Fisheries and Oceans Canada — Pêches et Océans Canada
Science — Sciences

C S A S — **S C C S**

Canadian Science Advisory Secretariat — **Secrétariat canadien de consultation scientifique**

Research Document 2005/031 — **Document de recherche 2005/031**

Not to be cited without Permission of the authors *

Ne pas citer sans autorisation des auteurs *

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. Haist[1], A.R. Kronlund[2] and M.R. Wyeth[2]

[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

ISSN 1499-3848 (Printed / Imprimé)

Canada

Table of Contents

List of Tables

List of Figures

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

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 0^{th}-33^{rd}, 34^{th}-66^{th}, and 67^{th}-100^{th} 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 $P\left(B_{2010} > B_{2002}\right)$. For performance measures based on end-of-year biomass, the probabilities of achieving the performance measures are less optimistic, but values of $P\left(B''_{2009} > B''_{2001}\right)$ 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, $P\left(B_{2010} > B_{2002}\right)$, 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.

Acknowledgements

Like most stock assessment documents, this paper reflects the contributions of many individuals. We are grateful for the thoughtful reviews provided by James Ianelli and Dana Hanselman. The Canadian Sablefish Association collaborated in the development, implementation and analysis of sablefish stock assessment programs by providing survey vessels and support for staff. We are grateful for the conscientious work of numerous individuals involved in the preparation and processing of data used in this document. In particular, the contributions of Wendy Mitton (Pacific Biological Station) and Margo Elfert (Archipelago Marine Research) are greatly appreciated. Eric Wickham, Chris Acheson, Bob Fraumeni, Erling Olsen, Henry Heggelund, Gene Pearl, Blair Pearl, Gary Williamson, Chris Heras, Richard Beauvais, Tim Joys and other members of the Canadian Sablefish Association provided advice on the interpretation of sablefish fishery data. Discussions with Bruce Turris, Brian Mose, and Brian Dickens from the Canadian Groundfish Research and Conservation Society were very helpful to the development of the trawl data analyses. Comments and advice provided by Steve Martell and Sean Cox helped to guide the development of the assessment. Michael Sigler kindly gave permission to include figures from the Gulf of Alaska sablefish stock assessment.

Literature Cited

Beamish, R.J. and G.A. McFarlane. 1983. Summary of results of the Canadian sablefish tagging program. p. 147-183. *In* Proceedings of the Second Lowell Wakefield Fisheries Symposium. Anchorage, AK. Alaska Sea Grant Report 83-8.

Beamish, R.J. and G.A. McFarlane. 1988. Resident and dispersal behavior of adult sablefish (*Anoplopoma fimbria*) in the slope waters off Canada's west coast. Can. J. Fish. Aquat. Sci. **45**: 152-164.

Gelman, A.B.; Carlin, J.S.; Stern, H.S.; Rubin, D.B. (1995): Bayesian data analysis. Chapman & Hall, London. 526 p.

Haist, V., A.R. Kronlund, M.R. Wyeth. 2004. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: Stock Assessment Update for 2003 and Advice to Managers for 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/055.

Haist, V. and R. Hilborn. 2000. Sablefish stock assessment for 2000 and recommended yield options for 2001. Can. Stock. Assess. Sec. Res. Doc. 2000/157. 78 p.

Haist, V., Hilborn, R., and M. Wyeth. 2001. Sablefish stock assessment for 2001 and advice to managers for 2002. Can. Sci. Advisory Res. Doc. 2001/135. 54 p.

Kimura, D.K., Shimade, A.M., and F.R. Shaw. 1998. Stock structure and movements of tagged sablefish, *Anoplopoma fimbria* in offshore northeastern Pacific waters and the effects of El Nino-southern oscillation on migration and growth. Fish. Bull. 96: 462-481.

King, J.R. McFarlane, G.A., and R.J. Beamish. 2000. Decadal-scale patterns in the relative year-class success of sablefish (*Anoplopoma fimbria*). Fish. Oceanogr. 98: 62-72.

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

Kronlund, A.R., V. Haist, and M.R. Wyeth. 2004. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2003 and advice to managers for 2004. PSARC Working Paper G2004-01.

Kronlund, A.R., M. Wyeth, and R. Hilborn. 2002. Review of survey, commercial fishery, and tagging data for sablefish (*Anoplopoma fimbria*) in British Columbia: Supplement to the November 2001 sablefish stock assessment. Can. Sci. Adv. Sec. Res. Doc. 2002/074. 109 p.

Sigler, M.F., Lunsford, C.R., J.T. Fujioka and S.A. Lowe. 2004. Alaska sablefish assessment for 2004. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2005. November 2004, Plan Team Draft (http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

Schirripa, M.J. and R. Methot. 2001. Status of the sablefish resource of the U.S. Pacific coast in 2001. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

Schirripa, M.J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

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

Analysis/Methodology	Change	Appendix
Request for advice	• Updated for 2005/2006 fishing year	Appendix A Request for Working Paper
Management history	• Not updated for 2004	
Stock assessment history	• Not updated for 2004	
Catch history	• Catch history updated to November 30, 2004	Appendix B Fishery Landings, Catch and Effort
Nominal trap catch rate index	• Nominal trap fishery catch rates updated to end of calendar year 2003	
Standardized catch rate index	• Standardized trap fishery catch rates updated to July 31, 2004	
Tag-recovery data	• Tag release and recovery data updated to July 31, 2004	Appendix C Analysis of Tag-Recovery Data
Tag data processing	• Tag allocation algorithm revised	
Tagging-based trap-vulnerable biomass	• Model updated for complete to include 2003 recoveries	
Survey data	• Analyses updated to include 2004 survey data	Appendix D Analysis of Standardized Survey Data
Survey index	• Linear model standardization dropped in favor of simple annual means	
Biomass dynamics model	• Replaced by integrated tagging model	Appendix E Integrated Tagging Model
Sablefish in non-directed surveys	• Not updated for 2004	
Status of sablefish in U.S. waters	• 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	• 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	• New summary of catch composition data in the directed sablefish trap and longline fisheries	Appendix H Sablefish Fishery Catch Composition
Escape ring analysis	• 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

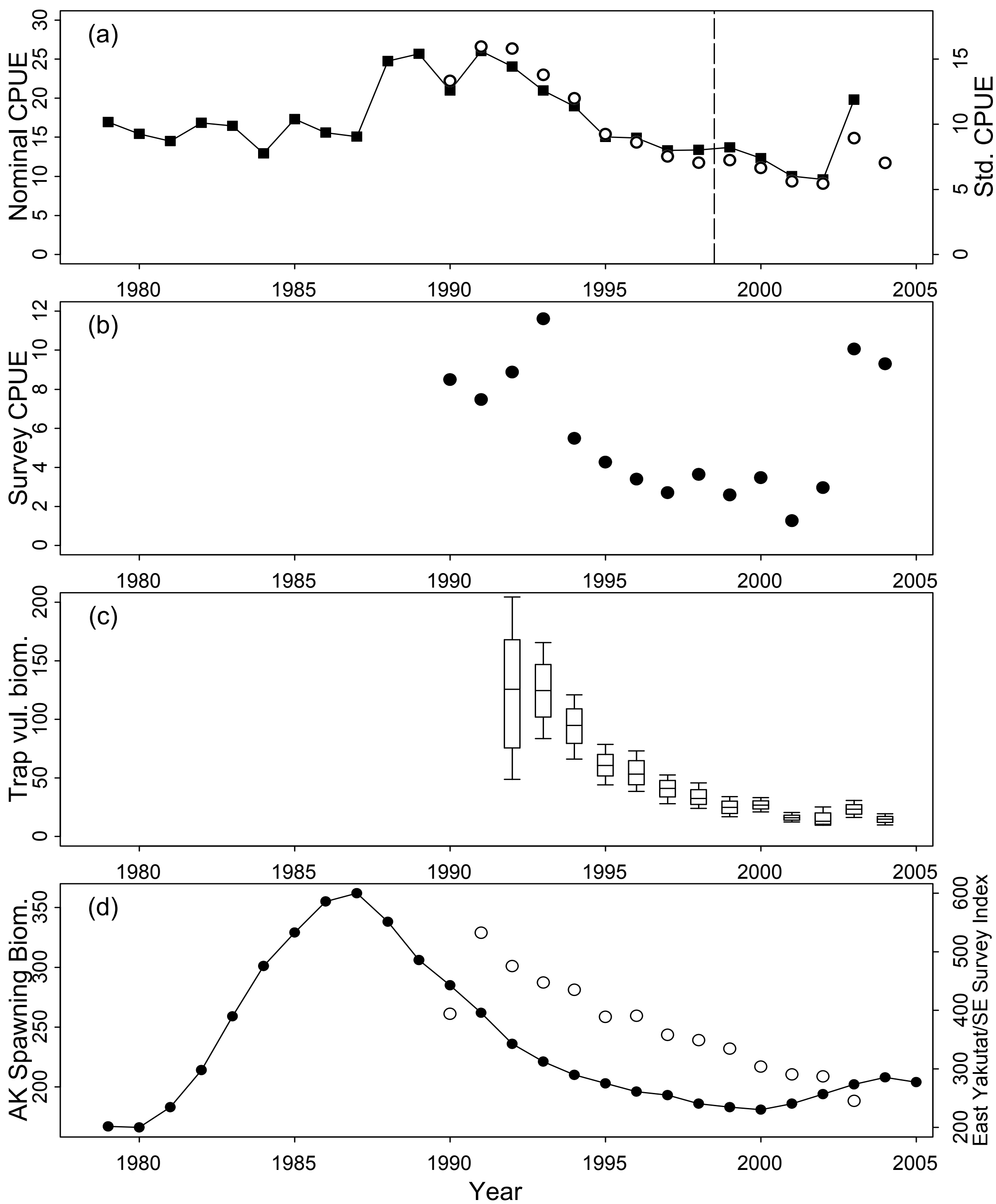

Figure 1 Coast-wide stock indices: (a) B.C. trap fishery nominal index (filled circles) and standardized (open circles) indices (kg/trap), (b) B.C. survey index (numbers/trap), and (c) B.C. trap-vulnerable biomass (1,000 t) posterior distributions for tagging data only, (d) Alaska spawning biomass (1,000 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.

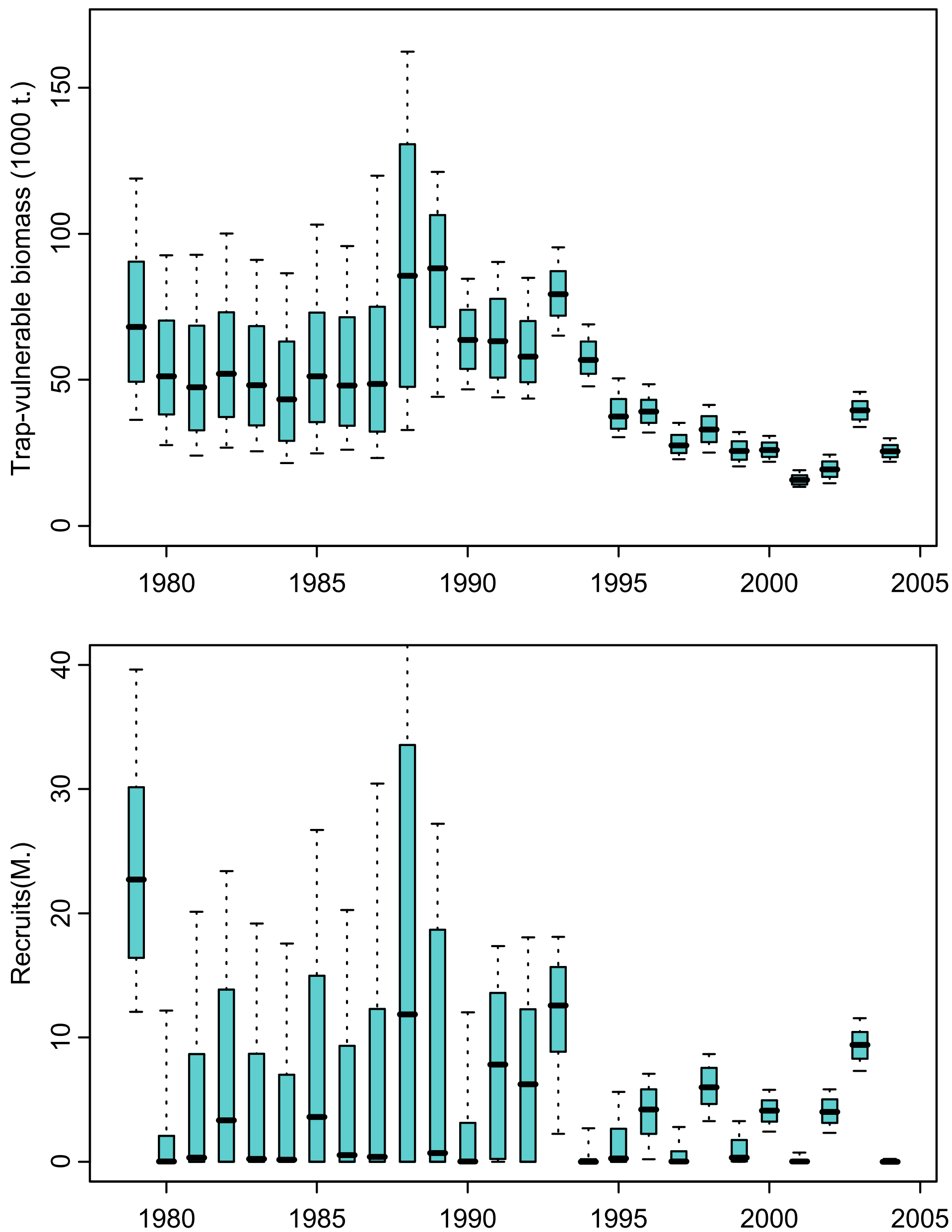

Figure 2 Quantile plots of the marginal posterior distributions of (a) trap-vulnerable biomass (1,000 t, upper panel) and (b) recruitments (millions, lower panel). The median is shown by heavy horizontal lines, the inter-quartile range by the shaded boxes, and the 5^{th} and 95^{th} percentiles by the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

APPENDIX A PSARC REQUEST FOR WORKING PAPER

Date Submitted: July 27, 2004

Individual or group requesting advice: Groundfish Management Unit

Proposed PSARC Presentation Date: January 20, 2005

Subject of Paper (title if developed): Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: Stock Assessment Update for 2004 and Advice to Managers for 2005

Stock Assessment Authors: V. Haist, A.R. Kronlund, M. Wyeth

Fisheries Management Author/Reviewer: Terri Bonnet/Al MacDonald

Rational for request: An annual assessment has been conducted for sablefish in the form of a decision table for Canadian harvests (commercial, First Nations, recreational, experimental). It is expected that there will be no major changes from the detailed assessment in 2004 therefore only an update with reference to the previous assessment is necessary for this year.

Question(s) to be addressed in the Working Paper:

1. What is the stock status of B.C. sablefish and are the previous/current harvest levels appropriate?

Objective of Working Paper:

1. To provide an updated assessment of the coast-wide sablefish stock.
2. To provide an updated decision table with appropriate yield options.

Stakeholders Affected: The range of sablefish is coast-wide and the species is found at various depths. The stakeholders affected include such groups as commercial K and T license holders, recreational users, processing plants, buyers, and others.

How Advice May Impact the Development of a Fishing Plan: The advice is critical for the development of fishing plans and management decisions.

Timing Issues Related to When Advice is Necessary: Results from this PSARC paper are required so that a TAC can be identified for the start of the commercial trawl fishery on April 1, 2005 and the sablefish fishery on August 1, 2005. It is anticipated that presentation of the paper at the PSARC Groundfish Subcommittee meeting on January 19-21, 2005 will permit the Department to meet its obligations in providing advice to fishery managers.

APPENDIX B FISHERY LANDINGS, CATCH AND EFFORT

B.1 Landings data

British Columbia

The history of sablefish fishery management is summarized in Table B.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 changed when an August 1 start was instituted in 1999. Details of the 2001/2002 to 2004/2005 fishing year quotas and allocations are provided in Table B.2 to document how the in-season reduction in the TAC during 2001/2002 was implemented over two fishing years with the transition to the 2004/2005 fishing year for completeness. Material in this section was drawn from management plans (see, for example, Fisheries and Oceans Canada 2002, 2003, 2004) and unpublished file material from the Groundfish Management Unit, Pacific Region, Fisheries and Oceans Canada.

Annual trap catches (t) were determined by summing the “official catch” weight of retained sablefish in each calendar year (see description in Appendix E.3 of Haist et al. 2004). Catches from research fishing at offshore locations were included in the landings summary listed in Table B.3 since they are counted against the quota. However, these catches were excluded from the catch rate calculations presented below since they may not be representative of commercial fishing. Landings from seamounts were excluded where they could be identified. Fishery landings and catch and effort data are not complete for 2004; fishery landings data are current to November 30, 2004 unless otherwise noted. Differences between landings reported in 2004 and those contained in this document are summarized in Table B.4.

The commercial fishery for sablefish has been active since the late nineteenth century and was described in detail by McFarlane and Beamish (1983). Total annual landings as high as 5,956 metric tons (t) were realized during the 1910s; however, landings remained modest from 1920 to 1965, ranging between 209 t and 1,895 t (Figure

B.1, panel A, Table B.3). Exploitation increased in the late 1960s with the arrival of foreign longline fleets from Japan, the US, the USSR and the Republic of Korea (McFarlane and Beamish 1983, Figure B.1, panel B). The largest annual landings of sablefish occurred during this period with a peak 7,408 t removed in 1975. Declaration of the Canadian 200 mile Economic Exclusive Zone in 1977 ended unrestricted foreign fishing. However, some foreign fishing was allowed between 1977 and 1980 to utilize yield surplus to Canadian domestic fleet needs. Total landings have ranged from 2,355 t (2003) to 7,408 t (1975) since 1969 and averaged 4,550 t over the 1969 to 2003 period (Figure B.1).

Canadian landings since 1951 have been reported by longline, trawl, and trap gear (Table B.3). The fishery has been managed since 1981 under quotas allocated to the "K" licence (longline and trap gear) and "T" licence (trawl gear) fleets (Table B.1). Sablefish are caught incidentally in the halibut (*Hippoglossus stenolepis*) longline fishery, and there are small allocations to research charters and to First Nations food fisheries (Table B.1, Table B.2). Since 1977, the trawl components of the landings have always been the smallest, ranging from 3 to 16 percent of the total (Figure B.1, panel B, Table B.3). Since 1981, the trawl fishery has been allocated a fixed percentage (8.75) of the total allowable catch based on historic average trawl landings.

Longline was the dominant gear type in the directed sablefish fishery for most years until 1973. At this time, the trap fishery began to develop and the proportion of the catch taken by longline gear declined (Figure B.1, panel B). Since 1978 trap gear clearly dominated domestic landings and the percentage of longline-caught fish in the total landings fluctuated between 6.3 percent (1979) and 28.0 percent (1990). The trap fishery landed an average of 449 t per year over the 1973 to 1978 period. Trap landings increased significantly in 1979, and beginning in 1980 have ranged from 1,486 t in 2003 to 4,142 t in 1993. Longline landings ranged from 249 t in 1980 to 1,372 t in 1990 over the same period.

During the period from 1990 to 1992, the first three years of Individual Vessel Quota (IVQ) management, the proportion of landings attributed to longline was high (17 to 28 percent) but then dropped to below 12 percent over the 1993 to 1998 period. The initial increase was due to larger vessels developing longline operations for groundfish species including sablefish caught under quota. This shift allowed these vessels to fish most of the year. The subsequent decline in sablefish landings by longline is attributed to a move away from the multi-species longline approach in favor of dedicated trap fishing with transferable quota. The adoption of a transferable quota system allowed a move away from derby fishery tactics and vessels could plan to fish sablefish most of the year. Traps were chosen as the most efficient gear. An increase in the proportion of the catch taken by longline from 1999 through 2004 may reflect a move back to a multiple target species approach, i.e. so-called "combination fishing" where halibut "L" or rockfish (*Sebastes*) "ZN" licenses may be fished in conjunction with a sablefish "K" license to avoid discarding imposed by license regulation. The increase in longline landings could also reflect reduced availability of sablefish to trap gear during the 1999 through 2002 period (Kronlund et al. 2002).

Pacific coast

Annual catches from Alaska, British Columbia and the continental United States are plotted in Figure B.2 to show the B.C. contribution to total Pacific coast sablefish catch. Data for Alaska are taken from Table 3.2 of Sigler et al. (2004), Table ES-1 of Schirripa (2002) and Table 8-1a of Pacific Fishery Management Council (2004). Coast-wide catches are dominated by the Alaskan fisheries, which currently take about 20,000 t of sablefish annually. In contrast to Alaska, sablefish catches in B.C. did not increase significantly during the late 1980s and early 1990s in response to increased abundance. By the same token, B.C. catches did not undergo significant reductions during the early 1970s and again in the 1990s when Alaskan catches were reduced well over 50 percent (Figure B.2). Catches in all jurisdictions showed a general decline after 1990; Alaskan catches have increased since 2001.

B.2 Nominal trap fishery catch rates

Sablefish catch and effort data for the "K" licensed fishery are available from logbooks and skipper interviews beginning in 1979. From 1979 to 1991 these data are not available by fishing event (set) but are aggregated such that more than one set is represented by each record. These data are most comprehensive for the trap fishery. Nominal catch per unit effort, U_t, in years $t = 1,\ldots,T$ was computed by forming the ratio of the sum of individual catches, C_{ti}, divided by the sum of the associated effort, E_{ti}, for all records $i = 1,\ldots,n_t$ that have valid observations for both catch and effort. Thus, the annual catch rate was the so-called ratio of means estimate

(1) $$U_t = \frac{\sum_{i=1}^{n_t} C_{ti}}{\sum_{i=1}^{n_t} E_{ti}} \quad .$$

Total annual effort cannot be computed by direct summation for all trap sets over the 1979 to 2004 period since effort data are sometimes incomplete. The proportion of total landings accounted for by logbook records with both catch and effort data ranged from 62 to 100 percent. Thus, total annual effort, $\widehat{E}_t$, was estimated by dividing the total annual landings, L_t, by the annual catch per unit effort

(2) $$\widehat{E}_t = \frac{L_t}{U_t} \quad .$$

Figure B.3 shows the trap fishery catch and effort time series by calendar year and area from 1979 to 2003, with partial 2004 data. The panels show a coast-wide summary and north and south stock summaries, where the north-south boundary is at 50.5 degrees latitude (in the vicinity of the northern extent of Vancouver Island). Within each panel of the figure, total annual catch (t) is represented by the open circles joined by a dashed line. Vertical solid bars show the annual effort estimated using equation (2) for all years except the most recent year where the bar is not filled. Annual nominal catch rates (kg/trap) computed using equation (1) are indicated by filled circles joined by a solid line. The dotted vertical reference line indicates the introduction of mandatory escape rings in traps in 1999.

Coast-wide catch rates were relatively stable from 1979 to 1987, but increased substantially in 1988 and remained high for several years. Catch rates from 1991 through 1995 declined to levels similar to, or slightly lower than, those observed prior to 1988. Catch rates declined from 1999 to an historic low in 2001. A substantial improvement in the nominal catch rate occurred in 2002. The coast-wide CPUE trend is largely driven by the catch rates in the north stock area, which has generally accounted for a larger proportion of both trap landings and effort. Nonetheless, the CPUE trajectory is similar in the south stock area with less contrast between high and low levels. Trap fishing was limited in the southern stock area in both 2003 and 2004.

The 1979 to 2001 period witnessed significant changes in the management regime for the sablefish fishery and in fishing practices. The introduction of IVQs in 1990 had a considerable impact on the distribution of trap effort. There was an abrupt shift in trap effort from the south (Major Areas 3 to 5) to the north (Major Areas 6 to 9) in 1991 as fishers under the IVQ program were attracted by higher catch rates and larger fish in the north (Figure B.3). The proportion of total trap catch taken from the north increased from an average of 0.57 from 1979 to 1990 to 0.87 in 1991 and 0.94 in 1992. In the late 1990s there was a shift back to the south and in 1998 landings from the south surpassed those from the north (Figure B.1). The shift can be attributed in part to declining catch rates in the north. However, fishery managers also requested the industry to distribute effort coast-wide to avoid the complexity of implementing area-specific TACs. Trap baiting practices have changed over the same period, with a shift from squid bait to a mixture of squid and Pacific hake (*Merluccius productus*) designed to improve trap efficiency. Escape rings were introduced by regulation in 1999, although some fishers experimented with escape rings in traps in 1998. The impact of this change was investigated in Appendix N of Haist et al. (2004).

Depth and seasonal differences in catch, effort and catch rates are shown in Figure B.4. The sablefish trap fishery extends from approximately 180 to 1,300 m (100 to 700 fm) although approximately three quarters of the fishing effort is expended between 460 to 825 m (250 to 450 fm). The longline fishery generally occurs at shallower depths, with over three quarters of the fishing effort in less than 250 fm (460 m). Each panel of Figure B.4 is identical in construction to those presented in Figure B.3. The data were stratified by stock area, two periods (January to March, and April to December) and three depth ranges (0 to 250 fm, 250 to 450 fm, and 450 fm and deeper). This stratification was used in previous analyses (eg., Saunders et al. 1996, Haist et al. 1997, 1999) because catch rates observed over the January to March period are generally higher than those during other periods. Also, the January to March period has not been fished consistently over time. Historically, the 250 to 450 fm depth interval has represented the “core” depths fished by the commercial trap fleet. Note that the apparent absence of landings and effort values in some years where CPUE values are displayed is due to relatively small amounts of landings, and hence effort, that do not show on the scale chosen for the plots. Such occurrences represent minimal fishing activity.

Trends evident in the aggregated data of Figure B.3 are reflected in the panels of Figure B.4 that correspond to April to December in the 250 to 450 fm depth stratum. Inspection of the panels confirms that this component of the data has represented the majority of fishing activity over time. However, the early 1990s showed an abrupt increase in trap fishing effort in the northern area in January to March. Since the mid to late 1990s, the proportion of trap effort in shallow depths (0 to 250 fm) has increased markedly, with the exception of the south stock area during the January to March period. Trap fishing in 2003 was limited due to the 2003/2004 quota being nearly caught by March. Effort in 2003 was largely in the north and at depths shallower than 250 fm.

Trap fishery catch rates tend to be higher in the December through March period in the northern waters of British Columbia, a pattern previously described by fishers. This effect is shown in Figure B.5 where catch rates are plotted as a function of latitude and month within each calendar year. Latitude intervals were defined by splitting the coast into 12 nautical mile strips from 48°N to 54.5°N. Within each block defined by latitude and year, the catch rate was computed as the mean of catch rates for individual fishing events observed in the block. In some years, such as 1991 through 1993, the higher winter catch rates began to develop at the end of the calendar year in November and December. There is also a tendency for the higher catch rates to move in a southerly direction through the year. Northern catch rate intensity for December through March decreased in 1997 and 1998, increased in 1999 and declined over the years 2000 through 2001. December 2002 and January and February 2003 showed relatively high catch rates before trap fishing ceased due to the quota being nearly subscribed. Available data for the first three months of 2003 show catch rate intensities similar to those observed in 1991 through 1993. Fishing conducted early in 2004 showed similarly high catch rates for northern B.C.

B.3 Standardized trap fishery catch rates

Catch and effort data selection

Analyses to standardize fishery catch rate (CPUE) data, using generalized linear models (GLMs), were first conducted for the 2002 sablefish stock assessment (section 4 of Kronlund et al. 2003). The annual trap fishery catch rate index from the year effects of the GLM was one of three indices used in a biomass dynamics model in the two most recent assessments (Kronlund et al. 2003, Haist et al. 2004). Annual indices resulting from a standardization analysis of the longline fishery data were not believed to reflect changes in stock abundance, so the longline catch rate data analysis is not updated here. The trap-fishery GLM analysis was updated using data through July 2004. The methodology used for the 2004 CPUE standardization is the same as that used previously, and only a cursory description of methodology and results is presented here.

Sablefish logbook data, which contain information from individual trap sets, were extracted from the *PacHarvSable* database for 1990 to 2004. Research fishing was excluded from the extraction. Collection of logbook data began earlier than 1990, but these data were aggregated over fishing events. Initially a voluntary program, the completion of logbook records when fishing under a "K" license became mandatory in 1990. A data selection and grooming process was undertaken with two objectives: (1) to limit the data to coastal offshore fishing events by excluding inshore and seamount fishing records, and (2) to remove records that were likely to contain erroneous information. The criteria used in the data grooming process and the number of logbook records that were selected are summarized in Table B.6.

General linear model standardization

For the 2002 CPUE standardization, a core set of fishing masters was selected for inclusion in the analysis. The selection was based on fishing master rather than fishing vessel because experience is more likely to be associated with fishing success in the sablefish trap fishery. A minimum of five years of documented fishing effort was the basis for selecting fishing masters, and the set of individuals selected for the 2002 analysis was used in the current analysis.

The log-normal linear model used for previous CPUE standardizations was used again this year. The stepwise analysis to evaluate alternative covariates in the model fit was not updated; rather, the previously selected set of covariates was used again this year. The dependent variable was the natural logarithm of catch rate, with catch rate measured as kilograms per trap. Independent variables that were treated as factors were *year*, *region* (northern BC, southern BC), *fishing master* and *minor area*. *Day of year* entered the model as a polynomial of degree 3. Note that a *year:region* interaction term was included in the model with the main effects (e.g., *year*region*), independent of statistical significance. An additional model was fit that excluded the *region* covariate for use in the tagging model.

Model results

Model results, in terms of the proportion of the total deviance explained, are shown in Table B.7. The first variable to enter the model was *fishing master* followed by *day of year* and *minor area*. Second order interactions involving *fishing master* were not evaluated because they would greatly increase the number of terms in the model, and would lead to a sparse design matrix. Inclusion of a *day of year:minor area* interaction did provide a fair improvement in the model fit, although the final model accounted for only 29 percent of the variance in the log CPUE (Table B.7). When the model was fit without the *region* term, the sequence in which the remaining model covariates entered the model was the same as for the model where the *region* term was included. Results for the model without the *region* covariate are presented in Table B.8.

The *year* effects estimated by the standardized CPUE model are shown in Figure B.6 for the northern region, southern region, and the entire coast. Also shown on the figure panels are the corresponding nominal CPUE estimates. There is very close agreement between the standardized and nominal CPUE indices. The vertical grey bars in Figure B.6, drawn between 1998 and 1999, demarcate the introduction of mandatory escape rings in the trap fishery. The use of escape rings is likely to decrease catch rates relative to the period prior to their use, thus creating two time series that are likely not comparable.

For the northern B.C. coast, the CPUE *year* effects show a continuous decline from 1991 through 1998. The magnitude of the southern region *year* effects in the early 1990s were not as large as those for the northern region, and the major decline in CPUE occurred between 1994 and 1995. It is not valid to compare *year* effects across 1998 because of the introduction of escape-rings. For the southern B.C. region, the *year* effects are relatively stable between 1999 and 2003 and decrease in 2004 to the lowest estimate in the time-series. The CPUE index for northern B.C. decreased from 1999 through 2001, increased substantially in 2003, and decreased again in 2004. The CPUE trends estimated for coast-wide data are intermediate between the northern and southern B.C. values.

The annual number of trap vessel trips, fishing masters, fishing events (sets) and months fished utilized for the GLM analysis are listed in Table B.9. For the southern B.C. analysis, logbook data from only one fishing master met the selection criteria in 2004. This fishing master made two trips totaling 80 sets in May and June of 2004. In 2003 two fishing masters made one trip each to the south stock area for a total of 47 sets, largely in December. In contrast, the number of trips, fishing masters and sets is substantially higher in 2003 and 2004 for the north and for both areas in all years prior to 2003 (Table B.9). These sets were not spatially distributed throughout the south stock area but were clustered off Barkley Canyon and the northern end of Vancouver Island. This sparseness of southern trap fishing effort suggests that the year effects may not be representative of fishing performance in 2003 and 2004 and therefore may be biased despite the attempt at standardization.

B.4 Exploratory analysis of fleet dynamics

Figure B.7 shows the cumulative proportion of trap catch by latitude over time. These catches were those reported in fisher logbooks excluding seamounts and research fishing. The dashed vertical line in each figure panel represents the division between north and south areas. The proportion of trap catch taken in the south has ranged from less than 10 percent in 1991 and 2003 to approximately 50 percent in 1990 and 1998. Data for 2004 are complete to July 31, 2004. Generally more catch is taken in the northern area by trap gear and this tendency was pronounced in the 2002 to 2004 period. The corresponding figure for longline gear is shown as Figure B.8. In general between 60 and 80 percent of fisher logbook catch by longline gear was taken in the south area with the exception of 1991-1992 and 2003-2004 when approximately 45 percent was removed from the south.

Depth fished by trap gear has decreased gradually coast-wide. Figure B.9 shows a plot of the mean depth fished by year, quarter of the year, and offshore region. The 10th and 90th percentiles of the distribution of depth fished on each set are shown in the figure in addition to the mean. A gradual tendency to shallower fishing begins in the mid-1990s in most quarters and regions.

B.5 Literature Cited

Fisheries and Oceans Canada. 2002. Integrated fishery management plan: sablefish, August 1, 2002 to July 31, 2003. Fisheries and Oceans Canada. 50 p.

Fisheries and Oceans Canada. 2003. Integrated fishery management plan: sablefish, August 1, 2003 to July 31, 2004. Fisheries and Oceans Canada. 82 p.

Fisheries and Oceans Canada. 2004. Integrated fishery management plan: sablefish, August 1, 2004 to March 31, 2005. Fisheries and Oceans Canada. 108 p.

Haist, V., Saunders, M.W., Hilborn, R., and M. Maunder. 1997. Sablefish stock assessment for 1997 and recommended yield options for 1998. Can. Stock Assess. Sec. Res. Doc. 97/146.

Haist, V., Fournier, D., and M.W. Saunders. 1999. Reconstruction of B.C. sablefish stocks, 1966-1998, and catch projections for 1999, using an integrated catch-age mark-recapture model with area and depth movement. Can. Stock Assess. Sec. Res. Doc. 99/79.

Haist, V., Hilborn, R., and M. Wyeth. 2001. Sablefish stock assessment for 2001 and advice to managers for 2002. Can. Sci. Advisory Res. Doc. 2001/135. 54 p.

Kronlund, A.R., M. Wyeth, and R. Hilborn. 2002. Review of survey, commercial fishery, and tagging data for sablefish (*Anoplopoma fimbria*) in British Columbia: Supplement to the November 2001 sablefish stock assessment. Can. Sci. Adv. Sec. Res. Doc. 2002/074. 109 p.

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

McFarlane, G.A. and R.J. Beamish. 1983. Overview of the fishery and management strategy for sablefish (*Anoplopoma fimbria*) in waters off the west coast of Canada. p. 13-35. *In* Proceedings of the Second Lowell Wakefield Fisheries Symposium, Anchorage, AK. Alaska Sea Grant Report 83-3.

Pacific Fishery Management Council. 2004. Proposed acceptable biological catch and optimum yield specifications and management measures for the 2005-2006 Pacific coast groundfish fishery: Final environmental impact statement including regulatory impact review and initial regulatory flexibility analysis. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384. (http://www.pcouncil.org/groundfish/gfspex/gfspex05-06.html).

Rutherford, K.L. 1999. A brief history of GFCATCH (1954-1995), the groundfish catch and effort database at the Pacific Biological Station. Can. Tech. Rep. Fish. Aquat. Sci. 2299: 66 p.

Saunders, M.W., Leaman, B.M., Haist, V., Hilborn, R., and G.A. McFarlane. 1996. Sablefish stock assessment for 1996 and recommended yield options for 1997. PSARC Working Paper G96-5.

Schirripa, M.J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

Sigler, M.F., Lunsford, C.R., J.T. Fujioka and S.A. Lowe. 2004. Alaska sablefish assessment for 2005. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2005. November 2004, Plan Team Draft (http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

Table B.1 Summary of sablefish management history. The 2004/2005 fishing year data are current to November 30, 2004.

Year	Fishery	Assessment Yield Rec.	TAC	K Quota	T Quota	First Nations	Science	Total Landings	Date Open	Date Closed	Days Open	FY Days	"K" Vessels Trap	"K" Vessels Longline
1981	Derby		3500	3190	310			3830	01-Feb-81	04-Oct-81	245	245	16	
1982	Derby		3500	3190	310			4028	01-Feb-82	22-Aug-82	202	202	15	
1983	Derby		3500	3190	310			4346	01-May-83	26-Sep-83	148	148	14	
1984	Derby		3500	3190	310			3827	01-Mar-84	22-Aug-84	174	174	13	
1985	Derby		4000	3650	350			4193	01-Feb-85	08-Mar-85	35	92	17	
									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	20	
									12-May-86	09-Jun-86	28			
1987	Derby		4100	3740	360			4630	16-Mar-87	10-Apr-87	25	45	19	
									01-Sep-87	21-Sep-87	20			
1988	Derby		4400	4015	385			5403	06-Mar-88	26-Mar-88	20	140	24	
									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	30	
									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	15	18
1991	IVQ	2,900-5,000	5000	4560	440			5112	01-Jan-91	31-Dec-91	365	365	14	14
1992	IVQ	2,900-5,000	5000	4560	440			5007	01-Jan-92	31-Dec-92	366	366	16	11

Year	Fishery	Assessment Yield Rec.	TAC	K Quota	T Quota	First Nations	Science	Total Landings	Date Open	Date Closed	Days Open	FY Days	"K" Vessels Trap	"K" Vessels Longline
1993	IVQ	2,900-5,000	5000	4560	440			5110	01-Jan-93	31-Dec-93	365	365	14	9
1994	IVQ	2,900-5,000	5000	4521	433			5002	01-Jan-94	31-Dec-94	365	365	15	9
1995	IVQ	2,725-5,550	4140	3709	356		29.48	4179	01-Jan-95	31-Dec-95	365	365	15	15
1996	IVQ	690-2,580	3600	3169	304		81.65	3471	01-Jan-96	31-Dec-96	366	366	12	11
1997	IVQ	6,227-16,285	4500	4023	386		45.36	4142	01-Jan-97	31-Dec-97	365	365	13	13
1998	IVQ	3,286-4,761	4500	4023	386		45.36	4592	01-Jan-98	31-Dec-98	365	365	13	12
1999/ 2000	IVQ	2,977-5,052	4500	6395	386		45.36	7012	01-Jan-99	31-Jul-00	578	578	12	19
2000/ 2001	IVQ	3,375-5,625	4000	3555	350		45.36	3884	01-Aug-00	31-Jul-01	365	365	12	23
2001/ 2002	IVQ	4,000	2800	2657	342	45	45.36	3079	01-Aug-01	31-Jul-02	365	365	12	21
2002/ 2003	IVQ	4,000, revised to 2100-2800	2450	1883	206	45	45	2206	01-Aug-02	31-Jul-03	365	365	8	20
2003/ 2004	IVQ	Decision table	3000	2647	254	45	54	2959	01-Aug-03	31-Jul-04	365	365	5	16
2004/ 2005	*IVQ*	Decision table	4500	3995	384	45	75	*845*	01-Aug-04	31Jul-05	365	365	NA	NA

Table B.2 TACs and allocations (metric tonnes) for the 2001/2002 to 2004/2005 fishing years.

Allocation and Landings	2001/2002	2002/2003	2-Year Totals	2003/2004	2004/2005
TAC	**2800**	**2450**	***5250***	**3000**	**4500**
Scientific purpose	25	45	*70*	54	75
First Nation allocation	45	45	*91*	45	45
Trawl "T" allocation	342	206	*548*	254	384
Sablefish "K" Allocation	3567	973	*4540*	2647	4005
Carry Forward	(910)	910	*0*	0	0
Final "K" Allocation	2657	1883	*4540*	2647	3995
Total Landings	3079	2206	***5285***	***2959***	*- na -*

Table B.3 Annual sablefish landings (t) in Canadian waters by gear type, excluding sablefish landed from seamounts. Data for 2004 are preliminary and current to November 30, 2004.

Year	Canadian	Foreign	Longline	Other	Trap	Trawl	Total
1913	1988.0						1988.0
1914	3209.0						3209.0
1915	2441.0						2441.0
1916	4312.0						4312.0
1917	5956.0						5956.0
1918	2039.0						2039.0
1919	716.0						716.0
1920	1754.0						1754.0
1921	1383.0						1383.0
1922	1293.0						1293.0
1923	1135.0						1135.0
1924	1238.0						1238.0
1925	1017.0						1017.0
1926	705.0						705.0
1927	1118.0						1118.0
1928	911.0						911.0
1929	1042.0						1042.0
1930	1124.0						1124.0
1931	397.0						397.0
1932	436.0						436.0
1933	413.0						413.0
1934	435.0						435.0
1935	659.0						659.0
1936	490.0						490.0
1937	912.0						912.0
1938	576.0						576.0
1939	617.0						617.0
1940	948.0						948.0
1941	1188.0						1188.0
1942	835.0						835.0
1943	1426.0						1426.0
1944	1519.0						1519.0
1945	1428.0						1428.0
1946	1619.0						1619.0
1947	905.0						905.0
1948	1483.0						1483.0
1949	1895.0						1895.0
1950	648.0						648.0
1951			772.8	0.5		23.1	796.4
1952			453.2	0.6		34.0	487.8
1953			335.6	1.1		8.0	344.7
1954			432.3		0.3	26.4	459.0
1955			359.0			15.2	374.2
1956			172.8			36.5	209.3
1957			465.6		0.3	51.0	516.9

Year	Canadian	Foreign	Longline	Other	Trap	Trawl	Total
1958			167.1		0.6	117.6	285.3
1959			298.3			88.2	386.5
1960			423.3			65.5	488.8
1961			321.3			97.9	419.2
1962			277.7	1.1		113.7	392.5
1963			222.3	0.2		64.8	287.3
1964		83.0	274.5	0.1		125.2	482.8
1965		92.0	193.2	0.3		261.9	547.4
1966		269.0	325.7	0.2		311.9	906.8
1967		1254.0	252.9	0.1		138.6	1645.6
1968		2455.0	292.3	15.1		167.0	2929.4
1969		4763.0	162.3	0.6		148.3	5074.2
1970		5246.0	142.1	0.5		165.9	5554.5
1971		3211.0	123.0			189.3	3523.3
1972		4818.0	399.7			688.3	5906.0
1973		3038.0	119.8		745.8	82.8	3986.4
1974		4287.0	41.3	1.8	327.1	121.8	4779.0
1975		6506.0	152.2	0.9	469.4	279.8	7408.3
1976		6302.0	89.4	0.1	303.4	382.0	7076.9
1977		3718.0	77.1	6.8	214.6	786.5	4803.0
1978		3051.0	57.2	7.8	634.6	130.5	3881.1
1979		2348.0	276.8	6.0	1480.1	276.1	4387.0
1980			248.6		3210.8	335.3	3794.7
1981			326.1		3275.3	228.8	3830.2
1982			343.6	0.3	3437.8	245.9	4027.7
1983			451.4	10.5	3610.5	274.1	4346.5
1984			365.1		3275.4	187.0	3827.4
1985			458.3		3501.3	233.1	4192.7
1986			619.2	0.8	3277.1	551.8	4448.8
1987			1268.6	0.7	2954.3	406.9	4630.5
1988			1273.6	3.2	3488.5	637.3	5402.6
1989			928.6	0.0	3772.0	623.4	5324.0
1990			1371.8		3072.4	460.7	4904.9
1991			1179.2		3494.4	438.8	5112.4
1992			847.5	1.1	3710.2	448.7	5007.5
1993			424.2	0.1	4142.4	543.1	5109.8
1994			467.7		4050.7	483.1	5001.5
1995			474.3	4.8	3272.2	427.4	4178.7
1996			278.9		2999.4	192.5	3470.8
1997			430.7		3555.1	156.3	4142.1
1998			443.7		3772.0	376.1	4591.7
1999			628.1	3.6	3682.9	403.0	4717.6
2000			752.3	0.0	2758.1	326.3	3836.7
2001			564.5		2750.1	299.6	3614.2
2002			564.7	2.4	2178.9	266.8	3012.7
2003			640.6		1486.6	227.6	2354.8
2004			*475.2*		*1744.1*	*270.1*	*2489.3*

Table B.4 Differences in landings history between this document and the summaries presented in 2004. Changes can be attributed to a number of factors including the addition of previously missing data from the 2001/2002 fishing year, removal of duplicated observer data, improved resolution of seamount data, and for 2003 addition of data for the balance of the calendar year.

Year	Gear	Current Landings	Previous Landings	Difference
2000	Longline	752	749	3
2001	Longline	564	484	80
2001	Trap	2750	2431	319
2002	Longline	565	543	22
2002	Trap	2179	1975	204
2003	Longline	641	528	113
2003	Trap	1487	809	678
2003	Trawl	228	112	116
2000	Total	3837	3834	3
2001	Total	3614	3215	399
2002	Total	3013	2787	226
2003	Total	2355	1449	906

Table B.5 Trap fishery landings, nominal catch rates (kg/trap) coast-wide and by north and south stock areas. Trips is the number of trips. P(Effort) is the proportion of landings with effort data while P(North) is the proportion of landings from the north stock area. Data for 2004 are preliminary and current to November 11, 2004.

	Coast				**North**				**South**				
Year	**Trips**	**Landings**	**Catch rate**	**P(Effort)**	**Trips**	**Landings**	**Catch rate**	**P(Effort)**	**Trips**	**Landings**	**Catch rate**	**P(Effort)**	**P(North)**
1979	63	1480.12	16.920	0.81	35	916.31	18.457	0.89	28	563.81	14.38	0.68	0.62
1980	76	3210.77	15.422	0.83	24	1203.29	15.422	0.96	52	2007.48	15.42	0.74	0.37
1981	61	3275.33	14.508	0.90	28	2083.68	17.026	0.91	33	1191.65	11.44	0.88	0.64
1982	33	3437.84	16.845	0.76	13	2071.47	19.039	0.79	20	1366.37	14.08	0.71	0.60
1983	48	3610.52	16.446	0.81	25	2398.11	18.315	0.84	23	1212.41	13.44	0.76	0.66
1984	58	3275.39	12.918	0.82	23	1762.32	13.909	0.89	35	1513.07	11.76	0.75	0.54
1985	34	3501.27	17.327	0.81	14	1625.81	19.630	0.90	20	1875.45	15.40	0.73	0.46
1986	34	3277.08	15.596	0.81	16	1951.10	19.711	0.86	18	1325.98	11.57	0.76	0.60
1987	27	2954.29	15.089	0.62	13	1455.76	17.909	0.69	14	1498.53	12.66	0.55	0.49
1988	29	3488.50	24.736	0.98	14	2181.92	32.670	0.97	15	1306.57	17.77	1.00	0.63
1989	31	3772.04	25.673	0.87	16	2052.65	27.699	0.81	15	1719.39	23.87	0.94	0.54
1990	101	3072.39	20.973	0.99	38	1792.46	25.587	1.00	63	1279.94	16.68	0.98	0.58
1991	104	3494.43	26.043	1.00	76	3025.88	29.104	1.00	28	468.55	15.51	1.00	0.87
1992	88	3710.23	24.058	0.91	78	3500.27	24.424	0.92	10	209.96	18.14	0.70	0.94
1993	106	4142.38	20.980	0.90	72	3012.24	21.019	0.90	34	1130.15	20.88	0.91	0.73
1994	108	4050.72	18.964	0.91	72	2782.82	18.779	0.99	36	1267.90	19.53	0.74	0.69
1995	80	3254.24	15.037	0.72	48	2044.56	15.963	0.81	32	1209.68	13.20	0.57	0.63
1996	83	2984.46	14.928	0.96	45	1992.88	16.728	0.94	38	991.57	12.40	1.00	0.67
1997	99	3553.61	13.317	0.99	55	2187.21	13.647	1.00	44	1366.39	12.81	0.98	0.62
1998	92	3771.98	13.388	0.99	43	1711.13	13.639	1.00	49	2060.85	13.18	0.99	0.45
1999	85	3677.24	13.705	1.00	54	2555.40	16.103	1.00	31	1121.83	10.23	1.00	0.69
2000	65	2745.18	12.326	0.99	47	2120.66	12.767	0.99	16	623.81	11.05	1.00	0.77
2001	78	2750.15	10.020	0.99	55	1662.66	9.831	1.00	23	1087.49	10.33	0.99	0.60
2002	61	2147.00	9.600	0.97	37	1475.62	10.384	0.97	24	671.38	8.23	0.97	0.69
2003	26	1419.12	19.812	1.00	23	1315.91	20.824	1.00	3	103.21	12.23	1.00	0.93
2004	*23*	*1452.96*	*13.466*	*0.76*	*19*	*1193.17*	*14.285*	*0.89*	*4*	*259.80*	*6.05*	*0.19*	*0.82*

Table B.6 Data selection criteria and the number of records selected for the standardized CPUE analysis.

Reason	Records excluded for the following reasons:	No. of records after selection criteria:
Depth	• Not recorded	49101
Traps	• Null or 0 or greater than 500	48790
Location information	• Fishing locations in Hecate Strait, Strait of Georgia, or Johnson Strait • Fishing locations at Seamounts	42672
Core skippers	• Not one of the 19 core skippers	35205
Catch	• Remove records with no sablefish catch reported	35017

Table B.7 Variables included in the sablefish trap fishery standardized CPUE model, by order of importance (proportion of deviance explained) for the regional CPUE model.

Order	Variable	Cumulative proportion of deviance explained (r^2)	Number of parameters
1	*year*region*	0.1700	30
2	*fishing master*	0.2312	48
3	*day of year*	0.2598	51
4	*minor area*	0.2708	62
5	*day of year:minor area*	0.2898	84

Table B.8 Variables included in the sablefish trap fishery standardized CPUE model, by order of importance (proportion of deviance explained) for the coast-wide CPUE model.

Order	Variable	Cumulative proportion of deviance explained (r^2)	Number of parameters
1	*year*	0.1393	15
2	*fishing master*	0.2030	33
3	*day of year*	0.2375	36
4	*minor area*	0.2538	47
5	*day of year:minor area*	0.2618	69

Table B.9 Summary of data used to derive the standardized commercial trap fishery catch rate index. The numbers of trips, fishing masters, fishing events (sets), and estimates of the commercial trap fishery catch rate index are listed for north and south areas. The overall catch rate index is provided for the coast. Gray cells indicate catch rates achieved with escape rings.

Year	Trips *North*	Trips *South*	Fishing Masters *North*	Fishing Masters *South*	Fishing Events *North*	Fishing Events *South*	Months Fished *North*	Months Fished *South*	Std. CPUE *North*	Std. CPUE *South*	Std. CPUE *Coast*
1990	17	30	6	6	546	445	8	7	16.353	8.767	13.330
1991	43	19	11	7	1044	217	11	6	17.314	12.478	15.957
1992	54	10	12	7	1414	114	12	7	16.836	12.019	15.820
1993	70	37	13	8	1843	650	11	9	14.698	11.854	13.794
1994	64	25	13	7	2091	508	12	9	12.332	12.367	11.984
1995	35	22	11	12	1695	669	11	9	10.070	8.551	9.241
1996	31	20	11	8	1393	956	10	10	9.761	7.664	8.596
1997	39	34	11	9	2109	1436	12	12	8.005	7.075	7.529
1998	40	42	13	13	1861	2282	11	10	7.077	6.994	7.048
1999	52	23	14	11	2455	1457	12	12	8.983	5.241	7.238
2000	40	12	11	5	2065	612	12	9	7.233	5.810	6.637
2001	44	18	11	7	2064	1131	11	11	5.969	5.568	5.615
2002	28	20	8	10	1559	896	10	10	6.292	4.449	5.432
2003	18	2	7	2	778	47	6	3	9.975	5.267	8.933
2004	12	2	6	1	600	80	6	2	8.448	2.149	7.035

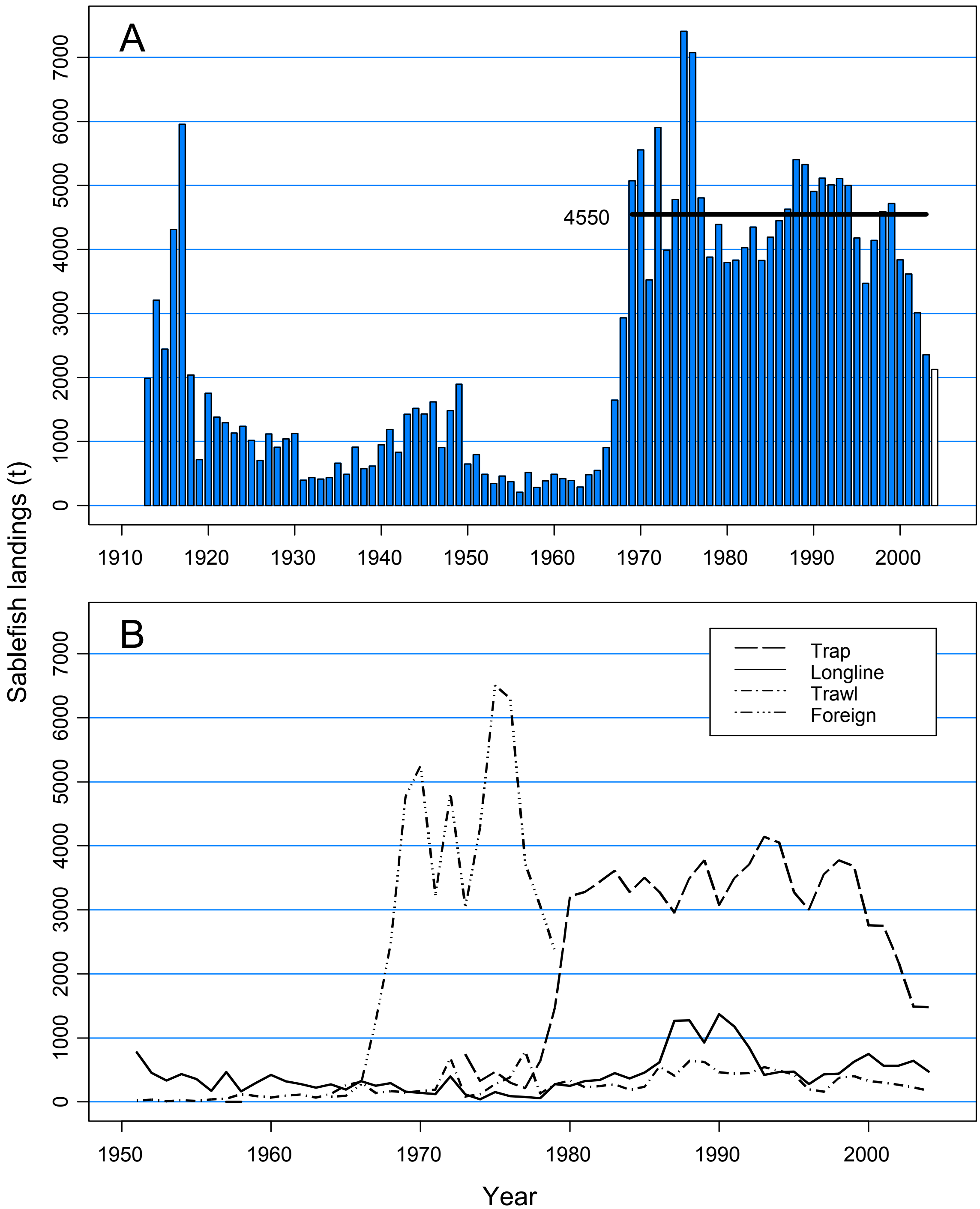

Figure B.1 Annual sablefish landings (t) from 1913 to 2004 from all sources (Panel A). The thick horizontal line shows the mean annual landings (4,550 t) from 1969 to 2003. Panel B shows annual landings by gear type for the period 1951 to 2004. Data for 2004 are incomplete.

