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 2002/074 / **Document de recherche 2002/074**

Not to be cited without permission of the authors *

Ne pas citer sans autorisation des auteurs *

Review of survey, commercial fishery and tagging data for sablefish (*Anoplopoma fimbria*) in British Columbia (Supplement to the November 2001 sablefish stock assessment)

Examen des données de relevé, de marquage et de pêche commerciale de la morue charbonnière (*Anoplopoma fimbria)* en Colombie-Britannique (supplément à l'évaluation du stock de morue charbonnière de novembre 2001))

A.R. Kronlund[1]
Malcolm Wyeth[1]
Ray Hilborn[2]

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

[2]School of Aquatic and Fisheries Sciences
University of Washington
Seattle, WA 98195

ISSN 1480-4883

Abstract

Catch rates observed during the 2001 sablefish (*Anoplopoma fimbria*) survey have declined significantly compared to those observed in the previous five years. In response, fishery managers requested a review of the 2001 survey data in the context of historical survey and fishery information, as well as an updated tag-recovery analysis. This paper was prepared as a supplement to the most recent assessment of sablefish (Haist et al. 2001) to accommodate the new survey information and to help evaluate whether the current assessment of sablefish stock status should be revised.

Survey catch rates showed declines from 1990 to 2001 in seven of nine localities and generally showed declines at all depth strata surveyed. The decline was steepest in the first half of the time series, and slowed from 1996 to 2000. Catch rates in 2001 were the lowest in the time series, and generally exhibited much smaller variance in comparison to previous years. Commercial catch rates calculated from logbook records showed trends similar to the survey data within the survey localities. Trends were less well defined outside of the survey areas, but suggested a decline from 1990 to 2001 and reduction in variance in the latter few years of the series. Interpretation of these trends is complicated by the adoption of escape rings in trap gear in 1998. Estimates from the tagging program for 2001 indicated a biomass of 37,300 t with an exploitation rate of 0.096. The estimates of abundance were without trend from 1995 to 2001, with no significant outliers evident within this period. The tagging program estimates showed no evidence of a dramatic decline in abundance from 2000 to 2001.

Recent assessments of sablefish in British Columbia have relied primarily on the results of tag-recovery analysis to provide estimates of stock biomass and harvest rate. Trends in survey and commercial catch rates were used to corroborate the trend in estimates from the tag-recovery analysis. This review of sablefish stock indicators, prompted by the low 2001 survey results, resulted in a re-interpretation of stock status that reflects the concern that the stock has experienced continuous decline during the 1990s. Recommendations to managers for the current 2001/2002 and 2002/2003 fishing years are provided.

Résumé

Les taux de capture observés lors du relevé de la morue charbonnière (*Anoplopoma fimbria*) de 2001 ont affiché une baisse significative par rapport à ceux des cinq années précédentes. Les gestionnaires de la pêche ont réagi en demandant que les données du relevé de 2001 soient examinées par rapport aux données de la pêche commerciale et des relevés passés et que l'on mette à jour l'analyse des expériences de marquage. Nous avons rédigé ce document comme supplément à la dernière évaluation des stocks de morue charbonnière (Haist *et al.*, 2001) afin de tenir compte des nouvelles données de relevé et d'aider à décider s'il faut réviser l'évaluation actuelle de l'état du stock de morue charbonnière.

De 1990 à 2001, les taux de capture obtenus lors des relevés ont baissé dans sept secteurs sur neuf, et, en général, le déclin a été observé à toutes les strates de profondeur. Plus marqué dans la première moitié de la série chronologique, le déclin a ralenti de 1996 à 2000. En 2001, les taux de capture ont atteint le niveau le plus bas de la série chronologique et ont généralement présenté une variance beaucoup plus petite que celles des années antérieures. Dans les secteurs de relevés, les taux de capture commerciale calculées à partir des données des registres de pêche présentent des tendances semblables à celles des données de relevés. À l'extérieur des secteurs de relevé, les tendances étaient moins évidentes, mais elles semblent aussi indiquer un déclin de 1990 à 2001, avec une baisse de la variance durant les dernières années de la série chronologique. L'utilisation d'anneaux d'échappée dans les casiers depuis 1998 complique l'interprétation de ces tendances. Dans le cadre du programme de marquage de 2001, on a estimé que la biomasse atteignait 37 300 t et que le taux d'exploitation était de 0,096. Les estimations de l'abondance ne présentent aucune tendance de 1995 à 2001 et ne comprennent aucune valeur aberrante significative durant cette période. Les estimations obtenues dans le cadre du programme de marquage n'indiquent aucun déclin marqué de 2000 à 2001.

Dans les récentes évaluations du stock de morue charbonnière de la Colombie-Britannique, la biomasse du stock et les taux de capture sont estimés surtout à partir des résultats des analyses de marquage-recapture. Nous nous sommes servis de l'évolution des taux de capture des relevés et de la pêche commerciale pour corroborer l'évolution des estimations faites à partir de l'analyse marquage-recapture. Donnant suite aux chiffres peu élevés du relevé de 2001, cet examen des indicateurs du stock de morue charbonnière a donné lieu à une nouvelle interprétation de l'état du stock, laquelle traduit l'inquiétude que suscite le déclin constant du stock au cours des années 1990. Nous présentons des recommandations aux gestionnaires pour les saisons de pêche 2001-2002 et 2002-2003.

Table of Contents

List of Tables

List of Figures

1. Introduction

Catch rates obtained from the 2001 sablefish (*Anoplopoma fimbria*) survey conducted in British Columbia have declined significantly in comparison to those observed in recent years. The mean number of sablefish caught per trap declined to about 0.6 of the 1996 to 2000 mean catch rate for the southern stock. The observed decline was greater for the northern stock, with 2001 catch rates at about 0.2 of the 1996 to 2000 mean catch rate. If interpreted as a stock abundance index, the survey results contradict the assessment of stock status (Haist et al. 2001). This recent assessment of sablefish relied primarily on the examination of abundance and exploitation rates computed from tag returns in the year following release (Haist et al. 2000, 2001). Trends in survey catch rates and, to a lesser extent, commercial trap fishery catch rates were used to corroborate the tag-recovery analysis. Based on the time series of exploitation rate estimates, the vulnerable biomass of sablefish in British Columbia (B.C.) was considered to be low and stable from 1996 to 2000 at about 35,000 metric tonnes. A total allowable catch (TAC) of 4,000 t coastwide was recommended for the 2002/2003 fishing year (Haist et al. 2001, Stocker and Cass 2001), the same harvest recommended for the previous fishing year (Haist et al. 2000, Haist et al. 2001, their Table 2).

The annual exploitation rate, computed as total catch divided by estimated biomass, was estimated to be in the range of about 0.075 to 0.15 from 1991 to 2000 (Haist et al. 2001, their Fig. 21). The year 2000 estimate of harvest rate was about 0.13. Sources of bias and uncertainty in the estimation of abundance and exploitation rates from tag-recovery data were reviewed by Haist et al. (2001, p. 38). To provide context for these estimates, Saunders et al. (1996) suggested that instantaneous fishing mortality, F, in the range of 0.11 to 0.13 would result in spawning biomass per recruit levels of 0.4 to 0.45 of unfished levels. This result is similar to that obtained for the Gulf of Alaska sablefish stock, where $F_{0.4}$ was estimated to be 0.12 (Sigler et al. 2000). Simulations using a spawning biomass per recruit model that explicitly incorporated a stock-recruitment relationship suggested that 30 to 35 percent of virgin biomass could be maintained if the vulnerable biomass were harvested at a rate of 0.06 to 0.14 (Haist et al. 2001, their Table 16).

