, le taux réel de reconstitution des stocks sera plus lent.

1 Introduction

1.1 Background

Canadian national fisheries policy prescribes that harvest strategies comply with the Precautionary Approach to Capture Fisheries (DFO 2006, FAO 1995). In addition, an emerging fisheries management framework (March 2007, http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/overview-cadre-eng.htm) endorsed the national harvest policy and outlined expectations for communicating the risk of resource decline under proposed management actions. The framework also identifies the need to involve stakeholders in the development of fishery objectives consistent with achieving the requirements of various eco-certification programs.

At the time sablefish (*Anoplopoma fimbria*) was last assessed in 2004 (Haist et al. 2005), stock abundance indices had increased relative to historically low levels observed in 2000 and 2001 (Appendix A). Since 2003, declines in these indices suggest that the stock may be approaching conditions experienced in 2001 to 2002 when a quota reduction from 4,000 t to 2,450 t was implemented (Fisheries and Oceans Canada 2002). Subsequent to this reduction, the quota was increased to 3,000 t for the directed sablefish 2003/2004 fishing year (Aug 1-Jul 31) and reached 4,600 t for the 2005/2006 fishing year as trap fishery and survey catch rates increased. As a result of pre-season consultation with the Sablefish Advisory Committee, the quota for the 2006/07 fishing year was reduced to 3,900 t and was similarly reduced to 3,300 t for the 2007/08 fishing year mainly as a result of declining survey indices of abundance and tagging estimates of exploitable biomass. Since 2006, the Science Committee under the DFO-CSA Joint Project Agreement has been developing a management strategy evaluation (MSE) approach aimed at identifying a consistent procedure for setting annual quotas. This process recently culminated in a methodology paper by Cox et al. (2008) that was endorsed by the Pacific Science Advise Review Committee.

This paper applies the MSE approach toward identifying an *interim* procedure for setting sablefish quotas in 2008 and beyond. Our presentation is organised into three main sections describing (*i*) the MSE approach, operating models, and candidate management procedures, (*ii*) detailed results comparing performance of alternative procedures against objectives, and (*iii*) management advice including the specific effects of alternative 2008 TACs on conservation and future yield. We show that 70-80% of procedures examined fail to meet specified conservation objectives. However, of the "admissible" management procedures, several show the capability to halt the current stock decline within 3-7 years with 90% certainty even under the most pessimistic scenario for the stock. TAC levels for 2008 under these admissible procedures range from 1,500 to 2,700 tonnes, however, most will decrease TACs rapidly between 2009 and 2014 if the current stock decline continues.

1.2 Fishery objectives

Recent consultations between sablefish industry stakeholders and fishery managers, as well as scientific review processes, have helped to establish two primary conservation objectives for B.C. sablefish fishery. In particular, fishery stakeholders developed an initial conservation objective to prevent further decline in the B.C. sablefish stock below the 2007 level of spawning biomass. This objective was subsequently refined by industry stakeholders and DFO managers to: increase the B.C. spawning stock above the 2007 level within 10 years with 90% certainty.

The second conservation objective, which was originally developed as a placeholder during the MSE process, was to maintain the B.C. spawning stock biomass above 20% of the unfished level. A conservation reference point of 20% of unfished spawning biomass was recently supported in the PSARC review of Cox et al. (2008). The difficulty with this particular objective, however, is that spawning biomass depletion is less than 20% of unfished when some scenario projections begin (e.g., scenario S1 below). Therefore, we developed an operational objective to rebuild spawning biomass above 20% of unfished within 1.5 sablefish generations.

Simulation analyses were performed to evaluate management procedure performance against the following operational objectives:

1. Rebuild B.C. spawning stock biomass to at least 20% of unfished within 1.5 generations (22.5 years assuming $M = 0.08$ and 50% maturity at age-5) with a minimum of 90% certainty;
2. Rebuild B.C. spawning stock biomass above the 2007 level within 10 years or less with a minimum of 90% certainty;
3. Maintain less than 20 % interannual variation in catch;
4. Maximize the median average annual catch over 1-10 years subject to the constraints imposed by Objectives 1-3.

Section 3.2 below provides a specific approach to using these objectives for choosing a management procedure.

1.3 Management strategy evaluation

Fishery management requested that evaluation of candidate management procedures against the above objectives utilize the management strategy evaluation (MSE) approach for sablefish developed in Cox et al. (2008). The methodology is a simulation-based framework for comparing the likely future consequences of applying candidate management procedures to alternative scenarios regarding the fish stock (Punt et al. 2001; Sainsbury et al. 2000). Scenarios represent structural hypotheses about the fish stock and/or fishery dynamics that are not currently resolved by the available data or those that may never be resolved. Development and evaluation of management procedures using a closed-loop simulation approach (Walters 1986, de la Mare 1986, 1996, 1998) addresses the requirements of the precautionary approach to fisheries management as well as DFO's decision-making framework. In particular, the approach: (*i*) considers alternative approaches for identifying stock status; (*ii*) evaluates alternative forms of decision rules that specify how harvest levels should be adjusted based on differences between stock status and operational targets; and (*iii*) demonstrates, via computer simulation, whether whole management procedures are likely to meet fishery management objectives.

At this early stage of sablefish MSE development, a specific management procedure has not been formally adopted by fishery managers or endorsed by the sablefish industry. Thus, we tested candidate *interim* procedures to illustrate their likely performance against various scenarios for the sablefish stock. Two specific modifications to procedures suggested through consultations with industry and managers were evaluated in addition to a subset of procedures examined by Cox et al. (2008). For the first modification, we introduced new procedures that set the 2008 TAC to either 1,500, 1,900, 2,300 or 2,700 tonnes, and then applied a particular data-based or catch-age model-based procedure thereafter. The second modification eliminated the necessity to constrain TAC changes between years to 15% or less during the first five years of management procedure implementation. However, as noted above, we retained the objective to limit interannual catch variability to less than 20% (i.e., it is now a lower priority objective than conservation rather than an absolute necessity). Note that we include results from the original constrained procedures for comparison with newly created alternatives.

1.4 Operating model

Candidate management procedures for sablefish were tested against scenarios S1 through S4 of the age-structured population dynamics operating model specified by Cox et al. (2008). Changes and updates to the management strategy evaluation between this paper and Cox et al. (2008) are given in Table 1. The main update is that the scenarios were parameterized by fitting the operating model to landings, standardized survey, trap fishery, and catch-age data updated to 2007. Scenarios S1-S4 are defined by combinations of stock productivity and spawning stock depletion as of 2007, namely: S1 - low productivity/low depletion; S2 - low productivity/moderate depletion; S3 - high productivity/moderate depletion; and S4 - high productivity/optimal depletion (Table 2).

It is important to note that the four operating model scenarios are not easily distinguished from the historical data based on commonly accepted statistical tests such as Akaike's information criterion. Such similarity implies that we should simply use the average results across scenarios to provide advice on an interim management procedure for sablefish. However, there exist potentially serious conservation and economic consequences should the future of sablefish turn out like scenario S1. Therefore, we judged conservation performance mainly against scenario S1 when conducting the evaluation.

1.5 Candidate interim management procedures

Cox et al. (2008) compared two general types of management procedure that both incorporated variable harvest rate control rules as required by DFO policy (2006). The two types are defined as:

1. Data-based (DB) procedures that set annual TACs by averaging the preceding year's total catch with a multiple of the three-year running average of fishery-independent surveys, (Table 3) and;
2. Model-based procedures that set annual catch limits using constant exploitation rate policies and estimates of stock biomass from catch-age (CA) models (Table 3).

We do not consider the most aggressive procedures evaluated by Cox et al. (2008) in light of (*i*) the requirement that the removal rate reference not exceed the removal rate at maximum sustainable yield (DFO 2006), and (*ii*) the objective to prevent decline of the spawning biomass below the 2007 level. These requirements eliminated model-based procedures with $U^{ref} = 0.10$ and data-based procedures with $\lambda_2 = \{210, 240\}$ based on their relatively poor conservation performance in Cox et al. (2008). It is possible, however, that an appropriately tuned catch-age procedure with $U^{ref} = 0.08$ might be adequate, so we retained these procedures for this evaluation. Note also that, in the simulation projections, allocation of catch among trap, longline, trawl, and survey gear types was done using the catch proportions from 2007.

1.5.1 Data-based procedures

For data-based procedures, we examined survey multipliers of $\lambda_2 = \{120, 150, 180\}$ with lower limit and upper stock reference values of I_{low} = 4 kg/trap and I_{high} = 15 kg/trap, respectively (Table 4). As described in Cox et al. (2008), the standardized survey is used for data-based procedures. Alternative tunings of the data-based procedure were also evaluated with lower limit I_{low} = 6 kg/trap and upper I_{high} = 18 kg/trap reference points to determine whether such procedures were capable of providing better catch-conservation trade-off performance. Presumably, increasing the lower limit reference point would increase the probability of avoiding high-risk situations associated with low stock biomass.

Most procedures set the smoothing parameter $\lambda_1 = 0.5$, however, in an attempt to evaluate procedures that allow more rapid TAC changes (increases or decreases) in response to changes in the survey average, we investigated selected tunings with $\lambda_1 = 0.2$.

Combining the above data-based configurations results in 3 general data-based procedure classes. For example, the data-based procedures with $\lambda_2 = 150$ can be grouped using the following notation (Table 4):

1. DB_{150} - a variable harvest rate data-based procedure as defined and evaluated by Cox et al. (2008);
2. $DB_{150,\,1900t}$ - identical to (1) above except that the TAC in 2008 is set to 1,900 t, or any other desired *catch* value;
3. $DB_{150,\,15\%}$ - change in catch is limited to a maximum of 15% of the previous year's catch for the first 5 years only. This strategy represents a hard constraint on changes in quotas that overrides management procedure recommendations. Such a constraint implies that slow reduction in quotas is a higher priority objective than any other, including conservation of the stock.

Each of these DB_{150} variants can then be combined with particular choices of λ_1 or harvest rule reference points I_{low} and I_{high} to better meet specific objectives provided by stakeholders and managers. Data-based combinations from Table 4 result in a total of 28 candidate procedures.

1.5.2 Catch-age procedures

The CA model-based procedures were evaluated at reference removal rates U^{ref}={0.04, 0.06, 0.08} (Table 4). Lower limit reference and upper stock reference limits of $D_{low} = 0.25$ and $D_{low} = 1.0$ were developed specifically in reference to 1992 spawning biomass; that is, when estimated biomass is at the 1992 level, the above U^{ref} values are used and when estimated spawning biomass is 25% of the 1992 level, the removal rate is zero (Table 3). The risk adjustment Q = 0.40 seemed to have a minor effect on the results of Cox et al. (2008) and was omitted from model-based procedures evaluated here.

Combinations of CA model-based procedures fall into two general classes. For example, catch-age procedures with $U^{ref} = 0.06$ can be grouped using the following notation (Table 4):

1. $CA_{0.06,\ 1900t}$ - a variable harvest rate CA model-based procedure with $U^{ref} = 0.06$ and 2008 TAC set to 1900 t, or any other desired *catch* value;
2. $CA_{0.06,\ 15\%}$ - change in catch is limited to a maximum of 15% of the previous year's catch for the first 5 years only. As for the data-based procedures, this strategy imposes slow reduction in quotas as a higher priority objective than conservation.

Catch-age combinations from Table 4 result in a total of 15 candidate procedures.

1.6 Performance measures

Quantitative evaluation of management procedure performance requires that fishery objectives specify the following five main components: (*i*) a performance statistic value or range of acceptable values, (*ii*) a method of calculating performance statistics from simulation output, (*iii*) a specific time point or time-period over which to compute the statistics, (*iv*) an acceptable probability that performance occurs within the target range, and (*v*) a scheme for weighting the results arising from different operating model scenarios. The major objectives categories we consider include catch, inter-annual stability of catch, and conservation, although each of these may have several sub-categories and performance statistics. For example, a fishery manager may wish to achieve a target stock size such as B_{MSY} with 50% certainty, but place a more stringent requirement (e.g., 90% probability) on staying above a lower limit reference point such as $B_{20\%}$. Performance statistics and calculation methods are described in Table 5. Although each statistic may be computed over an arbitrary time period (i.e., t_1 - t_2), we provide 1 – 5, 6 – 10, 11 – 20, and 21 – 40 year summaries to reflect short-, medium-, and long-term planning horizons. Performance statistics are summarized across 100 simulation replicates and, where appropriate, we use medians of the above statistics to reduce the effects of extreme values.

We developed two new performance statistics to evaluate procedures against conservation Objectives 1 and 2. The first, $T_{0.2}$, is the projected number of years until the spawning biomass exceeded 20% of the unfished spawning biomass, $0.2B_0$, with 90% certainty. The target range for $T_{0.2}$ is 22.5 years (i.e., 1.5 sablefish generations) or less. The second additional performance measure, T_{init}, was added to this evaluation to measure the number of years until spawning biomass exceeds the initial spawning stock depletion in 2007 with 90% certainty. The target value for T_{init} is 10 years or less. Both conservation performance statistics, $T_{0.2}$ and T_{init}, were computed as the number of years until the 10^{th} percentile of the annual distribution of spawning biomass depletion values exceeded the limit reference point spawning biomass depletion values (i.e., 20% of B_0 and depletion in 2007 (D_{init}), respectively). It is important to note that these performance statistics relate to the overall distribution of simulated depletion values in any given year of the projection. In contrast, any particular replicate trajectory might increase above, say $0.2B_0$, sooner, go above/below $0.2B_0$ more than once during the projection, or may never actually exceed $0.2B_0$. The minimum possible values for both conservation measures is 1 year because, for example, the 2008 catch will not be implemented in the simulations until beginning-of-year spawning biomass is computed for 2009.

We illustrate performance differences among certain procedures using scenarios S1 and S2 because these are most relevant to current conservation concerns. The complete set of tabular results and graphical counterparts for scenarios S3 and S4 may be found in Appendix B. In general, all procedures perform relatively well for the more optimistic scenarios S3 and S4.

2 Results

2.1 Data-based procedures

Of the 28 data-based procedures we examined, only 8 passed the first conservation objective to rebuild the spawning stock above $B_{20\%}$ within 22.5 years or less with 90% certainty based on scenario S1 (Table 6). These admissible procedures fell exclusively within the DB_{120} and DB_{150} classes. Although median depletion of most DB_{180} procedures increased beyond 20% within 11-20 years (Figure 1), none were able to provide the required 90% certainty within 22.5 years. All 8 of the admissible procedures also met the second conservation objective to rebuild the spawning stock above the initial level within 10 years or less with at least 90% certainty. In fact, these procedures required only 3 to 7 years to accomplish the objective. Three of these procedures, which involved combining DB_{150} with the "conservation-based" harvest control rule references points I_{low} = 6 kg/trap and I_{high} = 18 kg/trap, did well in terms of conservation performance, but also increased interannual variability in catch because the λ_2 multiplier was adjusted more frequently. Other procedures obtained lower interannual variability in catch and greater average yields while providing similar conservation performance. Therefore, we did not consider these "conservation-based' procedures further.

Median depletion levels by year 10 of scenario S1 projections ranged from 0.183 to 0.193 for the 8 admissible data-based procedures. Meeting conservation objectives under scenario S1 involved 2008 quota levels ranging from 1,500 to 2,700 tonnes (Table 6); however, relatively low median annual average catches, ranging from 905 to 1,126 tonnes over years 1-10 resulted from applying the procedures over the remaining years. The procedure meeting all conservation and catch variability objectives while maximising the median average annual catch over years 1-10 was the $DB_{120,\,2700}$ $\lambda_1 = 0.5$, {4,15} (Table 6).

Under scenario S2, all data-based procedures met Objective (1) because the spawning stock biomass was initially well above 20% of the unfished level. We did not eliminate procedures based on the observation that only 4 procedures met Objective (2) because the stock is maintained quite close to its maximum sustainable yield level under this scenario (Table 7). The top-ranked procedure under scenario S1 obtained median depletion levels under S2 that were close to the MSY level by 11-20 years, and above MSY levels by 21-40 years (Figure 2).

For both scenarios S1 and S2, the "constrained" data-based procedures that limited interannual changes in catch to 15% or less performed the worst within their class in terms of both conservation and catch (note outlier points in Figures 1 and 2). A constant catch procedure that applies the 2007/2008 fishing year TAC of 3,300 t to every future year is included in Table 6 and Figures 1 and 2 to illustrate the consequences of not adjusting catches in proportion to abundance. For scenario S1, the median depletion is reduced to 0.074 at 10 years under this constant catch procedure and the stock collapses soon after. Under scenario 2, the median stock increases slightly above 20% of unfished by years 11-20; however, in the long-term (21-40 years), the stock fails to recover to the MSY level and the 10^{th} percentile of spawning biomass depletion remains below 0.10 (Figure 2). Therefore, both the constrained and constant catch procedures fail to meet conservation objectives and are not considered further (this has already been recognized by industry and managers as part of Cox et al. (2008) evaluation).

2.2 Catch-age model procedures

Of the 15 catch-age procedures we examined, only 3 passed the first conservation objective to rebuild the spawning stock above $B_{20\%}$ within 22.5 years with at least 90% certainty based on scenario S1 (Table 8). These admissible procedures fell exclusively within the $CA_{0.04,catch}$ class, which is not particularly surprising because the removal rate reference $U^{ref} = 0.04$ is slightly less than the exploitation rate at MSY ($U_{MSY} = 0.045$). Meeting conservation objectives under scenario S1 using $CA_{0.06,catch}$ procedures involved 2008 quota levels ranging of 1,500, 1,900, or 2,300 tonnes. These procedures all met the $T_{0.2}$ objective while also providing 90% certainty that the stock would recover above the 2007 level within 3-4 years (Table 8, T_{init}). Although median depletion of the $CA_{0.06}$ and $CA_{0.06,\,catch}$ classes increased to approximately 20% within 11-20 years (Figure 3), none were able to provide the required 90% certainty within 22.5 years or less under scenario S1.

Median spawning biomass depletion levels by year 10 of the scenario S1 projections ranged from 0.184 to 0.186 for the 3 admissible catch-age procedures. Similar to the data-based procedure results, meeting conservation objectives under scenario S1 involved relatively low median annual average catches over years 1-10 ranging from 1,121 to 1,163 tonnes. The procedure meeting all conservation and catch variability objectives while maximising the median average annual catch over years 1-10 was the $CA_{0.04,\,2300}$ {0.25,1.0} (Table 8).

Under scenario S2, all catch-age procedures met Objective (1) because the spawning stock biomass is well above 20% of unfished biomass initially. Like the data-based situation described above, we did not eliminate procedures based on the observation that none met Objective (2) under scenario S2. We made this choice because the stock is maintained on average quite close to its maximum sustainable yield level for all $CA_{0.04}$ procedures that were admissible under scenario S1 (Table 8). Note that all other CA procedures failed to rebuild or maintain the stock above the initial level with 90% certainty, so T_{init} could not be calculated. Again, because the stock begins near the MSY level, failure to meet this objective is not critical in the short term. Procedures within the $CA_{0.08}$ class do increase the stock above the initial level by 21-40 years, however, there remains a high probability that the stock will be maintained below $B_{20\%}$ for scenario S1 and a small probability for S2 (Figures 3 and 4). Thus, we did not consider the $CA_{0.08}$ procedures further here, although future work should evaluate this class with alternative reference points. Also, like their data-based counterparts, procedures using the 15% constraint on year-to-year changes in TAC performed the worst in their respective classes in terms of both conservation and catch (Figures 3 and 4).

3 Advice to managers

This section provides a detailed description of the effects of 2008 TAC choices on the ability to meet conservation objectives. We then invoke a relatively straightforward strategy for selecting a management procedure from among the 33 possible candidates while explicitly taking fishery objectives into account. Finally, we describe some of the limitations of our advice; in particular, the potential sensitivity of our approach to current uncertainties.

3.1 Effects of 2008 quota on fishery performance

Procedures within the DB_{120} class performed similarly (using S1) in terms of average annual catch, but differed substantially in short-term conservation performance depending upon the 2008 quota. For example, although the $DB_{120,\,2700}$ (note: other rule parameters are omitted to reduce clutter) procedure results in a median average catch of 1,126 t over 10 years, the $DB_{120,\,1900}$ procedure obtained 1,012 t per year on average while increasing the spawning stock above 2007 levels within 4 years instead of 7. Figure 5 shows four variations of DB_{120}. Although all of these candidates provide similar long-term depletion and catch performance (recall that long-term performance is determined mainly by $\lambda_2 = 120$, which is common to all these procedures), lower 2008 quotas decrease the immediate rate of stock decline and thereby increase the rate of recovery. Ultimately, by year 10 the $DB_{120,\,1900}$ procedure provides almost 100 t greater expected average catch (Table 5; Catch (t=10)) and 40 t greater expected minimum catch (Table 5; Min. catch (1-10 years)). Differences between these four procedures are less pronounced under scenario S2 (Figure 6).

Procedures in the catch-age $CA_{0.04}$ class show similar short-term differences under scenario S1 as those observed for the DB_{120} class; that is, a 2008 quota of 1,900 t compared to 2,700 shortens the time required to increase the stock above the initial level by half (i.e., from 5 years to 3), while differing by only 42 t in expected 10-year average catch (Figure 7). Under scenario S2, the 2008 quota has no noticeable effect on conservation performance because the stock begins at a higher level. Thus, there is actually not as much "room for growth" compared to scenario S1, where there is a wide gap between the 2007 level and the MSY level.

3.2 Choosing a management procedure

We applied the hierarchical strategy for choosing among candidate management procedures that was described by Cox et al. (2008). The approach orders fishery management objectives linearly according to their level of priority under a precautionary fishery management policy in which conservation objectives predominate over volatility and yield considerations. Treatment of uncertainty is accomplished by stating specific operational objectives in probabilistic terms while being equally specific about the time frames over which objectives should be achieved. Management procedures failing to meet an objective at any level are discarded as not being effective at generating desirable outcomes.

Table 9 provides a decision-making strategy that evaluates management procedure performance against the four objectives identified in the Introduction to this document. The final column of Table 9 shows the number of data-based (DB) and catch-age (CA) procedures capable of meeting the objectives at each level of the hierarchy. It is clear that the first conservation objective dominates the others because it eliminated approximately 70% and 80% of data-based and catch-age procedures, respectively. The second and third objectives did not eliminate any procedures that had already passed Objective 1. Despite this lack of sensitivity, performance under Objective 2 important to decision-making because it provides an immediate goal to be achieved compared to the goal of Objective 1, which may not be achieved for up to two decades in some cases. In particular, our analysis has revealed that shortening the time horizon for Objective 2 to, say, 3-5 years as opposed to 10 years may allow faster progress toward conservation objectives while sacrificing little in terms of average annual yield. Faster progress under the top-ranked data-based procedure (i.e., $DB_{120,\,catch}$) is achieved as the sole result of the 2008 quota. **Under the $DB_{120,\,catch}$ procedure, 2008 TACs of 2,700, 2,300, and 1,900 t are associated with times of 7, 6, and 4 years, respectively to maintain spawning stock biomass above the 2007 level with 90% certainty.** It is important to note that these timeframes are predicated on following the particular management procedure for the full duration of the period. Also, given that we only simulated 100 replicate trajectories, differences in rebuilding performance of 1-year should essentially be ignored.

3.3 Limitations of advice

The operating model scenarios for B.C. sablefish were determined using structural assumptions and methods typical of fisheries stock assessment and each therefore contains the inherent uncertainties found in most fisheries models. However, unlike the traditional single "best assessment" approach, we evaluated the sensitivity of proposed management procedures over a range of stock scenarios that we think encompass several plausible alternatives. The reader may have noticed that we downplayed the importance of optimistic scenarios S3 and S4 in this assessment. We did this for two reasons. First, almost all procedures performed well under these scenarios in both the short- and long-term. Thus, it is reassuring that if the stock is actually better off than we anticipate, conservation and catch performance will improve relatively rapidly based on advice derived from this type of assessment. Second, we did not feel justified in treating scenarios S3 and S4 equally with S1 and S2 despite similarities based on statistical grounds. Scenarios S3 and S4 contain highly optimistic productivity and linear fishery CPUE assumptions that have both been rightly criticized in the fisheries literature (Hilborn and Walters 1992).

Scenarios considered in this paper focused on B.C. sablefish stock productivity and the present level of spawning biomass depletion. Although these two uncertainties are amongst the most critical to evaluate in management strategy simulations, these scenarios do not capture the broader range of uncertainties associated with the B.C. sablefish stock and fishery (Table 10). Cox et al. (2008) provided a list of key uncertainties that could cause failure of the sablefish management procedures evaluated in this document. High discard rates in all fisheries are of particular concern because (*i*) our operating model estimates of stock status would be optimistic and (*ii*) failing to account for discard mortality in future projections means that actual recovery rates will be slower.

Simulated performance of management procedures also assumes that data collection programs required to support those procedures are in place in the future. Some of these data collection programs are currently in doubt. For example, the commercial catch sampling program that would provide fishery catch-at-age is being re-introduced and may be fully in place by mid-2008. If re-introduction of this program is unsuccessful, then management planning on the basis of catch-age model-based procedures is moot. On the basis of statistical principles and industry desires, the standardized trap survey program is likely to be replaced by the existing stratified random trap survey, which began in 2003. Regardless of the fate of the standardised survey program, industry stakeholders have expressed a preference for using the stratified random survey in data-based management procedures. Thus, MSE development will necessarily have to begin work on a succession procedure for the future using an index derived from the stratified random survey.

3.4 Conclusions

The purpose of management strategy evaluation is to identify a fishery management procedure that, when followed over time, adequately meets objectives that are agreed upon by industry stakeholders and fishery managers. This paper demonstrated that embedding different 2008 quota choices into several candidate management procedures mainly affected short-term performance relative to conservation objectives. Although the full range of 2008 TAC options (1,500 - 2,700 t) was included in the admissible management procedures, we expect that quotas in the range 2,000-2,400 t will achieve conservation objectives more rapidly and with greater certainty, while potentially buffering against known uncertainties such as discarding. Importantly, similar average annual catch is expected over 10-years for all quota levels considered. It should also be noted that improved conservation performance also improves profitability because fishery catch-per-unit effort is also expected to be higher.

For both data-based and CA model-based procedures, the long-term performance does not vary widely within scenarios because a single TAC value within the range tested cannot dominate the long-term properties of the procedures. All admissible data-based procedures indicate a significant decline in median catch to at least the 2,000 t level (scenario S4) and as low as ~1000 t (scenario S1) during the first 10 years of the projection with the minimum occurring about 5 years into the projection period. This outcome mainly reflects the apparent lack of significant sablefish recruitment as suggested by recent data (e.g., stock indices, age proportions). The management procedures we evaluated attempt to deal with declining stock abundance indices by reducing directed catch, and thus are expected to maintain stock sizes at reasonable levels despite such poor recruitment. Ultimately, use of variable harvest rate decision rules as required by national fisheries policy is intended to encourage stock growth towards their most productive levels. Based on the simulation results, the costs of not reducing catches according to a consistent procedure are longer times to meet conservation objectives and increased risks associated with depletion levels lower than the 2007 level.

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Table 1 Differences between this document and Cox et al. (2008).

Topic	Change	Location
Objectives	• Revised for FY2008/2009 to emphasize conservation objectives determined from consultations • Added objective to prevent decline of the spawning biomass below the current level with 90% certainty • Added objective to rebuild stock above $B_{20\%}$ • Lowered priority of objective to limit year-to-year changes to 15% or less during the first 5 projection years	Section 1.2
Operating model	• Removed Japanese longline CPUE series • Removed tagging biomass index • Set growth parameter L_1=35 cm and re-estimated k and L_∞ • Added 2006 standardized survey age proportions	Section 1.4 Appendix A
Procedures: *Data*	• Updated landings history to December 31, 2007 • Updated nominal trap fishery catch rates to December 31, 2007 • Added 2007 standardized survey index point • Added age proportions added for 2006 standardized survey	Appendix A
Procedures: *Methods*	• Dropped assessment methods based on a production model • Removed precautionary risk adjustment from CA model-based methods	Section 1.5
Procedures: *Rules*	• Considered only variable harvest rate decision rules • Evaluated procedures that fix catch at selected values in the first projection year • Evaluated procedures without 15% constraint on year-to-year TAC changes during the first 5 projection years	Section 1.5.1 Section 1.5.2
Other indicators	• Added sablefish abundance indices derived from multi-species trawl surveys, inlets survey results	Appendix A
Management history	• Updated to 2007	Appendix A

Table 2 Distinguishing features of operating model scenarios S1-S4. Parameters are the steepness of the Beverton-Holt stock-recruitment function (h) and trap fishery hyperstability ($q_{2,trap}$). Equilibrium yield characteristics include the MSY, exploitation rate at MSY (U_{MSY}), unfished spawning biomass (B_0), spawning biomass (B_{MSY}) and depletion at MSY (D_{MSY}). Initial spawning biomass conditions for the operating models are given as spawning stock biomass (B_{2007}) and depletion (D_{2007}) in 2007. Biomass units are metric tonnes.

Scenario	**Parameters**	**Description**	**MSY**	U_{MSY}	B_0	B_{MSY}	B_{2007}	D_{MSY}	D_{2007}
S1	$h = 0.45$ $\hat{q}_{2,trap} = 0.422$	Low productivity Low initial depletion	2,931	0.047	146,907	55,022	22,918	0.375	0.156
S2	$h = 0.45$ $q_{2,trap} = 1.0$	Low productivity Moderate initial depletion	3,003	0.047	150,534	56,381	42,315	0.375	0.281
S3	$h = 0.65$ $\hat{q}_{2,trap} = 0.483$	High productivity Low initial depletion	4,211	0.084	138,586	42,357	29,230	0.306	0.211
S4	$h = 0.65$ $q_{2,trap} = 1.0$	High productivity Initial depletion at MSY	4,340	0.084	142,813	43,649	44,038	0.306	0.308

Table 3 Equations and definitions for data-based and catch-age harvest control rules.

Data-based Harvest Control Rule		**Notation**
T3.1	$C_{T+1} = \lambda_1 C_T + (1-\lambda_1)\tilde{\lambda}_{2,T+1} I_T^*, \quad 0 \le \lambda_1 \le 1$	C_T catch in year T λ_1 weight on C_T $\tilde{\lambda}_2$ adjusted survey multiplier I_T^* 3-yr survey average
T3.2	$\tilde{\lambda}_{2,T+1} = \begin{cases} 0 & I_T^* < I_{low} \\ \lambda_2 \left(\dfrac{I_T^* - I_{low}}{I_{high} - I_{low}} \right) & I_{low} \le I_T^* < I_{high} \\ \lambda_2 & I_T^* \ge I_{high} \end{cases}$	I_{low} limit reference point I_{high} upper stock reference λ_2 reference survey multiplier
Catch-age Model-based Harvest Control Rule		
T3.3	$C_{T+1} = U_{T+1} \hat{B}_{T+1}$	C_{T+1} catch in year T+1 U_{T+1} adjusted harvest rate $\hat{B}_{T+1}$ projected trap biomass
T3.4	$U_{T+1} = \begin{cases} 0 & \hat{D}_T < D_{low} \\ U^{ref} \left(\dfrac{D_{high}}{\hat{D}_T} \right) \left(\dfrac{\hat{D}_T - D_{low}}{D_{high} - D_{low}} \right) & D_{low} \le \hat{D}_T < D_{high} \\ U^{ref} & \hat{D}_T \ge D_{high} \end{cases}$	D_{low} limit reference point D_{high} upper stock reference U^{ref} reference harvest rate
T3.5	$\hat{D}_T = \hat{S}_T / \hat{S}_{1992}$	$\hat{D}_T$ spawning biomass depletion $\hat{S}_T$ spawning biomass

Table 4 Summary of candidate *interim* management procedures for B.C. sablefish. Each procedure consists of data, an assessment method, and a harvest control rule defined by a set of parameters.

