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**Sablefish (*Anoplopoma fimbria*) in
British Columbia, Canada: Stock
Assessment Update for 2004 and
Advice to Managers for 2005**

**La morue charbonnière (*Anoplopoma
fimbria*) en Colombie-Britannique
(Canada) : mise à jour de l'évaluation
de l'état du stock en 2004 et avis aux
gestionnaires pour 2005**

V. Haist¹, A.R. Kronlund² and M.R. Wyeth²

¹ Canadian Sablefish Association
406-535 Howe Street
Vancouver, BC V6C 2Z4

² Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

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Abstract

Sablefish (*Anoplopoma fimbria*) stock status in British Columbia for 2004 is updated and advice to managers provided for the 2005/2006 fishing year. Four stock abundance indices are evaluated including (1) trap survey catch rates, (2) trap-vulnerable biomass estimates derived from tag-recovery data, (3) standardized catch rates based on commercial trap fishing logbooks, and (4) nominal catch rates based on commercial trap fishing logbooks and landings. Non-tagging based indices of abundance are integrated into a monthly tagging model which is used to conduct stock biomass projections. Performance measures are summarized in decision tables to allow the projected stock biomass to be compared at different levels of total annual catch. In general, performance measures adopted in this assessment are related to biomass levels that should be avoided to ensure conservation concerns for sablefish do not arise.

Trap survey catch rates in 2004 were similar to those observed in 2003 however commercial catch rates declined from 2003 to 2004. Beginning-year trap vulnerable biomass estimated for 2004 is estimated to be similar to levels in the mid-1990s. General agreement among the time series of indices indicated that sablefish vulnerable to trap gear experienced a decrease in abundance from higher levels in the early 1990s to low levels in the mid 1990s. The rate of decline slowed in the mid 1990s in both the north and south areas. For the north area, a period of relative stability occurred in the mid 1990s until 2001 when historically low commercial CPUE and survey results were observed. Survey catch rates in the north increased modestly in 2002 and then improved substantially in 2003. The decline in commercial trap and survey indices for the south area was more gradual through the mid 1990s and continued through 2002. However, significant improvement of the 2003 survey index for the south area was observed. Survey catch rates observed in 2004 are similar to 2003 levels. Commercial catch rates declined in 2004, tempering the outlook for the stock. The pattern of tagging model estimates of trap-vulnerable biomass was generally consistent with the trends indicated by the commercial catch rates and standardized survey series through 2002 and 2003, but diverges from the trap survey in 2004.

The decision tables allow evaluation of tradeoffs along the conservation, stability, and yield axes of fishery objectives. If greater importance is placed on long-term stability, at the expense of increasing yield, then a reasonable trade-off between catch stability and stock conservation objectives would support no change to the current TAC of 4,500 t for the 2005/2006 fishing year. Higher tolerance for variability in catches, perhaps requiring larger reductions in future TACs, may provide the rationale for the selection of a higher TAC.

Résumé

L'état des stocks de morue charbonnière (*Anoplopoma fimbria*) en Colombie-Britannique en 2004 a été évalué et des avis présentés aux gestionnaires pour la saison de pêche de 2005-2006. L'évaluation reposait sur l'interprétation de quatre indices d'abondance des stocks, soit (1) les taux de capture obtenus dans le cadre de relevés aux casiers, (2) des estimations de la biomasse vulnérable à la pêche reposant sur les données d'étiquettes récupérées, (3) les taux de capture commerciale normalisés reposant sur les données des journaux de bord des pêcheurs aux casiers et (4) les taux de capture commerciale nominale reposant sur les données des journaux de bord des pêcheurs aux casiers et les débarquements. Les indices d'abondance ne reposant pas sur les données d'étiquetage ont été intégrés dans un modèle d'étiquetage mensuel pour faire des projections de la biomasse des stocks. Les mesures de rendement ont été résumées sous forme de tableaux de décision afin de pouvoir comparer la biomasse projetée des stocks à des niveaux différents de prises totales annuelles. En général, les mesures de rendement adoptées dans cette évaluation sont reliées aux niveaux de biomasse qui devraient être évités afin d'assurer que la conservation de la morue charbonnière ne devienne pas une préoccupation.

Les taux de capture aux casiers obtenus dans le cadre des relevés réalisés en 2004 se comparent à ceux observés en 2003. Par contre, les taux de capture commerciale en 2004 ont diminué par rapport à 2003. La biomasse estimative de morue charbonnière vulnérable à la capture aux casiers pour la première fois en 2004 se rapproche des niveaux observés au milieu des années 1990. Les séries chronologiques d'indices semblent en général toutes indiquer que le nombre de morue charbonnière vulnérable à la capture aux casiers a diminué, passant de niveaux élevés au début des années 1990 à de bas niveaux au milieu de cette décennie. Le taux de décroissance a ralenti à ce moment-là dans les secteurs nord et sud. Le secteur nord a connu une période de stabilité relative du milieu des années 1990 jusqu'en 2001, lorsque les PUE de la pêche commerciale et les prises de relevé ont atteint des creux historiques. Les taux de capture obtenus dans ce secteur lors des relevés ont légèrement augmenté en 2002 et nettement augmenté en 2003. La décroissance des indices de la pêche commerciale aux casiers et des relevés pour le secteur sud a été plus graduelle jusqu'au milieu des années 1990, mais a continué jusqu'en 2002. Une nette amélioration de l'indice de relevé a cependant été observée pour le secteur sud en 2003. Les taux de capture réalisés dans le cadre des relevés en 2004 se comparent à ceux de 2003; par contre, les taux de capture commerciale ont diminué en 2004, ce qui colore les perspectives pour le stock. La tendance des estimations de la biomasse de morue charbonnière vulnérable à la capture aux casiers, reposant sur le modèle d'étiquetage, correspondait généralement aux tendances indiquées par les taux de capture commerciale et les séries normalisées de données de relevé pour 2002 et 2003, mais s'éloigne de la tendance indiquée par les données de relevé pour 2004.