Preliminary results from the 2001 sablefish survey became available subsequent to the preparation and review of the November 2001 assessment (Haist et al. 2001). In view of the preliminary results, fishery managers requested that the survey data and sablefish stock status be reviewed (Appendix A). Managers identified the following objectives for the working paper:

1. to review the 2001 survey results in the context of the historical survey data, identifying changes in survey conduct that influence interpretation of results;
2. to review commercial catch and effort data for sablefish, comparing trends derived from these data to those obtained from the sablefish survey data;
3. to update the tagging analysis used to compute exploitation rates of sablefish;

4. to provide a supplement to the November 2001 assessment of sablefish stock status, and provide yield options for the remainder of the 2001/2002 fishery and for the 2002/2003 fishery;
5. to identify biological concerns regarding the temporal distribution of catch between now and July 31, 2003;
6. to confirm that advice provided on the carry-forward policy in November 2001 remains consistent with the stock assessment advice.

In addition, industry participants expressed concerns that concurrent commercial fishing within survey localities may have produced an anomalous 2001 survey, and that the survey localities may not be broadly representative of coast wide trends in catch rates. It was also suggested that fish distributed at depths greater than those typically fished by the sablefish fleet form a deepwater reserve, or buffer, against exploitation. Analyses have been included in this document to examine these possibilities.

This document is supplemental to Haist et al (2001) and is not intended to be a stand-alone assessment. Readers are referred to Haist et al. (2001), which contains descriptions of fishery and management history, catch and effort summaries, spawning biomass per recruit analyses to identify appropriate harvest levels, and various analyses of tag recovery data. Key figures and tables from that document are referenced rather than reproduced here. Similarly, readers are referred to Haist et al. (2001, their Section 6) for documentation of the tag-recovery model for computing abundance and exploitation rate.

2. Data Sources

Sources of data used for the analyses in this paper are briefly described in this section. These include sablefish survey data, commercial catch and effort data from sablefish fishery logbooks, tag-recovery data, and sablefish catch in a longspine thornyhead (*Sebastolobus altivelus*) trawl survey. Data preparation for sablefish survey and fishery logbook information is described in Appendices B through D.

2.1 Fishery-independent survey data

This section summarizes the history of fishery-independent surveys for sablefish during the period 1988 to 2001. Documentation can be found in Smith et al. (1996) for 1988 to 1993, Downes et al. (1997) for 1994 and 1995, and Archipelago Marine Research (2000) for 2000. Surveys conducted from 1996 to 1999 and 2001 are not documented in a published report. Tagging and biological studies conducted during 1982 to 1987 (Murie et al. 1995) are not considered comparable to the 1988 to 2001 surveys.

2.1.1 Survey design

In 1988, eight indexing localities were purposively chosen for inclusion in an annual fishery-independent survey (Figs. 1-3). The eight localities were selected because they were fished by commercial vessels and were spatially dispersed about 60 nm apart such that normal weather conditions would permit all localities to be occupied within a 30 day period. A ninth locality (Cape St. James) was added in 1994. Sets conducted sporadically over time and space at other sites have not been included in the survey time series. The survey was initiated to apply tags, collect biological data, and to establish index sites. Data observed from the standardized index sets are used in this analysis; data observed from tagging sets have been excluded as described in Appendix B. Not all survey localities were sampled in each year of the time series.

The survey was depth stratified in the sense that sets in each locality were targeted within five depth ranges (Table 1, three depth ranges in 1988 and 1989). However, with rare exceptions there was no replication of sets by depth and locality; usually a single set was conducted within each depth stratum for a given locality (Table 2). Also, due to the logistical difficulties of setting gear, a survey set may not actually fall into the intended depth stratum. Thus, the modal depth was used to assign a depth stratum to each set for purpose of analysis. The modal depth was determined by averaging the observed depth at one-minute recording intervals between anchors. Spatial positions of the survey sets were not randomized, rather the fishing master had discretion to set gear within each designated depth stratum in each locality.

In 2000, a sixth depth stratum was added to the survey between 600 and 800 fm. In 2001, three deep strata were added off the west coast of Vancouver Island: 650 to 700 fm, 750 to 800 fm, and 800 fm and deeper. A single 600 to 800 fm depth stratum was retained off the Queen Charlotte Islands due to the difficulty of setting gear accurately within 50 fm strata bounds in rugged bathymetric features. Data obtained from the 600-800 fm depth range was not included in the examination of the time series since data are available only for 2000 and 2001.

2.1.2 Survey timing and vessels

The timing of the survey sets from 1990 to 2001 has ranged from September 24 (1998) to November 20 (1990). Table 3 lists the start and end dates of the survey by year and locality, where the start date is the day of the first survey index set and end date is the day of the last survey index haul. A given research cruise or charter may have been longer in duration than indicated in Table 3 to accommodate tagging sets and a component of the work conducted in inlets. Figure 4 shows the overlap in annual survey timing graphically, where each circle represents the start date of one survey set. The circles have been randomly perturbed, or jittered, along the y-axis of the plot to expose sets conducted on the same day. Survey timing shows a progressive enthusiasm for starting earlier in the fall until 1998. The timing of the 2001 survey was near the middle of the historical range, and finished about three weeks earlier than the 2000 survey. Detailed figures of the timing of sets within each survey locality are shown in Appendix Fig. E.1.

Table 3 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 industry. Surveys in other years have utilized a commercial charter vessel and experienced skipper. With the exception of 2000, surveys conducted from 1996 to 2001 have used the same vessel and skipper. Onboard scientific staff from

Fisheries and Oceans Canada, or provided through contract, have varied over the 1990 to 2001 series.

2.1.3 Gear and baiting

Surveys were conducted using trap gear as described by Smith et al. (1996). Trap design since 1990 has been a modified Korean trap consistent with that used by the commercial sablefish fleet. Beginning in 1990, a standardized string of 25 traps was deployed on each survey set. Traps were prepared prior to setting; bottoms were closed, tunnels stretched into place, and a bag of 1.0 to 1.5 kg of frozen squid fastened to the inside of the trap close to the tunnel entrance. Traps were attached to the ring and becket at 25 fm (46m) intervals along the groundline.

In 1988 and 1989 traps were baited with 1.0 to 1.5 kg of frozen squid in bait bags and four frozen hake (*Merluccius productus*) of 0.6 to 0.8 kg apiece. In 1988 approximately 100 traps were fished on each set so that the length of the string made it difficult to maintain traps within the designated depth stratum. In 1989, the number of traps on a string was reduced to approximately 70. Because of these differences, and pending analyses to standardize the 1988 and 1989 data to the 1990 through 2001 data, the 1988 and 1989 surveys were excluded from formal analyses. This departure from previous assessment documents was deemed necessary because hake-baited traps are known to fish more successfully than traps baited with squid alone (B. Leaman, unpublished manuscript). Haist et al. (2001, their Table 4) showed that catch rates (kg/trap) were substantially higher for the tagging sets baited with squid and hake than for survey index sets baited with squid alone. Furthermore, strings of gear with 70 or more traps might have different areas of sablefish attraction than strings of 25 traps, and the majority of traps set may not lie fully in a single depth stratum due to the length of the groundline.