MP class	Data	Assessment Method	Rule Type	Rule Parameters
DB λ_2	Catch Survey index	3-year running mean of survey	Variable harvest rate	$\lambda_1 = \{0.2, 0.5\}, \lambda_2 = \{120, 150, 180\}$ $I_{low} = \{4,6\}$, $I_{high} = \{15, 18\}$
DB $\lambda_{2, catch}$	Catch Survey index	3-year running mean of survey index	Variable harvest rate, 2008 catch set to *catch*	$\lambda_1 = \{0.5\}$, $\lambda_2 = \{120, 150, 180\}$ $I_{low} = \{4\}$, $I_{high} = \{15\}$ $catch = \{1500, 1900, 2300, 2700\}$
DB $\lambda_{2,15\%}$	Catch Survey index	3-year running mean of survey index	Variable harvest rate, 15% per year limit on TAC change over first 5 years	$\lambda_1 = \{0.5\}$, $\lambda_2 = \{120,150,180\}$ $I_{low} = \{4\}$, $I_{high} = \{15\}$
$CA_{U^{ref}}$	Catch Survey index Trap fishery	Catch-at-age model	Variable harvest rate	$U^{ref} = \{0.04, 0.06, 0.08\}$ $D_{low} = \{0.25\}$, $D_{high} = \{1.0\}$
$CA_{U^{ref}, catch}$	Catch Survey index Trap fishery ages Survey ages	Catch-at-age model	Variable harvest rate, 2008 catch set to *catch*	$U^{ref} = \{0.04, 0.06, 0.08\}$ $D_{low} = \{0.25\}$, $D_{high} = \{1.0\}$ $catch = \{1500, 1900, 2300, 2700\}$
$CA_{U^{ref},15\%}$	Catch Survey index Trap fishery ages Survey ages	Catch-at-age model	Variable harvest rate, 15% per year limit on TAC change over first 5 years	$U^{ref} = \{0.04, 0.06, 0.08\}$ $D_{low} = \{0.25\}$, $D_{high} = \{1.0\}$

Table 5 Definitions of performance statistics used for sablefish management strategy evaluation. The interval $t = t_1, \ldots, t_2$ defines the time period over which statistics are calculated. The "-" symbol indicates that the explanation of the Performance statistic is a sufficient Definition.

Objective Type	Performance statistic	Symbol	Definition
Conservation	Arithmetic mean of annual spawning biomass depletion.	$\bar{D}$	$\bar{D} = \frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} \left(\frac{S_t}{B_0} \right)$
Conservation	Number of years until the 10th percentile of annual spawning biomass depletion exceeds initial depletion, D_{init}.	T_{init}	-
Conservation	Number of years until the 10th percentile of annual spawning biomass depletion exceeds 20% of B_0.	$T_{0.2}$	-
Conservation	Probability that the spawning biomass, S_t, exceeds 20% of B_0.	P_{cons}	$P\left(S_t > 0.2B_0\right)$
Catch variability	Average annual absolute change in catch.	AAV	$AAV = \sum_{t=t_1}^{t_2} \left\vert C_t - C_{t-1} \right\vert \Big/ \sum_{t=t_1}^{t_2} C_t$
Catch	Arithmetic mean of annual catches.	$\bar{C}$	$\bar{C} = \frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} C_t$
Catch	Minimum catch over the time interval.	$C_{\min}$	Minimum catch from $t = t_1, \ldots, t_2$.
Catch	Maximum average catch over the time interval.	$\bar{C}_{0.95}$	95th percentile of distribution of $\bar{C}$

Table 6 Performance statistics for data-based procedures applied to scenario S1. Results are sorted in priority order by (1) $T_{0.2}$ (descending), (2) T_{init} (descending) and (3) Average catch over 1-10 years (ascending). The "-" symbol indicates that the time extended beyond the total 40-year simulation period. Procedures shown in bold font meet the two conservation objectives and the top ranked procedure overall is marked with "**".

Procedure	$T_{0.2}$	T_{init}	Depletion (t = 10)	2008 Catch	Avg. catch (1-10 yrs)	Catch (t= 10)	Min. catch (1-10 yrs)	Max. catch (1-10 yrs)
$DB_{120,1500t}$ λ_1=0.5 {4,15}	**21**	**3**	**0.193**	**1500**	**956**	**1038**	**588**	**1356**
$DB_{150,1900t}$ λ_1=0.5 {6,18}	**22**	**3**	**0.195**	**1900**	**905**	**891**	**433**	**1336**
$DB_{120,1900t}$ λ_1=0.5 {4,15}	**22**	**4**	**0.190**	**1900**	**1012**	**991**	**570**	**1408**
$DB_{150,2300t}$ λ_1=0.5 {6,18}	**22**	**5**	**0.192**	**2300**	**960**	**841**	**416**	**1380**
$DB_{120,2300t}$ λ_1=0.5 {4,15}	**22**	**6**	**0.186**	**2300**	**1068**	**945**	**552**	**1460**
DB_{150} λ_1=0.5 {6,18}	**22**	**6**	**0.189**	**2660**	**1011**	**798**	**397**	**1417**
$DB_{120,2700t}$ λ_1=0.5 {4,15}**	**22**	**7**	**0.183**	**2700**	**1126**	**898**	**532**	**1512**
DB_{120} λ_1=0.5 {4,15}	**22**	**7**	**0.183**	**2649**	**1118**	**905**	**533**	**1505**
$DB_{180,1900t}$ λ_1=0.5 {6,18}	25	4	0.191	1900	997	1015	500	1497
$DB_{180,2300t}$ λ_1=0.5 {6,18}	25	6	0.187	2300	1049	958	473	1537
DB_{180} λ_1=0.5 {6,18}	25	7	0.183	2850	1122	884	440	1589
$DB_{120,15\%}$ λ_1=0.5 {4,15}	25	13	0.158	2901	1569	772	772	1741
$DB_{150,1500t}$ λ_1=0.5 {4,15}	32	3	0.186	1500	1100	1222	701	1591
$DB_{150,1900t}$ λ_1=0.2 {4,15}	32	4	0.185	1900	1121	1293	562	1604
DB_{150} λ_1=0.2 {4,15}	32	6	0.182	2568	1167	1234	530	1645
$DB_{150,1900t}$ λ_1=0.5 {4,15}	32	6	0.183	1900	1150	1164	679	1634
$DB_{150,2300t}$ λ_1=0.5 {4,15}	33	7	0.180	2300	1201	1113	655	1678
$DB_{150,2700t}$ λ_1=0.5 {4,15}	33	9	0.177	2700	1253	1057	627	1722
DB_{150} λ_1=0.5 {4,15}	33	10	0.175	2885	1278	1029	622	1742
$DB_{150,15\%}$ λ_1=0.5 {4,15}	33	13	0.157	2901	1594	909	871	1859
$DB_{180,1900t}$ λ_1=0.2 {4,15}	-	6	0.178	1900	1266	1444	655	1832
$DB_{180,1500t}$ λ_1=0.5 {4,15}	-	6	0.181	1500	1236	1384	805	1808
DB_{180} λ_1=0.2 {4,15}	-	7	0.173	2945	1329	1346	595	1881
$DB_{180,1900t}$ λ_1=0.5 {4,15}	-	7	0.177	1900	1280	1314	778	1845
$DB_{180,2300t}$ λ_1=0.5 {4,15}	-	10	0.174	2300	1327	1256	752	1882
DB_{180} λ_1=0.5 {4,15}	-	11	0.168	3120	1425	1121	698	1959
$DB_{180,2700t}$ λ_1=0.5 {4,15}	-	11	0.171	2700	1374	1194	722	1920
$DB_{180,15\%}$ λ_1=0.5 {4,15}	-	14	0.149	3120	1723	995	953	2040
Constant Catch	-	-	0.074	3300	3300	3300	3300	3300

Table 7 Performance statistics for data-based procedures applied to scenario S2. Results are sorted in priority order by (1) $T_{0.2}$ (descending), (2) T_{init} (descending) and (3) Average catch over 1-10 years (ascending). The "-" symbol indicates that the time extended beyond the total 40-year simulation period. Procedures shown in bold font meet the two conservation objectives. Procedures shown in bold font meet the two conservation objectives and the top ranked procedure overall is marked with "**".

Procedure	$T_{0.2}$	T_{init}	Depletion (t = 10)	2008 Catch	Avg. catch (1-10 yrs)	Catch (t= 10)	Min. catch (1-10 yrs)	Max. catch (1-10 yrs)
$DB_{120,1500t}$ λ_1=0.5 {4,15}	**1**	**3**	**0.323**	**1500**	**1364**	**1631**	**981**	**1804**
$DB_{150,1900t}$ λ_1=0.5 {6,18}	**1**	**7**	**0.325**	**1900**	**1346**	**1572**	**857**	**1975**
$DB_{120,1900t}$ λ_1=0.5 {4,15}	**1**	**10**	**0.320**	**1900**	**1427**	**1603**	**991**	**1868**
$DB_{150,2300t}$ λ_1=0.5 {6,18}	**1**	**10**	**0.322**	**2300**	**1403**	**1531**	**859**	**2027**
$DB_{150,1900t}$ λ_1=0.2 {4,15}	1	11	0.311	1900	1680	1979	1047	2241
$DB_{150,1900t}$ λ_1=0.5 {4,15}	1	11	0.312	1900	1671	1934	1185	2222
DB_{180} λ_1=0.5 {6,18}	1	11	0.308	2850	1644	1692	982	2371
$DB_{150,1500t}$ λ_1=0.5 {4,15}	1	11	0.315	1500	1612	1970	1188	2162
$DB_{180,2300t}$ λ_1=0.5 {6,18}	1	11	0.311	2300	1571	1759	992	2305
$DB_{120,2700t}$ λ_1=0.5 {4,15}**	1	11	0.313	2700	1553	1547	991	1997
DB_{120} λ_1=0.5 {4,15}	1	11	0.314	2649	1545	1550	993	1989
$DB_{180,1900t}$ λ_1=0.5 {6,18}	1	11	0.314	1900	1519	1808	994	2258
$DB_{120,2300t}$ λ_1=0.5 {4,15}	1	11	0.317	2300	1490	1575	995	1933
DB_{150} λ_1=0.5 {6,18}	1	11	0.319	2660	1454	1493	856	2074
DB_{150} λ_1=0.5 {4,15}	1	12	0.304	2885	1809	1832	1168	2371
$DB_{150,2700t}$ λ_1=0.5 {4,15}	1	12	0.306	2700	1784	1851	1176	2343
DB_{150} λ_1=0.2 {4,15}	1	12	0.308	2568	1732	1936	1026	2292
$DB_{150,2300t}$ λ_1=0.5 {4,15}	1	12	0.309	2300	1729	1892	1192	2283
$DB_{120,15\%}$ λ_1=0.5 {4,15}	1	13	0.301	2901	1765	1465	1186	2094
$DB_{150,15\%}$ λ_1=0.5 {4,15}	1	14	0.293	2901	1901	1736	1352	2402
$DB_{180,2700t}$ λ_1=0.5 {4,15}	1	15	0.295	2700	2004	2127	1369	2679
DB_{180} λ_1=0.2 {4,15}	1	15	0.295	2945	1997	2165	1188	2654
$DB_{180,2300t}$ λ_1=0.5 {4,15}	1	15	0.298	2300	1954	2173	1375	2625
$DB_{180,1900t}$ λ_1=0.2 {4,15}	1	15	0.299	1900	1926	2239	1221	2581
$DB_{180,1900t}$ λ_1=0.5 {4,15}	1	15	0.301	1900	1903	2221	1385	2569
$DB_{180,1500t}$ λ_1=0.5 {4,15}	1	15	0.304	1500	1851	2264	1377	2512
$DB_{180,15\%}$ λ_1=0.5 {4,15}	1	16	0.286	3120	2112	1967	1545	2733
DB_{180} λ_1=0.5 {4,15}	1	16	0.292	3120	2056	2073	1339	2736
Constant Catch	1	-	0.230	3300	3300	3300	3300	3300

Table 8 Performance statistics for CA based procedures applied to scenarios S1 and S2. Results are sorted in priority order by (1) $T_{0.2}$ (descending), (2) T_{init} (descending) and (3) Average catch over 1-10 years (ascending). The "-" symbol indicates that the time extended beyond the total 40-year simulation period. Procedures shown in bold font meet the two conservation objectives and the top ranked procedure overall is marked with "**".

Procedure	$T_{0.2}$	T_{init}	**Depletion (t = 10)**	**2008 Catch**	**Avg. catch (1-10 yrs)**	**Catch (t= 10)**	**Min. catch (1-10 yrs)**	**Max. catch (1-10 yrs)**
Scenario S1								
$CA_{0.04,1900t}$ {0.25,1.0}	**22**	**3**	**0.186**	**1900**	**1142**	**1100**	**865**	**1437**
$CA_{0.04,1500t}$ {0.25,1.0}	**22**	**3**	**0.187**	**1500**	**1121**	**1118**	**888**	**1418**
$CA_{0.04,2300t}$ {0.25,1.0}**	**22**	**4**	**0.184**	**2300**	**1163**	**1083**	**845**	**1455**
$CA_{0.04,2700t}$ {0.25,1.0}	23	5	0.182	2700	1184	1066	823	1476
$CA_{0.04,15\%}$ {0.25,1.0}	28	12	0.164	2901	1485	892	680	1713
$CA_{0.06,1500t}$ {0.25,1.0}	36	11	0.170	1500	1480	1410	1139	1885
$CA_{0.06,2300t}$ {0.25,1.0}	36	12	0.168	2300	1506	1371	1087	1908
$CA_{0.06,1900t}$ {0.25,1.0}	36	12	0.169	1900	1494	1391	1112	1898
$CA_{0.06,2700t}$ {0.25,1.0}	36	13	0.166	2700	1518	1354	1063	1919
$CA_{0.06,15\%}$ {0.25,1.0}	36	15	0.156	2901	1659	1217	988	1991
$CA_{0.08,1500t}$ {0.25,1.0}	-	22	0.155	1500	1763	1605	1296	2258
$CA_{0.08,15\%}$ {0.25,1.0}	-	24	0.148	2901	1852	1459	1182	2295
$CA_{0.08,2700t}$ {0.25,1.0}	-	24	0.152	2700	1779	1539	1199	2280
$CA_{0.08,2300t}$ {0.25,1.0}	-	24	0.153	2300	1774	1562	1225	2275
$CA_{0.08,1900t}$ {0.25,1.0}	-	24	0.154	1900	1769	1584	1256	2268
Scenario S2								
$CA_{0.04,2700t}$ {0.25,1.0}	1	14	0.306	2700	1755	1806	1320	2177
$CA_{0.04,2300t}$ {0.25,1.0}**	1	14	0.307	2300	1727	1818	1340	2154
$CA_{0.04,1900t}$ {0.25,1.0}	1	14	0.309	1900	1699	1829	1357	2130
$CA_{0.04,1500t}$ {0.25,1.0}	1	14	0.310	1500	1670	1841	1377	2107
$CA_{0.04,15\%}$ {0.25,1.0}	1	15	0.296	2901	1918	1759	1459	2285
$CA_{0.08,15\%}$ {0.25,1.0}	1	-	0.254	2901	2848	2787	2285	3523
$CA_{0.08,2700t}$ {0.25,1.0}	1	-	0.255	2700	2827	2816	2246	3547
$CA_{0.08,2300t}$ {0.25,1.0}	1	-	0.256	2300	2813	2832	2278	3527
$CA_{0.08,1900t}$ {0.25,1.0}	1	-	0.257	1900	2796	2847	1900	3507
$CA_{0.08,1500t}$ {0.25,1.0}	1	-	0.258	1500	2776	2862	1500	3486
$CA_{0.06,15\%}$ {0.25,1.0}	1	-	0.277	2901	2368	2382	1915	2949
$CA_{0.06,2700t}$ {0.25,1.0}	1	-	0.280	2700	2338	2393	1871	2940
$CA_{0.06,2300t}$ {0.25,1.0}	1	-	0.281	2300	2318	2408	1889	2916
$CA_{0.06,1900t}$ {0.25,1.0}	1	-	0.282	1900	2295	2422	1899	2892
$CA_{0.06,1500t}$ {0.25,1.0}	1	-	0.283	1500	2270	2436	1500	2868

Table 9 Performance evaluation for choosing a management procedure. The final column indicate the number of candidate management procedures that meet the objectives.

Type	Objective	Performance statistic	Target value	Time period	Scenario	MPs remaining
Conservation	Rebuild spawning stock above $B_{20\%}$ within 1.5 generations with 90% certainty	$T_{0.2}$	≤ 22.5 years	-	S1	DB: 8/28 CA: 3/15
Conservation	Rebuild spawning stock above D_{init} within 10 years or less with 90% certainty	T_{init}	≤ 10 years	-	S1	DB: 8/28 CA: 3/15
Catch variability	Maintain less than 20% interannual variability	*AAV*	≤ 20%	11-20	S1-S2	DB: 8/28 CA: 3/15
Catch	Maximise average annual catch	$\bar{C}$	Max	1-10	S1-S2	$DB_{120,2700}$ $CA_{0.04,2300}$

Table 10 Summary of uncertainties, operating model assumptions and qualitative effects on management procedures.

Uncertainty (priority order)	**Assumptions in operating model**	**Confidence in Assumption**	**Effect on management procedure**	
			Data-based	**Catch-at-age**
Historical discards	None	Very low	High (proportional to discard rate)	Age composition may indicate higher *F* or reduced recruitment
Age proportion sampling and ageing errors	Unbiased	Low	None	Medium
Std. survey catchability	Constant	Medium/low (survey in core areas)	High/persistent	Medium/persistent
Std. survey selectivity	Constant	Medium (surveys along juvenile migration path)	High/transient	Medium transient
Spatial structure	Closed B.C.	Low	Medium	Medium/low
Life history parameters	No male/female differences Known *M* Known growth parameters	Low	Low	Medium/low

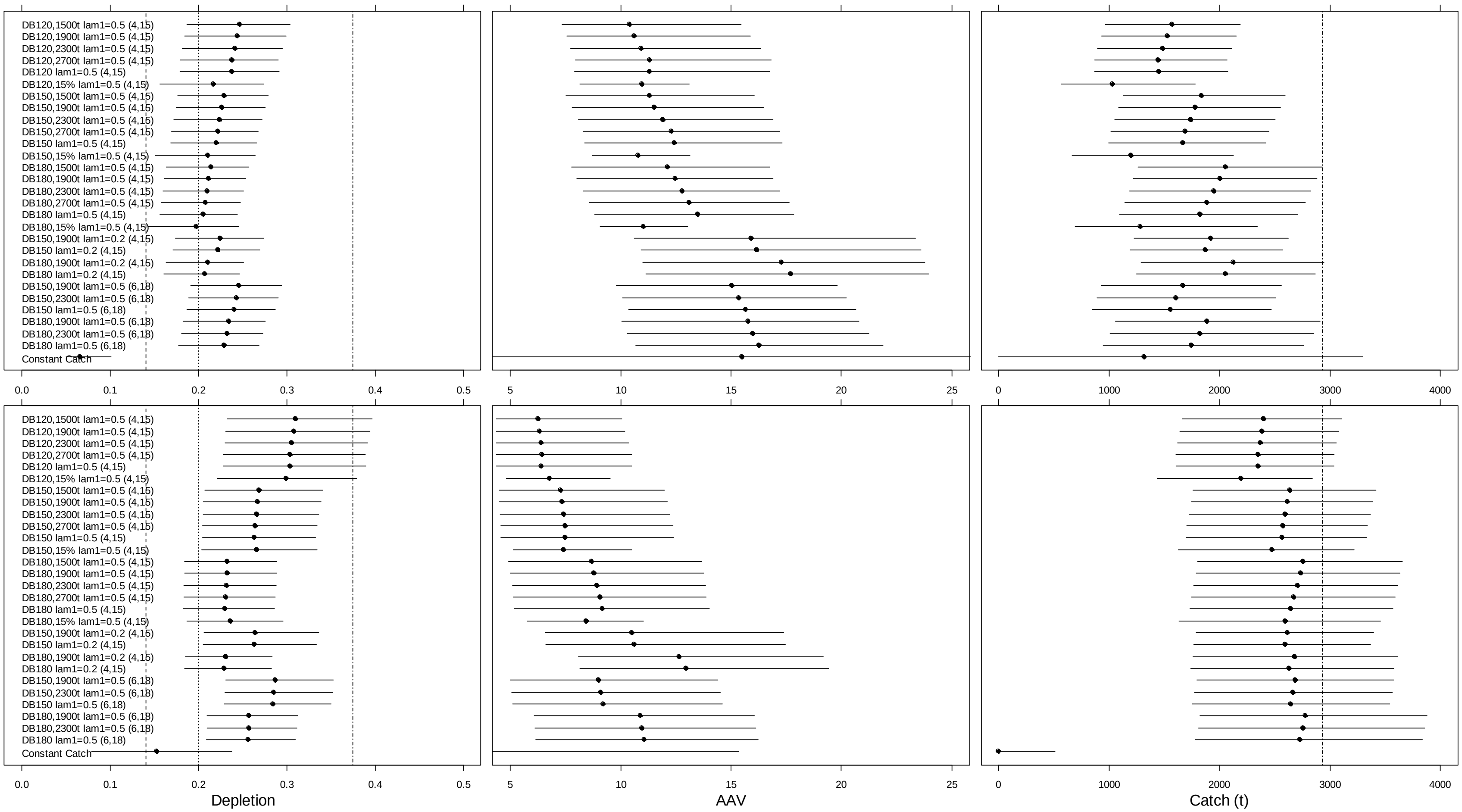

Figure 1 Summary under scenario S1 of spawning biomass depletion (left), catch variability (middle), and catch (right) performance for data-based procedures over 11-20 years (top) and 21-40 years (bottom). Horizontal bars cover 10th to 90th percentiles and circles indicate medians (N=100). Depletion panels include D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line) and catch panels show the MSY (dot-dash line).

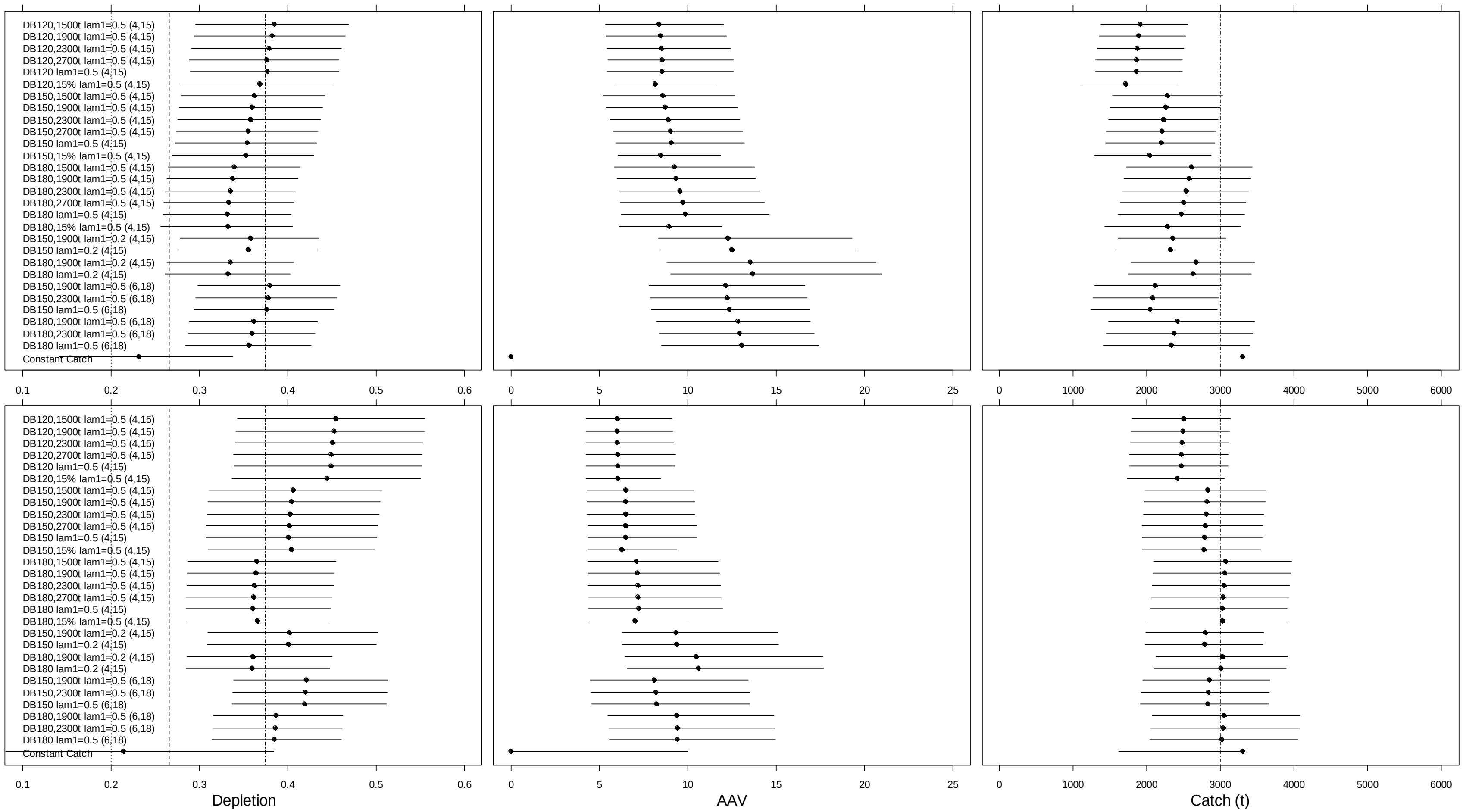

Figure 2 Summary under scenario S2 of spawning biomass depletion (left), catch variability (middle), and catch (right) performance for data-based procedures over 11-20 years (top) and 21-40 years (bottom). Horizontal bars cover 10th to 90th percentiles and circles indicate medians (N=100). Depletion panels include D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line) and catch panels show the MSY (dot-dash line).

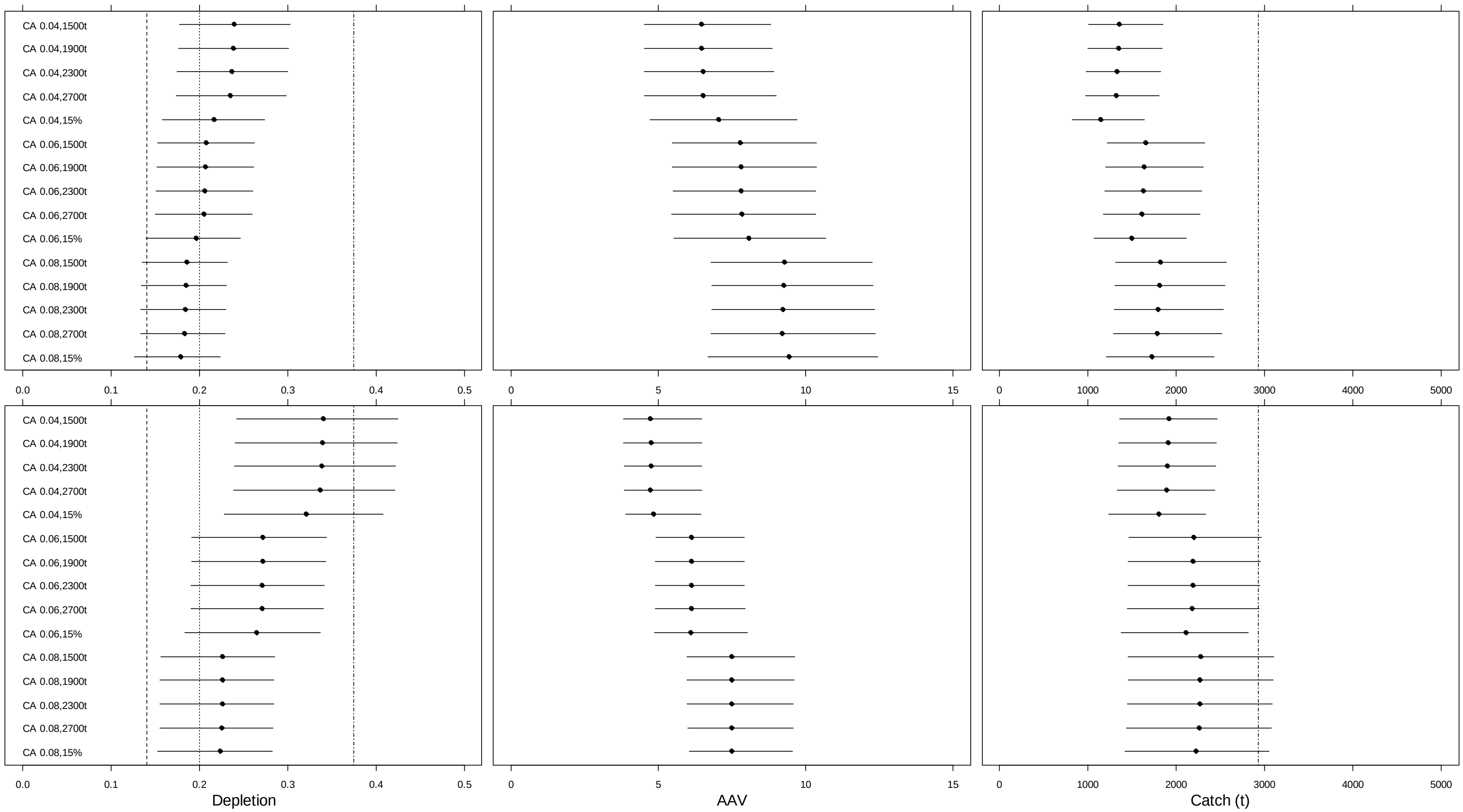

Figure 3 Summary under scenario S1 of spawning biomass depletion (left), catch variability (middle), and catch (right) performance for catch-age procedures over 11-20 years (top) and 21-40 years (bottom). Horizontal bars cover 10th to 90th percentiles and circles indicate medians (N=100). Depletion panels include D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line) and catch panels show the MSY (dot-dash line)..

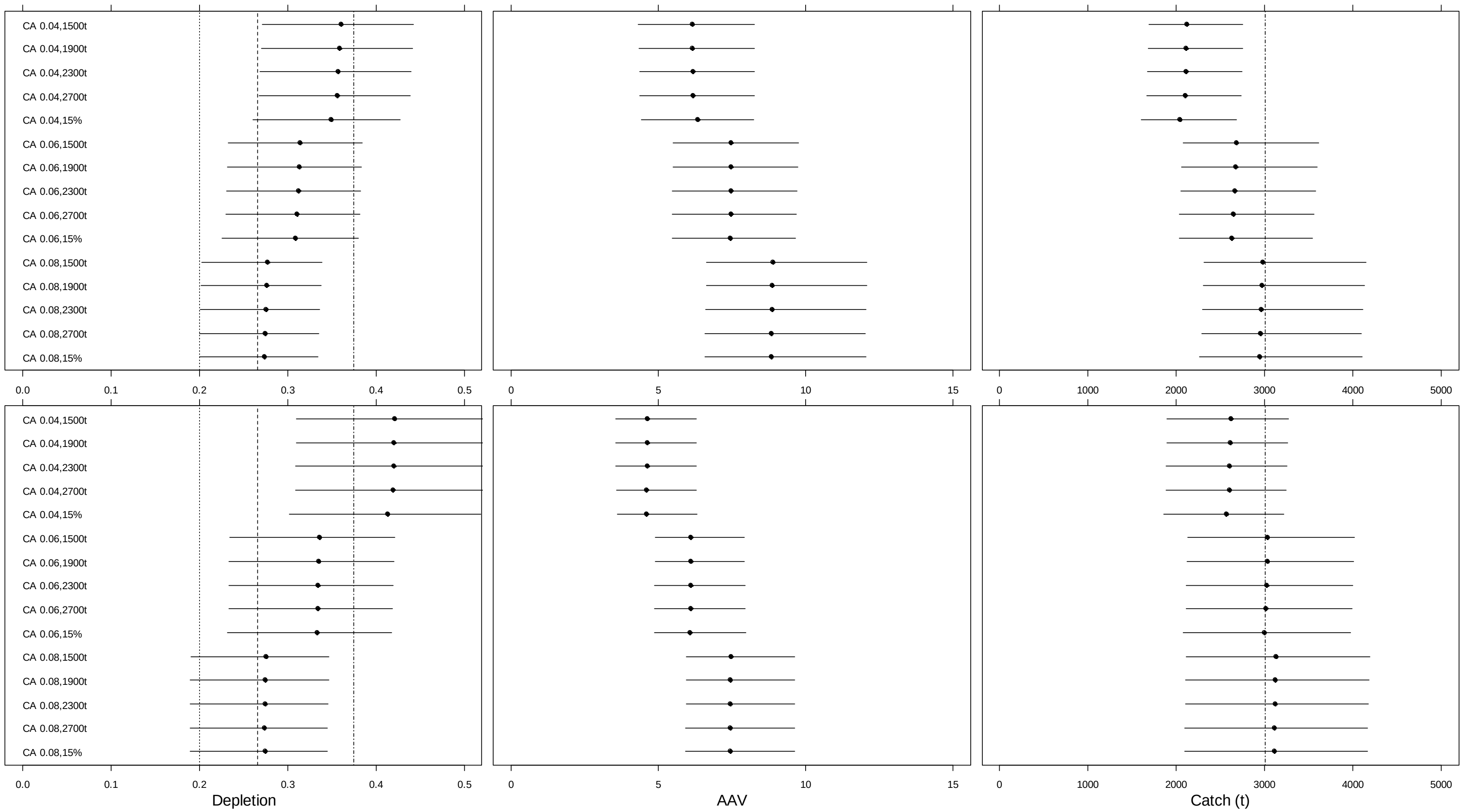

Figure 4 Summary under scenario S1 of spawning biomass depletion (left), catch variability (middle), and catch (right) performance for catch-age procedures over 11-20 years (top) and 21-40 years (bottom). Horizontal bars cover 10^{th} to 90^{th} percentiles and circles indicate medians (N=100). Depletion panels include D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line) and catch panels show the MSY (dot-dash line).