Les tableaux de décision permettent d'évaluer des compromis le long des axes de la conservation, de la stabilité et du rendement des objectifs de pêche. Si une importance plus grande est accordée à la stabilité à long terme, aux dépens d'un accroissement du

rendement, alors un compromis raisonnable entre la stabilité des prises et les objectifs de conservation des stocks pourrait servir à justifier le maintien du TAC actuel de 4 500 t pour la saison de pêche de 2005-2006. Une tolérance plus élevée d'une variabilité des prises, nécessitant peut-être des réductions plus marquées des TAC futurs, peut servir à justifier le choix d'un TAC plus élevé.

1 Introduction

This document provides an updated assessment of offshore sablefish (*Anoplopoma fimbria*) stock status in British Columbia for 2004 and advice to managers for the 2005/2006 fishing year. The assessment of sablefish stock status in recent years has depended upon the interpretation of up to four stock abundance indices: (1) annual estimates of trap-vulnerable biomass derived from a tag-recovery model, (2) standardized catch rates obtained from a coast-wide survey, (3) nominal commercial catch rates drawn from sablefish trap fishery logbook and landings data, and (4) standardized commercial catch rates derived from sablefish trap fishery logbook data (Haist and Hilborn 2000, Haist et al. 2001, Kronlund et al. 2002, Kronlund et al. 2003, Haist et al. 2004).

This assessment is focused on the offshore component of sablefish in British Columbia (B.C.), excluding seamounts and inside waters such as Hecate Strait, mainland inlets and the Strait of Georgia. In the most recent stock assessments (Kronlund et al. 2003, Haist et al. 2004), a simple biomass dynamics model was used to integrate the stock indices and to provide a pragmatic tool for projecting abundance and identifying choices of future total annual catch. Substantially increased values from the standardized survey and commercial trap fishery indices for 2003 provided optimism that sablefish production had increased markedly over the low levels experienced during the 1996 to 2002 period (Kronlund et al. 2003, Haist et al. 2004). Fishery performance measures were cast in the context of short-term (5 year) projected trap-vulnerable biomass being (1) greater than the 2002 biomass, and (2) greater than an *ad hoc* conservation level determined from simulation analyses. These performance measures were selected as biomass levels that should be avoided to ensure conservation concerns for sablefish do not arise. Results from the biomass dynamics model were used to construct decision tables that summarized the probability of achieving the performance measures at various levels of total catch.

A specific harvest policy (e.g., a fixed fishing mortality rate) is not recommended for B.C. sablefish at this time for two reasons. First, operational objectives for the fishery developed in cooperation with stakeholders, managers, and analysts have not been specified for B.C. sablefish. Second, annual, seasonal, and spatial patterns in catch rates (Appendix B) and the results of tagging analyses (Beamish and McFarlane 1983, 1988, Kimura et al. 1998, Kronlund et al. 2003, Appendix C, Appendix E) provide strong evidence that B.C. sablefish do not comprise a closed population. Over the available data series, catch rates in the commercial trap fishery are relatively high in the December to March period in northern B.C.; these high catch rates tend to progress in a southerly direction through the calendar year. Tags recovered per tonne of sablefish landed typically decrease in the December to March period, consistent with an influx of untagged fish into the tagged population which subsequently become unavailable to the fishery through removals or movement to non-vulnerable areas. Given the longevity of sablefish, large changes that have occurred in the stock indices (e.g., 1993 to 1994, 2000 to 2001, 2002 to 2003 changes in standardized survey index values) cannot be explained using standard population dynamics such as recruitment and fishing mortality. Thus,

stock reconstructions based on age-structured population dynamics models are not used for B.C. sablefish assessments at this time. For the same reason, attempts to calculate biological reference points (e.g., F -based reference points) are problematic. An open population assumption was explicit in the structure of the tagging model developed by Haist et al. (2004) and the same structural concession is carried into the integrated tagging model used here (Appendix E). Previous attempts to integrate age-structured data with tagging data lead to problems in explaining movement of tagged fish and stock reconstructions were subject to potential bias. Furthermore, difficulties in methodology have resulted in a lack of age-structured data for B.C. sablefish since 1996. Sablefish were last assessed using an age-structured population dynamics model that integrated tag-recovery information by Haist and Hilborn (2000).

Abundance indices available for B.C. sablefish include the following sources:

1. 1990 to 2004 survey catch rates;
2. 1991 to 2004 trap-vulnerable biomass estimates derived from tag-recovery data;
3. 1990 to July 2004 standardized commercial trap catch rates based on logbook data;
4. 1979 to 2003 nominal commercial trap catch rates based on logbooks and landings data.

These time series all relate to the trap-vulnerable component of the B.C. stock. Thus, implied changes in biomass suggested by trends in the indices apply to the component of sablefish in B.C. that are captured by trap gear. The fraction of available fish that enter and are retained by trap gear is not known and is likely dependent on behavioral reasons as well as physical mechanisms. Thus, indices based on catch rates respond only to sablefish that enter traps in the geographic areas fished by the survey and commercial fishery. This would exclude sablefish residing in Hecate Strait, the eastern waters of Queen Charlotte Sound, coastal inlets and seamounts. Estimates of biomass derived from tag-recovery data also apply to trap-vulnerable fish since the tags have been applied through capture by trap gear and only recoveries obtained through the trap fishery are utilized in the analyses. Thus, it is incorrect to interpret tagging estimates of biomass as absolute estimates of the entire sablefish population in British Columbia. Furthermore, sablefish distributed shallower or deeper than those vulnerable to the commercial, survey, and tagging effort would not be indexed.

The PSARC Request for Working Paper (Appendix A) submitted by fishery managers identified the following objectives for this document:

1. To determine the stock status of B.C. sablefish and evaluate whether the previous/current harvest levels are appropriate;
2. To provide an updated assessment of the coast-wide sablefish stock.
3. To provide an updated decision table with appropriate yield options.