2.1.4 Biological sampling

Sablefish caught on survey sets, as opposed to sets designated for tag application, were sampled for length, sex, and maturity. Otoliths were excised for subsequent age determination. Sablefish weight and girth were measured at times, and stomachs were sometimes sampled for gut content analysis. Tags may have been applied when large catches were achieved.

2.2 Commercial logbook data

Commercial logbook data reported by longline and trap vessels fishing under a sablefish “K” licence are stored in a Microsoft Access database called **Logbooks.MDB** at the Pacific Biological Station, Nanaimo, B.C. The data include fishing event information by set such as the vessel, date, time, position to decimal minute, and a gear description. Catch information is recorded for each set including the species, product and a use code to indicate whether the fish were retained or discarded, used as bait, etc. Because the format of logbook data changed in 1995, data collected from 1987 to 1994 are stored in a separate set of tables from the 1995 to 2001 data (Appendix C). With few exceptions, at-sea observers do not validate logbook data, although dockside validation of the landed catch was instituted in 1990. Filtering criteria used to extract logbook data for analyses in this paper are described in Appendix D. Analyses in this paper use logbook data from the 1990 to 2001 period for comparison with the sablefish survey time series.

2.3 Tag-recovery data

The sablefish tag-recovery program began in 1977 and has been described in previous assessments (Haist et al. 1999, 2000, 2001). Beginning in 1991, a tagging component was integrated into the fall sablefish surveys to release tagged fish at each survey locality and at depths where most commercial fishing effort occurs (Haist et al. 2001). Sets designated for tag releases are distinct from those used as survey catch rate index sets. Tagging sets generally have included more than 25 traps and have been baited with hake in addition to squid to maximize the number of tags released. In 2000 a new type of tag was introduced that changed the information printed on the tag. Haist et al. (2001, their Section 5.4) reported little difference in the proportion recovered of "old" B-type tags and "new" CSA-type from data where equal numbers of both types of tags had been released over 7 tagging sets in southern British Columbia.

The tagging analysis uses returns in the year following release. All tag-recovery data used in the calculation of abundance and exploitation rates are obtained from "adult" offshore releases in Fisheries and Oceans Canada Major Areas 3 to 6 and 9 (3C to 5B and 5E, Rutherford 1999), excluding Fitzhugh Sound. Juvenile sablefish (those coded as "J") tagged primarily in inlets are not utilized. Only tag-recoveries obtained from the sablefish trap fishery are used in the calculations. However, tag recoveries obtained from sablefish longline, groundfish trawl, halibut longline, and other hook and line fisheries (eg. rockfish, lingcod, dogfish) are not included in calculations of abundance and exploitation rates.

2.4 2001 Longspine thornyhead trawl survey data

A random stratified trawl survey targeted at longspine thornyhead (*Sebastolobus altivelis*) was conducted off the west coast of Vancouver Island from September 15 to October 2, 2001. Preliminary results including biomass estimates for sablefish in the survey area were made available in December 2001 (Starr 2001, unpublished manuscript). A total of 63 trawl sets were completed, distributed spatially among five areas and three depth strata. Area strata were located from immediately south of Quatsino Sound (approximately 50° 17′ N) to a southern boundary defined by the Canada-US border. The three depth strata ranged from 500 to 1600 m: 500-800 m, 800-1200 m, and 1200-1600 m. Sablefish represented the largest total catch weight among species observed during the survey.

The net used on this survey was a "#2 Box Trawl" commonly used by the B.C. groundfish trawl fleet to fish thornyheads in deep water. Thyboron 107 doors, also in common use by the trawl fleet, were deployed. A 50 mm mesh net liner was used in the codend. With one exception, a bottom contact sensing device was deployed for every survey tow to measure actual on-bottom time. Results reported here have been corrected for on-bottom time rather than using elapsed time between winch lock-up and start of net retrieval. Biological data collected during the survey were not examined.

3. Exploratory analysis of catch and effort data

3.1 Computation of catch rates

For each annual sablefish survey, strings of 25 traps were deployed within pre-specified depth strata at each survey locality. Sablefish catch in numbers of fish and aggregate weight were recorded for each trap. Effort (number of traps) was recorded for each set. The catch rate for each set was computed both in terms of numbers of fish per trap and weight (kg) of fish per trap. Effective traps were those considered to be fishing successfully. Thus, the catch rate was computed by summing the catch over effective traps on a set and dividing by the number of effective traps. Note that the number of effective traps may be less than the number of traps deployed for a variety of reasons such as fouled or holed gear. For commercial logbook data, the total retained catch (kg) for the set was divided by the number of traps recorded in the logbook for the set to yield a catch weight per trap.

3.2 Survey catch rates over time and space

Sablefish in B.C. have traditionally been viewed as consisting of a northern and a southern stock, with the dividing latitude at about 51° 15′ N. The northern stock region includes the Langara Island-North Frederick, Hippa Island, Buck Point, Gowgaia Bay, and Cape St. James survey localities (Figs. 1-2). The southern stock region incorporates the Triangle Island, Quatsino Sound, Esperanza Inlet and Barkley Canyon survey localities (Figure 3).

Catch rate trends for the northern and southern stocks are shown in Figure 5. The distribution of catch rates (number of fish per trap) achieved for each set is summarized by boxplots for each survey year. For all boxplots presented in this paper, the lower bound of the “box” indicates the first quartile (25^{th} percentile) of the data and the upper bound the third quartile (75^{th} percentile). The horizontal line that divides the box is the median (50^{th} percentile). The upper and lower whiskers of the 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. In Figure 5, the lightly shaded rectangle indicates an approximate 95 percent confidence interval for the sample median. The survey catch rates in both areas show a decline from the early 1990s to a relatively stable period beginning in the mid-1990s until 2000. The 2001 survey mean and medians are the lowest in the series. The distribution of catch rates for the northern stock in 2001 exhibits much reduced variability compared to previous years.

Since the mean catch rates may vary among localities, catch rate (numbers of fish per trap) trends by locality were computed and are presented in Figure 6 and Table 4. Table 5 contains a similar catch rate summary, where the catch rates are stated in terms of mean weight (kg) per trap. Note that on average these values may underestimate the actual weight per trap due to the consumption of fish in the trap by amphipods; an aggregate weight of sablefish is taken for the trap, but on occasion the number of fish includes animals partially consumed or reduced to frames. Each panel of Figure 6 shows the catch rate trend over time for the indicated survey locality. The catch rates (mean number of fish per trap) achieved on survey sets over time are plotted as open circles. The solid circles represent the mean annual catch rate. The solid curve in each panel is a trend line fit by a loess smoothing regression (Cleveland 1985) of catch rates per set conditioned on year for the 1990 to 2001 period. Seven of the nine survey localities show declines in catch rates from the early 1990s to 2001, where the decline is steepest in the first half of the times series and slows or actually increases slightly in the mid to late 1990s. Catch rates at Cape St. James are variable over time with not much signal in the time trend. Quatsino Sound catch rates show an increasing trend from the late 1990s to 2000. The 2001 survey data generally cause a downturn in the trend at each location. There is a significant reduction of the variance of 2001 survey catch rates at Buck Point, Esperanza Inlet, Gowgaia Bay, Hippa Island, Langara Island-North Frederick, and Triangle Island due to an absence of high values.

The dashed curve in each panel of Figure 6 indicates the trend line with the 2001 survey point removed from the series. Based on data from the 1990 to 2000 period, the trends among the localities are mixed. The Hippa Island and Langara Island-North Frederick localities exhibit a declining trend from 1990 to 2000, while the influence of the 2000 data point produced an increasing trend for Quatsino Sound and Barkley Canyon, and to a lesser extent for Esperanza Inlet and Triangle Island. The catch rate series was without trend for other localities.