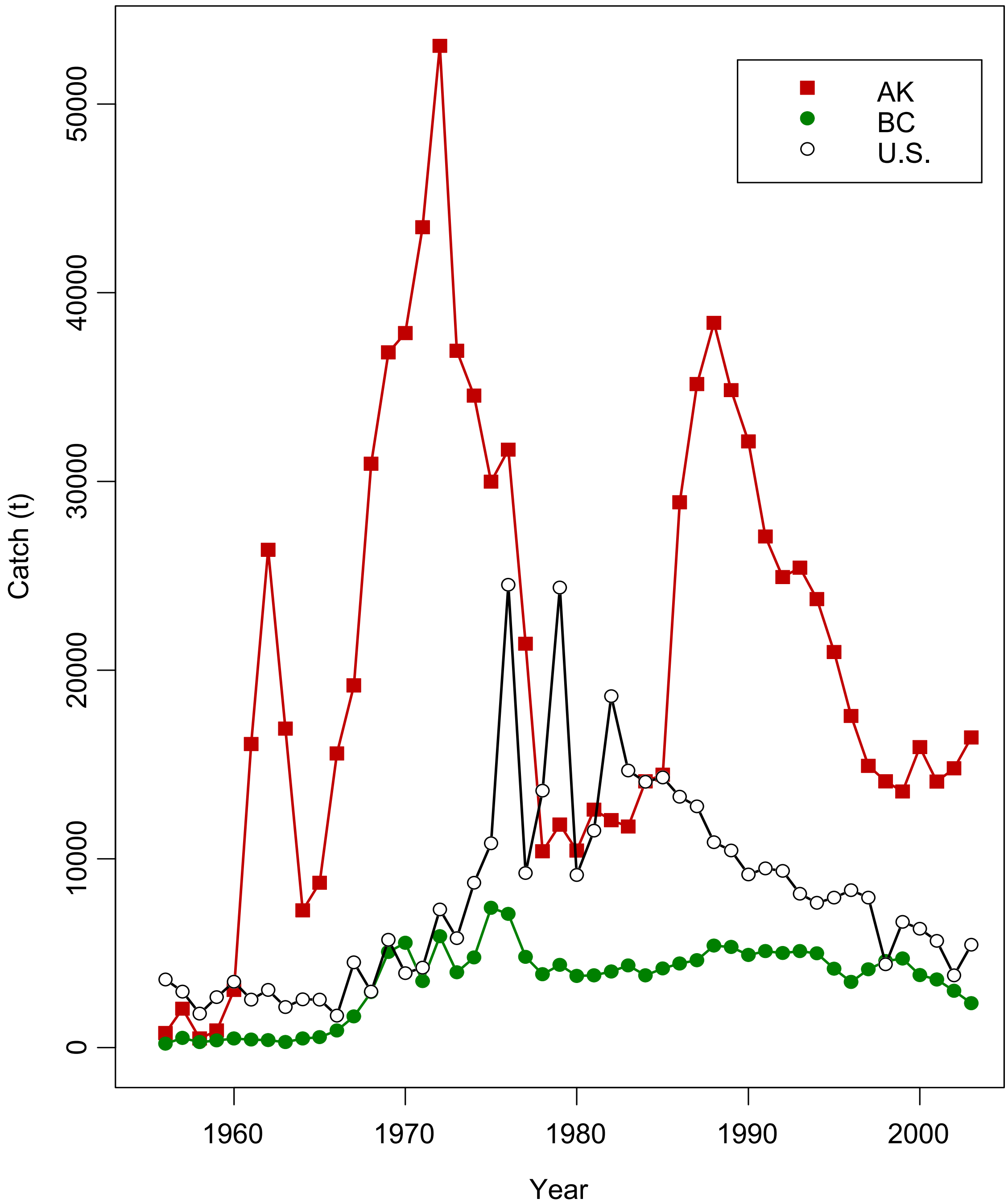

Figure B.2 Comparison of Canadian (filled circle), Alaskan (filled square), and continental U.S. (open circle) annual catches (t).

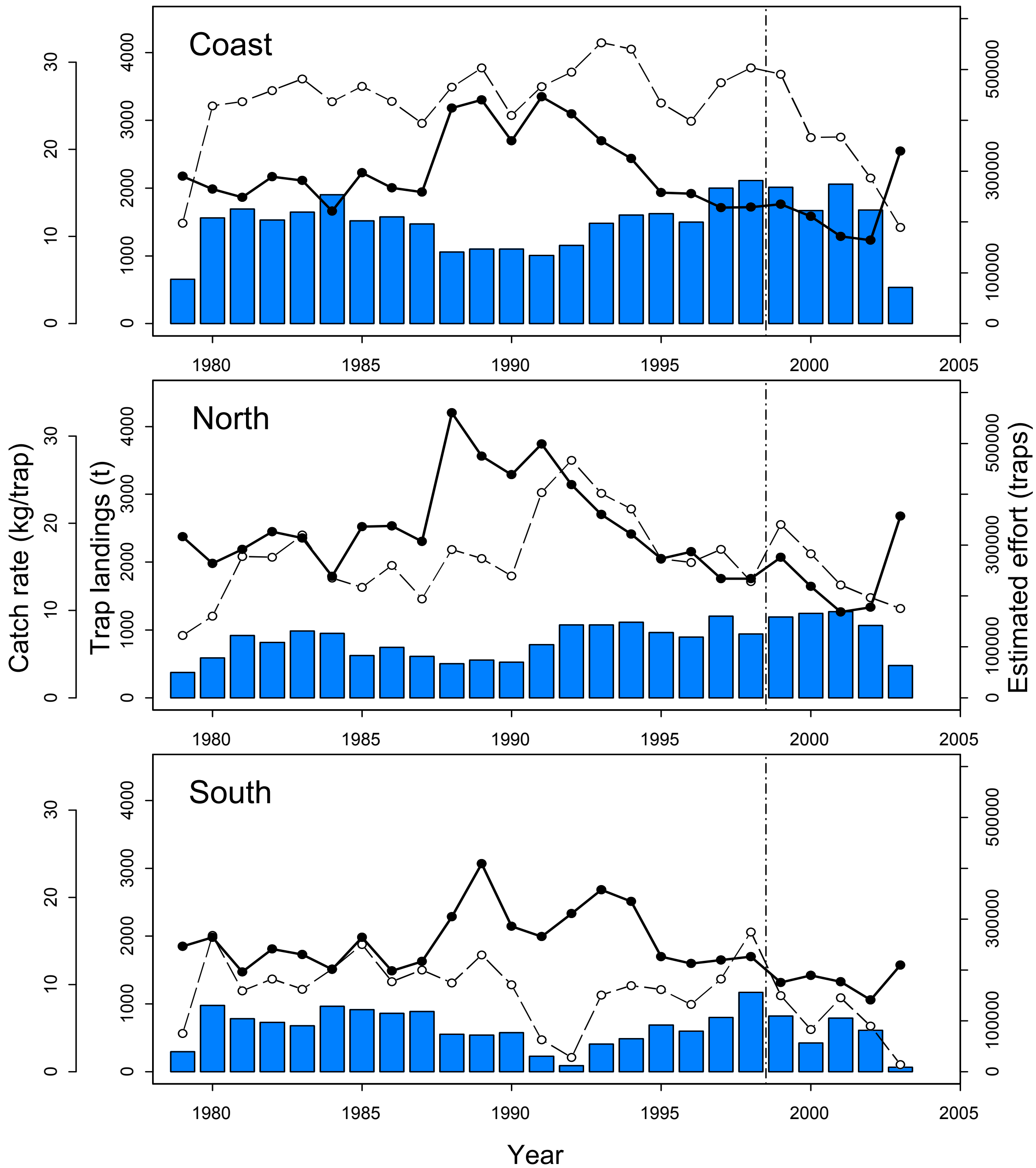

Figure B.3 Nominal trap fishery CPUE (kg/trap, filled circles, solid line), catch (t) (open circles, dashed line) and estimated effort (traps, vertical bars) by area. The vertical dot-dash line indicates the inception of mandatory escape rings in the commercial trap fishery.

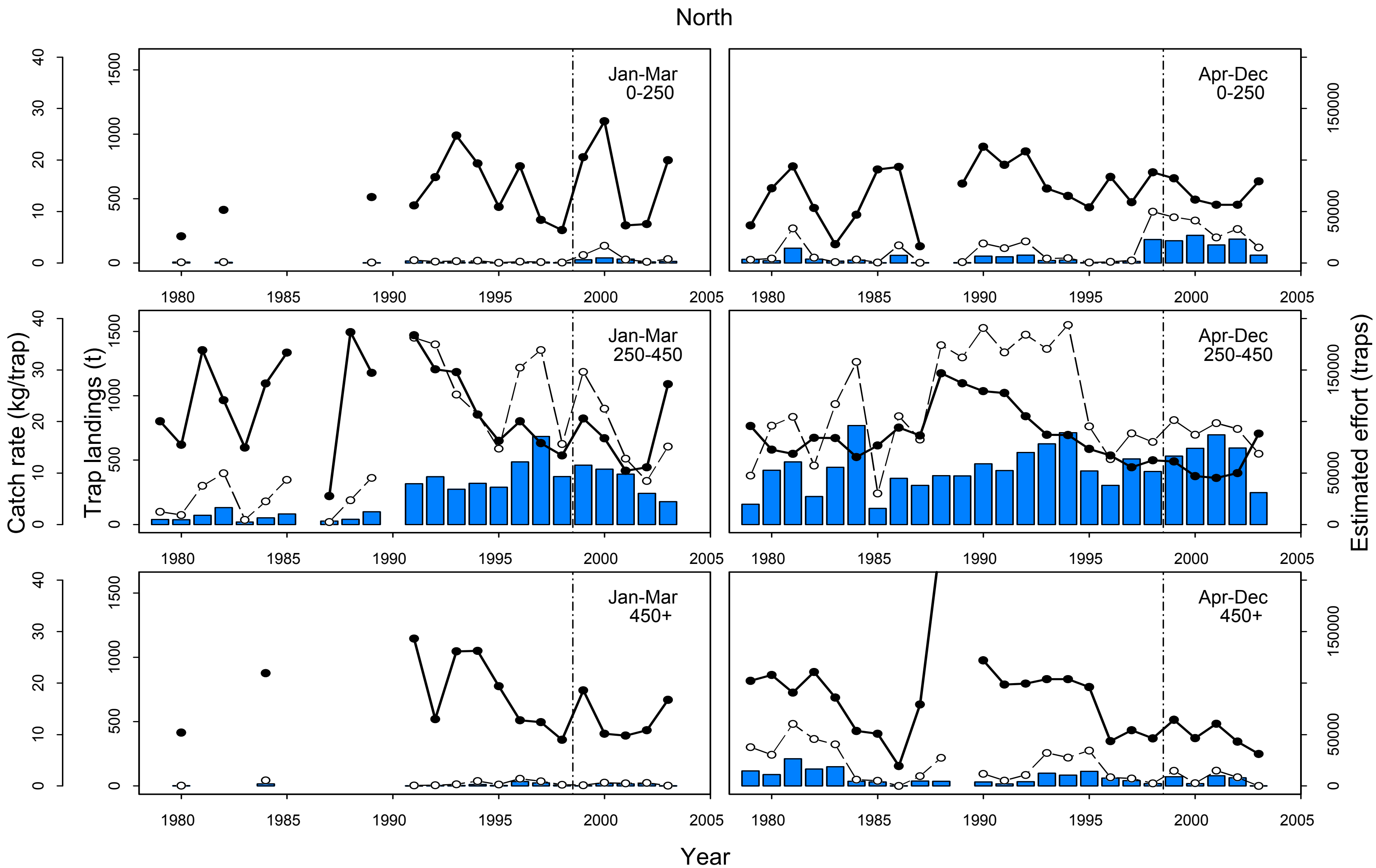

Figure B.4 Annual trap fishery landings (t, dotted line), CPUE (kg/trap, solid line), and estimated effort (traps, vertical bars) by area, season, and depth stratum (fm).

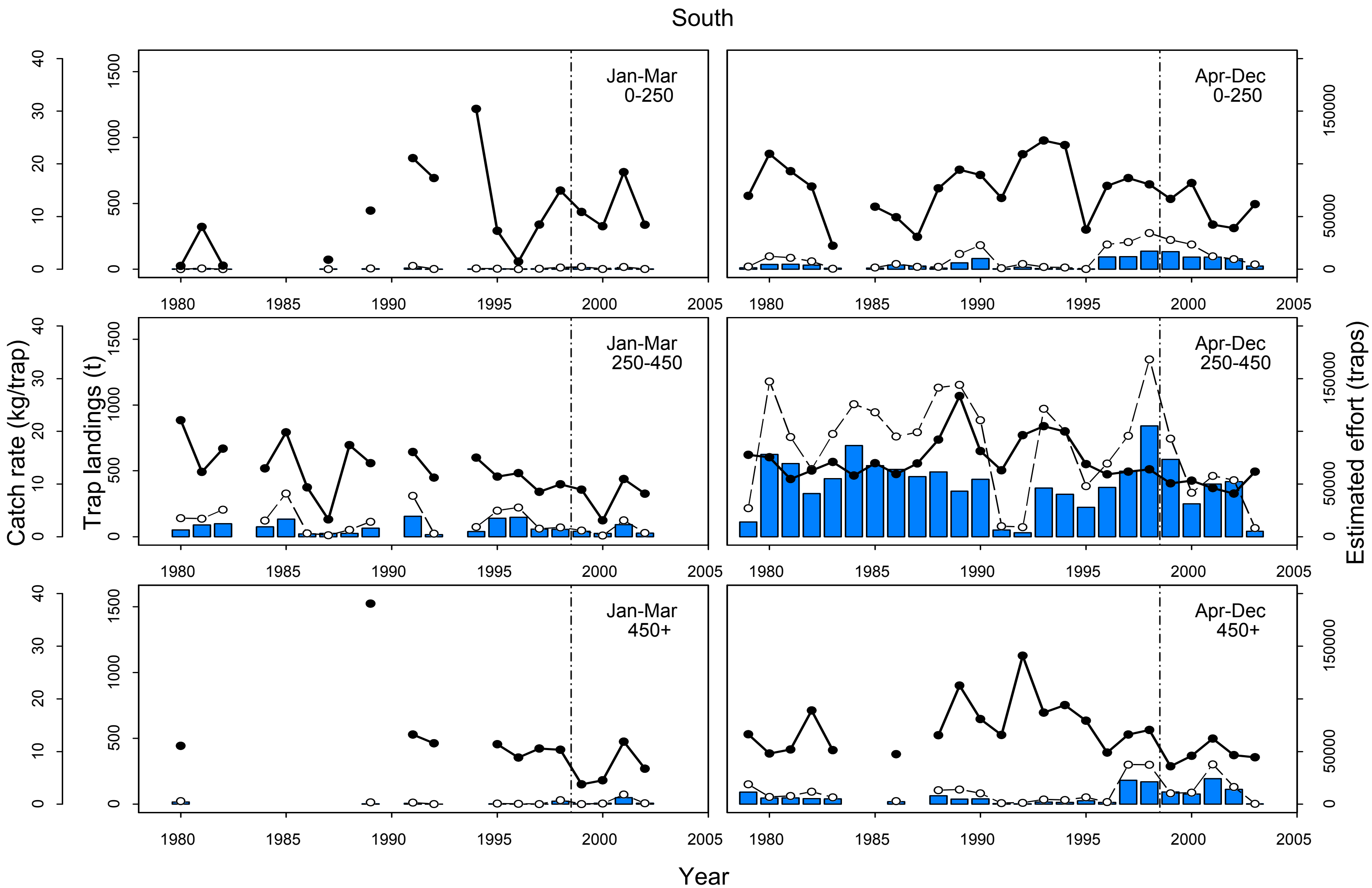

Figure B.4 continued.

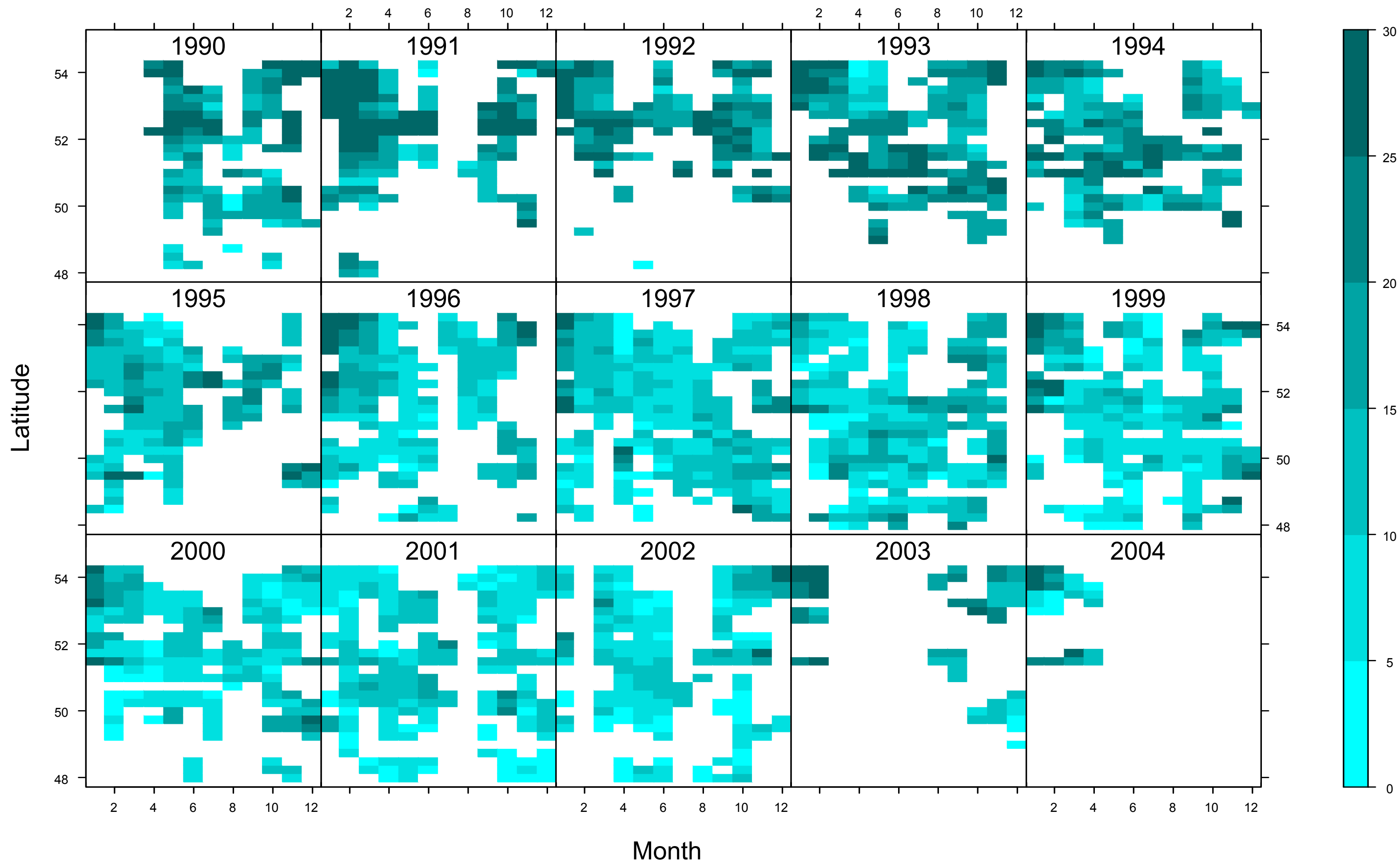

Figure B.5 Sablefish trap CPUE (kg/trap) by latitude, month and year. The intensity of shading is proportional to the catch rate for each block of latitude and month with the 25 to 30 kg/trap category representing 25 kg/trap and greater.

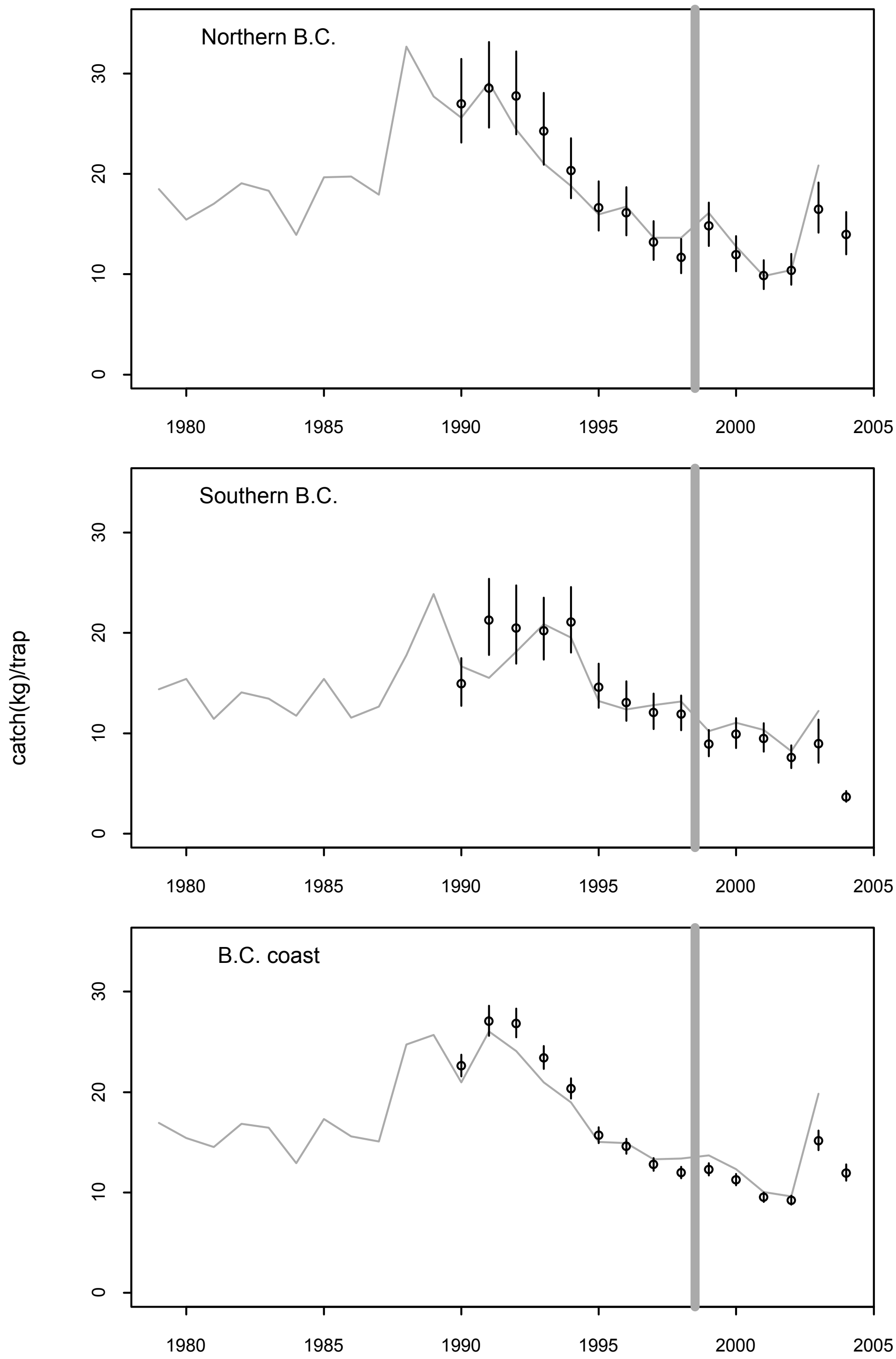

Figure B.6 Estimated *year* effects for the regional (upper two panels) and coast-wide CPUE standardization model (open symbols) with ± 2 standard errors shown by vertical bars. For comparison, the nominal CPUE series are shown (gray lines). Standardized indices have been scaled to have the same mean as the nominal CPUE series over their common year range.

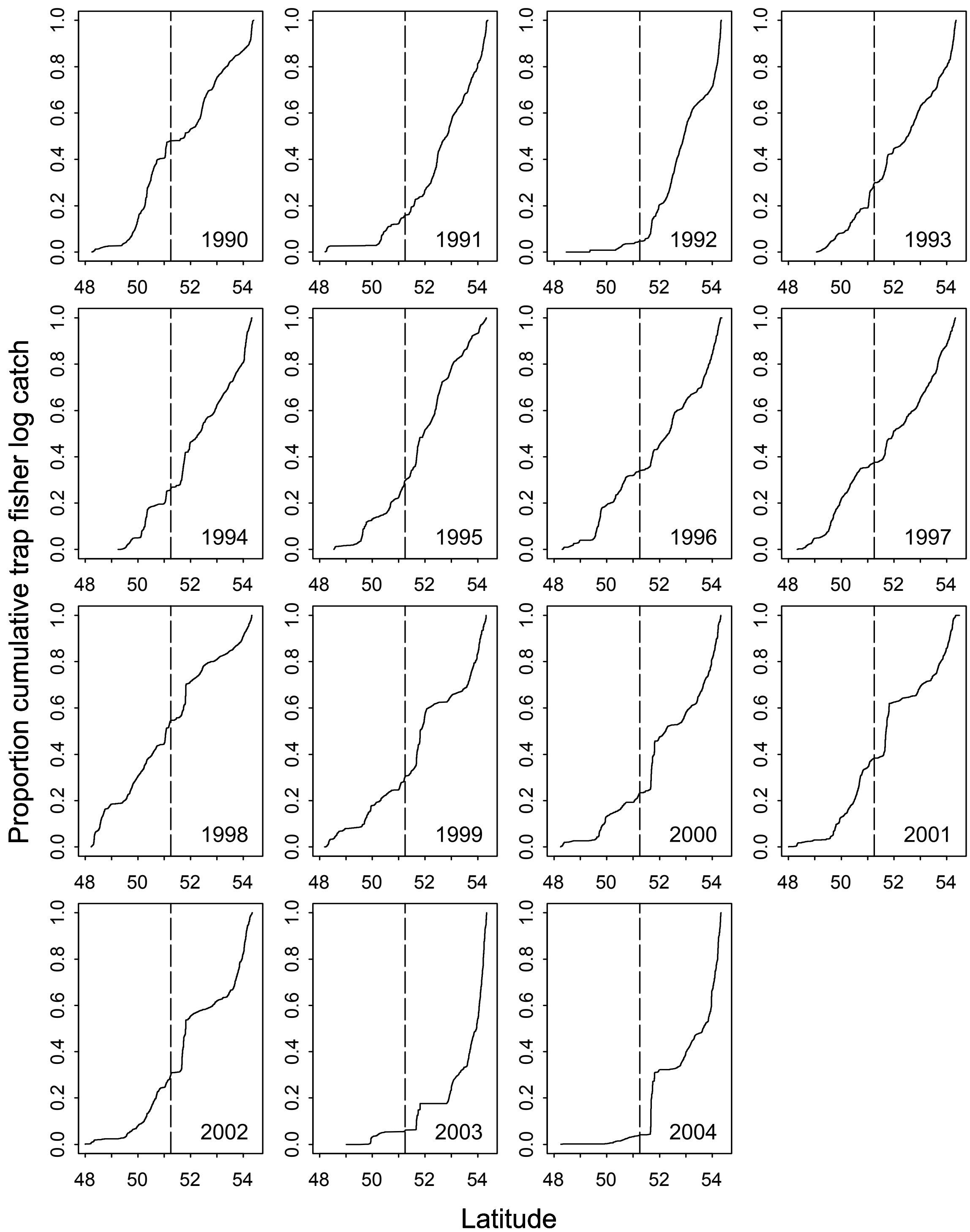

Figure B.7 Cumulative proportion of fisher logbook reported sablefish trap catch by latitude and year. The dashed vertical line represents the division between south and north areas.

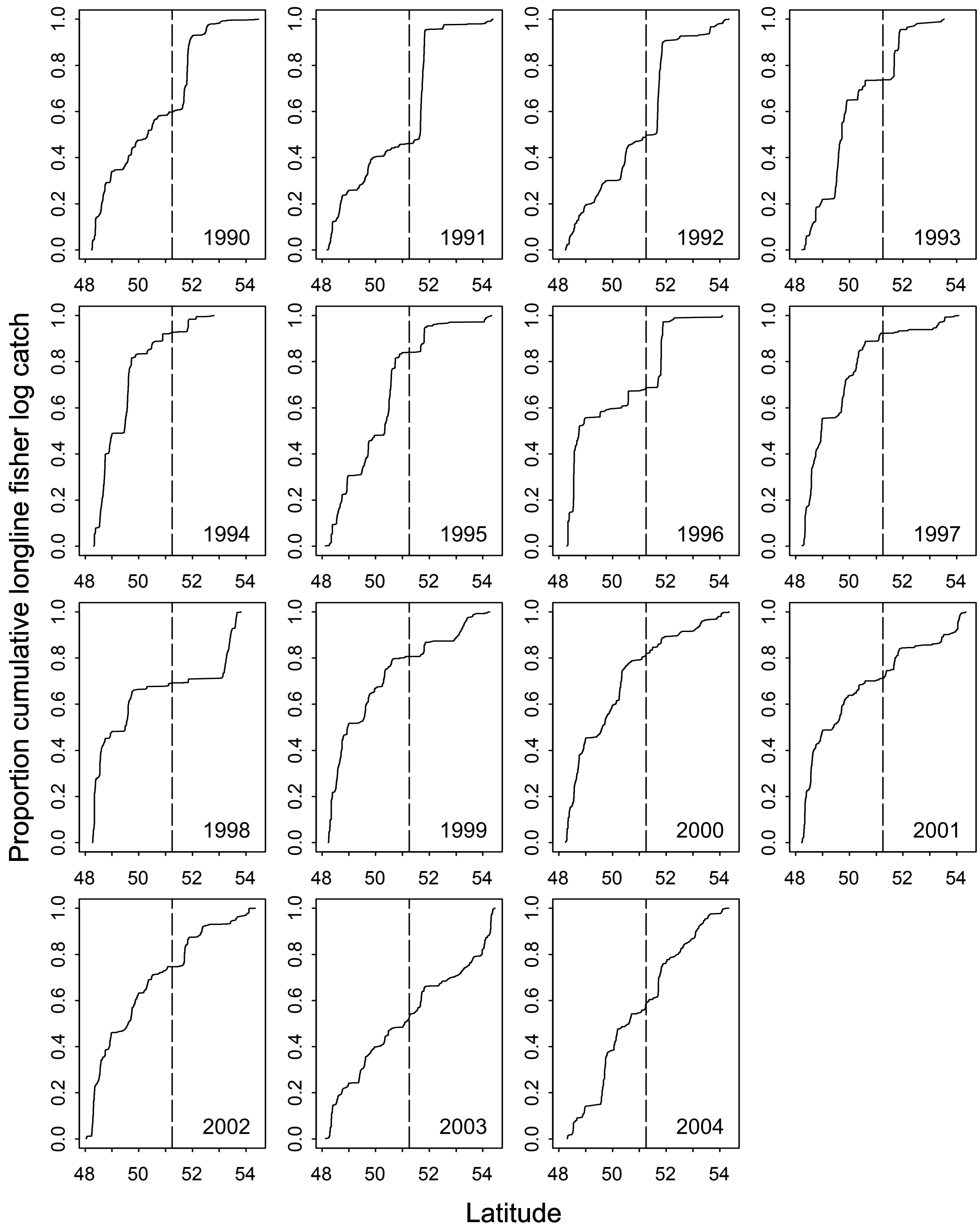

Figure B.8 Cumulative proportion of fisher logbook reported longline catch by latitude and year. The dashed vertical line represents the division between south and north areas.

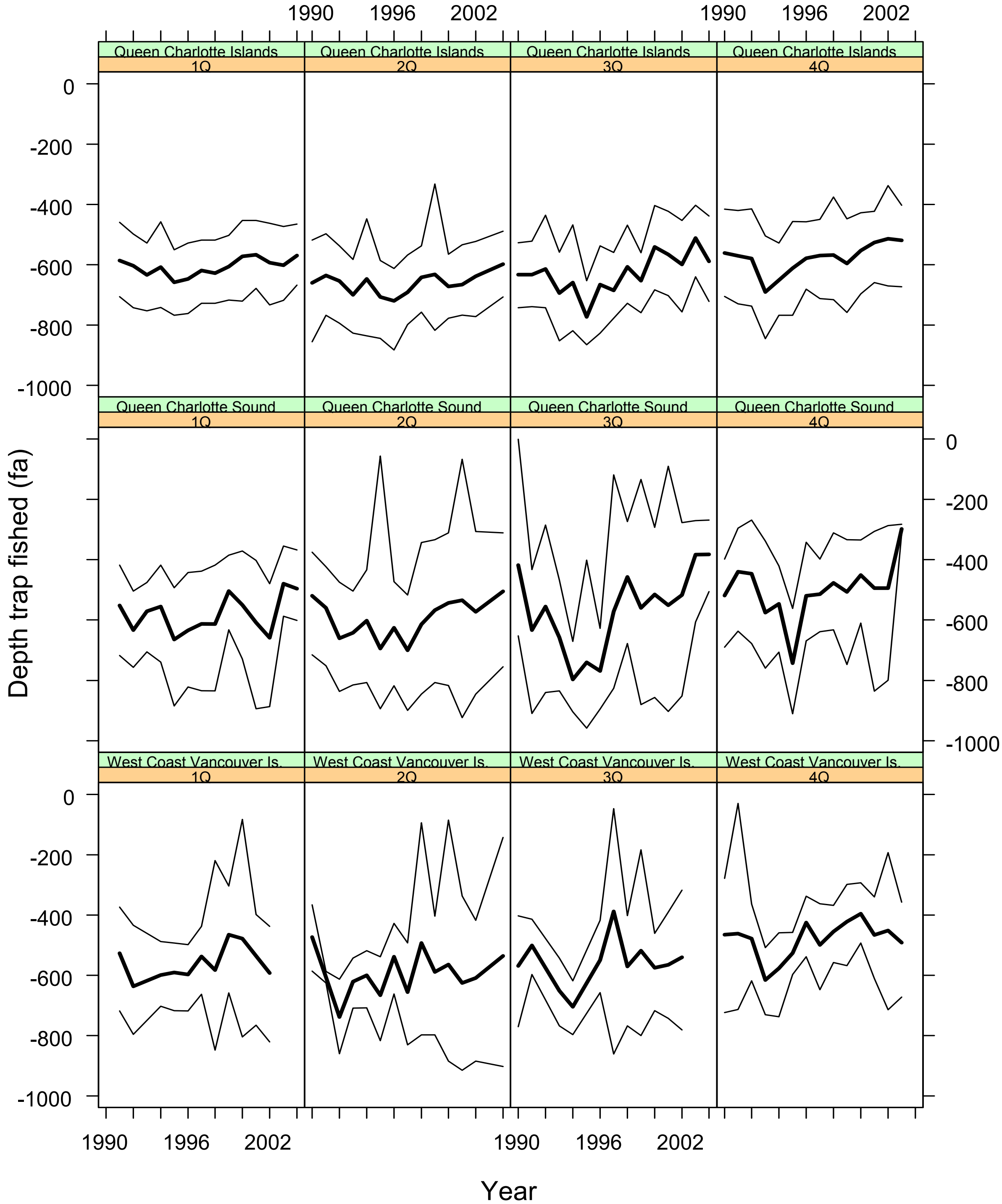

Figure B.9 Depth of fishing by year, quarter, and region. The upper and lower lines represent the 10th and 90th percentiles of depth fished while the thick center line is the mean depth fished.

APPENDIX C ANALYSIS OF TAG RECOVERY DATA

C.1 Tagging Program

Details of the tagging program have been described in previous assessments (e.g., Kronlund et al. 2003, Haist et al. 2004) and in survey data reports (Wyeth and Kronlund 2003, Wyeth et al. 2003, 2004a, 2004b). Sablefish have been tagged in most regions of British Columbia since 1977 (Table C.1, Figure C.1). Integration of tagging operations into the fall survey began in 1991. At the outset of the 1991 survey, replicate standardized sets were made at some localities and sablefish from the second set at each locality were tagged and released. As the 1991 survey progressed, the protocol shifted to tagging sablefish in excess of the biological sampling requirements of the set. For example, if fish from every third trap were sampled, fish from the first and second traps were tagged. This protocol remained in effect for the standardized survey sets through 1995. Standardized sets consisted of 25 traps each baited with approximately 1 kg of frozen squid in a bait bag and were targeted at five 183 m (100 fm) depth strata from 275 to 1189 m (150 to 650 fm, e.g., Wyeth et al. 2003).

In 1994 "tagging sets" directed at capturing sablefish for tag and release became part of the fall survey. Following the protocol of standardized survey sets, the fishing master of the survey vessel had discretion over the exact position of the tagging set within each locality. Tagging sets consisted of strings of 50 to 75 traps baited with approximately 1 kg of frozen squid in a bait bag and, in later years, 3 to 5 kg (6-10 lbs) of loose frozen Pacific hake (*Merluccius productus*) was also added to the traps. Tagging sets were targeted between 457 and 824 m (250 and 450 fm).

From 1991 to 1994, tagging was conducted at the offshore indexing localities (Figure C.2). In 1995, seven offshore "tagging" localities were added for the express purpose of conducting tagging sets. The localities off the West Coast of Vancouver Island (Pisces Canyon, Estevan Point, and Father Charles Canyon) and in Queen Charlotte Sound (Middle Ground) were visited from 1995 through 2003. However, the tagging localities off the West Coast of the Queen Charlotte Islands visited in 1995 were not visited again. Rather, new localities were chosen (Rennell Sound and Tasu Sound) which, when combined with the existing indexing localities, provided better coverage of the coast. Additional localities were visited in 1997 and 1998 (Hogback and Kyuoquot Sound to Ouokinish Inlet). Beginning in 1999 a single tagging set was also conducted at each of the nine offshore indexing localities. Tagging has also been conducted in selected mainland inlets since 1994. For the 2002 survey only, tagging sets were fished in each of eight depth strata within the standardized survey localities to distribute tags more broadly across the depth distribution of the species. This protocol was replaced in 2003 by an area and depth stratified random design for tag application.

Tagging sets can be classified according to the following scheme:

1. Type 1 (**traditional**) tagging sets consisted of 65 traps and were conducted at tagging or indexing localities and targeted at 250-450 fm (457-824 m). From 2002-2004, the goal of Type 1 sets was to maintain the historical protocol so that existing tagging analyses could be continued. Specifically, 1000 sablefish were tagged in each tagging locality and 300 fish in each indexing locality;
2. Type 2 (**systematic**) tagging sets consisted of 25 traps and were conducted at the offshore indexing localities. The objective of these sets was to release tagged sablefish across the depth distribution of the species in offshore waters. One set was made in each of the seven standardized survey depth strata. All sablefish captured in the Type 2 sets were tagged and released. Type 2 sets were conducted in 2002 only (Wyeth et al. 2004a).
3. Type 3 (**random**) tagging sets used the same gear as the Type 2 sets, but were conducted at randomly positioned fishing sites.

The random tagging sets were positioned as follows. In 2002, five random coordinate pairs were selected from within the Barkley Canyon and Hippa Island indexing localities. In 2003 and 2004 the Type 3 random tagging program was extended to a pilot study consisting of 75 sets allocated according to a stratified random design. The objective of the design was to randomly tag and release fish across depth and spatial strata inhabited by sablefish on the "offshore" B.C. coast. The design had the following characteristics and is described in detail by Wyeth et al. (2004b):

1. Each set consisted of 25 traps baited with approximately 1 kg of frozen squid in a bait bag and 4.5 kg (10 lbs) of frozen offshore Pacific hake loose in the trap.
2. The offshore area was partitioned into five spatial strata with three depth strata within each spatial stratum for a total of 15 strata;
3. For 2003-2004, a total of 5 replicate sets were assigned to each stratum;
4. The sampling unit selected at random within each stratum was a 2 km by 2 km square;
5. The tagging set was required to be contained within the requisite depth stratum and pass through the selected square.
6. In 2003, sablefish caught in every second trap were tagged; the remainder was used for biological samples. In 2004 the tagging and sampling rate was reduced to one out of every three traps and the catch from the third trap was discarded.

The long term plan for the stratified random design is to use the tag-recovery information for abundance estimation and movement studies, and to utilize the catch rates as an index of stock abundance in place of the existing standardized survey. The latter application will require a period of overlap of some years between the existing standardized survey and the new stratified random survey to allow calibration of the two time series.

All sablefish were tagged using a Floy FD-68B T-bar anchor tag until 2000. Beginning in 2001, a Floy FD-94 tag was used that has similar characteristics to the FD-68B model. For tagging sets, most of the sablefish were tagged and released with the exception of fish from an *ad hoc* selection of traps that were used for biological samples. Tagged sablefish were recovered through voluntary returns from the B.C. commercial groundfish fisheries (trawl, trap, and longline) as well as from commercial fishing in Alaska and the continental United States. Some tags are also returned from other commercial and sport fisheries. A reward system is offered through the Canadian Sablefish Association as incentive to return tags.

C.2 Tagging data and data selection

Tag releases by year are listed in Table C.1 for the general geographic regions shown in Figure C.1. Total releases have ranged from 1,717 tagged fish released in 1987 to 41,269 released in 1979. The annual numbers of releases since 1991 are shown in Table C.2 for the offshore localities shown in Figure C.2 and for the stratified random sets. Table C.3 summarizes the annual number of tags recovered for all gear types by release year. The sablefish trap fishery accounts for the majority of tag returns among trap, longline and trawl gear types. Table C.4 shows the summary of tags recovered by trap gear by release year.

Selection criteria applied to the tagging data depend on the specific analysis. Data used in the tagging model described in Appendix E were based on tag release and recovery data current to July 31, 2004. Fish tagged and released were included in the analyses if the following criteria were met:

1. The tag release took place from 1991 to 2003 (consistency of tagging program);
2. The released fish was greater than 450 mm fork length or the length was unknown (adult fish);
3. Tag application occurred from August through December (tags released at consistent time as part of the annual fall survey).
4. For tags released starting in 2002, the set followed a “traditional” fishing protocol (Type 1 sets and those Type 2 sets targeted between 250 and 450 fm (depth strata D2 and D3, 457-824 m);
5. Tag application took place in offshore waters (offshore trap-vulnerable population) as defined by Groundfish Statistical Areas in the following table.

Fisheries and Oceans, Groundfish Statistical Areas		
Major	**Minor**	**Locality**
3	all	all
4	all	all
9	all	all
6	8	0, 6, 9, 10, 12, 14, 15
5	11	0, 4, 6-12,

These criteria define the traditional (selected) adult offshore release data. Table C.5 lists the number of traditional releases by release year. Note that in 2002 only a systematic (Type 2) application of tags was conducted across the seven survey depth strata. For 2002 only there were 6,464 “Type 2” tags applied in depth strata other than D2 and D3 that do not meet the selection criteria. In addition, a total of 1,342 tags were applied in a pilot study of 10 random sets (Wyeth et al. 2004a) that do not meet the selection criteria.

Recovered tagged sablefish were included in the tagging analyses provided the following criteria were met:

1. The recovered tag was from a traditional (selected) release;
2. The tagged fish was recovered by a commercial sablefish trap vessel (trap-vulnerable adult population);
3. The tagged fish was not recovered as part of research fishing (sablefish survey sets in particular have a higher probability of tag recapture than the commercial fishery);
4. The tagged fish was not recovered at a seamount (offshore trap-vulnerable population as for releases).

These criteria defined the traditional (selected) recoveries.

C.3 Exploratory Data Analysis of Tag Recoveries

Tagging analyses utilize the assumption that the proportion of tags in the recovered samples is related to the proportion of tags in the population of interest. Thus, examination of the tags recovered per metric tonne (t) of fish caught is a useful first step in exploratory analyses. Tag recovery rates for the traditional (selected) releases and recoveries were plotted by release year and area (Figure C.3, Figure C.4). A small number (0.001) was added to the observed tag recoveries before calculating the recovery rate to accommodate combinations of release year, recovery year, and month where no tags were recovered but catch was recorded. The vertical lines in each panel represent January. The plots for release years 1991 and 1992 in both stock areas are somewhat noisy which is expected given the relatively low number of releases. The following observations can be drawn from inspection of the figures:

1. The decline in the recovery rate was greater in the first three to five years after release than in subsequent years, at least for those release years with sufficient data (eg. 1994 to 1997);
2. For the north stock area, there is a consistent seasonal pattern of decrease in the recovery rate in December through March, with the low point typically occurring in January.
3. The seasonal pattern evident in the north stock area can be seen for some release and recovery years in the south stock area, but is not as consistent as the northern pattern. Indeed, in many recovery years the highest recovery rate observations are highest during the first few months of the year.

For the north stock area, the seasonal patterns are consistent with the hypothesis that an influx of untagged fish enters the B.C. population in the December to March period, causing a reduction in tags per tonne returned through dilution of the tagged population. Apparently these fish subsequently become unavailable to the trap fishery after about March through fishery removals, a behavioral change, and/or movement to areas of reduced vulnerability, i.e., they leave the trap-vulnerable biomass.

C.4 Allocation of tags recovered with partial information

Most traditional (selected) tag recoveries are accompanied by recapture information such as the recovery year, recovery month, and gear type. However, some tags are recovered with partial information where the one or more of the explanatory variables is unknown. In order to utilize these tag returns in the model, an algorithm was developed to allocate tags returned with partial information to known categories of the explanatory variables. The probability of a tag being allocated to a particular category was derived from tags recovered with observed data. The recapture data required by the tagging model included release year, recovery year, recovery month, and gear type. In addition, the area of recapture was considered to allow the possibility of area-specific analyses. The algorithm requires a series of assumptions, beginning with the following two conditions:

1. Recovered tags where the *release year is unknown* are ignored;
2. Recovered tags where the *recovery year is unknown* are ignored.

Given these assumptions, a total of 19,980 tag recoveries from 1991 to 2003 were selected for input to the tagging model. Of these tags, a total of 1,550 had at least one of recovery month, gear or area missing. The categories required for the tagging model are contained in the following table.

Variable	Data Categories	Model Categories
Recovery Month	1,..,12, Unknown	1,…,12, Unknown
Gear	Trap, Trawl, Longline, Other, Unknown	Trap, Other
Area	North, South, Unknown	North, South

Thus, the gear categories Trawl, Longline, and Other in the data were recoded as “Other”.

The distribution of tag recoveries by information case is shown in Table C.6 for tag recoveries from traditional releases used as input to the tagging model. Let “M” indicate the case where recovery month is known, while “m” represents the case where recovery month is unknown. Similarly let gear and area be represented by (G,g) and (A,a), respectively. Thus, the code “MAG” indicates that all three variables are known, while “Mag” indicates that area and gear type are missing.

Previous tagging model analyses for sablefish have generally treated the "observed" tag recoveries to be the sum of tags with complete information and the tags with unknowns that were allocated to known categories. Each step of the allocation algorithm involves computing the probability of a tag with one or more unknowns falling into a particular category for each variable. Blocks of tags that correspond to a particular combination of release year (*i=1991,…,2003*) and recovery year (*j=1991,2004*) were processed for $j \geq i$. The probability of a tag being allocated to a particular category for any variable was considered to be an attribute of the recovery year. Thus, all tags with observed information for a given recovery year were used to compute the required probabilities. Probabilities for tags recovered with 0 to 3 unknowns must be considered as listed in the following table and described below.

Number of Unknowns	Case	Probabilities Required to Allocate Tags
0	No unknowns	None
1	Gear unknown, month and area known	P(G|MA)
	Month unknown, gear and areas known	P(M|GA)
	Area unknown, gear and month known	P(A|GM)
2	Gear and area unknown, month known	P(G|M), P(A|GM)
	Gear and month unknown, area known	P(G|A), P(M|GA)
	Month and area unknown, gear known	P(M|G), P(A|GM)
3	Gear, month, and area unknown	P(G), P(M|G), P(A|GM)

Tags were allocated to a category for each recapture variable in fractional amounts. For example, if the probability of "Trap" gear was 0.6 for a given case, then a single tag with unknown gear was allocated as 0.6 to the "Trap" gear category and 0.4 to the "Other" gear category.

Complete Information (1 Case)

No action is required when recapture information is complete for a tag recovery.

One Unknown (3 Cases)

Suppose gear was unknown but the recovery month and area were known. The probability of a tag being allocated to the "Trap" or "Other" gear categories was computed by determining the probability of each gear category ***given*** recovery month and area, denoted P(G|MA). These calculations were based on the complete data for the recovery year. Thus, the tags with one unknown were processed as followed:

3. <u>Gear Unknown</u>. Allocate tags to gear using P(G|MA) computed from tags with gear, recovery month and area known;

4. Month Unknown. Allocate tags to gear using P(M|GA) computed from tags gear , month and area known.
5. Area Unknown. Allocate tags to area using P(A|GM) computed from tags with gear, month and area known.

Probabilities were computed only from observed information in the sense that when tags were allocated to a gear category, the newly formed "complete" information was not used to compute the probabilities in the next step. The order that the three cases with one unknown are processed does not matter as they occur independently, i.e., only tag recoveries with complete information were used to allocate tags with one unknown.

Two Unknowns (3 Cases)

For cases with more than one unknown, the order that unknown variables were allocated to known categories was determined by considering the quality of the observed data. Tags with unknown gear were allocated first since gear was most likely to possess good observed information and there are only two categories. Tags with unknown month were allocated second because of the larger number of categories. Tags with unknown area were allocated last because it was anticipated that most analyses would not require area information. Thus, tag recoveries allocated to the north and south categories could simply be summed for coast-wide analyses based on release year, recovery year, recovery month and gear. The three cases were processed by "sweeping" the tags with unknowns from unknown to known categories. For example, if gear and area were unknown these tags where first allocated to a gear category. The tags, now assigned a gear category, where then swept into an area category with the result that the known month was now accompanied by an estimated gear and area.

1. Gear and area unknown. (a) Allocate the tags to gear using P(G|M) computed from tag recoveries where gear and month were known, regardless of whether area was known. (b) Allocate the tags to area using P(A|GM) computed from tag recoveries where gear, month, and area were known;
2. Gear and month unknown. (a) Allocate the tags to gear using P(G|A) computed from tag recoveries where gear and area were known, regardless of whether month was known. (b) Allocate the tags to month using P(M|GA) computed from tag recoveries where gear, month, and area were known.
3. Month and area unknown. (a) Allocate the tags to month using P(M|G) computed from tag recoveries where month and gear were known, regardless of whether area was known. (b) Allocate the tags to area using P(A|GM) computed from tag recoveries where gear, month, and area were known.

Only observed data for the given recovery year were used to compute the probabilities for tag allocation within combination of release and recovery year. Note that tags allocated to various categories were not utilized in computing probabilities in subsequent steps to avoid "manufacturing" information.

Three Unknowns (1 Case)

For the case where all recapture variables were unknown for tag recoveries, the tags were processed by applying the following steps:

1. Gear. Allocate the tags to gear category using P(G) computed from tag recoveries with gear known, regardless of whether other variables were known;
2. Month. Allocate the tags to recovery month by using P(M|G) computed from tag recoveries where gear and month were known regardless of whether area was known;
3. Area. Allocate the tags to area using P(A|GM) computed from tag recoveries where gear, month and area were known.

Again, all observed data for the given recovery year were used to allocate tags for a combination of release and recovery year. Only tags where the variables were actually observed were used to form the required probabilities to avoid “manufacturing” information. Area was chosen to be processed last since it was anticipated that most analyses would not require data by area.

Situations arise during tag allocation where a tag with unknowns contains observed information that did not occur in the tags used to compute the category probabilities. For example, suppose a tag with unknown gear was observed for the month of August in the North area. However, the data with complete observed information contained no recoveries for August in the North. In this situation the tag was allocated to month by using the marginal probability P(M) computed from all tag recoveries with month known, regardless of whether gear and area where known. In this way the “dropping” of tags was avoided so that all tags with unknowns were assigned to known categories. The solution to the problem of tag allocation is not unique; other choices of the order to process explanatory variables will lead to slightly different allocation of tags with unknown information.

C.5 Literature Cited

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

Haist, V., A.R. Kronlund and M. Wyeth. 2004. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2003 and advice to managers for 2004. PSARC Working Paper G2004-01.

Wyeth, M.R. and A.R. Kronlund. 2003. Sablefish (*Anoplopoma fimbria*) research and assessment surveys conducted in British Columbia waters from 1996 to 2000. Can. Data Rep. Fish. Aquat. Sci. 1116: 130p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2003. Summary of the 2001 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1118. 54p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2004a. Summary of the 2002 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1140. 59 p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2004b. Summary of the 2003 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1148. 68 p.

Table C.1 Total number of tagged sablefish released by year and region for all gears.

Year	Georgia Strait	Hecate Strait	Mainland Inlets	Dixon Entrance	Queen Charlotte Sound	Offshore Queen Charlotte Sound	West Coast Queen Charlotte Islands	West Coast Vancouver Island	Seamount	Total
1977							5,158	5,505		**10,663**
1978						1,454	5,331	4,111		**10,896**
1979		10,415			15,121		6,621	9,112		**41,269**
1980	18	10,674	7,019	466	474	3,110	3,619	4,703		**30,083**
1981		2,983			9,323		10,430			**22,736**
1982						1,019	3,008	3,013		**7,040**
1983							4,002	4,023		**8,025**
1984					90	5,023	5,379	236		**10,728**
1985							3,025	5,301		**8,326**
1987								1,101	616	**1,717**
1991						69	958	1,420		**2,447**
1992						420	1,308	1,856		**3,584**
1993						575	2,487	3,956		**7,018**
1994			3,435			539	1,321	1,744		**7,039**
1995			3,199			2,331	5,731	4,644		**15,905**
1996			3,897			5,035	7,942	11,403		**28,277**
1997			3,146			3,459	3,919	9,118		**19,642**
1998			6,009			2,372	2,963	10,622		**21,966**
1999			9,620			3,731	5,787	8,273		**27,411**
2000			3,114			3,469	6,216	10,116		**22,915**
2001			4,117			3,175	3,535	7,442		**18,269**
2002			3,549			3,433	5,880	6,995		**19,857**
2003			4,407			4,177	7,474	8,599		**24,657**
All	**18**	**24,072**	**51,512**	**466**	**25,008**	**43,391**	**102,094**	**123,293**	**616**	**370,470**

Table C.2 Number of offshore tag releases by locality and for stratified random sets during fall sablefish surveys using trap gear from 1991 to 2003. Note that this summary does not include 899 tags released from a trawl research trip in 1996 as well as 15,139 and 9,355 tags released during spring surveys in 1996 and 1997, respectively.

Locality	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Langara Island-North Frederick	507	217	483	227	154	138		258	846	442	141	562	305	**4,280**
Rennell Sound						699	508		2,139	2,428	1,357	990	1,001	**9,122**
Hippa Island		258	504	279	198	325		262	380	366	270	1,307	309	**4,458**
Buck Point	170	483	570	346	155	230	64	194	289	678	557	1,176	334	**5,246**
Tasu Sound						715	488	2,013	1,664	1,731	1,124	996	1,068	**9,799**
Gowgaia Bay	281	350	930	469	1,287	139	109	236	469	561	86	849	305	**6,071**
Cape St. James				301	145	147		47	839	522	552	1,152	306	**4,011**
Middle Ground					1,688	1,578	1,082	2,048	2,108	1,953	2,126	977	935	**14,495**
Triangle Island	69	420	575	238	498	179	66	277	784	994	497	1,304	301	**6,202**
Pisces Canyon					158	1,284	1,119	2,051	2,016	1,991	1,171	972	1,016	**11,778**
Quatsino Sound	466	528	687	198	290			156	581	744	659	937	302	**5,548**
Esperanza Inlet		587	1,396	464	564	196	297	302	291	1,034	348	1,027	321	**6,827**
Estevan Point					1,360	1,238	1,476	4,321	1,712	2,271	2,608	1,125	1,006	**17,117**
Father Charles Canyon					1,296	946	1,087	1,172	2,294	2,256	1,764	843	973	**12,631**
Barkley Canyon	954	741	1,873	882	696	498	535	281	1,379	1,820	892	2,091	326	**12,968**
Frederick Island					1,954									**1,954**
Hogback							309							**309**
Chads Point					956									**956**
Tasu Sound-Marble Island										10				**10**
Anthony Island					1,027									**1,027**
Solander Island				200	280									**480**
Kyuquot Sound-Ouokinish Inlet								2,339						**2,339**
Offshore Locality Total	**2,447**	**3,584**	**7,018**	**3,604**	**12,706**	**8,312**	**7,140**	**15,957**	**17,791**	**19,801**	**14,152**	**16,308**	**8,804**	**137,628**
Offshore Stratified Random Sets													11,433	**11,433**
Offshore Total	**2,447**	**3,584**	**7,018**	**3,604**	**12,706**	**8,312**	**7,140**	**15,957**	**17,791**	**19,801**	**14,152**	**16,308**	**20,237**	**149,057**

Table C.3 Number of tagged sablefish recovered by all gear types in each year by year of tag release (includes all releases and all recoveries).