Changes to the stock assessment data analyses and modeling methodology between this document and Haist et al. (2004) are outlined in Table 1. The most significant change in methodology for the current assessment is that fitting of the three

non-tagging based abundance indices is integrated within the framework of the tagging model analysis developed in the previous assessment (Haist et al. 2004). This new integrated tagging model is used to project future abundance of trap-vulnerable sablefish biomass and thereby replaces the production model used in recent B.C. sablefish stock assessments. The change to combining the key abundance indices with the tagging analysis was suggested by a reviewer and was adopted because it provides a more parsimonious solution. In addition, new performance measures are introduced in this assessment to supplement those used previously as discussed below and in Appendix E.

This document consists of a main document with supporting Appendices A through H that can be consulted for more detailed information, as required (Table 1). Tables and figures referred to in the main text are sequentially numbered. Tables and figures in appendices are labeled with the letter code of the appendix and a sequential number, e.g., Table B.2 for the second table in Appendix B. Equations presented in the main text are numbered sequentially, as are equations within each appendix.

2 Stock Indices

Four stock indices are utilized in this assessment (Figure 1). Two indices are based on commercial trap fishery catch rates (CPUE) derived from logbook and landings data. A fishery-independent index of abundance is available from a standardized survey that utilizes trap fishing gear. The fourth index is derived from annual estimates of trap-vulnerable biomass developed from a tagging model. The stock indices are described below:

Nominal trap catch rates (1979-2003, Figure 1a, Appendix B). Coast-wide nominal catch rates (kg/trap) increased substantially in 2003 relative to levels experienced from 1999 to 2001. Prior to 2003 nominal catch rates remained at, or slightly below, levels experienced in the early 1980s. This time series is not standardized and coincides with a period of change in the fishery management regime and fishing practices including the mandatory introduction of escape rings into trap gear in 1999 (Kronlund et al. 2003, Haist et al. 2004). Nevertheless, the value of incorporating the longer times series outweighs the disadvantages of potential biases by including a period of contrasting stock abundance. The timing of the peak in nominal trap CPUE during the early 1990s is consistent with a similar pattern observed for the Gulf of Alaska stock (Appendix F), though the peak is lagged in B.C. relative to that in Alaska.

Standardized commercial trap catch rates (1990- July 2004, Figure 1a, Appendix B). Logbook data for catch rate standardization are available from 1990 through July, 2004. Standardized trap fishery catch rates (kg/trap) for the north coastal area declined continuously from 1991 to 1998 prior to the mandatory adoption of escape rings in the trap fishery. Subsequent to 1998 the four-year trend indicates a decline, with a low in 2001, modest improvement in 2002 and substantial improvement in 2003 in agreement with the standardized survey trajectory. The northern catch rate for 2004 decreased to a level intermediate between 2002 and 2003. The south area catch rates initially increased

and then declined from 1992 through 1998 with a major decline occurring between 1994 and 1995. Subsequent to 1998, southern catch rates were relatively stable between 1999 and 2003 but decreased to the lowest index value in the time-series in 2004. Limited data are available for 2004 in the south with only one vessel meeting the data selection criteria (Appendix B). The coast-wide standardized catch rates are intermediate between northern and southern values (Figure 1).

Standardized trap survey (1990-2004, Figure 1b, Appendix D). Coast-wide results from the standardized trap survey show substantially increased catch rates (numbers/trap and kg/trap) in 2003 and 2004 and reflect results in both the north and south areas. The trend for both north and south areas shows a general decline in catch rates from highs in the early 1990s. Beginning in the mid-1990s, the rate of decline generally decreased, and there was a period of relative stability through to 2000. The 2001 survey produced the lowest mean and median catch rates observed in the times series, with marked reduction of the variance for the north area in particular. Catch rates for the north area improved in 2002 relative to 2001, and were comparable to those observed in the mid-1990s, but with higher variability. Catch rates in 2003 increased substantially to a historical high and moderated slightly in 2004. Catch rates in the south area exhibited a continuous decline from the mid-1990s to 2002, but increased significantly in 2003 largely due to improved catches in three shallower depth strata. Catch rates in 2004 were similar in level to those observed in 2003 with similar variability, again largely due to high catch rates in three shallower depth strata.

Tagging model estimates of trap-vulnerable biomass (1991-2004, Figure 1c, Appendix E). Beginning of year trap-vulnerable biomass is estimated for the 1992 to 2004 period by fitting the tagging model to tag-recovery data only. The estimated biomass declined rapidly from an initial peak in 1992 and 1993 through to 1999. It has remained at low levels since then, with historical lows in 2001 and 2002 followed by a slight increase in 2003. Beginning of year trap-vulnerable 2004 biomass estimated from tag-recovery data only remains at a relatively low level.

3 Stock Indicators

Stock indicators considered in this assessment are summarized below. The indicators include results of neighboring stock assessments in Alaska and the continental U.S., sablefish catch in the west coast Vancouver Island shrimp survey, and analyses of sablefish catch, effort and catch rate trends derived from trawl at-sea observer data.

Gulf of Alaska sablefish stock status (Appendix F). Abundance is considered to be at a moderate level with the 1997 year-class projected to comprise 23 percent of the 2005 spawning biomass. Relative abundance in 2004 was 4 percent higher than in 2000. Although the 1998 year-class was initially expected to be above average, it now appears to be weak. The 2000 year-class may be above average but more data are required to confirm its relative contribution to stock abundance (Sigler et al. 2004). Projected 2005 spawning biomass is 37 percent of unfished biomass and is projected to fall to 35 percent

by 2007 under the maximum permissible yield under the U.S. adjusted $F_{40\%}$ harvest policy. Longline survey relative abundance for the East Yakutat/Southeast area has undergone a long-term decline that began in 1991. However, in contrast to the survey time series, commercial longline catch rates derived from observer data increased substantially from 2001 to 2003.