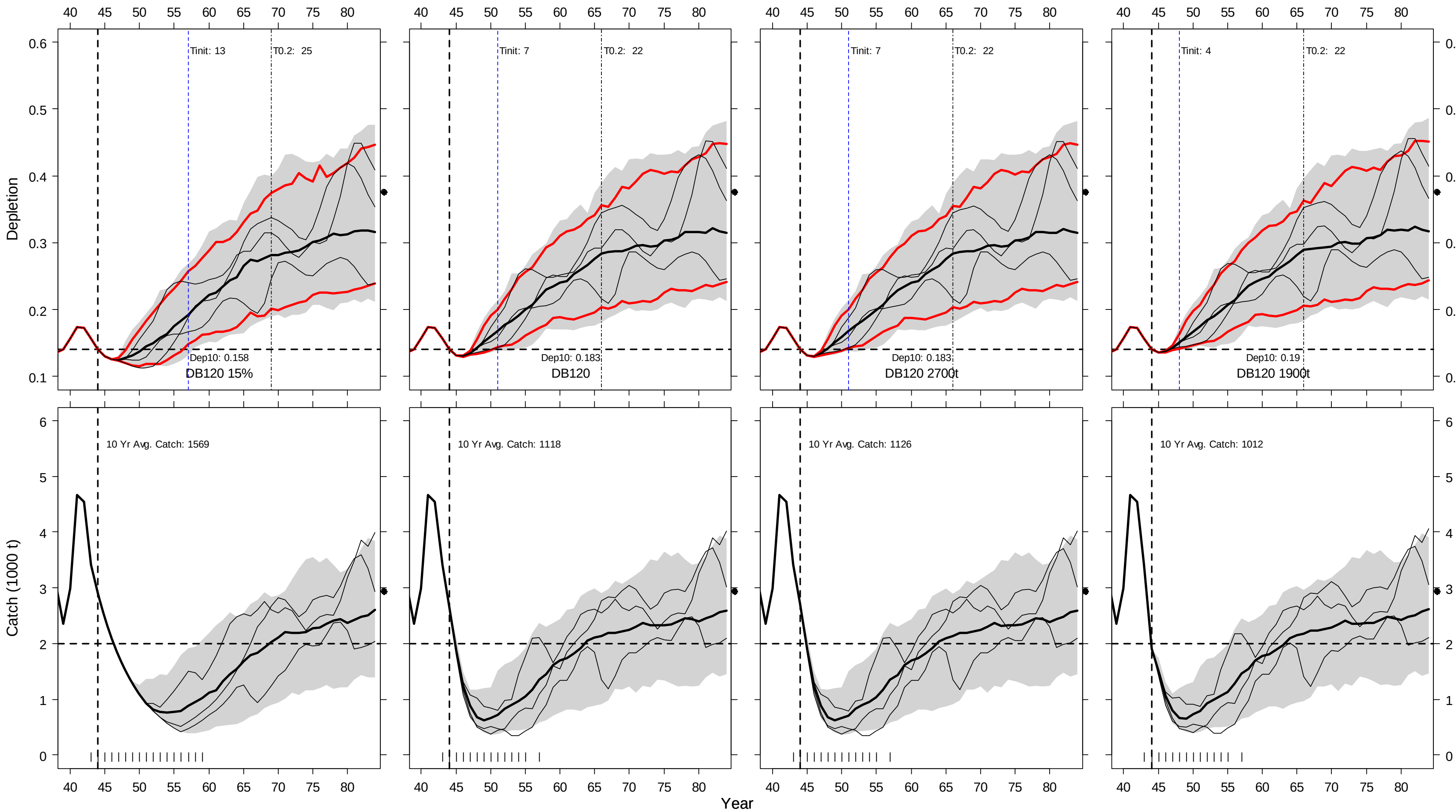

Figure 5 Simulation envelopes of spawning biomass depletion (top) and catch (bottom) for four DB_{120} procedures under scenario S1. Envelopes include the 5th to 95th percentiles (shaded area), 10th and 90th percentiles (red lines; not shown for Catch), medians (thick black lines), and three individual trajectories (thin black lines). Depletion panels indicate D_{init} (horizontal dash), $T_{0.2}$ (vertical dot-dash), and T_{init} (vertical blue dash). Hash marks at bottom of Catch panels indicate *Cautious Zone* of harvest rule based on median. Dots on right of panels indicate D_{MSY} and MSY levels.

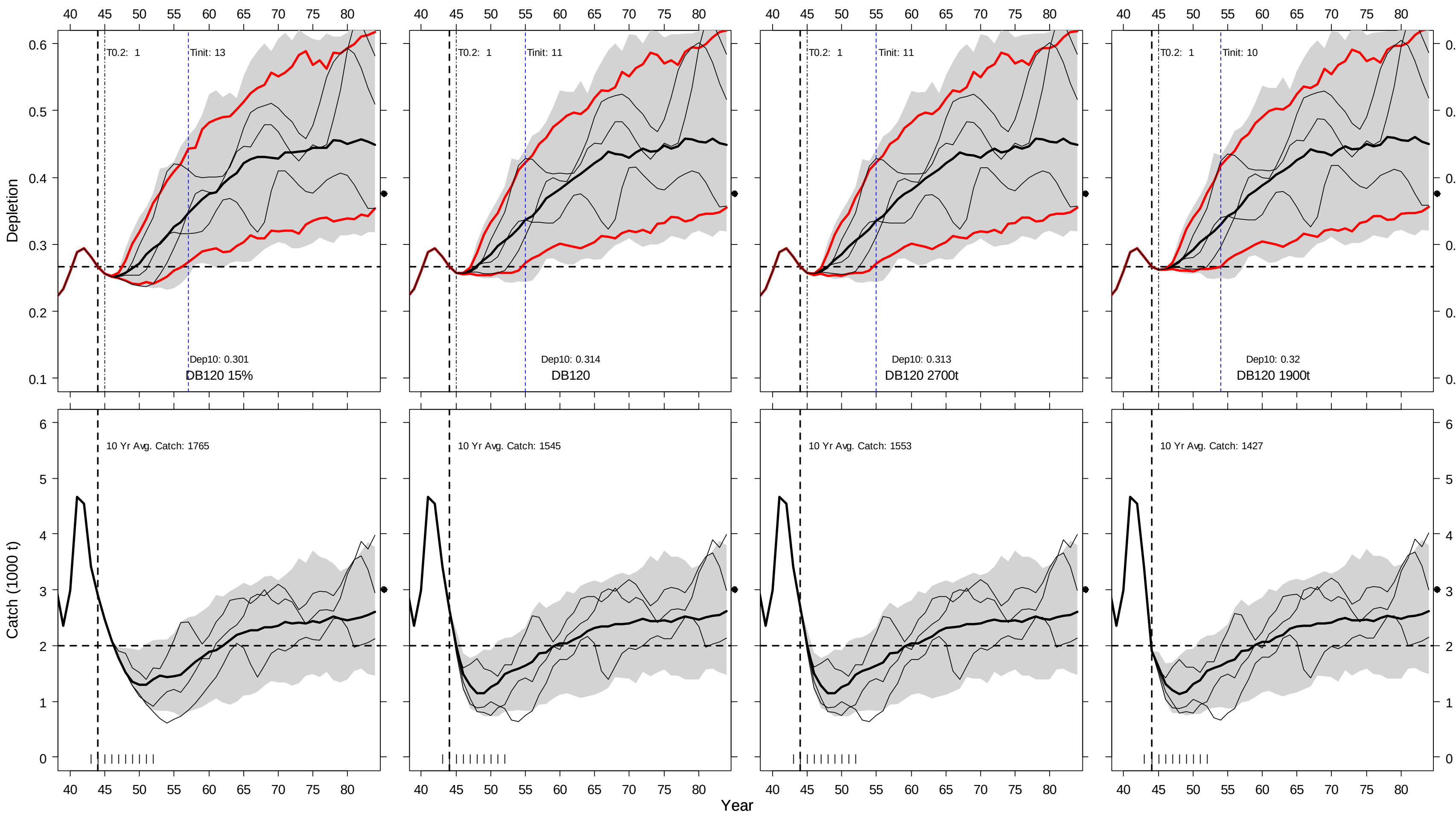

Figure 6 Simulation envelopes of spawning biomass depletion (top) and catch (bottom) for four DB_{120} procedures under scenario S2. Envelopes include the 5^{th} to 95^{th} percentiles (shaded area), 10^{th} and 90^{th} percentiles (red lines; not shown for Catch), medians (thick black lines), and three individual trajectories (thin black lines). Depletion panels indicate D_{init} (horizontal dash), $T_{0.2}$ (vertical dot-dash), and T_{init} (vertical blue dash). Hash marks at bottom of Catch panels indicate *Cautious Zone* of harvest rule based on median. Dots on right of panels indicate D_{MSY} and MSY levels.

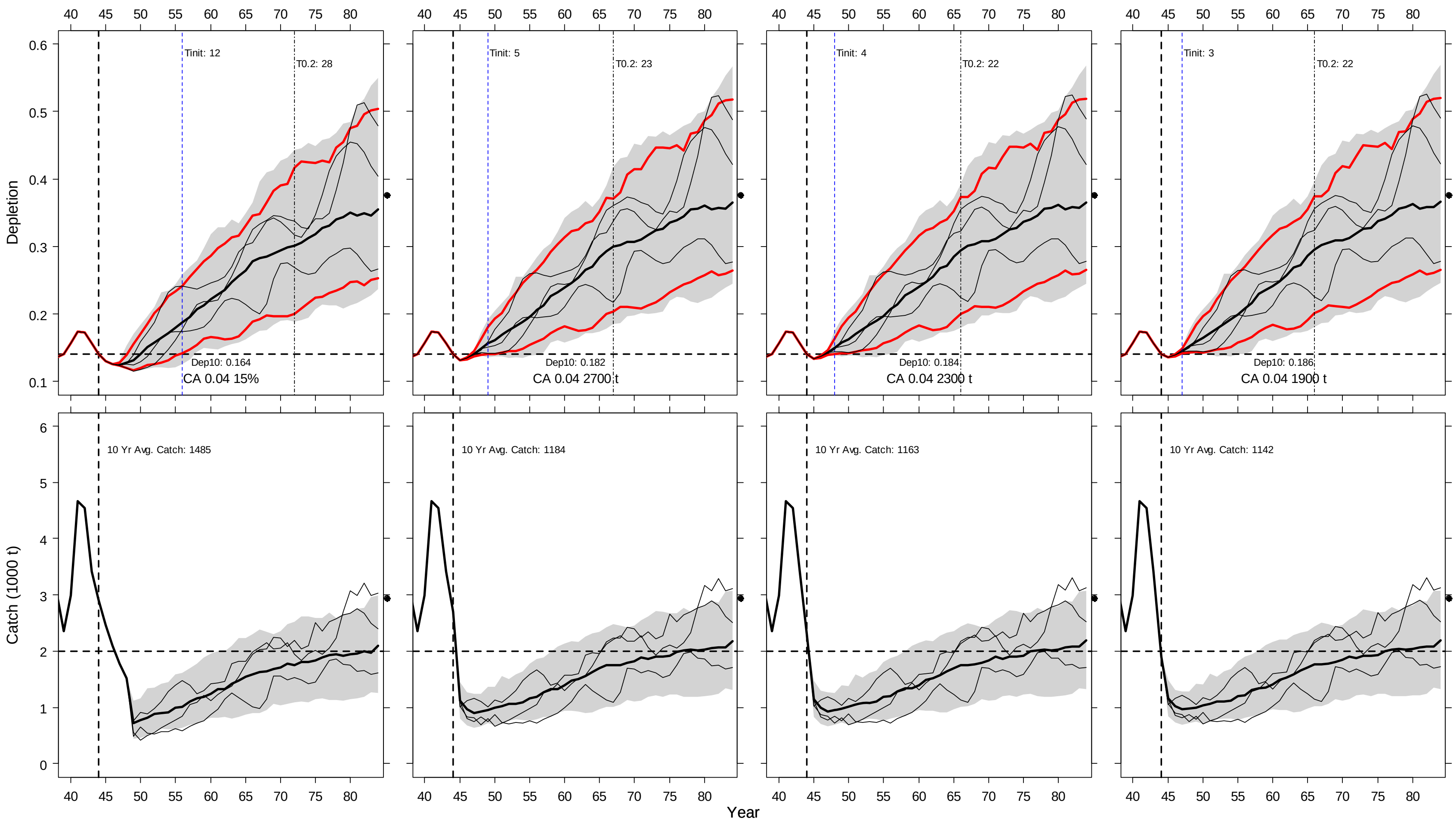

Figure 7 Simulation envelopes of spawning biomass depletion (top) and catch (bottom) for four $CA_{0.04}$ procedures under scenario S1. Envelopes include the 5th to 95th percentiles (shaded area), 10th and 90th percentiles (red lines; not shown for Catch), medians (thick black lines), and three individual trajectories (thin black lines). Depletion panels indicate D_{init} (horizontal dash), $T_{0.2}$ (vertical dot-dash), and T_{init} (vertical blue dash). Dots on right of panels indicate D_{MSY} and MSY levels.

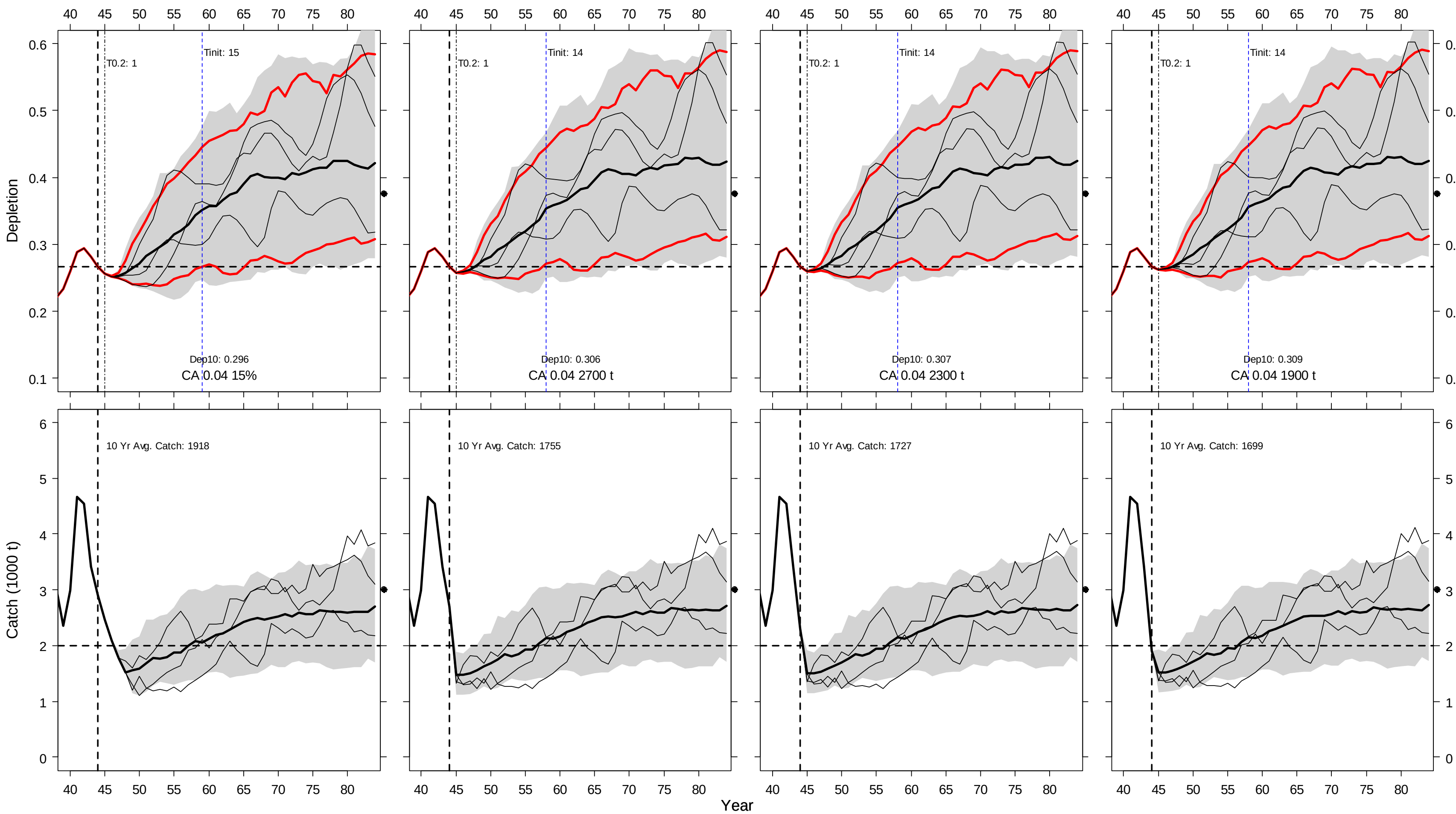

Figure 8 Simulation envelopes of spawning biomass depletion (top) and catch (bottom) for four $CA_{0.04}$ procedures under scenario S1. Envelopes include the 5^{th} to 95^{th} percentiles (shaded area), 10^{th} and 90^{th} percentiles (red lines; not shown for Catch), medians (thick black lines), and three individual trajectories (thin black lines). Depletion panels indicate D_{init} (horizontal dash), $T_{0.2}$ (vertical dot-dash), and T_{init} (vertical blue dash). Dots on right of panels indicate D_{MSY} and MSY levels.

Appendix A Data

Landings data (retained catch) used for the simulation analysis were summarized for calendar years 1965 to 2007 from the GFCatch, PacHarvSable, and FOS databases maintained by Fisheries and Oceans Canada as by Cox et al. (2008). Landings from seamount fishing were excluded where they could be identified since seamount harvest is not included in the coast-wide quota management area. Landings data prior to 1965 are available but averaged less than 1,000 t after 1920 prior to the ramping-up of the Canadian domestic sablefish fishery in the late 1960s (Figure A-1, upper panel).

The history of sablefish fishery management is summarized in Table A-1. The table contains a list of the annual total allowable catches (TACs) and quota allocations to the directed sablefish "K" fleet, the non-directed trawl "T" fleet, First Nations, and science projects. Landings by fishing year are also listed though note that the timing and duration of fishing years has changed over time, e.g., when an August 1 start date for the directed sablefish fishery was instituted in 1999 a fishing year of 19 months duration resulted. Also note that the trawl fishing year is defined as April 1 to March 31. Thus the "Total commercial allocation" does not apply to a 12 month period. For example, the 282 t trawl allocation for 2007/08 begins April 1, 2008 which is 8 months after the start of the 2007/08 fishing year for sablefish. Fishery landings data are preliminary for 2007 and incomplete for 2008.

Canadian landings since 1951 have been reported by longline, trawl, and trap gear (Figure A-1, Table A-2). The fishery has been managed since 1981 under quotas allocated to the "K" licence (longline and trap gear) and "T" licence (trawl gear). Sablefish are caught incidentally in the halibut (*Hippoglossus stenolepis*) longline hook fishery, directed "Zn" rockfish longline hook, and there were allocations to research and to First Nations food fisheries (Table A-1).

For the simulations landings were grouped by various sources to allow gear allocation during simulation experiments (Table A-3). In particular, the following data were combined:

3. Foreign longline hook landings are the sum of Japanese and Republic of Korea longline hook landings;
4. US landings from 1965 to 1980 are assumed to be taken by trawl gear;

5. Trawl landings are the sum of U.S., U.S.S.R. and Canadian domestic trawl landings;
6. Longline hook landings are the sum of domestic longline hook plus minor research longline retained catches (where they could be identified);
7. Trap survey research catches were separated from commercial trap fishery catches;
8. Landings attributed to "Other" were ignored (maximum 10 t in 1983).

Nominal sablefish trap fishery CPUE was calculated using a ratio-of-means estimator as the sum of trap catches divided by the sum of trap effort for all records that have valid observations for both retained catch and effort. Nominal trap CPUE shows a trend that suggests relatively high stock abundance in the late 1980s and early 1990s, followed by a period of lower and slowly declining catch rates from the mid-1990s to a historic low experienced in 2001 and 2002 (Figure A-2, Table A-3).

The standardized sablefish trap survey (Wyeth et al. 2006, 2007) has been conducted from 1990 to 2007. A chartered trap fishing vessel visits nine survey localities that were intentionally selected because the localities were fished by commercial vessels and were spatially dispersed about 60 nm apart. This spatial arrangement permitted all localities to be visited within a 30 day period given favourable weather. Trap escape rings are closed during survey fishing. Because only one set is conducted within each specified depth interval at each survey locality, there is no replication of sets within each combination of depth and locality. The exact spatial position of each set is also at the discretion of the fishing master rather than being randomly selected. Placement of survey sets within depth strata at the discretion of the fishing master has likely produced higher catch rate values than would be achieved with randomly positioned sets. This issue is not important to the purpose of developing a relative abundance index if bias has been similar over time. Typically, survey localities include high-relief bathymetric features such as gullies or canyons, which reflect the original intent to index sablefish abundance in core fishing areas that represent prime fishable habitat. A key issue here is that the standardized survey places unknown weights on the various depth and area zones fished. Over-representing certain habitats may cause index values to be overly sensitive to changes the shallow depths of the survey area as new fish recruit into the survey zone.

Within each locality, the standardized survey was partitioned by five core depth intervals between 274 and 1189 m (or 150 to 650 fm). The depth intervals are D1 (274-457 m), D2 (457-641 m), D3 (641-824 m), D4 (824-1006 m), and D5 (1006-1189 m). Various other localities and depth intervals have been introduced and discontinued over time. Data included in the calculation of the index are restricted to depth intervals D1 through D5 since these intervals have been most consistently fished at the nine localities over time. In general there was little replication of sets by depth and locality during the 1990 to 2007 period except for selected southern localities in 1990, 1991, and 1993 and three selected localities in 2002. In most cases a single set was conducted within each depth stratum for a given locality (Haist et al. 2005, Wyeth et al. 2006).

The survey catch rate values reported in Table A-3 are the arithmetic mean of the catch per trap (kg/trap) for depth intervals D1-D5 as was the practice of Haist et al. (2005) who determined general linear model standardization had little effect. The distributions of catch rates for each set by year are depicted using boxplots in Figure A-3. The upper panel of Figure A-3 shows the catch rates in units of numbers per trap while the lower panel is presented as weight (kg) per trap. The coast-wide trends of survey catch rates show a decline from high values in the early 1990s to a period of relative stability beginning in the mid-1990s. The 2001 survey produced the lowest mean and median catch rates observed in the time series, with marked reduction of the variance. Catch rates improved from 2001 to 2002 to a level similar to those observed in the mid-1990s. The catch rates in 2003 and 2004 were similar and both years were substantially higher than those observed from the mid-1990s through 2000. Since 2003 catch rates have steadily declined to 2007 and are now at level comparable to the mid to late 1990s. The 2007 survey index value is approximately 40% lower than the 2006 index value.

Although not used for assessment of the offshore component of sablefish in B.C., a survey conducted at four mainland inlets since 1995 shows a similar decline in mean catch rates but beginning in 2004 (Figure A-4). The mainland inlets have been closed to directed sablefish fishing since 1995 although minor amounts of sablefish may now be intercepted by non-directed fishing under the Groundfish Pilot Integration Proposal. Five sets are conducted annually at each inlet as described by Wyeth et al. (2006).

A second annual fishery-independent survey that follows a depth and area stratified random sampling (StRS) design was initiated in 2003, initially for the purposes of distributing tags coast-wide at random locations over five area strata and three depth strata of the offshore habitat range of sablefish (i.e., 183 to 1372 m; Wyeth et al. 2006). Fishing practices were standardized at the outset of the survey in hopes of yielding a second survey abundance index with statistical properties superior to the existing standardized survey. The stratified random survey annual index values were calculated (details not shown here) using the usual survey stratified random sampling estimator (e.g., Cochran 1979) and the stratum population sizes provided by Wyeth et al. (2006).

The StRS survey mean catch rate annual trend is shown in Figure A-5 and indicates a general decline over the short time series punctuated by high observation in 2006 (see Appendix E for a similar 2006 feature in the Gulf of Alaska longline survey). The 2007 stratified mean catch rate declined approximately 30% from the 2006 mean.

The design differences, as well as increased sample size for the stratified random survey (75 to 90 sets per year), mean that the two surveys may react differently in response to changes in actual stock abundance. Potential differences between these surveys may not become apparent until major changes (increases or decreases) in abundance occur in the sablefish stock. At this time we have not conducted assessments using the stratified random survey because the time-series is short and ageing data for sablefish caught during this survey are not complete. We cannot place much meaning in the fact that the standardized and stratified random surveys show very similar average catch rates (Figure A-5). The two surveys use different baits and follow very different sampling designs. The stratified random survey uses a combination of squid and hake bait, which is similar to commercial trap fishery baiting practices, while the standardized survey uses only squid bait. Trap escape rings are closed for both surveys.

We revised the data inputs to the operating models by removing the Japanese longline and tagging index of abundance used by Cox et al. (2008). Our original inclusion of the Japanese longline data was motivated by a desire to have stock index data early in the time series and because the trend appeared to coincide approximately, and plausibly, with abundance trends for the Gulf of Alaska sablefish stock. These data have been used in other assessments of B.C. sablefish (e.g., Stocker and Saunders 1997), but have very little influence on the fit of the operating models for this analyses. Although Cox et al. (2008) had fixed Japanese long-line selectivity at the values used for domestic longline gear, which may not be appropriate given the difference in gears, we elected to remove this data source until investigations into estimating selectivity parameters can be conducted.

Tagging data are attractive since they can provide direct estimates of abundance. However, the implications of time-varying and unknown reporting annual tag-reporting rates creates concerns about potential bias, in addition to possible failures of basic tagging assumptions such as random mixing/recovery discussed by Haist et al. (2004, 2005). Conclusions about the tagging index ultimately depend on assumptions about tag reporting rates as well as (*i*) movement, (*ii*) contagiously distributed tag recoveries, (*iii*) tag retention, (*iv*) tagging mortality, (*v*) tag reporting rate, and (*vi*) sort/grading effects as fisherman sort through fish to be discarded to retain tags. For these reasons we have removed the relative tagging index from the operating model. Furthermore, it is a non-trivial exercise to simulate realistic tag-recovery data generation in the operating model. Extensions of the work by Mathur (2007), which simulated the tag release-recovery process and estimation procedures, might be undertaken in future work and allow robustness testing of the procedures against the uncertainties in abundance trends derived from tagging data. However, the tag-recovery data are retained for use in the estimation of gear selectivity parameters provided to both the operating model and to the catch-age model used by model-based procedures.

Age proportions from commercial trap fishery and standardized trap survey sources are provided in Table A-4. Ages readings obtained using the burnt-otolith section method were pooled by sex. The first age class was set to 3 and a plus group was created for age 25 fish and older. Samples from trap gear fishing were included provided they were not obtained at seamounts or inshore waters (e.g., mainland inlets). Samples were excluded if the sample type code was “selected” or “stratified”, i.e., only “total catch” and “random samples” were included. In comparison to Cox et al. (2008) we removed some commercial ageing data from 1980, 1981, 1982, and 1983 that were not random or total catch samples. Trap survey samples were limited to those collected from the standardized trap survey (Wyeth et al. 2006) and commercial trap fishery samples were included if the trip type was “observed commercial” or “non-observed commercial”. Age proportions and sample sizes by source are listed in Table A-4. Figure A-6 shows the age frequency distributions obtained from commercial trap fishery samples and those obtained from the standardized trap survey are presented as Figure A-7.

Length-at-age 1 reported in the literature from Gulf of Alaska sablefish ranges from 31 to 39 cm fork length (Sigler et al. 2001). McFarlane and Beamish (1983) reported 28 cm fork length for the 1977 year class by November at the end of their first year of growth, 31 to 33 cm fork length by the following spring, 37 cm by September and 39.7 cm by November of the second year of growth, i.e., an age 1+ sablefish. Specimens of age 1+ in the database averaged 40.7 cm fork length but were largely collected in the fall and were therefore closer in size to an age-2 fish early in the calendar year. Lacking specimens of age-1+ fish collected early in the calendar year, we fixed the length at age1 to 35 cm and determined the corresponding growth parameters for use in the simulations (Appendices C and D).

A suite of multi-species bottom trawl surveys was initiated in 2003 as a collaborative effort between DFO and the Canadian Groundfish Research and Conservation Society (see for example, Olsen et al. 2007a,b,c, Stanley et al. 2007, Workman et al. 2007, 2008a,b). These surveys provide high density coverage (approx. 200+ trawl sets each) using depth-stratified random sampling designs for Queen Charlotte Sound (QCS, Major Areas 5AB, 37-543 m), Hecate Strait (HS, Major Areas 5CD, 11-230 m), West Coast Queen Charlotte Islands (WCQCI, Major Area 5E, 180-1800 m) and the West Coast of Vancouver Island (WCVI, Major Area 3CD, 46-750 m). Intended to be conducted every second year in each area, the QCS survey benefited from three successive survey years from 2003 to 2005 before adopting a biennial schedule. Swept-area (relative) biomass estimates can be developed from these surveys for many species including sablefish. Although we do not yet include these indices in formal analyses due to the brevity of the time series, they are presented here in anticipation of future use in sablefish assessments.

Table A-5 contains the results of 1,000 bootstrap replications of the catch rates expanded for area swept (Norm Olsen, *pers. comm.*). The biomass estimates are bias-corrected and lower and upper confidence intervals are bounded by the 5^{th} and 95^{th} percentiles of the bootstrap distributions. The “Catch Weight” column of Table A-5 is the sum of the total sablefish catch (kg), with the total number of survey sets and the number of sets containing positive catches of sablefish shown. Roughly half the survey sets encounter sablefish across survey areas and years. The bootstrap estimates are plotted in Figure A-8. The qualitative trend for the QCS survey is a modest increase in biomass from 2003 to 2004 followed by lower biomass index values in 2005 and 2007. The brevity of the series for other areas precludes speculation on trend, but all biomass estimates show the expected proportionality between the magnitude of the biomass estimate and variance.

Table A-1 Summary of management history. Note that the 1999/2000 fishing year was 19 months in duration to accommodate a shift in the fishing year from Jan 1 to August 1. Preliminary data for 2007/2008 current as of September 2007.