Release Year	Recovery Year																													
	Unknown	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**All**
1977	3	138	631	266	200	131	73	47	41	27	19	8	12	6	4	9	7	8	1	1	2	10	5	4	2	8	6		2	**1671**
1978	1		221	319	286	128	51	43	30	9	8	5	9	11	5	3	4	2	1		1	2	3	4	2	1	2	1	1	**1153**
1979	16			831	1384	616	409	206	169	169	224	65	89	55	34	20	32	26	7	3	22	23	40	20	6	22	15	10	4	**4517**
1980	5				1077	979	646	388	312	103	113	50	60	71	44	28	22	32	6	2	25	20	16	10	15	24	10	8	5	**4071**
1981	2					273	583	343	188	99	97	47	53	53	48	32	34	27	4		26	13	16	14	13	10	3	5	2	**1985**
1982	4							665	356	91	60	18	32	39	24	13	23	15	1		7	11	8	8	5	7	2	6	2	**1397**
1983	1								106	39	55	26	19	18	11	3	3	6	1		3	6	1	3	6	4	1	1		**313**
1984	7								252	166	165	57	39	24	24	25	22	10	2		14	13	17	16	9	8	11	1	2	**884**
1985	7									114	347	72	62	43	35	15	31	19	2	1	8	16	25	9	6	9	3	4	3	**831**
1987												6	25	21	8	5	2				1	1	2		2	1				**74**
1991	3															16	100	48	39	29	17	17	15	8	9	11	5	5	4	**326**
1992	14																13	121	97	64	45	29	44	32	9	20	15	6	2	**511**
1993	18																	6	421	218	75	91	95	72	45	42	29	7	7	**1126**
1994	8																		13	416	210	227	216	127	76	61	46	14	13	**1427**
1995	83																			85	1295	916	593	374	247	165	91	50	41	**3940**
1996	101																				441	2141	1341	673	454	373	239	87	61	**5911**
1997	109																					1213	2261	907	494	368	239	93	55	**5739**
1998	34																						321	1742	1109	751	486	183	112	**4738**
1999	21																							234	2280	1432	935	351	274	**5527**
2000	13																								149	2046	926	315	203	**3652**
2001	19																									135	1557	408	301	**2420**
2002	3																										95	896	516	**1510**
2003	5																											166	823	**994**
All	**477**	**138**	**852**	**1416**	**2947**	**2127**	**1762**	**1692**	**1454**	**817**	**1088**	**354**	**400**	**341**	**237**	**169**	**293**	**320**	**595**	**819**	**2192**	**4749**	**5019**	**4257**	**4938**	**5498**	**4716**	**2617**	**2433**	**54717**

Table C.4 Number of tagged sablefish recovered by trap gear in each year by year of tag release (includes all releases and all recoveries).

Release Year	Recovery Year																												
	1977	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**All**
1977	122	578	187	163	115	66	35	36	17	15	4	9	2		2	3	2			1	5	3		1	3	3		1	**1373**
1978		200	246	257	113	47	30	26	7	5	1	3	7	4		2	1				2	1	1			1			**954**
1979			617	1146	517	338	132	118	122	180	13	48	17	8	7	10	8	2		9	13	21	9	2	10	7			**3354**
1980				991	832	527	283	264	66	56	14	17	20	13	12	5	11	3		8	13	6	5	4	7		1	2	**3160**
1981					207	453	231	140	55	45	7	14	8	8	6	11	6	2		12	5	5	6	5	3		1		**1230**
1982							521	321	60	34	5	13	13	8	2	5	3	1		4	6	4	3	4	4	1			**1012**
1983								72	24	36	4	8	2	1		1				1	3	1	1	1	3				**158**
1984								229	122	114	20	19	5	6	9	7	3	1		9	8	12	11	8	2	5		1	**591**
1985									75	291	29	44	15	18	5	10	7		1	5	11	23	4	4	3				**545**
1987											3	14	5	2	2	1						1		1					**29**
1991															13	71	30	18	19	9	13	13	7	2	1	4		2	**202**
1992																10	75	58	41	29	23	25	20	5	12	8			**306**
1993																	2	261	139	49	56	70	44	13	27	13			**674**
1994																		11	317	167	183	184	93	46	43	29	3	6	**1082**
1995																			80	1092	742	505	270	142	87	45	9	20	**2992**
1996																				334	1851	1107	454	261	216	118	28	33	**4402**
1997																					1125	1986	666	301	243	130	27	22	**4500**
1998																						296	1381	729	492	285	47	60	**3290**
1999																							148	1571	931	564	115	133	**3462**
2000																								100	1587	617	119	104	**2527**
2001																									116	1161	197	182	**1656**
2002																										73	613	335	**1021**
2003																											132	557	**689**
All	**122**	**778**	**1050**	**2557**	**1784**	**1431**	**1232**	**1206**	**548**	**776**	**100**	**189**	**94**	**68**	**58**	**136**	**148**	**357**	**597**	**1729**	**4059**	**4263**	**3123**	**3200**	**3790**	**3064**	**1292**	**1458**	**39209**

Table C.5 Annual number of traditional (selected) tag releases.

Release Year	Number of Selected Releases
1991	2439
1992	3581
1993	7012
1994	3603
1995	12701
1996	9143
1997	7139
1998	15916
1999	17763
2000	19764
2001	14143
2002	9841
2003	8804

Table C.6 Distribution of traditional recovered tags for different combinations of known and unknown recovery month (M,m), area (A,a), and gear (G,g). Lower case letters indicate the variable was unknown.

Year	MAG	MAg	MaG	Mag	mAG	mAg	maG	mag
1991	13	NA	NA	NA	NA	NA	NA	2
1992	95	7	2	2	NA	1	1	3
1993	117	14	10	6	NA	NA	12	8
1994	321	54	38	12	14	2	71	43
1995	471	10	34	7	9	2	111	34
1996	1004	29	52	4	6	4	228	12
1997	1888	3	41	3	NA	NA	7	NA
1998	2215	2	22	6	1	NA	NA	NA
1999	2107	17	43	4	1	2	1	NA
2000	2440	36	39	5	2	5	2	1
2001	2930	6	44	8	2	5	8	NA
2002	2709	40	76	7	7	NA	1	8
2003	1164	28	41	5	2	3	2	6
2004	956	18	140	1	1	1	1	2

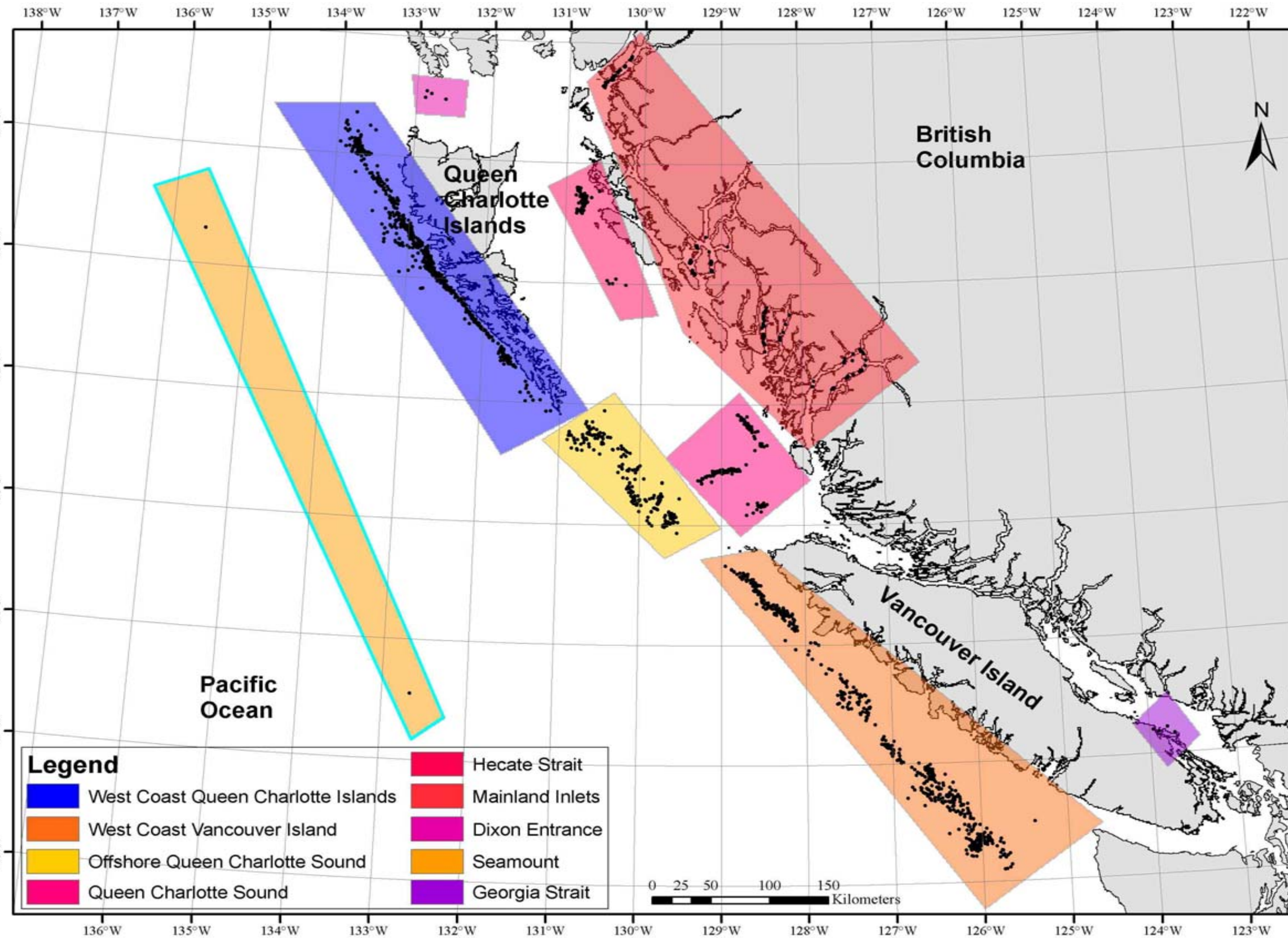

Figure C.1 Sablefish tag release regions. The locations of release sets from 1977 to 2003 are indicated by black dots.

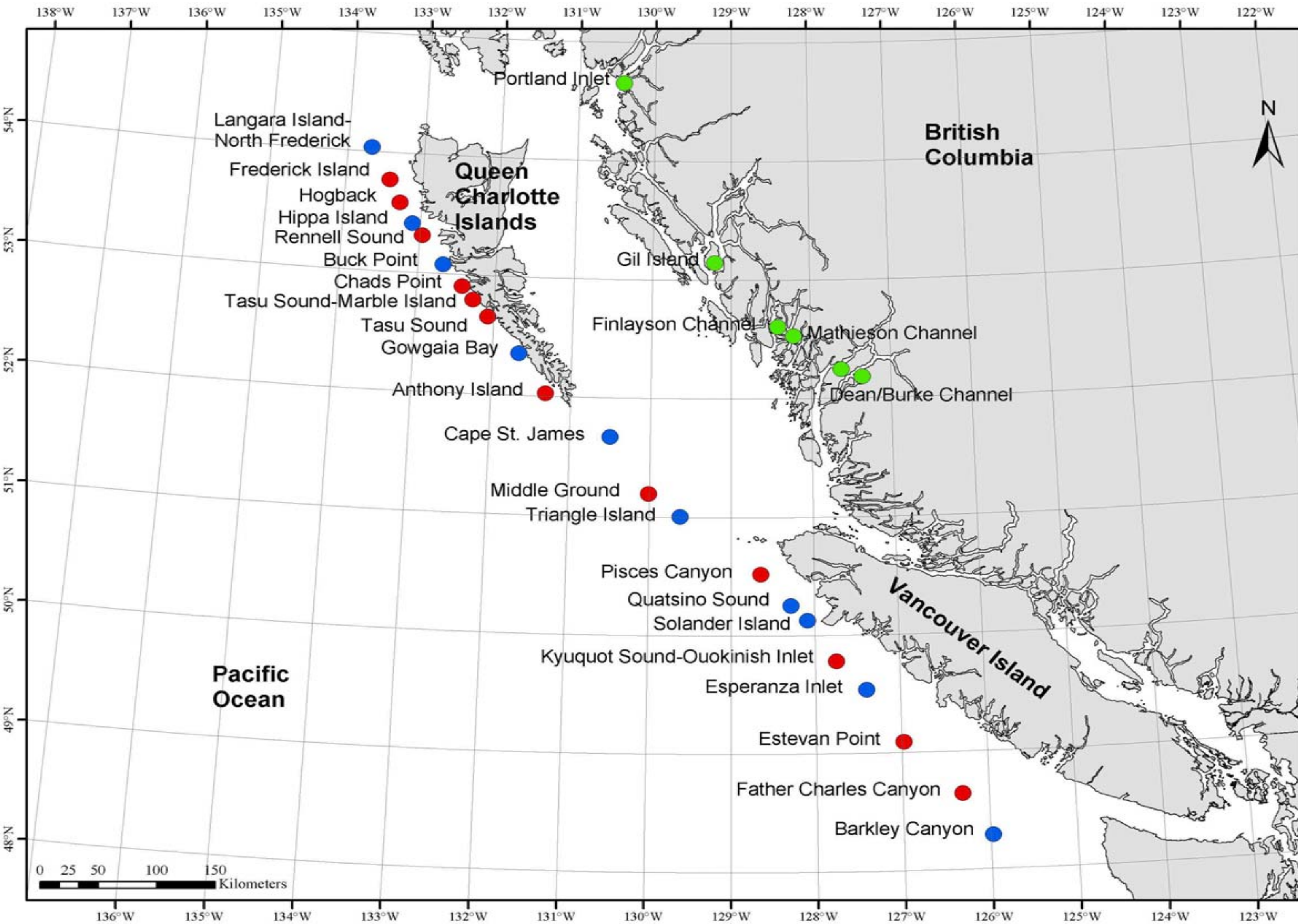

Figure C.2 Tag release localities visited during the annual sablefish stock assessment surveys from 1991 to 2004. Blue circles represent index localities, red circles represent tagging localities and green circles represent inlet localities.

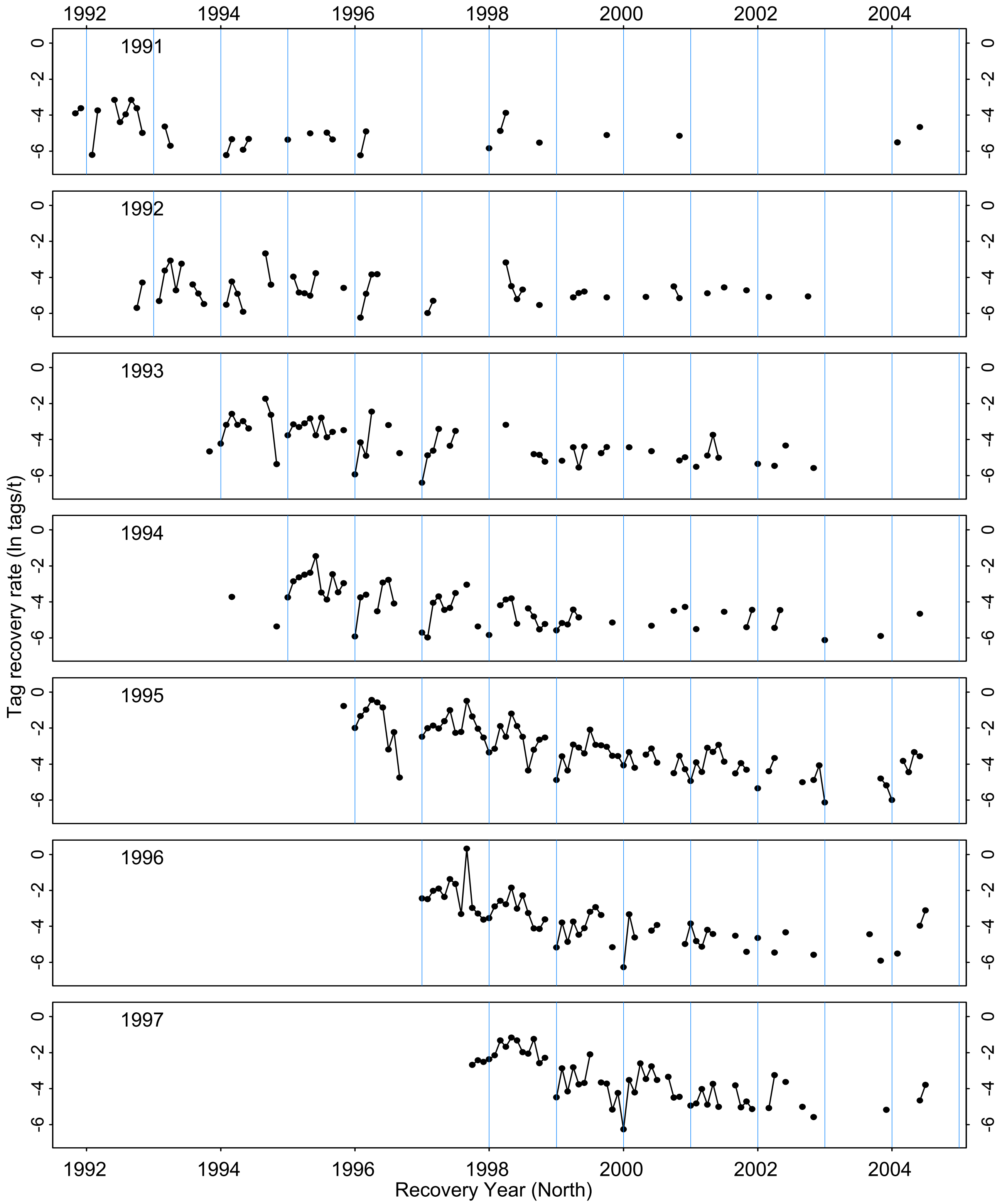

Figure C.3 Tag recovery rate (observed ln tags/t) plotted against recovery year by release year (panels) for the north stock area.

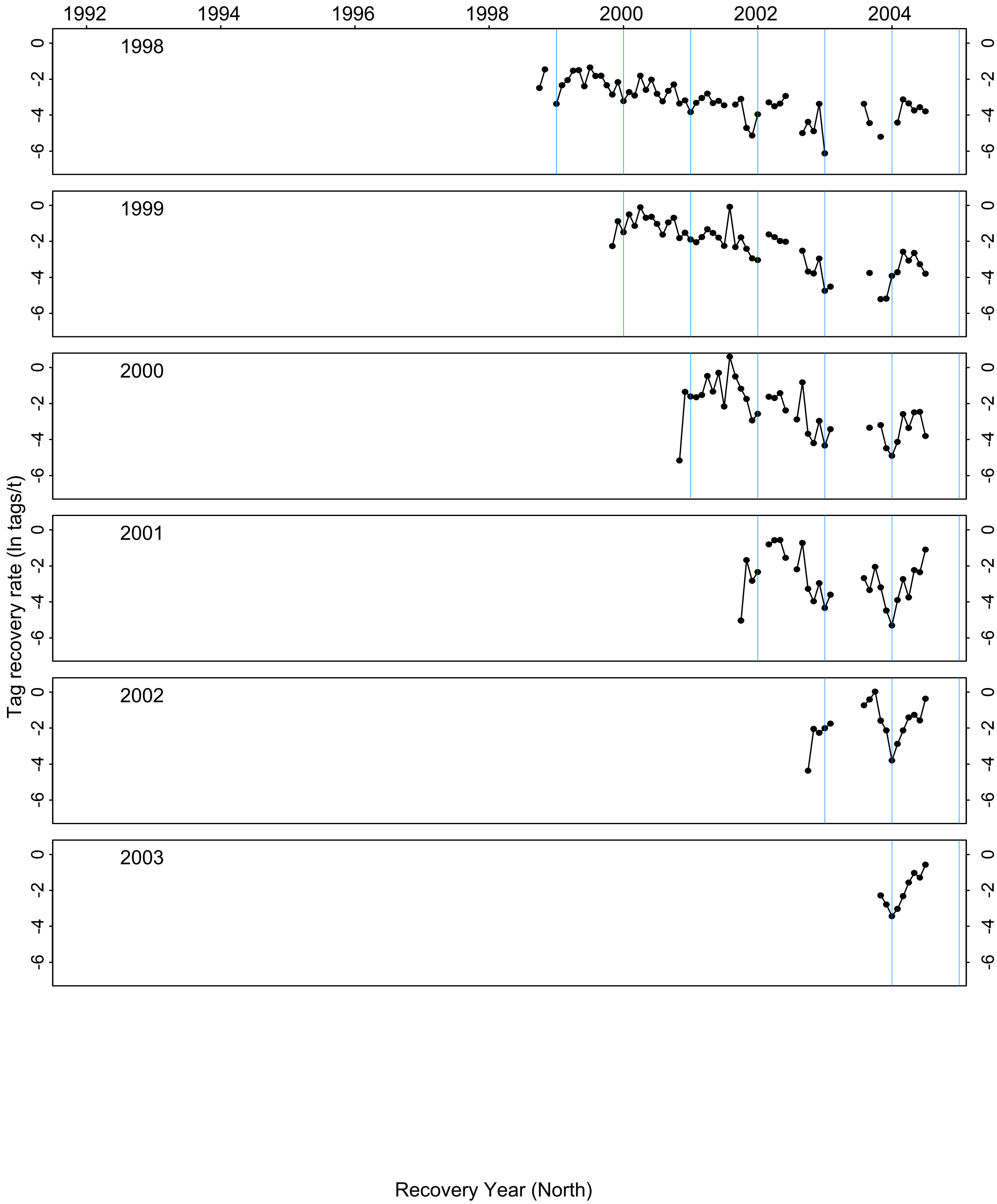

Figure C.3 continued.

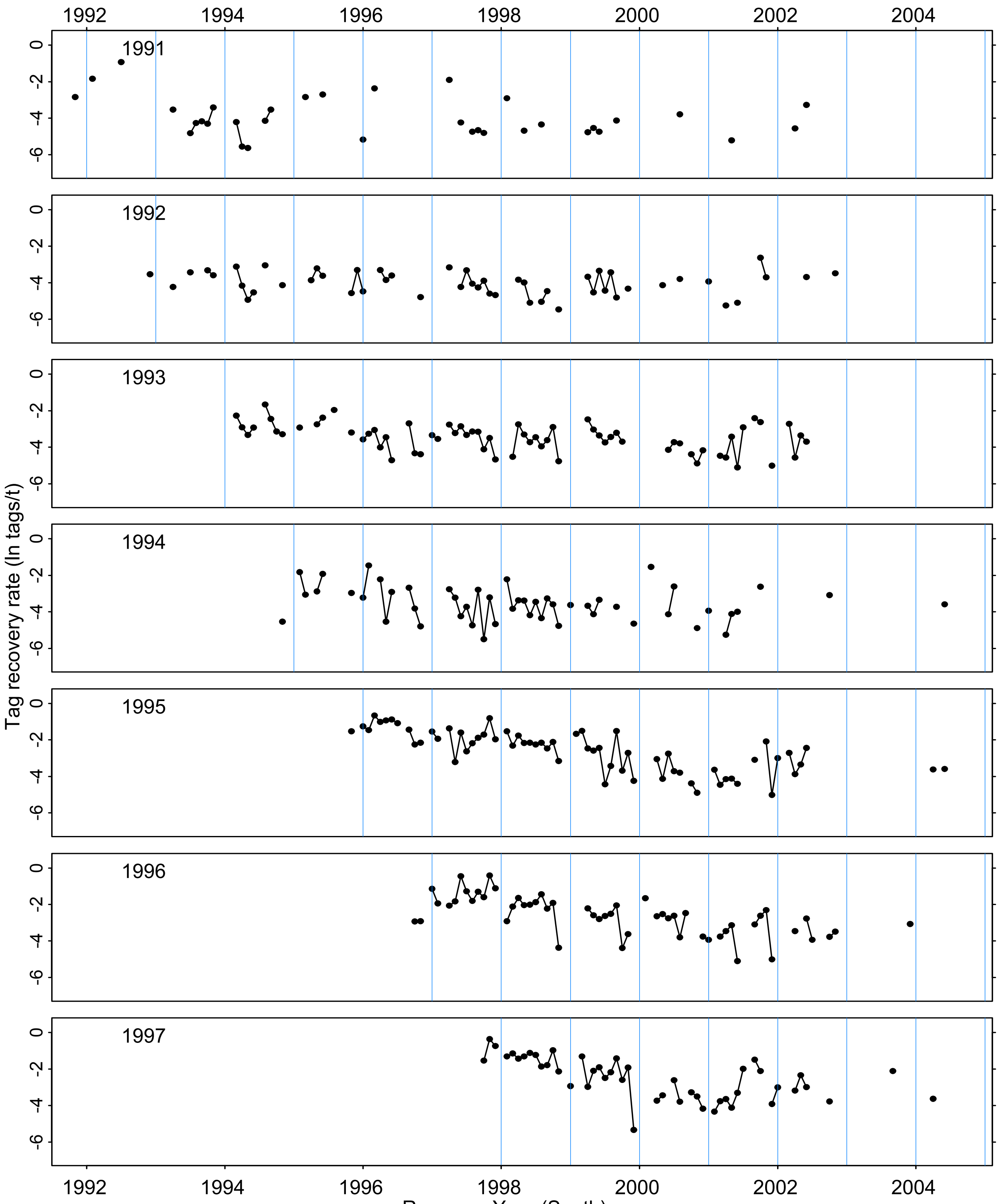

Figure C.4 Tag recovery rate (observed ln tags/t) plotted against recovery year by release year (panels) for the south stock area.

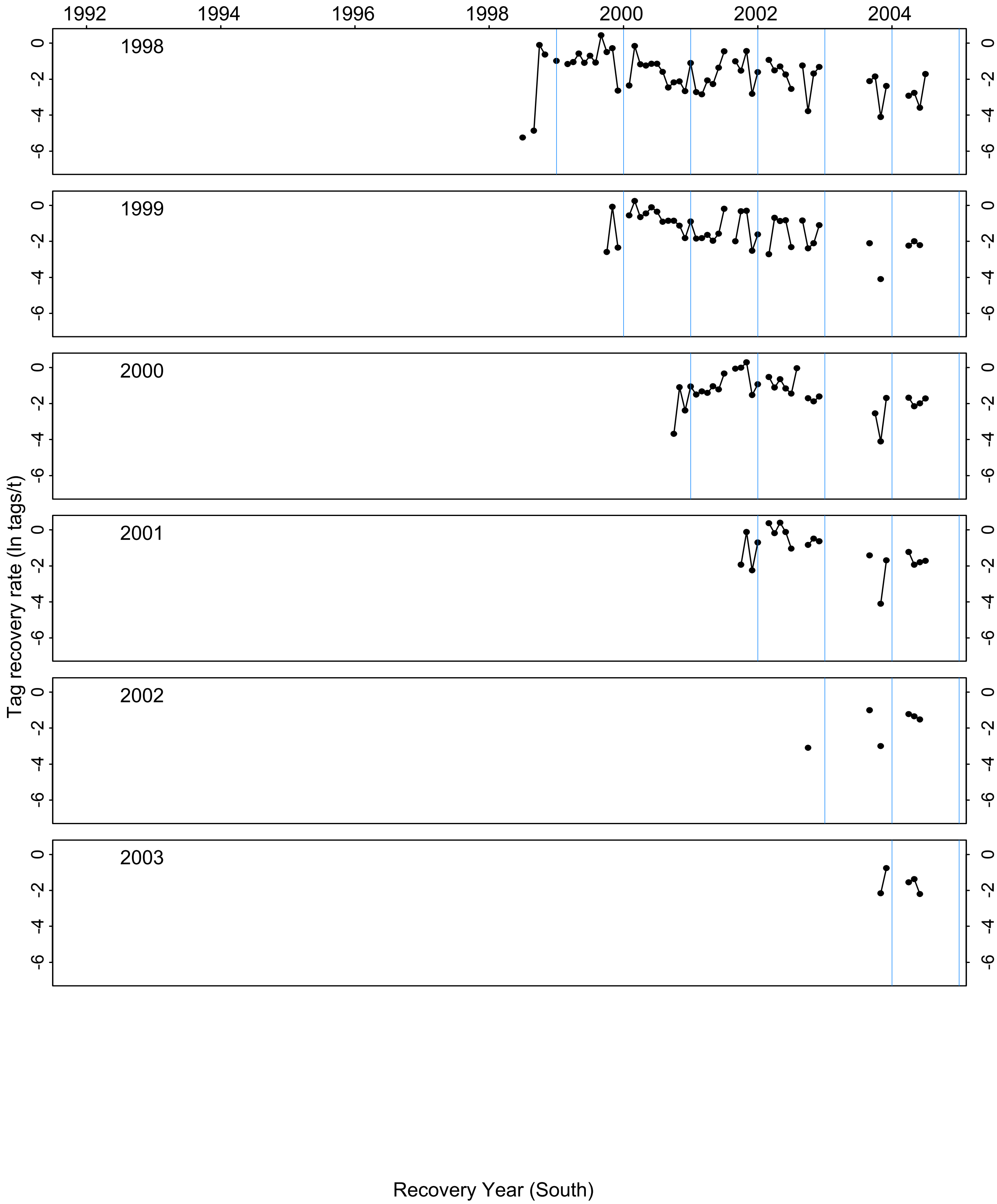

Figure C.4 continued.

APPENDIX D ANALYSIS OF STANDARDIZED SURVEY DATA

D.1 Survey Protocol

The protocol for the sablefish standardized survey has been described in previous assessment documents (eg., Kronlund et al. 2004, Haist et al. 2004) and in various technical reports (Wyeth and Kronlund 2003, Wyeth et al. 2003, 2004a, 2004b). Catch rates observed during survey sets have been regarded as an index of trap-vulnerable sablefish by Haist and Hilborn (2000), Haist et al. (2001), Kronlund et al. (2002), Kronlund et al. (2003), and Haist et al. (2004).

The survey used for indexing the trap-vulnerable biomass has been conducted annually since 1988, though only data beginning with the 1990 survey are currently used to develop a stock index (Table D.1). Nine survey localities (Table D.2, Figure D.1) were purposively selected for the survey because they were fished by commercial vessels and were spatially dispersed about 60 nm apart. This spatial arrangement permitted the localities to be visited within a 30 day period given favorable weather. The indexing survey was depth stratified by fishing trap gear within five core depth intervals between 275 and 1189 m (150 and 650 fm) from 1990 to 2004 (Table D.3). Other strata have been added to these five core strata over time. However, only data from strata D1 through D5 have been utilized in the calculation of a catch rate index of trap-vulnerable stock abundance. Spatial positions of the survey sets within each locality were not selected at random; rather the fishing master had discretion to set gear within each designated depth stratum. In general there was little replication of sets by depth and locality during the 1990 to 2004 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 (Kronlund et al. 2003, Wyeth et al. 2004).

Table D.1 also lists the vessel and skipper used in each survey year. The R/V W.E. Ricker carried out the surveys in 1991 to 1993 under the on-board direction of an experienced skipper from the sablefish commercial fleet. Surveys in other years have utilized a commercial charter vessel and experienced skipper. Standardized surveys conducted from 1996 to 1999, and in 2001 used the same vessel and skipper. Similarly, the 2000 and 2002 standardized survey shared a common vessel and skipper and that same skipper was employed in 2004. Onboard scientific technicians from Fisheries and Oceans Canada, or technicians provided through contractors, have varied over the 1990 to 2004 series although the survey has employed the same Chief Scientist since 2001.

Surveys were conducted using trap gear as described by Smith et al. (1996) and Wyeth et al. (2003, 2004). Trap design since 1988 has been a modified Korean trap consistent with that used by the commercial sablefish fleet. Beginning in 1990, a standardized string of 25 traps, each trap baited with 1.0 to 1.5 kg of frozen squid, was deployed on each survey set. Catch was recorded in numbers of sablefish per trap and aggregate sablefish weight (kg) per trap. The aggregate weight may be an underestimate of the true catch because fish may be partially eaten or reduced to frames by amphipod predation for some traps. The survey gear was inspected upon retrieval to determine if each trap was actually fishing ("effective") and not fouled or holed.

Sablefish caught on standardized survey sets, as opposed to sets designated for tag application or other specific projects, were sampled for length, sex, and maturity. Otoliths were excised for subsequent age determination. Sablefish weight and girth were measured and stomachs were sampled for gut content analysis in some years. Tags may have been applied to sablefish caught by survey sets when large catches were achieved (e.g., Wyeth and Kronlund 2003).

D.2 Data selection and calculation of catch rate per set

Data from the standardized survey were assembled from 1990 to 2004. Fishing event data were included in analyses if the following conditions were met:

- the set was made as part of the standardized survey (Access database table field [B02_FISHING_EVENT]![REASON.CODE]=13);
- the trap usability code indicated that the gear was fishing correctly and was not fouled or holed (Access database table code [B02d_Trap_Specs]![USABILITY_CODE]=1) or that at least some traps were fishing correctly (Access database table code [B02d_Trap_Specs]![USABILITY_CODE]==12);
- the depth fished was contained in stratum D1 to stratum D5 (Table D.3), as determined by assigning the set to a depth stratum based on the mean of depths recorded at one minute intervals during deployment of the gear (Access database table field [B02_FISHING_EVENT]![FE_MODAL_BOTTOM_DEPTH]).

Specific sets were excluded from the analysis as identified in Table D.4. Sets where the mean depth of the set fell into depth stratum 0, 6 and 7 were not included in the analyses because their occurrence is limited to the 2002 (D6, D7), 2003 (D0, D6, D7) and 2004 (D0, D6, D7) survey years. The mean depth of one 1994 Esperanza Inlet set was slightly shallower than the boundary of stratum D0 and D1 but was included in the standardized survey index calculation because the minimum and maximum depths of the set straddled the boundary.

The catch rate for each set was computed by summing the number (or weight) of sablefish in each effective trap, C_{tijkl}, and dividing by the number of effective traps for the set, n_{tijk}

(1) $$U_{tijk} = \frac{\sum_{l=1}^{n_{tijl}} C_{tijkl}}{n_{tijk}} \quad ,$$

where U_{tijk} is the mean catch per trap for set *k* in depth stratum *j* of survey locality *i* for year *t*. Although U_{tijk} is the mean catch per trap for a set, the terms catch rate, or catch per unit effort (CPUE) for the set are used interchangeably. Note that the number of effective traps may differ from 25 traps due to miscounting of traps on deployment of the gear, detection of fouled or holed gear upon retrieval, or lost traps.

D.3 Survey Results

2004 standardized survey results

Table D.5 is a summary of the catches and sampling for the 2004 sablefish standardized survey. There are no criteria applied to the selection of data in this table. Entries in the table show (1) the intended depth stratum rather than the depth stratum actually achieved, (2) the number of traps hauled rather than the traps fishing correctly, and (3) the nominal catch per trap by numbers and weight computed from the table entries. In contrast to previous surveys, the standardized survey vessel did not conduct offshore tagging from 2002 to 2004 since tagging was carried out by a second charter vessel during these years.

Annual survey catch rates

Catch rates are reported for each survey locality in units of mean numbers per trap (Table D.6) and mean weight (kg) per trap (Table D.7) for the five core depth strata (D1-D5) used in calculating the survey-based abundance index.

Boxplots arrayed by year were used to summarize the distribution of catch rates achieved for all sets coast-wide (Figure D.2). The upper panel of Figure D.2 shows the catch rates in units of mean numbers per trap while the lower panel utilizes mean weight (kg) per trap. The lower bound of the each box indicates the first quartile (25th percentile) of the data and the upper bound of the box is the third quartile (75th percentile). The horizontal line that divides the box is the median (50th percentile). The upper and lower whiskers of each boxplot are positioned at 1.5 times the inter-quartile range. Open circles indicate data values that fall outside the whiskers, or outliers. A filled circle represents the mean value of the data summarized in the boxplot. The lightly shaded rectangle positioned in each box represents an approximate 95 percent confidence interval for the sample median.

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 (Figure D.2). 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. Indeed, catch rates in 2003 and 2004 were at a level comparable to those observed during the early 1990s but show greater variability among sets.

Exploratory analysis of time trends in the observed catch rate data (weight per trap) was conducted separately for the north and south stock areas (Figure D.3). As for data aggregated over the entire coast, the survey catch rates in both stock areas 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 times series, with marked reduction of the variance for the north stock area in particular. Catch rates for the north stock area improved in 2002 relative to 2001, and were comparable to those observed in the mid-1990s but were more variable. The mean catch rate in 2003 increased substantially to a historical high for the north, but with substantial variability among sets. Catch rates observed in 2003 for the south also increased greatly to a level similar to that observed in 1992. Catch rates in 2004 were similar to those observed in 2003 for both areas, but with greater variability for the north stock area relative to the south.

Spatial effects

Different catch rate characteristics were observed among the nine indexing localities. Multi-panel displays of catch rates by year for each locality are shown in Figure D.4. Data presented here correspond to depth strata D1 through D5 (Table D.3) which were fished in all survey years. Note that the catch rate scales differ among the panels to allow details of the time trends within each locality to be emphasized. Open circles represent the catch rate (mean weight (kg) per trap) achieved on each set. Filled circles are the arithmetic mean of the catch rates for each year. Two loess (Cleveland 1985) trend lines are superposed on each panel to illustrate the impact of the most recent survey; the solid line is the trend over the entire time series while the dashed line excludes the most recent survey point. The loess trend lines are fit using the observed catch rates rather than the annual means.

In general, time trends among all survey localities show a similar decline in catch rates from highs in the early 1990s. Beginning in the mid-1990s the rate of decline generally decreased or there was no trend through to 2002, depending on the locality.

However, notable increases in trap CPUEs for 2002 were recorded for the north stock area at the Langara Island-North Frederick and Hippa Island survey localities while catch rates at the Buck Point and Gowgaia Bay localities were comparable to those observed in the mid 1990s. Catch rates increased substantially in 2003 and 2004, with similar mean catch rates being observed for most localities between the two years. The Barkley Canyon locality continues to depart in trend from other localities where only stratum D2 returned a significantly improved catch rate, albeit a large value.

Depth effects

In all cases the sets in 2004 achieved the target depth stratum. Catch rates in depth strata D6 and D7 continue to be low, reflecting either lower sablefish densities at these depths and/or decreased efficiency of trap gear at depth. Catch rates at the shallow depth stratum, D0, are generally very low, with the exception of the high catch rate observed at Barkley Canyon. In comparing 2003-2004 and 1993 catch rates, note that 1993 catch rates were high within more depth strata than was the case in 2003-2004. That is, higher catch rates where achieved at strata D4 and D5 in addition to strata D1 through D3.

Catch rates (kg per trap) by year, depth and locality are shown in Figure D.5 for depth strata D1 through D5 which have been targeted in all survey years. The trends apparent at the coast-wide level of aggregation are broadly reflected within each locality and depth. Significant improvements were observed in 2003-2004 catch rates relative to the mid-1990s until 2002. Most increases occurred within depth strata D1 through D3, with small or negligible increases for depth strata D4 and D5 (e.g., Hippa Island). Barkley Canyon showed a modest increase for depth stratum D1 in 2004 with an extremely high catch rate observed for stratum D2. Depth strata D3 through D4 continue to show little evidence of increased abundance. There are two general features of these data to note. First, the variation of observations around the trend line is relatively small. Second, there is interaction among years and depths, e.g., high catch rates were observed at deep depths early in the time series for Barkley Canyon, but low catch rates in the latter half of the time series. Thus, the effect of depth over survey localities depends on which years are considered, but without replication of sets at each combination of locality, depth, and survey year, the interaction effects cannot be estimated. The implication is that depth-dependent year effects exist.

D.4 Selection of a survey-based index of trap-vulnerable abundance

Annual mean catch rates in units of number of sablefish per trap and weight (kg) of sablefish per trap are shown in Table D.8. The annual rates were based on data from depth strata D1 through D5 only since these strata were consistently fished throughout the survey time series. Annual means were computed by

(2) $$U_t = \frac{\sum_{i=1}^{n_t} U_{ti}}{n_t} \quad ,$$

where $i = 1, \ldots, n_t$ indexes all observed catch rates in year t for the coast or by stock area.

Recent stock assessments (Kronlund et al. 2003, Haist et al. 2004) have used a general linear model (GLM) in an attempt to standardize survey CPUE data over the time series and to separate effects due to locality and depth. The model used was specified by

(3) $$U_{tijk} = \mu + \alpha_t + \beta_i + \gamma_j + \varepsilon_{tijk} \quad ,$$

where μ is the overall mean effect, α_t is the effect of the *t*th level of the year factor, β_i is the effect of the *i*th level of the depth factor, γ_j is the *j*th effect of the locality factor, and ε_{tijk} is a random error component. Random errors were assumed to be normally distributed with mean 0 and variance σ^2. The model was utilized because if the survey catch rates are assumed to be proportional to stock abundance, the year effects (α_t) from the GLM analysis can be utilized as a stock index (Hilborn and Walters 1992).

This main effects model does not include interaction terms of the form $(\beta\gamma)_{ij}$ since there were very few replicates by depth and locality (Kronlund et al. 2003, Haist et al. 2004). The design of the indexing survey lacks the replication within each combination of locality and depth stratum required to assess interactions among years, localities, and depth. Inspection of the plots of survey catch rates by these explanatory factors (Figure D.5) suggest interaction terms would be important if they could be supported by the data.

In practice, the GLM standardization procedure used in previous analyses achieved little in terms of adjustments for year, locality and depth effects as noted by reviewers of previous stock assessments. This result can be seen by inspection of Figure D.6 which shows three indices of trap-vulnerable abundance based on coast-wide survey data, namely:

1. annual catch rate expressed as the mean number of fish per trap from 1990 to 2004;
2. annual catch rate expressed as the mean weight (kg) per trap for 1990 to 2004;
3. the GLM year effects obtained by Haist et al. (2004) which were derived from application of model (2) for 1990 to 2003.

The first two indices are those reported in Table D.8. The data were rescaled to have the same mean over the period of overlap from 1990 to 2003. The time series were centered on the mean of the weight (kg) per trap catch rate series from 1990 to 2003 and the rescaling preserved the initial coefficient of variation (CV) of each series. Figure D.6 shows that the rescaled series closely overlap with the largest differences occurring in 1990 and 1993. However, the general similarity of the trends implies there is little basis for choosing among the three indices. Thus, the linear model standardization is not applied for this assessment.

D.5 Summary

Coast-wide and area specific catch rates in 2004 were similar to those observed in 2003. Catch rates in 2003 and 2004 are substantially higher than those observed from the mid-1990s until 2002 and are similar to highs observed during the early 1990s for the north stock area. The trends over time at all survey localities show similar characteristics. Catch rates show typical correlation between mean and variance; higher catch rates are associated with higher observed variance. Survey results over time can be summarized as follows:

- a decline in catch rates from highs in the early 1990s coast-wide and within both the north and south stock areas;
- beginning in the mid-1990s, the rate of decline generally decreased or there was a period of relative stability through to 2000, depending on the survey locality;
- 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 stock area in particular;
- catch rates for the north stock 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, with high variability among sets;
- catch rates in the south stock area exhibit a continuous decline from the mid-1990s to 2002, but show significant increases in 2003 to levels similar to those observed in 1992;
- catch rates in 2004 were similar in level to those observed in 2003 but with reduced variability, nonetheless they remain more variability than similarly high catch rates observed during the early 1990s.

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. The strengths of the survey are the consistency in the conduct of standardized fishing over time and the broad geographic and depth coverage. The credibility of survey catch rates as an abundance index is reinforced by similarities in the time trends in catch rates from 1990 to 2004 among most localities and within most depth strata.

D.6 Literature Cited

Cleveland, W.S. 1985. The elements of graphing data. Wadsworth, Monterey, California. xii+323 p.

Haist, V. and R. Hilborn. 2000. Sablefish stock assessment for 2000 and recommended yield options for 2001. Can. Stock. Assess. Sec. Res. Doc. 2000/157. 78 p.

Haist, V., Hilborn, R., and M. Wyeth. 2001. Sablefish stock assessment for 2001 and advice to managers for 2002. Can. Sci. Advisory Res. Doc. 2001/135. 54 p.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York. xiii+570 p.

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

Kronlund, A.R., M. Wyeth, and R. Hilborn. 2002. Review of survey, commercial fishery, and tagging data for sablefish (*Anoplopoma fimbria*) in British Columbia: Supplement to the November 2001 sablefish stock assessment. Can. Sci. Adv. Sec. Res. Doc. 2002/074. 109 p.

Smith, M.S., Saunders, M.W. and W.T. Andrews. 1996. Cruise details of sablefish (*Anoplopoma fimbria*) surveys conducted in B.C. waters 1988-1993. Can. Data Rep. Fish. Aquat. Sci. 976: 129 p.

Surry, A.M., Leaman, B.M., and M.W. Saunders. Examination of the effect of bait loading in fish traps on catch rates of sablefish (*Anoplopoma fimbria*), M/V *OCEAN PEARL*, October 8-10, 1996. Canadian Manuscript Report of Fisheries and Aquatic Sciences. *In prep*.

Wyeth, M.R. and A.R. Kronlund. 2003. Sablefish (*Anoplopoma fimbria*) research and assessment surveys conducted in British Columbia waters from 1996 to 2000. Can. Data Rep. Fish. Aquat. Sci. 1116: 130 p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2003. Summary of the 2001 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1118. 54 p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2004. Summary of the 2002 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1140. 59 p.

Wyeth, M.R., A.R. Kronlund, and M. Elfert. 2004. Summary of the 2003 British Columbia sablefish (*Anoplopoma fimbria*) research and assessment survey. Can. Data Rep. Fish. Aquat. Sci. 1148. 68 p.

Table D.1 Indexing vessel timing, and skipper, for 1988 to 2004. Start Date is the date of the first indexing set and End Date is the date of the last indexing haul.

Year	Vessel	Skipper	Start Date	End Date	Trip ID
1988	F/V Vicious Fisher	Fletcher	October 31	November 23	43990
1989	F/V La Porsche	Brynjolfsen	October 21	November 17	43910
1990	F/V Viking Star	D. Farrington	November 08	November 18	43750
1991	R/V W.E. Ricker	A. Farrington	October 10	October 28	43673
1992	R/V W.E. Ricker	Roberts	October 15	November 03	43670
1993	R/V W.E. Ricker	A. Farrington	October 23	November 10	43650
1994	F/V La Porsche	Beauvais	October 15	October 25	43630
	F/V Western Viking	Jones	October 19	November 07	43390
1995	F/V Victor F	Derry	October 15	October 28	43330
	F/V Viking Sunrise	Olsen	October 10	October 25	43350
	F/V Ocean Pearl	Fraumeni/Gold	October 08	October 18	43270
1996	F/V Viking Star	Elvan	October 08	October 20	43210
	F/V Ocean Pearl	Derry	September 27	October 06	43039
1997	F/V Ocean Pearl	Derry	September 27	October 14	42699
1998	F/V Ocean Pearl	Derry	September 24	October 10	41122
1999	F/V Ocean Pearl	Derry	September 29	October 17	40589
2000	F/V Pacific Viking	Melynchuck	October 08	November 11	40517
2001	F/V Ocean Pearl	Derry	October 07	October 29	43233
2002	F/V Pacific Viking	Melynchuck	October 03	November 06	48120
2003	F/V Viking Star	J. Farrington	October 09	November 08	52120
2004	F/V Ocean Marauder	Melynchuck	October 06	October 23	NA

Table D.2 Geographic boundaries of the standard survey localities.

Locality	Latitude North				Longitude West			
	Maximum		Minimum		Maximum		Minimum	
Langara Is.-North Frederick	54º	9’	53º	59’	134º	2’	133º	32’
Hippa Island	53º	32’	53º	20’	133º	24’	132º	55’
Buck Point	53º	14’	53º	1’	133º	10’	132º	35’
Gowgaia Bay	52º	27’	52º	17’	131º	51’	131º	33’
Cape St. James	51º	50’	51º	37’	130º	59’	130º	19’
Triangle Island	51º	8’	50º	58’	129º	55’	129º	31’
Quatsino Sound	50º	25’	50º	12’	128º	38’	128º	8’
Esperanza Inlet	49º	47’	49º	24’	127º	39’	127º	13’
Barkley Canyon	48º	24’	48º	10’	126º	12’	125º	53’

Table D.3 Depth strata boundaries by survey year.

Year	Stratum	Start depth fm (m)	End depth fm (m)
1988-1989	1	200 (366)	300 (549)
	2	300 (549)	400 (732)
	3	400 (732)	500 (915)
1990-2001	1	150 (275)	250 (457)
	2	250 (458)	350 (641)
	3	350 (642)	450 (824)
	4	450 (825)	550 (1006)
	5	550 (1007)	Deeper
2002	D1	150 (274)	249 (457)
	D2	250 (457)	349 (641)
	D3	350 (641)	449 (824)
	D4	450 (824)	549 (1006)
	D5	550 (1006)	649 (1189)
	D6	650 (1189)	749 (1372)
	D7	750 (1372)	999 (1827)
2003-2004	D0	50 (91)	149 (274)
	D1	150 (274)	249 (457)
	D2	250 (457)	349 (641)
	D3	350 (641)	449 (824)
	D4	450 (824)	549 (1006)
	D5	550 (1006)	649 (1189)
	D6	650 (1189)	749 (1372)
	D7	750 (1372)	999 (1827)

Table D.4 List of index sets excluded from survey data analysis.

Year	Location	Set	Depth Stratum	Reason for exclusion
1990	Barkley Canyon	23	5	only 3 traps hauled, remainder of the string lost
1994	Cape St. James	3	5	bridge log indicates extra 25 set for vessel, but not in data report, baiting unclear
1994	Gowgaia Bay	6	5	extra 50 traps for vessel, catch not recorded, baiting unclear
1994	Gowgaia Bay	11	2	extra 35 traps for vessel baited with hake and squid bait
1994	Hippa Island	18	5	extra traps for vessel, catch not recorded, baiting unclear
1994	Langara Island-North Frederick	24	5	extra 33 traps for vessel baited with hake and squid bait
1995	Cape St. James	11	3	trap set every second becket
1998	Esperanza Inlet	13	1	unsure count of traps
1998	Buck Point	57	3	tangled with another string
2001	Gowgaia Bay	66	4	set across another vessel's string
2004	Hippa Island	52	5	unsure count of traps

Table D.5 Summary of 2004 standardized survey data by locality.