Several factors suggest that the apparent abundance of sablefish in northern B.C. waters is related to the abundance of the Gulf of Alaska stock and the degree to which that large, i.e., an estimated 2005 spawning biomass of 204,000 t, extends southwards into Canadian waters. First, seasonal patterns in catch rates and tags recovered per tonne landed in northern B.C. suggest movement of fish into the trap-vulnerable population and dilution of tagged fish by unmarked fish. Second, the longline survey indices for the eastern Gulf of Alaska show an increase from the late 1970s to higher levels during the late 1980s and a decline from the early 1990s until 2001. Survey index values have remained at about the 2001 level through 2004. Trends in B.C. indices are qualitatively similar during the period of overlap with the exception of the increase in all B.C. indices for 2003 and the trap survey index in 2003-2004. Finally, tagging studies (e.g., Kimura et al. 1998) suggest two stocks of sablefish on the west coast divided at about the northern extent of Vancouver Island, although exchange between the two groups occurs.

Examination of the Gulf of Alaska stock reconstruction may be useful for providing perspective to current abundance trends in northern B.C. The Gulf of Alaska stock has undergone two large increases in biomass within the available time series peaking first during the late 1960s and again during the late 1980s (panel (d) of Figure 1). The Gulf of Alaska stock has increased about 4 percent from a low in 1998 to 2000 with current spawning stock biomass at about 204,000 t. This recent increase can be compared to spawning stock biomass estimates at peak abundances in 1987 (362,000 t) and 1968 (364,000 t) when the biomass was approximately 80 percent larger. The contribution of the 2000 year-class may be above average but there are insufficient data at this time to fully assess its potential, and initial impressions of the strength of the 1998 year-class now appear to have been overly optimistic as more data accumulates (Sigler et al. 2004). The longline survey index from the East Yakutat/South East region of Alaska declined from a relatively high level in 1992 to a low in 2003; the 2004 value is comparable to that observed in 2002 (Sigler et al. 2004). In contrast, the survey index in B.C. increased sharply in 2003 and a similarly high index value was observed in 2004.

Continental U.S. indicators (Appendix F). Relatively strong 1999 and 2000 year-classes were observed by the triennial shelf survey, and the 2001 shelf survey results are the highest in the 1980 to 2001 series (Schirripa 2002). These signs that the 1999 and 2000 year-classes may be very strong in the waters off the continental U.S. follows poor recruitment through the 1990s (Schirripa and Methot 2001, King et al. 2001) and a concurrent decline in sablefish spawning stock biomass off the continental U.S. over the same period.

West Coast Vancouver Island Shrimp Survey (1979-2003). The west coast Vancouver Island (WCVI) shrimp survey, conducted at shallow depths (50 to 200 m) in management

areas 124 and 125, intercepts juvenile sablefish. Sablefish catch rates increased markedly in 2001 and 2002, and subsequently declined in 2003 (Kronlund et al. 2003, Haist et al. 2004). These results are in agreement with sablefish catch rates from the continental U.S. shelf and slope surveys and bycatch rates in the U.S. Pacific hake (*Merluccius productus*) fishery (Schirripa 2002), where the 1999 and 2000 year-classes appeared to be above average.

Sablefish catch in the B.C. trawl fishery (1996-2004, Appendix G). Trends in trawl catch rates of sablefish in Major Areas 3C and 3D (west coast Vancouver Island) are consistent with the occurrence of juvenile sablefish in the WCVI shrimp survey and U.S. shelf and slope surveys, although they provide no basis for determining which year-classes are present to explain changes in abundance. At depths shallower than 550 m catch rates for Area 3C in the fall increased beginning in 2001 and have remained high relative to previous years, peaking when fishing occurs at about 100 to 200 m on average. November to May catch rates at depths deeper than 550 m peaked in 2000, decreased in 2001, and have increased through to 2004. For Area 3D, the catch rate trends are similar at depths shallower than 550 m; although the relative magnitude of the increase starting in 2001 is not as pronounced as the increase at similarly shallow depths in Area 3C. For Area 5E at depths deeper than 311 m, peak catch rates in winter months have increased since 2000. The available time series of trawl observer data is limited, but results suggest ongoing monitoring of sablefish catch and effort in the trawl fishery may have utility, particularly if coupled with an adequate level of length frequency sampling to detect the presence of recruiting year-classes.

4 Integrated Tagging Model and Performance Measures

For this stock assessment, the monthly tagging model introduced by Haist et al. (2004) is extended to integrate fitting to the non-tagging based abundance indices. This eliminates the need for a separate biomass dynamics model. The model assumes constant rates of natural mortality and emigration from the B.C. trap-vulnerable population. Recruitment parameters are estimated for each year and these represent all additions to the trap-vulnerable biomass in B.C. A Bayesian approach, based on the Markov Chain Monte Carlo (MCMC) algorithm (Gelman et al. 1995), is used to estimate the joint posterior distribution of model parameters. Distributions of the trap vulnerable biomass estimates and of the recruitment estimates are shown as Figure 2.

Trap-vulnerable sablefish biomass is estimated with the integrated tagging model for the 1970 to 2004 period. Although presented as absolute biomass estimates with associated uncertainty from the Bayesian estimation algorithm, the absolute values are highly dependent on assumptions integral to the tagging analysis. These assumptions correspond to the treatment of tag reporting rates, tagging induced fish mortality, and a constant rate of emigration. Abundance trends are likely better determined than are absolute abundance values.

For the 1979 to 1990 period where there are nominal trap CPUE data only, there is considerable uncertainty in the abundance estimates although an increase in the late 1980s and early 1990s is likely and is consistent with trends observed for the Gulf of Alaska stock. The peak abundances estimated for the 1988 to 1993 period are followed by a sharp decline through 1995, which moderates through the late 1990s to a historic low in 2001. The estimated increase in trap-vulnerable biomass in 2003 is largely dependent on the increased trap survey index for 2003 and 2004. For 2004, the biomass estimate decreased to values similar to the mid-1990s.