Survey data were further explored by separating the depth effect within each locality. Panels in Figure 7 show the catch rate (mean number of fish per trap) achieved on each set by year, depth stratum, and locality. Again, the solid curve in each panel represents a trend line fit by loess smoothing regression of catch rate conditioned on year. The prevailing trend over all localities, depths, and years is a decline in catch rates where the 2001 data points are the lowest observed. The pattern of decline is often similar to that observed in the aggregate data where a steep decline in the first half of the time series is followed by slower declines or stability until the influence of the 2001 data point is exerted. There are exceptions, most notably depth strata 3 and 4 at Quatsino Sound, and depth stratum 4 at Barkley Canyon, where catch rates have increased since about 1997. Cape St. James shows more coherent trends when separating out the effects of depth, and the 2001 data point is clearly the lowest observed at all depths.

The relative positions of survey sets in each year and locality were inspected for anomalies in 2001. The spatial distribution of survey sets in 2001 did not appear to depart radically from surveys conducted in the late 1990s (Appendix Fig. E.2).

3.3 Logbook catch rates over time and space

Commercial catch and effort statistics for the sablefish trap fishery were presented for the north and south by Haist et al. (2001, their Fig. 4). The prevailing trend in catch rates in both stock areas is one of decline since the late 1980s to early 1990s, particularly in the northern region. Effort (number of traps) has been stable since the early 1990s in the north, but has generally increased in the south.

Trends in the mean annual commercial trap catch rates reported from logbooks are shown in Figure 8. Each panel of the figure plots the mean of catch rates (kg retained weight per trap) on each set in a calendar year for a survey locality. The time series has been treated as two periods broken by the introduction of escape rings into commercial trap gear in 1998. The solid curve in each panel represents a trend line fit to the 1990 to 1997 period using loess regression, while the vertical dashed line marks the introduction of escape rings into the trap fishery in 1998. The trend over the 1999 to 2001 period is summarized using simple linear regression. The figure reveals a lack of fishing activity from 1992 to 1995 at latitudes in the vicinity of Barkley Canyon. The trends in the commercial data show a remarkable similarity to those observed for the survey data, including the more variable features of the Cape St. James catch rates, and the tendency for steep decline in the first half of the time series and a slowing of the rate of decline beginning in the mid 1990s. The mean catch rates (kg retained per trap) are reported in Table 6 for each locality, outside of localities, and by north and south stock areas for the annual and September to November time periods.

Figure 9 shows commercial catch rate data displayed using boxplots, as described previously for survey data summarized in Figure 5. Logbook data were used to identify sets that were contained at least partially within a survey locality (Appendix D). Each panel of the figure shows boxplots of the mean catch rate (kg retained per trap) recorded for commercial sets by calendar year. The vertical dash-dot line in each panel indicates the inception of escape rings. The sample size (number of sets) for each boxplot is indicated above the top axis of each figure panel. Low catch rates and a reduction of variance in 2001 due to the absence of high catch rate values are evident for Langara Island-North Frederick, Buck Point, Gowgaia Bay, Barkley Canyon, and Esperanza Inlet. Some localities show a progressive decrease in the magnitude of extreme catch values subsequent to the adoption of escape rings in 1998 (eg. Hippa Island, Gowgaia Bay, Barkley Canyon).

Figure 10 is identical in construction to Figure 9, except only data from sets conducted in September through November are represented in the plots to approximate the seasonal timing of the fall sablefish survey. Mean values represented by the filled circle in each boxplot are the lowest in the series for all localities except Hippa Island, Cape St. James, Langara Island-North Frederick, and Quatsino Sound. Again, the 2001 data exhibit much-reduced variance in all localities except Hippa Island and Quatsino Sound.

The distribution of trap gear sets by locality and outside of survey localities is summarized in Table 7 by year. Each column of the table corresponding to a survey locality indicates the proportion of sets using trap gear that were fished in the locality for the calendar year. During the 1990 to 2001 period, about 0.42 of all sets with valid position information were reported to be within the survey localities. The proportion of sets has declined since 1998 for Barkley Canyon, Quatsino Sound, Esperanza Inlet, Triangle Island, and Gowgaia Bay. Increases have occurred in Cape St. James and Langara Island-North Frederick; other areas show no pattern. Overall, the proportion of sets has increased outside of the survey areas since 1998. The results are similar if effort is summarized by locality using number of traps (not shown).

Figure 11 depicts the annual distribution of catch rates determined from logbooks by 0.5 degree bands of latitude from south to north. Each panel of the figure follows the same format as that for Figure 9, except that the data are now selected by the 0.5 degree band of latitude rather than by survey locality. Trends are similar to those observed within localities: general decline in mean level, and indication of decreasing variance over time for some latitude bands. Data corresponding to other latitude bands (e.g. 50.5 through 51.0) are without trend, except that the 2001 central tendency may be low. To see the effect of removing the commercial data corresponding to localities, Figure 12 shows the same presentation for sets conducted outside of survey localities. The two presentations are qualitatively similar.

Monthly components of the catch rate time trend are portrayed in Figure 13. Each panel of the figure shows a boxplot display of the commercial catch rates (kg retained per trap) achieved for one calendar month from 1990 to 2001. In general, the time trends within each month are qualitatively similar to annual patterns shown in Figure 9 through Figure 12. A decline in the mean (median) catch rate occurs from 1990 to 1997 prior to the introduction of escape rings, with the largest catch rates achieved in the winter months of January through March. The compression of variance noted in the annual summaries of catch rates is evident in many months. During the 1998 to 2001 period, mean catch rates are without trend (eg. March, April, June, July, August) or are in decline. Note that two outliers are not shown that correspond to a catch rate of 115 kg per trap in January 1991 and 203 kg per trap in February 1994.

The spatial distribution of commercial fishing (trap gear only) over time in each of the survey localities is plotted in Appendix Fig. E.3. Each panel of the figure represents sets conducted in the months of September through November for a given survey year. A set was included in the locality if either the start or end position of the set was inside the locality bounds. A solid line connects the start and end positions of individual sets. With the exception of Cape St. James and Barkley Canyon, the plots give the impression that localities appear to have experienced fewer sets in 2001 during the September to November period. Commercial logbook data are current to the end of December, 2001, although 2001 data should be regarded as preliminary.

3.4 Coincidence of commercial and survey fishing

Commercial fishing is not excluded from survey localities during the survey. Thus, the survey vessel may be fishing coincidentally in the vicinity of a sablefish commercial vessel. It has been suggested that the proximity of commercial trap gear baited with hake and squid might lower catch rates achieved by the survey gear baited with squid only. Another possibility is that commercial effort in the weeks prior to the survey could reduce sablefish density and thereby reduce catch rates during survey sets. Appendix Fig. E.4 shows commercial effort (total number of traps set) in weekly periods in September to November for each locality and year. Each panel of the figure shows the occurrence of trap effort in a week as a vertical bar. The week of the survey is indicated by the shaded rectangle. Weeks were defined for each year by designating the first Sunday to Saturday period containing January 1 as Week 1. In general, inspection of the figures suggests that survey localities experienced less commercial effort prior to survey sets in 2001 than in past years. For example, significant commercial effort was expended before the survey at Buck Point in 2000, but relatively little in 2001. In contrast, Cape St. James experienced more commercial effort prior to the survey in 2001 than in 2000, however the level of effort was similar to that recorded in 1998 and 1999.