				Sablefish					Nominal CPUE	
Locality	**Intended Depth Stratum**	**Set Number**	**Traps Hauled**	**LSMO Sampled**	**LSM Sampled**	**Recovered**	**Total**	**Weight (kg)**	**Fish/ Trap**	**kg/ Trap**
Barkley Canyon	D0	1	25	47	298	0	470	1405	18.80	56.20
	D1	2	24		74	0	213	639	8.88	26.63
	D2	3	24		137	1	800	2349	33.33	97.88
	D3	4	25		115	4	165	336	6.60	13.44
	D4	5	25	47	64	2	113	227	4.52	9.08
	D5	6	25	34	15	1	68	162	2.72	6.48
	D6	7	25	43	58	3	103	286	4.12	11.44
	D7	8	25	32	0	0	32	132	1.28	5.28
Esperanza Inlet	D0	15	23	0	0	0	6	15	0.26	0.65
	D1	14	24	37	86	0	353	1195	14.71	49.79
	D2	13	25	40	93	2	335	962	13.40	38.48
	D3	12	24	46	57	0	112	240	4.67	10.00
	D4	11	25	46	119	0	160	367	6.40	14.68
	D5	10	25	49	77	0	125	378	5.00	15.12
	D6	9	25	29	0	0	29	89	1.16	3.56
Quatsino Sound	D0	16	24	7	0	0	7	15	0.29	0.63
	D1	17	25	33	80	0	143	444	5.72	17.76
	D2	18	25	53	121	0	381	1095	15.24	43.80
	D3	19	25	50	97	1	306	829	12.24	33.16
	D4	20	25	58	0	0	58	130	2.32	5.20
	D5	21	25	56	35	2	93	197	3.72	7.88
	D6	22	24	11	0	0	11	38	0.46	1.58
Triangle Island	D0	29	25	63	0	0	66	232	2.64	9.28
	D1	28	24	68	94	4	413	1203	17.21	50.13
	D2	27	25	45	77	1	446	1247	17.84	49.88

Locality	Intended Depth Stratum	Set Number	Traps Hauled	Sablefish LSMO Sampled	LSM Sampled	Recovered	Total	Weight (kg)	Nominal CPUE Fish/ Trap	kg/ Trap
	D3	26	25	57	126	1	512	977	20.48	39.08
	D4	25	25	45	61	1	109	233	4.36	9.32
	D5	24	25	41	0	0	41	136	1.64	5.44
	D6	23	25	20	0	0	20	75	0.80	3.00
Cape St. James	D0	30	24	46	0	0	46	135	1.92	5.63
	D1	31	24	53	96	0	247	735	10.29	30.63
	D2	32	24	42	114	17	383	1028	15.96	42.83
	D3	33	25	37	92	1	181	523	7.24	20.92
	D4	34	25	41	43	0	85	244	3.40	9.76
	D5	35	23	16	0	0	16	49	0.70	2.13
	D6	36	24	32	0	0	32	118	1.33	4.92
Gowgaia Bay	D0	43	25	13	0	0	13	48	0.52	1.92
	D1	42	22	65	86	0	317	992	14.41	45.09
	D2	41	25	76	123	2	461	1339	18.44	53.56
	D3	40	25	42	85	1	210	620	8.40	24.80
	D4	39	25	67	0	0	67	197	2.68	7.88
	D5	38	25	26	0	0	26	98	1.04	3.92
	D6	37	25	5	0	0	5	22	0.20	0.88
Buck Point	D0	44	25	18	0	0	18	70	0.72	2.80
	D1	45	25	60	98	0	545	1850	21.80	74.00
	D2	46	24	51	91	0	305	942	12.71	39.25
	D3	47	25	53	91	1	252	667	10.08	26.68
	D4	48	25	51	38	0	86	247	3.44	9.88
	D5	49	25	32	0	1	33	94	1.32	3.76
	D6	50	25	18	0	0	18	61	0.72	2.44
Hippa Island	D0	57	25	12	0	0	12	54	0.48	2.16
	D1	55	25	54	109	0	230	821	9.20	32.84

Locality	Intended Depth Stratum	Set Number	Traps Hauled	Sablefish LSMO Sampled	LSM Sampled	Recovered	Total	Weight (kg)	Nominal CPUE Fish/ Trap	kg/ Trap
	D2	54	25	47	110	2	365	1080	14.60	43.20
	D3	56	25	47	70	0	139	456	5.56	18.24
	D4	53	25	48	92	0	141	446	5.64	17.84
	D5	52	25	49	41	1	90	204	3.60	8.16
	D6	51	25	23	0	0	23	83	0.92	3.32
Langara Island-North Frederick	D0	63	24	4	0	0	4	21	0.17	0.88
	D1	64	25	45	79	0	255	965	10.20	38.60
	D2	62	25	49	103	1	409	1260	16.36	50.40
	D3	61	25	52	84	0	260	707	10.40	28.28
	D4	60	25	25	0	0	25	85	1.00	3.40
	D5	59	25	25	0	0	25	75	1.00	3.00
	D6	58	25	19	0	0	19	79	0.76	3.16
Total		**64**	**1,580**	**2,400**	**3,529**	**50**	**11,033**	**32,048**	**6.98**	**20.28**

Table D.6 Sample catch rate (mean number fish per trap) of survey index sets by core depth stratum, locality, stock, and year. Sets are assigned to depth strata based on the mean of depth observations taken at one minute intervals. Fouled or holed traps are excluded. All means are calculated using the catch rates observed for each set at the level of aggregation.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Barkley Canyon	1			13.76	23.04		7.92	3.12	7.52	1.46	2.15	2.78	0.16	1.83	3.64	8.88
	2	15.74	6.73	24.65	26.32	22.42	8.92	3.72	6.92	2.16	1.56		0.64	2.52	10.83	33.33
	3	7.38	9.50	18.92	16.78	7.84	6.40	6.08	6.88	2.36	1.87	13.28	2.64	5.84	2.92	6.60
	4	14.85	23.60	21.04	19.44	18.54	10.40	8.24	5.44	7.21	6.53	12.48	8.13	5.88	2.20	4.52
	5	11.72	15.82	19.16	12.56		7.92	9.68	6.64	8.76		11.04	5.28	4.00	4.18	2.72
	Mean	12.52	13.91	19.51	19.25	16.83	8.31	6.17	6.68	4.39	3.73	8.47	3.37	4.02	4.74	11.21
Esperanza Inlet	1			7.48	13.63	9.40	4.84	5.32	10.12	4.04	4.13	6.48	1.68	1.04	19.16	14.71
	2	8.16		12.40	16.76	8.64	8.17	2.40	4.28		2.67	5.00	0.29	1.11	9.76	13.40
	3	5.14		8.24	12.16	6.36	4.72	1.72		1.63	2.32	2.42	0.81	3.47	5.00	4.67
	4	10.33		10.60	20.48	3.52	13.45	2.72	1.58	1.52	2.04	7.33	0.96	5.44	1.80	6.40
	5	9.60		16.36	21.88	8.44	5.25	6.64	5.70	7.42	5.61	3.00	4.81	7.02	5.08	5.00
	Mean	8.4		11.02	16.98	7.27	7.29	3.76	5.19	3.65	3.35	4.85	1.71	3.33	8.16	8.84
Quatsino Sound	1	3.68		5.38	6.88	3.96	3.30	2.52	2.33	2.75	3.50	3.08	1.57	0.84	37.80	5.72
	2	5.70	2.66	8.36	11.63	6.96	3.76	2.56	1.04	4.20	3.28	4.08	0.88	3.00	13.12	15.24
	3	3.30	2.76	7.08	10.24	3.20	2.16	1.88	0.21	5.68	3.32	3.84	5.76	1.96	15.48	12.24
	4	5.40	9.50	14.64	4.08	1.72	3.32	1.76	0.24	2.36	3.60	8.05	5.88	0.58	3.88	2.32
	5	6.90	5.94	9.32	5.32		4.30	2.52	0.52	2.12	4.88	2.24	1.64	1.60	1.13	3.72
	Mean	5.07	5.21	8.96	7.63	3.81	3.37	2.25	0.87	3.42	3.72	4.26	3.15	1.6	14.32	7.85
Triangle Island	1			5.44		3.52	4.48	5.08	2.30	1.64	2.68	4.36	0.96	0.28	11.68	17.21
	2		4.67	11.12	11.56	9.44	7.52	4.72		3.84	3.16		0.78	1.68	14.04	17.84
	3		1.33	10.36	9.20	4.42	7.76	2.84	3.56	2.36	2.67	5.12	0.48	2.88	26.40	20.48
	4		1.71	4.64	7.25	0.36	4.00	1.60	0.44	4.88	1.36	1.12	0.56	0.52	6.06	4.36
	5		1.13	4.32	6.76	0.36	4.28	2.40	1.37	6.28	1.14	1.21	0.44	0.90		1.64
	Mean		2.21	7.18	8.69	3.62	5.61	3.33	1.99	3.8	2.2	3.23	0.65	1.19	12.85	12.31
Southern Stock	**Mean**	8.5	8.09	11.66	14.39	7.41	6.14	3.88	3.68	3.82	3.25	5.2	2.22	2.75	10.02	8.67
Coast	**Mean**	8.5	7.46	8.88	11.61	5.49	4.26	3.39	2.7	3.64	2.58	3.47	1.27	2.96	10.05	9.3

Table D.6 Continued.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cape St. James	1					1.62	3.17	2.44	1.56	2.13	4.22	2.04	1.08	0.24	20.28	10.39
	2					3.32	2.08	3.52		3.80	5.74	4.95	2.72	2.56	14.68	15.96
	3					4.20		4.43	3.24	1.96	3.36	3.08	0.64	6.00	8.96	7.54
	4					3.91	0.88	1.80	1.52		1.71	1.74	0.17	0.84	1.28	3.67
	5						1.38	1.64	0.56	1.15	0.38	0.35	0.11	0.32	0.75	0.62
	Mean					3.26	1.88	2.77	1.69	2.04	3.08	2.43	0.95	1.99	9.19	7.63
Gowgaia Bay	1					1.81	3.48	3.67	3.48	3.00	0.68	0.58	0.36	2.93	22.56	14.41
	2		11.75	11.63	14.83		7.24	2.56	4.00	4.84	2.09	6.13	0.42	3.28	19.30	18.44
	3		4.33	8.71	13.81	9.25	6.40	2.76	1.36	4.72	1.03	2.61	0.69	2.03	7.16	8.61
	4		2.63	3.56	7.12	3.76	5.40	2.00	0.64	3.29		2.08		1.39	1.92	2.68
	5		3.96	4.76	6.84		1.68	1.68	0.60	3.92	0.28	1.32	0.35	1.01	0.61	1.04
	Mean		5.67	7.16	11.28	4.94	4.84	2.53	2.02	3.95	1.02	2.54	0.45	2.06	8.69	9.04
Buck Point	1			3.12	9.32	2.00	2.40	2.62	0.64	3.85	2.09	2.96	0.44	3.67	19.38	21.96
	2		7.21	11.71	12.50	6.80	2.72	4.80	3.92	4.80	2.32	4.60	0.67	5.16	21.96	13.04
	3		2.13	10.32	5.00	4.09	3.92	1.60	0.96		2.04	1.20	0.24	2.84	15.78	10.08
	4		3.79	7.35	4.16	4.36	1.50		0.48	1.72	0.80	1.72	0.16	0.68	1.16	3.57
	5		2.29	4.92	3.36	3.12	1.40	3.54	0.60	4.52	0.31	1.24	0.40	0.72	0.54	1.32
	Mean		3.85	7.48	6.87	4.07	2.39	3.47	1.32	3.72	1.51	2.34	0.38	2.61	11.76	9.99
Hippa Island	1				1.14	2.96	1.80	2.27		1.96	0.88	1.56	0.56	4.46	1.44	9.54
	2			4.79	10.84	2.40	2.16	4.21		4.92	1.48	2.44	0.72	5.69	17.63	14.6
	3			3.76	8.76	2.88	4.40	6.38		6.60	0.84	1.96	0.08	5.52	22.85	5.56
	4			7.36	6.62	5.52	2.00	4.00		3.92		1.40	0.43	2.00	3.68	5.64
	5			4.44			2.24	5.13		0.58	2.64	0.52	0.28	2.26	2.16	
	Mean			5.09	6.8	3.44	2.52	4.4		3.6	1.34	1.58	0.41	3.9	10.9	8.84
Langara Island-North Frederick	1			1.72		1.74	0.28	1.88	2.48	3.40	0.24	2.67	0.08	3.80	8.48	10.20
	2		10.29	4.16	10.43	3.96	2.71	2.52		6.29	6.44	1.50	0.36	16.16	19.65	16.36
	3		8.33	1.24	9.28	2.32	2.34	0.98	1.24	2.96	4.20	1.33	0.11	5.12	17.24	10.87
	4		9.13	4.20	6.04	3.16			1.12	4.76	3.08		0.16	1.56	3.84	0.91
	5		11.16	6.60	5.92		0.68	2.72	2.08	3.52	2.48	0.44	0.40	0.84	0.56	1.05
	Mean		9.73	3.58	7.92	2.79	1.67	1.82	1.88	4.19	3.29	1.49	0.22	5.5	9.95	7.88
Northern Stock	**Mean**		6.42	5.8	8.23	3.66	2.69	3.0	1.73	3.49	2.05	2.08	0.48	3.10	10.1	8.67
Coast	**Mean**	8.5	7.46	8.88	11.61	5.49	4.26	3.39	2.7	3.64	2.58	3.47	1.27	2.96	10.05	9.3

Table D.7 Sample mean catch rate (mean kg per trap) of survey index sets by core depth stratum, locality, stock and year. Sets are assigned to depth strata based on the mean of depth observations taken at one minute intervals. Fouled or holed traps are excluded. All means are calculated using the catch rate observations from each set at the level of aggregation.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Barkley Canyon	**1**			33.44	54.84		28.44	12.08	23.90	5.21	7.55	8.30	0.38	5.03	9.69	26.64
	2	39.86	12.65	74.00	65.82	58.54	26.33	13.04	20.76	5.84	4.91		1.53	5.50	27.03	97.87
	3	18.98	16.34	39.67	49.46	24.76	21.64	16.20	14.65	6.68	4.26	25.68	5.70	11.90	5.55	13.45
	4	30.24	41.54	41.80	46.64	37.70	26.76	21.28	13.13	14.63	15.14	25.60	17.97	11.12	4.86	9.08
	5	25.40	33.40	39.96	32.58		18.32	23.28	15.71	17.12		27.48	13.71	8.79	8.54	6.49
	Mean	29.08	25.98	45.77	49.32	39.68	24.3	17.18	17.63	9.89	9.4	19.07	7.86	8.47	11.14	30.70
Esperanza Inlet	**1**			25.48	51.63	24.84	15.08	19.04	28.92	13.00	14.02	20.92	5.84	3.46	53.83	49.79
	2	21.80		36.56	39.12	15.52	26.71	7.80	6.29		7.21	15.42	0.89	3.23	25.96	38.50
	3	13.12		24.16	40.60	15.68	13.60	4.52		4.67	5.90	5.21	1.60	6.61	13.38	10.00
	4	21.13		27.24	54.88	9.56	28.65	7.36	2.90	3.33	4.79	15.46	2.19	9.98	4.42	14.68
	5	18.28		38.12	59.40	21.60	14.55	14.00	10.84	16.23	14.29	7.80	11.50	16.04	12.81	15.12
	Mean	18.94		30.31	49.13	17.44	19.72	10.54	11.05	9.31	9.24	12.96	4.4	7.42	22.08	25.62
Quatsino Sound	**1**	12.56		20.29	26.96	17.72	11.04	8.04	6.72	10.75	14.41	8.50	4.59	2.72	102.54	17.75
	2	12.00	5.92	27.52	34.93	19.20	12.04	8.60	2.72	13.36	9.62	10.00	2.20	7.69	35.14	43.81
	3	9.72	7.02	20.48	33.36	9.14	5.64	5.00	0.49	14.80	9.05	9.32	11.96	4.00	39.69	33.16
	4	15.94	18.79	35.32	16.08	3.96	8.68	5.88	0.41	8.00	12.58	15.41	10.57	1.26	10.64	5.21
	5	14.72	14.92	22.96	19.96		15.70	8.72	0.86	6.28	14.43	5.96	3.29	3.99	4.16	7.89
	Mean	13.16	11.66	25.31	26.26	11.83	10.62	7.25	2.24	10.64	12.02	9.84	6.52	3.93	38.43	21.57
Triangle Island	**1**			23.96		9.36	14.48	17.28	8.31	5.48	8.76	13.30	3.34	0.81	27.99	50.13
	2		13.79	33.16	36.04	22.60	24.61	14.92		11.32	8.26		2.06	4.46	36.13	49.89
	3		3.63	26.56	25.20	12.25	26.72	9.24	10.73	7.76	7.88	11.52	1.11	6.58	49.39	39.07
	4		6.96	18.04	33.29	0.76	15.96	7.52	1.25	16.56	4.08	4.12	1.78	1.76	12.82	9.31
	5		5.42	15.20	29.40	1.40	17.28	9.36	5.66	26.00	5.26	4.79	1.53	3.17		5.44
	Mean		7.45	23.38	30.98	9.27	19.81	11.66	6.85	13.42	6.85	9.41	1.97	3.32	27.83	30.77
Southern Stock	**Mean**	20.02	16.55	31.2	41.07	18.5	18.61	11.66	9.44	10.9	9.38	12.82	5.19	6.23	24.87	27.16
Coast	**Mean**	20.02	19.34	25.57	36.51	15.57	13.66	11.26	7.72	12.04	7.72	9.3	3.09	8.21	27.59	26.85

Table D.7 Continued.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Cape St. James	**1**					6.88	11.42	8.11	5.40	7.22	13.67	6.54	3.14	0.74	57.90	31.01
	2					9.56	7.42	13.20		13.20	17.34	14.27	6.51	6.65	40.63	42.83
	3					13.20		14.57	8.86	5.58	9.32	8.79	1.49	14.32	24.75	21.78
	4					16.23	3.08	6.56	4.74		5.22	6.30	0.49	2.16	3.52	10.63
	5						6.54	8.32	2.37	4.73	1.53	1.22	0.42	1.52	2.68	2.23
	Mean					11.47	7.11	10.15	5.36	7.09	9.42	7.43	2.41	5.08	25.90	21.70
Gowgaia Bay	**1**					7.67	14.08	15.00	12.13	10.76	2.43	2.08	0.94	10.50	71.80	45.08
	2		47.04	41.96	61.25		24.88	8.72	12.22	18.20	5.30	17.63	1.35	9.83	53.77	53.55
	3		15.54	20.25	52.17	35.71	21.20	10.04	3.94	17.08	3.46	8.04	2.20	5.69	19.05	25.37
	4		11.58	11.52	29.56	17.44	19.96	7.52	2.30	13.25		6.36		3.62	7.06	7.88
	5		17.25	18.24	31.64		6.96	6.60	2.78	16.75	1.20	4.52	0.97	3.41	2.39	3.91
	Mean		22.85	22.99	45.36	20.27	17.42	9.58	6.67	15.21	3.17	7.73	1.36	6.41	26.08	27.16
Buck Point	**1**			12.65	44.12	7.20	9.16	9.19	2.08	14.35	6.63	10.04	1.31	12.23	60.63	74.51
	2		26.75	40.42	33.00	20.28	9.20	13.84	11.05	16.12	5.86	13.24	1.74	13.51	63.96	40.34
	3		5.58	27.36	14.40	11.65	11.68	4.44	2.49		4.12	2.96	0.56	7.75	42.98	26.68
	4		11.33	24.30	15.56	15.80	4.29		1.55	6.20	2.50	5.00	0.49	1.74	3.46	10.42
	5		7.67	16.00	12.84	11.80	4.68	11.04	1.91	14.04	1.20	3.96	1.17	2.30	1.75	3.76
	Mean		12.83	24.15	23.98	13.35	7.8	10.47	3.82	12.68	4.06	7.04	1.06	7.51	34.56	31.14
Hippa Island	**1**				3.95	9.52	6.80	7.82		7.33	2.64	4.72	2.06	14.78	5.11	33.93
	2			18.46	30.68	9.68	6.76	18.25		17.50	4.12	9.68	1.65	18.31	54.75	43.20
	3			11.64	30.68	9.52	13.52	26.13		22.52	1.73	5.56	0.16	16.15	58.42	18.25
	4			24.64	24.54	13.40	6.77	15.72		15.80		5.08	1.49	5.81	10.16	17.84
	5			14.48			7.56	18.75		2.63	11.13	2.00	0.83	5.72	4.05	
	Mean			17.3	22.88	10.53	8.28	17.33		13.16	4.27	5.41	1.24	11.75	31.21	28.30
Langara Island-North Frederick	**1**			6.68		7.91	0.84	7.67	12.99	17.16	0.78	9.75	0.44	15.29	26.71	38.59
	2		37.79	14.84	45.61	14.48	12.33	11.84		26.21	23.65	4.42	1.09	53.57	60.70	50.38
	3		30.00	4.64	32.16	7.96	8.64	3.74	4.48	11.88	13.29	3.58	0.17	16.14	50.50	29.69
	4		34.35	14.72	22.72	9.96			3.47	15.56	8.74		0.51	5.24	13.67	3.16
	5		42.92	24.92	27.12		2.60	8.80	6.83	11.80	8.82	1.76	1.12	3.25	1.82	3.33
	Mean		36.26	13.16	31.9	10.08	6.61	7.16	8.15	16.52	11.06	4.79	0.67	18.7	30.68	25.03
Northern Stock	**Mean**		23.98	19.32	30.98	12.79	9.54	10.94	6	12.94	6.39	6.48	1.35	9.51	29.61	26.60
Coast	**Mean**	20.02	19.34	25.57	36.51	15.57	13.66	11.26	7.72	12.04	7.72	9.3	3.09	8.21	27.59	26.85

Table D.8 Annual sablefish catch rates from strata D1 through D5 from 1990 to 2004 for the coast.

Year	Numbers per trap	Weight (kg) per trap	Number of Sets
1990	8.497	20.017	23
1991	7.464	19.336	32
1992	8.884	25.569	38
1993	11.607	36.509	42
1994	5.487	15.571	39
1995	4.260	13.665	44
1996	3.388	11.258	45
1997	2.705	7.721	40
1998	3.638	12.037	43
1999	2.581	7.720	45
2000	3.466	9.296	45
2001	1.272	3.092	44
2002	2.960	8.206	78
2003	10.052	27.590	47
2004	9.296	26.855	44

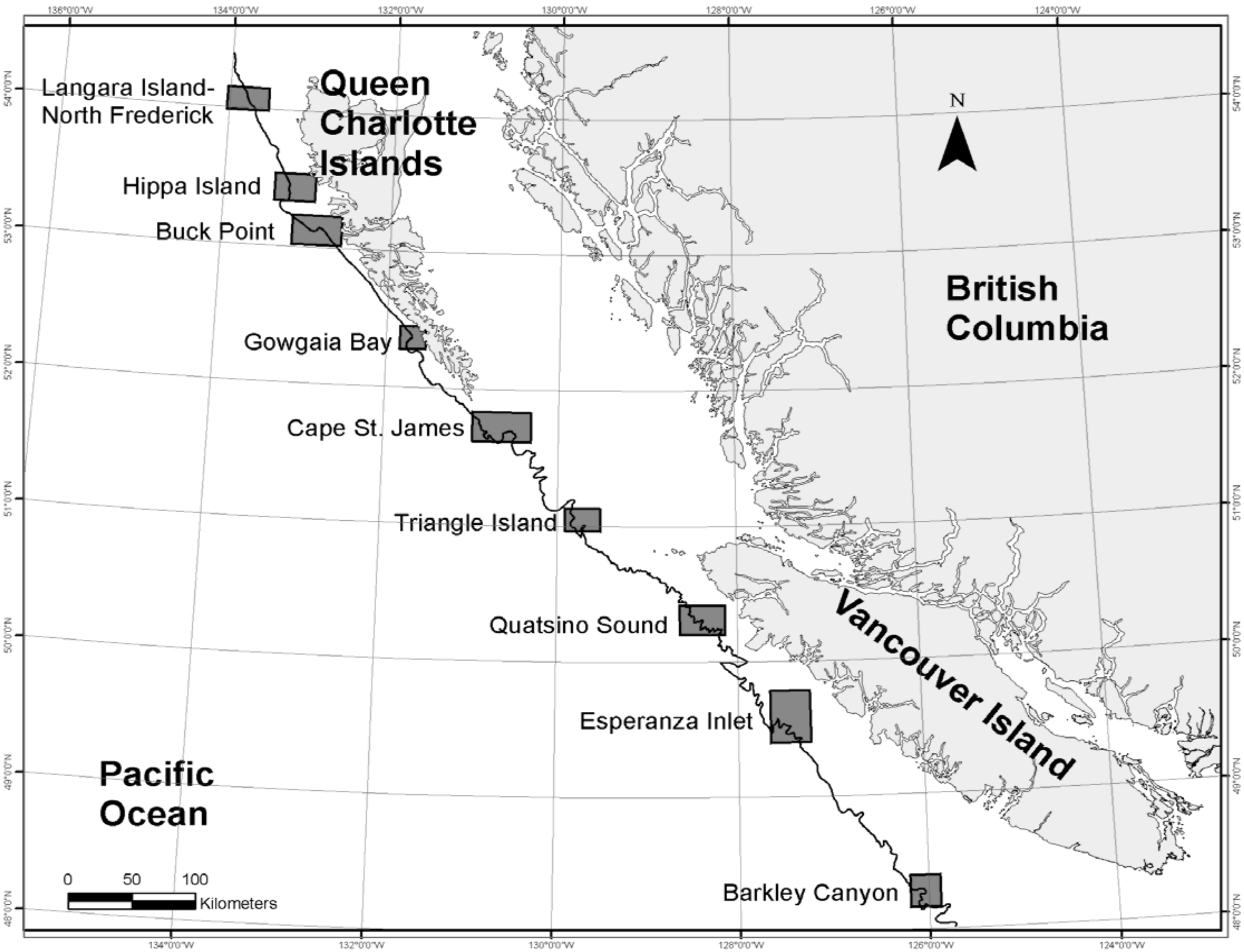

Figure D.1 Standardized survey localities used for indexing trap-vulnerable abundance. The shaded rectangles indicate the locality boundaries. The 1000 m contour is shown.

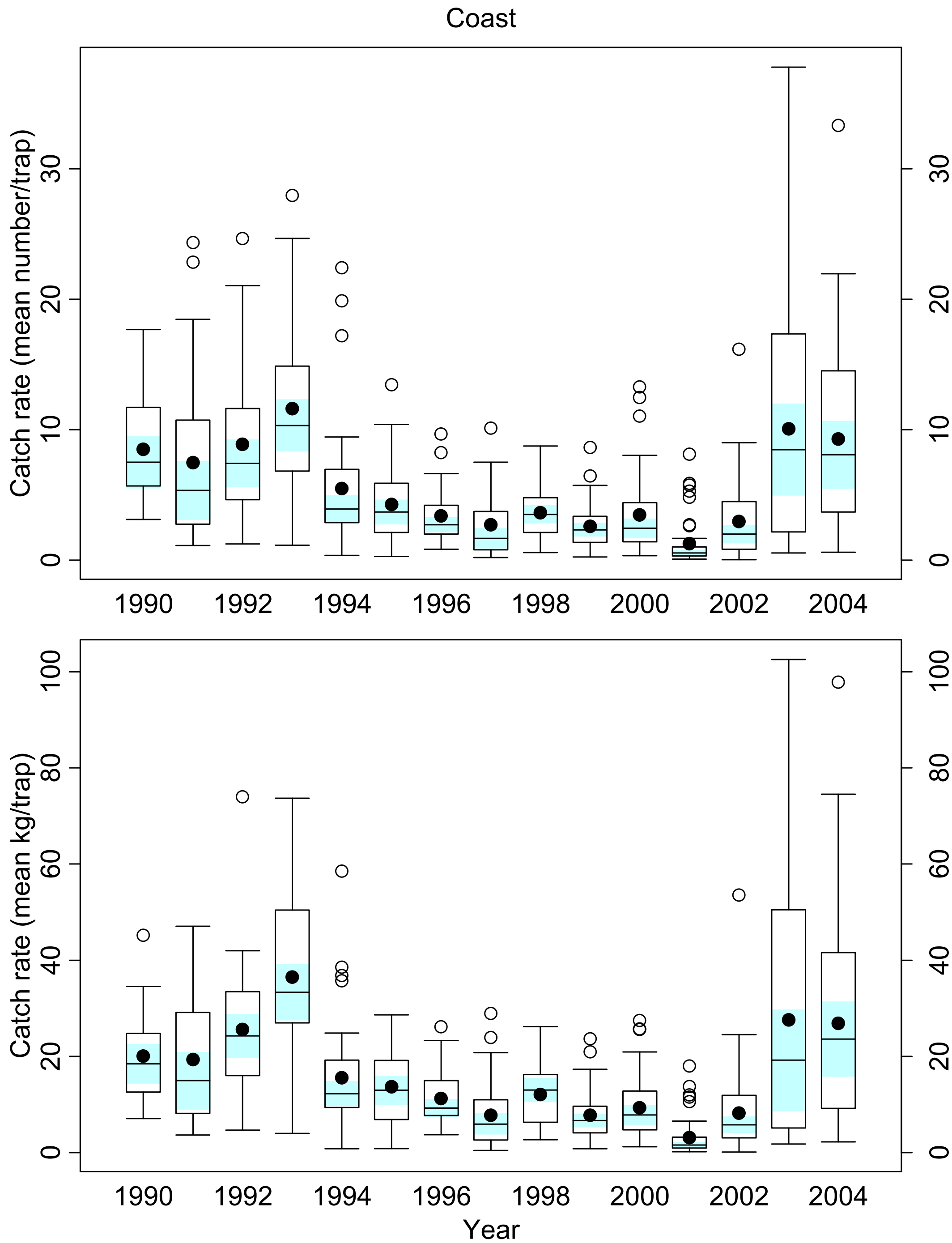

Figure D.2 Distribution of annual catch rates for standardized survey sets conducted coast-wide. Data for depth strata D1 through D5 are shown. The filled circles show the annual mean catch rate. The shaded rectangle for each year indicates an approximate 95 percent confidence interval on the median annual catch rate.

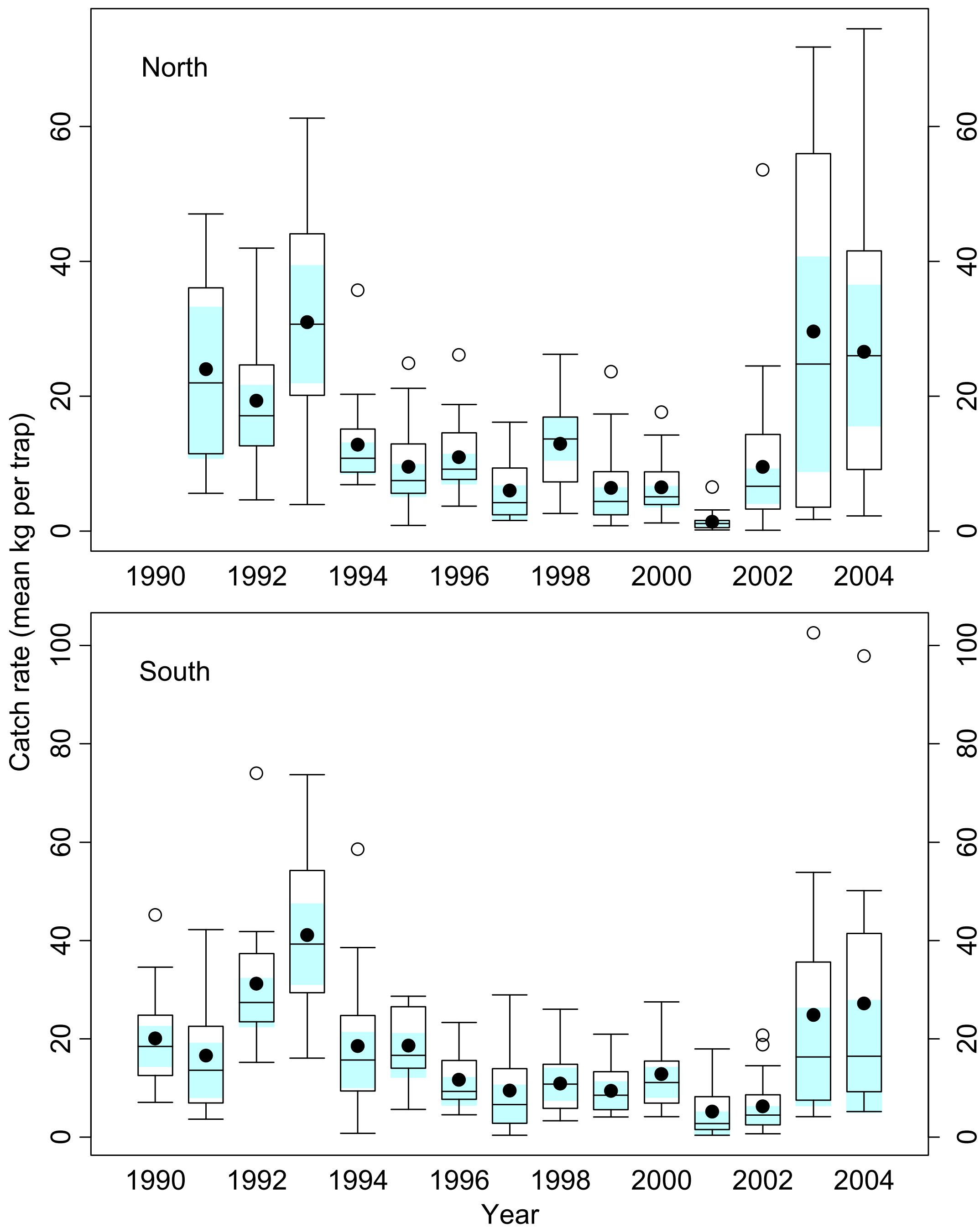

Figure D.3 Distribution of annual catch rates (kg/trap) for standardized survey sets summarized by stock area. Data for depth strata D1 through D5 are shown. The filled circles show the annual mean catch rate. The shaded rectangle for each year indicates an approximate 95 percent confidence interval on the median annual catch rate.

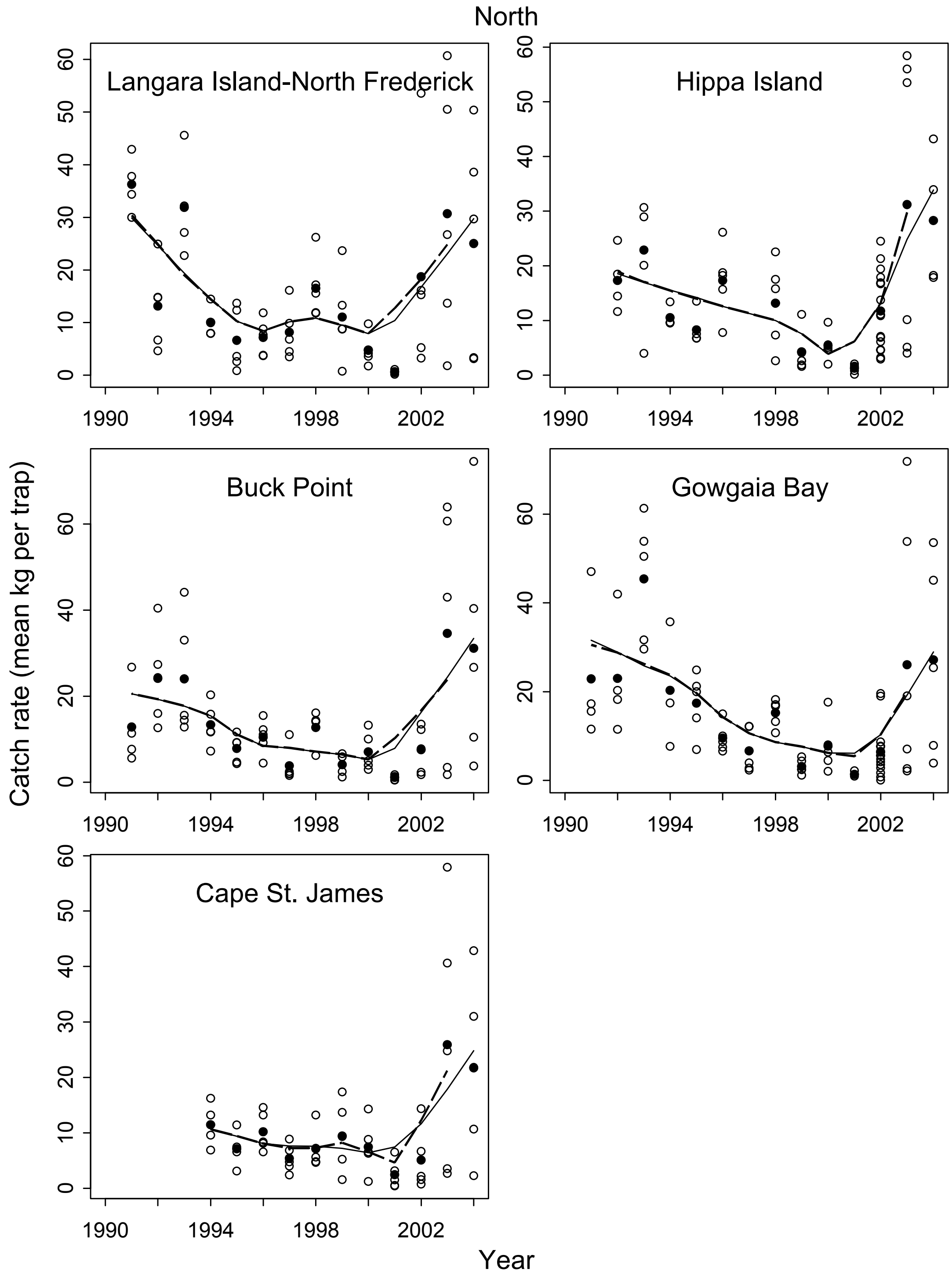

Figure D.4 Catch rates (numbers per trap) for standardized sets by year and locality. Open circles represent the catch rate for each set in depth strata D1 to D5. Filled circles indicate the annual mean of the catch rate observations. The solid curve shows a loess trend line fit to the entire time series, while the dashed line excludes data for 2004.

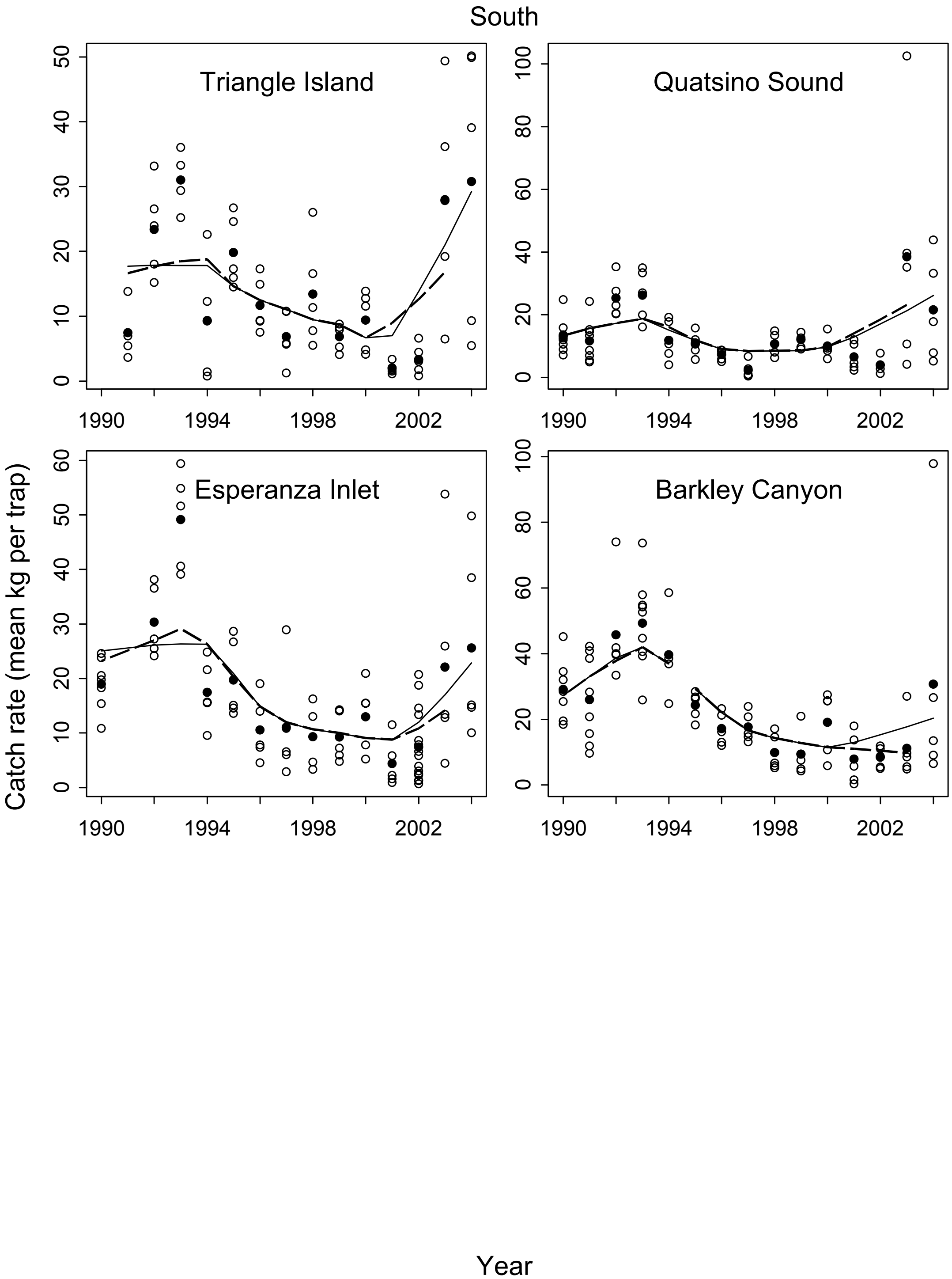

Figure D.4 Continued.

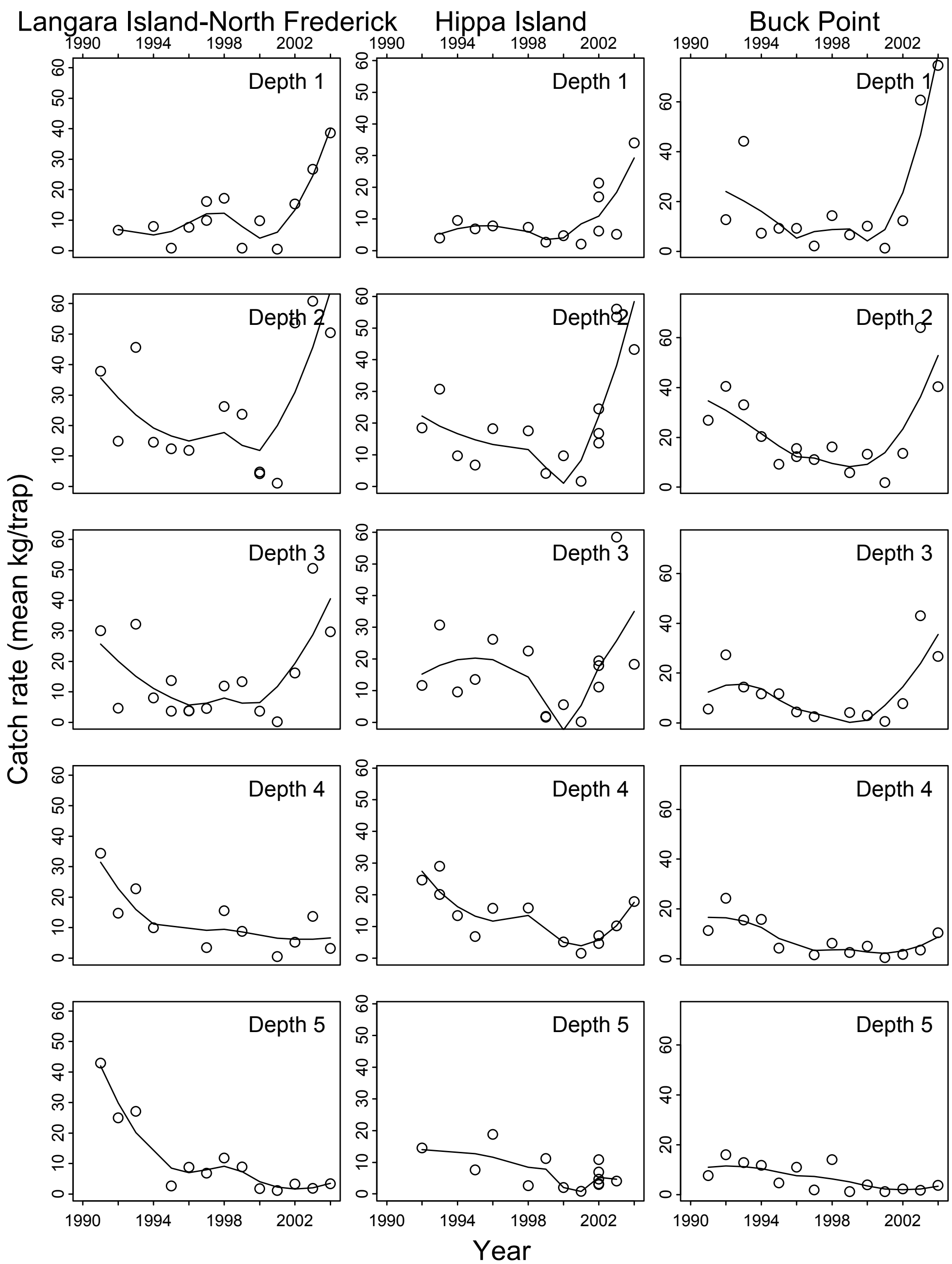

Figure D.5 Survey catch rates (mean kg per trap) by year, depth strata D1 through D5, and locality. The solid curve is a regression smoother through the observed catch rates for each set.

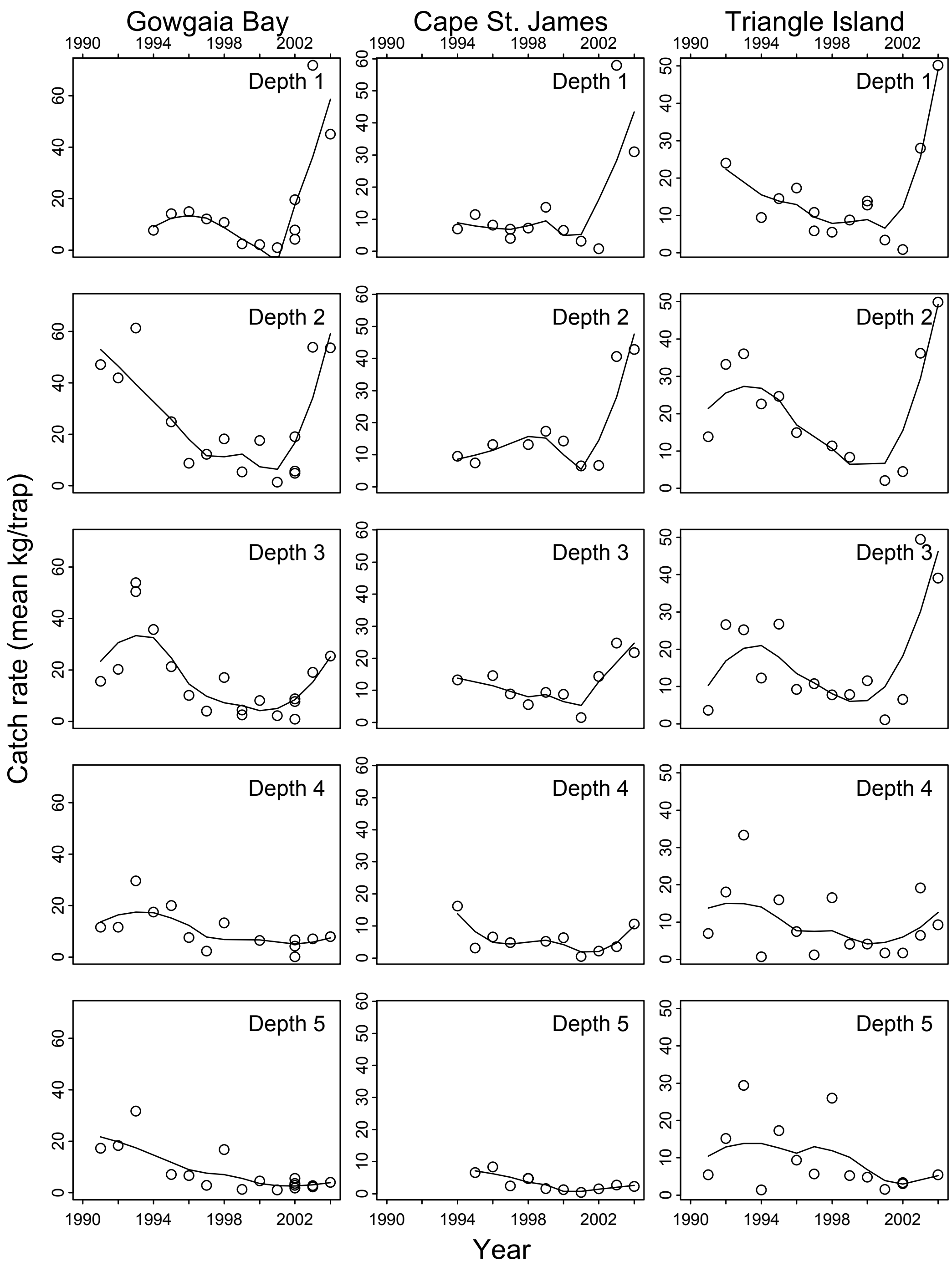
Gowgaia Bay
Cape St. James
Triangle Island
Depth 1
Depth 2
Depth 3
Depth 4
Depth 5
Catch rate (mean kg/trap)
Year

Figure D.5

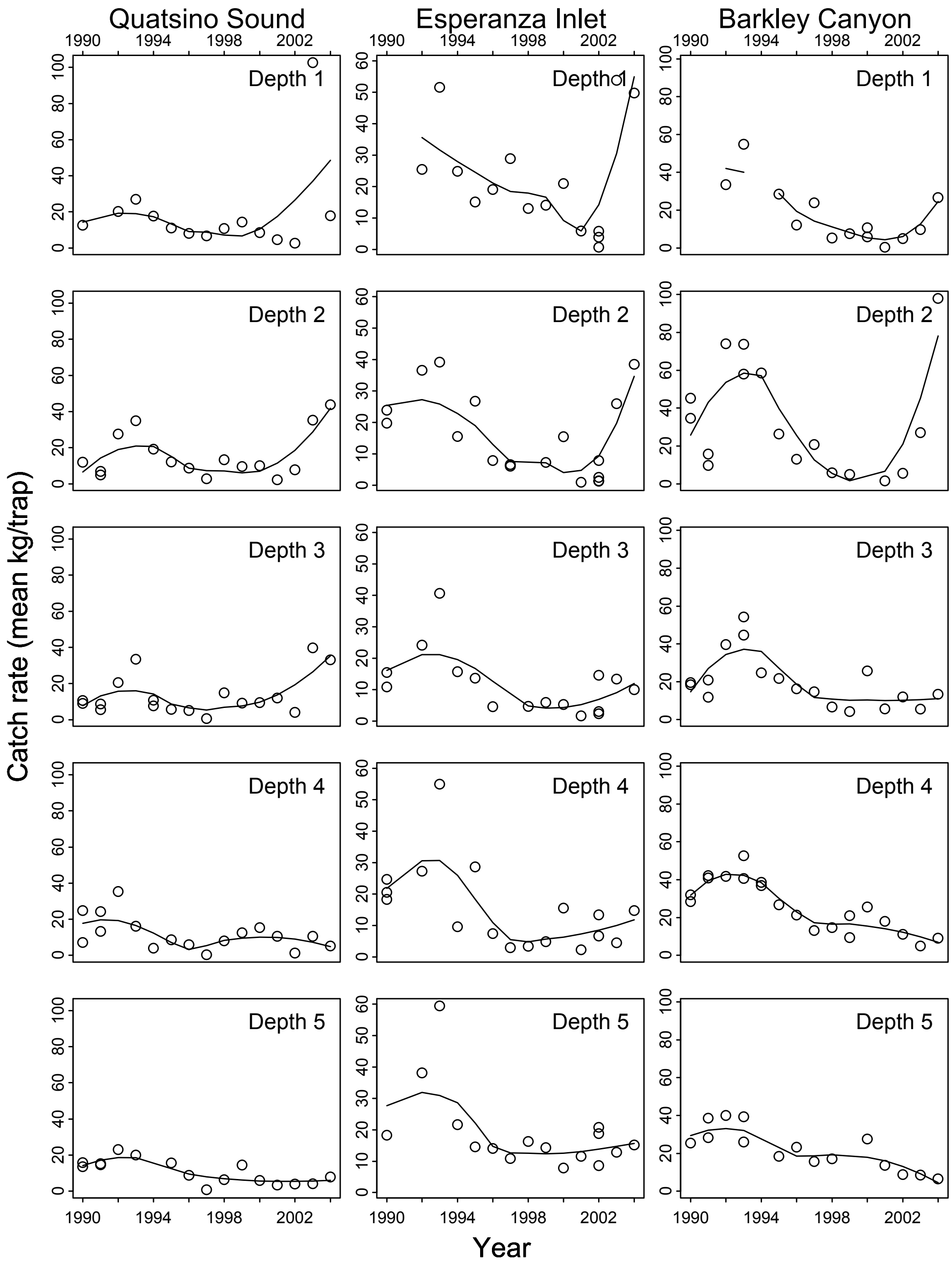
Quatsino Sound
Esperanza Inlet
Barkley Canyon
Depth 1
Depth 2
Depth 3
Depth 4
Depth 5
Catch rate (mean kg/trap)
Year

Figure D.5

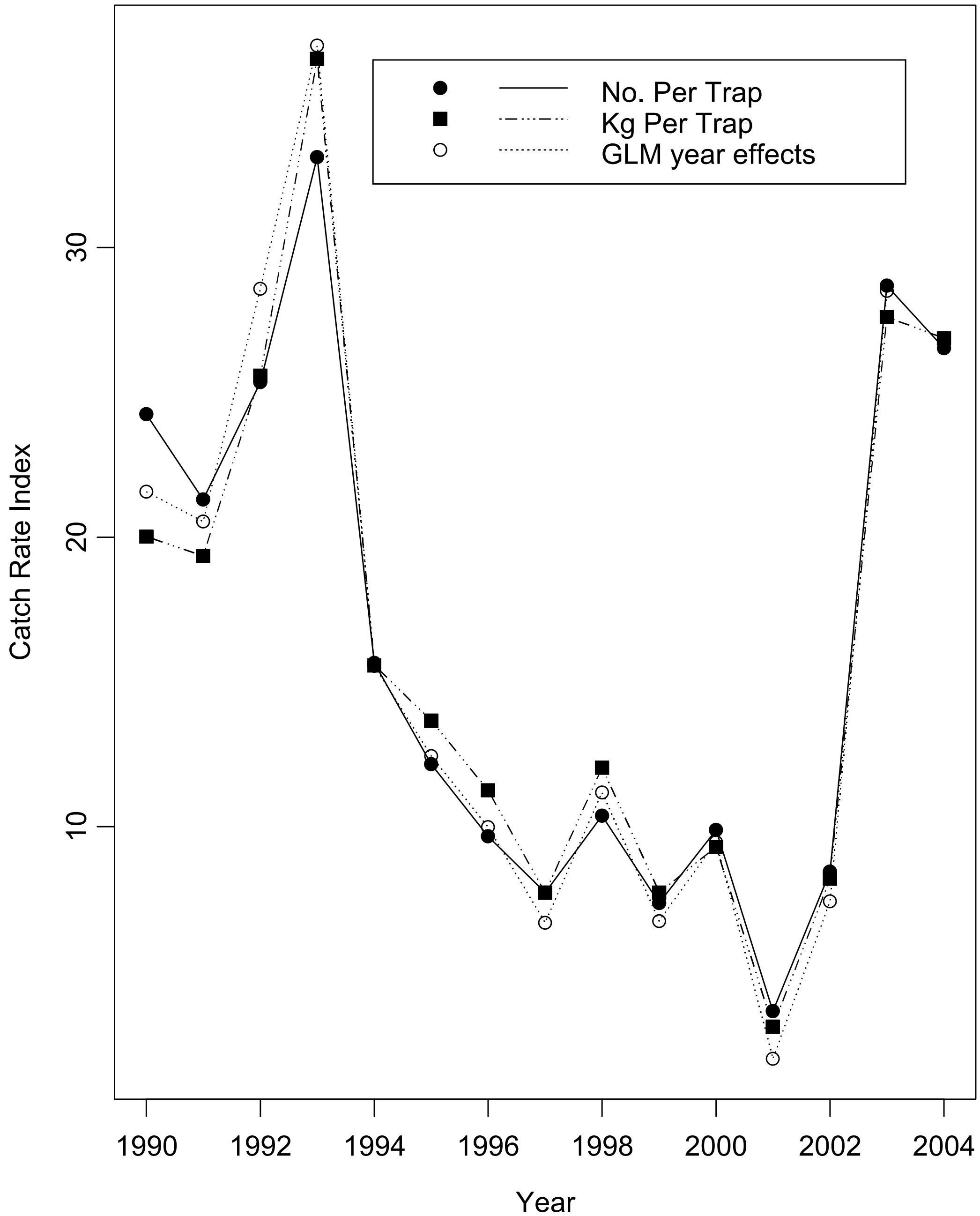

Figure D.6 Three indices of trap-vulnerable abundance based on survey data from depth strata D1 through D5. Each series has been scaled to preserve the coefficient of variation of the original series but centered at the mean of the kg per trap series from 1990 to 2003.

APPENDIX E INTEGRATED TAGGING MODEL

E.1 Introduction

Stock assessments of British Columbia sablefish have relied on tag-recovery information to index stock abundance since the late 1990s and a summary of the various approaches is presented in Appendices D and H of Haist et al. (2004). While absolute abundance can theoretically be estimated from tag release and recovery data, all approaches to abundance estimation require some additional information and/or assumptions. Misspecification of these will lead to biased abundance estimates. Haist et al. (2004) provided details on assumptions employed in the sablefish analyses that could result in biased abundance estimation. These included assumptions related to tag reporting rates, monthly patterns in tag-recoveries, and the treatment of recruitment and emigration.

For recent sablefish stock assessments, abundance estimates from tagging analyses have been integrated with other sablefish abundance indices through biomass dynamics, or production, models. The biomass dynamics models allowed synthesis of the abundance time trend information from fishery and survey CPUE indices with the absolute abundance estimates from the tagging analysis. These models provided a pragmatic tool for projecting relative abundance and evaluating consequences of alternative annual total annual catch (TAC) levels (Kronlund et al. 2003, Haist et al. 2004).

For the current sablefish assessment, a reviewer suggested that the non-tagging based sablefish abundance indices could be integrated with the tagging model analysis, thereby eliminating the need for the biomass dynamics model to synthesize the various data series. This approach is simpler, and therefore more parsimonious, than fitting the tag-recovery data separately and then integrating the various data series via a biomass dynamics model. In addition, some preliminary tests suggested that the integrated approach resulted in plausible patterns in the estimated tag reporting rate parameters. Hence, the integrated tagging model approach was adopted, and the monthly tagging model used for last year's sablefish assessment was extended to incorporate fits to the additional abundance index data series.

As with recent sablefish tagging models, the new integrated tagging model is not intended to capture all the complexities of sablefish population dynamics. Model estimates of annual recruitment reflect all additions to the trap-vulnerable population including new year-classes entering the trap-vulnerable population for the first time, fish immigrating to the region and becoming vulnerable to the trap fishery, and fish becoming vulnerable to trap gear through behavioral or other mechanisms. As with previous analyses, the model is formulated as a Bayesian analysis, which allows the uncertainty in quantities like rates of emigration from the trap-vulnerable population and rates of tag reporting to be reflected in the posterior distributions of the abundance estimates.

As described in Haist et al. (2004), estimation of tag reporting rate for the sablefish trap fishery is problematic and involves *ad hoc* assumptions. Previous attempts to estimate tag reporting rates independently of the tagging model were based on a group of reference vessels. This practice was discontinued because analyses of recoveries for particular tag release groups showed that vessel fishing patterns may be more important in determining tags per tonne than the diligence of a vessel crew in reporting tags. Haist et al. (2001) found that fishing near tag release sites significantly raises the probability of recovering tags. Seasonal effects may also influence the tags per tonne landed independently of the diligence of the vessel crew in reporting tags. These observations suggested that assumptions of previous reporting rate analyses are not as acceptable as when first proposed. As an alternative, the new tagging model integrates reporting rates as stochastic variables in a Bayesian framework to allow the data to indicate whether there is information on reporting rates.

Extension of the monthly tagging model to incorporate the non-tagging based fishery and survey indices eliminates the need for the biomass dynamics model. Instead, the integrated tagging model is used directly for stock projections. Stock projection results are presented in decision tables similar to those produced for previous sablefish stock assessments (Kronlund et al. 2003, Haist et al. 2004) and are used to evaluate a variety of performance measures.