Year	Fishery	Assessment Yield Rec.	TAC	K Quota	T Quota	First Nations	Research	Landings FY	Date Open	Date Closed	Days Open	FY Days
1981	Derby		3500	3190	310			3830	01-Feb-81	04-Oct-81	245	245
1982	Derby		3500	3190	310			4028	01-Feb-82	22-Aug-82	202	202
1983	Derby		3500	3190	310			4346	01-May-83	26-Sep-83	148	148
1984	Derby		3500	3190	310			3827	01-Mar-84	22-Aug-84	174	174
1985	Derby		4000	3650	350			4193	01-Feb-85	08-Mar-85	35	92
									29-Mar-85	02-May-85	34	
									19-Jul-85	11-Aug-85	23	
1986	Derby		4000	3650	350			4449	17-Mar-86	21-Apr-86	35	63
									12-May-86	09-Jun-86	28	
1987	Derby		4100	3740	360			4630	16-Mar-87	10-Apr-87	25	45
									01-Sep-87	21-Sep-87	20	
1988	Derby		4400	4015	385			5403	06-Mar-88	26-Mar-88	20	140
									05-Apr-88	25-Apr-88	20	
									05-May-88	25-May-88	20	
									05-Jun-88	25-Jun-88	20	
									05-Jul-88	25-Jul-88	20	
									02-Aug-88	22-Aug-88	20	
									04-Sep-88	24-Sep-88	20	
1989	Derby		4400	4015	385			5324	14-Feb-89	28-Feb-89	14	112
									14-Mar-89	28-Mar-89	14	
									14-Apr-89	28-Apr-89	14	
									10-May-89	24-May-89	14	
									10-Jun-89	24-Jun-89	14	
									06-Jul-89	20-Jul-89	14	
									04-Aug-89	18-Aug-89	14	
									15-Sep-89	29-Sep-89	14	
1990	IVQ		4670	4260	410			4905	21-Apr-90	31-Dec-90	255	255
1991	IVQ	2,900-5,000	5000	4560	440			5112	01-Jan-91	31-Dec-91	365	365

Year	Fishery	Assessment Yield Rec.	TAC	K Quota	T Quota	First Nations	Research	Landings FY	Date Open	Date Closed	Days Open	FY Days
1992	IVQ	2,900-5,000	5000	4560	440			5007	01-Jan-92	31-Dec-92	366	366
1993	IVQ	2,900-5,000	5000	4560	440			5110	01-Jan-93	31-Dec-93	365	365
1994	IVQ	2,900-5,000	5000	4521	433			5002	01-Jan-94	31-Dec-94	365	365
1995	IVQ	2,725-5,550	4140	3709	356		29.48	4179	01-Jan-95	31-Dec-95	365	365
1996	IVQ	690-2,580	3600	3169	304		81.65	3471	01-Jan-96	31-Dec-96	366	366
1997	IVQ	6,227-16,285	4500	4023	386		45.36	4142	01-Jan-97	31-Dec-97	365	365
1998	IVQ	3,286-4,761	4500	4023	386		45.36	4592	01-Jan-98	31-Dec-98	365	365
1999/ 2000*	IVQ	2,977-5,052	4500	6395	386		45.36	7012	**01-Jan-99**	**31-Jul-00**	578	578
2000/ 2001	IVQ	3,375-5,625	4000	3555	350		45.36	3884	01-Aug-00	31-Jul-01	365	365
2001/ 2002	IVQ	4,000	2800	2657	342	45	45.36	3075	01-Aug-01	31-Jul-02	365	365
2002/ 2003	IVQ	4,000, revised to 2100-2800	2450	1883	206	45	45	2206	01-Aug-02	31-Jul-03	365	365
2003/ 2004	IVQ	Decision table	3000	2647	254	45	54	2983	01-Aug-03	31-Jul-04	365	365
2004/ 2005	IVQ	Decision table	4500	3995	384	45	75	4249	01-Aug-04	31-Jul-05	365	365
2005/ 2006	IVQ	Decision table	4600	4056	389	45	110	4498	01-Aug-05	31-Jul-06	365	365
2006/ 2007	IVQ	No Assessment	3900	3417	328	45	110	3950	01-Aug-06	31-Jul-07	365	365
2007/ 2008	IVQ	No Assessment	3300	2938	282	45	35	-	01-Aug-07	31-Jul-08	365	365

Table A-2 Annual sablefish landings (t) in Canadian waters by source from 1965-2007.

Year	Trap	Res. Trap	Japan LL	ROK LL	Longline	Trawl	US (Trawl)	USSR Trawl	Other	Total
1965					193	262	92		0	547
1966			174		326	312	95		0	907
1967			1189		253	139	65		0	1646
1968			2390		292	167	65		15	2929
1969			4720		162	148	43		1	5074
1970			5142		142	166	104		1	5554
1971			3050		123	189	161			3523
1972			4236		400	688	582			5906
1973	746		2950		120	83	82	6		3986
1974	327		3866	129	41	122	227	65	2	4779
1975	469		4702	1263	152	280	541		1	7408
1976	303		3494	2335	89	382	473		0	7077
1977	215		2961	186	77	787	571		7	4803
1978	635		2103		57	131	948		8	3881
1979	1480		1112		277	276	1236		6	4387
1980	3211		199		249	335	317		3	4314
1981	3275				326	229				3830
1982	3438				344	246			0	4028
1983	3611				451	274			11	4347
1984	3275				365	187				3827
1985	3501				458	233				4193
1986	3277				619	552			1	4449
1987	2954				1269	407			1	4630
1988	3488				1274	637			3	5403
1989	3772				929	623			0	5324
1990	3072				1372	461				4905
1991	3494				1179	439			0	5112
1992	3710				849	449			0	5007
1993	4142				424	543			0	5110
1994	4051				468	483				5002
1995	3282				474	427			5	4189
1996	2984	15			279	191				3470
1997	3554	2			431	156				4142
1998	3772	0			444	376				4592
1999	3677	6			628	403				4714
2000	2745	13			752	326				3836
2001	2743	8			564	300				3614
2002	2159	20			564	267			0	3010
2003	1419	68			641	228				2355
2004	2129	48			467	345				2989
2005	3197	42			1147	277				4662
2006	2699	61			1329	445				4537
2007	2063	19			1042	287				3413

Table A-3 Landings (t) and stock indices input to the operating and assessment models.

Year	Time Step	Trap	Research Trap	Foreign Longline	Longline	Trawl	Total Landings	Fishery CPUE (kg/trap)	Survey CPUE (kg/trap)
1965	1	0	0	0	193.2	353.9	547.1		
1966	2	0	0	174	325.7	406.9	906.6		
1967	3	0	0	1189	252.9	203.6	1645.5		
1968	4	0	0	2390	292.3	232.0	2914.3		
1969	5	0	0	4720	162.3	191.3	5073.6		
1970	6	0	0	5142	142.1	269.9	5554.0		
1971	7	0	0	3050	123.0	350.3	3523.3		
1972	8	0	0	4236	399.7	1270.3	5906.0		
1973	9	745.8	0	2950	119.8	170.8	3986.4		
1974	10	327.1	0	3995	41.3	413.8	4777.2		
1975	11	469.4	0	5965	152.2	820.8	7407.4		
1976	12	303.4	0	5829	89.4	855.0	7076.8		
1977	13	214.6	0	3147	77.1	1357.5	4796.2		
1978	14	634.6	0	2103	57.2	1078.5	3873.3		
1979	15	1480.1	0	1112	276.8	1512.1	4381.0	17.661	
1980	16	3210.8	0	199	248.6	652.3	4310.7	15.312	
1981	17	3275.3	0	0	326.1	228.8	3830.2	15.056	
1982	18	3437.8	0	0	343.6	245.9	4027.3	16.973	
1983	19	3610.5	0	0	451.4	274.1	4336.0	16.819	
1984	20	3275.4	0	0	365.1	187.0	3827.5	13.059	
1985	21	3501.3	0	0	458.3	233.1	4192.7	17.687	
1986	22	3277.1	0	0	619.2	551.8	4448.1	15.602	
1987	23	2954.3	0	0	1268.6	406.9	4629.8	16.160	
1988	24	3488.5	0	0	1273.6	637.3	5399.4	24.736	
1989	25	3772.0	0	0	928.6	623.4	5324.0	25.695	
1990	26	3072.4	0	0	1371.8	460.7	4904.9	19.222	20.017
1991	27	3494.4	0	0	1179.2	438.8	5112.4	24.562	19.336
1992	28	3710.2	0	0	848.6	448.7	5007.5	24.730	25.569
1993	29	4142.4	0	0	424.2	543.1	5109.7	20.421	36.509
1994	30	4050.7	0	0	467.7	483.1	5001.5	18.300	15.571
1995	31	3282.2	0	0	474.3	427.4	4183.9	15.255	13.665
1996	32	2984.3	14.9	0	278.7	190.9	3468.8	14.928	11.258
1997	33	3553.6	1.5	0	430.6	156.3	4142.0	13.305	7.721
1998	34	3772.0	0	0	443.6	376.1	4591.7	13.387	12.037
1999	35	3677.3	5.7	0	627.9	403.0	4713.9	13.711	7.720
2000	36	2745.3	12.9	0	751.9	326.1	3836.2	12.456	9.296
2001	37	2742.8	7.5	0	564.4	299.6	3614.3	10.116	3.092
2002	38	2159.0	19.9	0	564.4	267.1	3010.4	9.650	8.206
2003	39	1419.2	67.5	0	640.5	227.6	2354.8	19.813	27.590
2004	40	2128.5	48.4	0	467.4	344.7	2989.0	13.194	26.415
2005	41	3196.5	41.6	0	1146.1	277.1	4661.7	11.846	19.432
2006	42	2699.0	61.1	0	1332.2	445.2	4537.1	10.194	17.382
2007	43	2062.8	18.8	0	1044.4	286.8	3412.8	9.707	10.406

Table A-4 Proportions at age (sexes pooled) and sample size (ages 3+) from commercial trap fishery and standardized survey samples.

	Age Class																						
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**N**
Trap																								
1979	0.002	0.002	0.004	0.000	0.002	0.012	0.014	0.027	0.052	0.052	0.039	0.075	0.068	0.079	0.073	0.073	0.077	0.052	0.056	0.031	0.046	0.041	0.122	517
1980	0.057	0.066	0.025	0.030	0.042	0.036	0.041	0.053	0.059	0.077	0.060	0.051	0.054	0.061	0.055	0.041	0.022	0.045	0.026	0.028	0.009	0.010	0.054	1123
1981																								
1982	0.009	0.022	0.075	0.058	0.033	0.031	0.042	0.036	0.031	0.051	0.038	0.056	0.031	0.038	0.025	0.031	0.018	0.031	0.020	0.038	0.013	0.022	0.251	550
1983	0.025	0.078	0.064	0.246	0.088	0.044	0.026	0.041	0.022	0.035	0.035	0.034	0.050	0.019	0.026	0.017	0.018	0.022	0.018	0.014	0.006	0.016	0.055	1162
1984																								
1985																								
1986																								
1987	0.010	0.026	0.126	0.127	0.148	0.182	0.157	0.068	0.024	0.015	0.011	0.007	0.005	0.004	0.006	0.002	0.013	0.010	0.005	0.005	0.006	0.005	0.040	842
1988	0.021	0.049	0.047	0.091	0.184	0.131	0.126	0.100	0.079	0.022	0.012	0.010	0.009	0.005	0.005	0.014	0.009	0.009	0.006	0.014	0.005	0.006	0.043	770
1989	0.025	0.006	0.009	0.019	0.050	0.071	0.118	0.134	0.102	0.075	0.050	0.025	0.012	0.006	0.016	0.019	0.003	0.037	0.012	0.009	0.009	0.006	0.186	322
1990																								
1991	0.074	0.093	0.096	0.107	0.067	0.084	0.060	0.089	0.060	0.063	0.063	0.037	0.012	0.004	0.007	0.004	0.011	0.005	0.009	0.005	0.005	0.009	0.039	571
1992	0.024	0.010	0.024	0.047	0.064	0.137	0.086	0.069	0.095	0.096	0.068	0.061	0.052	0.041	0.037	0.010	0.007	0.003	0.003	0.003	0.003	0.008	0.051	592
1993	0.099	0.089	0.057	0.067	0.086	0.081	0.082	0.056	0.068	0.054	0.040	0.038	0.042	0.025	0.015	0.016	0.007	0.008	0.005	0.005	0.001	0.001	0.057	1377
1994	0.042	0.115	0.103	0.053	0.088	0.058	0.063	0.053	0.064	0.037	0.042	0.049	0.029	0.032	0.031	0.024	0.015	0.016	0.007	0.007	0.006	0.005	0.060	862
1995	0.008	0.045	0.152	0.066	0.033	0.053	0.065	0.079	0.054	0.051	0.037	0.042	0.038	0.032	0.030	0.037	0.020	0.024	0.004	0.011	0.004	0.005	0.111	837
1996	0.010	0.030	0.060	0.107	0.082	0.044	0.045	0.056	0.058	0.058	0.044	0.046	0.041	0.045	0.042	0.039	0.034	0.023	0.010	0.006	0.003	0.003	0.117	711
1997																								
1998	0.011	0.037	0.037	0.064	0.103	0.112	0.078	0.070	0.059	0.050	0.029	0.032	0.025	0.023	0.020	0.016	0.034	0.020	0.029	0.005	0.009	0.018	0.119	561
1999	0.000	0.051	0.063	0.071	0.090	0.101	0.099	0.080	0.054	0.039	0.037	0.023	0.031	0.017	0.014	0.019	0.012	0.025	0.014	0.020	0.014	0.008	0.118	646
2000	0.017	0.055	0.199	0.177	0.083	0.062	0.073	0.076	0.038	0.036	0.019	0.016	0.012	0.023	0.005	0.019	0.003	0.021	0.005	0.014	0.003	0.002	0.040	577
2001																								
2002	0.048	0.102	0.161	0.108	0.089	0.041	0.033	0.039	0.033	0.043	0.030	0.007	0.022	0.022	0.007	0.011	0.004	0.009	0.022	0.013	0.013	0.017	0.128	461

												Age Class												
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**N**
Survey																								
1990	0.081	0.097	0.068	0.039	0.042	0.046	0.031	0.038	0.038	0.016	0.022	0.012	0.005	0.011	0.005	0.001	0.008	0.015	0.008	0.009	0.011	0.015	0.381	740
1991	0.033	0.039	0.063	0.089	0.088	0.073	0.073	0.063	0.092	0.045	0.053	0.032	0.016	0.006	0.009	0.008	0.009	0.005	0.006	0.004	0.005	0.009	0.183	1044
1992	0.041	0.025	0.054	0.073	0.089	0.080	0.071	0.054	0.054	0.057	0.044	0.043	0.027	0.021	0.012	0.008	0.009	0.006	0.007	0.003	0.007	0.008	0.205	1784
1993	0.095	0.079	0.054	0.065	0.067	0.078	0.067	0.046	0.037	0.049	0.048	0.042	0.031	0.024	0.021	0.011	0.010	0.003	0.006	0.003	0.003	0.003	0.158	1744
1994	0.031	0.092	0.070	0.057	0.061	0.052	0.058	0.056	0.049	0.044	0.043	0.041	0.034	0.035	0.024	0.024	0.013	0.011	0.012	0.010	0.008	0.008	0.167	2053
1995	0.009	0.065	0.136	0.103	0.049	0.047	0.043	0.050	0.050	0.030	0.032	0.042	0.035	0.040	0.026	0.020	0.018	0.011	0.010	0.006	0.008	0.007	0.162	1706
1996	0.016	0.038	0.080	0.109	0.068	0.036	0.049	0.037	0.036	0.038	0.038	0.032	0.035	0.042	0.035	0.031	0.027	0.020	0.014	0.009	0.006	0.006	0.199	976
1997	0.055	0.044	0.066	0.126	0.192	0.055	0.077	0.055	0.044	0.027	0.011	0.022	0.022	0.011	0.022	0.022	0.022	0.022	0.005	0.000	0.005	0.005	0.088	182
1998																								
1999	0.025	0.057	0.085	0.074	0.068	0.045	0.085	0.030	0.025	0.036	0.045	0.021	0.025	0.023	0.030	0.034	0.023	0.026	0.019	0.008	0.008	0.002	0.208	529
2000	0.017	0.004	0.154	0.056	0.034	0.021	0.056	0.047	0.021	0.013	0.021	0.026	0.021	0.017	0.009	0.017	0.013	0.017	0.030	0.017	0.021	0.017	0.350	234
2001																								
2002	0.030	0.069	0.082	0.084	0.096	0.057	0.029	0.020	0.028	0.030	0.027	0.014	0.023	0.013	0.016	0.015	0.017	0.010	0.018	0.012	0.015	0.017	0.278	866
2003	0.095	0.116	0.147	0.104	0.039	0.064	0.056	0.017	0.031	0.017	0.015	0.010	0.025	0.010	0.010	0.010	0.015	0.012	0.012	0.012	0.010	0.015	0.156	482
2004	0.038	0.177	0.179	0.136	0.086	0.077	0.038	0.010	0.029	0.010	0.010	0.007	0.000	0.012	0.002	0.005	0.005	0.010	0.012	0.005	0.005	0.012	0.136	418
2005																								
2006	0.015	0.015	0.100	0.284	0.108	0.097	0.081	0.051	0.022	0.018	0.012	0.010	0.007	0.007	0.006	0.009	0.010	0.013	0.006	0.003	0.009	0.009	0.105	668

Table A-5 Estimated biomass (kg) indices for sablefish in four multi-species groundfish trawl surveys derived from 1,000 bootstrap replications.

Survey	Biomass	Lower Confidence Interval (5%)	Upper Confidence Interval (95%)	Bootstrap Relative Error	Catch Weight (kg)	N	Number of Sets with Positive Catches
2006 WQQCI (2007 stratification)	819,626.8	293,284.9	2,451,298.3	0.521	2,394.7	96	64
2007 WCQCI	555,447.8	388,352.0	757,735.8	0.167	1,314.6	112	68
2007 Hecate Strait	858,613.6	562,654.8	1,235,239.4	0.198	408.8	143	53
2003 QCS	1,168,089.2	934,777.8	1,533,648.8	0.127	1,966.3	235	133
2004 QCS	1,780,986.3	1,168,436.5	2,979,729.4	0.235	2,163.5	233	108
2005 QCS	1,126,702.1	851,923.8	1,584,318.9	0.156	1,589.0	224	126
2007 QCS	881,736.7	713,652.4	1,162,607.6	0.121	1,180.6	257	114
2005 Hecate Strait	2,720,402.9	1,652,120.3	4,519,376.2	0.259	2,969.6	226	84
2004 WCVI	4,589,873.8	2,642,678.2	7,996,562.6	0.287	5,801.9	90	58
2006 WCVI	1,939,805.0	1,430,041.4	2,621,514.5	0.150	4,826.2	166	81
2004 WCVI (Triennial Region)	1,783,055.9	1,037,663.9	3,394,480.7	0.292	1,818.0	60	39
2006 WCVI (Triennial Region)	1,058,067.5	736,306.4	1,657,299.6	0.197	2,831.6	108	51

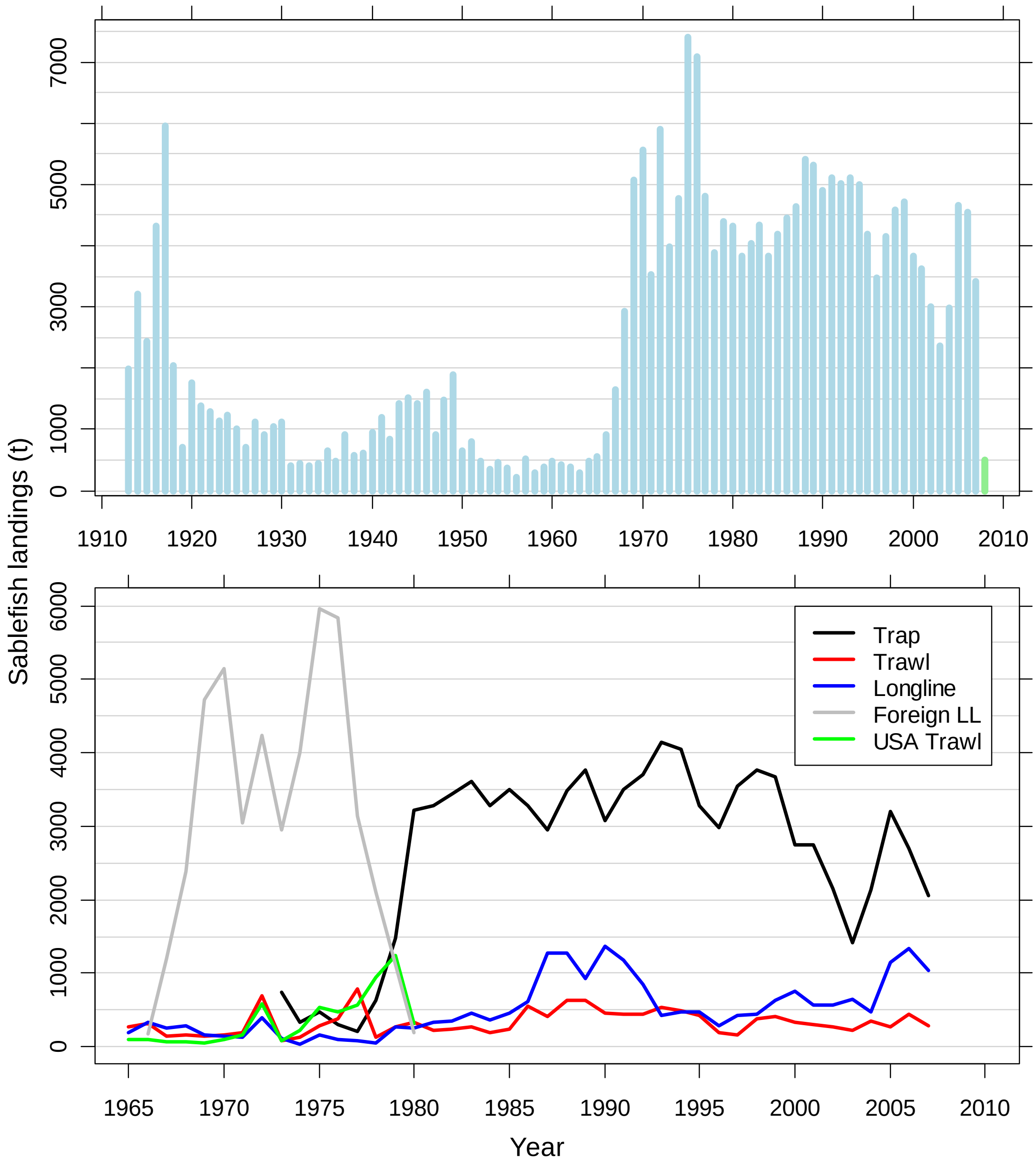

Figure A-1 Annual sablefish landings (t) from 1913 to 2007 from all sources (top panel). Annual landings by gear type for the period 1965 to 2007 are shown in the bottom panel. Landings for 2008 are reported to April 2008 and are preliminary data.

Figure A-2 Nominal and GLM standardized fishery retained catch rate relative indices. The GLM standardized series has been scaled to the mean of the nominal series over the years of overlap. The vertical dashed line indicates the adoption of escape rings in traps.

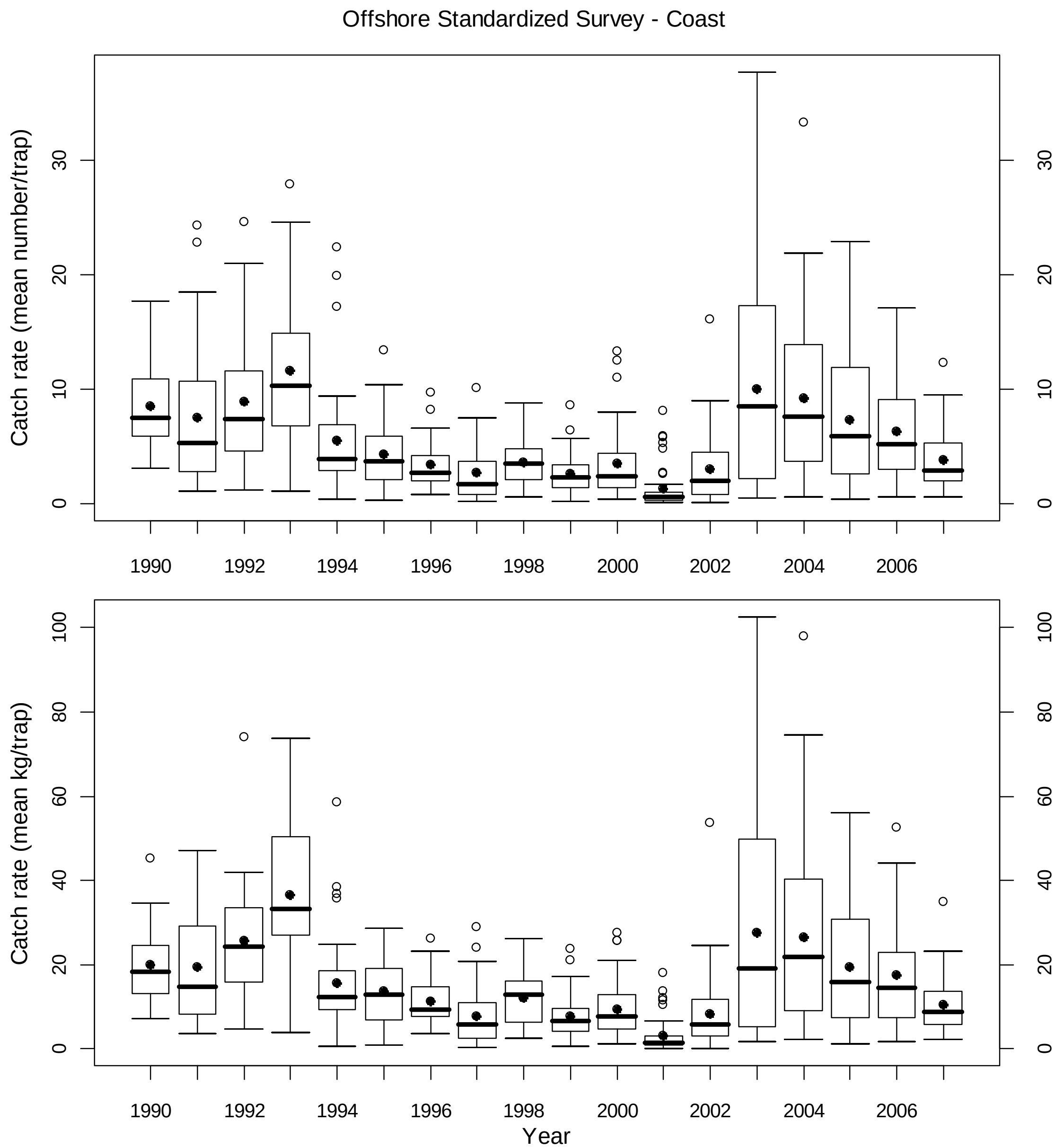

Figure A-3 Distribution of catch rates summarized by boxplots for offshore standardized survey sets over time. Catch rates are shown in units of numbers per trap (upper panel) and kg per trap (lower panel). The median catch rates (thick horizontal lines) and mean catch rates (solid circles) are shown. The box limits indicate the 25th and 75th percentiles of the catch rate distribution with upper and lower whiskers at 1.5 times the inter-quartiles range. Outliers are shown as open circles.

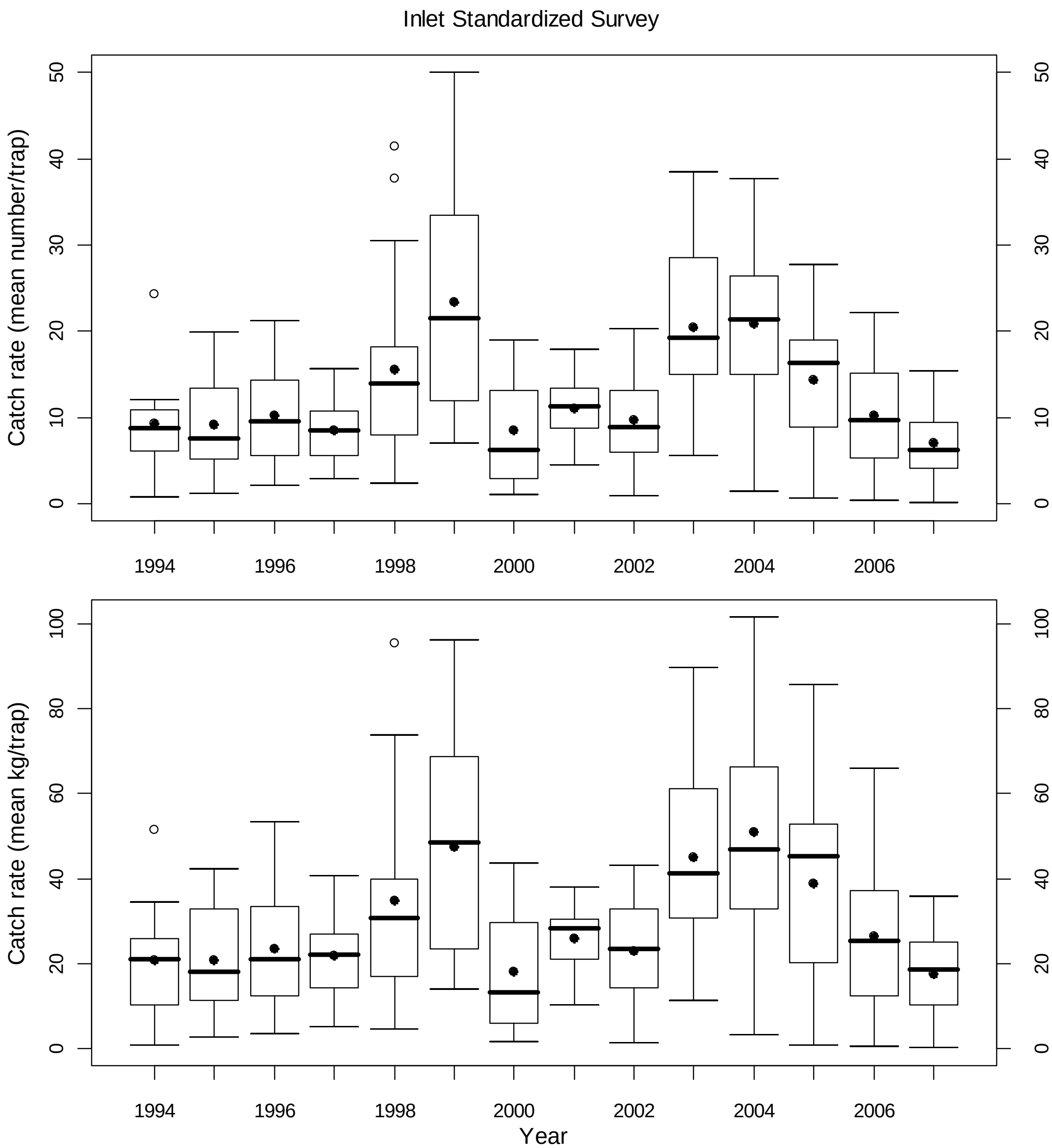

Figure A-4 Distribution of catch rates summarized by boxplots for inlets survey sets over time. Catch rates are shown in units of numbers per trap (upper panel) and kg per trap (lower panel).). The median catch rates (thick horizontal lines) and mean catch rates (solid circles) are shown. The box limits indicate the 25th and 75th percentiles of the catch rate distribution with upper and lower whiskers at 1.5 times the inter-quartiles range. Outliers are shown as open circles.

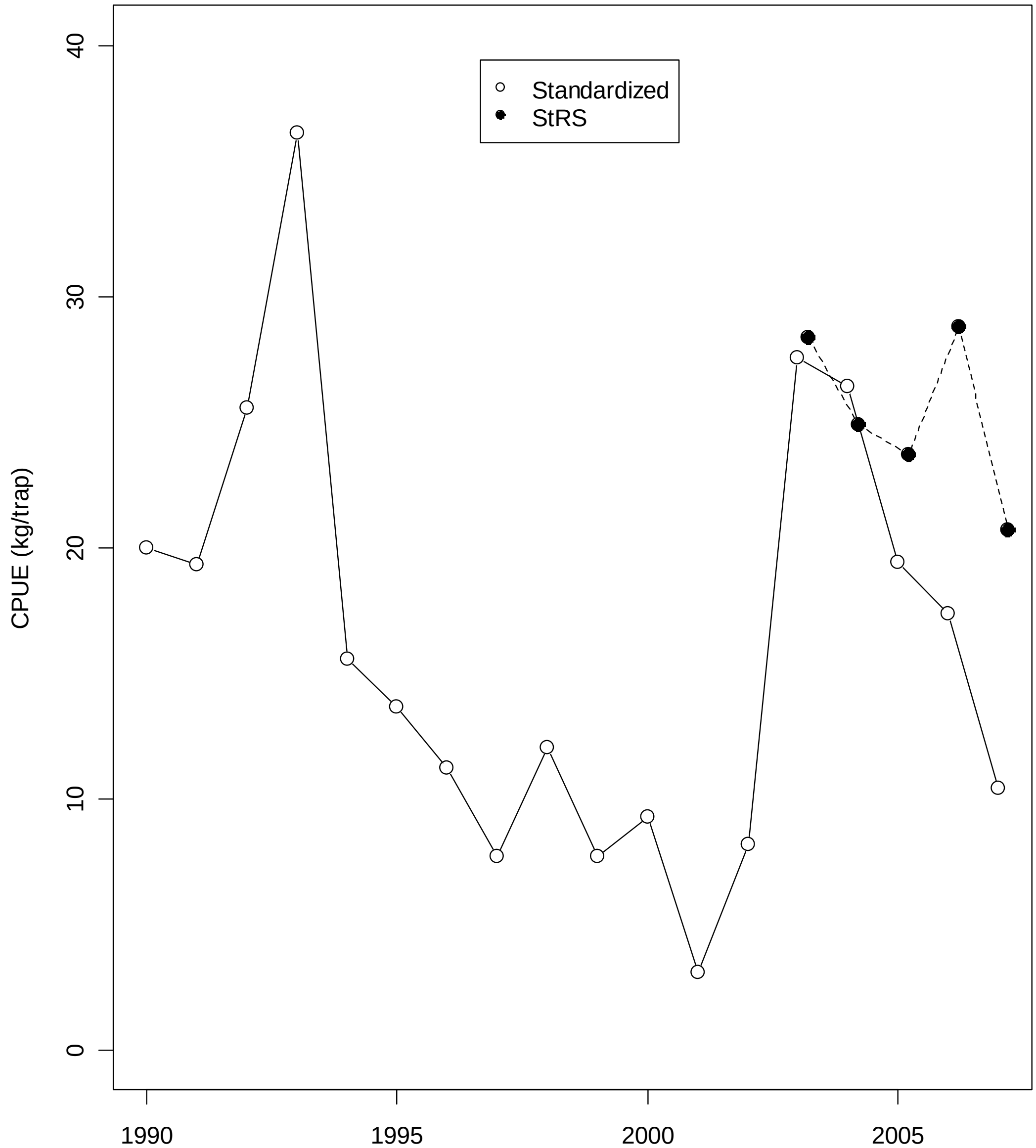

Figure A-5 Standardized trap survey mean catch rates (open circles) compared with catch rates .