4. Tag-recovery analysis

4.1 Update of exploitation rates based on tag-recoveries

The tag-recovery data has provided a key component of the stock assessment in recent years. Table 8 shows the results of an updated tagging analysis using recovery information through to the end of December 2001. The estimates reported in Haist et al. (2001, their Section 6) incorporated tag recoveries through April, 2001. The 2001 estimate of 37,253 t is close to the 1995 to 2000 mean of 35,260 t, and is consistent with the trends noted in Haist et al. (2001). The 2001 estimate of abundance does not suggest a dramatic decline from 2000 to 2001, nor does the 1995 to 2001 trend indicate a significant decrease in abundance in the last 6 years. However, the abundance estimates from 1993 to the mid-1990s do show the declining trend seen in survey and commercial logbook data.

Figure 14 shows the percent tags returned the next year, the estimated abundance and the estimated harvest rate by year. The trend in abundance is stable from 1996 to 2001 and there is no suggestion of a dramatic decline in abundance from 2000 to 2001. No significant outliers are apparent in the last six years. Thus, the tagging estimates, and the survey and logbook catch rates are all consistent in showing a decline from the early 1990s to 1995, and relative stability in the mid 1990s. The tagging estimates remain stable through to 2001, whereas the catch rate indices generally do not under the influence of the 2001 data.

Haist et al. (2001) argued that since the tags are applied primarily at the same depths where most of the fishing takes place, the estimated exploitation rates for the entire stock are biased high and the true exploitation rates are lower. In turn, this implies the biomass estimates are biased low (they reflect the vulnerable adult component of the stock) and the true biomass is higher than indicated from the tagging data.

4.2 Analysis of Alaskan tagging data and exchange with B.C.

The following analysis is based on the analysis and data presented in two papers, Kimura et al. (1998), and Heifetz and Maloney (2001). These results will be combined with earlier analysis of tagging from B.C. to try to estimate the exchange between Alaskan and B.C. sablefish stocks. One feature of the B.C. data is the rapid initial disappearance of tags (Figure 15). Tags disappear at about 50 percent per year for the first five years, then the rate decreases to about 20 percent each year. In contrast, the Alaskan tags disappear at a consistent 20 percent per year (Figure 16). A second important feature of the B.C. tagging data is that tag returns from Alaska rise rapidly over time as shown in Figure 17.

The Alaskan tagging data also show movements from Alaska to B.C. Table 9 is drawn from Table 6 of Kimura et al. (1998) and shows the number of tags recovered by area of release. These data range from Kimura's area 13 west of Kodiak to his area 19, and the southern Queen Charlotte Islands to the tip of Vancouver Island. Area 19 is of the most interest because it is wholly within B.C. and yet tied into the "Alaska" stock. Area 18 encompasses most of the Queen Charlotte Islands and southern portion of southeast Alaska. A major conclusion of the following analysis is that about 5 percent of the tags were recovered in area 19, and therefore more than 5 percent of the Alaskan tags were recovered in B.C. because part of area 18 is in B.C., as is most of area 20. This result holds regardless of the area of release.

Finally, the estimated rate of Canadian tag returns is roughly 75 percent in B.C. (Haist et al. 1999, their Appendix B) and about 35 percent of Alaskan tags are returned in Alaska (Heifetz and Maloney 2000). The tag return rate for Canadian tags in Alaska was assumed to be 5 percent.

These results can be synthesized using a simple two-area model of tag exchange:

$$N_{B,B,y+1} = N_{B,B,y}s(1-u) - N_{B,B,y}m_{BA} + N_{B,A,y}s(1-u)m_{AB}$$
$$N_{B,A,y+1} = N_{B,A,y}s(1-u) - N_{B,A,y}m_{AB} + N_{B,B,y}s(1-u)m_{BA}$$
$$N_{A,A,y+1} = N_{A,A,y}s(1-u) - N_{A,A,y}m_{AB} + N_{A,B,y}s(1-u)m_{AB}$$
$$N_{A,B,y+1} = N_{A,B,y}s(1-u) - N_{A,B,y}m_{BA} + N_{A,A,y}s(1-u)m_{AB}$$

where,

N_{AAy} is the number of fish tagged in Alaska that are in Alaska at time y;
N_{ABy} is the number of fish tagged in Alaska that are in BC at time y;

N_{BAy} is the number of fish tagged in B.C. that are in Alaska at time y;
N_{BBy} is the number of fish tagged in B.C. that are in B.C. at time y;
s is the survival rate from natural mortality;
u is the fishing mortality rate;
m_{AB} is the movement rate from Alaska to B.C.; and,
m_{BA} is the movement rate from B.C. to Alaska.

Recoveries of tags in each area are simply numbers times exploitation rates times tag return rates

$$R_{B,B,y} = N_{B,B,y} u r_{BB}$$
$$R_{B,A,y} = N_{B,A,y} u r_{BA}$$
$$R_{A,A,y} = N_{A,A,y} u r_{AA}$$
$$R_{A,B,y} = N_{A,B,y} u r_{AB}$$

where,

R_{BBy} is the number of tags released in B.C. recovered in B.C.;
r_{BB} is the proportion of tags released in B.C. that will be returned if captured in B.C.; and, the other subscripts for area released and recovered remain the same.

Using an s=0.92 and u=0.1, and an m_{BA} of 0.15 and m_{AB} of 0.025, we are able to match the pattern of tag recoveries of B.C. tags from Alaska (Figure 18) and replicate the declining estimate of Z with time at large (Figure 19).

The above model is a reasonably simple hypothesis about tag exchange rates and reporting rates that is consistent with all that is known about sablefish biology and the available data from B.C. and Alaska. The two parameters that might seem a bit unlikely are the particularly low return rate of B.C. tags from Alaska, and the high movement rate from B.C. to Alaska. These two parameters are closely tied. For example, B.C. tags must have a 0.5 annual disappearance rate initially, then natural mortality, fishing mortality and movement must add up to roughly 0.5. If only 30 percent of the tag returns can come back from Alaska, then the tag return rate from Alaska must be particularly low.

There are several implications of this analysis. First, it suggests a flux of roughly 5,000 t per year between B.C. and Alaska. This is primarily a result of the movement rate from Alaska to B.C. (2.5 percent required to get 5 percent of Alaskan releases returned from B.C.), and an estimated Alaska biomass of roughly 200,000 tons. This level of exchange, in turn, would provide a considerable buffer for conservation concerns in northern B.C. because the northern B.C. stock is so closely connected to the much larger Alaskan stock. While there is a need for wise management of B.C. sablefish stocks, the results of the exchange rate analysis imply there is a comfortable buffer in the case of problems. The following quote is taken from Kimura et al. (1998), and they use the term “Alaskan” to refer to all fish north of Vancouver Island: “*Alaskan sablefish, which commonly migrate over 500 nm, are more mobile than west coast* [Vancouver Island and south] *sablefish. Tag recoveries for sablefish tagged in Alaska have shown strong mutual exchange between nearly all areas.*”

The exchange rate analysis may be partially confounded by the locally high exploitation rates on some of the release groups demonstrated by Haist et al. (2001, their Section 5.2). This could explain part of the observed decline in B.C. tag-recoveries. Also, the analysis does not consider age-specific patterns of migration which would help to resolve the likely size of the buffer provided by the Alaskan stock. For example, juveniles from the portion of the stock from Vancouver Island northwards migrates west and return east as adults. Strong year classes are first abundant at age 5 in the Bering Sea, Aleutian Islands, and western Gulf of Alaska. They occur at ages 7 to 9 in the central Gulf of Alaska, and at ages 7 to 10 in the eastern Gulf of Alaska (Sigler et al. 2001, their section 9.4.6, Heifetz and Fujioka 1991). The combination of age-specific migration and annual recruitment patterns may affect the magnitude of the exchange among areas including B.C. and Alaska.