E.2 Integrating tagging model

Model description

The integrated tagging model is a logical extension of the monthly tagging model presented for the previous sablefish stock assessment, so only a cursory description is provided here. A detailed description of the motivation for the model structure, and potential issues with respect to model assumptions is given in Appendix H of Haist et al. (2004). Table E.1 presents notation for the integrated tagging model for B.C. sablefish. Changes to the trap-vulnerable population, described in Table E.2, are determined by both annual and monthly population dynamics equations. The annual equations are new, and are used for years prior to tag release and recovery data becoming available. These equations are also used to project the trap-vulnerable biomass forward in time. The equations that deal with abundance changes on a monthly basis are used for those years where tag recovery data are fitted in the model. In addition to beginning-year abundance estimates from the annual equations, the model estimates mid-year abundance, assuming half of the catch is taken at the mid-year point. The mid-year estimates are used in fitting to the catch rate-based abundance indices. For the period where tag-recovery data are fitted in the model, the monthly population dynamics are used. The primary difference with these equations is that catch is removed on a monthly basis so that the month-specific exploitation rates can be used to predict monthly tag recoveries. The tag dynamics equations have the same form as the monthly population dynamics equations with two exceptions. First, there is an additional mortality term to account for tagging-induced mortality. Second, there are no additions to the tag cohorts from recruitment. The integrated tagging model has the following structural characteristics:

1. Tag recoveries are utilized regardless of the number of years at large, rather than limiting data to tags recovered in the year following release;
2. Tags recovered in December through March are not included in the model fit to accommodate the significant decrease in tags per tonne landed that typically occurs during this period;
3. New untagged fish enter the B.C. trap-vulnerable population through recruitment or immigration in the first month of each year;
4. Fish, both tagged and untagged, leave the B.C. trap-vulnerable population each month, and this emigration rate is treated as a stochastic variable;
5. Tag reporting rates are treated as stochastic variables rather than fixed inputs;
6. Adjustments are made for initial tag loss due to tag shedding and tag induced mortality in the period between tag application and the first subsequent recovery period;
7. Adjustments are made for on-board fish sorting, whereby smaller fish are released if they have no tag.

The fundamental model parameters, i.e., those directly estimated through the fitting algorithm, are: the number of fish alive at the beginning of the analysis, $\exp(\alpha)$, parameters that are proportional to the numbers of fish entering the population each year, $\exp(\gamma_y)$, the monthly fraction of fish retained in B.C., ν, the annual tag reporting rate parameters ω_y, and proportionality constants that relate the value of abundance index *i* to model population estimates, q_i.

A Bayesian approach is used to estimate model parameters (Gelman et al. 1995). This approach allows the distribution of the reporting rates to be estimated while recognizing the considerable uncertainty associated with these estimates. The following prior distributions were specified for the model parameters, where *U* denotes the Uniform statistical distributions:

$$\alpha \sim U[0,\infty] \ ,$$
$$\gamma_y \sim U[-\infty,\infty] \ ,$$
$$\omega_y \sim U[0.3, 0.95] \ ,$$
$$\nu \sim U[0.95, 0.993] \ ,$$
$$q_i \sim U[0,\infty]$$

In Bayesian analysis the objective function is defined as a negative log-posterior

$$Objective(\Theta) = -\sum_i \log\left(L(\Theta \mid D)\right) - \log\left(\pi(\Theta)\right) \quad ,$$

where Θ is the vector of free parameters, L, is the likelihood function, D is the set of observations, and π is the joint prior density of parameters, Θ. An over-dispersed Poisson distribution is assumed for the tag recovery data. For a standard Poisson distribution the variance of a random variable is equal to its expectation. Like many fisheries tagging data sets, the residuals from model fits to the sablefish tag-recovery data are much larger than expected from sampling theory since the model does not account for the entire process underlying the data. Therefore, a scalar variable, d, is included in the objective function to account for the higher variance of the observations. This is effectively the same as reducing the actual sample sizes (number of tags released and resultant recoveries). Ignoring constants, the negative log-likelihood for the data observations is

$$-\log\left(L(\Theta \mid D)\right) = d \sum_{g=G_1}^{G_2} \sum_{y=g+1}^{Y_2} \sum_{m=4}^{11} \left\{ P_{ym}^g - O_{ym}^g \log\left(dP_{ym}^g\right) \right\} \quad .$$

Note that the December to March data are not included in the summation over m. The value of d used in the final analysis was determined through an iterative process. The distributions of Pearson residuals (described below) were examined for alternative values of d. The value that resulted in a distribution of Pearson residuals that was approximately standard normal was selected. Closeness to standard normal was judged relative to two measures: (1) a value of 1 for the variance of the residuals, and (2) a measure more robust to outliers, the median of the absolute residuals (expected value of 0.68). On this basis, a value of 0.12 was selected for d. Pearson residuals were calculated as

$$r_{ym}^g = \frac{dO_{ym}^g - dP_{ym}^g}{\sqrt{dP_{ym}^g}} = \frac{O_{ym}^g - P_{ym}^g}{\sqrt{P_{ym}^g / d}} \quad .$$

As the time at liberty increases, the tag recoveries become sparse in the combinations of recovery year and month for a given release year. The negative log likelihood function was modified to allow collection of tag recoveries into an accumulator class after t years-at-liberty for each release year:

$$-\log\left(L(\Theta \mid D)\right) = d \sum_{g=G_1}^{G_2} \left\{ \sum_{y=g+1}^{T} \sum_{m=4}^{11} \left\{ P_{ym}^g - O_{ym}^g \log\left(dP_{ym}^g\right) \right\} + \left\{ P_{\cdot\cdot}^g - O_{\cdot\cdot}^g \log\left(dP_{\cdot\cdot}^g\right) \right\} \right\} \quad ,$$

where $T = \min\left(g+t, Y_2\right)$, t is the number of years of tag recoveries fit before the accumulator category, and the dot notation indicates summation over indices $y = T+1, \ldots, Y_2$ and $m = 4, \ldots, 11$, respectively. Experimentation with various values suggested t=6 was a parsimonious choice.

For fitting to the abundance index data we assume that the logarithms of the abundance index data are normally distributed. Analytical estimates of the standard errors of the survey and trap fishery standardized CPUE indices reflect only sampling error, whereas lack-of-fit in the integrated tagging model is a result of both sampling and process error. For this reason we select *ad hoc* values of 0.3 for the standard deviations of these data. The nominal CPUE index series is included only to extend the analysis to an earlier starting year. The standardized fishery CPUE estimates should be superior to the nominal estimates because they theoretically account for changes in fishing patterns. We do not want the nominal CPUE index to influence the model fits for years where both measures are available. However, we do need to have overlap in the two series so that the relative value between their *q*'s can be estimated. Thus, we assume a standard deviation of 0.6 for the nominal CPUE abundance index data. Ignoring constants, the negative log-likelihood for the abundance index data series is

$$-\log\left[L(\Theta \mid D)\right] = \sum_{i=1}^{3} \sum_{y=J_i}^{y=K_i} \log\left(\sigma^i\right) + 0.5\left(\frac{\log\left(q_i \tilde{I}_y^i / \hat{I}_y^i\right)}{\sigma^i}\right)^2 ,$$

where J_i and K_i are the first and last years of abundance index *i* data, $\tilde{I}_y^i$ and $\hat{I}_y^i$ are the observed and predicted values for abundance index *i* in year *y*, and q_i and σ^i are the proportionality constant and the assumed standard deviation for the log of index data *i*. The equations for estimating the $\hat{I}_y^i$ are given in Table E.2.

The negative log posterior for a uniform prior distribution is a constant, so it can be ignored in the model fitting and MCMC algorithm. Likewise for parameters with a uniform distribution that is bounded within a specified range, the probability is constant across the specified range and zero probability outside that range. Therefore, the log posterior contribution to the total objective function can be ignored.

Estimates of trap-vulnerable biomass were calculated as the product of the number of fish (Table E.2) and the average weight of a trap-vulnerable sablefish (Table E.3). The background and derivation of fixed parameters input to the model are listed in Table E.4.

Note that the computer code for the integrated tagging model was designed so that it can be run without fitting additional abundance index data. In that configuration the model is essentially identical to the monthly tagging model described by Haist et al. (2004). The only departure from the monthly tagging model of Haist et al. (2004) is that the recruitment parameters, α and the γ_y, were re-parameterized to improve the MCMC performance as described in Table E.2

Data selection

Tag recovery data used in the model analysis were obtained from adult offshore releases and recoveries as described in Appendix C. Tag recoveries were included without regard to the years-at-liberty. Tag recoveries in the period between tag application in year *g* and the start of year recovery year *y*=*g*+1 were not included. The abundance index data series included in the model fits are: nominal trap-fishery CPUE (Appendix B); standardized trap-fishery CPUE (Appendix B); and survey CPUE (Appendix D).

Integrated tagging model results

The new integrated tagging model was implemented using the AD-Model Builder software package which provides for Markov Chain Monte Carlo (MCMC) estimation of the Bayesian posterior density (Otter Research 1999). This software package uses a MCMC method based on the Metropolis-Hastings algorithm (Gelman et al. 1995) to obtain samples from the full posterior distribution. An MCMC chain of 200 million samples was run to describe the joint posterior distribution of model parameters. This chain was thinned to a sub-sample of 2000 points for running projections and presenting marginal posterior distribution results.

Figure E.1 shows the traces for selected model parameters, including the emigration parameter, reporting rates, and annual estimates of vulnerable biomass. Superimposed on the traces are the running medians and the running 5^{th} and 95^{th} quantiles over 50 samples from the thinned chains. These diagnostics indicate reasonable convergence to the joint posterior distribution, although some of the vulnerable biomass traces indicate pathological behavior, e.g., trap-vulnerable biomass in 1988, 1990 and 1991. Fortunately, traces for the more critical recent trap-vulnerable biomass estimates suggest reasonable convergence of the marginal posterior distributions.

The marginal posterior distributions of the Pearson residuals for the tag recovery data fits and for the abundance index fits, e.g., [observed-fitted]/[standard deviation], are shown in Figure E.2 and Figure E.3. For the tag recovery residuals the mean residuals are calculated for every recovery year resulting from each release year. Specifically, the means are calculated across the eight months from April through November that are individually fitted for each combination of release and recovery year. This is a graphical device intended to decrease the number of points that are plotted so that overall trends are easier to see. A fairly strong pattern emerges as shown in Figure E.2. Residuals for the tag recovery fits in the first year after release are generally positive while the residuals for the tag recovery fits in the second and third years after release are generally negative. This suggests some form of model misspecification, although what mechanisms could be responsible is not clear.

The modal residuals for the fits to the relative abundance data series, shown in Figure E.3, appear to be reasonably consistent with the assumed values for the residual variances so that approximately 80 percent of the residual values lie between -1.3 and 1.3. The major outliers in the fits are the survey CPUE residuals for 2003 and 2004. It is possible that the survey, where the trap escape rings are closed, is catching significant numbers of smaller sablefish that are not retained in the commercial traps.

Distributions of the vulnerable biomass estimates, recruitment estimates, and tag reporting rate estimates are shown as quantile plots in Figure E.4. The integrated analysis suggests relatively stable abundance during the period 1980 to 1987, although the uncertainty in the estimates is high. Over the span of the analysis, peak coast-wide abundance occurred between 1988 and 1993. Thereafter abundance declined sharply over the next two years with a more gradual decline between 1995 and 2001. The estimated abundance increased significantly in 2003, followed by a slight decline to 2004.

The analysis suggests two fairly distinct periods of stock production (Figure E.4). The first period continued through 1993 where the model estimated fairly consistent high recruitments to the trap-vulnerable biomass. Then, from 1994 onward, the recruitment estimates are much lower with the exception of the 2003 estimates. It is unknown whether the higher 2003 recruitment estimates signal resumption of production levels similar to the pre-1994 period; more years of similarly high values will be required to substantiate entry to a period of relatively high production.

For the integrated model analysis the trends in the tag reporting rates appear to be fairly plausible. That is, with the exception of the values estimated for 1992 and 2001, there is an increasing trend in the parameter values, consistent with fishermen's comments that tag reporting increased through the 1990s. The values estimated for the 2004 tag reporting rate tend to be very close to the upper bound for that parameter (0.95), and suggest a high level of confidence in the estimated values. This result is likely a consequence of the inconsistency between tag-recovery data and the survey index for 2004.

Fits of tagging model tagging data only

The tagging model was fit to tagging data without the survey and fishery indices so that that source of information could be viewed as another independent observation of the time trend in trap-vulnerable biomass. For these model runs, stock reconstructions were done only for the 1992 through 2004 period. For all aspects of the model, with the exception of the negative log-likelihood term for the relative abundance data series, the model specification was the same as for the integrated analysis. An MCMC chain of 100 million simulations was conducted, from which a sub-sample of 2000 points was systematically taken to allow summarization of marginal posterior distributions.

Distributions of the vulnerable biomass estimates, recruitment estimates, and tag reporting rate estimates are shown as quantile plots in Figure E.5. Although results from the tagging-data only analysis show similarities to those from the integrated model analysis, there are some substantial differences. In particular, there is greater uncertainty in the tag reporting rate parameters and also a different pattern in their trends. The analysis suggests tag-reporting rates from 2001 through 2003 were somewhat lower than those in other years. This result is at odds with the opinions expressed by fishermen who maintain tag reporting rates have been consistently high in recent years. Given this view, and because the model is a simple interpretation of sablefish in B.C., it is likely that the tag reporting rate parameters are aliasing for other aspects of the stocks dynamics that are not accounted for in the model.

Estimates of trap-vulnerable stock biomass from the tagging-data only model fit are compared with those from the integrated model fit in Figure E.6. In the absence of the survey and fishery-based indices, the tagging model abundance estimates for the initial years (1992-1994) are substantially higher, and those for the terminal years (2003, 2004) substantially lower, than those obtained from the integrated model analysis.

E.3 Model projections, performance indicators, and decision tables

The integrated tagging model was used to project vulnerable stock biomass trends into the future. Short-term (five year) projections were conducted for a range of potential future catch levels. Each of these simulated projections held the catch fixed over the projection period. Additionally, long-term (50 years) projections were conducted for a "no catch" scenario. These runs provide estimates of the distribution of unfished vulnerable biomass used in some performance measures. Similar simulations were conducted by Haist et al. (2004) using the biomass dynamics model, and the 5th quantile of the distribution of unfished stock biomass, $B^{0.05}$, was used in the context of a "conservation" performance measure (Haist et al. 2004). Note that the value corresponding to $B^{0.05}$ is model-dependent.

The long-term simulations were conducted under different scenarios: (1) sampling from the 1980-1993 "good" recruitment period, (2) sampling from the 1994-2004 "poor" recruitment period, and (3) sampling from the "average", or entire recruitment period. These simulations were conducted with no catch. The following table shows selected quantiles of the distribution of beginning-of-year stock biomass (B_y) that were obtained from these simulations.

	quantiles of B_y (thousand t.)		
Recruitment-to-fishery period	5th	median	95th
Average (1980-2004)	11.3	45.6	125.9
Good (1980-1993)	15.5	66.8	164.1
Poor (1994-2004)	8.2	26.7	53.1

These simulations suggest that, given the continuation of the longer-term historic levels of recruitment to the fishery, the stock biomass will fall below 11,300 t about 5 percent of the time when no fishing occurs. Given that biomass levels at and below 11,300 t are expected with some frequency (i.e., 1 year in every 20) without fisheries, this level should not lead to conservation concerns. We use the probability that stock biomass is below the 5% unfished level $\left(B^{0.05}\right)$ at the end of the projection period as one of our performance measures. Additionally we evaluate the ratio of biomass at the end of the projection period relative to the $B^{0.05}$ level.

For the 2002 sablefish stock assessment (Kronlund et al. 2003), the probability that the stock would increase from the 2002 level was used as one of the performance measures. The rationale was that the stock was at a low level, and an increase in biomass was desirable for the fishery. We continue to use performance measures that evaluate stock biomass relative to the 2002 level. The rationale is that the stock rebuilt from the 2002 level, so there should be no reason for conservation concerns if the stock remains above this point. As for the performance measures related to $B^{0.05}$, we calculate both the probability of being above the B_{2002} level and the ratio of terminal biomass relative to the B_{2002} level.

In addition to the performance measures presented by Haist et al. (2004), we introduce some new measures. The first of these measures are based on end-of-year trap-vulnerable biomass $\left(B''_y\right)$ estimates rather than the beginning-of-year trap-vulnerable biomass estimates $\left(B_y\right)$ that were developed for sablefish assessments by Kronlund et al. (2003) and Haist et al. (2004). The use of end-of-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 second set of new performance measures evaluate vulnerable stock biomass after the completion of two years of fishing at a constant TAC level, rather than after the full five years fishing at the constant level. The five-year projections are presented so that there are more discernable differences between the alternate TAC levels that are evaluated. The shorter-term results are presented because sablefish stock assessments have been conducted annually, allowing modification of TACs as suggested by updates of the data. Performance measures are summarized below:

1. the *probability* that beginning-year vulnerable stock biomass is above B_{2002} at the end of the projection period, $P\left(B_{2010} > B_{2002}\right)$;
2. the *magnitude* of the expected change in beginning-year vulnerable stock biomass over the projection period, $E\left(B_{2010} / B_{2002}\right)$;
3. the *probability* that beginning-year vulnerable stock biomass is above the $B^{0.05}$ level (11,300 t) at the end of the projection period, $P\left(B_{2010} > B^{0.05}\right)$;
4. the *magnitude* of the expected change in beginning-year vulnerable stock biomass over the projection period, relative to $B^{0.05}$ level, $E\left(B_{2010} / B^{0.05}\right)$;
5. the *probability* that end-year vulnerable stock biomass is above B''_{2001} at the end of the projection period, $P\left(B''_{2009} > B''_{2001}\right)$;
6. the *magnitude* of the expected change in end-year vulnerable stock biomass over the projection period, $E\left(B''_{2009} / B''_{2001}\right)$;
7. the *probability* that end-year vulnerable stock biomass is above B''_{2001} after two years, $P\left(B''_{2006} > B''_{2001}\right)$;
8. the *probability* that beginning-year vulnerable stock biomass is above B_{2002} after two years, $P\left(B_{2007} > B_{2002}\right)$.

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 when re-sampling from the shorter-term and more recent 1994 to 2004 time series. 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. When the specified projection catch is greater than 95% of the projections trap vulnerable biomass the projection catch is set equal to 95% of the biomass. Note that the decision procedure used here is not intended to set harvest levels over the duration of the five year projection period.

Performance measures are presented in decision tables that allow stock status at different future catch levels to be compared. 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 0^{th}-33^{rd}, 34^{th}-66^{th}, and 67^{th}-100^{th} 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.

Performance statistics calculated for the simulations based on the longer-term historic recruitments are presented in Table E.5 and Table E.6 while those calculated for the simulations based on the shorter-term historic recruitments are presented in Table E.7 and Table E.8.

E.4 Interpretation of decision tables

The five year stock projections are conducted with no catch and with catch levels ranging from 3500 to 10000 t for the two recruitment scenarios that incorporate the long-term 1980 to 2004 period and the short-term recent 1994 to 2004 period, respectively. The following table summarizes some of the performance measures presented in Table E.5 through Table E.8. Note that only the expectations across all current states, ie., B_{2004}, are presented in this table.

	$P(B_{2010} > B_{2002})$		$P(B''_{2009} > B''_{2001})$		$P(B''_{2006} > B''_{2001})$	
Total Annual Catch 2005-2009	Rec. 1980-2004	Rec. 1994-2004	Rec. 1980-2004	Rec. 1994-2004	Rec. 1980-2004	Rec. 1994-2004
0	0.81	0.68	0.74	0.59	0.57	0.51
3500	0.73	0.52	0.63	0.37	0.50	0.38
4500	0.71	0.48	0.60	0.32	0.48	0.35
5500	0.69	0.44	0.57	0.26	0.46	0.33
7500	0.65	0.37	0.51	0.18	0.44	0.27
10000	0.61	0.30	0.44	0.11	0.40	0.21

Several general observations that can be made about these results:

1. the probabilities 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 3500-10000 t. range evaluated;
2. the end-year statistics are consistently lower than the beginning-year statistics and the differences increase with higher TAC levels;
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.

E.5 Summary

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.

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 uncertainly 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 corresponds to trends observed for the Gulf of Alaska stock (Sigler et al. 2003). 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.

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 of recruitments to the trap-vulnerable biomass. The catch levels investigated in the stock projections 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 five-year projection period.

E.6 Literature Cited

Beamish, R.J. and G.A. McFarlane. 1988. Resident and dispersal behavior of adult sablefish (*Anoplopoma fimbria*) in the slope waters off Canada's west coast. Can. J. Fish. Aquat. Sci. **45**: 152-164.

Gelman, A.B.; Carlin, J.S.; Stern, H.S.; Rubin, D.B. (1995): Bayesian data analysis. Chapman & Hall, London. 526 p.

Haist, V., Hilborn, R., and M.W. Saunders. 1999. Sablefish stock assessment for 1999 and recommended yield options for 2000 and 2001. Can. Stock Assess. Sec. Res. Doc. 99/195.

Haist, V. and R. Hilborn. 2000. Sablefish stock assessment for 2000 and recommended yield options for 2001. Can. Stock. Assess. Sec. Res. Doc. 2000/157. 78p.

Haist, V., Hilborn, R., and M. Wyeth. 2001. Sablefish stock assessment for 2001 and advice to managers for 2002. Can. Sci. Advisory Res. Doc. 2001/135. 54p.

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

Lenarz, W.H. and F.R. Shaw. 1997. Estimates of tag loss from double-tagged sablefish *Anoplopoma fimbria*. Fish. Bull. **95**: 293-299.

Otter Research Ltd. 1999. AD Model Builder documentation on line. http://otter-rsch.com/admodel.htm.

Saunders, M.W. and N. Surry. 1998. Preliminary results of blackcod escape ring study, F/V Ocean Pearl, November-December 1997. Report prepared for the Pacific Coast Blackcod Fisherman's Association.

Schirripa, M.J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

Sigler, M.F., Lunsford, C.R., J.T. Fujioka and S.A. Lowe. 2003. Alaska sablefish assessment for 2003. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2004. November 2003, Plan Team Draft (http://www.afsc.noaa.gov/refm/stocks/assessments.htm).

Table E.1 Notation for the integrating tagging model.

Symbol	Description
	Indices and Index Ranges
g	Tag release year index, $g = G_1,\ldots,G_2$, where $G_1 = 1991, G_2 = 2003$.
y	Year index $y = Y_0,\ldots Y_1,\ldots Y_2$, where $Y_0 = 1979, Y_1 = 1992, Y_2 = 2004$.
m	Month index $\left(m = M_1,\ldots,M_2\right)$.
k	Area index $\left(k = 1,\ldots,K\right)$
i	Index for relative abundance series $\left(i = 1,\ldots,I\right)$
	Data
D_{kym}	Total landed biomass in month *m* of year *y* for area *k*.
D^*_{kym}	Trap landed biomass in month *m* of year *y* for area *k*.
$\overline{w}^L_{ky}$	Mean weight of landed fish in year *y* for area *k*.
$\overline{w}^V_y$	Mean weight of trap vulnerable fish in year *y*.
$\dddot{C}_{ym}$	Total landings in numbers in month *m* of year *y* $\left(y = Y_1,\ldots Y_2\right)$: $\dddot{C}_{ym} = \sum_{k=1}^{K} \frac{D_{kym}}{\overline{w}^L_{ky}}$
$\dddot{C}^*_{ym}$	Total trap-fishery landings in numbers in month *m* of year *y* $\left(y = Y_1,\ldots Y_2\right)$: $\dddot{C}^*_{ym} = \sum_{k=1}^{K} \frac{D^*_{kym}}{\overline{w}^L_{ky}}$
C_y	Total landings in year *y* $\left(y = Y_0,\ldots Y_1 - 1\right)$: $C_y = \frac{\sum_{m=M_1}^{M_2} D_{kym}}{0.5\left(\overline{w}^L_{1,y} + \overline{w}^L_{2,y}\right)}$
$\ddot{c}_{ky}$	Ratio of number of fish caught to number landed for recovery year *y* in area *k*.
c_{ym}	Ratio of number of fish caught to number landed for recovery month *m* in year *y*: $c_{ym} = \sum_k \dddot{c}_{ky} C^*_{ym} \Big/ \sum_k C^*_{ym}$
R^g	Number of "traditional" tag releases in release year *g*.
O^g_{ym}	Observed tag recoveries from trap gear in month *m*, year *y*, release group *g*.
$\tilde{I}^i_y$	The observed relative abundance index value index i in year *y*
	Fixed Parameters
a	Monthly survival from natural mortality.
l	Tag survival rate after initial tag shedding, tagging mortality.
s	Fraction of fish retaining tags each month.
σ^i	The standard deviation of the log of relative abundance index *i*

Symbol	Description
	Estimated Parameters
α	Average number of recruits to the trap-vulnerable B.C. population (includes recruitment from immigration and from new year-classes entering the fishery)
γ_y	Deviation from average recruits for year *y* $\left(y = Y_0, ... Y_2\right)$
ω_y	Reporting rate in year *y*. $\left(y = Y_0, ... Y_2\right)$
ν	Monthly fraction of the number of fish retained in B.C.
q_i	Proportionality constant for abundance index i $\left(i = 1, 2, 3\right)$
Θ	Parameter vector
	Derived Parameters
N_y	Total number of fish at the beginning of year *y*
N'_y	Total number of fish at mid-year *y*
N''_y	Total number of fish at end-year *y*
$\ddot{N}_{ym}$	Total number of fish at the beginning of month *m* of year *y*.
C_{ym}	Total catch numbers in month *m* of year *y*.
C^*_{ym}	Total trap catch numbers in month *m* of year *y*.
u_{ym}	Exploitation rate for month *m* of recovery year *y*.
u^*_{ym}	Exploitation rate by trap gear for month *m* of recovery year *y*.
T^g_{ym}	Tags alive in month *m* of recovery year *y*, that were released in year *g*.
P^g_{ym}	Predicted tag recoveries for release year *g*, in month *m* of recovery year *y*.
$\hat{I}^i_y$	The predicted value for relative abundance index *i* in year *y*

Table E.2 Population and tag dynamics for the integrated tagging model.

Parameters

$$\Theta = \left(\alpha, \gamma_y, \omega_y, \nu, q_i\right)$$

Population Dynamics

Annual dynamics:

$$N_{Y_0} = \exp\left(\alpha + \gamma_{Y_0} \Big/ \sum \gamma_y\right)$$

$$N'_y = \left(\left(N_y a^6 \nu^6\right) - 0.5 C_{y\bullet}\right) \qquad \left(y = Y_0, \ldots Y_1 - 1\right)$$

$$N''_y = \left(\left(N'_y - 0.5 C_{y\bullet}\right) a^6 \nu^6\right) \qquad \left(y = Y_0, \ldots Y_1 - 1\right)$$

$$N_{y+1} = N''_y + \exp\left(\alpha + \gamma_{y+1} \Big/ \sum \gamma_y\right) \qquad \left(y = Y_0, \ldots Y_1 - 1\right)$$

Monthly dynamics:

$$\dddot{N}_{y,M_1} = N_y \qquad `\left(y = Y_1, \ldots Y_2\right)$$

$$\dddot{N}_{ym} = \dddot{N}_{y,m-1} a \nu \left(1 - u_{y,m-1}\right) \qquad \left(y = Y_1, \ldots Y_2; m = M_1 + 1, \ldots M_2\right)$$

$$N''_y = \dddot{N}_{y,M_2} a \nu \left(1 - u_{y,M_2}\right) \qquad \left(y = Y_1, \ldots Y_2\right)$$

$$N_{y+1} = N''_y + \exp\left(\alpha + \gamma_{y+1} \Big/ \sum \gamma_y\right) \qquad \left(y = Y_1, \ldots Y_2 - 1\right)$$

Exploitation rate calculation:

$$u_{ym} = \frac{\dddot{C}_{ym}}{\dddot{N}_{ym}}; \quad u^*_{ym} = \frac{\dddot{C}^*_{ym}}{\dddot{N}_{ym}}$$

Table E.2 continued.

Tag Dynamics

$\left(g = G_1, \ldots, G_2;\ y = g+1, \ldots Y_2;\ m = M_1, \ldots, M_2\right)$

$$T^g_{y,M_1} = R^g l \qquad y = g+1$$

$$T^g_{ym} = T^g_{y,m-1} asv\left(1 - u_{y,m-1}\right) \qquad m > M_1$$

$$T^g_{y,M_1} = T^g_{y-1,M_2} asv\left(1 - u_{y-1,M_2}\right)$$

Predicted tag recoveries:

$$P^g_{ym} = T^g_{ym} u^*_{ym} \omega_y c_{ym}$$

Predicted relative abundance indices

(i=1 for nominal CPUE series; i=2 for standardized CPUE series; i=3 for survey CPUE series)

$$\hat{I}^i_y = 0.5\left(\overline{w}^L_{1,y} + \overline{w}^L_{2,y}\right) N'_y \qquad i = 1,2 \text{ and } Y_0 \le y < Y_1$$

$$\hat{I}^i_y = N'_y \qquad i = 3 \text{ and } Y_0 \le y < Y_1$$

$$\hat{I}^i_y = 0.5\left(\overline{w}^L_{1,y} + \overline{w}^L_{2,y}\right) \ddot{N}_{y,6} \qquad i = 1,2 \text{ and } Y_1 \le y \le Y_2$$

$$\hat{I}^i_y = \ddot{N}_{y,10} \qquad i = 3 \text{ and } Y_1 \le y \le Y_2$$

Table E.3 Sorting ratios and mean weight of landed and vulnerable sablefish by year (after Table H.1 of Haist et al. 2004).

	Sorting Ratio (R_y)		Mean Weight Vulnerable (kg)	Mean Weight Landed (kg)	
Year	South R_{1y}	North R_{2y}	Coast $\overline{w}_y^V$	South $\overline{w}_{1y}^L$	North $\overline{w}_{2y}^L$
1979-1991	-	-	3.0	3.50	3.50
1992	1.02	0.50	2.904	3.63	4.00
1993	.	.	3.151	.	.
1994	.	.	3.390	.	.
1995	.	.	3.137	.	.
1996	.	.	3.345	.	.
1997	.	.	3.469	.	.
1998	1.02	0.50	3.043	3.63	4.00
1999	0.32	0.16	3.417	3.89	4.22
2000	.	.	3.090	.	.
2001	.	.	2.985	.	.
2002	.	.	2.770	.	.
2003	.	.	2.906	.	.
2004	0.32	0.16	2.902	3.89	4.22
2005-2010	-	-	3.0	4.1	4.1

Table E.4 Background and derivation of fixed inputs to the integrated tagging model.

Natural mortality. The instantaneous rate of natural mortality was assumed to be M=0.08, which is between the value of 0.07 assumed for the continental U.S. assessment (Schirripa 2002) and the value of 0.107 estimated by Sigler et al. (2003) for Gulf of Alaska sablefish. This assumption implies a monthly survival rate of $a = \exp\left(-0.08/12\right) = 0.993$.
Tag loss. Beamish and McFarlane (1988) estimated tag loss at 10 percent over the first year, and two percent thereafter, based on data from sablefish tagged with one Floy anchor tag and one suture tag and for data collected until 1985. Lenarz and Shaw (1997) analyzed U.S. sablefish recovery data from double-tagged fish and estimated tag loss in the first year to be 5 percent and instantaneous tag shedding rates of 0.03 and 0.069 for Floy anchor tags positioned anterior and posterior to the first dorsal fin, respectively. Appendix D of Haist and Hilborn (2000) examined a data set similar to that used by Beamish and McFarlane (1988) and estimated an initial tag loss rate of 0.0416 and a subsequent instantaneous loss rate of 0.0366, which are the estimates used here. Tag application typically occurred in mid-October, meaning that about 2.5 months elapsed prior to the start of the next year. The rate of tag loss over this period is $1-\exp\left\{-0.0366\left(2.5/12\right)\right\} = 0.007625$. Thus, the rate of tag survival after tagging induced mortality, initial tag loss and tag shedding in the interval between tag application and year y=g+1 was fixed at $l = 1-\left\{0.0951+0.0416+0.007625\right\} = 0.856$. The fraction of fish retaining tags in each month is given by $s = \exp\left(-0.0366/12\right) = 0.997$.
Sorting factors. Adjustment for the number fish inspected for tags is required because fishermen release some smaller sablefish except when the fish is tagged. Additionally, the adoption of escape rings by the sablefish trap fishery impacted the size frequency, and therefore the mean weight, of sablefish captured. The change in size frequency altered the number of fish sampled for tags relative to the number landed and the conversion of biomass landed to numbers landed. Appendix C of Haist and Hilborn (2000) analysed data from an escape ring study to estimated the ratio of the number of fish sorted to numbers landed. The study compared the performance of trap gear fitted with 3 1/2 and 3 7/8 inch escape rings to control traps without escape rings at different locations and for various soak times (Saunders and Surry 1998). The number of fish landed per metric tonne pre and post inception of escape rings was estimated by north and south areas, and for shallow, medium, and deep depth strata. The number of fish sampled per metric ton landed with, and without, escape rings was estimated from observer data collected in 1992 and 1993 by Haist et al. (1999b) for the same stratification. This analysis was updated for 2003 for the medium depth stratum of the north and south stock areas using data from an escape ring study completed in 2001 (Appendix N of Haist et al. 2004). The sorting factors are expressed in terms of the number of fish sampled for tags by the number of fish landed, in order to correct for retention of small tagged sablefish that would otherwise be released. The area and year specific sorting ratios, R_{ky}, for 2003 were used to compute sorting factors for each year and month as $c_{ym} = \left(\sum_{k=1}^{K} D^{*}_{kym} \frac{1}{\overline{w}^{L}_{ky}} \left(1+R_{ky}\right)\right) \Big/ C^{*}_{ym}$.
Mean fish weight. Data from the standardized survey were used to compute the mean weights of vulnerable fish, $\overline{w}^{V}_{y}$. For each standardized survey set conducted in depth strata 1 through 5, a ratio estimate of mean weight was calculated by dividing the total weight of fish captured by the total number of fish captured. The annual mean weight was determined by taking the mean of the ratio estimates of mean fish weight by set and year. The mean weights of landed fish, $\overline{w}^{L}_{y}$, were determined by analysis of the 2001 escape ring data and are provided pre and post inception of escape rings in the fishery.

Table E.5 Decision tables of performance statistics for projections based on longer-term historic recruitment levels and a range of future catch levels. Results are presented relative to current vulnerable biomass with the "expectation" integrating over the range of current biomass levels.

Total Annual Catch 2005-2009	$P\left(B_{2010} > B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.82	0.80	0.82	0.81
3500	0.73	0.72	0.74	0.73
4500	0.72	0.70	0.71	0.71
5500	0.68	0.68	0.70	0.69
7500	0.64	0.64	0.67	0.65
10000	0.60	0.61	0.61	0.61

Total Annual Catch 2004-2009	$E\left(B_{2010}/B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	2.63	2.59	2.80	2.67
3500	2.33	2.31	2.53	2.39
4500	2.25	2.23	2.45	2.31
5500	2.17	2.16	2.38	2.24
7500	2.03	2.03	2.25	2.10
10000	1.88	1.88	2.10	1.95

Total Annual Catch 2005-2009	$P\left(B_{2010} > B^{0.05}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.92	0.90	0.92	0.91
3500	0.85	0.83	0.87	0.85
4500	0.83	0.81	0.85	0.83
5500	0.81	0.80	0.84	0.82
7500	0.77	0.77	0.80	0.78
10000	0.73	0.72	0.77	0.74

Total Annual Catch 2005-2009	$E\left(B_{2010}/B^{0.05}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	4.16	4.37	4.92	4.49
3500	3.69	3.90	4.45	4.01
4500	3.57	3.77	4.32	3.89
5500	3.45	3.66	4.20	3.77
7500	3.23	3.43	3.97	3.54
10000	2.98	3.19	3.71	3.29

Table E.6 Decision tables of performance statistics for projections based on longer-term historic recruitment levels and a range of future catch levels. Results are presented relative to current vulnerable biomass with the "expectation" integrating over the range of current biomass levels.

Total Annual Catch 2005-2009	$P\left(B''_{2009} > B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.74	0.72	0.75	0.74
3500	0.63	0.63	0.63	0.63
4500	0.60	0.59	0.61	0.60
5500	0.57	0.56	0.58	0.57
7500	0.51	0.50	0.53	0.51
10000	0.42	0.44	0.47	0.44

Total Annual Catch 2004-2009	$E\left(B''_{2009} / B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	3.77	3.66	3.76	3.73
3500	3.14	3.06	3.19	3.13
4500	2.98	2.90	3.03	2.97
5500	2.83	2.76	2.89	2.82
7500	2.54	2.48	2.61	2.54
10000	2.22	2.17	2.30	2.23

Total Annual Catch 2005-2009	$P\left(B_{2007} > B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.71	0.71	0.73	0.72
3500	0.65	0.68	0.69	0.67
4500	0.64	0.66	0.67	0.66
5500	0.64	0.66	0.65	0.65
7500	0.61	0.62	0.64	0.63
10000	0.58	0.59	0.61	0.59

Total Annual Catch 2005-2009	$P\left(B''_{2006} > B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.57	0.55	0.59	0.57
3500	0.48	0.48	0.53	0.50
4500	0.46	0.47	0.51	0.48
5500	0.45	0.44	0.50	0.46
7500	0.41	0.42	0.47	0.44
10000	0.38	0.39	0.44	0.40

Table E.7 Decision tables of performance statistics for projections based on recent-history recruitment levels and a range of future catch levels. Results are presented relative to current vulnerable biomass with the "expectation" integrating over the range of current biomass levels.

Total Annual Catch 2005-2009	$P\left(B_{2010} > B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.70	0.67	0.68	0.68
3500	0.53	0.49	0.53	0.52
4500	0.48	0.45	0.49	0.48
5500	0.44	0.42	0.46	0.44
7500	0.38	0.35	0.39	0.37
10000	0.30	0.30	0.31	0.30

Total Annual Catch 2004-2009	$E\left(B_{2010} / B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	1.45	1.41	1.45	1.44
3500	1.15	1.12	1.18	1.15
4500	1.07	1.05	1.11	1.07
5500	1.00	0.98	1.04	1.00
7500	0.87	0.85	0.91	0.88
10000	0.74	0.73	0.79	0.75

Total Annual Catch 2005-2009	$P\left(B_{2010} > B^{0.05}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.87	0.90	0.90	0.89
3500	0.74	0.75	0.79	0.76
4500	0.70	0.72	0.74	0.72
5500	0.66	0.67	0.70	0.68
7500	0.61	0.60	0.63	0.61
10000	0.53	0.53	0.55	0.54

Total Annual Catch 2005-2009	$E\left(B_{2010} / B^{0.05}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	2.28	2.35	2.58	2.40
3500	1.81	1.88	2.10	1.93
4500	1.69	1.75	1.97	1.80
5500	1.57	1.64	1.85	1.68
7500	1.37	1.43	1.63	1.48
10000	1.17	1.22	1.40	1.27

Table E.8 Decision tables of performance statistics for projections based on recent-history recruitment levels and a range of future catch levels. Results are presented relative to current vulnerable biomass with the "expectation" integrating over the range of current biomass levels.

Total Annual Catch 2005-2009	$P\left(B''_{2009} > B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.58	0.58	0.59	0.59
3500	0.38	0.33	0.40	0.37
4500	0.32	0.30	0.34	0.32
5500	0.26	0.25	0.28	0.26
7500	0.18	0.16	0.21	0.18
10000	0.09	0.10	0.13	0.11

Total Annual Catch 2004-2009	$E\left(B''_{2009} / B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	2.10	2.03	2.13	2.09
3500	1.47	1.43	1.56	1.49
4500	1.31	1.27	1.40	1.33
5500	1.15	1.12	1.26	1.18
7500	0.89	0.86	1.00	0.92
10000	0.62	0.60	0.73	0.65

Total Annual Catch 2005-2009	$P\left(B_{2007} > B_{2002}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.65	0.66	0.67	0.66
3500	0.59	0.55	0.60	0.58
4500	0.57	0.52	0.58	0.56
5500	0.55	0.50	0.55	0.54
7500	0.49	0.46	0.51	0.49
10000	0.43	0.41	0.44	0.43

Total Annual Catch 2005-2009	$P\left(B''_{2006} > B''_{2001}\right)$			
	Current Biomass			
	Low	Average	High	Expectation
0	0.45	0.51	0.56	0.51
3500	0.33	0.37	0.44	0.38
4500	0.30	0.34	0.42	0.35
5500	0.28	0.31	0.40	0.33
7500	0.22	0.26	0.33	0.27
10000	0.15	0.20	0.28	0.21

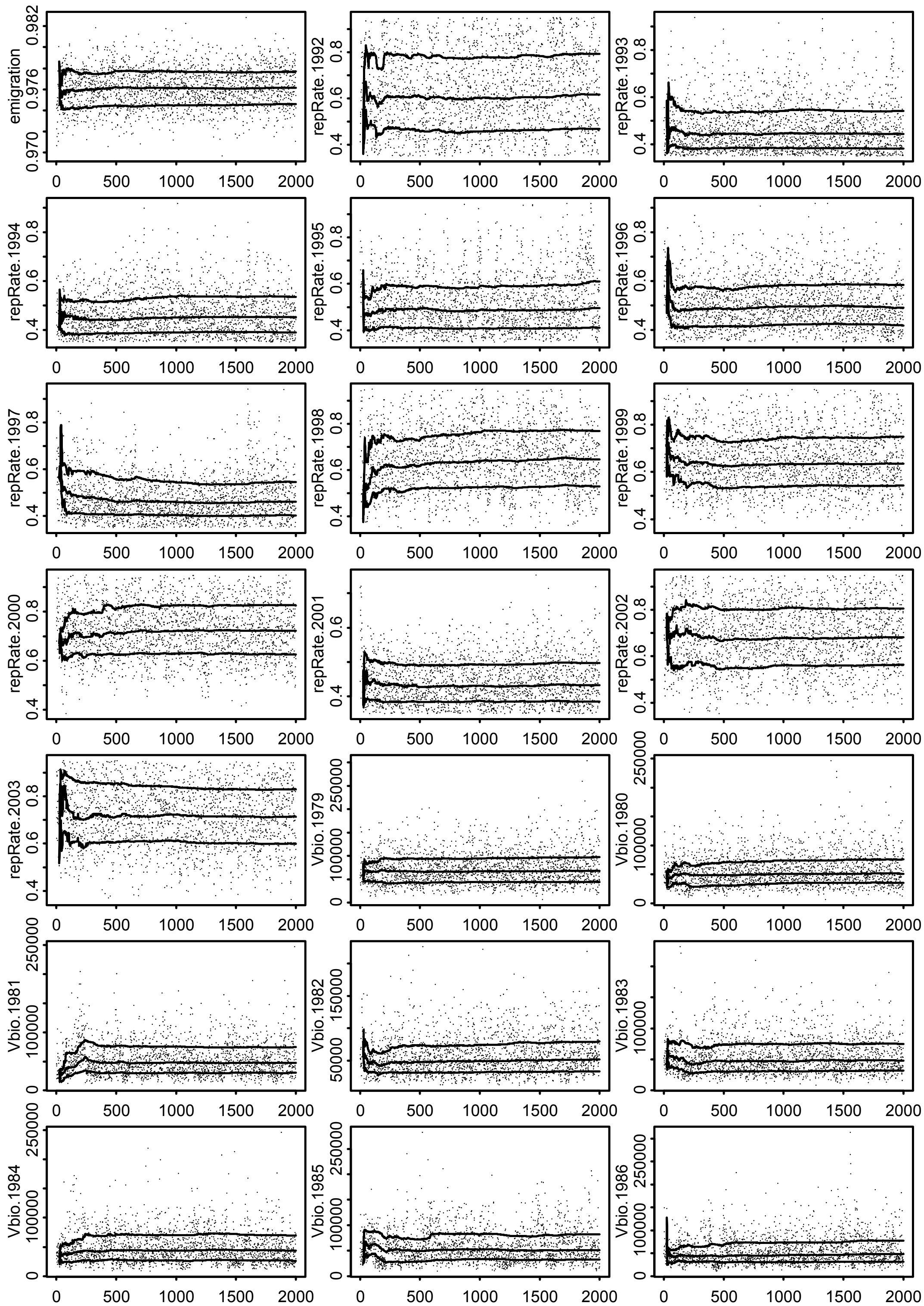

Figure E.1 MCMC chain traces for selected parameters from the integrated tagging model fit. The solid lines show the running median and the running 5th and 95th quantiles over 50 samples.

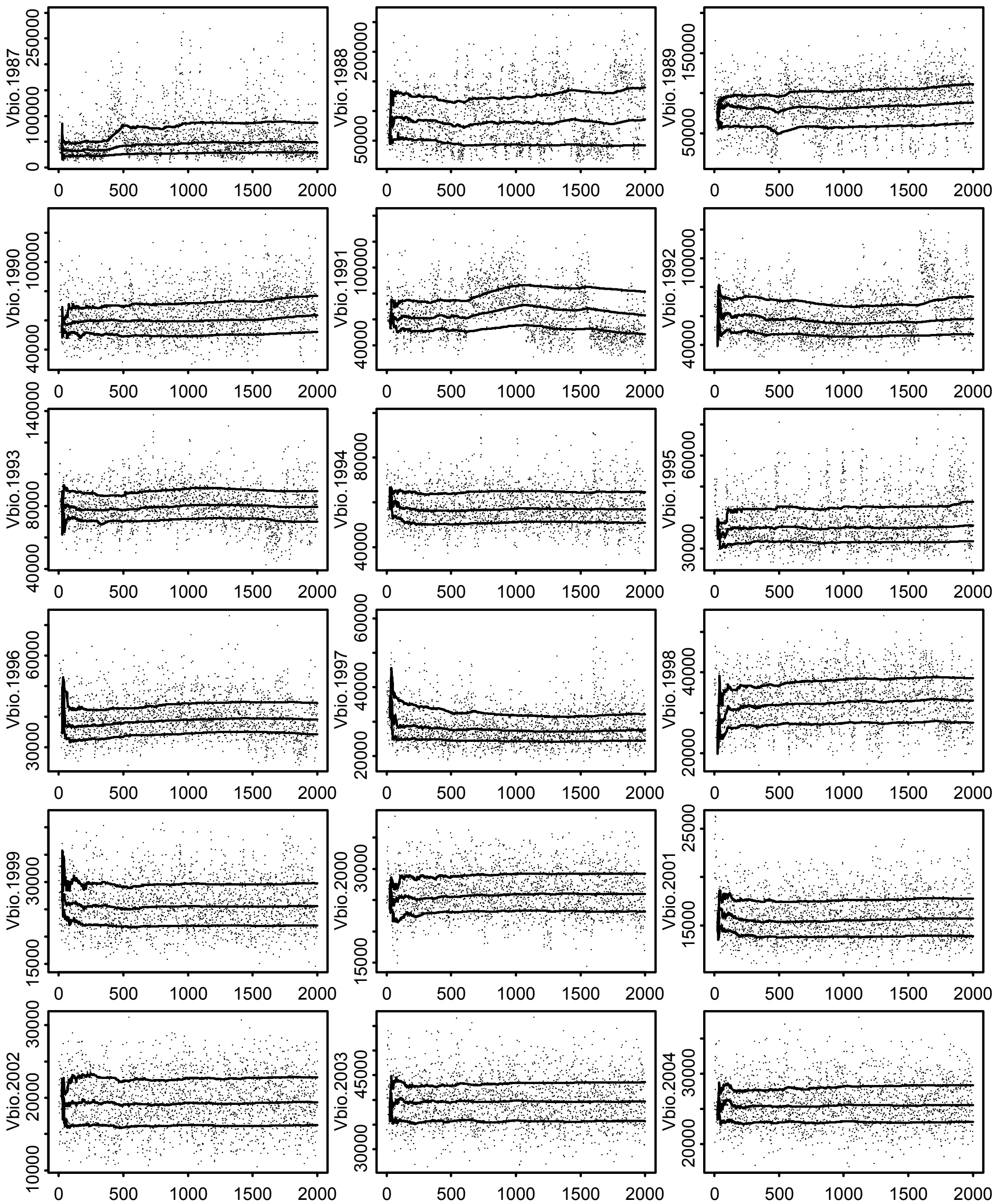

Figure E.1 continued.

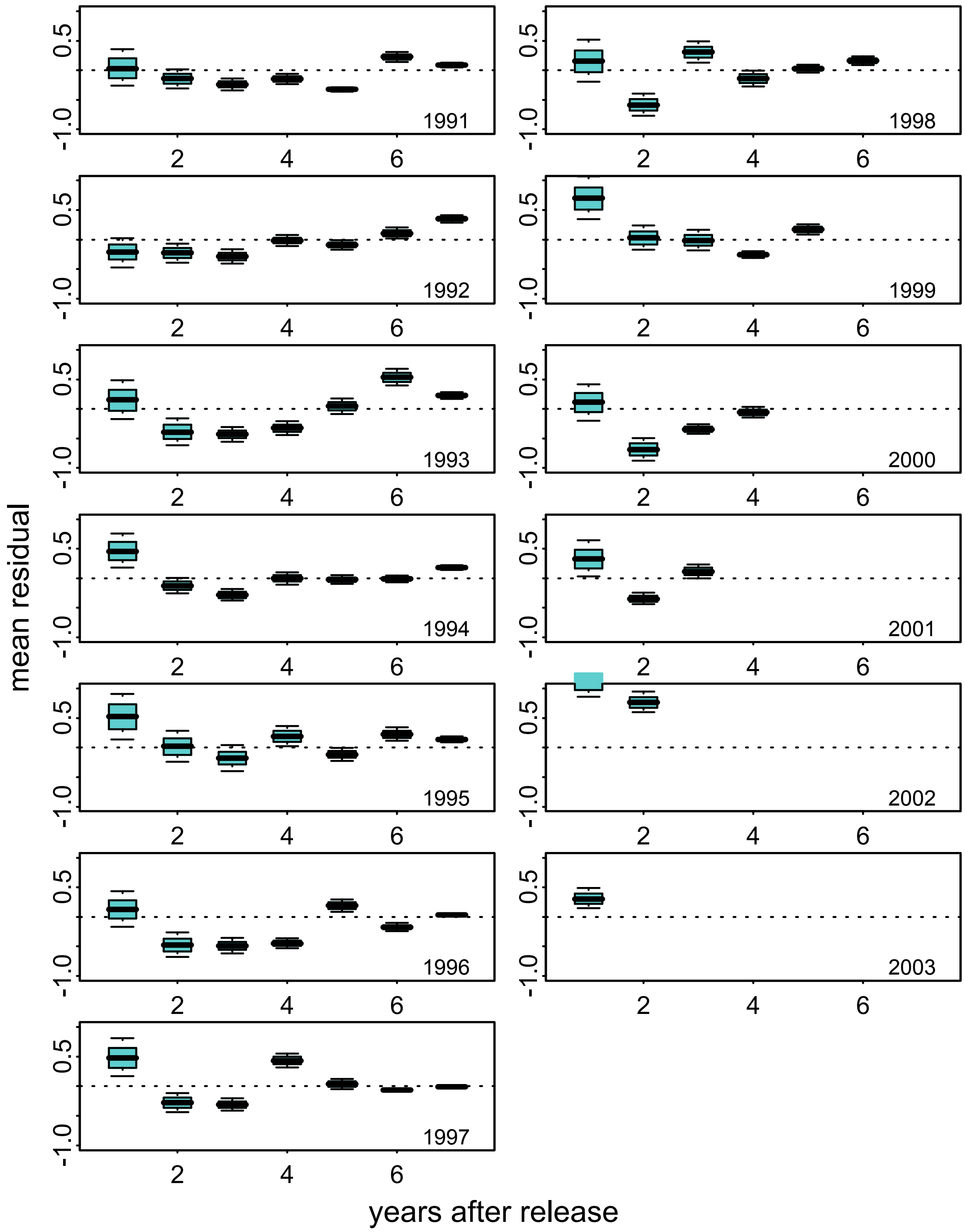

Figure E.2 Quantile plots of the marginal posterior distributions of the mean residuals of fits to the tag-recovery data by tag release year and number of years after release. Means are calculated over the 8 months (April through November) where recovery data is fitted in the model. The boxes indicate the median and 25th and 75th quantiles and the whiskers show the 10th and 90th quantiles.

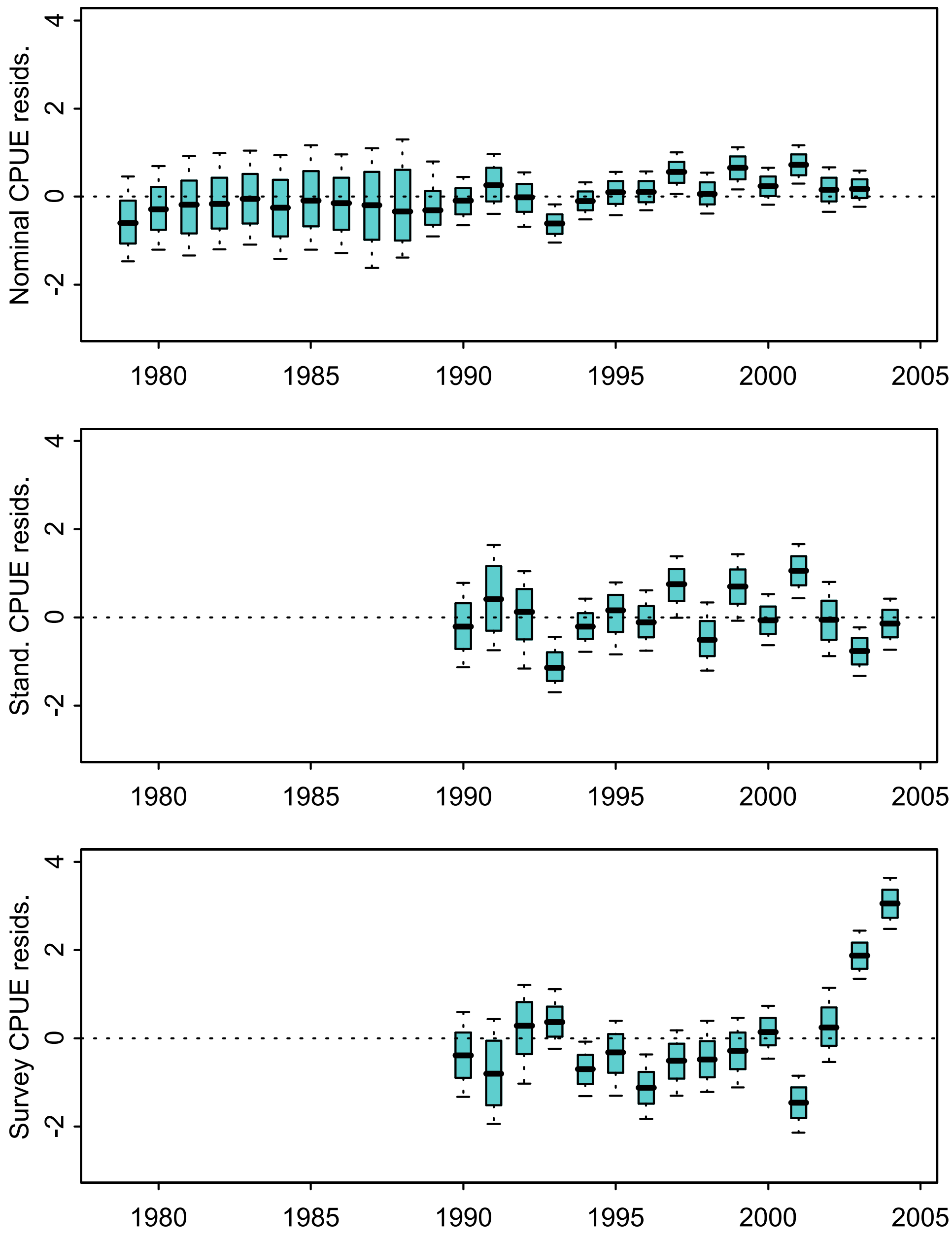

Figure E.3 Quantile plots of the marginal posterior distributions of the model residuals for fits to the abundance index data series. The boxes indicate the median and the 25th and 75th quantiles, and the whiskers show the 10th and 90th quantiles.