The integrated tagging model is used to conduct 5-year stock projections at constant TAC levels. As in previous sablefish assessments, a series of performance measures are calculated for each projection to assist in the selection of short-term TACs (Kronlund et al. 2003, Haist et al. 2004). The performance measures relate to biomass levels that should be avoided to ensure conservation concerns for sablefish do not arise. For the current assessment new performance measures are calculated in addition to those used previously (Appendix G), however only a sub-set of those are presented here:

1. The *probability* that the beginning-year vulnerable stock biomass in 2010 is above the beginning-year 2002 vulnerable stock biomass, $P(B_{2010} > B_{2002})$;
2. The *probability* that the end-year vulnerable stock biomass in 2009 is above the end-year 2001 vulnerable stock biomass, $P(B''_{2009} > B''_{2001})$;
3. The *probability* that the end-year vulnerable stock biomass in 2006 is above the end-year 2001 vulnerable stock biomass, $P(B''_{2006} > B''_{2001})$;

Performance measures are presented in decision tables that allow stock status at different future catch levels to be compared (Appendix E). The integrated tagging model constructs the marginal distribution of B_{2004} over the sample from the MCMC chain. Then, the distribution of B_{2004} values is used in decision tables to summarize results relative to current stock condition, i.e., the impacts of the B_{2004} being at the lower (or higher) end of the range of estimated values. This was achieved by dividing the marginal posterior distribution of 2004 vulnerable biomass estimates into three ranked groups using the 0th-33rd, 34th-66th, and 67th-100th quantiles. Performance measures are presented for each of these groups to represent expected outcomes given poor, medium, or good levels of biomass in 2004. Note that the group differences are relative.

Five year stock projections are conducted under two scenarios with respect to future recruitments to the trap-vulnerable biomass. For the more optimistic scenario recruitments over the projection period are re-sampled from those estimated over the 1980 through 2004 time series. The more pessimistic scenario arises from re-sampling from the more recent, and shorter-term, 1994 to 2004 time series. The performance statistics calculated for each of these scenarios is presented in Table 2. The catch levels in the decision tables are arbitrarily selected to include the TAC for the 2004/2005 fishing year and to show contrast in the table values over a range of possible catch scenarios. Note that the decision procedure used here is not intended to set harvest levels over the duration of the projection period.

There are a number of observations that can be made about the results presented in Table 2. These include: (1) results are highly sensitive to what recruitments occur over the projection period, and this has greater influence on the probabilities than does the selection of TAC level within the 3500 to 10000 t range evaluated, (2) the end-year statistics are consistently lower than the beginning-year statistics and the differences increase with higher TAC levels, and (3) the influence of the TAC level on the performance measure is less pronounced when looking at stock biomass after two years than when looking at stock biomass after five years.

5 Stock Status

There was substantial improvement in the standardized survey and commercial catch rates indices in 2003 relative to values observed during the late 1990s through 2002. Trap survey catch rates achieved in 2004 are similar to the 2003 levels but commercial catch rates through July 2004 declined. General agreement among the time series of indices suggests that sablefish vulnerable to trap gear experienced a decrease in abundance from (relatively) high levels in the early 1990s to low levels in the mid 1990s. The rate of decline slowed in the mid-1990s for both the north and the south areas. For the northern area, a period of relative stability occurred in the mid 1990s until 2001-2002 when historically low commercial CPUE, standardized survey, and tagging results were observed. Standardized survey catch rates in the north increased modestly in 2002 and then improved substantially in 2003 and 2004. The decline in commercial trap and survey indices for the south area was more gradual through the mid 1990s and continued through 2002. The increase in the 2003 standardized commercial catch rates is consistent with the upturn seen in the trap survey, though is of much lower magnitude. The standardized commercial trap CPUE index declined about 20 percent coast-wide from 2003 to mid-2004. This is in contrast to the 2004 standardized survey index value which is essentially unchanged from 2003. The pattern of tagging model estimates of trap-vulnerable biomass was generally consistent with the trends indicated by the commercial catch rates and standardized survey series through 2003.

All of the stock indices analyzed in this assessment are short time series compared to sablefish longevity (70+ years) and hence long generation time. The indices also relate only to sablefish that are vulnerable to trap gear. With the exception of the nominal catch rate series (1979 to 2003), each series is limited to about 15 years of data that must be judged relative to the long history of sablefish exploitation. Three of the stock indices do not provide the potential for an absolute estimate of sablefish abundance and should be viewed as providing a relative index for the trap-vulnerable component of the offshore sablefish population. The tagging model estimates of trap-vulnerable biomass are stated in terms of biomass, but are associated with considerable uncertainty, particularly early in the time series. These indices relate to the offshore biomass (excluding seamounts) vulnerable to trap gear and do not, for example, index juvenile sablefish or those residing in the inside waters of Hecate Strait, eastern Queen Charlotte Sound or coastal inlets. It is not known what factors motivate sablefish to enter traps, and hence it is not clear what

component of the stock is vulnerable to the gear. Also, the relative proportion of the B.C. sablefish stock indexed by the trap indices cannot be estimated using the available data.

Results from indicators such as the west coast Vancouver Island shrimp survey and U.S. triennial shelf and slope surveys suggest production due to the 2000 year-class may materialize in the trap-vulnerable biomass in the next few years. Also, analysis of sablefish catch by trawl gear off the west coast Vancouver Island suggests catch rate trends consistent with the shrimp survey results.

6 Advice to Fishery Managers

For this stock assessment, several alternative performance measures are considered in addition to those utilized previously (Kronlund et al. 2003, Haist et al. 2004). Performance measures based on end-of-year biomass are presented in addition to traditional measures based on beginning-year biomass. The use of end-year biomass is motivated by two issues: (1) the survey index value reflects the trap-vulnerable population during the mid-fall whereas available tagging and commercial catch indices lag the survey by four to six months, and (2) the results will be less impacted by occasionally large beginning-of-year recruitments to the trap-vulnerable biomass projected by the model. The decision tables, however, are more affected by assumptions regarding future recruitment to the trap-vulnerable biomass than by the choice of performance measures. It is also important to note that while the performance measures evaluated for this analysis are consistent with the model assumptions other measures are possible and may lead to different choices of yield. The performance measures are *ad hoc*, and the continuing absence of fishery objectives for B.C. sablefish means that there is no basis for evaluating alternative harvest policies.