5. Other data sources

5.1 Sablefish in the 2001 longspine thornyhead survey

Haist et al. (2001, their Table 4) reported high fish densities, as judged from catch rates at depths greater than 450 fm, noting that a small fraction of tag releases and commercial fishing effort occurs below these depths. Thus, the trends in stock abundance indices and exploitation rate may pertain largely to the currently exploited component of the stock. The deep water component of the stock is not fished to a great extent by sablefish vessels, but is accessed by the deep-water trawl fishery in pursuit of thornyheads (*Sebastolobus*) (Starr and Haigh 2000).

Although there is no abundance index for the deep water component of the sablefish stock, a stratified random swept-area trawl survey was conducted in September 2001 (Starr 2001, unpublished manuscript). Biomass estimates of 13,479 t (standard error of 2,035 t) and 8,775 t (standard error of 1,148 t) were reported, where the former estimate was corrected for bottom time and latter estimate used the time between winch lockup and net retrieval. Catchability was assumed to be q=1.0, i.e. all fish in the swept path of the net were captured. About 7,215 t of the estimated total biomass can be attributed to the 500 m to 800 m depth stratum of the survey, which approximately overlaps the 250 fm (457 m) to 450 fm (823 m) range where most sablefish commercial fishing occurs (Table 10). An estimated 5,252 t and 1,012 t of sablefish lie in the 800 to 1200 m and 1200 to 1600 m depth strata, respectively.

Figure 20 shows the set locations of the 2001 longspine thornyhead survey using open circles sized proportional to the weight of sablefish caught in each tow. The sablefish index survey sets are shown as filled circles. The gray dots indicate sablefish commercial fishing sets. Three tows out of 63 total in the longspine thornyhead survey contributed observed weights of 410, 435, and 528 kg. Eleven tows caught between 100 and 300 kg, while all other tows yielded weights of less than 100 kg.

The implications of these data for the management of sablefish can be investigated with some simple calculations. The distribution of tag releases, catch, and sablefish survey catch rates by depth in 2000 is shown in Figure 21. Inspection of Figure 21 shows that most of the catch is removed from less than 450 fm, and that the stock density appears to be high below 450 fm. The longspine thornyhead survey confirms this pattern, with almost half of the total biomass estimate in the strata deeper than about 437 fm (Table 10). This reaffirms the evidence from the trap survey (Haist et al. 2001, their Table 4) that a considerable portion of the sablefish stock is deeper than most of the commercial fishery. Thus, this would cause a downwards bias in the estimated stock abundance from tagging because the "vulnerable" population is much more heavily tagged than the deeper fish.

The absolute estimate of sablefish stock size from the longspine thornyhead survey is of considerable interest. Using a catchability value of q=1.0 resulted in an estimated biomass of 13,479 t. If q=0.5, the estimate biomass would become roughly 27,000 t. The longspine thornyhead survey covered a portion of the total area of B.C., extending from the southern Canada-U.S. border to a latitude south of Quatsino Sound short of the northern tip of Vancouver Island. Furthermore, depths less than 250 fathoms were not included in the survey frame. Assuming, for instance, that only half of the total sablefish resource was surveyed, and that q=0.5, the estimated biomass is about 54,000 t. The implications of the expansions are that for reasonable choices of q and area surveyed, the survey results generate absolute biomass estimates of between 30,000 t and 50,000 t (q=0.5 and proportion and 0.5 area surveyed).

The average biomass estimated from the tagging program is about 35,000 t since the mid 1990s, an estimate though to be applicable to the vulnerable adult component of the stock as argued by Haist et al. (2001). Simple expansions of the longspine thornyhead survey data provide reassurance that the sablefish fishery is in no danger of reaching exploitation rates that would pose a conservation threat to the stock in the next year or two. For example, if the biomass is only 15,000 tons, a catch of 3,000 tons would be a 20 percent exploitation rate, far higher than desirable in the long term, but unlikely to produce an immediate stock collapse.

Table 11 and Table 12 present the implications of various combinations of assumed q and area surveyed on the biomass and exploitation rate, respectively. Appropriate values of q are not available from the longspine thornyhead survey and are not well determined in other contexts. For example, the assessment of sablefish off the U.S. Pacific coast (Schirripa and Methot 2001) adopted a fixed value of q=0.75 for the slope trawl survey, but was not able to successfully discriminate among values in the range of 0.2 to 1.8. These calculations illustrate how information from the longspine thornyhead survey might be incorporated into future assessments as survey points are accumulated and among survey variability is quantified. For example, there are relatively few combinations of *q* and area surveyed that admit harvest rates of less than 0.08.

There are no other trawl survey estimates available to quantify sablefish biomass north of the longspine thornyhead survey area. Deepwater surveys for tanner crab (*Chionoecetes tanneri*) were conducted in mid-summer 1999 (Workman et al. 2001), and the late summer of 2000 and 2001. These surveys intercepted sablefish as bycatch, however, the appropriateness of developing biomass estimates from these data has not been evaluated. Furthermore, the northern extent of the surveys was the south west tip of the Queen Charlotte Islands in 2001 only.

5.2 Recruitment indices

Haist et al. (2001) proposed recruitment indices for B.C. sablefish based on three sources: at-sea observer data from the Hecate Strait trawl fleet, the Hecate Strait assemblage survey (Choromanski et al. 2001), and the annual Hecate Strait inlet survey for sablefish. Preliminary analyses of these data (Haist et al. 2001, their Figure 9) suggested an increase in the abundance of juvenile sablefish in 1998 and 1999 as recorded by trawl observers and the sablefish inlets survey. Analysis of the International Pacific Halibut Commission standardized longline survey suggested an increase in the abundance of sablefish in Hecate Strait in 1998 (Kronlund 2001), however no size data for sablefish are available from this survey. Unfortunately the time-series consist of ten or fewer data points for each of these proposed indices, making it difficult to judge the relative strength of 1998 or 1999 recruitment. Note that a 1998 or 1999 year class would not fully recruit to the fishery until about 2005 or 2006.

King et al. (2000) developed a sablefish recruitment index from the Hecate Strait assemblage survey, larval surveys, fishery and survey age-frequency data, and climate-ocean indices. Their conclusion was that sablefish year-class abundance from 1978 to 1990 was generally above average, but was below average from 1990 to 1998, the last year in their analysis. These results are in agreement with a recruitment index derived from a shelf trawl survey off Washington, Oregon, and California (Schirripa and Methot 2001), where declines in sablefish abundance over the 1990s are attributed, in part, to poor recruitment. In the case of the Gulf of Alaska sablefish stock, the number of age 2 recruits was derived from an age-structured assessment model. The years 1960, 1964, 1967, 1974, 1977, 1980, 1984, 1988, 1990, 1995, and 1997 were characterized by Sigler et al. (2002, their Figure 9.9) as being strong year classes. Intervening year classes were designated as relatively weak, and the strength of a potentially good 1998 year-class cannot be fully evaluated without another 1-2 years of survey data since these fish are only partially recruited. The characterization of “strong” year class should be qualified by noting that the largest year classes (62-129 million age 2 fish) occurred in 1960, 1964, 1967, 1977, and 1980. Year classes during the 1990s have ranged from 5.2 to 30 million fish at age 2 and have generally been less than 20 million age 2 fish (Sigler et. al. 2002, their Table 9.9, their Figure 9.9).