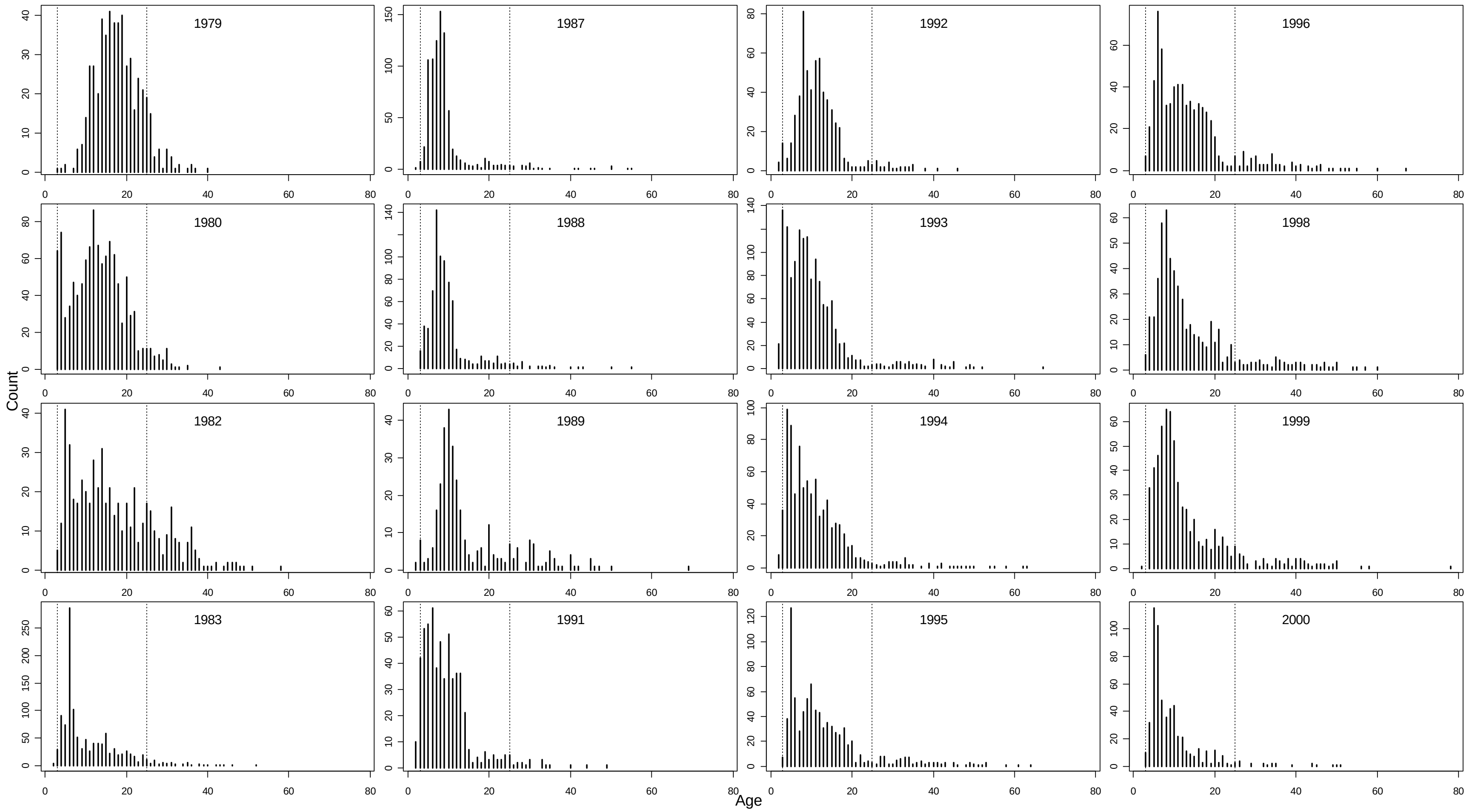

Figure A-6 Age frequency distributions for commercial trap fishery samples by year. The vertical dotted lines indicate age classes 3 and 25.

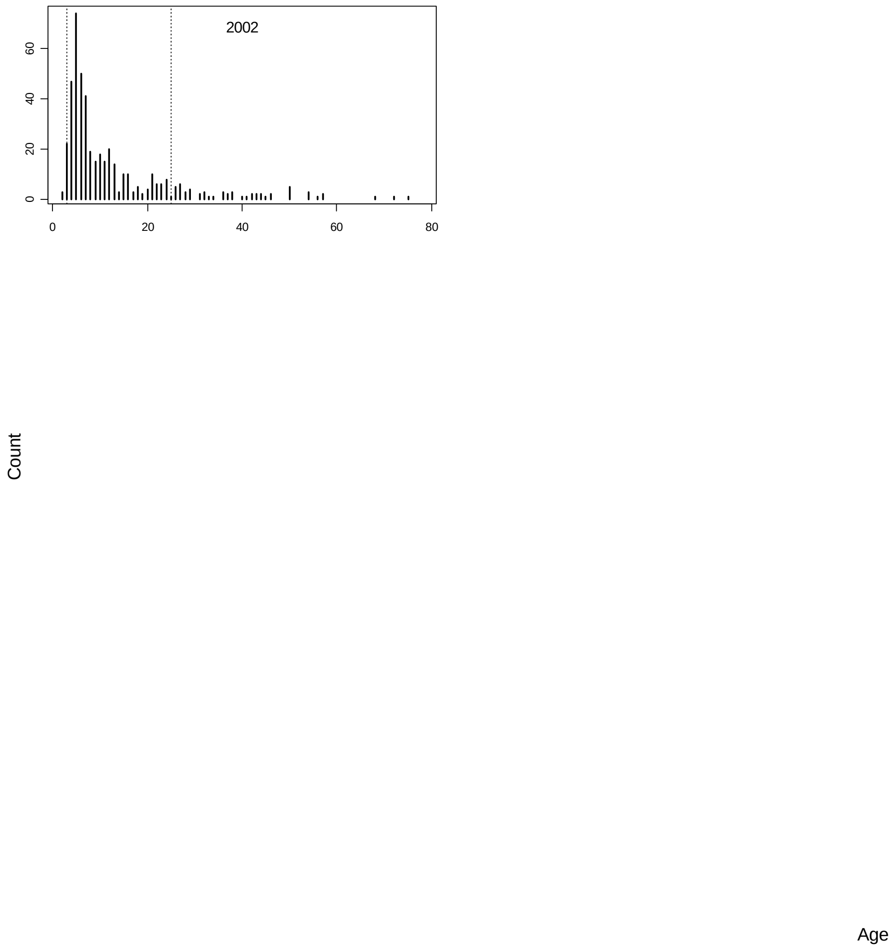

Figure A-6 continued.

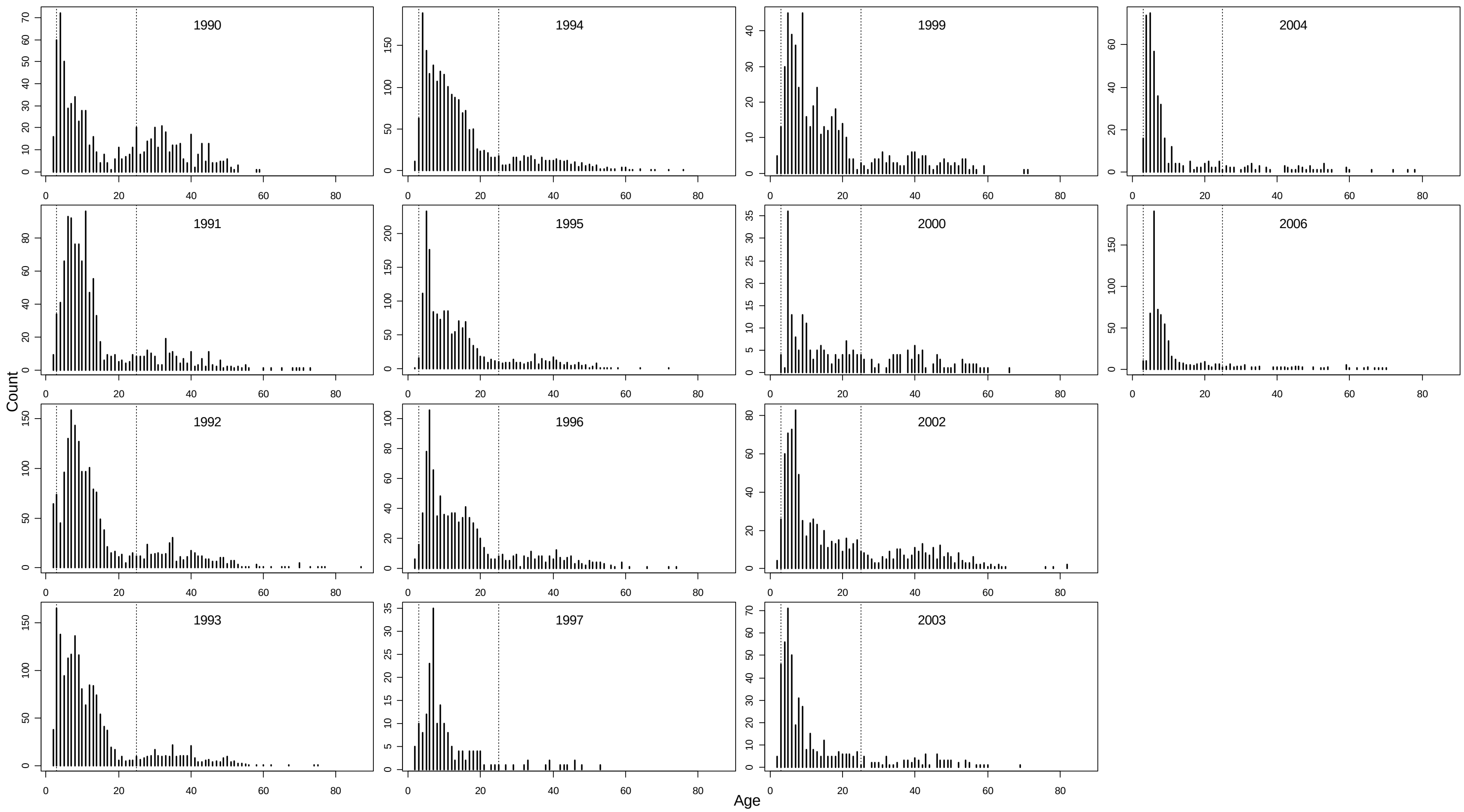

Figure A-7 Age frequency distributions for standardized trap survey samples by year. The vertical dotted lines indicate age classes 3 and 25.

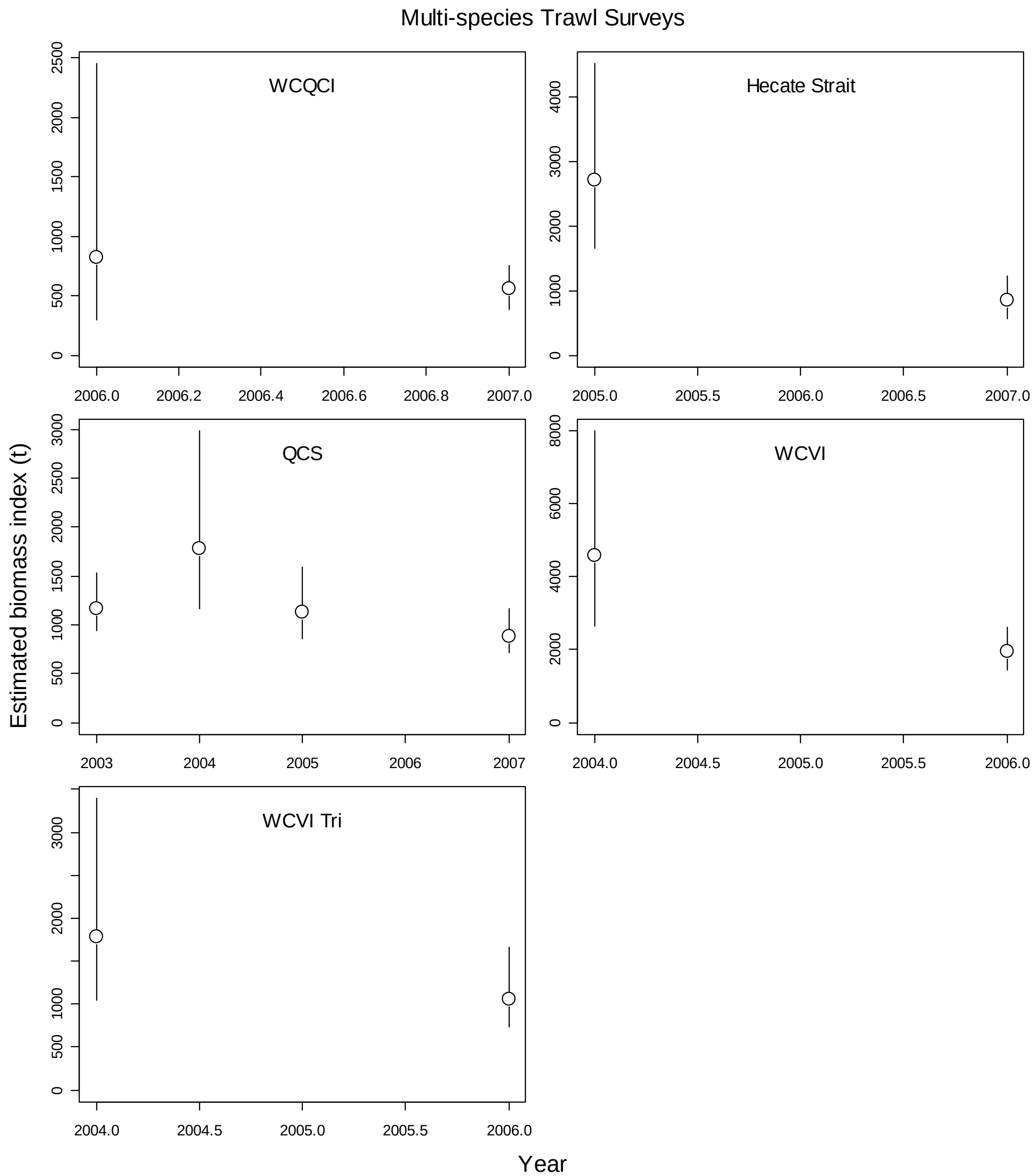

Figure A-8 Estimated sablefish relative biomass index values (circles) with lower 5% and upper 95% percentiles of 1,000 bootstrap replications for four multi-species groundfish bottom trawl surveys. The label WCVI Tri denote the West Coast Vancouver Island survey stratified to mimic the coverage of the NMFS Triennial survey.

Appendix B Performance Statistics

This appendix provides tabular and graphical performance summaries for selected data-based and all catch-age model based procedures listed in Table 3. Performance measures related to conservation objectives and selected statistics at (*i*) projection year 10 year and (*ii*) over 1-10 years are provided for data-based rules in Table B-1 and Table B-2 for scenarios S3 and S4. Similar results for catch-age procedures applied to scenarios S3 and S4 are listed in Table B-3. These tables are the companions to those described in detail in the main body of the document for scenarios S1 and S2.

Performance measures (Table 4) are computed for non-overlapping time blocks corresponding to projection years 1-5, 6-10, 11-20 and 21-40. The performance statistics represent the median value of statistics calculated for each of 100 simulation replicates. Selected results for data-based procedures are presented in Table B-4 through Table B-7 for each of the scenarios S1 through S4. Because of the volume of output and the number of data-based procedures evaluated, we restricted the time periods to projection years 6-10 and 11-20 for scenarios S1 and S2. Full results for all time periods and scenarios are available upon request. Results for catch-age model-based procedures are presented in Table B-8 through Table B-11 for scenarios S1 through S4, respectively, and for projection years 1-5, 6-10, 11-20 and 21-40.

This appendix also includes companion figures to those described in detail for scenarios S1 and S2 in the main body of the paper. These graphical analyses include:

1. Spawning biomass depletion and catch simulation envelopes for selected data-based procedures within the DB_{150} family (Figure B-1, Figure B-2) and catch-age model based procedures with U^{ref}=0.06 (Figure B-3, Figure B-4) as applied to scenarios S3 and S4;
2. Distributions of average spawning biomass depletion, catch volatility, and catch by data-based (Figure B-5, Figure B-6) and catch age model-based (Figure B-7, Figure B-8) procedures as applied to scenarios S3 and S4.

Table B-1 Performance statistics for data-based procedures applied to scenario S3.

Procedure	Median depletion at yr 10	$T_{0.2}$ 90%	T_{init} 90%	2008 Catch	Median average catch (1-10 yrs)	Median catch at yr 10	Median minimum catch (1-10 yrs)	Max. avg. catch $\overline{C}_{0.95}$ (1-10 yrs)
$DB_{120,1500t}$ λ_1=0.5 {4,15}	0.326	1	1	1500	1466	2019	1003	1919
$DB_{120,1900t}$ λ_1=0.5 {4,15}	0.323	2	1	1900	1526	1992	1038	1981
$DB_{120,2300t}$ λ_1=0.5 {4,15}	0.319	2	2	2300	1586	1966	1042	2042
$DB_{120,2700t}$ λ_1=0.5 {4,15}	0.316	3	2	2700	1645	1938	1047	2103
DB_{120} λ_1=0.5 {4,15}	0.317	3	2	2649	1637	1941	1045	2095
$DB_{120,15\%}$ λ_1=0.5 {4,15}	0.303	3	3	2901	1864	1772	1299	2196
$DB_{150,1500t}$ λ_1=0.5 {4,15}	0.314	1	1	1500	1738	2461	1198	2298
$DB_{150,1900t}$ λ_1=0.5 {4,15}	0.311	2	1	1900	1792	2427	1236	2356
$DB_{150,2300t}$ λ_1=0.5 {4,15}	0.308	2	2	2300	1844	2393	1247	2413
$DB_{150,2700t}$ λ_1=0.5 {4,15}	0.305	3	2	2700	1897	2359	1239	2469
DB_{150} λ_1=0.5 {4,15}	0.304	3	3	2885	1919	2343	1241	2495
$DB_{150,15\%}$ λ_1=0.5 {4,15}	0.295	3	3	2901	2017	2096	1465	2530
$DB_{180,1500t}$ λ_1=0.5 {4,15}	0.303	1	1	1500	1998	2875	1398	2668
$DB_{180,1900t}$ λ_1=0.5 {4,15}	0.300	2	1	1900	2047	2836	1428	2721
$DB_{180,2300t}$ λ_1=0.5 {4,15}	0.297	2	2	2300	2091	2796	1435	2772
$DB_{180,2700t}$ λ_1=0.5 {4,15}	0.294	3	3	2700	2136	2746	1439	2821
DB_{180} λ_1=0.5 {4,15}	0.291	4	3	3120	2186	2696	1434	2873
$DB_{180,15\%}$ λ_1=0.5 {4,15}	0.285	5	4	3120	2240	2376	1629	2843
$DB_{150,1900t}$ λ_1=0.2 {4,15}	0.310	2	1	1900	1832	2534	1056	2396
DB_{150} λ_1=0.2 {4,15}	0.307	2	2	2568	1879	2507	1049	2449
$DB_{180,1900t}$ λ_1=0.2 {4,15}	0.296	2	1	1900	2106	2953	1246	2779
DB_{180} λ_1=0.2 {4,15}	0.292	3	3	2945	2178	2905	1205	2847
$DB_{150,1900t}$ λ_1=0.5 {6,18}	0.325	2	1	1900	1512	2309	906	2174
$DB_{150,2300t}$ λ_1=0.5 {6,18}	0.322	2	2	2300	1564	2250	908	2224
DB_{150} λ_1=0.5 {6,18}	0.319	3	2	2660	1610	2191	911	2268
$DB_{180,1900t}$ λ_1=0.5 {6,18}	0.314	2	1	1900	1715	2647	1048	2498
$DB_{180,2300t}$ λ_1=0.5 {6,18}	0.311	2	2	2300	1761	2571	1052	2543
DB_{180} λ_1=0.5 {6,18}	0.307	3	3	2850	1822	2465	1044	2605
Constant Catch	0.229	26	23	3300	3300	3300	3300	3300

Table B-2 Performance statistics for data-based procedures applied to scenario S4.

Procedure	**Median depletion at yr 10**	**$T_{0.2}$ 90%**	**T_{init} 90%**	**2008 Catch**	**Median average catch (1-10 yrs)**	**Median catch at yr 10**	**Median minimum catch (1-10 yrs)**	**Max. avg. catch $\overline{C}_{0.95}$ (1-10 yrs)**
$DB_{120,1500t}$ λ_1=0.5 {4,15}	0.415	1	1	1500	1608	2066	1180	2159
$DB_{120,1900t}$ λ_1=0.5 {4,15}	0.412	1	1	1900	1671	2045	1219	2139
$DB_{120,2300t}$ λ_1=0.5 {4,15}	0.409	1	2	2300	1736	2024	1247	2300
$DB_{120,2700t}$ λ_1=0.5 {4,15}	0.406	1	3	2700	1801	2003	1256	2700
DB_{120} λ_1=0.5 {4,15}	0.407	1	3	2649	1793	2005	1254	2649
$DB_{120,15\%}$ λ_1=0.5 {4,15}	0.397	1	3	2901	1972	1931	1456	2901
$DB_{150,1500t}$ λ_1=0.5 {4,15}	0.402	1	1	1500	1915	2521	1404	2641
$DB_{150,1900t}$ λ_1=0.5 {4,15}	0.400	1	1	1900	1976	2493	1448	2615
$DB_{150,2300t}$ λ_1=0.5 {4,15}	0.397	1	2	2300	2038	2467	1473	2588
$DB_{150,2700t}$ λ_1=0.5 {4,15}	0.394	1	3	2700	2098	2441	1504	2700
DB_{150} λ_1=0.5 {4,15}	0.393	1	3	2885	2125	2429	1511	2885
$DB_{150,15\%}$ λ_1=0.5 {4,15}	0.390	1	3	2901	2183	2350	1655	2901
$DB_{180,1500t}$ λ_1=0.5 {4,15}	0.390	1	1	1500	2217	2948	1500	3097
$DB_{180,1900t}$ λ_1=0.5 {4,15}	0.387	1	1	1900	2275	2918	1688	3067
$DB_{180,2300t}$ λ_1=0.5 {4,15}	0.385	1	2	2300	2331	2887	1706	3036
$DB_{180,2700t}$ λ_1=0.5 {4,15}	0.382	1	3	2700	2386	2857	1736	3005
DB_{180} λ_1=0.5 {4,15}	0.379	1	7	3120	2443	2825	1746	3120
$DB_{180,15\%}$ λ_1=0.5 {4,15}	0.374	1	7	3120	2457	2695	1902	3120
$DB_{150,1900t}$ λ_1=0.2 {4,15}	0.398	1	1	1900	2030	2564	1286	2727
DB_{150} λ_1=0.2 {4,15}	0.395	1	3	2568	2086	2542	1275	2701
$DB_{180,1900t}$ λ_1=0.2 {4,15}	0.385	1	1	1900	2341	3003	1514	3200
DB_{180} λ_1=0.2 {4,15}	0.381	1	3	2945	2425	2964	1493	3156
$DB_{150,1900t}$ λ_1=0.5 {6,18}	0.415	1	1	1900	1704	2378	1097	2550
$DB_{150,2300t}$ λ_1=0.5 {6,18}	0.412	1	2	2300	1762	2344	1122	2518
DB_{150} λ_1=0.5 {6,18}	0.410	1	3	2660	1813	2313	1128	2660
$DB_{180,1900t}$ λ_1=0.5 {6,18}	0.404	1	1	1900	1951	2777	1259	2993
$DB_{180,2300t}$ λ_1=0.5 {6,18}	0.401	1	2	2300	2003	2728	1282	2949
DB_{180} λ_1=0.5 {6,18}	0.398	1	3	2850	2074	2656	1303	2886
Constant Catch	0.333	1	23	3300	3300	3300	3300	3300

Table B-3 Performance statistics for CA based procedures applied to scenarios S3 and S4.

Procedure	Median depletion at yr 10	$T_{0.2}$ 90%	T_{init} 90%	2008 Catch	Median average catch (1-10 yrs)	Median catch at yr 10	Median minimum catch (1-10 yrs)	Max. avg. catch $\overline{C}_{0.95}$ (1-10 yrs)
Scenario S3								
$CA_{0.04,1500t}$ {0.25,1.0}	0.327	1	1	1500	1470	1771	1120	1859
$CA_{0.04,1900t}$ {0.25,1.0}	0.326	2	1	1900	1495	1762	1098	1883
$CA_{0.04,2300t}$ {0.25,1.0}	0.325	2	2	2300	1517	1752	1077	1906
$CA_{0.04,2700t}$ {0.25,1.0}	0.323	2	2	2700	1542	1741	1055	1930
$CA_{0.04,15\%}$ {0.25,1.0}	0.307	3	3	2901	1784	1623	1165	2126
$CA_{0.06,1500t}$ {0.25,1.0}	0.303	1	1	1500	1974	2358	1500	2518
$CA_{0.06,1900t}$ {0.25,1.0}	0.302	2	1	1900	1992	2340	1565	2536
$CA_{0.06,2300t}$ {0.25,1.0}	0.301	2	2	2300	2008	2322	1535	2553
$CA_{0.06,2700t}$ {0.25,1.0}	0.299	3	2	2700	2024	2306	1502	2571
$CA_{0.06,15\%}$ {0.25,1.0}	0.294	3	3	2901	2123	2223	1566	2613
$CA_{0.08,1500t}$ {0.25,1.0}	0.280	1	1	1500	2404	2788	1500	3070
$CA_{0.08,1900t}$ {0.25,1.0}	0.279	3	1	1900	2417	2771	1900	3083
$CA_{0.08,2300t}$ {0.25,1.0}	0.278	3	3	2300	2430	2754	1923	3097
$CA_{0.08,2700t}$ {0.25,1.0}	0.277	4	3	2700	2441	2734	1881	3112
$CA_{0.08,15\%}$ {0.25,1.0}	0.276	7	4	2901	2481	2711	1924	3111
Scenario S4								
$CA_{0.04,1500t}$ {0.25,1.0}	0.409	1	1	1500	1792	2165	1382	2282
$CA_{0.04,1900t}$ {0.25,1.0}	0.408	1	1	1900	1821	2159	1362	2309
$CA_{0.04,2300t}$ {0.25,1.0}	0.406	1	2	2300	1847	2153	1341	2337
$CA_{0.04,2700t}$ {0.25,1.0}	0.405	1	2	2700	1874	2145	1321	2364
$CA_{0.04,15\%}$ {0.25,1.0}	0.397	1	3	2901	2056	2093	1515	2459
$CA_{0.06,1500t}$ {0.25,1.0}	0.379	1	1	1500	2451	2929	1500	3124
$CA_{0.06,1900t}$ {0.25,1.0}	0.378	1	1	1900	2476	2916	1900	3150
$CA_{0.06,2300t}$ {0.25,1.0}	0.377	1	3	2300	2501	2904	1963	3176
$CA_{0.06,2700t}$ {0.25,1.0}	0.376	1	3	2700	2524	2891	1934	3202
$CA_{0.06,15\%}$ {0.25,1.0}	0.373	1	9	2901	2549	2878	2052	3213
$CA_{0.08,1500t}$ {0.25,1.0}	0.351	1	1	1500	3029	3499	1500	3831
$CA_{0.08,1900t}$ {0.25,1.0}	0.351	1	1	1900	3044	3485	1900	3854
$CA_{0.08,2300t}$ {0.25,1.0}	0.350	1	15	2300	3059	3472	2300	3876
$CA_{0.08,2700t}$ {0.25,1.0}	0.349	1	15	2700	3073	3459	2459	3898
$CA_{0.08,15\%}$ {0.25,1.0}	0.348	1	15	2901	3107	3446	2469	3865

Table B-4 Summary of performance statistics by data-based management procedures for scenario S1 $\{h = 0.45, \hat{q}_{2,trap}\}$. Table values represent the median performance statistic for 100 replicates over projection times $t=t_1,\ldots t_2$.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S1	$DB_{120,1500t}$ λ_1=0.5 {4,15}	6	10	0.186	0.201	0.20	14.3	876	608	1489
S1	$DB_{120,1900t}$ λ_1=0.5 {4,15}	6	10	0.183	0.197	0.00	14.4	840	584	1451
S1	$DB_{120,2300t}$ λ_1=0.5 {4,15}	6	10	0.179	0.194	0.00	14.2	804	558	1408
S1	$DB_{120,2700t}$ λ_1=0.5 {4,15}	6	10	0.176	0.191	0.00	14.6	768	538	1363
S1	DB_{120} λ_1=0.5 {4,15}	6	10	0.176	0.191	0.00	14.5	773	540	1369
S1	$DB_{120,15\%}$ λ_1=0.5 {4,15}	6	10	0.151	0.164	0.00	15.6	986	772	1330
S1	$DB_{150,1500t}$ λ_1=0.5 {4,15}	6	10	0.180	0.193	0.00	14.3	1055	730	1808
S1	$DB_{150,1900t}$ λ_1=0.5 {4,15}	6	10	0.177	0.189	0.00	14.4	1009	696	1757
S1	$DB_{150,2300t}$ λ_1=0.5 {4,15}	6	10	0.174	0.186	0.00	14.3	963	664	1710
S1	$DB_{150,2700t}$ λ_1=0.5 {4,15}	6	10	0.170	0.183	0.00	14.7	917	639	1657
S1	DB_{150} λ_1=0.5 {4,15}	6	10	0.169	0.181	0.00	15.0	896	627	1626
S1	$DB_{150,15\%}$ λ_1=0.5 {4,15}	6	10	0.150	0.162	0.00	14.5	1037	871	1561
S1	$DB_{180,1500t}$ λ_1=0.5 {4,15}	6	10	0.174	0.184	0.00	14.3	1217	834	2114
S1	$DB_{180,1900t}$ λ_1=0.5 {4,15}	6	10	0.171	0.181	0.00	14.5	1159	800	2046
S1	$DB_{180,2300t}$ λ_1=0.5 {4,15}	6	10	0.168	0.178	0.00	14.7	1102	767	1977
S1	$DB_{180,2700t}$ λ_1=0.5 {4,15}	6	10	0.164	0.175	0.00	15.0	1048	735	1900
S1	DB_{180} λ_1=0.5 {4,15}	6	10	0.161	0.172	0.00	15.6	992	708	1820
S1	$DB_{180,15\%}$ λ_1=0.5 {4,15}	6	10	0.144	0.154	0.00	14.5	1120	953	1750
S1	$DB_{150,1900t}$ λ_1=0.2 {4,15}	6	10	0.179	0.190	0.00	20.4	1092	681	1958
S1	DB_{150} λ_1=0.2 {4,15}	6	10	0.176	0.187	0.00	20.6	1033	634	1895
S1	$DB_{180,1900t}$ λ_1=0.2 {4,15}	6	10	0.173	0.181	0.00	20.7	1248	778	2284
S1	DB_{180} λ_1=0.2 {4,15}	6	10	0.168	0.177	0.00	21.0	1141	702	2151
S1	$DB_{150,1900t}$ λ_1=0.5 {6,18}	6	10	0.187	0.203	0.20	18.5	719	448	1429
S1	$DB_{150,2300t}$ λ_1=0.5 {6,18}	6	10	0.184	0.199	0.10	18.8	682	422	1369
S1	DB_{150} λ_1=0.5 {6,18}	6	10	0.181	0.196	0.00	19.0	650	403	1313
S1	$DB_{180,1900t}$ λ_1=0.5 {6,18}	6	10	0.184	0.197	0.00	18.6	835	516	1644
S1	$DB_{180,2300t}$ λ_1=0.5 {6,18}	6	10	0.180	0.194	0.00	18.9	790	485	1574
S1	DB_{180} λ_1=0.5 {6,18}	6	10	0.176	0.190	0.00	19.1	727	448	1479
S1	Constant Catch	6	10	0.081	0.065	0.00	0.0	3300	3300	3300
S1	$DB_{120,1500t}$ λ_1=0.5 {4,15}	11	20	0.247	0.275	1.00	10.4	1569	1000	2364
S1	$DB_{120,1900t}$ λ_1=0.5 {4,15}	11	20	0.244	0.272	1.00	10.6	1527	955	2325
S1	$DB_{120,2300t}$ λ_1=0.5 {4,15}	11	20	0.241	0.269	0.90	10.9	1484	910	2284
S1	$DB_{120,2700t}$ λ_1=0.5 {4,15}	11	20	0.238	0.266	0.90	11.3	1442	871	2240
S1	DB_{120} λ_1=0.5 {4,15}	11	20	0.238	0.266	0.90	11.3	1447	876	2246
S1	$DB_{120,15\%}$ λ_1=0.5 {4,15}	11	20	0.217	0.249	0.60	10.9	1031	695	1935
S1	$DB_{150,1500t}$ λ_1=0.5 {4,15}	11	20	0.229	0.245	0.85	11.3	1834	1157	2814
S1	$DB_{150,1900t}$ λ_1=0.5 {4,15}	11	20	0.226	0.243	0.80	11.5	1784	1111	2764
S1	$DB_{150,2300t}$ λ_1=0.5 {4,15}	11	20	0.224	0.241	0.80	11.9	1737	1058	2711
S1	$DB_{150,2700t}$ λ_1=0.5 {4,15}	11	20	0.222	0.239	0.80	12.3	1691	1006	2655