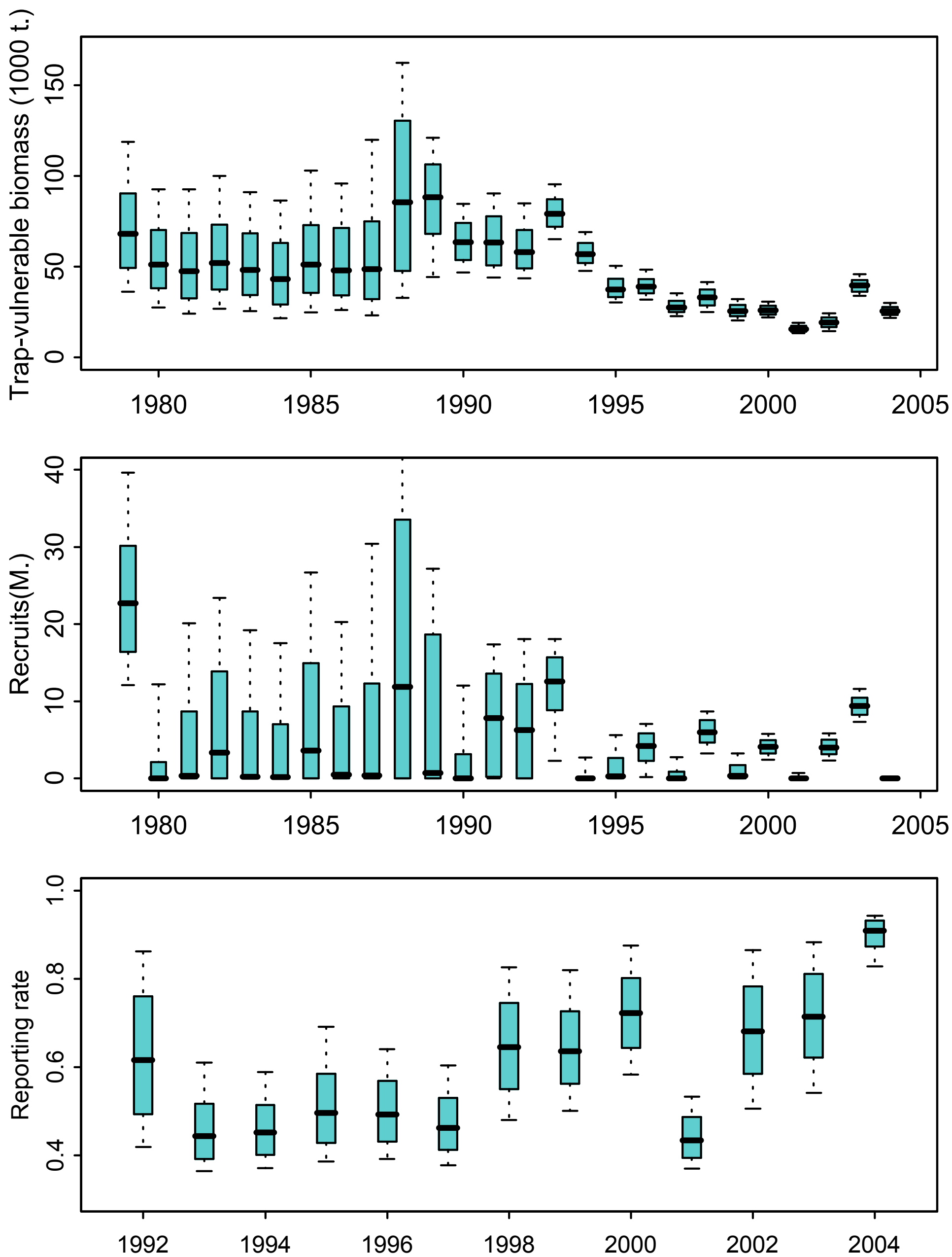

Figure E.4 Quantile plot of trap-vulnerable biomass estimates (1,000 t), recruitment estimates (millions), and tag reporting rate estimates for the integrated tagging model fit. The boxes indicate the median and the 25th and 75th quantiles; the whiskers show the 10th and 90th quantiles.

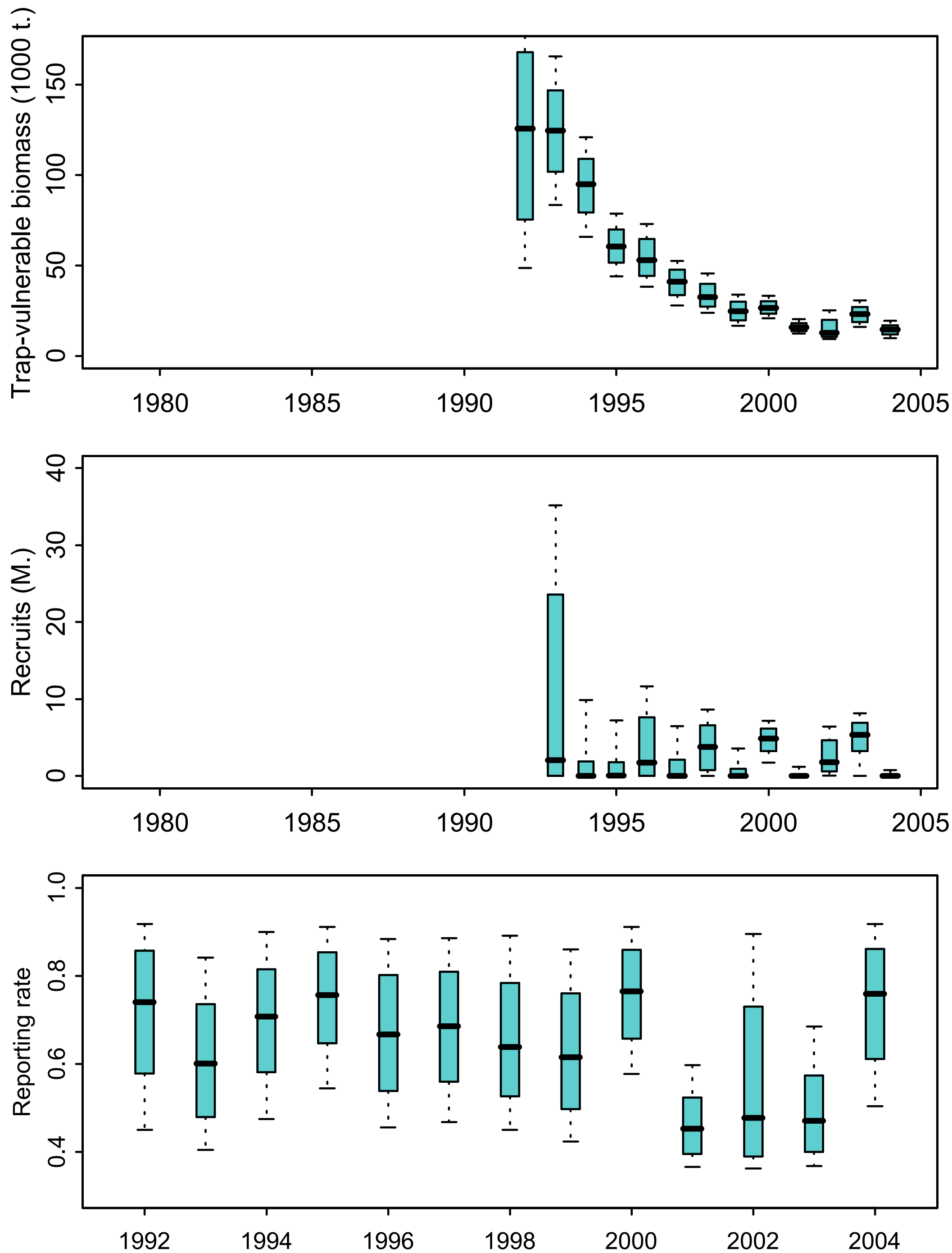

Figure E.5 Quantile plots of trap-vulnerable biomass estimates (1,000 t), recruitment estimates (millions), and tag reporting rate estimates for the tagging-data only model fit. The boxes indicate the 25th and 75th quantiles; the whiskers show the 10th and 90th quantiles.

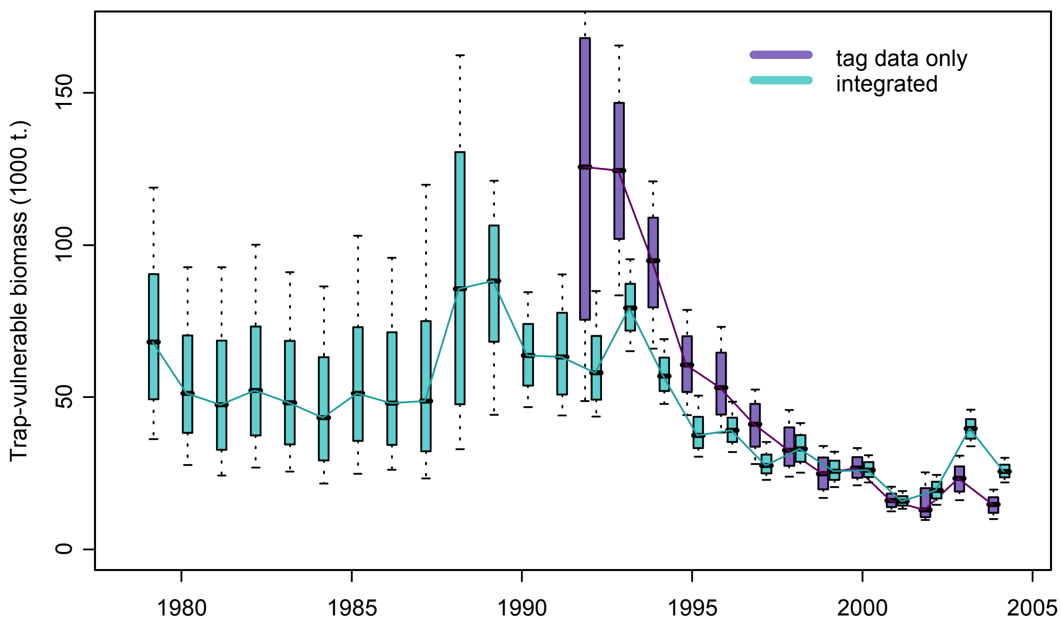

Figure E.6 Quantile plots of trap-vulnerable biomass estimates from the integrated model analysis and from the tagging-data only model fit. The boxes indicate the median and the 25th and 75th quantiles; the whiskers show the 10th and 90th quantiles.

APPENDIX F STATUS OF SABLEFISH IN U.S. WATERS

F.1 Gulf of Alaska Sablefish

Assessment Methodology

Data available for the Gulf of Alaska stock assessment (Sigler et al. 2004) are summarized in Table F.1. The assessment model was a Bayesian age-structured sequential population reconstruction tuned to catch rate indices derived from longline surveys and commercial fisheries (Sigler 1999). Sablefish abundances were estimated for 1960 to 2004 and age classes 2 to 31, where the last age class represented fish assigned age 31 and older. An ageing error matrix was included in the model based on a sample of known-age otoliths (Heifetz et al. 1999). Model structure included gear-specific asymptotic selectivity functions for the longline commercial fishery and longline survey. The trawl fishery selectivity was modeled using a dome-shaped selectivity function. Separate estimates of catchability for the Japanese longline fishery, U.S. longline fishery, Japan-U.S. longline survey and U.S. longline survey were incorporated. Natural mortality was estimated in the model to be $\widehat{M} = 0.10$, similar to the estimate of 0.107 obtained in 2003 (Sigler et al. 2003). Growth and maturity parameters were estimated independently of the assessment model and enter the model as fixed parameters.

Stock Status

Gulf of Alaska sablefish spawning abundance declined during the 1970s due to fishing mortality but recovered due to contributions from exceptional year-classes in the late 1970s and reached a peak in 1987 (Sigler et al. 2004, Figure F.1). The population declined over the course of the late 1980s and 1990s until 2000. A modest increase in population abundance occurred from 2000 to 2004. Key findings from the population reconstruction and harvest projections include the following results:

- Gulf of Alaska sablefish are not overfished nor is the stock approaching an overfished condition;

- Abundance was characterized as moderate relative to historic levels at a spawning biomass (males and females) of 204,000 t;
- Spawning biomass was estimated to be 37 percent of the unfished population and has increased from a low of 33 percent during 1998 to 2000;
- Spawning biomass is projected to fall to 36 percent in 2006 and 35 percent in 2007 under the maximum permissible yield specified by the U.S. adjusted $F_{40\%}$ harvest policy.

The projected decline in spawning biomass through 2008 depends on the actual harvests and future average recruitment, and the ultimate strength of the 1997 and 2000 year-classes.

Gulf of Alaska sablefish stock indices have declined in the last two years following recent increases:

- The longline survey abundance index decreased 5 percent from 2003 to 2004 following an 8 percent decrease from 2002 to 2003. The survey abundance index in 2004 is 4 percent higher than in 2000;
- The longline fishery abundance index decreased 12 percent from 2002 to 2003 (2004 data unavailable). The fishery abundance index is 6 percent lower than in 2000;
- Concern over a long term decline in the East Yakutat/Southeast noted in the previous stock assessment (Sigler et al. 2003) was re-iterated in 2004 despite a modest increase in the U.S. longline survey index for the area from 2003 to 2004 (Figure F.3).

Recruitment strength of year-classes in the Gulf of Alaska is categorized as weak if the year-class abundance is less than 80 percent of the 1960 to 2002 average and strong if the year-class abundance is greater than 120 percent of the average. The accumulation of additional data has provided perspective on the relative strength of recent year-classes:

- The 1997 year-class is projected to comprise 23 percent of the 2005 spawning biomass which is reduced from a projected value of 31 percent in 2004.
- Although the 1998 year-class initially appeared as though it would be a strong year-class it now appears to be weak (Figure F.2);
- The 2000 year-class may be strong though more data are required to confirm its relative contribution to the stock.

Fishery Management Decisions

The fishery harvest rule applied to the Gulf of Alaska stock is a target fishing mortality of $F_{40\%}$ with a $F_{40\text{-}10}$ adjustment (a proxy for maximum sustained yield, $F_{40\%}$ is the fishing mortality that reduces the biomass to 40 percent of the unfished level while the $F_{40\text{-}10}$ adjustment imposes a linear decline in F beginning at 40 percent of unfished biomass to zero when the biomass is at 10 percent of the unfished level). The Gulf of Alaska sablefish Assessment Team recommended yield under the adjusted $F_{40\%}$ strategy is an Acceptable Biological Catch (ABS) of 21,000 t in 2005, down 9 percent from the recommendation of 23,000 t for 2004. The maximum permissible ABC is expected to be 19,900 t in 2006 and 18,500 t in 2007. The actual values will depend on future recruitment, behavior of the stock indices, and actual removals.

The survey relative abundance index for the eastern Gulf of Alaska declined about 54 percent over the period 1991 to 2003, and about 27 percent since 1999 (Figure 3.6 of Sigler et al. 2003, Figure F.3). The index showed a modest increase in 2002 that was coincident with positive signs in northern B.C. from the 2002 standardized survey, but declined in 2003 from a relative population weight of 287,133 to 245,367 (Figure F.3). The survey index increased modestly in 2004 (Figure F.3). Alaskan tag movement studies indicated small fish move north and west from their release sites, and return eastward as a function of age. Thus, biomass in the southeast region is expected to lag behind more westward regions as strong year-classes recruit (Sigler et al. 2004, p. 12). Nevertheless, U.S. analysts noted the general decline in the survey index as a cause for concern. In contrast, commercial longline fishery catch rates (observed lbs/hook) increased about 13 percent from 2002 to 2003 in the east Yakutat/Southeast area (Figure F.4).

F.2 Continental U.S. Sablefish

Assessment Methodology

The most recent full assessment of sablefish in the waters of the continental United States was conducted by Schirripa and Methot (2001). An updated assessment was completed in 2002 (Schirripa 2002) and the next assessment is scheduled for 2005. Data utilized for the 2001 and 2002 assessment analyses are listed in Table F.2. Note that pot (trap) surveys conducted in the north (Vancouver and Columbia INPFC areas) were not conducted in the same years as those in the south (Eureka, Monterey and Conception areas). The trap surveys provided abundance indices and size-stratified abundance indices. A fishery-dependent abundance index was obtained from trawl fishery logbooks. Size and age distributions were obtained from the commercial longline, trawl, and trap fisheries (1986-2001), and from the shelf and slope trawl surveys. Age-distributions were constructed using age-length keys.

The assessment model was based on a stock synthesis (Methot 1989) population reconstruction with age-structured and length-structured components. The model was tuned to five abundance indices: (1) the AFSC shelf survey biomass estimates (1980-1998), (2) the AFSC and NWFSC slope survey biomass estimates (1988-2000), (3) the NMFS northern trap survey for “medium” and “large” size sablefish (1971-1989), (4) the NMFS southern trap survey for “medium” and “large” size sablefish (1984-1991), and (5) the trawl logbook catch rates standardized using a general linear model (1978-1988). Dome-shaped selectivity was adopted for fishery and trawl survey indices and some selectivity parameters were time-varying. Ageing error was modeled based on among reader agreement. A Beverton-Holt stock-recruitment function was utilized for generating annual recruitment. Natural mortality was fixed at $M = 0.07$.

Stock Status

The 2001 assessment of sablefish stocks off Washington, Oregon, and California north of Point Conception indicated that poor recruitment over the last ten years had contributed to a significantly decreased spawning biomass (Schirripa and Methot 2001). In all model configurations examined, the ratio of the current estimate of spawning stock biomass to the virgin state was at 25 percent, below which the stock is considered overfished under U.S. Federal legislation. Spawning stock biomass was estimated to have declined from a high of 122,000 t in 1980 to a low of about 60,000 t in 2000. An update of the continental U.S. sablefish assessment for 2002 (Schirripa 2002) added data from 2001 fishery and survey sources. Re-analysis with the new data produced an increase in the absolute biomass estimate to 72,000 t, but there was little change in the ratio of current spawning stock biomass to virgin biomass. Results from the shelf and slope trawl surveys indicated two relatively strong incoming cohorts corresponding to the 1999 and 2000 year-classes. The 2001 shelf survey biomass estimates are the highest in the 1980 to 2001 time series and were attributed to the 2000 year-class.

Fishery Management Decisions

The fishery harvest rule applied to sablefish off the continental United States specifies a target fishing mortality of $F_{45\%}$ with an $F_{40\text{-}10}$ adjustment (a proxy for maximum sustained yield). This harvest rule was applied to current biomass estimates in order to project future stock status under constant harvest and a range of recruitment assumptions. The Scientific and Statistical Committee of the Pacific Fishery Management Council (PFMC) recommended an optimum yield of 3,200 t for the 2002 fishing season, a reduction of 54 percent from the 2001 harvest. The Groundfish Management Team (GMT) of the PFMC suggested a three-year strategy that required a reduction in harvest to 4,000 t in 2002. The PFMC adopted a yield of 4,500 t (a 36 percent reduction from the 2001 harvest) citing evidence from the 2001 National Marine Fishery Service (NMFS) shelf survey of a strong 2000 year-class. In 2003, the yield was increased from 4,500 t to about 6,794 t. This substantial increase in yield was the consequence of a change in the estimated value of the model catchability parameter for the slope trawl survey. The survey catchability shifted from q=0.601 to q=0.460, in part because young fish seen in the 2001 shelf survey were not subsequently observed in the 2002 slope survey. This change in catchability altered the yield range from (3877-4630 t) to (7640-8437 t). The U.S. STAT review team noted that there was no means of determining whether the revised estimate of q was superior to the original 2001 estimate. An Optimal Yield (OY) of 7,786 t was selected for 2004.

For the 2005 and 2006 fishing years the GMT utilized the harvest level alternatives as derived in the 2002 assessment update (Schirripa 2002). The 40-10 adjustment was applied when estimating the yields since the spawning biomass was predicted to be less than 40 percent of its unfished level. The PFMC chose the medium OY harvest specification of 7,761 t for 2005. In keeping with a small projected decrease in exploitable sablefish biomass, a yield of 7,634 t was selected for 2006 (Pacific Fisheries Management Council 2004).

F.3 Literature Cited

Heifetz, J., Anderl, D., Maloney, N.E., and T.L. Rutecki. 1999. Age validation and analysis of ageing error from marked and recaptured sablefish, *Anoplopoma fimbria*. Fish. Bull. **97**: 256-263.

Methot, R.D. 1989. Synthetic estimates of historical abundance and mortality in northern anchovy. Amer. Fish. Soc. Symp. **6**: 66-82.

Pacific Fishery Management Council. 2004. Proposed acceptable biological catch and optimum yield specifications and management measures for the 2005-2006 Pacific coast groundfish fishery: Final environmental impact statement including regulatory impact review and initial regulatory flexibility analysis. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384. (http://www.pcouncil.org/groundfish/gfspex/gfspex05-06.html).

Sigler, M. F. 1999. Abundance estimation of Alaskan sablefish with an age-structured population model. Fish. Bull. 97: 591-603.

Sigler, M.F., C.R. Lunsford, J.T. Fujioka and S.A. Lowe. 2003. Alaska sablefish assessment for 2004. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2004. Available from North Pacific Fishery Management Council, 605 West 4th Avenue, Suite 306, Anchorage, Alaska 99501-2252.

Sigler, M.F., Lunsford, C.R., J.T. Fujioka and S.A. Lowe. 2004. Alaska sablefish assessment for 2005. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2005. Available from Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 7600 Sand Point Way, N.E., Building 4, Seattle, Washington 98115. (http://www.afsc.noaa.gov/refm/stocks/assessments.html).

Schirripa, M.J. and R. Methot. 2001. Status of the sablefish resource of the U.S. Pacific coast in 2001. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

Schirripa, M.J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

Table F.1 Summary of data utilized for the Gulf of Alaska stock assessment.

Data Type	Source	Data Range
Commercial Catch	***All fisheries*** • Japanese longline • Japanese trawl • U.S. longline • U.S. trawl	***1960-2004***
Commercial Discards	• U.S. fisheries	1990-2004
Commercial Effort	• Japanese longline • U.S. longline	1964-1981 1990-2003
Survey Catch and Effort	• Japan-U.S. longline survey • Domestic longline survey	1979-1994 1990-2004
Fish lengths	• Japanese longline fishery • Japanese trawl fishery • U.S. longline fishery • U.S. trawl fishery • Japan-U.S. longline survey • Domestic longline survey	1963-1980 1964-1971 1990-2003 1990, 1991, 1999 1979-2004 1990-2004
Fish ages	• U.S. longline fishery • Japan-U.S. longline survey • Domestic longline survey	1999-2003 1981, 1983, 1985, 1987, 1989, 1991, 1993 1996-2003

Table F.2 Summary of data utilized for the continental United States stock assessment.

Data Type	Source	Data Range
Commercial Landings	***All fisheries*** • Hook and line • Trawl • Pot (trap)	***1956-2001*** 1956-2001 1956-2001 1970-2001
Commercial Discards	• Trawl	1982-2000
Commercial Catch	• Trawl logbook data	1978-1988
Survey Catch and Effort	• Slope trawl surveys • Shelf trawl survey • Pot survey (north) • Pot survey (south)	1988-2001 1980-2001 1979-1981, 1983, 1985, 1987, 1989 1984, 1986, 1988, 1991
Fish lengths/sex	• Hook and line fishery • Trawl fishery • Pot (trap) fishery • Pot survey (north or south) • AFSC trawl slope survey • NWFSC trawl slope survey	1986-2000 1986-2000 1986-2000 1979-1981, 1983-1989, 1991 1988, 1990-1997, 1999-2000 1998-2000
Fish ages	• Hook and line fishery • Trawl fishery • Pot (trap) fishery • Pot survey (north or south) • Shelf trawl survey • AFSC trawl slope survey • NWFSC trawl slope survey	1987-1995, 1997 1987-1995, 1997 1987-1997, 2000 1983, 1986, 1989, 1991 Unknown 1991, 1995, 1997, 1998, 2000 1998, 1999

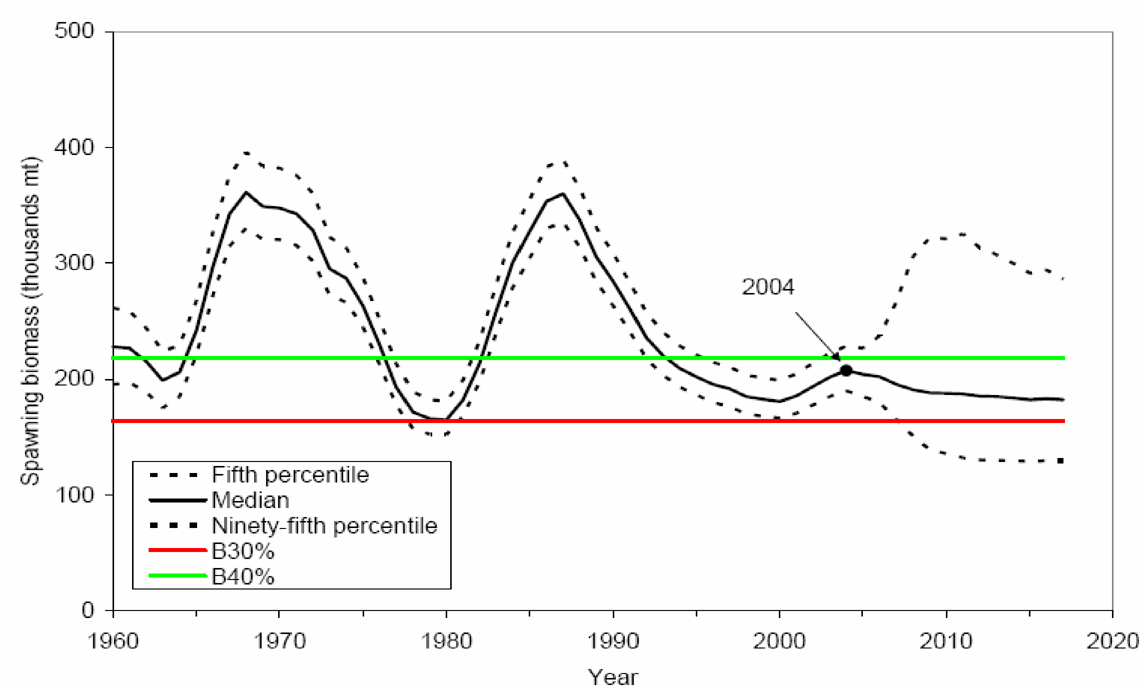

Figure F.1 Gulf of Alaska estimates of annual male and female spawning biomass (thousands t) with uncertainty. The 5th and 95th percentiles are derived from the posterior probability of spawning biomass. B30% and B40% represent the estimated biomass at 30 and 40 percent of unfished levels, respectively. From Fig. 3.10 of Sigler et al. (2004).

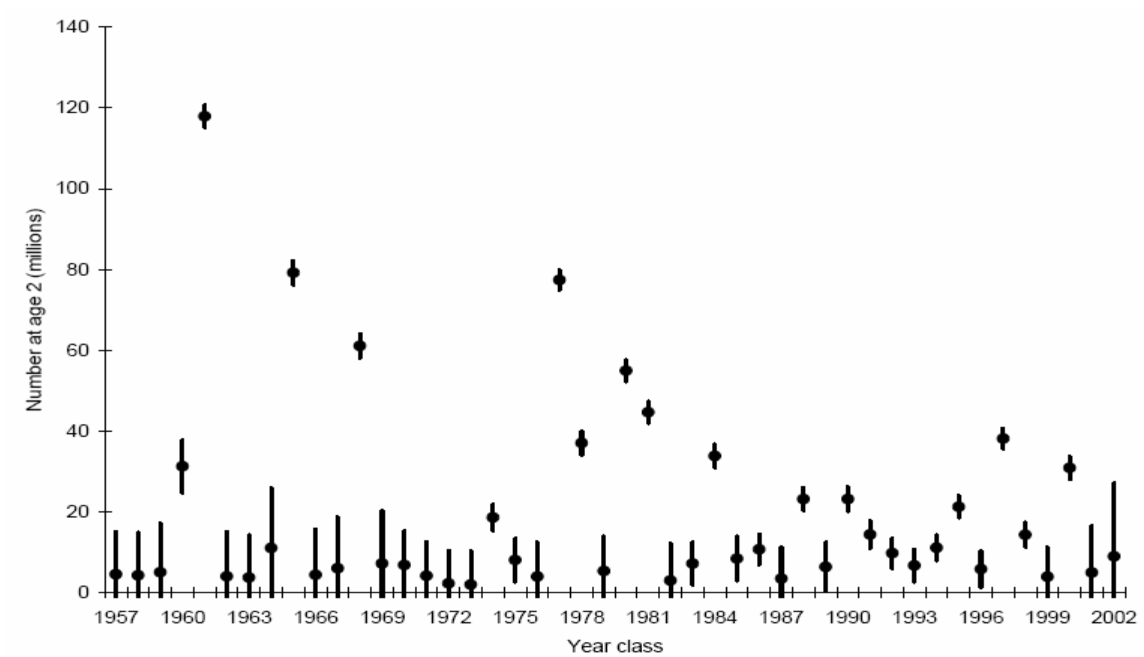

Figure F.2 Gulf of Alaska estimates of the number of age-2 sablefish (millions) by year-lass ± 2 standard errors based on the covariance matrix of age-structured model output. From Fig. 3.11 of Sigler et al. (2004).

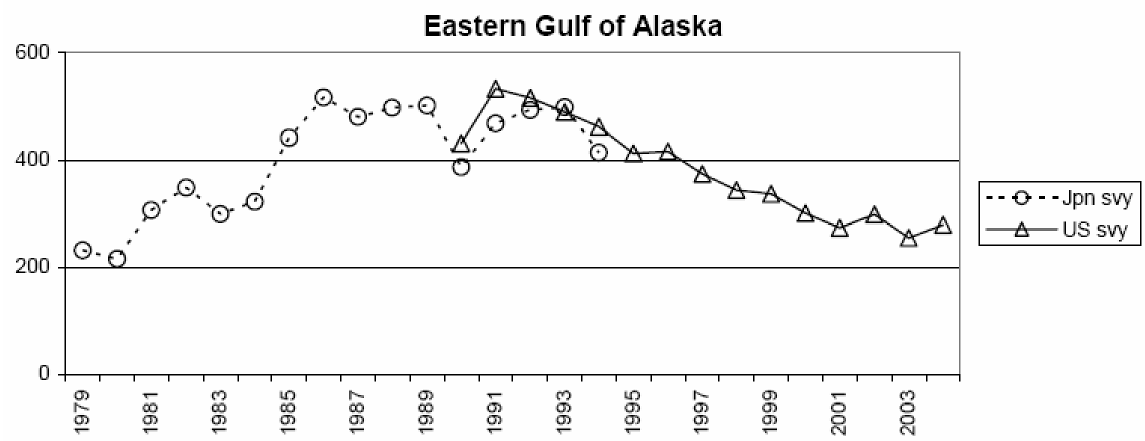

Figure F.3 Relative annual abundance (weight) determined from Japan-U.S. and U.S. domestic longline surveys for the eastern Gulf of Alaska. Values for the U.S. survey were adjusted to account for the higher efficiency of the U.S. survey gear. From Fig. 3.6 of Sigler et al. (2004).

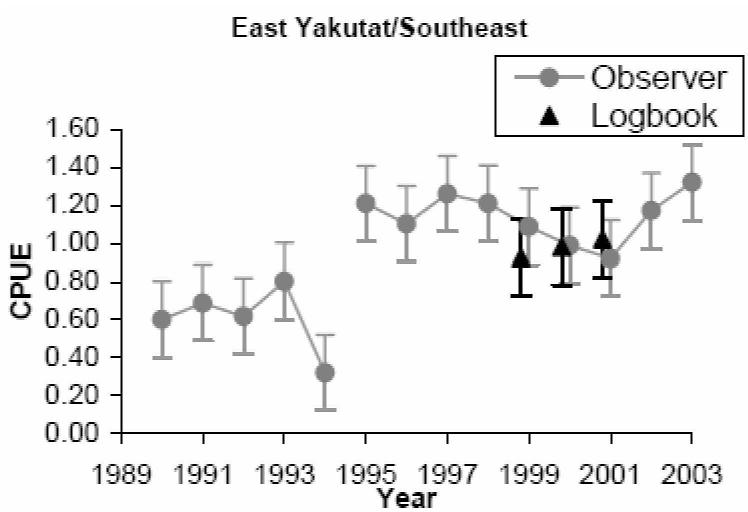

Figure F.4 Mean annual fishery catch rates (CPUE lbs/hook) for east Yakutat/Southeast Alaska. Vertical bars represent 95 percent confidence intervals. The fishery changed from open access to quota management in 1995. From Fig. 3.5 of Sigler et al. (2004).

APPENDIX G OTHER INDICATORS

G.1 Commercial Trawl Sablefish Catch and Effort

Background

Commercial trawl vessels that fish under a "T" category license receive an 8.75 percent allocation of the sablefish TAC (Fisheries and Oceans 2004). A 100 percent at-sea observer program was regulated for the trawl fishery beginning in 1996. This program currently excludes vessels operating under the Option B fishery in the Strait of Georgia. Domestic vessels fishing Pacific hake (*Merluccius productus*) were subject to approximately 10 percent observer coverage hake trips beginning with the 2002/2003 fishing year while Joint Venture vessels processing hake were required to have 100 percent observer coverage. The legal size limit for sablefish landed from trawl fishing, as for other groundfish fisheries, is set at 55 cm fork length. The trawl fishery operates under an Individual Transferable Vessel Quota (IVQ) system instituted in 1997. Currently there is a 5 percent cap on the percentage of trawl allocated sablefish that any one IVQ holder can accumulate.

Under the terms of the trawl fishery management plan, sablefish that are determined to be unmarketable, i.e., smaller than the legal size limit, can be released at-sea without the catch counting against the IVQ or TAC (Fisheries and Oceans 2004). Trawl vessels may release marketable sablefish to avoid the catch counting against their quota or the TAC subject to mortality rate penalties. The sablefish mortality rate was set at 10 percent for the first 2 hours fished or portion thereof, and an additional 10 percent for each additional hour fished (Fisheries and Oceans 2004). The fisheries management plan states that the mortality rate does not necessarily reflect the true mortality of sablefish but was intended to provide an incentive to reduce tow times and avoid catch of sablefish where possible.

In recent years trawl fishing masters have reported their observations and interpretations of trends in sablefish abundance and distribution. Their comments cited the following issues:

- The need by some quota holders to purchase additional sablefish quota to maintain access to other species in 2002 and 2003 and increased concerns about sablefish catch during 2002 and 2003 relative to 4 to 5 years ago when it was not considered a general concern;
- The increased use of larger than usual 6 inch cod-end off the west coast of Vancouver Island to reduce retention of sablefish and voluntary use of large-mesh cod-ends in the Goose Island Bank region of Area 5B;
- Remarks on the unusual distribution of sablefish in waters of 146 to 275 m (80 to 150 fm) into November and December of 2002 when normally sablefish would not be found in abundance at those depths after October. This observation was reported by several vessel masters, particularly for the southern west coast of Vancouver Island;
- Observations of very young fish (e.g., approximately 8 to 12 inches fork length) in the 82 to 92 m (45 to 50 fm) depth range in 2002 off the west coast of Vancouver Island and an unusual number of smaller fish off LaPerouse and Swiftsure Banks;
- Observations of an abundance of smaller sablefish in Area 5A in 2000 at depths shallower than 220 m (120 fm);
- Observations of an abundance of juveniles in Area 5B in 2000 and 2001 in the Goose Island Bank area;
- Observations of unusually late persistence of sablefish shallower than the 183 to 220 m (100 to 120 fm) edge into October; the experience of trawl fishing masters is that sablefish will descend below the 100 to 120 fm edge in early fall first in the north and then progressively towards the south.

These observations coincide with fishery independent reports of increased abundance of sablefish, in particular off the west coast of Vancouver Island. New recruitment consistent with the 2000 year-class was detected by the west coast Vancouver Island shrimp survey in the shallowest trawl depths (< 200 m) in 2000 through 2002 and has been documented in previous assessments (Kronlund et al. 2003, Haist et al. 2004). Results from continental U.S. shelf and slope trawl surveys indicated two relatively strong incoming cohorts corresponding to the 1999 and 2000 year-classes (Schirripa 2002). The 2001 U.S. shelf survey biomass estimates were the highest in the 1980 to 2001 time series and were attributed to the 2000 year-class.

The synchrony of trawl industry observations and survey results suggested that the trawl observer data be examined for changes in sablefish catch rates and evidence of altered fishing behavior. Sablefish abundance in B.C. has increased from the low levels of the late 1990s through 2001 (Haist et al. 2004). This recent abundance increase, coupled with the reduction in sablefish quota that occurred in early 2002 and continued through the first half of 2004, may have created situations where trawl quota holders would alter fishing behavior or have difficulties staying within their allocation. In particular, analyses were conducted to attempt to find signals consistent with the onset of the 2000 year-class detected by the west coast Vancouver Island shrimp survey and U.S.

surveys. Also, previous sablefish assessments (Kronlund et al. 2003, Haist et al. 2004) have proposed that seasonal fluxes of fish into northern B.C. waters from Alaska significantly influence availability of sablefish to the trap fishery. This view has been supported indirectly by demonstrating seasonal patterns in the numbers of tag returns per ton landed and catch rates in trap fishery. Thus, examination of data from Area 5E trawl observer logs may provide further corroborative evidence for this hypothesis. Ideally changes in catch rates due to a year-class effect would be accompanied by corroborative biological data however commercial catch sampling of trawl caught sablefish is not adequate for this purpose.

Data selection

Trawl at-sea observer logbook data from 1996 to fall 2004 were extracted from the *PacHarvTrawl* database maintained at the Pacific Biological Station, Nanaimo, B.C. Data from fishing events were excluded from the analysis under the following conditions:

- Records where date information was missing;
- Records where tow duration was missing or 0;
- Records where latitude was missing;
- Records where the DFO Major Statistical Area was missing;
- Records where fishing occurred in the Strait of Georgia;
- Records where the catch of Pacific hake was greater than 3000 kg (an attempt to filter out the majority of targeted hake fishing).

Applications of the data selection criteria reduce the available fishing event observations from 191,710 to 156,811 records. Where depth dependent analyses were conducted, the observed fishing event data were extracted by depth interval prior to pre-processing for graphical display.

Graphical analyses of trends in catch, effort and CPUE

Graphical analyses were developed to examine changes in time trends for key variables of interest. Data from the west coast of Vancouver Island (Major Areas 3C and 3D), Queen Charlotte Sound (Major Areas 5A and 5B) and the west coast of the Queen Charlotte Islands (Major Area 5E) were extracted by area for analysis (Figure G.1). Consultation with representatives from the trawl industry suggested that data should be stratified by depth of fishing to separate components of the fishery that focus on a fresh versus frozen product and to accommodate depth stratification by species assemblages. There are clearly spatial components to the patterns in the data that are not accommodated by simple division into the major statistical areas and more detailed spatial stratification would produce trends that better reflect specific fishing grounds. However, for the purposes of this analysis, depth stratification was based on intervals suggested by trawl-sector representatives for each major area. Figure G.2 shows the depth distribution of individual fishing events (mean depth of tow) over time by major statistical area and clearly show clustering of fishing by time and depth related to different components of the fishery (e.g. deep fishing in Area 3C in winter months corresponds to directed fishing for thornyheads (*Sebastolobus*)).

The following variables were plotted by year and month: effort (total hrs fished), depth fished (m) by fishing event, sablefish catch (t), and sablefish discarded (t). For example, the multi-panel display in Figure G.3 shows plots of these variables for Area 3C fishing shallower than 550 m. Each panel contains vertical dotted lines that indicate the start of the calendar year and vertical dot-dash lines to indicate the start of the trawl fishing year on April 1. A corresponding multi-panel graph (e.g., Figure G.4) was developed to summarize trends in mean catch rates (kg/hr), mean depth fished (m), mean proportion of sablefish by weight in the total catch of all species, and the mean proportion by weight of sablefish discarded from the total sablefish catch. The data were processed in the following manner for each variable:

1. Observed fishing event data were aggregated by day within each year;
2. The mean of the daily observations was calculated;
3. The daily means from Step (2) were filtered by applying a running moving average (30 day centered window) to emphasize signal due to underlying seasonal and annual trends. No attempt was made to optimize the choice of window width.

It is important to keep in mind that the graphical results presented here reflect the characteristics of the data subject to the selection criteria and depth stratification; they should not be interpreted as overall summaries for the commercial trawl fishery.

Trends for Area 3C

Depth stratification at 550 m (300 fm) was suggested by trawl industry representatives as a generally appropriate break point for Area 3C. Figure G.2 shows a break in the depth distribution of fishing in the 550 to 600 m interval. For fishing conducted at depths shallower than 550 m in Area 3C (Figure G.3, Figure G.4):

1. **Effort**. Effort exhibited a regular seasonal pattern in concert with depth fished. More effort was expended in winter months and decreased modestly after 2001.
2. **Depth fished**. Fishing at depths of approximately 350 to 600 m reflects the winter fishery for Dover sole (*Microstomus pacificus*) which begins as early as November and continues until about May.
3. **Catch and discards**. Total catch of sablefish increased in 2001 as did the total amount of sablefish discarded. Note that the quota was reduced over the 2002 to mid 2004 period relative to pre-2002 levels.
4. **Proportion catch and discarded**. The proportion of sablefish in the total catch of all species has remained about the same over time at about 5 percent, peaking at about 10 percent in concert with summer fishing at shallower depths. The proportion of sablefish caught that are discarded cycled in opposition to depth of fishing prior to 2001, but increased in 2001 to a relatively high rate of approximately 80 percent over

the 2002 to March 2004 period. The discarding rate appears to have decreased when an increased quota was allocated in April 2004.

Mean daily catch rates exhibited strong seasonal patterns coincident with changes in the mean depth of fishing; fishing at shallower depths in the fall coincides with higher catch rates and more catch despite reduced effort. Catch rates achieved in the fall increased beginning in 2001 and have remained high relative to previous years. Catch rates in the winter fishery at average depths of about 300 m are relatively low. In 2003 and 2004 there was a tendency for higher catch rates to persist later in the calendar year, a phenomena consistent with trawl industry reports. The highest catch rates for sablefish in Area 3C were achieved beginning in 2001 when trawling occurred at shallow depths of about 100 to 200 m during the fall. Maximum sustained catch rates were the highest observed among the major statistical areas.

Fishing conducted deeper than 550 m in Area 3C largely reflects the thornyhead (*Sebastolobus*) fishery (Figure G.5, Figure G.6):

1. **Effort**. Effort has declined since market conditions peaked in 1998 and high operating costs (e.g., fuel) have mounted in recent years. Most effort now appears to occur in the late winter and early spring.
2. **Depth fished**. The cycling in depth fished is likely an artifact of the depth stratum boundary with the deepest extent of the Dover sole fishery being averaged into the deepwater thornyhead fishery. Coincident with decreased effort directed at thornyheads, fluctuations in mean depths fished have decreased.
3. **Catch and discards**. Total catch and the total amount of sablefish discarded decreased over time as market conditions declined for the thornyhead fishery.
4. **Proportion catch and discarded**. Sablefish represented between about 10 and 20 percent of the catch at depths deeper than 550 m. The discard rate is lower than for fishing shallower than 550 m, at about 50 percent by weight of sablefish. However an increase occurred in 2002 in synchrony with an increase in peak catch rates during winter fishing.

Mean catch rates peak when fishing occurs in the 600 to 800 m range during winter months. Peak catch rates have increased since 2001 though this may be confounded with a reduction in effort for thornyheads.

Trends for Area 3D

Interception of sablefish by trawl in the shallower waters of Area 3D has been characterized by industry members as an "avoidance fishery" when fishing for a fresh product. Thus, changes in CPUE may then be as much due to fleet behavior as changes in abundance. Depth stratification at 550 m (300 fm) was suggested by trawl industry representatives as a generally appropriate break point for Area 3D and Figure G.2 shows a break in the depth distribution of fishing in the 550 to 600 m interval. For fishing conducted at depths shallower than 550 m in Area 3D (Figure G.7, Figure G.8):

1. **Effort**. Effort was strongly seasonal and coincides with depth of fishing. A relatively consistent pattern of more effort during winter to spring months has occurred since 1998.
2. **Depth fished**. Fishing at depths of approximately 350 to 600 m reflects the winter fishery for Dover sole (*Microstomus pacificus*) which begins as early as November and continues until about May.
3. **Catch and discards**. Total catch of sablefish tended to increase over the 2001 to 2004 period as has the total amount of sablefish discarded. However the catches and discards are at about half the corresponding levels in Area 3C.
4. **Proportion catch and discarded**. The proportion of sablefish in the total catch of all species has remained low at about 5 percent, peaking in concert with summer fishing at shallower depths. The proportion of sablefish caught that are discarded fluctuated between 20 and 80 percent in opposite cycle to depth of fishing throughout the available time series.

Mean daily catch rates exhibit strong seasonal patterns coincident with changes in the mean depth of fishing; fishing at shallower depths in the late spring to fall months corresponds to higher catch rates. Peak catch rates have increased steadily over the 2001 to 2004 period, while the fluctuation in depth fished has remained relatively consistent. Very high catch rates for the stratum were achieved in mid 2004.

Fishing conducted deeper than 550 m in Area 3D largely reflects the thornyhead fishery (Figure G.9, Figure G.10):

1. **Effort**. Effort has declined since market conditions peaked in 1998 and high operating costs (e.g., fuel) have mounted in recent years. Most effort now appears to occur in the late winter and early spring.
2. **Depth fished**. The cycles in depth fished is likely an artifact of the depth stratum boundary with the deepest extent of the Dover sole fishery being averaged into the deepwater thornyhead fishery. The progression to shallower depths is likely due to less effort for thornyhead in deepwater.
3. **Catch and discards**. Total catch and the total amount of sablefish discarded decreased since 1999 as market conditions declined for the thornyhead fishery.
4. **Proportion catch and discarded**. Sablefish represent between about 10 and 20 percent of the catch at depths deeper than 550 m; peak proportions are achieved at shallower depths in winter. Seasonal influences are less pronounced for the discard rate than for fishing shallower than 550 m, but averages about the same level.

Mean daily catch rates deeper than 550 m exhibit strong seasonal patterns coincident with changes in the mean depth of fishing. High catch rates occur during the shallowest fishing in the winter months. Peak catch rates appear to have declined at depths deeper than 550m from a high in 1998 to a low in 2001. Beginning in 2001, the peak catch rates have increased; this may be confounded with a trend to shallower fishing at these depths.

Trends for Area 5A

Depth stratification at 275 m (150 fm) was suggested by trawl industry representatives as a generally appropriate break point for Area 5A. Figure G.2 shows a clear concentration of fishing from about 75 to 300 m. For fishing conducted at depths shallower than 275 m in Area 5A (Figure G.11, Figure G.12):

1. **Effort**. Effort exhibited a strong seasonal pattern in synchrony with depth fished. More effort was expended in the late spring to fall months as fishing moves into the 120 to 160 m depth range. Effort has been relatively consistent since 1999.
2. **Depth fished**. On average, depth fished ranges seasonally between about 120 and 180 m over the time series.
3. **Catch and discards**. Peak monthly catches of sablefish have decreased considerably from a high in 2002. Discards have followed a similar pattern and the overall levels of catch are similar to those observed in Area 3D.
4. **Proportion catch and discarded**. Sablefish represent a relatively small proportion of the catch in Area 5A at depths shallower than 275 m. The rate of discards is uniformly high, i.e., a low retention rate, over the time series with a decreasing trend beginning at the start of the fishing year in April 2004.

Mean daily catch rates exhibit strong seasonal patterns coincident with changes in the mean depth of fishing; fishing at shallower depths in the late spring to fall produces the highest catch rates on average. Peak catch rates were relatively high in 2000 and 2002 and eased substantially beginning in 2003.

For fishing conducted deeper than 275 m in Area 5A the figures are not shown because the amount of catch is very modest, usually less than 4 t per month, relative to the shallower depths and other areas. However, the trends are summarized below:

1. **Effort**. Most effort is expended in the summer months and is much less than that expended in the shallower depth stratum. Effort over the 2000 to 2003 period was much greater than in previous years or during 2004.
2. **Depth fished**. The cycling in depth fished is likely an artifact of the depth stratum boundary. The deepwater fishery in Area 5A is almost exclusively restricted to summer months largely because of the Tide Marks closure from October 1 to May 31 that was instituted in the late 1980s (Fisheries and Oceans 2004).
3. **Catch and discards**. Total catch of sablefish and the total amount of sablefish discarded is modest relative to other areas. Monthly catches are synchronous with changes in effort and fishing depth. Industry remarked that there are no appreciable amounts of juvenile sablefish caught by trawl deeper than 275 m in Area 5A.
4. **Proportion catch and discarded**. Sablefish represented less than 10 percent of the catch and peak proportions were achieved at the deepest depths in summer. The discard rate ranges between about 40 and 80 percent, with more variability introduced by the increase in deepwater fishing beginning in 2000 as the thornyhead fishery extended northwards.

Mean daily catch rates exhibit seasonal patterns coincident with changes in the mean depth of fishing; fishing at shallower depths in the winter months when Tide Marks is closed resulted in higher catch rates. However, the signal is weak due to low effort.

Trends for Area 5B

Depth stratification at 275 m (150 fm) was suggested by trawl industry representatives as a generally appropriate break point for Area 5B to separate fishing by the fresh and frozen product components of the fleet. Figure G.2 shows a clear concentration of fishing from about 75 to 300 m in the summer which extends deeper to about 400 m in the winter months. Deeper fishing at about 600 to 1000 m starting in 2000 is presumably due to development of fishing for thornyheads. For fishing at depths shallower than 275 m in Area 5B (Figure G.13 and Figure G.14):

1. **Effort**. Effort exhibits a strong seasonal pattern in synchrony with depth fished. More effort was expended in the late spring to fall months as fishing moves into shallow waters at about 120 to 160 m depth on average. Effort tended to be greater from 2000 to 2003 than in previous years.
2. **Depth fished**. Depth fished ranged between 120 to 220 m on average over the time series. Depth of fishing in winter 2004 tended to be shallower than in 2000 to 2003.
3. **Catch and discards**. Peak monthly catches of sablefish have declined from a high in 2000 through 2004. Discards have followed a similar pattern and the overall levels of catch are similar to those observed in Area 3D.
4. **Proportion catch and discarded**. The proportion of sablefish in the total catch of all species has remained about the same over time at less than 5 percent. The proportion of sablefish caught that are discarded cycled in opposition to depth of fishing at about 80 percent. The discarding rate appears to have decreased when an increased quota was allocated in April 2004.

Results for fishing deeper than 275 m in Area 5B are not shown due to the low monthly catches, usually less than 5 or 6 t. In brief, the mean daily catch rates exhibit strong seasonal patterns coincident with changes in the mean depth of fishing; fishing at shallower depths in the late spring to fall coincides with higher catch rates. Peak catch rates achieved in the fall increased relative to 1998 and 1999 beginning in 2000 and remained high until late 2002. Catch rates beginning in April 2003 have remained low without characteristic seasonal fluctuation. The range of depths fished has decreased on average over this period.

Trends for Area 5E

Depth stratification at 311 m (170 fm) was suggested by trawl industry representatives as a generally appropriate break point for Area 5E to separate fishing by the fresh and frozen product components of the fleet. Industry representatives noted that typically fishing depths of 366 to 400 m (200 to 220 fm) produced peak sablefish production for trawl gear in Area 5E. Figure G.2 shows a demarcation of fishing depths between about 200 and 600 m and deepwater fishing between about 600 and 1000 m that began in about 2000 as the thornyhead fishery expanded into new grounds in Area 5E. For fishing conducted at depths shallower than 311 m in Area 5E the sablefish catch is very low, usually less than 1 t per month. Figures are not shown, but trends are summarized below:

1. **Effort**. Effort exhibited a regular seasonal pattern in concert with depth fished but at monthly levels much less than those observed for other areas. More effort was expended in the late fall to early spring months as fishing moved into 220 to 240 m depth on average. Annual effort was greater from 2000 to 2004 than in prior years.
2. **Depth fished**. Depth fished ranged between about 220 and 270 m on average over the time series with unusually shallow fishing in the last half of 2003 and mid-2004.
3. **Catch and discards**. Monthly catches and discards of sablefish were low.
4. **Proportion catch and discarded**. The proportion of sablefish in the total catch of all species has remained about the same over time at less than 5 percent. The discard rate tended to increase in winter months.

Overall effort is low at depths shallower than 311 m in Area 5E. Mean daily catch rates decline as depth of fishing decreases. Catch rates achieved in the fall decreased from 1997 to 2001, increased in 2002 and have since remained at about the 2002 level

For fishing conducted deeper than 311 m in Area 5E (Figure G.15, Figure G.16):

1. **Effort**. Effort has increased substantially in the summer months due to the increased fishing at depths of about 550 to 1000 m beginning in 2000.
2. **Depth fished**. Seasonal fluctuations in depth fished were introduced with the development of the deepwater fishery beginning in 2000; prior to 2000 the mean depth of fishing deeper than 311 m was relatively constant.
3. **Catch and discards**. Total catch of sablefish and the total amount of sablefish discarded has increased coincident with the development of deepwater trawling. Monthly catches are largest in the summer months beginning in 2000.
4. **Proportion catch and discarded**. Sablefish represented about 5 to 15 percent of the total catch, with higher proportions in summer months, with the exception of 2002 when the late fall and early winter produced the highest values. The discard rate ranged between 20 and 60 percent, with greater variability introduced with the commencement of deepwater fishing in 2000.

Mean daily catch rates exhibited seasonal patterns coinciding with changes in the mean depth of fishing; fishing at shallower depths in the winter months results in higher sablefish catch rates. Peak catch rates in winter months have increased steadily since 2000. This trend may be due to increased abundance or exploitation of new grounds.

In summary, results for Areas 3C and 3D are consistent with the occurrence of juvenile sablefish in the WCVI shrimp survey and U.S. shelf and slope surveys. At depths shallower than 550 m in Area 3C, fall catch rates increased beginning in 2001 and have remained high relative to previous years. Catch rates peak when fishing occurs at about 100 to 200 m. November to May catch rates at depths deeper than 550 m peaked in 2000, fell, and have increased to 2004. Maximum sustained catch rates were the highest observed in Area 3C among the major statistical areas. For fishing shallower than 550 m in Area 3D, the trends are similar though the relative magnitude of the increase starting in 2001 is not as pronounced.

For fishing at depths shallower than 311 m in Area 5E, peak catch rates in winter months have increased steadily since 2000. It is not clear whether this trend reflects a greater availability of sablefish as detected by the standardized survey and commercial trap fishery beginning in 2002 and substantiated in 2003 and 2004, or whether exploitation of new grounds is leading to greater catch of sablefish by trawl gear.

This graphical analysis is somewhat cursory having crude spatial resolution. Some of the time trends are likely confounded by depth of fishing effects and behavioral changes by trawl fishers in the face of lower sablefish quotas from 2002 until April 2004 (i.e., avoidance fishing). Nevertheless, further refinement of the analyses and corroboration with adequate at-sea observer biological sampling may lead to improved understanding of year-class strength at depths shallower than the sablefish trap fishery.