6. Discussion

Catch rates obtained from sablefish survey localities generally show a steep decline from 1990 to the mid-1990s. The decline slows, or halts, beginning in the mid-1990s, consistent with the perception that sablefish stock abundance was stable during the latter 1990s (Haist et al 2001). The 2001 sablefish survey catch rates are the lowest observed in the series, and exhibit low variability compared to historical data due to the absence of high values. Their effect is to redefine the trend beginning in the mid to late 1990s from relative stability, or slow decline, to a marked downward trend in seven of the nine survey localities. The decline in catch rates is pervasive, occurring at most depth strata within most localities. Similar trends over the last decade are evident in some spatial areas for commercial catch derived from sablefish trap fishery logbooks. Interpretation of the recent trend is complicated by introduction of minimum-size 89 mm escape rings in traps in 1998. Nevertheless, the commercial sets appear to be measuring the same signal as the survey sets, judging from the low mean commercial catch rates and reduced variance observed in 2001 at some locations.

Estimates from the tagging program for 2001 indicate a biomass of 37,253 t with an exploitation rate of 0.096. The estimates of abundance are without trend from 1995 to 2001, and no significant outliers are evident. The tagging program estimates show no evidence of a dramatic decline in abundance from 2000 to 2001.

6.1 Use of sablefish survey data in sablefish stock assessments

In recent years the survey abundance indices have not figured prominently in the assessments (Saunders et al. 1996, Haist et al. 1999, 2000). Biological data from the surveys were utilized in the 1996 assessment (Saunders et al. 1996) but survey catch rates were not. Survey data were used as an abundance index in 1997 (Haist et al. 1997), at which time a decline in catch rates over all depth intervals in the northern area was noted. Depth-stratified annual abundance indices, weighted by relative size of each depth stratum, were computed from survey catch rate data (numbers of fish per trap). The survey index was input to an integrated catch-at-age, mark-recapture model (Haist et al. 1997). Modifications of this model were used in the 1998 and 1999 assessments. Haist et al. (2000) noted similarity among the trends in commercial catch rates, annual abundance determined from first year tag recoveries, and the survey catch rates. The dominant feature common to the three data sources was the period of decline during the early 1990s. However, the recommended yields for 2000/2001 were based on projections developed from a mark-recapture model based on multi-year tag recoveries. Haist et al. (2001) reiterated the observation that trends in the trap fishery catch rates, survey catch rates, and abundance determined from first year tag recoveries were similar. In view of the apparent stability of the three stock indices, and the suspected negative bias of the abundance estimates from the tag analysis, the author’s recommended that the 2000/2001 total allowable catch of 4,000 t be adopted for 2001/2002 fishing year.

The design of the survey series is weakened by the lack of replication within each combination of depth stratum and locality, and the shortness of the time series relative to the longevity of sablefish. However, the credibility of the survey as an abundance index is increased by similarities in the pattern of decline from 1990 to 2001 among most locations and within most depth strata. Also, the general coincidence of the survey catch rates, commercial trap catch rates, and tagging-based abundance estimates noted by Haist et al. (2001) provides support for the survey trends.

6.2 Commercial logbook data in sablefish stock assessments

Commercial catch rate trends derived from the longline and trap fisheries have not been given much weight in the stock assessment due to concerns with bait-loading in traps, behavioral changes in fishing practices in the late 1980s prior to the introduction of individual vessel quotas (IVQs) in 1990, and the introduction of escape rings in 1998. However, the general agreement of commercial catch rate data with the survey data suggests that efforts should be made to standardize the commercial time series as much as possible, perhaps using generalized linear or additive modeling tools.

6.3 Tagging analysis

Assessments of sablefish have relied primarily on the results of tagging analysis that utilized tag returns in the year following release to estimate abundance and thereby exploitation rate. The tagging program has a long history, dating to 1977 for the purposes of stock identification (Beamish and McFarlane 1988) and tagging for abundance estimation was re-initiated in 1991 as part of the annual sablefish survey program. Tag releases have been large, and tag-reporting rates are thought to be high (Haist et al. 1999, their Appendix B). From a critical perspective, the tag-recovery data fail to meet the assumptions of the tagging model:

1. Tags are not applied randomly, rather they are applied in locations and depth zones that represent the “core” of commercial fishing effort (over 80 percent of tags are applied between 250 and 450 fm);
2. Tags are not recovered randomly - only sablefish trap recoveries are utilized;
3. There is no complete mixing of fish. Haist et al. (2001, their Table 9) documented high correlation of tag recoveries with the site of tag release.
4. The northern B.C. stock in particular is not a closed population due to exchange of fish with Alaska.

Sources of bias in the tag-recovery estimates were described by Haist et al. (2001), who argued that exploitation rates should be over-estimated. The 2001 tagging estimates mark the first year that returns from “new” CSA-type tags have been utilized. Also, during the tagging component of the 2001 sablefish survey, approximately equal numbers of “old” B-type and “new” CSA-type tags were applied at each tagging event to help to evaluate the effect of the introduction of CSA-type tags.

6.4 Current stock status and management for U.S. sablefish stocks

A recent assessment of sablefish stocks of Washington, Oregon, and California north of Point Conception indicated that poor recruitment over the last ten years has contributed to a significantly decreased spawning biomass (Schirripa and Methot 2001). The Scientific and Statistical Committee of the Pacific Fishery Management Council (PFMC) recommended an optimum yield of 3,200 mt for the 2002 fishing season, a reduction of 54 percent from the 2001 harvest (PFMC 2001). The Groundfish Management Team of the PFMC suggested a three-year strategy that required a reduction in harvest to 4,000 mt in 2002. The PFMC adopted a yield of 4,500 mt (a 36 percent reduction from the 2001 harvest) citing evidence from the 2001 National Marine Fishery Service shelf survey of a strong 2000 year class.

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. 2002). The population declined over the course of the late 1980s until 2000, and a modest increase was observed from 2000 to 2001. The Gulf of Alaska sablefish spawning abundance is currently viewed as being low and slowly increasing overall, but sablefish abundance in the eastern Gulf of Alaska is decreasing (Sigler et al. 2001, their Figure 9.6). The pattern of decline in eastern Gulf of Alaska stock index is similar to that observed for the B.C. survey index. A decision analysis that examined the probability of decreasing 2006 abundance below 2002 abundance was conducted, and a two percent increase in the acceptable biological catch to 17,300 t was recommended for 2002. Overall, the Gulf of Alaska stock is thought to be slowly increasing, however, the eastern Gulf of Alaska stock remains in decline (Sigler et al. 2001, their Figure 9.6).

7. Summary and recommendations

The primary sources of data considered in the assessment of sablefish stock status are the survey series, commercial logbook records, and tag-recovery information. Possible hypotheses consistent with the 2001 survey estimate are:

1. the survey results reflect a dramatic decline in stock abundance;
2. the stock has been locally depleted at the localities fished by the survey;
3. the survey result in 2001 reflects a decline in availability, rather than a decline in the stock;
4. stock abundance is unchanged but the 2001 survey point is anomalous;
5. one or more surveys estimates in the stable 1996 to 2000 period are biased high (low) by chance, masking the true downward trajectory of the catch rate series.