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S1	DB_{150} λ_1=0.5 {4,15}	11	20	0.221	0.238	0.75	12.4	1668	983	2630
S1	$DB_{150,15\%}$ λ_1=0.5 {4,15}	11	20	0.211	0.238	0.60	10.8	1200	825	2315
S1	$DB_{180,1500t}$ λ_1=0.5 {4,15}	11	20	0.214	0.223	0.70	12.1	2058	1256	3193
S1	$DB_{180,1900t}$ λ_1=0.5 {4,15}	11	20	0.212	0.221	0.60	12.5	2004	1215	3134
S1	$DB_{180,2300t}$ λ_1=0.5 {4,15}	11	20	0.210	0.220	0.60	12.8	1947	1166	3073
S1	$DB_{180,2700t}$ λ_1=0.5 {4,15}	11	20	0.208	0.219	0.60	13.1	1888	1115	3011
S1	DB_{180} λ_1=0.5 {4,15}	11	20	0.205	0.217	0.60	13.5	1825	1056	2945
S1	$DB_{180,15\%}$ λ_1=0.5 {4,15}	11	20	0.197	0.222	0.40	11.0	1285	885	2614
S1	$DB_{150,1900t}$ λ_1=0.2 {4,15}	11	20	0.225	0.241	0.80	15.9	1921	1036	2874
S1	DB_{150} λ_1=0.2 {4,15}	11	20	0.222	0.239	0.80	16.2	1874	992	2820
S1	$DB_{180,1900t}$ λ_1=0.2 {4,15}	11	20	0.211	0.220	0.60	17.3	2124	1129	3227
S1	DB_{180} λ_1=0.2 {4,15}	11	20	0.207	0.217	0.60	17.7	2052	1055	3135
S1	$DB_{150,1900t}$ λ_1=0.5 {6,18}	11	20	0.246	0.264	1.00	15.0	1665	867	2774
S1	$DB_{150,2300t}$ λ_1=0.5 {6,18}	11	20	0.243	0.262	1.00	15.4	1606	825	2716
S1	DB_{150} λ_1=0.5 {6,18}	11	20	0.241	0.260	1.00	15.7	1554	792	2661
S1	$DB_{180,1900t}$ λ_1=0.5 {6,18}	11	20	0.235	0.247	0.90	15.8	1887	965	3162
S1	$DB_{180,2300t}$ λ_1=0.5 {6,18}	11	20	0.232	0.245	0.90	16.0	1825	927	3096
S1	DB_{180} λ_1=0.5 {6,18}	11	20	0.229	0.243	0.80	16.3	1743	854	3005
S1	Constant Catch	11	20	0.065	0.078	0.00	-	1320	0	3300

Table B-5 Summary of performance statistics by data-based management procedures for scenario S2 $\{h = 0.45, \hat{q}_{2,trap}\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S2	$DB_{120,1500t}$ λ_1=0.5 {4,15}	6	10	0.314	0.333	1	11.5	1436	1088	2007
S2	$DB_{120,1900t}$ λ_1=0.5 {4,15}	6	10	0.311	0.330	1	11.4	1409	1061	1989
S2	$DB_{120,2300t}$ λ_1=0.5 {4,15}	6	10	0.307	0.326	1	11.5	1382	1038	1973
S2	$DB_{120,2700t}$ λ_1=0.5 {4,15}	6	10	0.304	0.323	1	11.3	1355	1026	1956
S2	DB_{120} λ_1=0.5 {4,15}	6	10	0.305	0.324	1	11.3	1359	1028	1958
S2	$DB_{120,15\%}$ λ_1=0.5 {4,15}	6	10	0.292	0.313	1	11.1	1354	1186	1951
S2	$DB_{150,1500t}$ λ_1=0.5 {4,15}	6	10	0.304	0.319	1	11.7	1754	1304	2471
S2	$DB_{150,1900t}$ λ_1=0.5 {4,15}	6	10	0.301	0.316	1	11.6	1720	1280	2447
S2	$DB_{150,2300t}$ λ_1=0.5 {4,15}	6	10	0.298	0.313	1	11.7	1684	1258	2422
S2	$DB_{150,2700t}$ λ_1=0.5 {4,15}	6	10	0.295	0.310	1	11.6	1648	1231	2397
S2	DB_{150} λ_1=0.5 {4,15}	6	10	0.293	0.309	1	11.7	1634	1221	2386
S2	$DB_{150,15\%}$ λ_1=0.5 {4,15}	6	10	0.288	0.306	1	10.1	1614	1352	2385
S2	$DB_{180,1500t}$ λ_1=0.5 {4,15}	6	10	0.295	0.307	1	11.5	2055	1524	2921
S2	$DB_{180,1900t}$ λ_1=0.5 {4,15}	6	10	0.292	0.304	1	11.7	2010	1493	2891
S2	$DB_{180,2300t}$ λ_1=0.5 {4,15}	6	10	0.289	0.302	1	11.8	1965	1466	2861
S2	$DB_{180,2700t}$ λ_1=0.5 {4,15}	6	10	0.286	0.299	1	11.9	1926	1437	2829
S2	DB_{180} λ_1=0.5 {4,15}	6	10	0.283	0.296	1	11.9	1886	1403	2792
S2	$DB_{180,15\%}$ λ_1=0.5 {4,15}	6	10	0.278	0.297	1	10.0	1845	1545	2792
S2	$DB_{150,1900t}$ λ_1=0.2 {4,15}	6	10	0.303	0.317	1	16.0	1812	1251	2578
S2	DB_{150} λ_1=0.2 {4,15}	6	10	0.300	0.314	1	16.3	1768	1206	2547
S2	$DB_{180,1900t}$ λ_1=0.2 {4,15}	6	10	0.292	0.302	1	16.4	2104	1448	3035
S2	DB_{180} λ_1=0.2 {4,15}	6	10	0.287	0.298	1	16.8	2015	1366	2979
S2	$DB_{150,1900t}$ λ_1=0.5 {6,18}	6	10	0.313	0.332	1	14.6	1348	937	2271
S2	$DB_{150,2300t}$ λ_1=0.5 {6,18}	6	10	0.310	0.329	1	14.6	1313	908	2236
S2	DB_{150} λ_1=0.5 {6,18}	6	10	0.307	0.326	1	14.5	1284	891	2206
S2	$DB_{180,1900t}$ λ_1=0.5 {6,18}	6	10	0.308	0.322	1	14.9	1577	1083	2699
S2	$DB_{180,2300t}$ λ_1=0.5 {6,18}	6	10	0.305	0.319	1	14.8	1537	1055	2657
S2	DB_{180} λ_1=0.5 {6,18}	6	10	0.300	0.315	1	14.7	1483	1025	2593
S2	Constant Catch	6	10	0.230	0.228	1	0.0	3300	3300	3300
S2	$DB_{120,1500t}$ λ_1=0.5 {4,15}	11	20	0.385	0.420	1	8.4	1913	1487	2703
S2	$DB_{120,1900t}$ λ_1=0.5 {4,15}	11	20	0.382	0.417	1	8.4	1894	1458	2681
S2	$DB_{120,2300t}$ λ_1=0.5 {4,15}	11	20	0.379	0.415	1	8.5	1875	1429	2658
S2	$DB_{120,2700t}$ λ_1=0.5 {4,15}	11	20	0.377	0.413	1	8.5	1856	1399	2636
S2	DB_{120} λ_1=0.5 {4,15}	11	20	0.377	0.413	1	8.5	1858	1403	2639
S2	$DB_{120,15\%}$ λ_1=0.5 {4,15}	11	20	0.369	0.406	1	8.2	1708	1276	2479
S2	$DB_{150,1500t}$ λ_1=0.5 {4,15}	11	20	0.362	0.387	1	8.6	2284	1733	3223
S2	$DB_{150,1900t}$ λ_1=0.5 {4,15}	11	20	0.360	0.385	1	8.7	2259	1697	3197
S2	$DB_{150,2300t}$ λ_1=0.5 {4,15}	11	20	0.358	0.383	1	8.9	2234	1660	3171
S2	$DB_{150,2700t}$ λ_1=0.5 {4,15}	11	20	0.355	0.381	1	9.0	2206	1625	3144

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S2	DB_{150} λ_1=0.5 {4,15}	11	20	0.354	0.380	1	9.1	2193	1611	3132
S2	$DB_{150,15\%}$ λ_1=0.5 {4,15}	11	20	0.353	0.379	1	8.5	2040	1503	2956
S2	$DB_{180,1500t}$ λ_1=0.5 {4,15}	11	20	0.340	0.355	1	9.2	2608	1941	3727
S2	$DB_{180,1900t}$ λ_1=0.5 {4,15}	11	20	0.338	0.353	1	9.3	2572	1897	3698
S2	$DB_{180,2300t}$ λ_1=0.5 {4,15}	11	20	0.336	0.351	1	9.5	2539	1853	3668
S2	$DB_{180,2700t}$ λ_1=0.5 {4,15}	11	20	0.333	0.350	1	9.7	2507	1809	3638
S2	DB_{180} λ_1=0.5 {4,15}	11	20	0.331	0.348	1	9.9	2471	1769	3606
S2	$DB_{180,15\%}$ λ_1=0.5 {4,15}	11	20	0.333	0.351	1	9.0	2284	1662	3390
S2	$DB_{150,1900t}$ λ_1=0.2 {4,15}	11	20	0.358	0.383	1	12.3	2350	1545	3283
S2	DB_{150} λ_1=0.2 {4,15}	11	20	0.356	0.381	1	12.5	2324	1522	3257
S2	$DB_{180,1900t}$ λ_1=0.2 {4,15}	11	20	0.335	0.350	1	13.6	2676	1706	3774
S2	DB_{180} λ_1=0.2 {4,15}	11	20	0.332	0.347	1	13.7	2625	1649	3728
S2	$DB_{150,1900t}$ λ_1=0.5 {6,18}	11	20	0.380	0.399	1	12.1	2116	1383	3275
S2	$DB_{150,2300t}$ λ_1=0.5 {6,18}	11	20	0.378	0.398	1	12.3	2081	1352	3250
S2	DB_{150} λ_1=0.5 {6,18}	11	20	0.376	0.396	1	12.4	2051	1327	3227
S2	$DB_{180,1900t}$ λ_1=0.5 {6,18}	11	20	0.361	0.371	1	12.8	2415	1560	3755
S2	$DB_{180,2300t}$ λ_1=0.5 {6,18}	11	20	0.360	0.370	1	12.9	2380	1517	3725
S2	DB_{180} λ_1=0.5 {6,18}	11	20	0.357	0.368	1	13.1	2332	1463	3681
S2	Constant Catch	11	20	0.232	0.237	0.9	0.0	3300	3300	3300

Table B-6 Summary of performance statistics by data-based management procedures for scenario S3 $\{h = 0.45, \hat{q}_{2,trap}\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S3	$DB_{120,1500t}$ λ_1=0.5 {4,15}	6	10	0.312	0.342	1.00	12.0	1695	1240	2282
S3	$DB_{120,1900t}$ λ_1=0.5 {4,15}	6	10	0.308	0.339	1.00	12.1	1665	1210	2259
S3	$DB_{120,2300t}$ λ_1=0.5 {4,15}	6	10	0.305	0.336	1.00	12.1	1636	1186	2238
S3	$DB_{120,2700t}$ λ_1=0.5 {4,15}	6	10	0.301	0.333	1.00	12.4	1607	1163	2218
S3	DB_{120} λ_1=0.5 {4,15}	6	10	0.301	0.333	1.00	12.4	1610	1166	2221
S3	$DB_{120,15\%}$ λ_1=0.5 {4,15}	6	10	0.288	0.323	1.00	9.7	1576	1299	2187
S3	$DB_{150,1500t}$ λ_1=0.5 {4,15}	6	10	0.300	0.328	1.00	12.3	2079	1511	2801
S3	$DB_{150,1900t}$ λ_1=0.5 {4,15}	6	10	0.296	0.325	1.00	12.3	2041	1477	2771
S3	$DB_{150,2300t}$ λ_1=0.5 {4,15}	6	10	0.293	0.322	1.00	12.3	2002	1440	2741
S3	$DB_{150,2700t}$ λ_1=0.5 {4,15}	6	10	0.290	0.319	1.00	12.6	1964	1400	2716
S3	DB_{150} λ_1=0.5 {4,15}	6	10	0.288	0.318	1.00	12.7	1947	1381	2704
S3	$DB_{150,15\%}$ λ_1=0.5 {4,15}	6	10	0.283	0.317	1.00	9.6	1823	1465	2606
S3	$DB_{180,1500t}$ λ_1=0.5 {4,15}	6	10	0.290	0.314	1.00	12.2	2449	1750	3325
S3	$DB_{180,1900t}$ λ_1=0.5 {4,15}	6	10	0.287	0.311	1.00	12.4	2403	1695	3288
S3	$DB_{180,2300t}$ λ_1=0.5 {4,15}	6	10	0.284	0.309	1.00	12.4	2356	1640	3252
S3	$DB_{180,2700t}$ λ_1=0.5 {4,15}	6	10	0.281	0.306	1.00	12.8	2310	1590	3216
S3	DB_{180} λ_1=0.5 {4,15}	6	10	0.278	0.303	1.00	12.9	2258	1541	3177
S3	$DB_{180,15\%}$ λ_1=0.5 {4,15}	6	10	0.271	0.303	1.00	10.1	2067	1660	3050
S3	$DB_{150,1900t}$ λ_1=0.2 {4,15}	6	10	0.297	0.323	1.00	14.9	2213	1523	2972
S3	DB_{150} λ_1=0.2 {4,15}	6	10	0.294	0.320	1.00	15.4	2170	1463	2936
S3	$DB_{180,1900t}$ λ_1=0.2 {4,15}	6	10	0.286	0.307	1.00	15.3	2584	1788	3505
S3	DB_{180} λ_1=0.2 {4,15}	6	10	0.282	0.302	1.00	16.1	2494	1680	3439
S3	$DB_{150,1900t}$ λ_1=0.5 {6,18}	6	10	0.309	0.341	1.00	16.2	1741	1085	2722
S3	$DB_{150,2300t}$ λ_1=0.5 {6,18}	6	10	0.306	0.338	1.00	16.2	1693	1059	2685
S3	DB_{150} λ_1=0.5 {6,18}	6	10	0.303	0.336	1.00	16.4	1647	1037	2653
S3	$DB_{180,1900t}$ λ_1=0.5 {6,18}	6	10	0.303	0.328	1.00	16.2	2044	1276	3230
S3	$DB_{180,2300t}$ λ_1=0.5 {6,18}	6	10	0.300	0.325	1.00	16.2	1978	1243	3184
S3	DB_{180} λ_1=0.5 {6,18}	6	10	0.295	0.322	1.00	16.6	1888	1198	3121
S3	Constant Catch	6	10	0.220	0.236	0.90	0.0	3300	3300	3300
S3	$DB_{120,1500t}$ λ_1=0.5 {4,15}	11	20	0.428	0.476	1.00	6.9	2574	2051	3578
S3	$DB_{120,1900t}$ λ_1=0.5 {4,15}	11	20	0.425	0.474	1.00	6.9	2552	2032	3553
S3	$DB_{120,2300t}$ λ_1=0.5 {4,15}	11	20	0.423	0.472	1.00	7.0	2531	2007	3527
S3	$DB_{120,2700t}$ λ_1=0.5 {4,15}	11	20	0.421	0.470	1.00	7.0	2510	1982	3502
S3	DB_{120} λ_1=0.5 {4,15}	11	20	0.421	0.471	1.00	7.0	2513	1985	3505
S3	$DB_{120,15\%}$ λ_1=0.5 {4,15}	11	20	0.416	0.470	1.00	7.2	2374	1803	3291
S3	$DB_{150,1500t}$ λ_1=0.5 {4,15}	11	20	0.400	0.433	1.00	6.9	3089	2465	4274
S3	$DB_{150,1900t}$ λ_1=0.5 {4,15}	11	20	0.398	0.432	1.00	6.9	3065	2436	4245
S3	$DB_{150,2300t}$ λ_1=0.5 {4,15}	11	20	0.396	0.430	1.00	7.0	3042	2414	4215
S3	$DB_{150,2700t}$ λ_1=0.5 {4,15}	11	20	0.394	0.429	1.00	7.1	3018	2386	4185

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S3	DB_{150} λ_1=0.5 {4,15}	11	20	0.393	0.428	1.00	7.1	3006	2372	4171
S3	$DB_{150,15\%}$ λ_1=0.5 {4,15}	11	20	0.394	0.438	1.00	7.3	2850	2147	3950
S3	$DB_{180,1500t}$ λ_1=0.5 {4,15}	11	20	0.373	0.394	1.00	7.1	3542	2836	4896
S3	$DB_{180,1900t}$ λ_1=0.5 {4,15}	11	20	0.372	0.393	1.00	7.1	3516	2805	4867
S3	$DB_{180,2300t}$ λ_1=0.5 {4,15}	11	20	0.369	0.392	1.00	7.3	3491	2775	4834
S3	$DB_{180,2700t}$ λ_1=0.5 {4,15}	11	20	0.367	0.391	1.00	7.4	3466	2740	4800
S3	DB_{180} λ_1=0.5 {4,15}	11	20	0.365	0.390	1.00	7.5	3438	2686	4764
S3	$DB_{180,15\%}$ λ_1=0.5 {4,15}	11	20	0.369	0.406	1.00	7.7	3248	2418	4513
S3	$DB_{150,1900t}$ λ_1=0.2 {4,15}	11	20	0.395	0.426	1.00	9.4	3145	2405	4344
S3	DB_{150} λ_1=0.2 {4,15}	11	20	0.392	0.424	1.00	9.4	3122	2383	4315
S3	$DB_{180,1900t}$ λ_1=0.2 {4,15}	11	20	0.366	0.388	1.00	9.5	3590	2722	4951
S3	DB_{180} λ_1=0.2 {4,15}	11	20	0.363	0.385	1.00	9.7	3551	2686	4902
S3	$DB_{150,1900t}$ λ_1=0.5 {6,18}	11	20	0.414	0.444	1.00	8.4	3085	2285	4307
S3	$DB_{150,2300t}$ λ_1=0.5 {6,18}	11	20	0.412	0.442	1.00	8.6	3057	2235	4289
S3	DB_{150} λ_1=0.5 {6,18}	11	20	0.410	0.441	1.00	8.7	3031	2191	4273
S3	$DB_{180,1900t}$ λ_1=0.5 {6,18}	11	20	0.388	0.408	1.00	8.6	3560	2608	4980
S3	$DB_{180,2300t}$ λ_1=0.5 {6,18}	11	20	0.387	0.407	1.00	8.7	3532	2551	4947
S3	DB_{180} λ_1=0.5 {6,18}	11	20	0.384	0.405	1.00	8.8	3487	2484	4901
S3	Constant Catch	11	20	0.290	0.351	1.00	0.0	3300	3300	3300

Table B-7 Summary of performance statistics by data-based management procedures for scenario S4 $\{h = 0.45, \hat{q}_{2,trap}\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S4	$DB_{120,1500t}$ λ_1=0.5 {4,15}	6	10	0.401	0.434	1.00	10.2	1807	1447	2381
S4	$DB_{120,1900t}$ λ_1=0.5 {4,15}	6	10	0.398	0.431	1.00	10.1	1787	1427	2364
S4	$DB_{120,2300t}$ λ_1=0.5 {4,15}	6	10	0.394	0.428	1.00	10.3	1768	1415	2348
S4	$DB_{120,2700t}$ λ_1=0.5 {4,15}	6	10	0.391	0.425	1.00	10.1	1750	1398	2332
S4	DB_{120} λ_1=0.5 {4,15}	6	10	0.392	0.426	1.00	10.1	1752	1400	2334
S4	$DB_{120,15\%}$ λ_1=0.5 {4,15}	6	10	0.383	0.419	1.00	8.3	1741	1456	2322
S4	$DB_{150,1500t}$ λ_1=0.5 {4,15}	6	10	0.389	0.416	1.00	10.4	2230	1769	2927
S4	$DB_{150,1900t}$ λ_1=0.5 {4,15}	6	10	0.386	0.413	1.00	10.4	2205	1741	2905
S4	$DB_{150,2300t}$ λ_1=0.5 {4,15}	6	10	0.382	0.410	1.00	10.4	2179	1709	2884
S4	$DB_{150,2700t}$ λ_1=0.5 {4,15}	6	10	0.379	0.407	1.00	10.5	2154	1681	2863
S4	DB_{150} λ_1=0.5 {4,15}	6	10	0.378	0.406	1.00	10.4	2143	1667	2853
S4	$DB_{150,15\%}$ λ_1=0.5 {4,15}	6	10	0.375	0.408	1.00	9.2	2094	1705	2859
S4	$DB_{180,1500t}$ λ_1=0.5 {4,15}	6	10	0.377	0.401	1.00	10.4	2643	2065	3457
S4	$DB_{180,1900t}$ λ_1=0.5 {4,15}	6	10	0.374	0.398	1.00	10.5	2612	2027	3433
S4	$DB_{180,2300t}$ λ_1=0.5 {4,15}	6	10	0.371	0.395	1.00	10.5	2582	1989	3408
S4	$DB_{180,2700t}$ λ_1=0.5 {4,15}	6	10	0.368	0.393	1.00	10.6	2551	1955	3384
S4	DB_{180} λ_1=0.5 {4,15}	6	10	0.365	0.390	1.00	10.6	2519	1921	3358
S4	$DB_{180,15\%}$ λ_1=0.5 {4,15}	6	10	0.362	0.392	1.00	9.3	2408	1948	3359
S4	$DB_{150,1900t}$ λ_1=0.2 {4,15}	6	10	0.385	0.412	1.00	13.1	2347	1752	3065
S4	DB_{150} λ_1=0.2 {4,15}	6	10	0.382	0.409	1.00	13.3	2318	1701	3037
S4	$DB_{180,1900t}$ λ_1=0.2 {4,15}	6	10	0.374	0.395	1.00	13.3	2761	2039	3624
S4	DB_{180} λ_1=0.2 {4,15}	6	10	0.369	0.391	1.00	13.5	2700	1958	3573
S4	$DB_{150,1900t}$ λ_1=0.5 {6,18}	6	10	0.398	0.429	1.00	14.5	1944	1332	2857
S4	$DB_{150,2300t}$ λ_1=0.5 {6,18}	6	10	0.395	0.426	1.00	14.5	1916	1308	2836
S4	DB_{150} λ_1=0.5 {6,18}	6	10	0.392	0.424	1.00	14.4	1887	1286	2814
S4	$DB_{180,1900t}$ λ_1=0.5 {6,18}	6	10	0.391	0.416	1.00	14.7	2298	1556	3378
S4	$DB_{180,2300t}$ λ_1=0.5 {6,18}	6	10	0.388	0.414	1.00	14.6	2263	1524	3352
S4	DB_{180} λ_1=0.5 {6,18}	6	10	0.383	0.411	1.00	14.5	2205	1487	3310
S4	Constant Catch	6	10	0.322	0.341	1.00	0.0	3300	3300	3300
S4	$DB_{120,1500t}$ λ_1=0.5 {4,15}	11	20	0.518	0.563	1.00	6.7	2456	2008	3390
S4	$DB_{120,1900t}$ λ_1=0.5 {4,15}	11	20	0.516	0.561	1.00	6.7	2442	1992	3378
S4	$DB_{120,2300t}$ λ_1=0.5 {4,15}	11	20	0.514	0.559	1.00	6.7	2428	1972	3366
S4	$DB_{120,2700t}$ λ_1=0.5 {4,15}	11	20	0.511	0.558	1.00	6.8	2414	1954	3349
S4	DB_{120} λ_1=0.5 {4,15}	11	20	0.512	0.558	1.00	6.8	2416	1956	3351
S4	$DB_{120,15\%}$ λ_1=0.5 {4,15}	11	20	0.507	0.557	1.00	6.9	2361	1913	3209
S4	$DB_{150,1500t}$ λ_1=0.5 {4,15}	11	20	0.487	0.522	1.00	6.8	2963	2444	4079
S4	$DB_{150,1900t}$ λ_1=0.5 {4,15}	11	20	0.485	0.520	1.00	6.9	2947	2426	4065
S4	$DB_{150,2300t}$ λ_1=0.5 {4,15}	11	20	0.483	0.519	1.00	6.9	2931	2406	4051
S4	$DB_{150,2700t}$ λ_1=0.5 {4,15}	11	20	0.481	0.518	1.00	6.9	2914	2385	4031

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S4	DB_{150} λ_1=0.5 {4,15}	11	20	0.480	0.517	1.00	6.9	2906	2374	4022
S4	$DB_{150,15\%}$ λ_1=0.5 {4,15}	11	20	0.481	0.521	1.00	7.1	2855	2282	3873
S4	$DB_{180,1500t}$ λ_1=0.5 {4,15}	11	20	0.461	0.484	1.00	7.0	3426	2842	4709
S4	$DB_{180,1900t}$ λ_1=0.5 {4,15}	11	20	0.459	0.483	1.00	7.0	3406	2817	4693
S4	$DB_{180,2300t}$ λ_1=0.5 {4,15}	11	20	0.457	0.481	1.00	7.1	3386	2791	4678
S4	$DB_{180,2700t}$ λ_1=0.5 {4,15}	11	20	0.456	0.480	1.00	7.2	3366	2766	4657
S4	DB_{180} λ_1=0.5 {4,15}	11	20	0.454	0.479	1.00	7.3	3344	2735	4633
S4	$DB_{180,15\%}$ λ_1=0.5 {4,15}	11	20	0.456	0.490	1.00	7.3	3307	2612	4465
S4	$DB_{150,1900t}$ λ_1=0.2 {4,15}	11	20	0.482	0.515	1.00	9.7	3014	2386	4140
S4	DB_{150} λ_1=0.2 {4,15}	11	20	0.480	0.514	1.00	9.7	2999	2369	4121
S4	$DB_{180,1900t}$ λ_1=0.2 {4,15}	11	20	0.455	0.477	1.00	9.8	3467	2697	4766
S4	DB_{180} λ_1=0.2 {4,15}	11	20	0.452	0.475	1.00	9.9	3442	2663	4734
S4	$DB_{150,1900t}$ λ_1=0.5 {6,18}	11	20	0.502	0.530	1.00	8.6	2955	2225	4098
S4	$DB_{150,2300t}$ λ_1=0.5 {6,18}	11	20	0.500	0.528	1.00	8.6	2932	2192	4085
S4	DB_{150} λ_1=0.5 {6,18}	11	20	0.498	0.527	1.00	8.7	2911	2163	4073
S4	$DB_{180,1900t}$ λ_1=0.5 {6,18}	11	20	0.476	0.501	1.00	8.6	3433	2518	4740
S4	$DB_{180,2300t}$ λ_1=0.5 {6,18}	11	20	0.475	0.500	1.00	8.7	3408	2479	4724
S4	DB_{180} λ_1=0.5 {6,18}	11	20	0.473	0.498	1.00	8.8	3373	2424	4703
S4	Constant Catch	11	20	0.405	0.457	1.00	0.0	3300	3300	3300

Table B-8 Summary of performance statistics by CA model-based management procedures for scenario S1 $\{h = 0.45, \hat{q}_{2,trap}\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S1	$CA_{0.04,1500t}$ {0.25,1.0}	1	5	0.148	0.161	0.00	46.3	1138	918	1343
S1	$CA_{0.04,1900t}$ {0.25,1.0}	1	5	0.146	0.159	0.00	44.3	1199	890	1405
S1	$CA_{0.04,2300t}$ {0.25,1.0}	1	5	0.144	0.158	0.00	42.6	1260	863	1468
S1	$CA_{0.04,2700t}$ {0.25,1.0}	1	5	0.142	0.156	0.00	41.0	1322	839	1529
S1	$CA_{0.04,15\%}$ {0.25,1.0}	1	5	0.128	0.132	0.00	17.6	2152	1515	2152
S1	$CA_{0.06,1500t}$ {0.25,1.0}	1	5	0.142	0.151	0.00	37.9	1508	1278	1801
S1	$CA_{0.06,1900t}$ {0.25,1.0}	1	5	0.140	0.149	0.00	31.0	1560	1245	1855
S1	$CA_{0.06,2300t}$ {0.25,1.0}	1	5	0.138	0.148	0.00	29.3	1613	1212	1909
S1	$CA_{0.06,2700t}$ {0.25,1.0}	1	5	0.137	0.147	0.00	28.6	1667	1181	1963
S1	$CA_{0.06,15\%}$ {0.25,1.0}	1	5	0.128	0.132	0.00	17.6	2152	1515	2171
S1	$CA_{0.08,1500t}$ {0.25,1.0}	1	5	0.137	0.140	0.00	40.5	1847	1500	2217
S1	$CA_{0.08,1900t}$ {0.25,1.0}	1	5	0.135	0.139	0.00	30.9	1890	1524	2264
S1	$CA_{0.08,2300t}$ {0.25,1.0}	1	5	0.133	0.138	0.00	24.7	1935	1488	2311
S1	$CA_{0.08,2700t}$ {0.25,1.0}	1	5	0.132	0.137	0.00	22.0	1982	1453	2357
S1	$CA_{0.08,15\%}$ {0.25,1.0}	1	5	0.127	0.130	0.00	17.2	2174	1543	2484
S1	$CA_{0.04,1500t}$ {0.25,1.0}	6	10	0.179	0.193	0.00	8.2	1078	945	1520
S1	$CA_{0.04,1900t}$ {0.25,1.0}	6	10	0.178	0.192	0.00	8.3	1057	926	1502
S1	$CA_{0.04,2300t}$ {0.25,1.0}	6	10	0.177	0.190	0.00	8.4	1035	908	1483
S1	$CA_{0.04,2700t}$ {0.25,1.0}	6	10	0.175	0.188	0.00	8.5	1016	889	1465
S1	$CA_{0.04,15\%}$ {0.25,1.0}	6	10	0.156	0.171	0.00	28.5	818	680	1274
S1	$CA_{0.06,1500t}$ {0.25,1.0}	6	10	0.163	0.174	0.00	9.7	1398	1216	2016
S1	$CA_{0.06,1900t}$ {0.25,1.0}	6	10	0.162	0.173	0.00	9.7	1375	1194	1986
S1	$CA_{0.06,2300t}$ {0.25,1.0}	6	10	0.161	0.172	0.00	9.8	1351	1172	1956
S1	$CA_{0.06,2700t}$ {0.25,1.0}	6	10	0.160	0.171	0.00	9.9	1327	1150	1932
S1	$CA_{0.06,15\%}$ {0.25,1.0}	6	10	0.151	0.163	0.00	16.5	1166	988	1826
S1	$CA_{0.08,1500t}$ {0.25,1.0}	6	10	0.151	0.158	0.00	11.6	1618	1380	2351
S1	$CA_{0.08,1900t}$ {0.25,1.0}	6	10	0.151	0.157	0.00	11.7	1594	1363	2317
S1	$CA_{0.08,2300t}$ {0.25,1.0}	6	10	0.150	0.156	0.00	11.8	1567	1339	2289
S1	$CA_{0.08,2700t}$ {0.25,1.0}	6	10	0.149	0.156	0.00	11.8	1543	1315	2264
S1	$CA_{0.08,15\%}$ {0.25,1.0}	6	10	0.142	0.153	0.00	14.9	1426	1182	2223
S1	$CA_{0.04,1500t}$ {0.25,1.0}	11	20	0.240	0.274	0.90	6.5	1360	1101	1974
S1	$CA_{0.04,1900t}$ {0.25,1.0}	11	20	0.238	0.273	0.90	6.5	1346	1085	1964
S1	$CA_{0.04,2300t}$ {0.25,1.0}	11	20	0.237	0.272	0.90	6.5	1332	1069	1954
S1	$CA_{0.04,2700t}$ {0.25,1.0}	11	20	0.236	0.270	0.90	6.5	1318	1055	1944
S1	$CA_{0.04,15\%}$ {0.25,1.0}	11	20	0.217	0.256	0.70	7.1	1150	903	1790
S1	$CA_{0.06,1500t}$ {0.25,1.0}	11	20	0.208	0.233	0.70	7.8	1654	1341	2500
S1	$CA_{0.06,1900t}$ {0.25,1.0}	11	20	0.207	0.232	0.60	7.8	1641	1326	2491
S1	$CA_{0.06,2300t}$ {0.25,1.0}	11	20	0.206	0.230	0.60	7.8	1627	1311	2482
S1	$CA_{0.06,2700t}$ {0.25,1.0}	11	20	0.205	0.229	0.60	7.8	1614	1295	2469