Interpretation of the decision tables depends on a number of factors. The analyses relate to the trap-vulnerable biomass of the sablefish population in British Columbia. In the context of the tagging model, recruitment is defined in terms of all additions to the trap-vulnerable biomass rather than only the new year-classes entering the vulnerable biomass for the first time. The structure of the integrated tagging model explicitly acknowledges that trap-vulnerable sablefish do not represent a closed population in B.C. and admits large variation of recruitments to the biomass as well as monthly emigration. The model estimates trends in the trap-vulnerable biomass and provides a tool for synthesizing indices rather than a representation of the complexity of sablefish population dynamics. The greatest contrast in the results is dependent on whether the future sequence of recruitments to the trap-vulnerable biomass is similar to the longer-term 1980 to 2004 history or more like shorter-term 1994 through 2004 period. The recent period includes the relatively low recruitments experienced during the mid 1990s through to 2002. It is not known whether the stock index results for 2004, and the possibility of an above average 2000 year-class, signal the beginning of a sustained period of recruitments to the trap-vulnerable biomass.

Annual sablefish landings over the 1969 to 2003 period averaged 4,550 t and were about 5,100 t during the 1988 to 1993 period. The latter period experienced sustained higher stock index values for about 5 to 7 years as measured by the nominal and standardized commercial catch rates. The standardized survey initiated in 1990, and the tagging program initiated in 1991, suggest a decline in abundance from high levels through the 1990s. Average landings were about 4,000 t from 1994 to 2002, which was maintained during a period of gradual decline in the stock indices until 2000. The substantial improvement in the 2003 survey index was cause for optimism, but this outlook has been tempered by declines in the tagging and commercial indices for 2004.

In determining an appropriate TAC, tradeoffs among the axes of conservation, fishery stability, and economic yield must be considered. Economic yield is not considered in this document, although biologists often utilize yield as a (sometimes poor) proxy for economic value. Some of the fishery performance measures relate to biomass levels that should be avoided to ensure conservation concerns for sablefish do not arise, specifically those measures relative to B_{2002} , B_{2001}'' , and $B^{0.05}$. The integrated tagging model outputs suggest that if the recruitments to the trap-vulnerable biomass are similar to those realized from 1980 to 2004, the probability is at least 0.69 that catches from 0 to 5,500 t should not lead to a short-term conservation concern for $P(B_{2010} > B_{2002})$. For performance measures based on end-of-year biomass, the probabilities of achieving the performance measures are less optimistic, but values of $P(B_{2009}'' > B_{2001}'')$ are 0.60 or greater for catches between 0 and 4,500 t.

The decision tables do allow evaluation of tradeoffs along the conservation, stability, and yield axes. Stability is increased by adopting a policy that specifies fewer and smaller changes to the TACs. If, however, the primary fishery objective is to maximize yield and the TACs are increased in response to upward trends in stock indices, the likelihood of future larger reductions in the TAC is increased. Note that misspecification of recruitments can also substantially affect the level of future catches. For example, suppose that yield is selected based on the assumption that future recruitment to the trap-vulnerable biomass will be similar to the longer-term 1980 to 2004 history when in fact the actual recruitments are more like those observed from 1994 to 2004. Inspection of the decision table (Table 2) shows that the probability of biomass remaining above the reference level, $P(B_{2010} > B_{2002})$, decreases to 0.5 from 0.7 given a 3,500 t TAC. The point in comparing results based on longer-term and recent history recruitments is that they more clearly demonstrate the potential trade-offs between yield and stability of TACs.

If greater importance is placed on long-term stability, at the expense of increasing yield, then a reasonable trade-off between catch stability and stock conservation objectives would support no change to the current TAC of 4,500 t for the 2005/2006 fishing year. Higher tolerance for variability in catches, perhaps requiring larger reductions in future TACs, may provide the rationale for the selection of a higher TAC. As noted above, this synthesis is incomplete since economic yield is not considered and operational harvest guidelines for B.C. sablefish have not been specified. Progress

towards the definition of operational criteria along the stability, yield and conservation axes of fishery objectives requires collaboration of all stakeholders, including the multi-sector commercial industry, fishery managers, and scientists.

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Table 1 Changes to this document compared to the January 2004 stock assessment.

Analysis/Methodology	Change	Appendix
Request for advice	<ul style="list-style-type: none">• Updated for 2005/2006 fishing year	Appendix A Request for Working Paper
Management history	<ul style="list-style-type: none">• Not updated for 2004	
Stock assessment history	<ul style="list-style-type: none">• Not updated for 2004	
Catch history	<ul style="list-style-type: none">• Catch history updated to November 30, 2004	Appendix B Fishery Landings, Catch and Effort
Nominal trap catch rate index	<ul style="list-style-type: none">• Nominal trap fishery catch rates updated to end of calendar year 2003	
Standardized catch rate index	<ul style="list-style-type: none">• Standardized trap fishery catch rates updated to July 31, 2004	
Tag-recovery data	<ul style="list-style-type: none">• Tag release and recovery data updated to July 31, 2004	Appendix C Analysis of Tag-Recovery Data
Tag data processing	<ul style="list-style-type: none">• Tag allocation algorithm revised	
Tagging-based trap-vulnerable biomass	<ul style="list-style-type: none">• Model updated for complete to include 2003 recoveries	
Survey data	<ul style="list-style-type: none">• Analyses updated to include 2004 survey data	Appendix D Analysis of Standardized Survey Data
Survey index	<ul style="list-style-type: none">• Linear model standardization dropped in favor of simple annual means	
Biomass dynamics model	<ul style="list-style-type: none">• Replaced by integrated tagging model	Appendix E Integrated Tagging Model
Sablefish in non-directed surveys	<ul style="list-style-type: none">• Not updated for 2004	
Status of sablefish in U.S. waters	<ul style="list-style-type: none">• Updated to include 2004 Alaska assessment and lower 48 quota decisions for 2005 through 2006	Appendix F Status of sablefish in U.S. waters
Other indicators	<ul style="list-style-type: none">• New analyses of sablefish catch, effort and catch rates from trawl at-sea observer logbooks• Updated review of the potential for length frequency analyses	Appendix G Other Indicators
Ecosystem considerations	<ul style="list-style-type: none">• New summary of catch composition data in the directed sablefish trap and longline fisheries	Appendix H Sablefish Fishery Catch Composition
Escape ring analysis	<ul style="list-style-type: none">• Analysis completed in 2004	