G.2 Length frequency data from trawl fishing

Sablefish length frequency data from the trawl at-sea observer program were last examined by Kronlund et al. (2003). For that analysis, sablefish biological sampling data collected through at-sea observers were selected from commercial tows conducted in Hecate Strait and Queen Charlotte Sound. Length frequency data from samples designated as “random samples” or “total catch” were utilized to avoid bias due to including stratified or selected samples. The length frequency data were summarized by year and quarter to determine whether year-class modes could be distinguished, with Hecate Strait data showing clearer patterns of modal progression. An adequate number of biological samples for tracking year-class growth were available in Hecate Strait only for the two-year period from mid-year 1998 through mid-year 2000. No further sablefish length frequency data has been collected since that analysis. There is an apparent year-class appearing in the samples in the fourth quarter of 1998 at a modal length of 24 cm (Figure G.17). Given the timing of sample collection, fish of this size are consistent with age 0+ or the 1998 year-class (see for example McFarlane and Beamish 1983, Rutecki and Varosi 1997). This year-class can be followed through the sampling data to the third quarter of 2000 where the modal length is 45 cm (age 2+).

Other than Hecate Strait, sablefish length frequency data obtained from at-sea observers are most comprehensive for the west coast of Vancouver Island (Figure G.18). Data for Areas 3C and 3D show the potential for detecting year-classes with the second quarter of 2001 showing clear modes at 25 and about 45 cm. However, the level of sampling has been low since 2001 and samples in 2004 (not shown) continue to be collected infrequently. Data for other major areas is rather sparser in comparison.

Collection of length frequency data by the at-sea observer program would provide valuable growth information for juvenile sablefish. Unlike the Hecate Strait trawl survey (Choromanski et al. 2001) samples obtained from the Hecate Strait at-sea observer program do not appear to consistently encounter age 1+ sablefish (Kronlund et al. 2003). The commercial trawl gear used in Hecate Strait has considerably larger cod-end mesh size than the research gear used in the Hecate Strait survey so smaller sablefish are likely less vulnerable to the commercial gear. However, because the trawl fishery operates throughout the year, it provides on opportunity to obtain samples where year-classes can be tracked through modal progression of size distributions. This would allow inter-annual variability in juvenile sablefish growth to be examined, and potentially to corroborate year-classes that are sampled by various groundfish trawl surveys (e.g., Queen Charlotte Sound, Hecate Strait, and west coast Vancouver Island trawl surveys).

G.3 Literature Cited

Choromanski, E.M., Fargo, J., and A.R. Kronlund. 2001. Species assemblage trawl survey of Hecate Strait, CCGS W.E. Ricker, May 31-June 13, 2000. Can. Data Rep. Fish. Aquat. Sci. 1085.

Fisheries and Oceans Canada. 2004. Integrated fishery management plan: sablefish, August 1, 2004 to July 31, 2005. Fisheries and Oceans Canada. 108 p.

Haist, V., Kronlund, A.R., and M.R. Wyeth. 2004. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2003 and advice to managers for 2004. PSARC Working Paper G2004-1.

Kronlund, A.R., V. Haist, M. Wyeth, and R. Hilborn. 2003. Sablefish (*Anoplopoma fimbria*) in British Columbia, Canada: stock assessment for 2002 and advice to managers for 2003. Can. Sci. Adv. Sec. Res. Doc. 2003/071.

McFarlane, G.A. and R.J. Beamish. 1983. Preliminary observations on the juvenile biology of sablefish (*Anoplopoma fimbria*) in waters off the west coast of Canada. p. 119-136. *In* Proceedings of the Second Lowell Wakefield Fisheries Symposium, Anchorage, AK. Alaska Sea Grant Report 83-3.

Rutecki, T.L. and E.R. Varosi. 1997. Distribution, age, and growth of juvenile sablefish, *Anoplopoma fimbria*, in southeast Alaska. *In* Biology and management of sablefish, *Anoplopoma fimbria*. p. 45-54. NOAA Technical Report NMFS 130.

Schirripa, M.J. 2002. Status of the sablefish resource off the continental U.S. Pacific coast in 2002. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 200, Portland, OR 97220-1384.

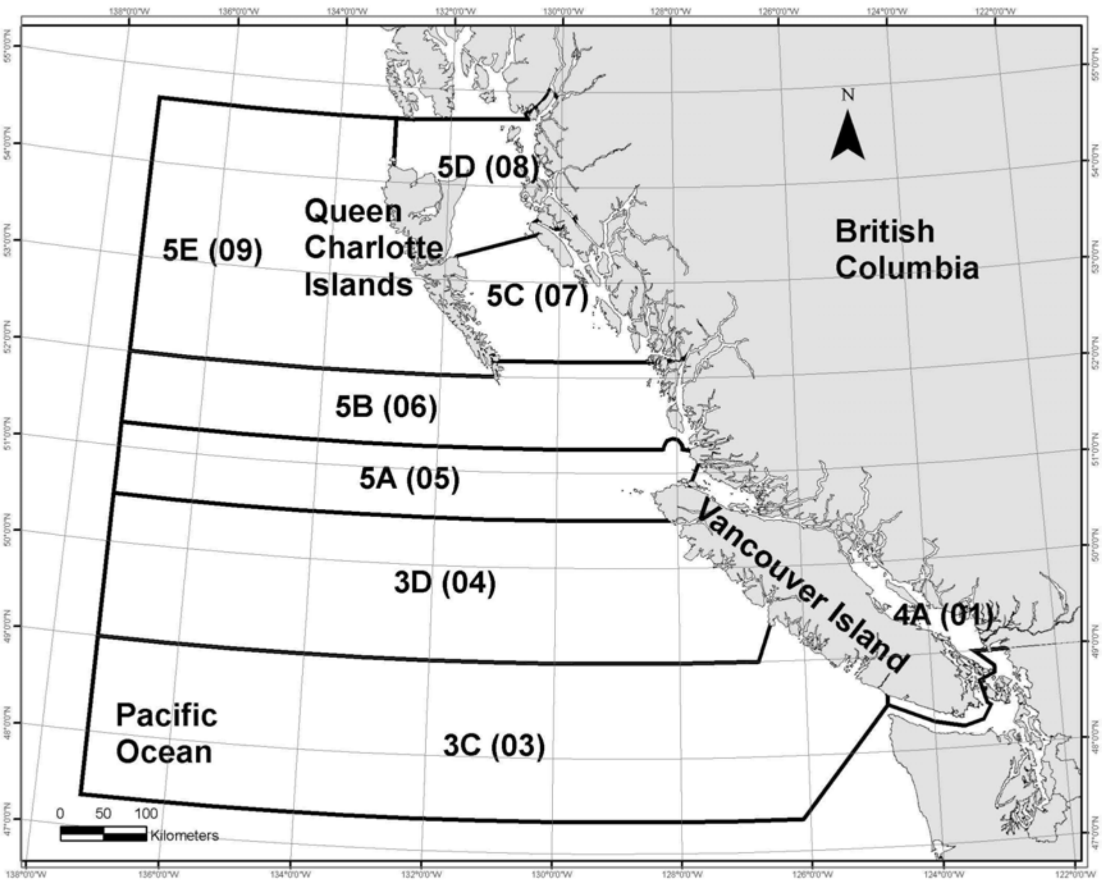

Figure G.1 Major Statistical Areas in British Columbia.

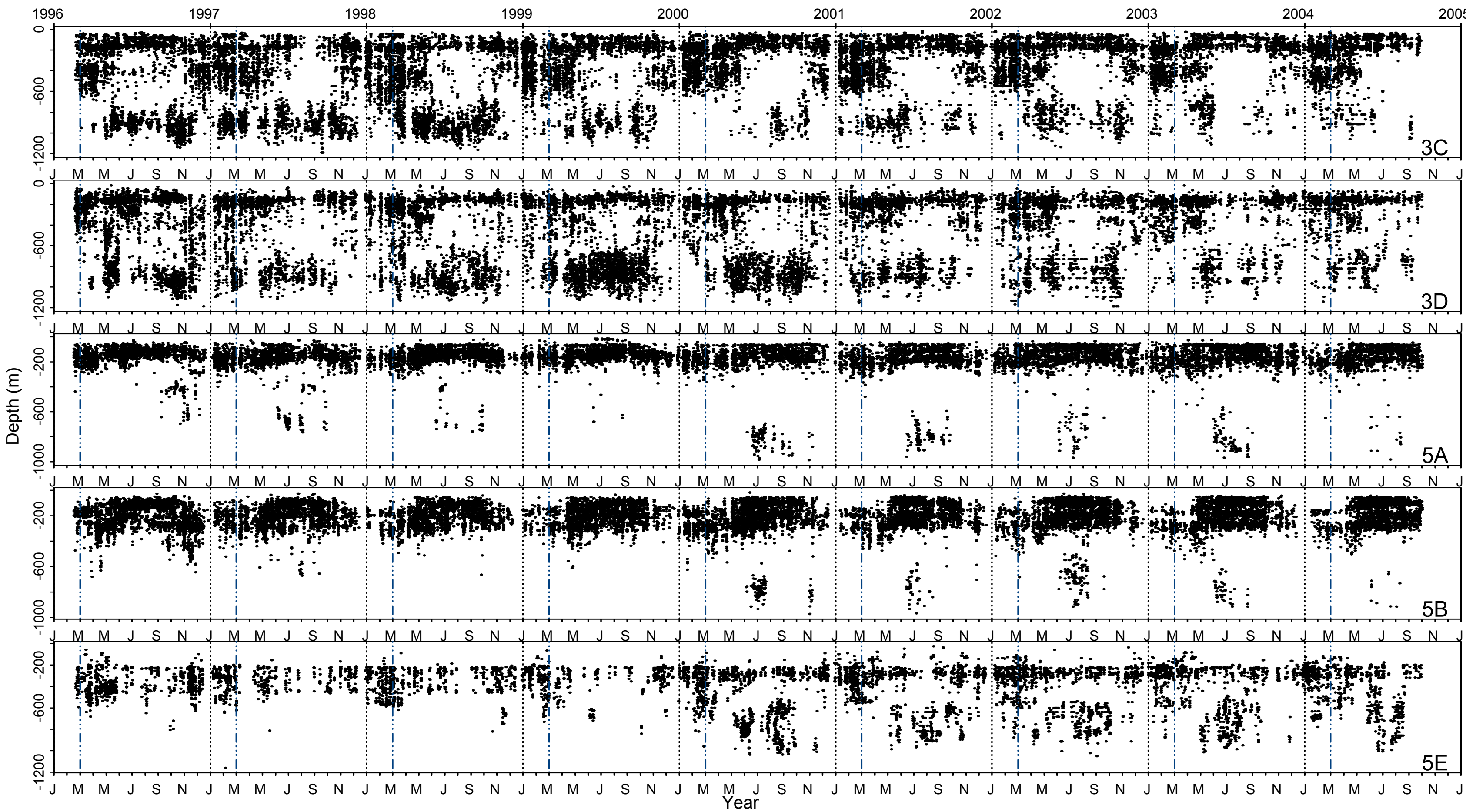

Figure G.2 Depth distribution of fishing events time of year and major statistical area. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

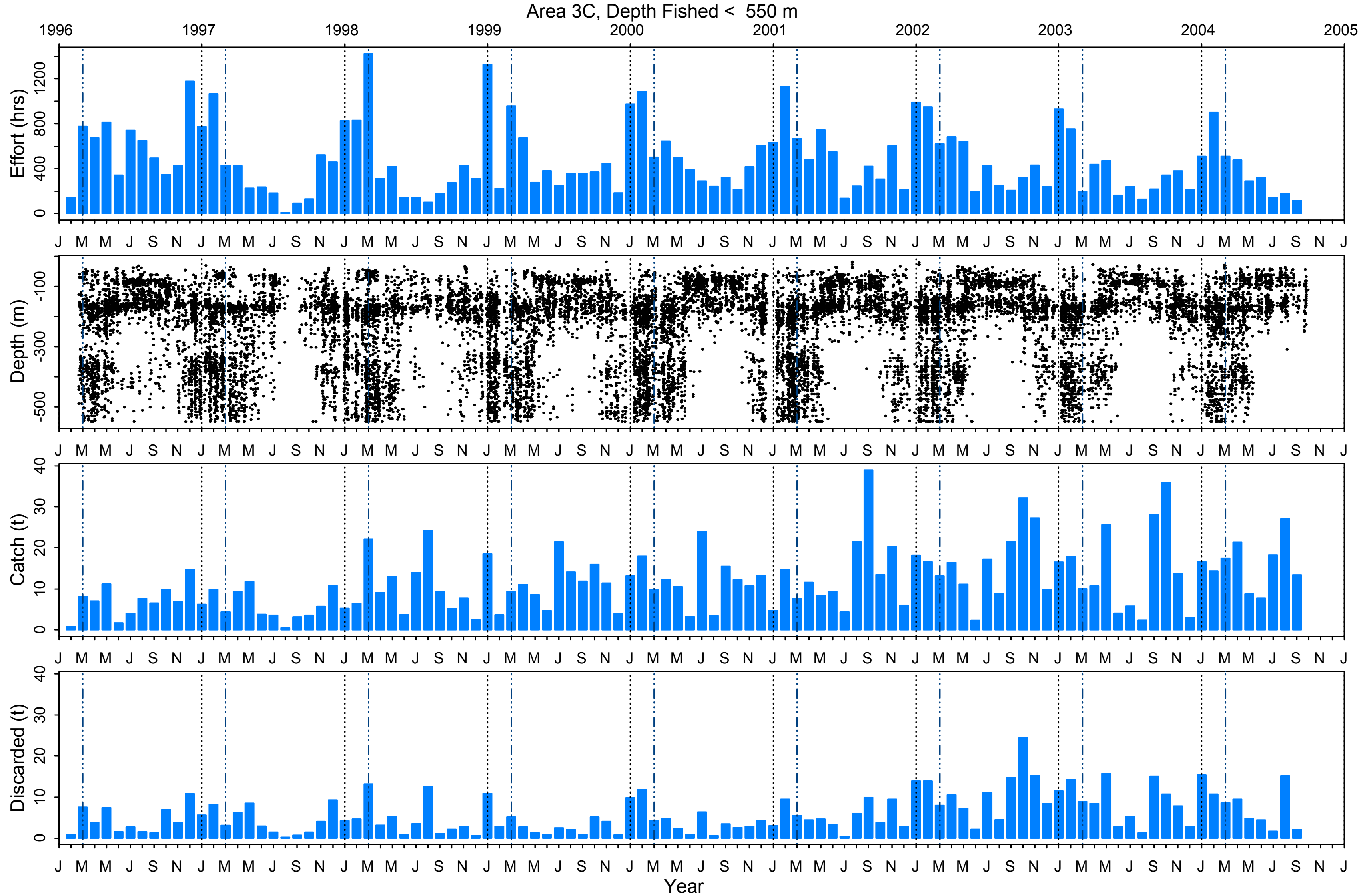

Figure G.3 Selected catch and effort totals by month within year for major statistical area 3C. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

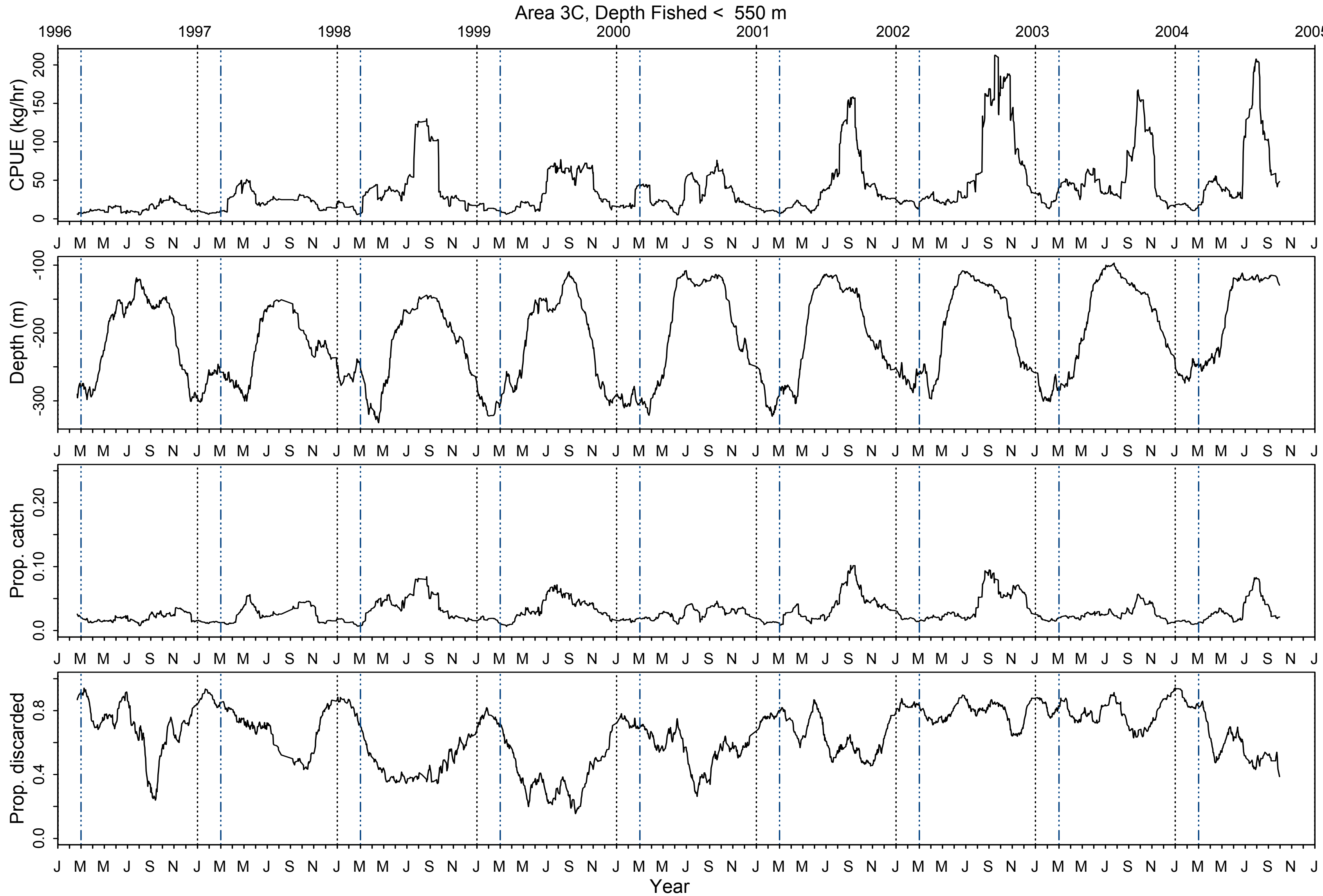

Figure G.4 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 3C. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

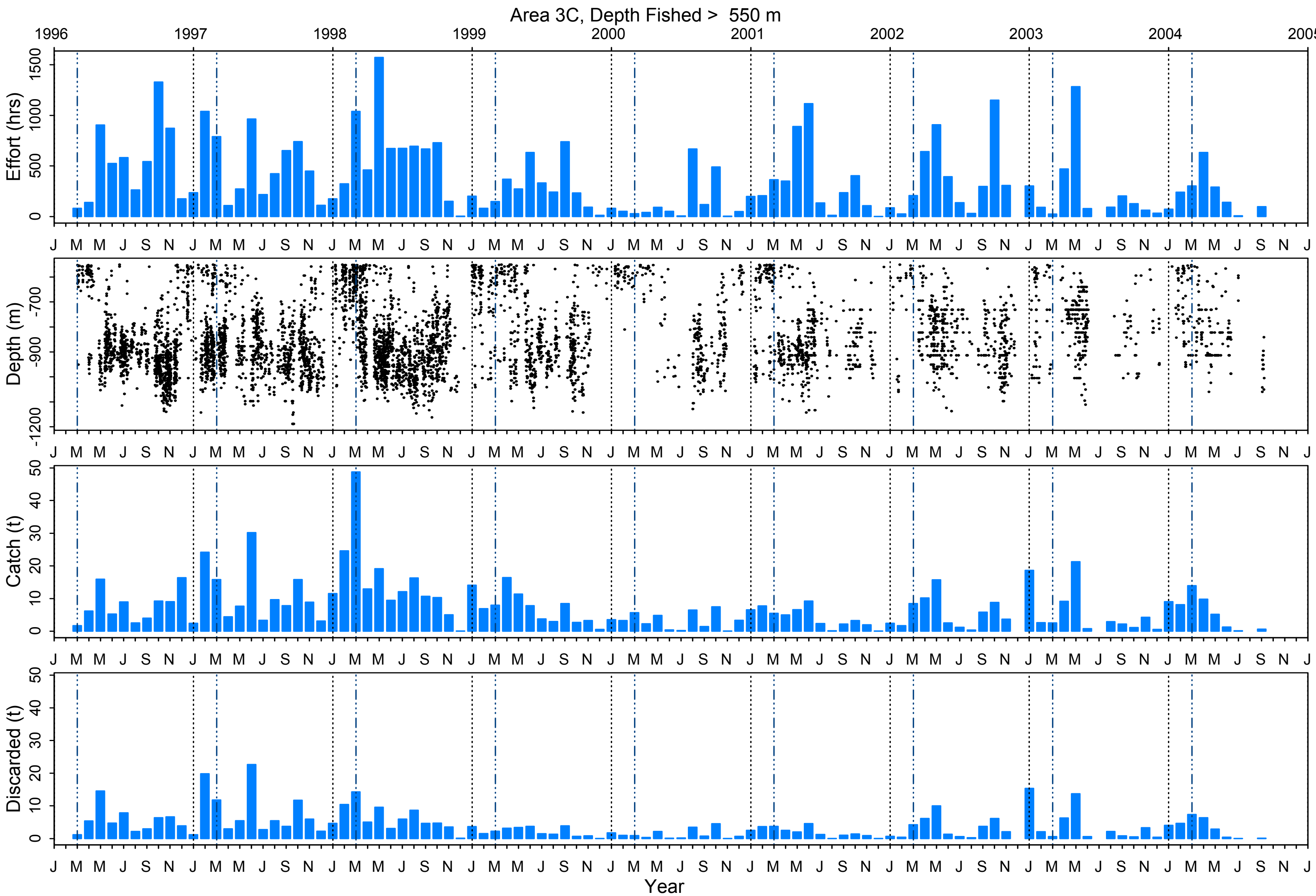

Figure G.5 Selected catch and effort totals by month within year for major statistical area 3C. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

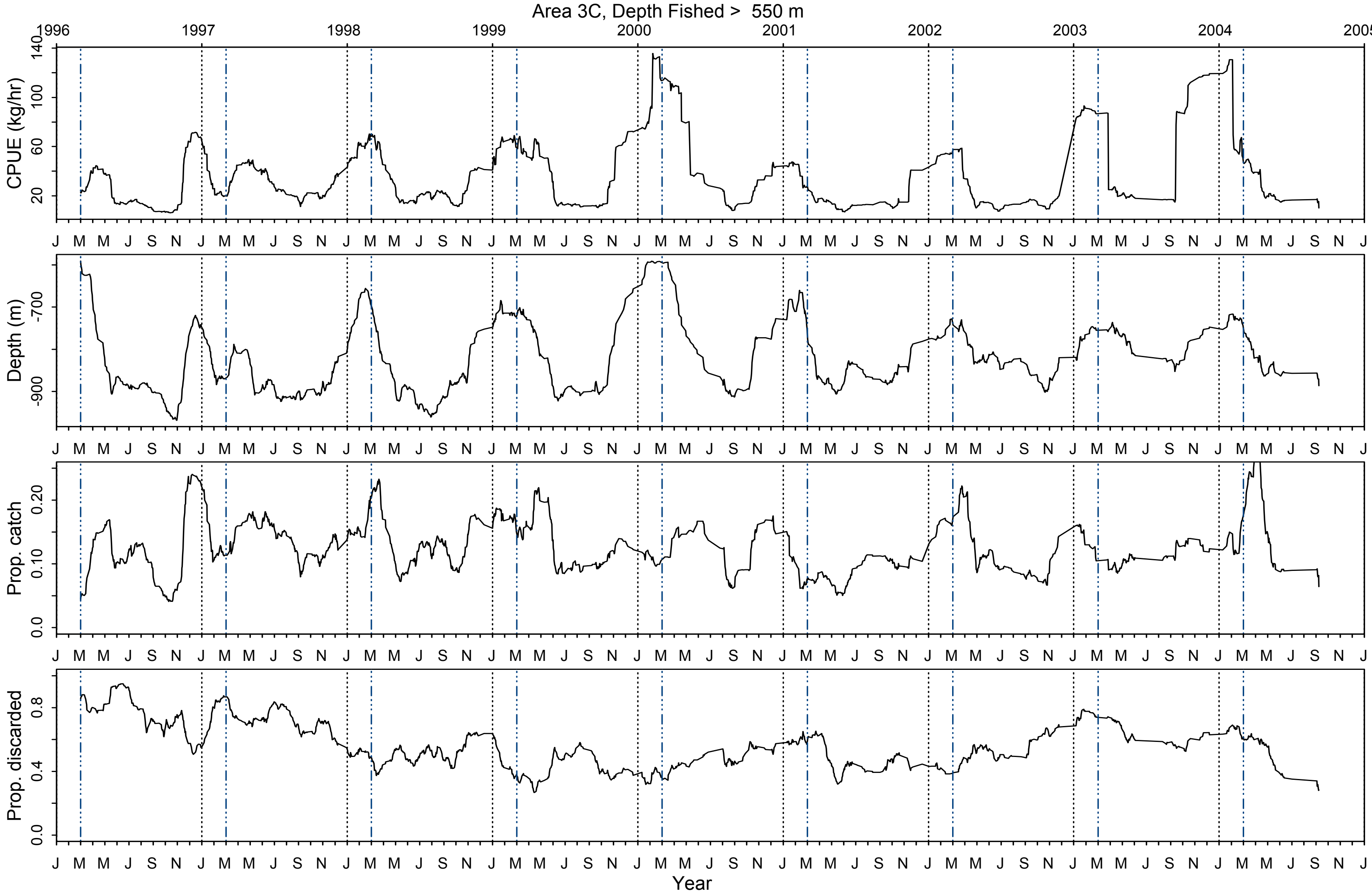

Figure G.6 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 3C. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

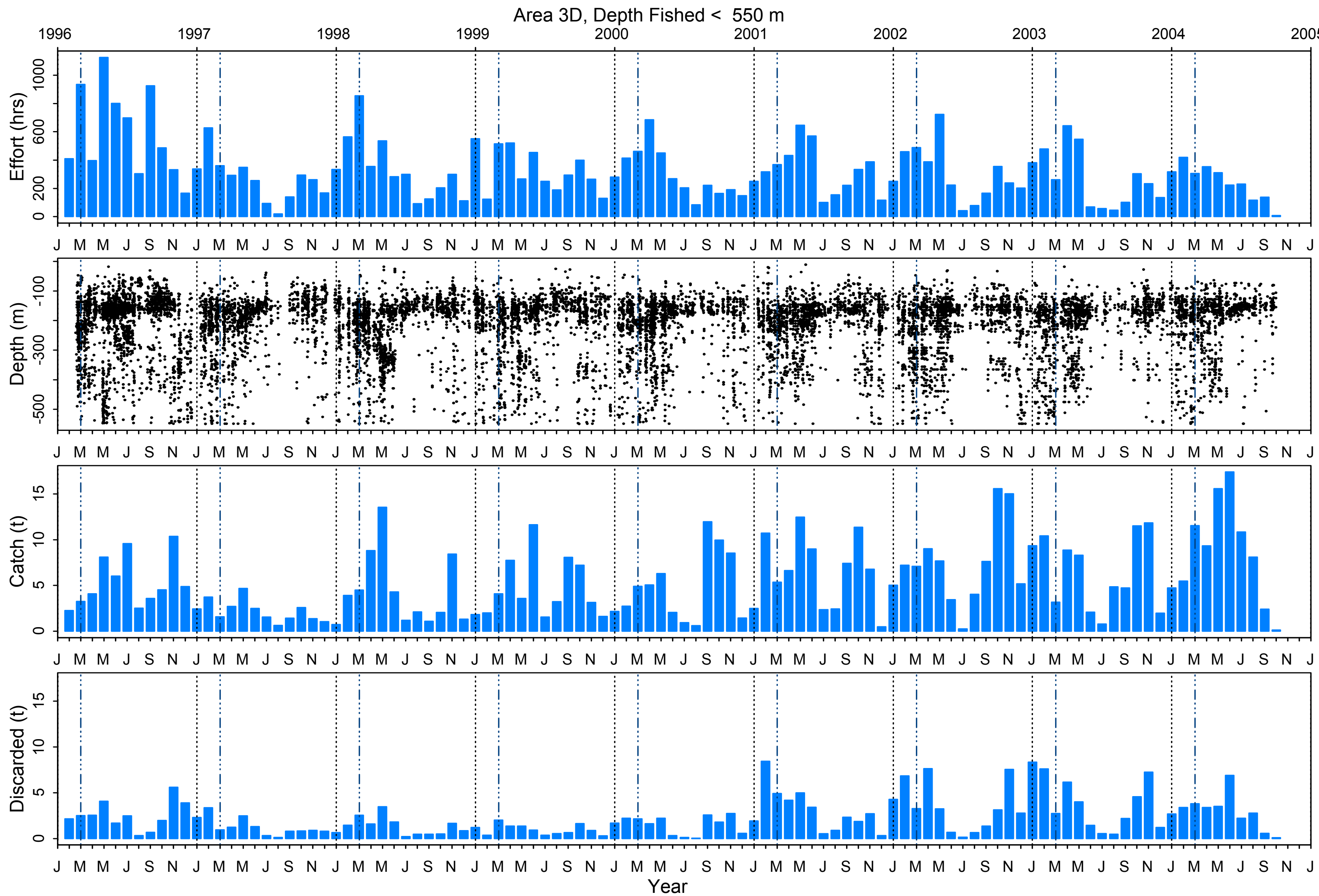

Figure G.7 Selected catch and effort totals by month within year for major statistical area 3D. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

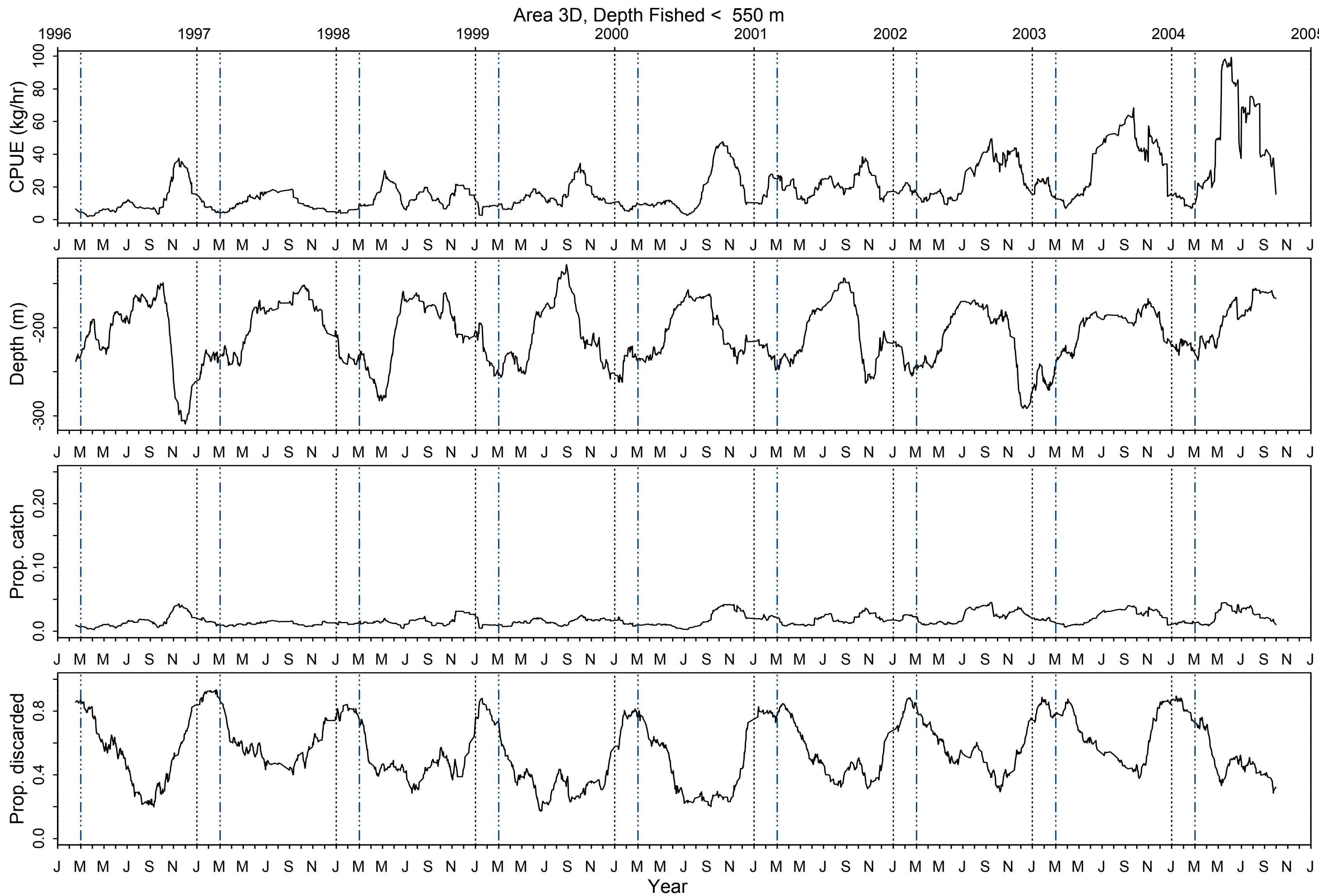

Figure G.8 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 3D. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

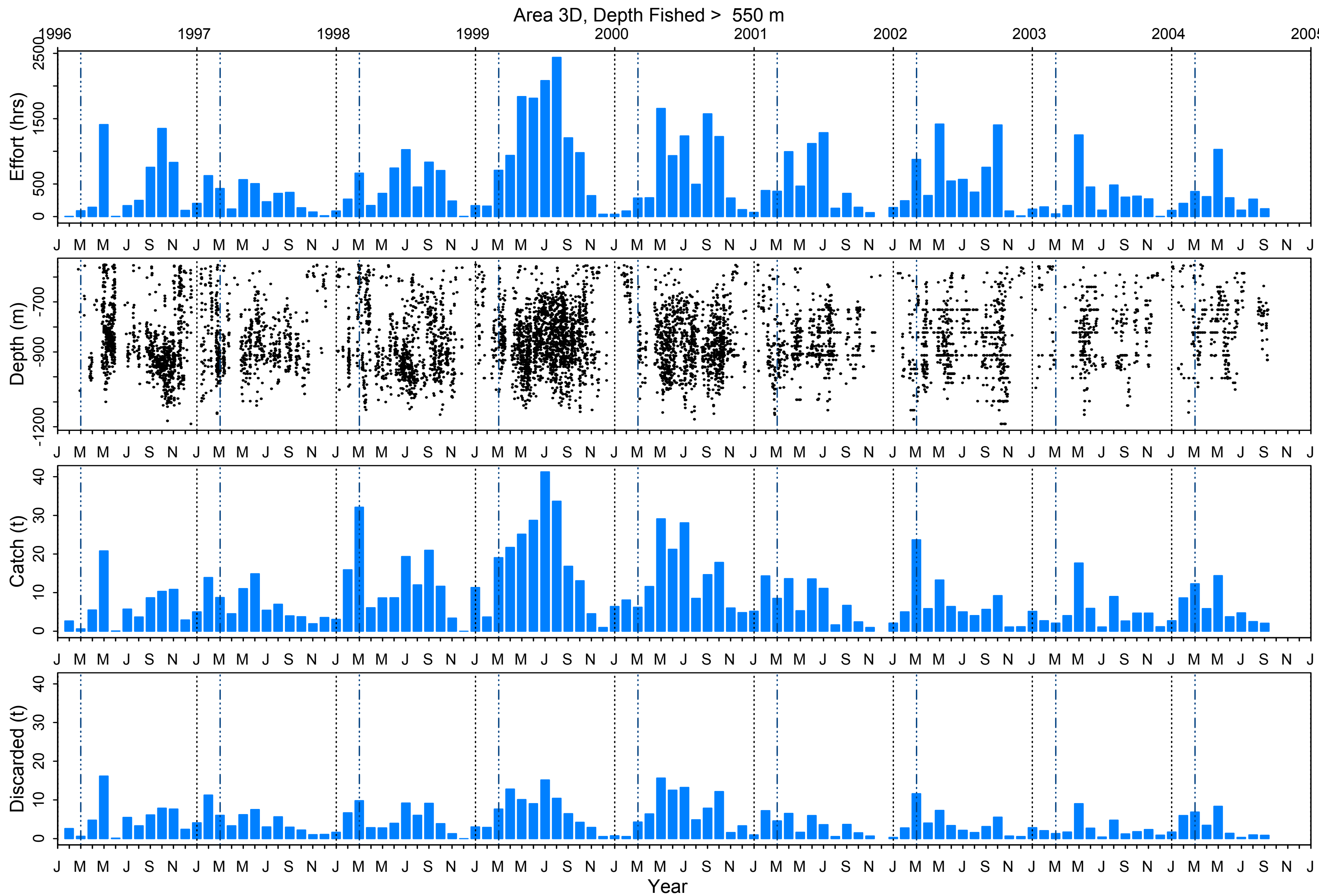

Figure G.9 Selected catch and effort totals by month within year for major statistical area 3D. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

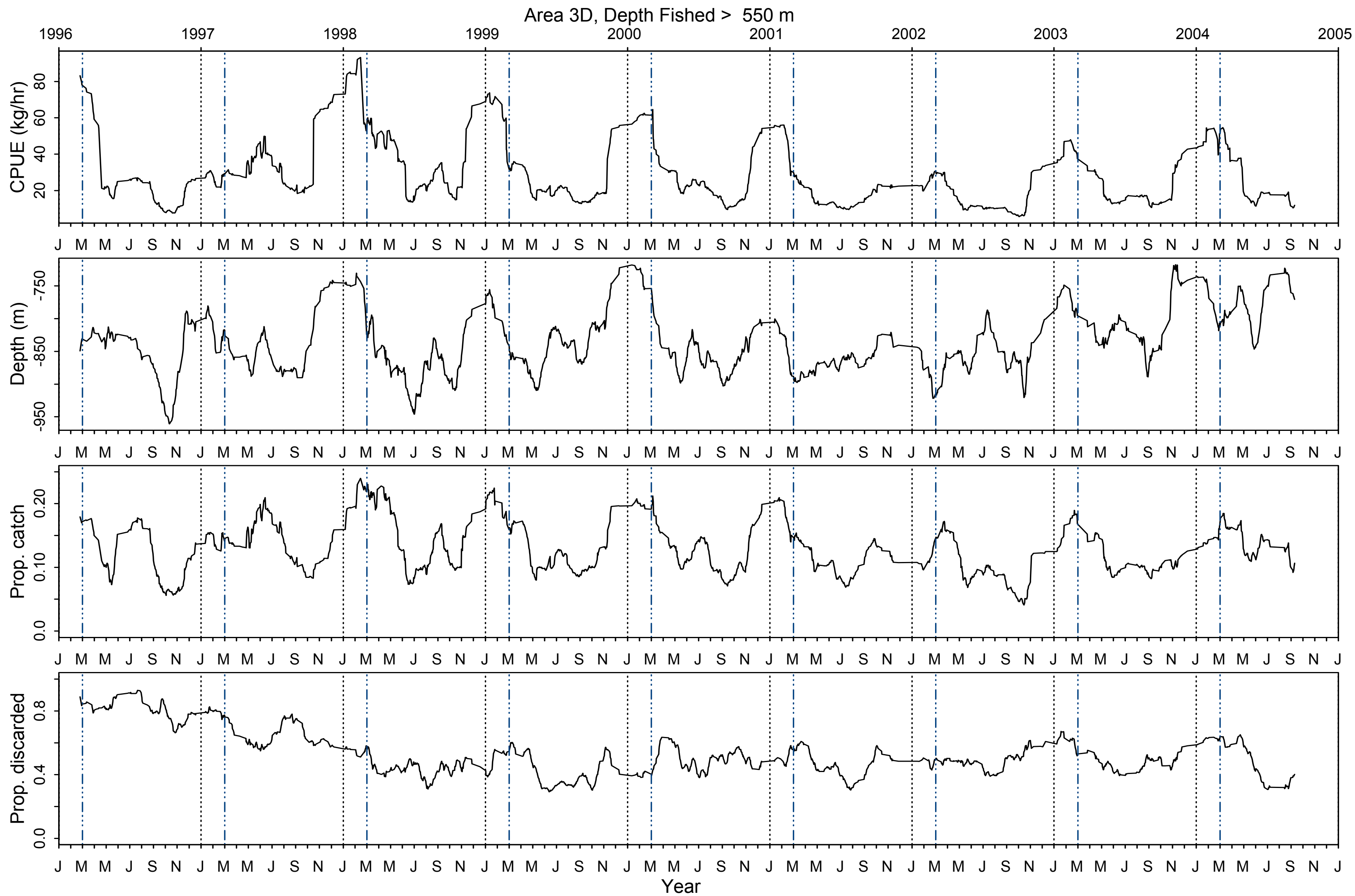

Figure G.10 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 3D. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

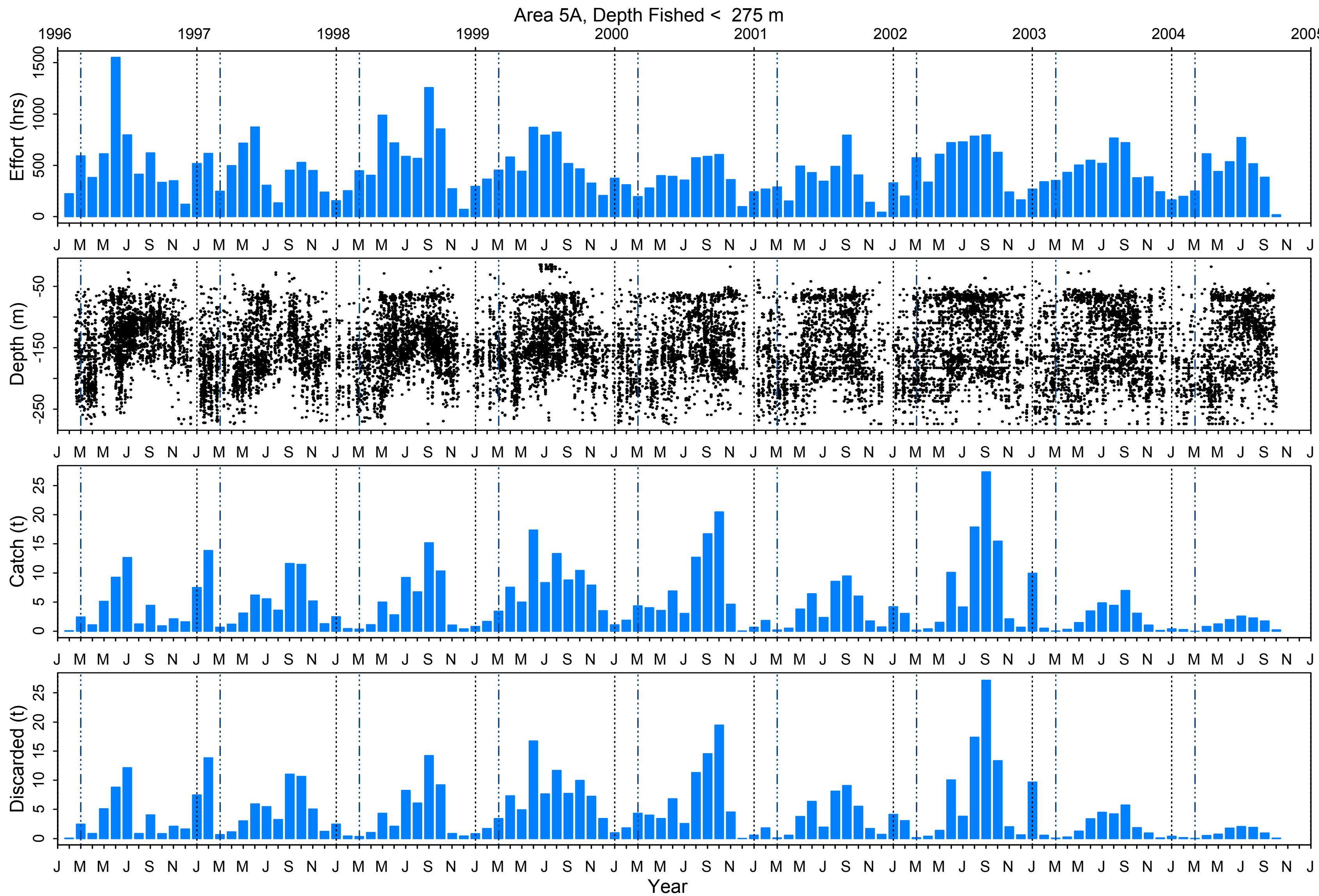

Figure G.11 Selected catch and effort totals by month within year for major statistical area 5A. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

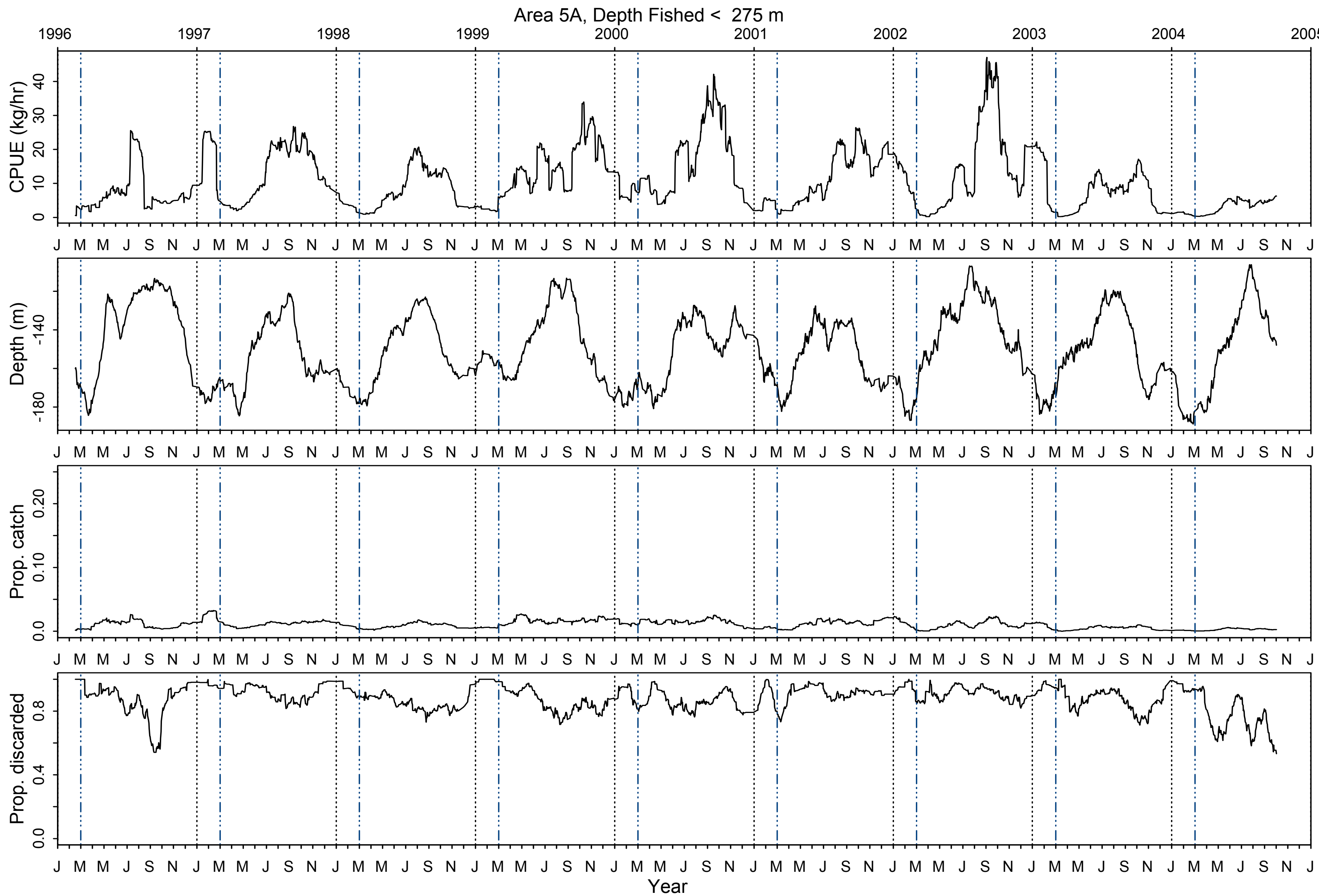

Figure G.12 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 5A. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

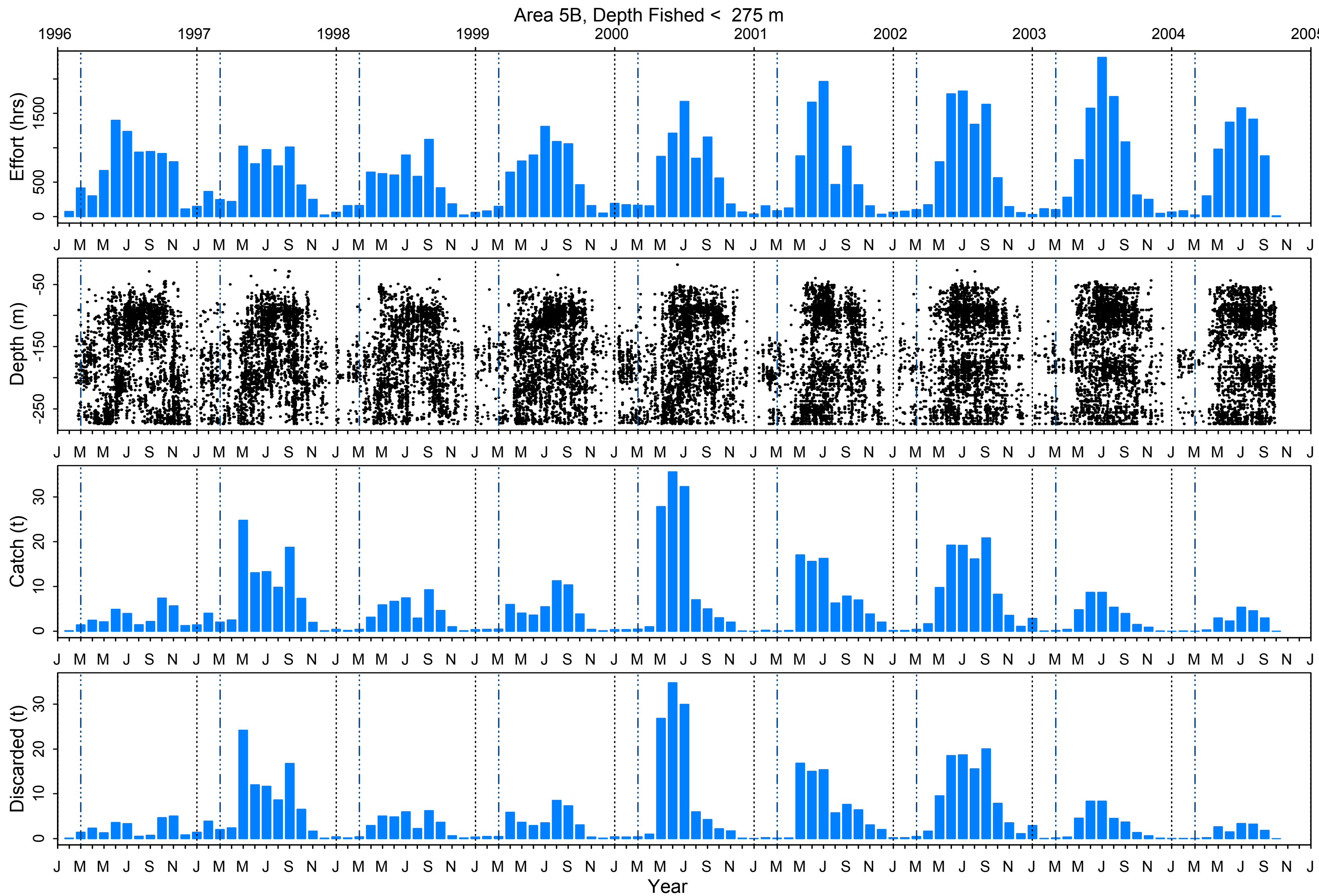

Figure G.13 Selected catch and effort totals by month within year for major statistical area 5B. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

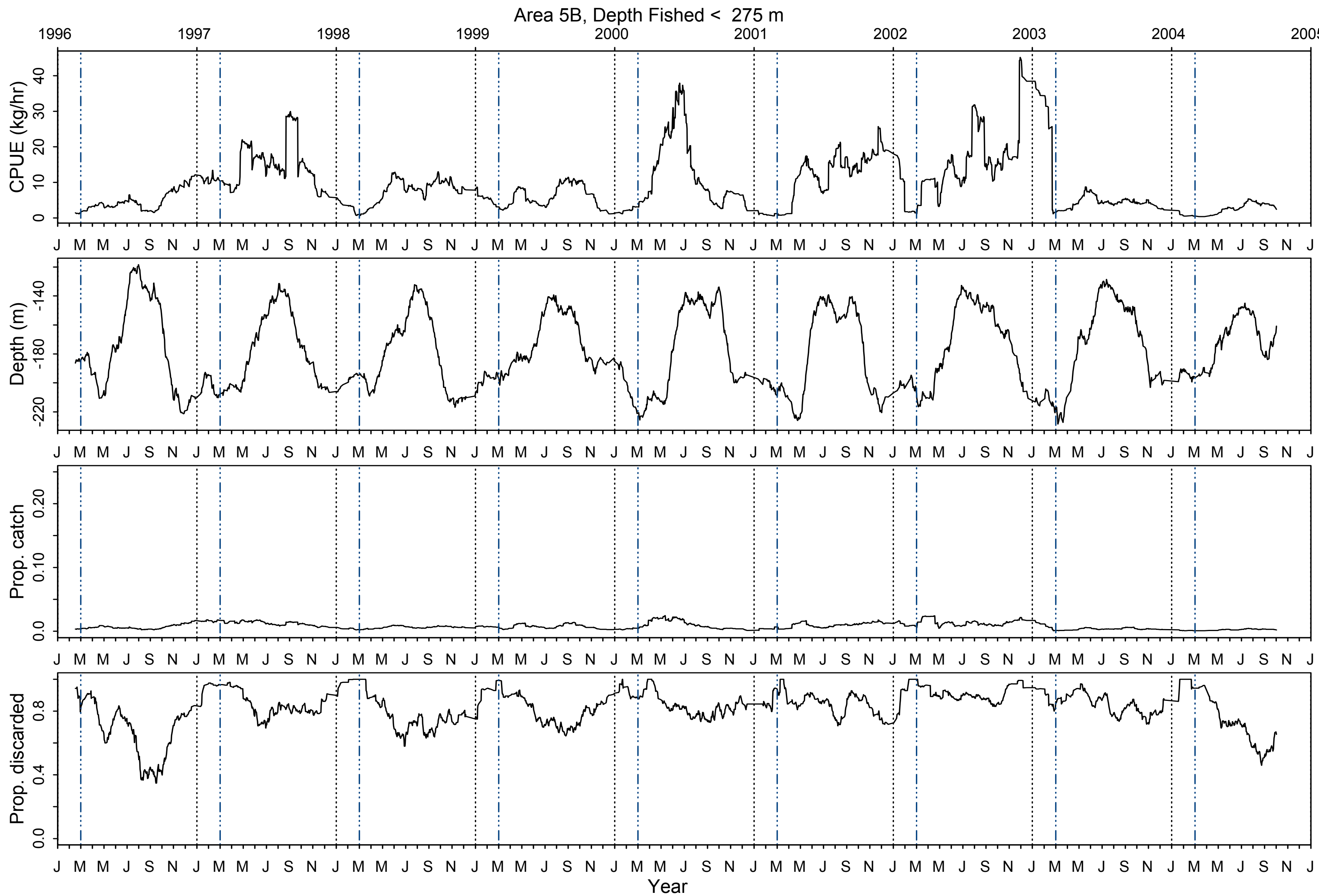

Figure G.14 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 5B. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

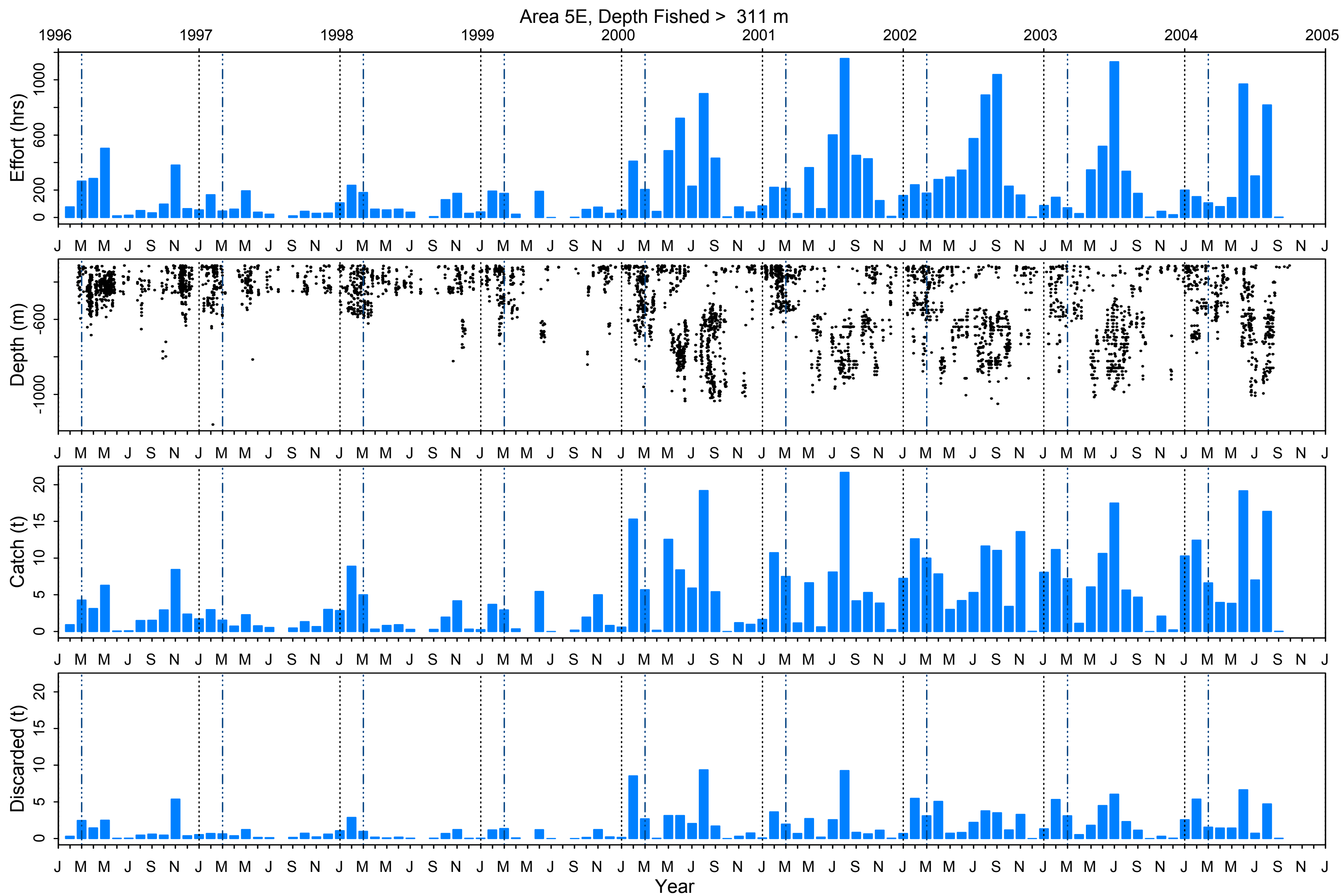

Figure G.15 Selected catch and effort totals by month within year for major statistical area 5E. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

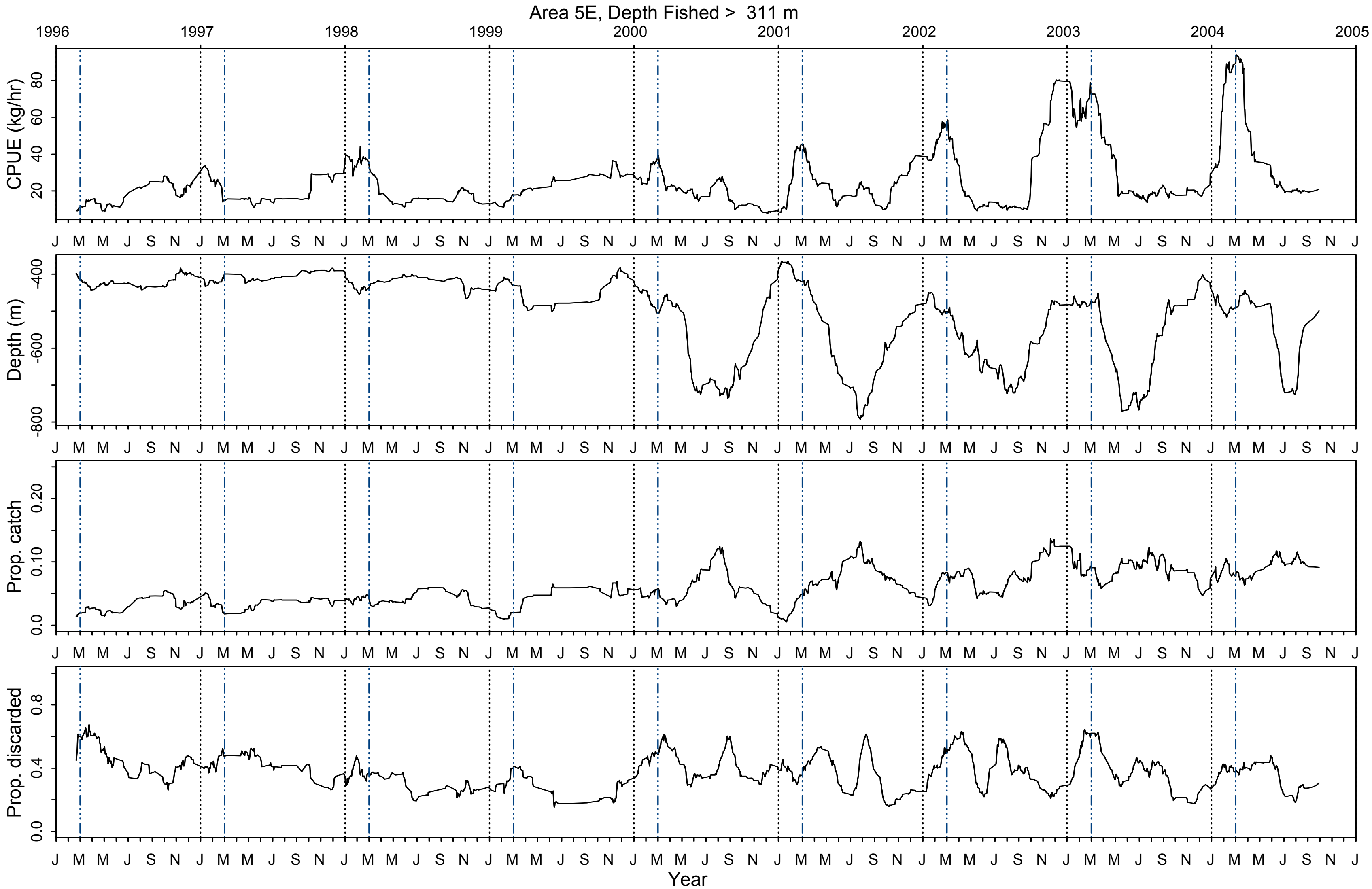

Figure G.16 Moving average trends for catch rate, depth, proportion sablefish in total catch, and proportion of sablefish discarded for major statistical area 5E. Vertical dotted and dot-dash lines denote the start of the calendar and fishing years, respectively.