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S1	$CA_{0.06,15\%}$ {0.25,1.0}	11	20	0.196	0.223	0.40	8.1	1498	1177	2323
S1	$CA_{0.08,1500t}$ {0.25,1.0}	11	20	0.186	0.203	0.20	9.3	1825	1455	2802
S1	$CA_{0.08,1900t}$ {0.25,1.0}	11	20	0.185	0.203	0.20	9.3	1813	1443	2785
S1	$CA_{0.08,2300t}$ {0.25,1.0}	11	20	0.184	0.202	0.20	9.2	1800	1431	2768
S1	$CA_{0.08,2700t}$ {0.25,1.0}	11	20	0.183	0.202	0.20	9.2	1787	1418	2751
S1	$CA_{0.08,15\%}$ {0.25,1.0}	11	20	0.179	0.198	0.10	9.4	1729	1352	2692
S1	$CA_{0.04,1500t}$ {0.25,1.0}	21	40	0.341	0.366	1.00	4.7	1918	1524	2580
S1	$CA_{0.04,1900t}$ {0.25,1.0}	21	40	0.339	0.366	1.00	4.7	1909	1519	2570
S1	$CA_{0.04,2300t}$ {0.25,1.0}	21	40	0.338	0.366	1.00	4.8	1901	1513	2560
S1	$CA_{0.04,2700t}$ {0.25,1.0}	21	40	0.337	0.365	1.00	4.7	1893	1507	2549
S1	$CA_{0.04,15\%}$ {0.25,1.0}	21	40	0.321	0.355	1.00	4.8	1801	1403	2463
S1	$CA_{0.06,1500t}$ {0.25,1.0}	21	40	0.273	0.292	1.00	6.1	2200	1680	3104
S1	$CA_{0.06,1900t}$ {0.25,1.0}	21	40	0.272	0.292	1.00	6.1	2194	1675	3099
S1	$CA_{0.06,2300t}$ {0.25,1.0}	21	40	0.272	0.291	1.00	6.1	2187	1669	3095
S1	$CA_{0.06,2700t}$ {0.25,1.0}	21	40	0.271	0.291	1.00	6.1	2180	1663	3087
S1	$CA_{0.06,15\%}$ {0.25,1.0}	21	40	0.265	0.289	1.00	6.1	2112	1610	3012
S1	$CA_{0.08,1500t}$ {0.25,1.0}	21	40	0.227	0.237	0.85	7.5	2280	1680	3341
S1	$CA_{0.08,1900t}$ {0.25,1.0}	21	40	0.226	0.237	0.80	7.5	2274	1673	3338
S1	$CA_{0.08,2300t}$ {0.25,1.0}	21	40	0.226	0.237	0.80	7.5	2268	1666	3336
S1	$CA_{0.08,2700t}$ {0.25,1.0}	21	40	0.226	0.237	0.80	7.5	2262	1660	3334
S1	$CA_{0.08,15\%}$ {0.25,1.0}	21	40	0.224	0.235	0.78	7.5	2222	1636	3309

Table B-9 Summary of performance statistics by CA model-based management procedures for scenario S2 $\{h = 0.45,\ q_{2,trap} = 1\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S2	$CA_{0.04,1500t}$ {0.25,1.0}	1	5	0.271	0.281	1.00	32.1	1549	1380	1829
S2	$CA_{0.04,1900t}$ {0.25,1.0}	1	5	0.269	0.280	1.00	29.4	1614	1363	1897
S2	$CA_{0.04,2300t}$ {0.25,1.0}	1	5	0.267	0.278	1.00	28.5	1678	1345	1964
S2	$CA_{0.04,2700t}$ {0.25,1.0}	1	5	0.265	0.277	1.00	27.6	1743	1324	2033
S2	$CA_{0.04,15\%}$ {0.25,1.0}	1	5	0.256	0.264	1.00	17.6	2152	1515	2259
S2	$CA_{0.06,1500t}$ {0.25,1.0}	1	5	0.262	0.267	1.00	31.2	2104	1500	2518
S2	$CA_{0.06,1900t}$ {0.25,1.0}	1	5	0.260	0.265	1.00	23.3	2163	1900	2580
S2	$CA_{0.06,2300t}$ {0.25,1.0}	1	5	0.258	0.264	1.00	18.4	2222	1966	2642
S2	$CA_{0.06,2700t}$ {0.25,1.0}	1	5	0.256	0.262	1.00	17.1	2284	1934	2704
S2	$CA_{0.06,15\%}$ {0.25,1.0}	1	5	0.254	0.259	1.00	13.3	2385	2072	2740
S2	$CA_{0.08,1500t}$ {0.25,1.0}	1	5	0.254	0.252	1.00	32.7	2623	1500	3158
S2	$CA_{0.08,1900t}$ {0.25,1.0}	1	5	0.252	0.250	1.00	26.0	2677	1900	3215
S2	$CA_{0.08,2300t}$ {0.25,1.0}	1	5	0.251	0.249	1.00	19.7	2731	2300	3272
S2	$CA_{0.08,2700t}$ {0.25,1.0}	1	5	0.249	0.248	1.00	14.4	2787	2502	3328
S2	$CA_{0.08,15\%}$ {0.25,1.0}	1	5	0.248	0.247	1.00	11.6	2822	2526	3288
S2	$CA_{0.04,1500t}$ {0.25,1.0}	6	10	0.302	0.317	1.00	7.3	1782	1590	2382
S2	$CA_{0.04,1900t}$ {0.25,1.0}	6	10	0.300	0.316	1.00	7.3	1773	1578	2372
S2	$CA_{0.04,2300t}$ {0.25,1.0}	6	10	0.299	0.314	1.00	7.4	1762	1568	2361
S2	$CA_{0.04,2700t}$ {0.25,1.0}	6	10	0.298	0.313	1.00	7.5	1749	1557	2350
S2	$CA_{0.04,15\%}$ {0.25,1.0}	6	10	0.288	0.304	1.00	8.3	1677	1459	2311
S2	$CA_{0.06,1500t}$ {0.25,1.0}	6	10	0.276	0.288	1.00	8.7	2392	2115	3271
S2	$CA_{0.06,1900t}$ {0.25,1.0}	6	10	0.275	0.286	1.00	8.7	2379	2097	3252
S2	$CA_{0.06,2300t}$ {0.25,1.0}	6	10	0.274	0.285	1.00	8.7	2361	2083	3234
S2	$CA_{0.06,2700t}$ {0.25,1.0}	6	10	0.273	0.284	1.00	8.8	2344	2069	3215
S2	$CA_{0.06,15\%}$ {0.25,1.0}	6	10	0.270	0.282	1.00	8.8	2324	2052	3180
S2	$CA_{0.08,1500t}$ {0.25,1.0}	6	10	0.255	0.260	1.00	10.4	2886	2438	4022
S2	$CA_{0.08,1900t}$ {0.25,1.0}	6	10	0.254	0.259	1.00	10.4	2869	2419	4003
S2	$CA_{0.08,2300t}$ {0.25,1.0}	6	10	0.253	0.258	1.00	10.5	2852	2404	3983
S2	$CA_{0.08,2700t}$ {0.25,1.0}	6	10	0.253	0.257	1.00	10.5	2834	2392	3963
S2	$CA_{0.08,15\%}$ {0.25,1.0}	6	10	0.253	0.257	1.00	10.6	2819	2381	3993
S2	$CA_{0.04,1500t}$ {0.25,1.0}	11	20	0.361	0.389	1.00	6.2	2124	1784	2923
S2	$CA_{0.04,1900t}$ {0.25,1.0}	11	20	0.359	0.387	1.00	6.2	2116	1773	2915
S2	$CA_{0.04,2300t}$ {0.25,1.0}	11	20	0.358	0.386	1.00	6.2	2108	1763	2906
S2	$CA_{0.04,2700t}$ {0.25,1.0}	11	20	0.356	0.385	1.00	6.2	2100	1752	2898
S2	$CA_{0.04,15\%}$ {0.25,1.0}	11	20	0.350	0.377	1.00	6.3	2042	1708	2851
S2	$CA_{0.06,1500t}$ {0.25,1.0}	11	20	0.314	0.326	1.00	7.5	2681	2235	3756
S2	$CA_{0.06,1900t}$ {0.25,1.0}	11	20	0.313	0.325	1.00	7.5	2672	2226	3749
S2	$CA_{0.06,2300t}$ {0.25,1.0}	11	20	0.312	0.324	1.00	7.5	2661	2218	3743
S2	$CA_{0.06,2700t}$ {0.25,1.0}	11	20	0.311	0.324	1.00	7.5	2650	2209	3736

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S2	$CA_{0.06,15\%}$ {0.25,1.0}	11	20	0.309	0.322	1.00	7.5	2630	2187	3733
S2	$CA_{0.08,1500t}$ {0.25,1.0}	11	20	0.277	0.281	1.00	8.9	2981	2482	4415
S2	$CA_{0.08,1900t}$ {0.25,1.0}	11	20	0.276	0.280	1.00	8.9	2971	2475	4408
S2	$CA_{0.08,2300t}$ {0.25,1.0}	11	20	0.275	0.280	1.00	8.9	2962	2468	4401
S2	$CA_{0.08,2700t}$ {0.25,1.0}	11	20	0.274	0.279	1.00	8.8	2953	2461	4395
S2	$CA_{0.08,15\%}$ {0.25,1.0}	11	20	0.274	0.278	1.00	8.8	2945	2451	4390
S2	$CA_{0.04,1500t}$ {0.25,1.0}	21	40	0.421	0.425	1.00	4.6	2617	2113	3385
S2	$CA_{0.04,1900t}$ {0.25,1.0}	21	40	0.421	0.425	1.00	4.6	2612	2108	3378
S2	$CA_{0.04,2300t}$ {0.25,1.0}	21	40	0.420	0.424	1.00	4.6	2607	2103	3370
S2	$CA_{0.04,2700t}$ {0.25,1.0}	21	40	0.419	0.424	1.00	4.6	2602	2099	3362
S2	$CA_{0.04,15\%}$ {0.25,1.0}	21	40	0.413	0.421	1.00	4.6	2572	2076	3324
S2	$CA_{0.06,1500t}$ {0.25,1.0}	21	40	0.336	0.331	1.00	6.1	3036	2409	4110
S2	$CA_{0.06,1900t}$ {0.25,1.0}	21	40	0.335	0.330	1.00	6.1	3031	2402	4106
S2	$CA_{0.06,2300t}$ {0.25,1.0}	21	40	0.335	0.330	1.00	6.1	3025	2396	4103
S2	$CA_{0.06,2700t}$ {0.25,1.0}	21	40	0.334	0.330	1.00	6.1	3019	2390	4099
S2	$CA_{0.06,15\%}$ {0.25,1.0}	21	40	0.334	0.328	1.00	6.1	2997	2379	4097
S2	$CA_{0.08,1500t}$ {0.25,1.0}	21	40	0.275	0.260	1.00	7.5	3131	2412	4433
S2	$CA_{0.08,1900t}$ {0.25,1.0}	21	40	0.275	0.260	1.00	7.5	3126	2409	4430
S2	$CA_{0.08,2300t}$ {0.25,1.0}	21	40	0.275	0.260	1.00	7.5	3121	2405	4428
S2	$CA_{0.08,2700t}$ {0.25,1.0}	21	40	0.274	0.260	1.00	7.4	3116	2401	4425
S2	$CA_{0.08,15\%}$ {0.25,1.0}	21	40	0.274	0.260	1.00	7.5	3113	2398	4422

Table B-10 Summary of performance statistics by CA model-based management procedures for scenario S3 $\left\{h=0.65,\ \hat{q}_{2,trap}\right\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S3	$CA_{0.04,1500t}$ {0.25,1.0}	1	5	0.229	0.260	1.00	39.2	1303	1120	1516
S3	$CA_{0.04,1900t}$ {0.25,1.0}	1	5	0.227	0.259	0.80	37.3	1366	1098	1581
S3	$CA_{0.04,2300t}$ {0.25,1.0}	1	5	0.224	0.257	0.80	36.2	1429	1077	1647
S3	$CA_{0.04,2700t}$ {0.25,1.0}	1	5	0.222	0.255	0.80	35.2	1492	1055	1712
S3	$CA_{0.04,15\%}$ {0.25,1.0}	1	5	0.209	0.234	0.60	17.6	2152	1515	2152
S3	$CA_{0.06,1500t}$ {0.25,1.0}	1	5	0.221	0.247	1.00	33.2	1751	1500	2064
S3	$CA_{0.06,1900t}$ {0.25,1.0}	1	5	0.219	0.245	0.80	25.7	1806	1583	2121
S3	$CA_{0.06,2300t}$ {0.25,1.0}	1	5	0.217	0.244	0.80	23.9	1861	1550	2178
S3	$CA_{0.06,2700t}$ {0.25,1.0}	1	5	0.215	0.243	0.80	23.5	1916	1515	2235
S3	$CA_{0.06,15\%}$ {0.25,1.0}	1	5	0.209	0.234	0.60	16.8	2183	1643	2353
S3	$CA_{0.08,1500t}$ {0.25,1.0}	1	5	0.214	0.235	1.00	34.7	2166	1500	2576
S3	$CA_{0.08,1900t}$ {0.25,1.0}	1	5	0.212	0.234	0.80	25.9	2215	1900	2627
S3	$CA_{0.08,2300t}$ {0.25,1.0}	1	5	0.210	0.233	0.60	19.7	2262	1979	2677
S3	$CA_{0.08,2700t}$ {0.25,1.0}	1	5	0.209	0.231	0.60	17.1	2309	1942	2727
S3	$CA_{0.08,15\%}$ {0.25,1.0}	1	5	0.207	0.227	0.60	13.6	2391	2022	2751
S3	$CA_{0.04,1500t}$ {0.25,1.0}	6	10	0.310	0.345	1.00	8.2	1600	1380	2225
S3	$CA_{0.04,1900t}$ {0.25,1.0}	6	10	0.308	0.344	1.00	8.3	1584	1364	2209
S3	$CA_{0.04,2300t}$ {0.25,1.0}	6	10	0.307	0.343	1.00	8.4	1570	1345	2194
S3	$CA_{0.04,2700t}$ {0.25,1.0}	6	10	0.305	0.342	1.00	8.5	1556	1328	2179
S3	$CA_{0.04,15\%}$ {0.25,1.0}	6	10	0.290	0.325	1.00	13.1	1417	1165	2064
S3	$CA_{0.06,1500t}$ {0.25,1.0}	6	10	0.286	0.316	1.00	8.9	2160	1859	3081
S3	$CA_{0.06,1900t}$ {0.25,1.0}	6	10	0.285	0.315	1.00	9.0	2139	1839	3058
S3	$CA_{0.06,2300t}$ {0.25,1.0}	6	10	0.284	0.314	1.00	9.1	2120	1817	3034
S3	$CA_{0.06,2700t}$ {0.25,1.0}	6	10	0.283	0.313	1.00	9.2	2100	1793	3011
S3	$CA_{0.06,15\%}$ {0.25,1.0}	6	10	0.278	0.308	1.00	9.7	2029	1702	2931
S3	$CA_{0.08,1500t}$ {0.25,1.0}	6	10	0.266	0.292	1.00	10.2	2604	2212	3704
S3	$CA_{0.08,1900t}$ {0.25,1.0}	6	10	0.265	0.291	1.00	10.2	2583	2194	3681
S3	$CA_{0.08,2300t}$ {0.25,1.0}	6	10	0.264	0.291	1.00	10.3	2561	2169	3657
S3	$CA_{0.08,2700t}$ {0.25,1.0}	6	10	0.263	0.290	1.00	10.4	2538	2144	3633
S3	$CA_{0.08,15\%}$ {0.25,1.0}	6	10	0.262	0.289	1.00	10.7	2496	2092	3653
S3	$CA_{0.04,1500t}$ {0.25,1.0}	11	20	0.437	0.496	1.00	5.6	2260	1823	2970
S3	$CA_{0.04,1900t}$ {0.25,1.0}	11	20	0.436	0.495	1.00	5.6	2251	1811	2961
S3	$CA_{0.04,2300t}$ {0.25,1.0}	11	20	0.434	0.494	1.00	5.6	2243	1798	2953
S3	$CA_{0.04,2700t}$ {0.25,1.0}	11	20	0.433	0.493	1.00	5.7	2235	1784	2944
S3	$CA_{0.04,15\%}$ {0.25,1.0}	11	20	0.423	0.484	1.00	5.9	2154	1686	2881
S3	$CA_{0.06,1500t}$ {0.25,1.0}	11	20	0.390	0.430	1.00	6.7	2943	2404	3995
S3	$CA_{0.06,1900t}$ {0.25,1.0}	11	20	0.389	0.429	1.00	6.7	2933	2395	3984
S3	$CA_{0.06,2300t}$ {0.25,1.0}	11	20	0.388	0.428	1.00	6.7	2922	2387	3973
S3	$CA_{0.06,2700t}$ {0.25,1.0}	11	20	0.387	0.428	1.00	6.7	2910	2374	3963

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S3	$CA_{0.06,15\%}$ {0.25,1.0}	11	20	0.384	0.424	1.00	6.7	2846	2305	3915
S3	$CA_{0.08,1500t}$ {0.25,1.0}	11	20	0.353	0.378	1.00	7.7	3391	2719	4714
S3	$CA_{0.08,1900t}$ {0.25,1.0}	11	20	0.353	0.378	1.00	7.7	3384	2711	4700
S3	$CA_{0.08,2300t}$ {0.25,1.0}	11	20	0.352	0.378	1.00	7.7	3376	2699	4686
S3	$CA_{0.08,2700t}$ {0.25,1.0}	11	20	0.351	0.377	1.00	7.7	3368	2686	4673
S3	$CA_{0.08,15\%}$ {0.25,1.0}	11	20	0.350	0.376	1.00	7.7	3350	2677	4663
S3	$CA_{0.04,1500t}$ {0.25,1.0}	21	40	0.550	0.555	1.00	3.7	2949	2521	3613
S3	$CA_{0.04,1900t}$ {0.25,1.0}	21	40	0.550	0.554	1.00	3.7	2945	2517	3608
S3	$CA_{0.04,2300t}$ {0.25,1.0}	21	40	0.549	0.554	1.00	3.7	2940	2514	3602
S3	$CA_{0.04,2700t}$ {0.25,1.0}	21	40	0.549	0.554	1.00	3.7	2937	2510	3597
S3	$CA_{0.04,15\%}$ {0.25,1.0}	21	40	0.545	0.550	1.00	3.7	2913	2475	3552
S3	$CA_{0.06,1500t}$ {0.25,1.0}	21	40	0.465	0.453	1.00	4.7	3775	3073	4645
S3	$CA_{0.06,1900t}$ {0.25,1.0}	21	40	0.465	0.453	1.00	4.7	3770	3068	4639
S3	$CA_{0.06,2300t}$ {0.25,1.0}	21	40	0.464	0.453	1.00	4.7	3766	3063	4633
S3	$CA_{0.06,2700t}$ {0.25,1.0}	21	40	0.464	0.453	1.00	4.7	3762	3058	4627
S3	$CA_{0.06,15\%}$ {0.25,1.0}	21	40	0.463	0.453	1.00	4.7	3748	3028	4594
S3	$CA_{0.08,1500t}$ {0.25,1.0}	21	40	0.394	0.378	1.00	6.0	4266	3315	5428
S3	$CA_{0.08,1900t}$ {0.25,1.0}	21	40	0.394	0.379	1.00	6.0	4262	3311	5423
S3	$CA_{0.08,2300t}$ {0.25,1.0}	21	40	0.394	0.379	1.00	6.0	4259	3308	5418
S3	$CA_{0.08,2700t}$ {0.25,1.0}	21	40	0.394	0.379	1.00	6.0	4256	3306	5413
S3	$CA_{0.08,15\%}$ {0.25,1.0}	21	40	0.393	0.379	1.00	6.0	4250	3301	5403

Table B-11 Summary of performance statistics by CA model-based management procedures for scenario S4 $\{h = 0.65,\ q_{2,trap} = 1\}$. Table values represent the median performance statistic for 100 replicates over projection times t=t_1,…t_2.

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S4	$CA_{0.04,1500t}$ {0.25,1.0}	1	5	0.321	0.348	1.00	31.8	1562	1382	1852
S4	$CA_{0.04,1900t}$ {0.25,1.0}	1	5	0.319	0.346	1.00	29.9	1627	1362	1921
S4	$CA_{0.04,2300t}$ {0.25,1.0}	1	5	0.317	0.344	1.00	29.1	1692	1341	1987
S4	$CA_{0.04,2700t}$ {0.25,1.0}	1	5	0.315	0.343	1.00	28.3	1759	1321	2053
S4	$CA_{0.04,15\%}$ {0.25,1.0}	1	5	0.305	0.329	1.00	17.2	2160	1555	2276
S4	$CA_{0.06,1500t}$ {0.25,1.0}	1	5	0.312	0.331	1.00	30.9	2127	1500	2548
S4	$CA_{0.06,1900t}$ {0.25,1.0}	1	5	0.310	0.329	1.00	23.1	2188	1900	2610
S4	$CA_{0.06,2300t}$ {0.25,1.0}	1	5	0.308	0.328	1.00	18.4	2248	1965	2670
S4	$CA_{0.06,2700t}$ {0.25,1.0}	1	5	0.306	0.327	1.00	17.3	2309	1934	2729
S4	$CA_{0.06,15\%}$ {0.25,1.0}	1	5	0.303	0.323	1.00	13.6	2417	2096	2784
S4	$CA_{0.08,1500t}$ {0.25,1.0}	1	5	0.303	0.317	1.00	32.1	2658	1500	3194
S4	$CA_{0.08,1900t}$ {0.25,1.0}	1	5	0.301	0.315	1.00	25.1	2713	1900	3249
S4	$CA_{0.08,2300t}$ {0.25,1.0}	1	5	0.299	0.314	1.00	18.9	2768	2300	3302
S4	$CA_{0.08,2700t}$ {0.25,1.0}	1	5	0.298	0.313	1.00	13.8	2823	2510	3359
S4	$CA_{0.08,15\%}$ {0.25,1.0}	1	5	0.297	0.310	1.00	11.3	2830	2557	3337
S4	$CA_{0.04,1500t}$ {0.25,1.0}	6	10	0.393	0.424	1.00	7.8	2009	1753	2701
S4	$CA_{0.04,1900t}$ {0.25,1.0}	6	10	0.392	0.423	1.00	7.9	2002	1740	2693
S4	$CA_{0.04,2300t}$ {0.25,1.0}	6	10	0.390	0.422	1.00	8.0	1995	1731	2685
S4	$CA_{0.04,2700t}$ {0.25,1.0}	6	10	0.389	0.421	1.00	8.1	1987	1720	2676
S4	$CA_{0.04,15\%}$ {0.25,1.0}	6	10	0.379	0.411	1.00	9.0	1924	1642	2629
S4	$CA_{0.06,1500t}$ {0.25,1.0}	6	10	0.364	0.389	1.00	8.5	2754	2394	3759
S4	$CA_{0.06,1900t}$ {0.25,1.0}	6	10	0.363	0.388	1.00	8.6	2739	2381	3745
S4	$CA_{0.06,2300t}$ {0.25,1.0}	6	10	0.361	0.388	1.00	8.7	2725	2365	3730
S4	$CA_{0.06,2700t}$ {0.25,1.0}	6	10	0.360	0.387	1.00	8.7	2710	2349	3716
S4	$CA_{0.06,15\%}$ {0.25,1.0}	6	10	0.359	0.385	1.00	9.0	2681	2323	3676
S4	$CA_{0.08,1500t}$ {0.25,1.0}	6	10	0.340	0.359	1.00	9.7	3351	2865	4697
S4	$CA_{0.08,1900t}$ {0.25,1.0}	6	10	0.339	0.359	1.00	9.7	3337	2851	4684
S4	$CA_{0.08,2300t}$ {0.25,1.0}	6	10	0.338	0.358	1.00	9.8	3320	2837	4671
S4	$CA_{0.08,2700t}$ {0.25,1.0}	6	10	0.337	0.358	1.00	9.8	3302	2821	4657
S4	$CA_{0.08,15\%}$ {0.25,1.0}	6	10	0.336	0.358	1.00	9.9	3293	2802	4661
S4	$CA_{0.04,1500t}$ {0.25,1.0}	11	20	0.502	0.546	1.00	5.5	2628	2208	3409
S4	$CA_{0.04,1900t}$ {0.25,1.0}	11	20	0.501	0.545	1.00	5.6	2624	2199	3404
S4	$CA_{0.04,2300t}$ {0.25,1.0}	11	20	0.500	0.544	1.00	5.6	2620	2189	3400
S4	$CA_{0.04,2700t}$ {0.25,1.0}	11	20	0.499	0.543	1.00	5.6	2616	2178	3395
S4	$CA_{0.04,15\%}$ {0.25,1.0}	11	20	0.492	0.539	1.00	5.6	2585	2132	3376
S4	$CA_{0.06,1500t}$ {0.25,1.0}	11	20	0.448	0.472	1.00	6.9	3436	2881	4648
S4	$CA_{0.06,1900t}$ {0.25,1.0}	11	20	0.447	0.472	1.00	6.9	3431	2874	4641
S4	$CA_{0.06,2300t}$ {0.25,1.0}	11	20	0.446	0.471	1.00	6.9	3426	2868	4635
S4	$CA_{0.06,2700t}$ {0.25,1.0}	11	20	0.445	0.470	1.00	6.9	3420	2861	4628

Scenario	Procedure	t1	t2	Average Depletion	Final Depletion	P_{cons}	AAV Catch	Average Catch	Min. Catch	Max. Catch $\overline{C}_{0.95}$
S4	$CA_{0.06,15\%}$ {0.25,1.0}	11	20	0.443	0.469	1.00	6.9	3407	2844	4614
S4	$CA_{0.08,1500t}$ {0.25,1.0}	11	20	0.402	0.412	1.00	8.1	4045	3306	5607
S4	$CA_{0.08,1900t}$ {0.25,1.0}	11	20	0.402	0.411	1.00	8.1	4035	3297	5596
S4	$CA_{0.08,2300t}$ {0.25,1.0}	11	20	0.401	0.411	1.00	8.0	4026	3287	5585
S4	$CA_{0.08,2700t}$ {0.25,1.0}	11	20	0.400	0.410	1.00	8.0	4017	3277	5575
S4	$CA_{0.08,15\%}$ {0.25,1.0}	11	20	0.400	0.410	1.00	8.0	4012	3274	5581
S4	$CA_{0.04,1500t}$ {0.25,1.0}	21	40	0.575	0.560	1.00	3.9	3260	2775	4008
S4	$CA_{0.04,1900t}$ {0.25,1.0}	21	40	0.574	0.560	1.00	3.9	3258	2774	4005
S4	$CA_{0.04,2300t}$ {0.25,1.0}	21	40	0.574	0.560	1.00	3.9	3256	2773	4001
S4	$CA_{0.04,2700t}$ {0.25,1.0}	21	40	0.574	0.560	1.00	3.9	3254	2772	3998
S4	$CA_{0.04,15\%}$ {0.25,1.0}	21	40	0.571	0.558	1.00	3.9	3242	2764	3983
S4	$CA_{0.06,1500t}$ {0.25,1.0}	21	40	0.478	0.452	1.00	5.2	4172	3372	5157
S4	$CA_{0.06,1900t}$ {0.25,1.0}	21	40	0.478	0.452	1.00	5.2	4169	3369	5153
S4	$CA_{0.06,2300t}$ {0.25,1.0}	21	40	0.477	0.452	1.00	5.2	4165	3366	5148
S4	$CA_{0.06,2700t}$ {0.25,1.0}	21	40	0.477	0.452	1.00	5.2	4162	3364	5144
S4	$CA_{0.06,15\%}$ {0.25,1.0}	21	40	0.477	0.451	1.00	5.2	4153	3361	5132
S4	$CA_{0.08,1500t}$ {0.25,1.0}	21	40	0.405	0.380	1.00	6.5	4658	3604	6003
S4	$CA_{0.08,1900t}$ {0.25,1.0}	21	40	0.405	0.381	1.00	6.5	4655	3601	5999
S4	$CA_{0.08,2300t}$ {0.25,1.0}	21	40	0.405	0.381	1.00	6.5	4652	3598	5995
S4	$CA_{0.08,2700t}$ {0.25,1.0}	21	40	0.405	0.381	1.00	6.5	4650	3596	5991
S4	$CA_{0.08,15\%}$ {0.25,1.0}	21	40	0.405	0.381	1.00	6.5	4651	3597	5989

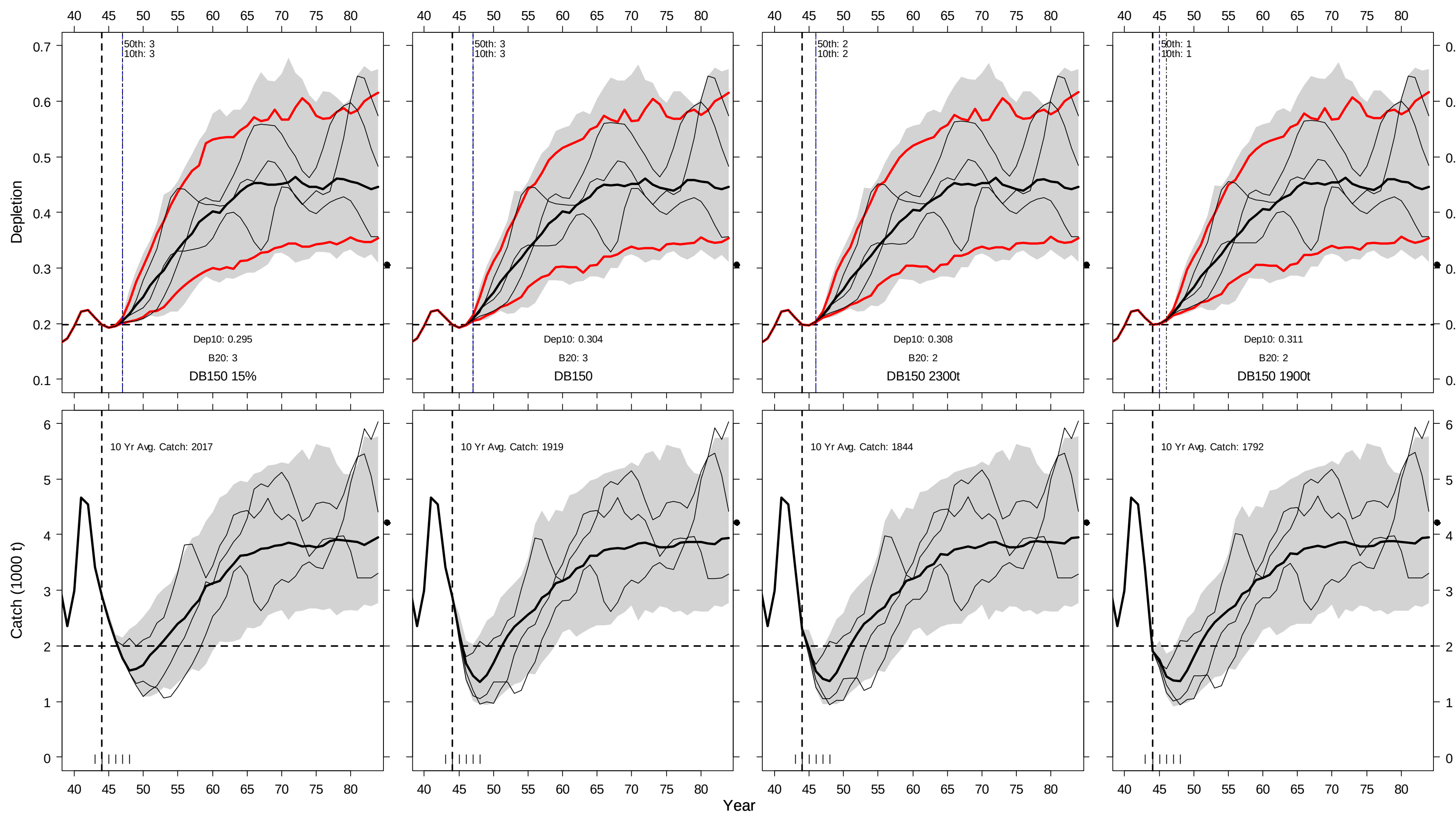

Figure B-1 Simulation results for $DB_{150,15\%}$, DB_{150}, $DB_{150,2300t}$ and $DB_{150,1900t}$ procedures under scenario S3 with $\lambda_1 = 0.5$ and $I_{low,high}$={4,15}. An envelope of annual spawning biomass depletion trajectories is bounded by the 5th and 95th percentiles (shaded area). The 10th and 90th percentiles (red lines) and median trajectories (heavy black lines) appear within the envelope. Three individual replicate trajectories of 100 are shown (thin black lines). Lower panels show catch envelopes with only the annual median trajectory indicated. Procedures are applied beginning at *t*=44 (heavy vertical dashed lines) and the initial depletion is indicated by a horizontal dashed line. Summary statistics and annotations appear within figure panels as described in text.