Table 2 Decision tables showing the values for three performance measures for projections at a range of future catch levels and alternate future recruitment scenarios. Results are presented relative to current (2004) vulnerable biomass, and the “expectation” integrates over the range of current biomass levels.

Total Annual Catch 2005-2009	$P(B_{2010} > B_{2002})$							
	Longer-term recs. (1980-2004)				Shorter-term recs. (1994-2004)			
	Low	Avg.	High	Exp	Low	Avg	High	Exp.
0	0.82	0.80	0.82	0.81	0.70	0.67	0.68	0.68
3500	0.73	0.72	0.74	0.73	0.53	0.49	0.53	0.52
4500	0.72	0.70	0.71	0.71	0.48	0.45	0.49	0.48
5500	0.68	0.68	0.70	0.69	0.44	0.42	0.46	0.44
7500	0.64	0.64	0.67	0.65	0.38	0.35	0.39	0.37
10000	0.60	0.61	0.61	0.61	0.30	0.30	0.31	0.30

Total Annual Catch 2005-2009	$P(B''_{2009} > B''_{2001})$							
	Longer-term recs. (1980-2004)				Shorter-term recs. (1994-2004)			
	Low	Avg.	High	Exp	Low	Avg	High	Exp.
0	0.74	0.72	0.75	0.74	0.58	0.58	0.59	0.59
3500	0.63	0.63	0.63	0.63	0.38	0.33	0.40	0.37
4500	0.60	0.59	0.61	0.60	0.32	0.30	0.34	0.32
5500	0.57	0.56	0.58	0.57	0.26	0.25	0.28	0.26
7500	0.51	0.50	0.53	0.51	0.18	0.16	0.21	0.18
10000	0.42	0.44	0.47	0.44	0.09	0.10	0.13	0.11

Total Annual Catch 2005-2009	$P(B''_{2006} > B''_{2001})$							
	Longer-term recs. (1980-2004)				Shorter-term recs. (1994-2004)			
	Low	Avg.	High	Exp	Low	Avg	High	Exp.
0	0.57	0.55	0.59	0.57	0.45	0.51	0.56	0.51
3500	0.48	0.48	0.53	0.50	0.33	0.37	0.44	0.38
4500	0.46	0.47	0.51	0.48	0.30	0.34	0.42	0.35
5500	0.45	0.44	0.50	0.46	0.28	0.31	0.40	0.33
7500	0.41	0.42	0.47	0.44	0.22	0.26	0.33	0.27
10000	0.38	0.39	0.44	0.40	0.15	0.20	0.28	0.21