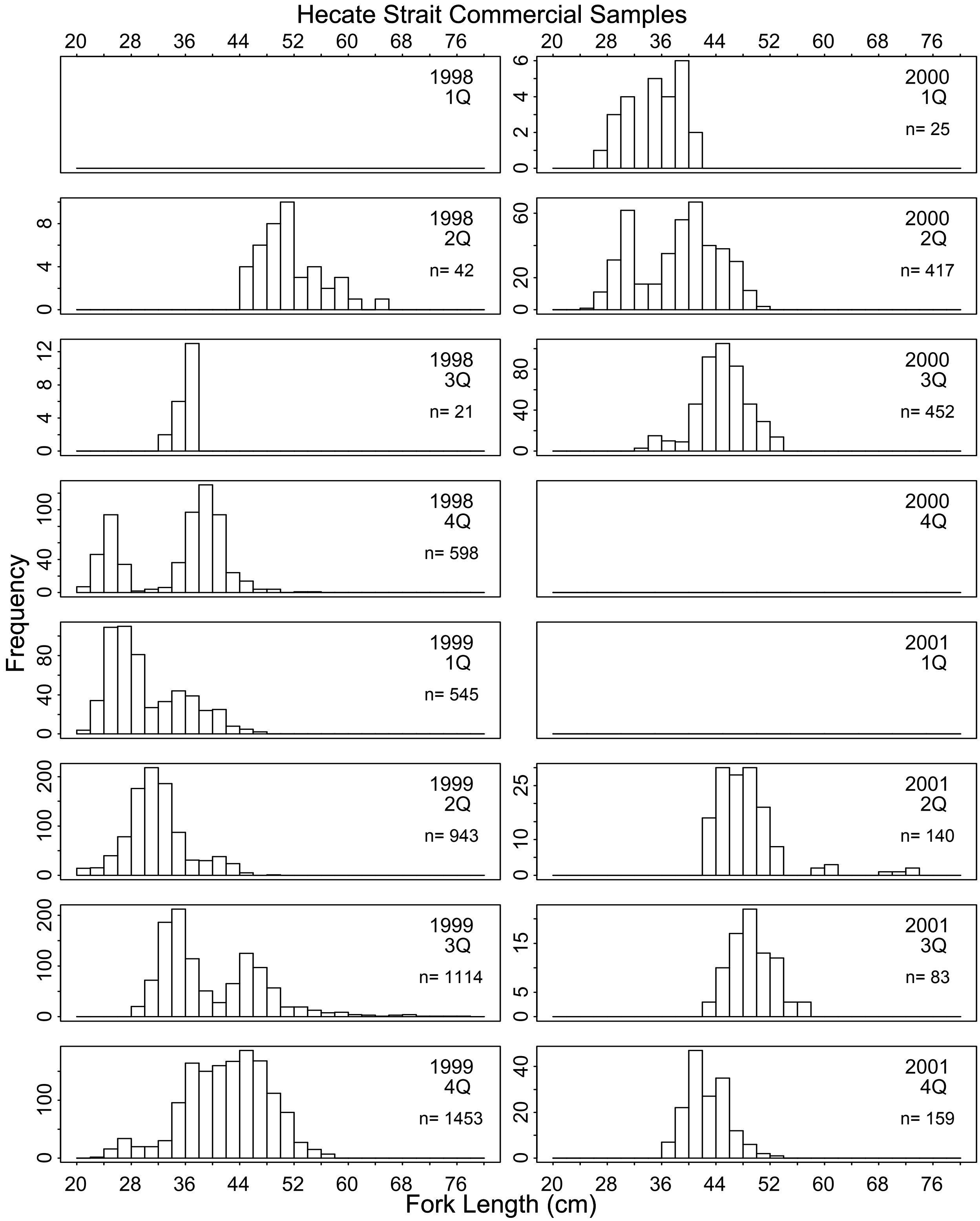

Figure G.17 Sablefish length frequency distributions by year and quarter from "random" or "total catch" observer samples taken in Hecate Strait (Major Areas 5C, 5D).

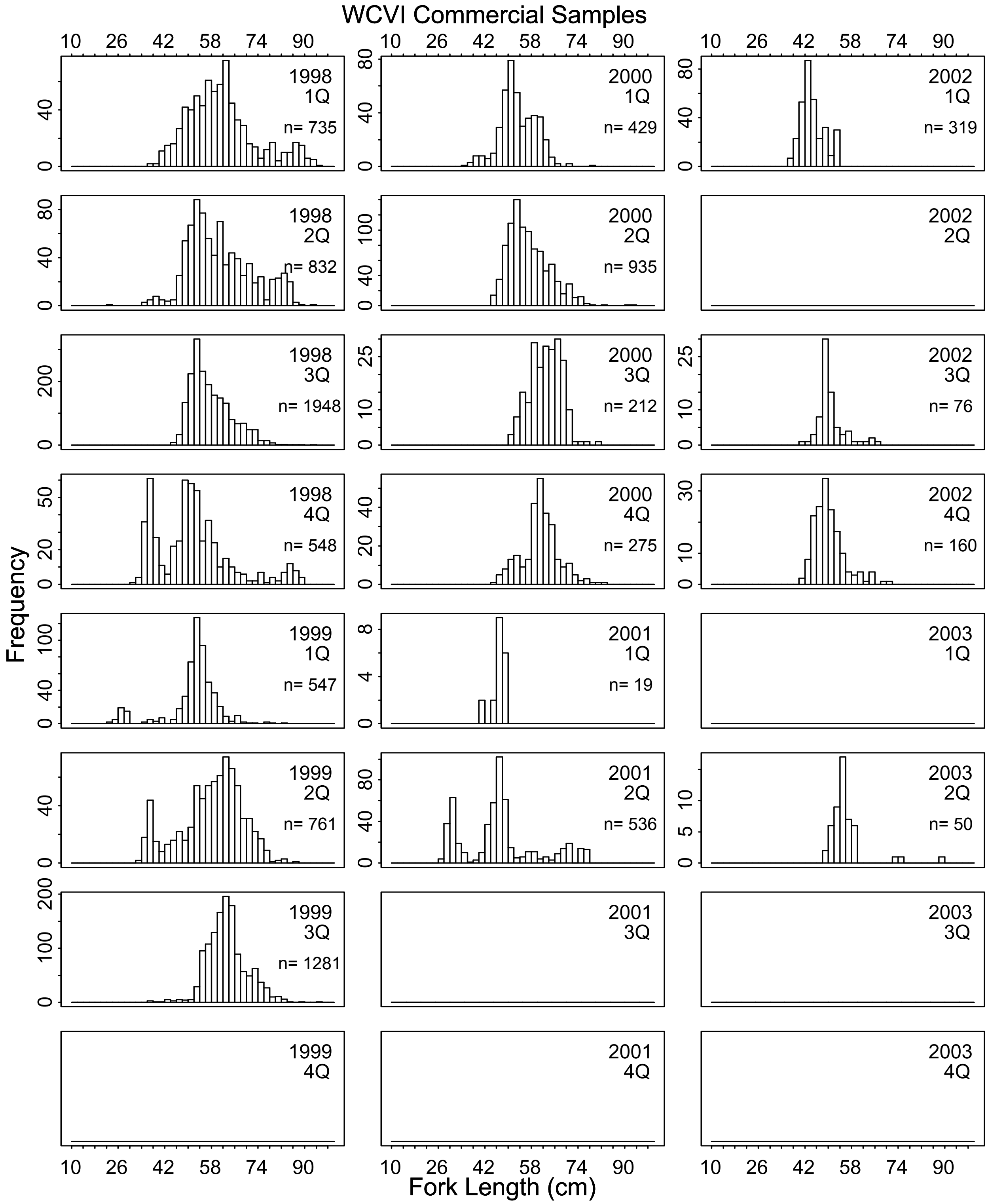

Figure G.18 Sablefish length frequency distributions by year and quarter from “random” or “total catch” observer samples taken off the WCVI (Major Areas 3C and 3D). Data from 2004 not shown.

APPENDIX H SABLEFISH FISHERY CATCH COMPOSITION

Species captured during directed sablefish commercial fishing are recorded on fisher and at-sea observer logbooks. Commercial fishers estimate catch weight by species. At-sea observers provide both weight estimates and counts of individual fish. These data are stored in the *PacHarvSable* database maintained at the Pacific Biological Station of Fisheries and Oceans Canada. The extent of data currently available from *PacHarvSable* is summarized in Table H.1 by year, logbook type, and gear. Seamount fishing is distinguished from coastal activity. Observer data currently available in *PacHarvSable* are limited to 11 trips from 2000 to 2002. These observer data are known to be incomplete; additional data and more recent trips are available but have not been proofed and loaded into the *PacHarvSable* database.

A total of 74 species or taxonomic groups are identified in fisher and observer logbook data. Of these, 29 are reported in observer data only (Table H.2). There are 9 species or groups that are reported in fisher logbook data that are not also reported by at-sea observers. The observer data tend to be identified to a finer level of taxonomic detail, with fisher logbook species often identified only to a taxonomic group such as genus or family. Of the 9 species or groups reported in the fisher logbook data that were not reported by observers, three are unspecified groups (sharks, flatfish, crabs) and 6 are species (Table H.2). In addition, the observer data include more records of non-commercial species and invertebrates.

For fishing that was reported from coastal versus seamount areas, trap fisher logbooks contained fewer species reported and less total catch of non-sablefish species than did longline fisher logbooks (Table H.3). Indeed, the trap catch of non-sablefish species reported from fisher logbooks is very modest, and generally much lower than that reported for longline gear despite trap gear accounting for the majority of the sablefish catch (Appendix B). However, the larger catches of rockfish (*Sebastes*) and Pacific halibut (*Hippoglossus stenolepis*) reported from longline fisher logbooks do not represent discarded amounts. Rather, these catches were the result of combined license fishing where a vessel fished for, and landed, permitted species in addition to sablefish. This so-called “combination fishing” is designed to allow a vessel to retain species legally permitted by simultaneously fishing under more than one license. Thus, the catches may reflect fishing that occurred under various combinations of “K” (sablefish), “L” (halibut), and “Zn” (rockfish) licenses.

Most species were reported sporadically over the years with some exceptions. For trap fishing, Rougheye rockfish (*Sebastes aleutianus*), Arrowtooth flounder (*Atheresthes stomias*), and Pacific halibut were reported in all years although the reported weight of halibut was relatively low. A significant amount of unidentified rockfish was reported which may represent catches of Rougheye rockfish, the species most commonly reported and in the largest amounts. The same three species reported most often for trap gear were also reported for longline gear, but additional species consistently reported for longline gear included Spiny dogfish (*Squalus acanthias*), Redbanded rockfish (*Sebastes babcocki*), Shortraker rockfish (*Sebastes borealis*), and lingcod (*Ophiodon elongatus*).

Characteristics of the species composition contained in logbook records reported from seamount fishing are similar to that for coastal fishing. Fewer species and less catch were reported from trap logbooks than by longline logbooks. The dominant species reported was Rougheye rockfish (Table H.3, Table H.4). In contrast to coastal fishing, significant trap catches of crabs were reported from seamount fishing. However, there were no reported catches of Arrowtooth flounder, Pacific halibut, or any other flatfish species from trap fishing. Pacific halibut and several rockfish species including Yelloweye rockfish (*Sebastes ruberrimus*) were reported for longline fishing.

Examination of the limited amount of observer data currently in *PacHarvSable* corroborated the trends identified in the fisher logbook data (Table H.2). Specifically, observer logbooks reported more species caught when longline fishing than when trap fishing. Similar differences in the dominant non-sablefish catch species occur for observer data when compared to fisher logbook data. More extensive analyses of observer logbook data are planned when more data become available.

If unidentified rockfish reported for trap fishing are assumed to be Rougheye rockfish, then high catches of Rougheye rockfish occur in years with relatively high catches of sablefish. This correlation occurs for trap gear in both coastal waters (Figure H.1) and at seamounts (Figure H.2). The same pattern is true for most of the dominant non-sablefish species captured by longline gear (Figure H.3). In contrast, reported trap catches of flatfishes do not appear to fluctuate with the catch of sablefish.

The spatial distribution of the trap catch of Rougheye rockfish over time is shown in Figure H.4. Catches were consistently reported from the west coast of the Queen Charlotte Islands and frequently from the west coast of Vancouver Island. Similar patterns can be seen for Arrowtooth flounder and Pacific halibut (not shown). In contrast, catches of all three species were infrequently reported from Queen Charlotte Sound. The highest catches of each species in each year were most frequently reported from the central west coast of the Queen Charlotte Islands. These patterns do not appear to be related to large-scale patterns in effort as there were substantial areas of the coast where trap fishing occurred and the catch of these species was not reported. However, it is possible that the patterns are due to consistent reporting of catch composition by some fishers who tended to fish these areas consistently. Available observer logbook data are not yet sufficiently extensive to corroborate the patterns evident from fisher logbook data.

Table H.1 Summary of available sablefish trap and longline data available in *PacHarvSable*.

Logbook	Gear	Trap				Longline			
	Location	Seamount		Coastal		Seamount		Coastal	
Type	Year	Trips	Sets	Trips	Sets	Trips	Sets	Trips	Sets
Fisher	1990	3	100	94	1896			95	2459
	1991	16	696	96	1867			71	1658
	1992	20	606	83	2000			43	1028
	1993	5	131	99	2712			37	675
	1994	6	206	101	3037			60	876
	1995	12	430	74	2800			68	916
	1996	13	319	68	3164	3	85	45	467
	1997	5	302	87	4460			59	637
	1998	2	84	76	4431	3	91	48	537
	1999	9	465	69	4172	3	68	78	1374
	2000	10	520	53	3436	3	101	113	1771
	2001	5	292	67	4407			78	1496
	2002	6	268	47	3541			84	1247
	2003	10	460	26	1326	1	16	84	1378
	2004	9	412	22	1483			50	689
Observer	2000	1	29						
	2001			2	25				
	2002	1	63	3	148			4	75

Table H.2 List of species and taxonomic groups recorded in the *PacHarvSable* database.

	Logbook Source	Fisher		Observer	
	Fishing Location	**Coastal**	**Seamount**	**Coastal**	**Seamount**
Description	**Scientific Name**				
Inanimate object				Yes	
Unspecified fish		Yes	Yes	Yes	
Unspecified hagfish	Myxinidae			Yes	
Unspecified shark		Yes			
Sixgill shark	*Hexanchus griseus*	Yes			
Brown cat shark	*Apristurus brunneus*	Yes		Yes	Yes
Blue shark	*Prionace glauca*	Yes		Yes	
Pacific sleeper shark	*Somniosus pacificus*	Yes	Yes	Yes	
Spiny dogfish	*Squalus acanthias*	Yes		Yes	
Unspecified skate	Rajidae	Yes	Yes	Yes	
Big skate	*Raja binoculata*			Yes	
Roughtail skate	*Bathyraja trachura*			Yes	
Sandpaper skate	*Bathyraja interrupta*			Yes	
Longnose skate	*Raja rhina*	Yes		Yes	
Spotted ratfish	*Hydrolagus colliei*	Yes		Yes	
Unspecified grenadier	Macrouridae	Yes	Yes	Yes	Yes
Roughscale grenadier	*Coryphaenoides acrolepis*			Yes	
Pectoral grenadier	*Albatrossia pectoralis*			Yes	
Prowfish	*Zaprora silenus*		Yes		
Ragfish	*Icosteus aenigmaticus*				Yes
Unspecified rockfish	Sebastinae	Yes	Yes	Yes	
Rougheye rockfish	*Sebastes aleutianus*	Yes	Yes	Yes	Yes
Pacific ocean perch	*Sebastes alutus*	Yes		Yes	
Aurora rockfish	*Sebastes aurora*				Yes
Redbanded rockfish	*Sebastes babcocki*	Yes	Yes	Yes	
Shortraker rockfish	*Sebastes borealis*	Yes	Yes	Yes	
Silvergray rockfish	*Sebastes brevispinis*	Yes	Yes	Yes	
Darkblotched rockfish	*Sebastes crameri*			Yes	
Greenstriped rockfish	*Sebastes elongatus*	Yes			
Widow rockfish	*Sebastes entomelas*		Yes		
Yellowtail rockfish	*Sebastes flavidus*	Yes		Yes	
Rosethorn rockfish	*Sebastes helvomaculatus*	Yes	Yes	Yes	Yes
Tiger rockfish	*Sebastes nigrocinctus*		Yes	Yes	
Bocaccio	*Sebastes Paucispinis*	Yes		Yes	
Canary rockfish	*Sebastes pinniger*	Yes		Yes	
Redstripe rockfish	*Sebastes proriger*	Yes		Yes	
Yellowmouth rockfish	*Sebastes reedi*	Yes	Yes		
Yelloweye rockfish	*Sebastes ruberrimus*	Yes	Yes	Yes	
Unspecified thornyhead	Sebastolobinae	Yes	Yes	Yes	

Shortspine thornyhead	*Sebastolobus alascanus*	Yes	Yes	Yes	Yes
Longspine thornyhead	*Sebastolobus altivelis*			Yes	
Sablefish	*Anoplopoma fimbria*	Yes	Yes	Yes	Yes
Unspecified snipe eel	Nemichthyidae			Yes	
Pacific cod	*Gadus macrocephalus*	Yes		Yes	
Pacific hake	*Merluccius productus*	Yes		Yes	
Skilfish	*Erilepis zonifer*	Yes			
Lingcod	*Ophiodon elongatus*	Yes		Yes	
Unspecified snailfish	Cyclopteridae			Yes	
Unspecified flatfish	Pleuronectiformes	Yes			
Arrowtooth flounder	*Atheresthes stomias*	Yes		Yes	
Deepsea sole	*Embassichthys bathybius*			Yes	
Petrale sole	*Eopsetta jordani*			Yes	
Pacific halibut	*Hippoglossus stenolepis*	Yes	Yes	Yes	
Dover sole	*Microstomus pacificus*	Yes		Yes	Yes
Unspecified invertebrate				Yes	
Sponges	Porifera			Yes	
Jellyfish	Scyphozoa			Yes	
Anemone	Actiniaria			Yes	
Stony coral	Madreporia			Yes	
Unspecified molluscs	Mollusca			Yes	
Unspecified octopus	Octopoda		Yes	Yes	Yes
Giant Pacific octopus	*Enteroctopus dofleini*			Yes	
Brittle and basket stars	Ophiuroidea			Yes	
Starfish	Asteriodea			Yes	Yes
Sea urchins	Echinacea			Yes	
Sea cucumber	Holothuroidea			Yes	
Unspecified crabs	Bracyura	Yes	Yes		
Tanner crabs	*Chionoecetes* sp.		Yes	Yes	Yes
Alaskan king crabs	*Paralithodes* sp.		Yes		Yes
Lithodes crabs	*Lithodes* sp.			Yes	Yes
Red queen crabs	*Lithodes couesi*			Yes	Yes
Box crabs	*Lopholithodes* sp.		Yes	Yes	
Squat lobster	*Munida quadrispina*			Yes	

Table H.3 Fisher logbook reported trap catches (kg) for coastal fishing excluding sablefish catches and research fishing activity. These catches represent data currently available in *PacHarvSable*.

Species Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coastal															
Trap															
Unspecified fish							25924								
Sixgill shark						445									
Brown cat shark						1									
Spiny dogfish	454	353	635			1040		45	272						
Spotted ratfish	54														
Pacific hake								11							
Unspecified grenadier			86		546		68			227	14	728			
Unspecified rockfish	303	546	2169	2339	2128	675							252	69	
Rougheye rockfish	885	3323	164	1755	3621	2692	2308	5088	2948	4814	1552	1884	1463	2628	1104
Pacific ocean perch	2160	3997	1978	868											
Redbanded rockfish						9				41					
Shortraker rockfish				817										46	
Yelloweye rockfish						2									
Shortspine thornyhead					5	98	473	560	14						
Unspecified thornyhead														1	
Lingcod										461					
Unspecified flatfish		762	594	621	275										
Arrowtooth flounder	3420	4005	4291	2831	4222	7823	17342	9196	2855	7106	1816	1742	1092	3754	375
Pacific halibut	953	4858	4153	1063	1166	2387	4078	6049	320	2430	616	226	105	1527	
Dover sole	313	60				1634									
Unspecified crab	2539											31			

Table H.4 Fisher logbook reported longline catches (kg) for coastal fishing excluding sablefish, research fishing, and data prior to 1990. These catches represent data currently available in *PacHarvSable*.

Species Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Coastal															
Longline															
Unspecified fish	863			363	13573										
Unspecified shark		272													
Blue shark									82		158				
Pacific sleeper shark						181									
Spiny dogfish	5178	554	1655	9163	6169	3183	3524	3783	6033	2859	7285	1684	1142	4649	2467
Unspecified skate	2549	4626				104	81	272	408		23		3799	8550	273
Longnose skate											317				
Pacific cod	7	119												380	112
Unspecified grenadier						91			9			14			182
Unspecified rockfish	79584	18334	3856		2054	8655	9227	2554		4968	18384	4220	14909	16756	
Rougheye rockfish	54064	13978	9384		680	4967	386	197	2458	1747	23865	3632	10959	14716	33574
Pacific ocean perch		823		2312					11				34		
Redbanded rockfish	17027	5108	2020	18	11645	9997	95	159	419	27		23	2955	1553	6986
Shortraker rockfish	34570	18495	136		249	3308			1269		215	608	10393	4996	13710
Silvergray rockfish					146	306									612
Greenstriped rockfish											1				
Yellowtail rockfish									4						
Rosethorn rockfish									7				546		
Bocaccio	464														
Canary rockfish	3583	88				317			50						
Redstripe rockfish	795														
Yellowmouth rockfish	197					543			21						
Yelloweye rockfish	8589	854		475	350	2018						23		68	
Shortspine thornyhead	3410	2690	446	549		494	41		576	198	42				
Unspecified thornyhead											461	65	1642	421	75
Skilfish						122									
Lingcod	1698	2867	521	88	1090	2940		671	18		171		1570	279	995
Arrowtooth flounder	1927	680				8473	1664	7188	1682	479	641		1792	1075	1246
Pacific halibut	71861	38230	8412	7149	30708	16696	21973	31338	14535	24307	32980	22403	22074	39677	25005

Table H.5 Fisher logbook reported catches (kg) for seamount fishing by trap and longline gear excluding sablefish. These catches represent data currently available in *PacHarvSable*.

Species Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Seamount															
Trap															
Unspecified fish					90										
Unspecified grenadier		566	2562		1093	2245					30	1353			
Unspecified rockfish		2599	3293		2719	237		417	330	201	4267	248	394	8276	3217
Rougheye rockfish		13718	4734	2259	1002	1589	1346	4972		635	12392	2063	1502	272	3306
Shortraker rockfish							277		136						
Yelloweye rockfish		2													
Shortspine thornyhead		14					5	2							
Box crabs							4								
Alaskan king crabs		9					1163								
Unspecified crabs		2026				1810					4661	1621			
Tanner crabs						589									
Longline															
Pacific sleeper shark							680								
Unspecified skate									45						
Unspecified grenadier							68								
Prowfish									4						
Unspecified rockfish							23			47638					
Rougheye rockfish							25872		23416		87185			908	
Redbanded rockfish							203		245						
Shortraker rockfish							579		174						
Silvergray rockfish							107		60						
Widow rockfish							22		5						
Rosethorn rockfish							417		880						
Tiger rockfish							4		9						
Yellowmouth rockfish							4		5						
Yelloweye rockfish							5678		10560						
Shortspine thornyhead							263		112	422					
Unspecified thornyhead														142	
Pacific halibut							2677		367						
Octopus							2								

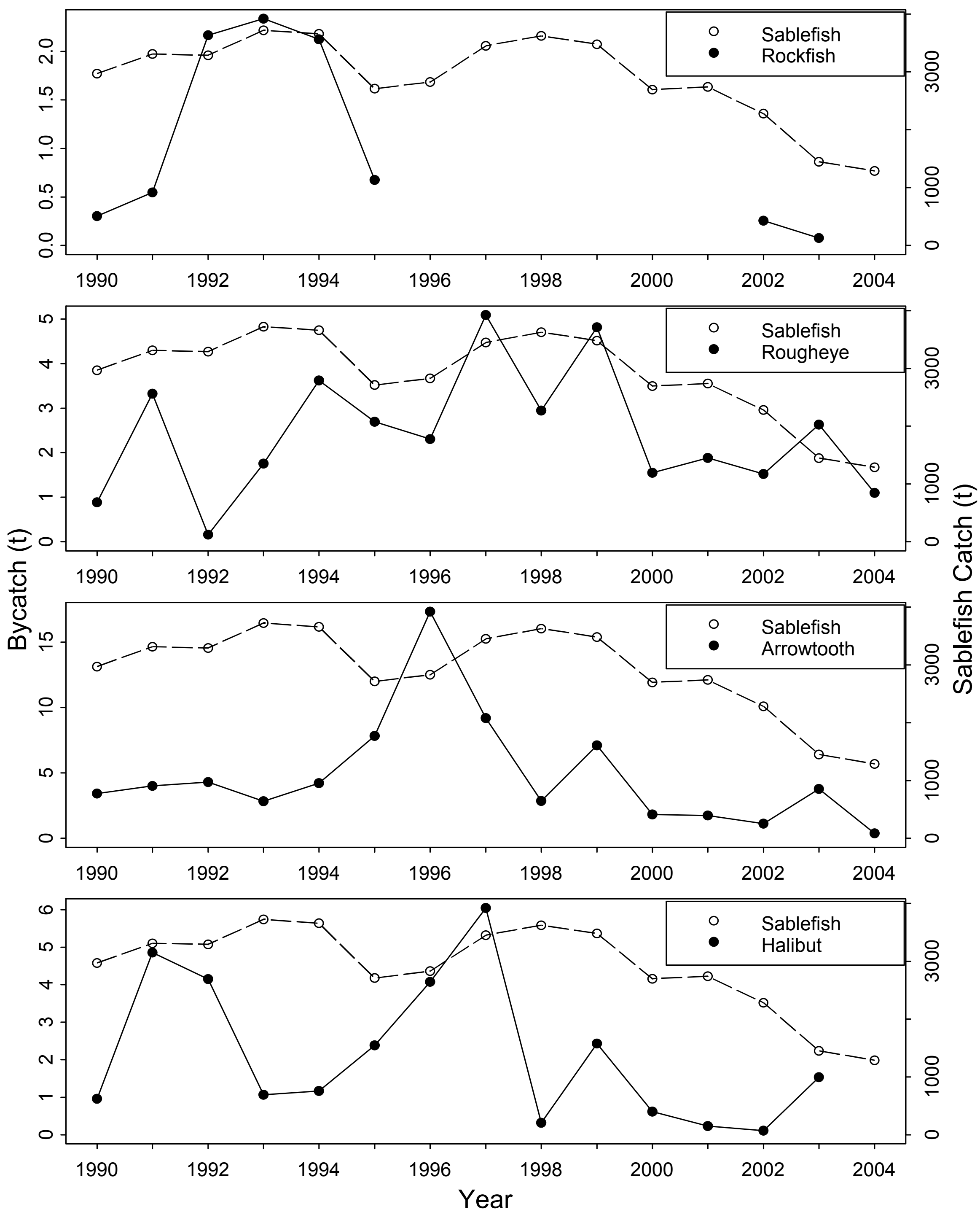

Figure H.1 Annual catch (t) for selected species reported in fisher logbooks from trap fishing in coastal waters. The logbook reported sablefish catch is also shown for reference.

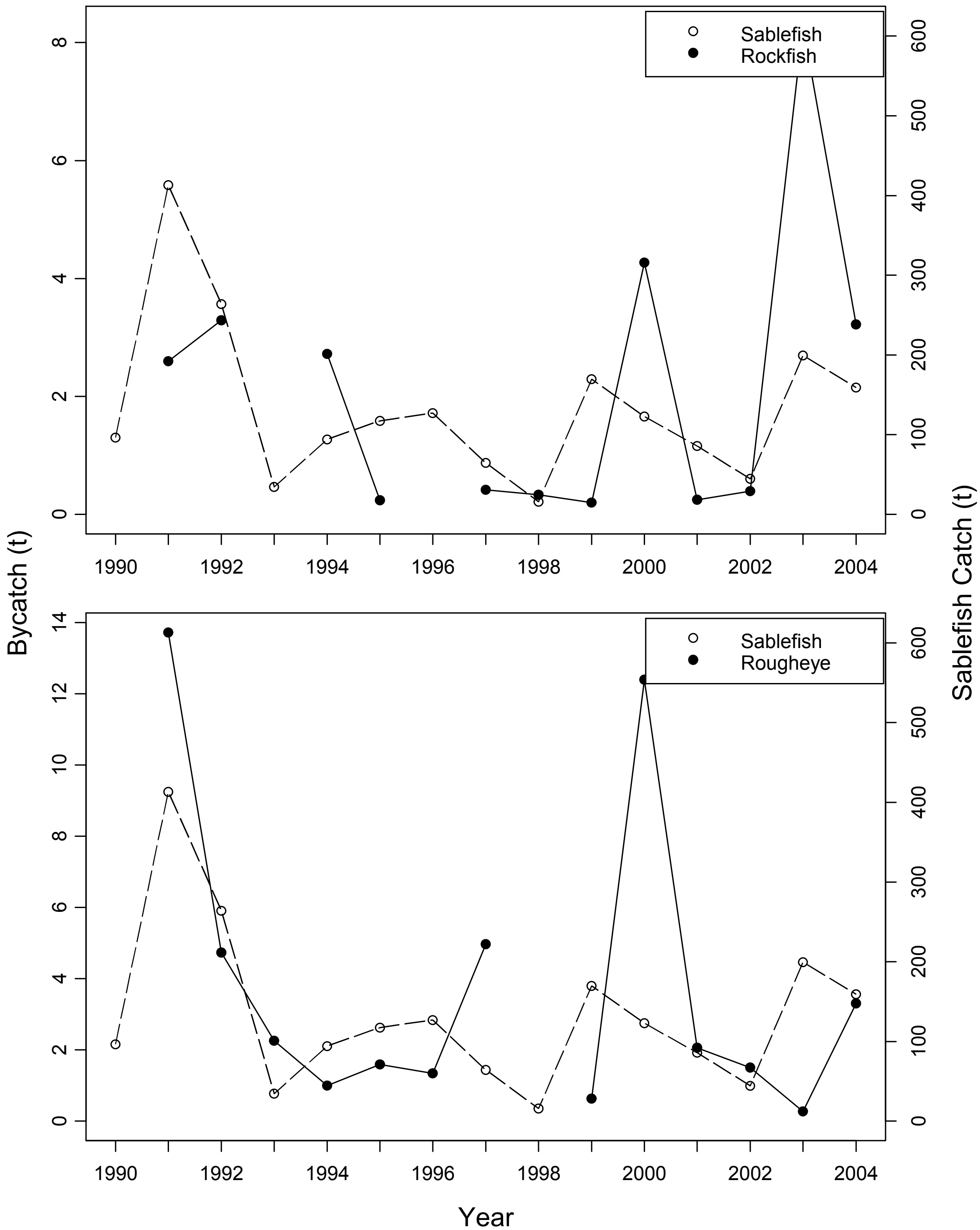

Figure H.2 Annual catch (t) for selected species reported in fisher logbooks from trap fishing at seamounts. The logbook reported sablefish catch is also shown for reference.

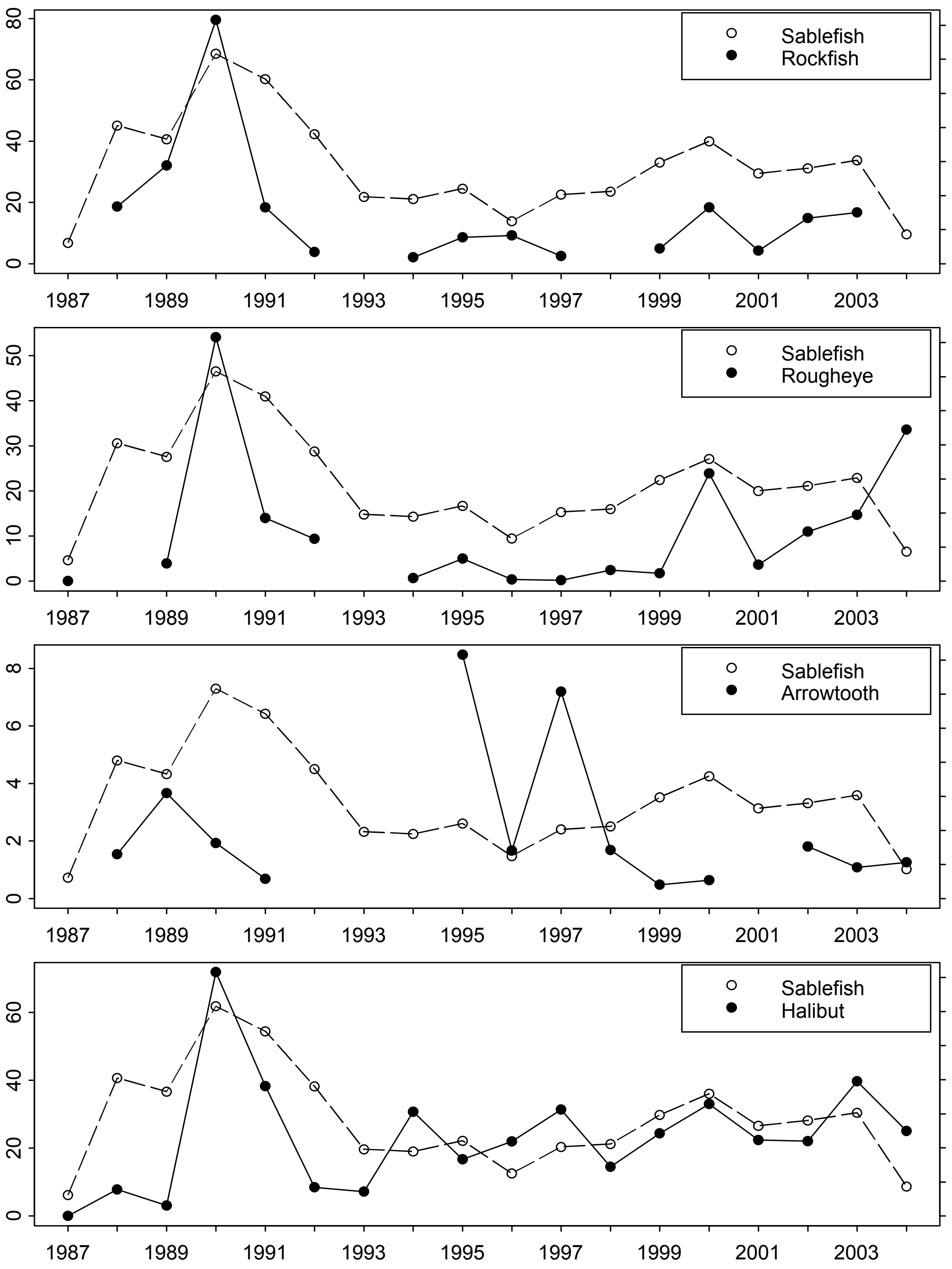

Figure H.3 Annual catch (t) for selected species reported in fisher logbooks from longline fishing in coastal waters. The logbook reported sablefish catch is also shown for reference.

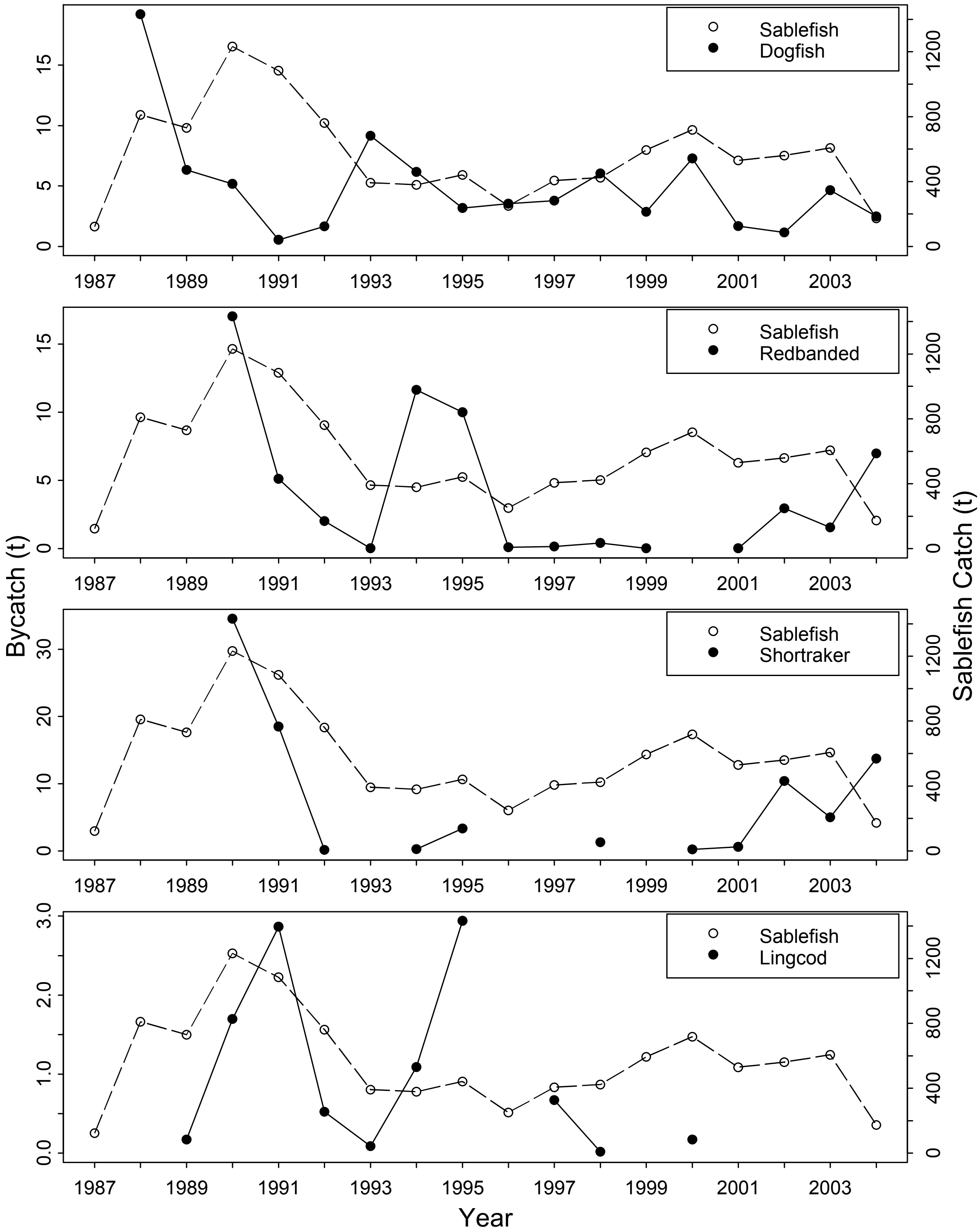

Figure H.3 continued.

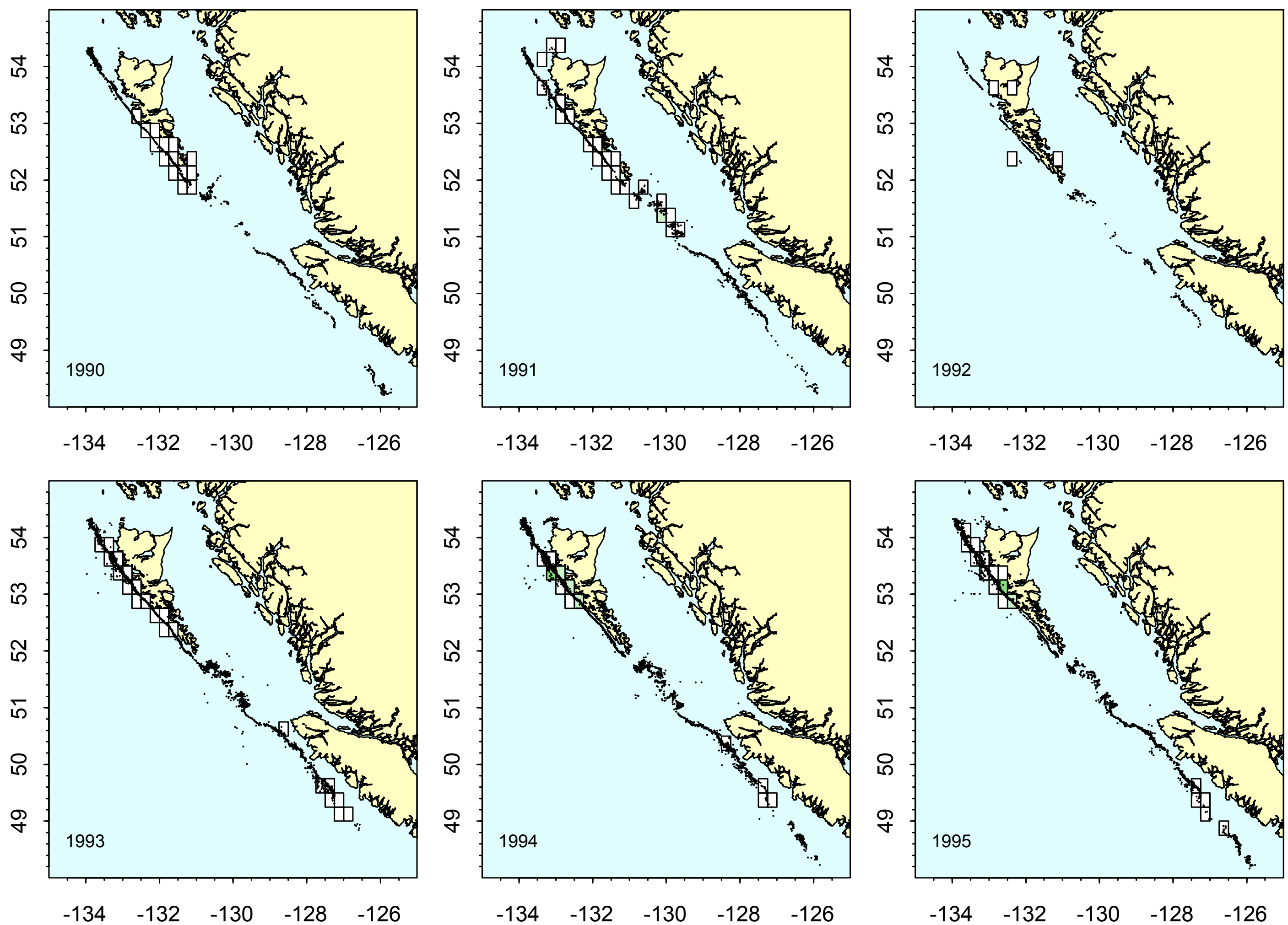

Figure H.4 Annual trap catches of Rougheye rockfish by 0.25 by 0.25 degree blocks of latitude and longitude. The colour intensity of the grid cells is proportional to the sum of the catches in the cell. Black dots indicate the locations of commercial sablefish trap fishery sets. Research fishing, seamount fishing and observer data are excluded.

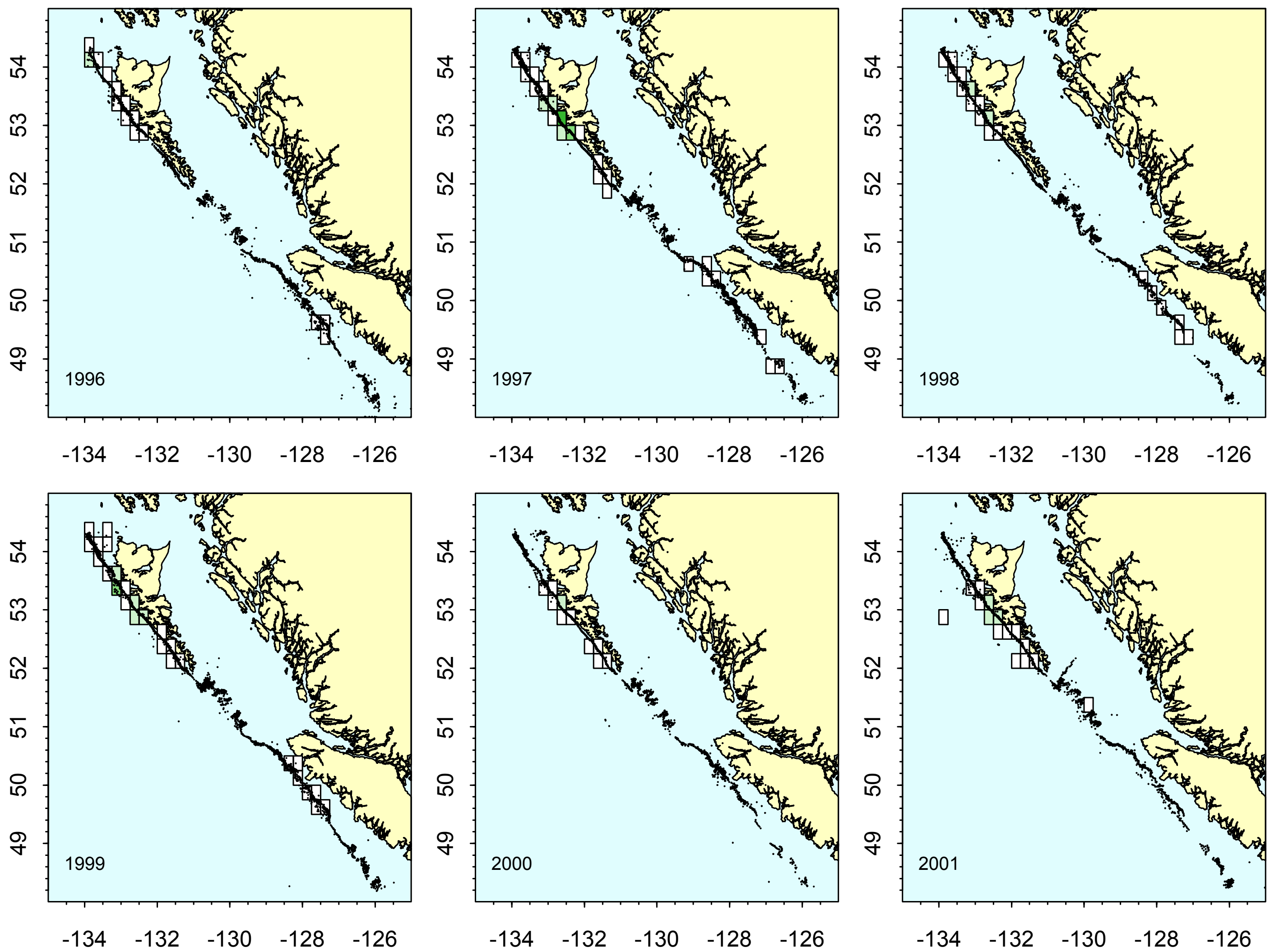

Figure H.4 continued.

Species Code = 394

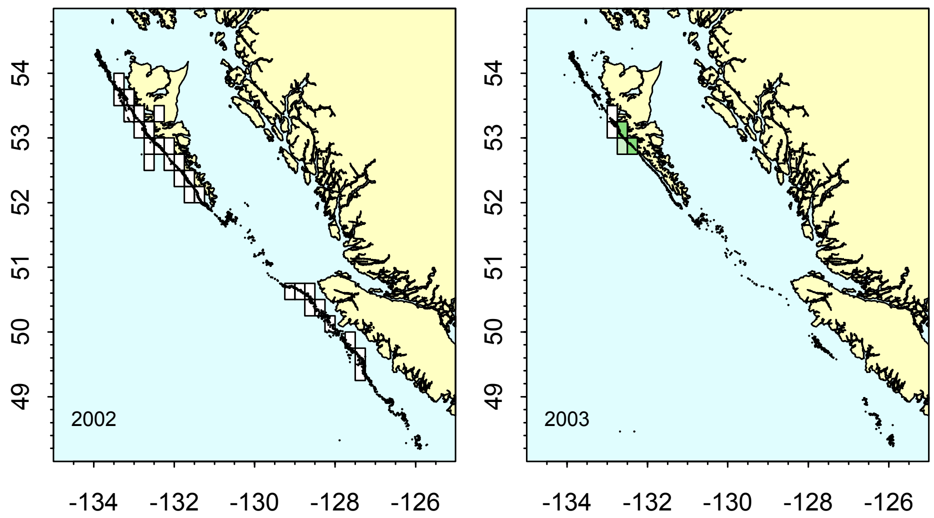

Figure H.4 continued.