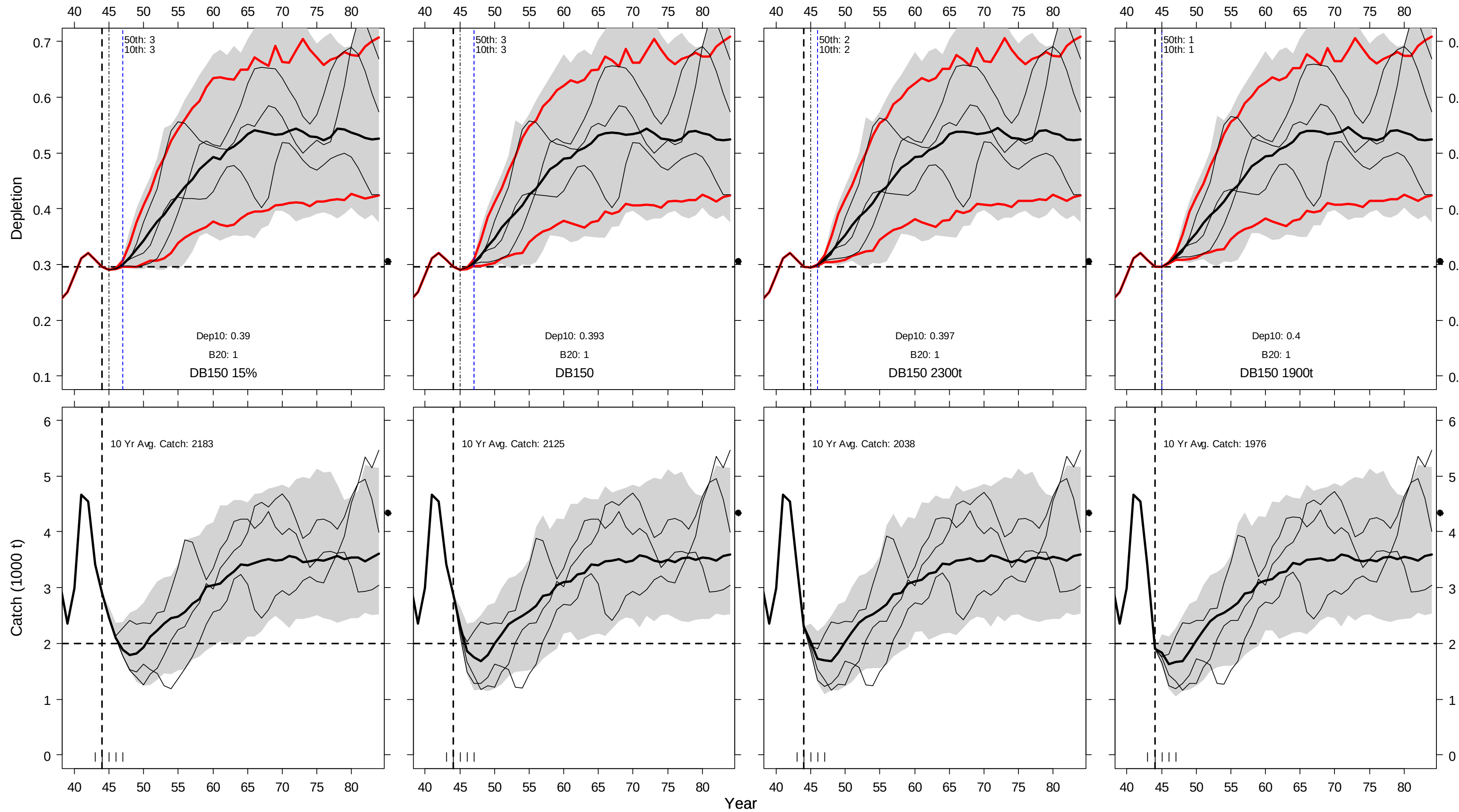

Figure B-2 Simulation results for $DB_{150,15\%}$, DB_{150}, $DB_{150,2300t}$ and $DB_{150,1900t}$ procedures under scenario S4 with $\lambda_1 = 0.5$ and $I_{low,high}$={4,15}. An envelope of annual spawning biomass depletion trajectories is bounded by the 5th and 95th percentiles (shaded area). The 10th and 90th percentiles (red lines) and median trajectories (heavy black lines) appear within the envelope. Three individual replicate trajectories of 100 are shown (thin black lines). Lower panels show catch envelopes with only the annual median trajectory indicated. Procedures are applied beginning at t=44 (heavy vertical dashed lines) and the initial depletion is indicated by a horizontal dashed line. Summary statistics and annotations appear within figure panels as described in text.

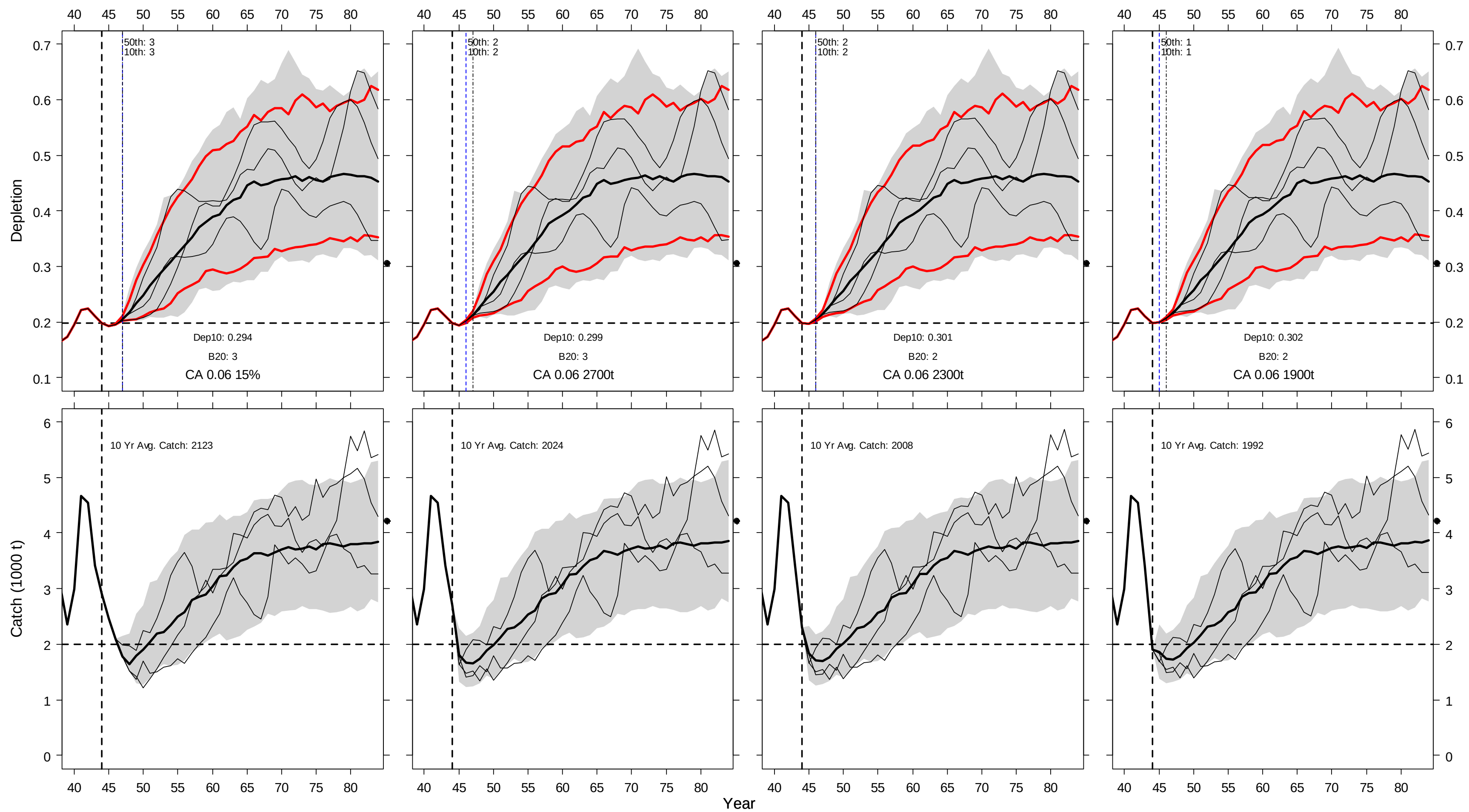

Figure B-3 Simulation envelopes for $CA_{0.06,15\%}$, $CA_{0.06,\ 2700t}$, $CA_{0.06,2300t}$ and $CA_{0.06,1900t}$ procedures under scenario S3 with $D_{low,high}$={0.25,1.0}. Upper panels show the distribution of annual spawning biomass depletion trajectories bounded by the 5th and 95th percentiles (shaded area). The 10th and 90th percentiles (red lines) and median trajectories (heavy black lines) appear within the envelope. Three individual replicate trajectories of 100 are shown (thin black lines). Lower panels show catch envelopes with only the annual median trajectory indicated. Procedures are applied beginning in 2008 at *t*=44 (vertical dashed line) and the initial depletion is indicated by a horizontal dashed line. Summary annotations appear within figure panels as described in text.

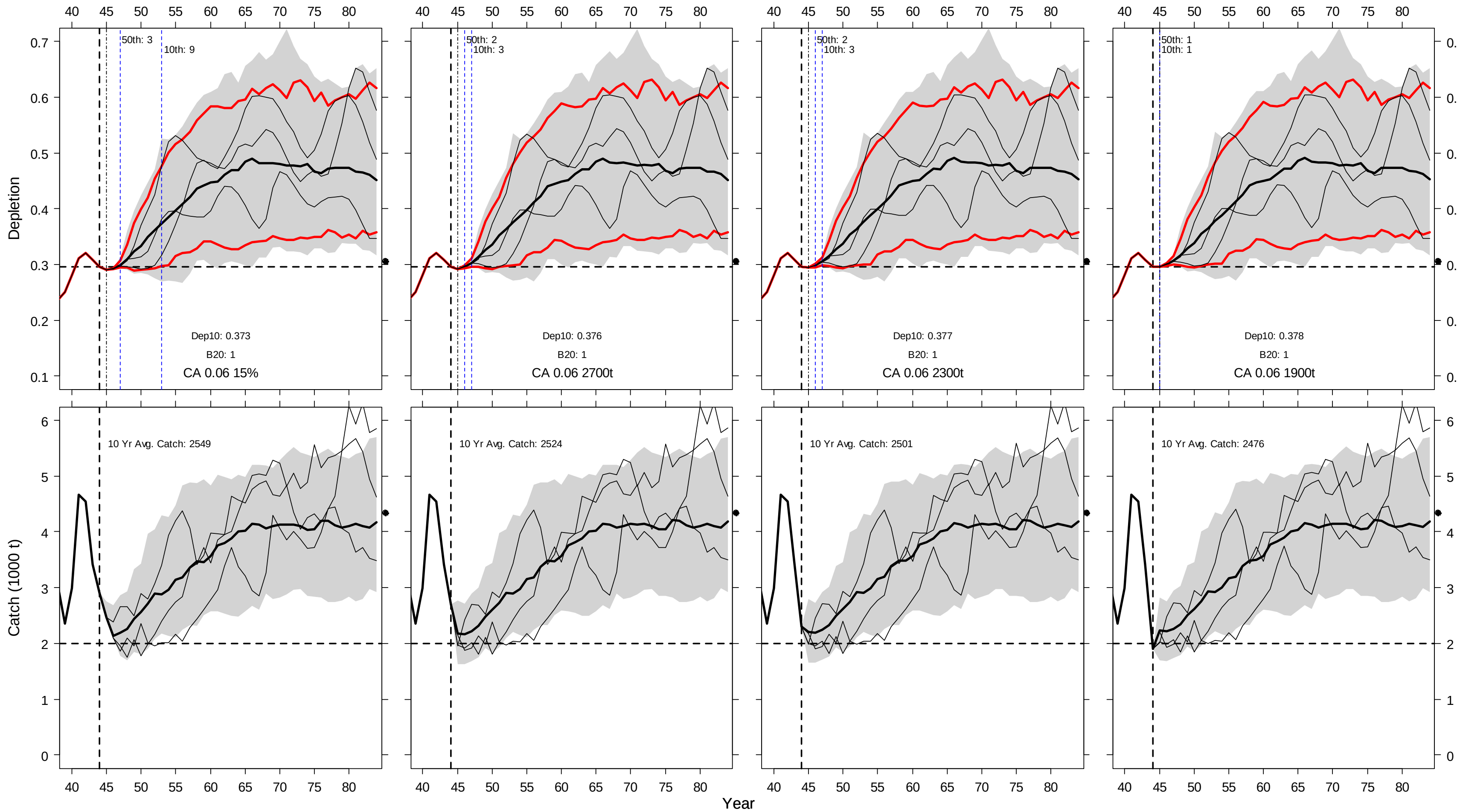

Figure B-4 Simulation envelopes for $CA_{0.06,15\%}$, $CA_{0.06,\,2700t}$, $CA_{0.06,2300t}$ and $CA_{0.06,1900t}$ procedures under scenario S4 with $D_{low,high}$={0.25,1.0}. Upper panels show the distribution of annual spawning biomass depletion trajectories bounded by the 5th and 95th percentiles (shaded area). The 10th and 90th percentiles (red lines) and median trajectories (heavy black lines) appear within the envelope. Three individual replicate trajectories of 100 are shown (thin black lines). Lower panels show catch envelopes with only the annual median trajectory indicated. Procedures are applied beginning in 2008 at t=44 (vertical dashed line) and the initial depletion is indicated by a horizontal dashed line. Summary annotations appear within figure panels as described in text.

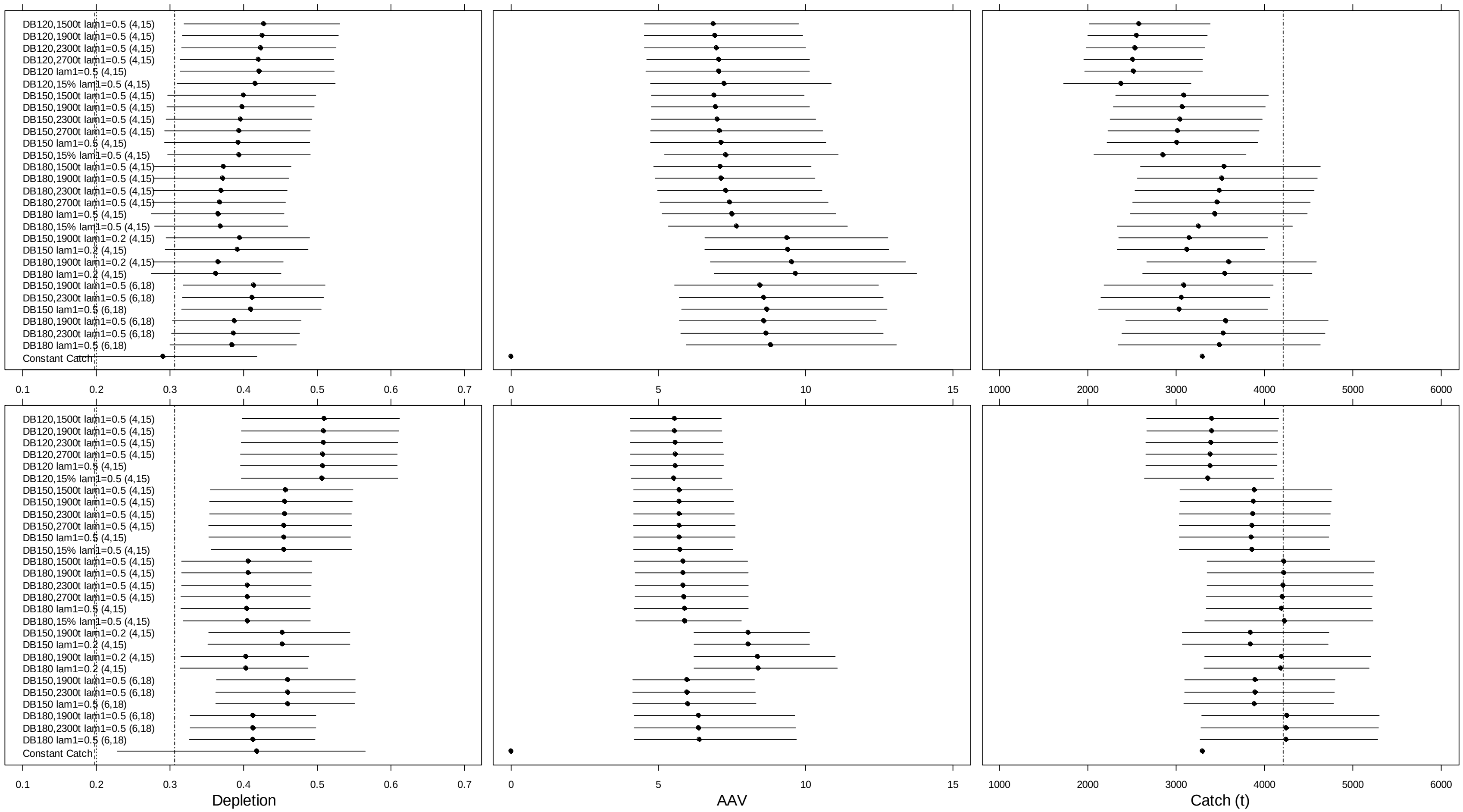

Figure B-5 Summary of spawning biomass depletion, catch variability, and catch performance for data-based procedures applied to scenario S3. The distribution of performance measures is represented by the median (solid circles) and 10th and 90th percentiles (bars) of 100 replicates for projection years 11-20 (upper panels) and 21-40 (lower panels). The depletion panels show D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line). Catch panels show the MSY yield (dot-dash line).

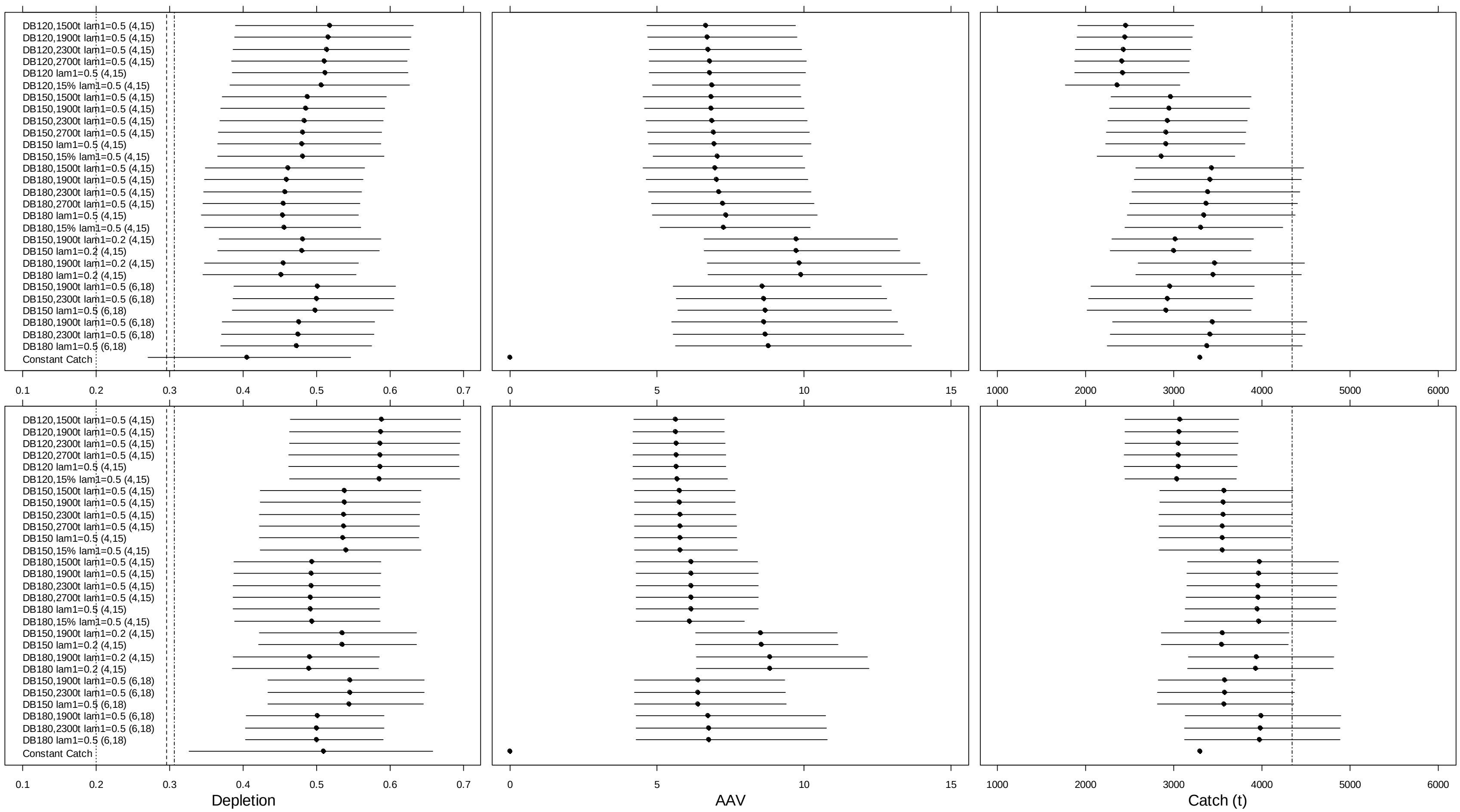

Figure B-6 Summary of spawning biomass depletion, catch variability, and catch performance for data-based procedures applied to scenario S4. The distribution of performance measures is represented by the median (solid circles) and 10th and 90th percentiles (bars) of 100 replicates for projection years 11-20 (upper panels) and 21-40 (lower panels). The depletion panels show D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line). Catch panels show the MSY yield (dot-dash line).

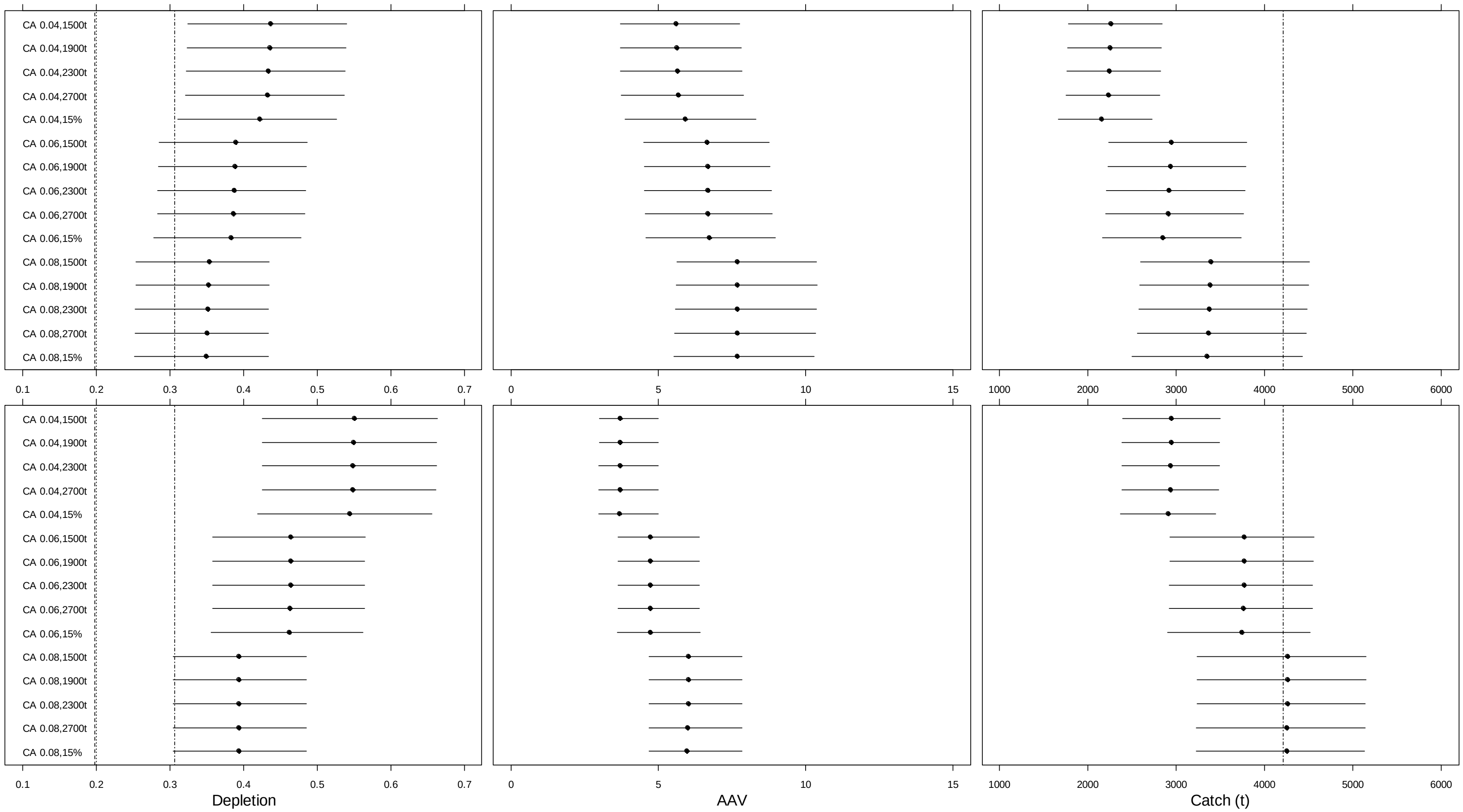

Figure B-7 Summary of spawning biomass depletion, catch variability, and catch performance for CA model-based procedures applied to scenario S3. The distribution of performance measures is represented by the median (solid circles) and 10th and 90th percentiles (bars) of 100 replicates for projection years 11-20 (upper panels) and 21-40 (lower panels). The depletion panels show D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line). Catch panels show the MSY yield (dot-dash line).

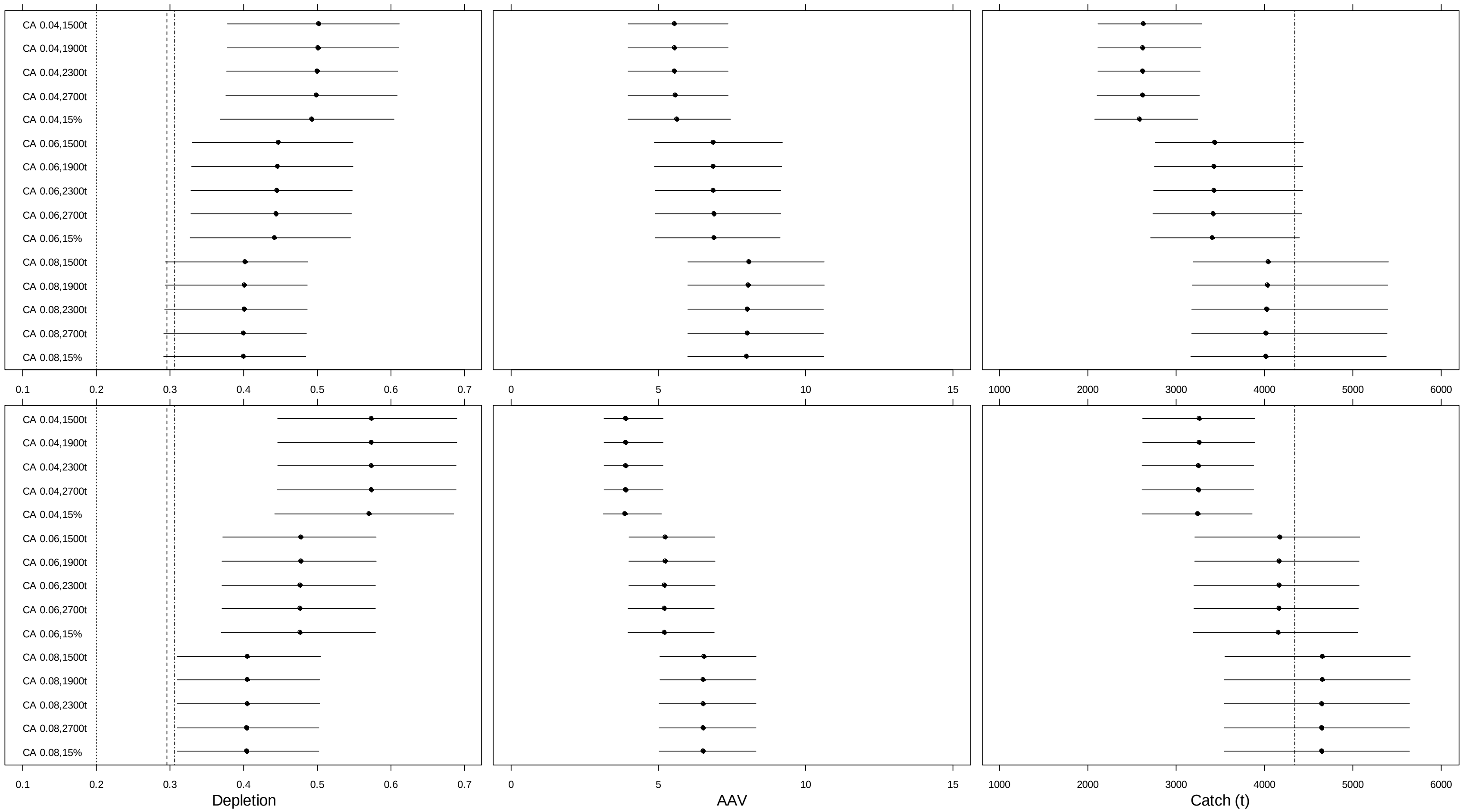

Figure B-8 Summary of spawning biomass depletion, catch variability, and catch performance for CA model-based procedures applied to scenario S4. The distribution of performance measures is represented by the median (solid circles) and 10th and 90th percentiles (bars) of 100 replicates for projection years 11-20 (upper panels) and 21-40 (lower panels). The depletion panels show D_{MSY} (dot-dash lines), $0.2B_0$ (dotted line) and D_{init} (dashed line). Catch panels show the MSY yield (dot-dash line).