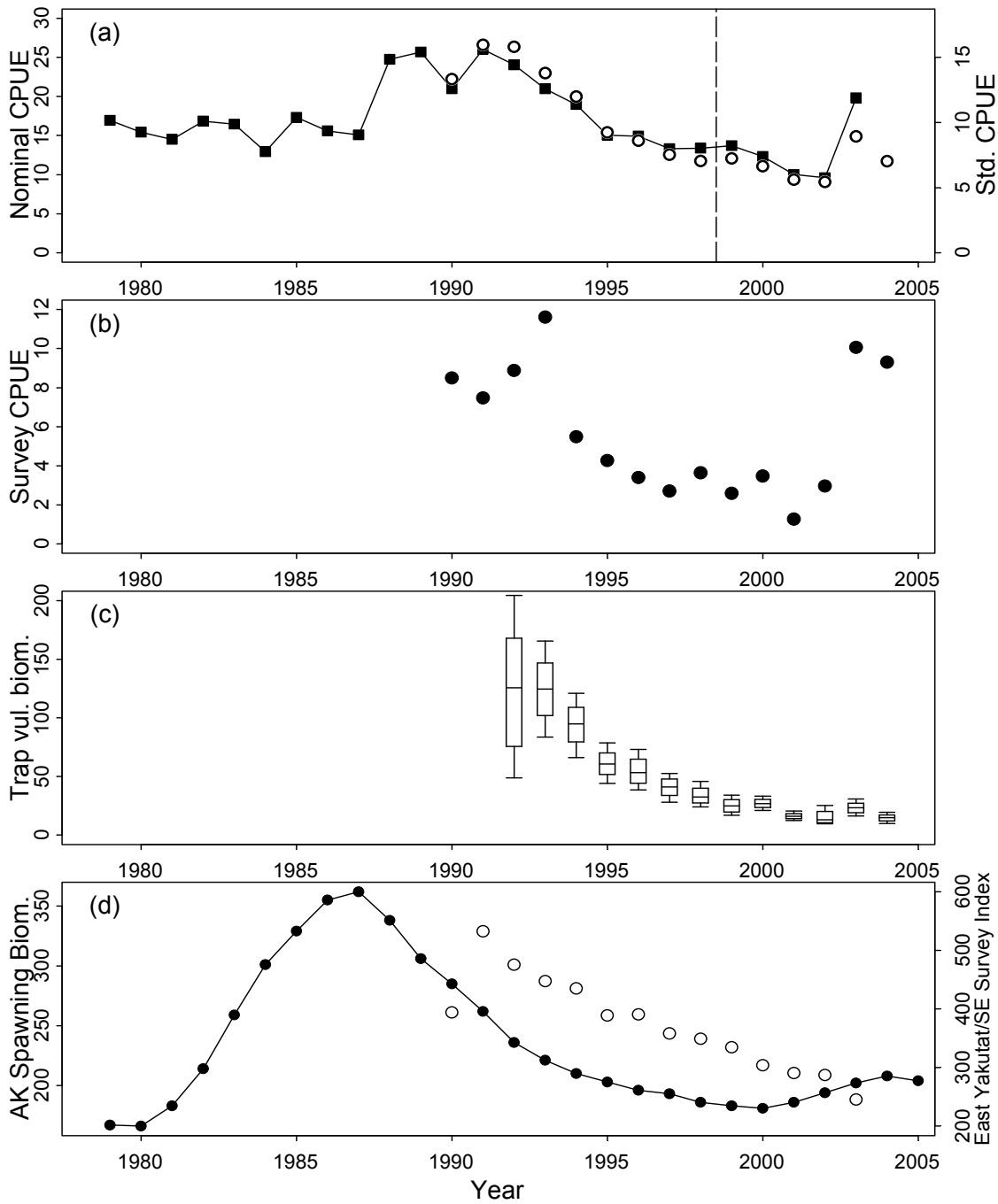


Figure 1 Coast-wide stock indices: (a) B.C. trap fishery nominal index (filled circles) and standardized (open circles) indices (kg/trap), (b) B.C. survey index (numbers/trap), and (c) B.C. trap-vulnerable biomass (1,000 t) posterior distributions for tagging data only, (d) Alaska spawning biomass (1,000 t, filled circles) and East Yakutat/South East survey index (open circles). The dashed vertical line in panel (a) indicates the inception of trap escape rings in the B.C. trap fishery.

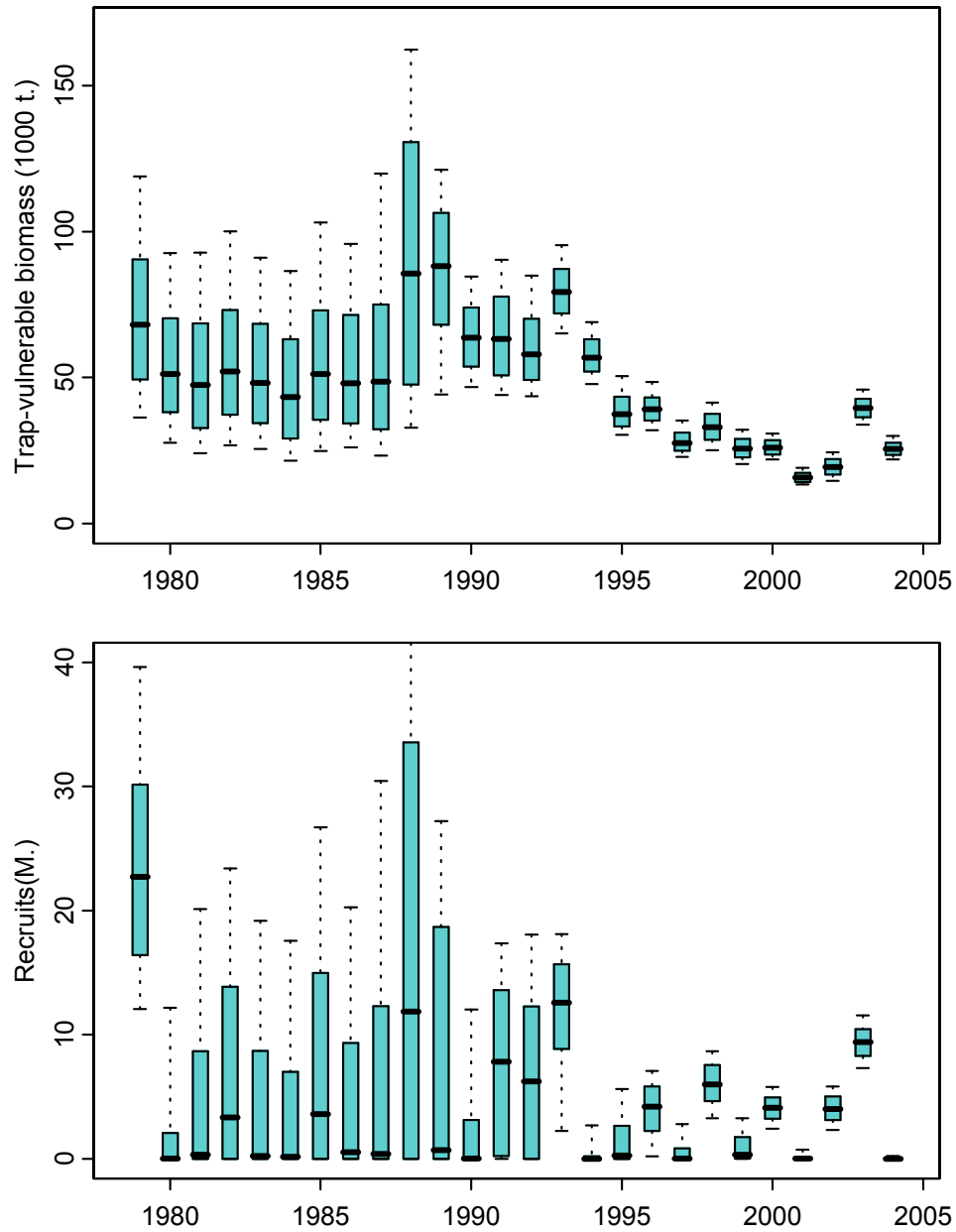


Figure 2 Quantile plots of the marginal posterior distributions of (a) trap-vulnerable biomass (1,000 t, upper panel) and (b) recruitments (millions, lower panel). The median is shown by heavy horizontal lines, the inter-quartile range by the shaded boxes, and the 5th and 95th percentiles by the whiskers.