Given the life history of sablefish, it is unlikely that a one-year decline in abundance of the magnitude suggested by the survey has occurred. The decline in catch rates over the 1990s is more obvious within survey localities, but these areas have also supported a significant fraction of the commercial trap effort. There is evidence for declines in catch rates outside of the survey areas, though not all latitudes inspected in this analysis showed clear downward trends. There are no data available to explain a change in availability due to movement within B.C. waters. One possible scenario is that perceived abundance in B.C., particularly in the north, is due to influx of fish from Alaska that did not materialize in 2001.

In the absence of evidence for a change in availability, it will not be possible to determine if the 2001 sablefish survey was badly biased without several more years survey data to determine to what degree 2001 is an outlier. There are no obvious problems in the recorded data, or reports from survey participants, that would suggest the conduct of the 2001 survey departed meaningfully from past survey practice. We note that the observations of low commercial catches in 2001 lends support to the negative direction of the 2001 survey result.

Based on this review, our view is that the survey data should receive more weight in the formulation of stock assessment advice for sablefish. We condition our advice on yield in light of evidence of generally poor recruitment of sablefish in the 1990s in B.C. (King et al. 2000), Washington, Oregon, and California (Schirripa and Methot 2001), and the Gulf of Alaska (Sigler et al. 2002). There are signs of improved recruitment in 1998/1999 in Hecate Strait, possibly for 1998 in the Gulf of Alaska, and possibly in 2000 off Washington, Oregon, and California (M. Schirripa, pers. comm.). Juvenile recruitment observed in B.C. in 1998 would partially recruit to the fishery as age 4+ in late 2003, and would be about 50 percent recruited at age 5+ or 6 in 2004 or 2005.

Some reassurance that the stock is buffered against immediate conservation concerns is provided by the analysis of sablefish catch in the longspine thornyhead survey, which reaffirms the other evidence that a significant portion of the sablefish resource is found deeper than most of the commercial trap effort. The range of abundance estimates provided by the thornyhead survey is dependent on a number of assumptions, but admit the possibility that current and recent removals have not posed high exploitation rates. Clearly, we would have more confidence in this analysis if estimates of among survey variability were available from multiple surveys, along with improved estimates of catchability and percent sablefish habitat surveyed.

Based on the revised trends in catch rates from the survey time series, and evidence of similar patterns in commercial catch rates, there is increased concern that sablefish abundance may have declined since the mid 1990s. Consideration of the arguments above leaves two possibilities:

1. The 2001 survey point is anomalous, and the stock continues to be low but stable, as suggested by the tagging data;
2. One or more of the survey points observed during the mid 1990s to 2000 was biased low (high), giving a misleading impression of stability, and the tagging estimates are biased or imprecise over time, masking a declining abundance trend.

Recommendations and advice to managers are listed below.

7.1 Revised yield options for the 2001/2002 fishing year

In order to accommodate concerns that the stock may be experiencing continued decline since the mid 1990s, the total allowable catch should be reduced for the current 2001/2002 fishing year, which began August 1, 2001. The mean of implied abundance estimates from the tagging program, uncorrected for the concentration of tags in the area of harvest, from 1995 to 2001 is about 35,000 metric tons. Tagging estimates of harvest rates from 1995 to 2001 ranged from 0.10 to 0.15 (mean 0.11), values in the high end of the 0.06 to 0.14 range identified as appropriate simulations (Haist et al. 2001). Our view is that exploitation rates of sablefish coast wide should be targeted lower, with 0.06 to 0.08 being a more conservative stance than recent estimates from the tagging analysis. The lower bound of 0.06, which may be regarded as pessimistic, reflects the view that if the evidence for a decline in the survey index persists then harvests should be reduced roughly in proportion to the decline from the relatively stable period in the mid-1990s. This translates into a recommended yield of about 2,100 to 2,800 metric tonnes for the 2001/2002 fishing year, and represents a 30 to 48 percent reduction of the existing 4000 t total allowable catch for 2001/2002. The recommended yield range includes all allocations including trawl, First Nations, research, and the directed sablefish fleet.

7.2 Yield options for the 2002/2003 fishing year

No new survey data will be available prior to onset of the 2002/2003 fishing year, although logbook and tag recovery data will accumulate commensurate with fishing activity. An external review of the stock assessment and management advice for sablefish is anticipated in the fall of 2002. In the absence of significant new stock assessment data, or advice coming from the review, we have no basis for changing the recommended yield of 2,100 to 2,800 t for the 2002/2003 fishing year.

However, if managers wish to change the timing of sablefish assessments to late winter, then an assessment could be conducted early in 2003, well in advance of the end of the fishing year. This assessment could incorporate additional tag-return and logbook data, the results of the fall 2002 sablefish index survey, and possibly results from another longspine thornyhead survey. The next assessment would presumably also benefit from the results of the planned external review.

We strongly caution managers and industry against the concept of "chasing the next survey point", and do not support formulating advice to managers on the basis of transitions from one survey estimate to the next, although we recognize that this PSARC review was initiated by the 2001 survey results. Opinion on stock status should be based on consideration of the suite of available data, including the survey time series, fishery-dependent data obtained from fisher logbooks and dockside validation, tag-recovery information, and biological data.

7.3 Other advice to managers

Biological concerns with timing of harvest prior to July 31, 2003

Our concerns about the timing of harvest between now and July 31, 2003 relate mainly to recovery of tags and impacts on the fall 2002 survey, rather than to biological implications. First, it is desirable to continue fishing activity year-round to recover tag information used for stock assessment. For example, a management plan that encouraged the balance of the 2001/2002 and the 2002/2003 quotas to be caught much sooner that July 31, 2003 would mean no recovery of tagging data for the balance of the time period. Second, it is important to re-establish as "normal" a pattern of fishing activity as possible prior to the conduct of the 2002 sablefish survey. The relative absence of fishing or, conversely, concentrated fishing activity in the weeks prior to and during the survey, could disrupt the comparability of the time series. Harvest between now and July 31, 2003 should be planned to provide a fishing pattern similar to that in recent years to avoid interruptions in the recovery of tag data and to establish typical fall fishing activity.

Applicability of the carry-over/overage policy

We re-iterate the advice provided in Haist et al. (2001). The carry-forward or overage management policy allows each quota holder to maintain a 5 percent discrepancy between individual quota and actual landings each fishing year. Thus, the extreme effects of this policy are to under or over harvest the total allowable catch in any given year by 5 percent. However, under the current policy, the difference is made up in the following fishing year. Given the longevity of sablefish, a carry-forward of 5 percent of the total allowable catch or less should have no detrimental impact on sablefish stocks.

8. Acknowledgements

We are grateful for the careful reviews provided by Michael Sigler and Alan Sinclair. Preliminary results from the 2001 longspine thornyhead survey were provided courtesy of Canadian Groundfish Research and Conservation Society. Paul Starr kindly provided additional results for sablefish from the 2001 longspine thornyhead survey. The Canadian Sablefish Association provided support for sablefish surveys and assessment work. We are grateful for the conscientious work of numerous individuals involved in the preparation and processing of data used in this analysis. In particular, the work of Margo Elfert of Archipelago Marine Research is appreciated. Discussions with Jeff Fargo, Vivian Haist, Sandy McFarlane, Mark Saunders, and Bruce Turris were greatly appreciated.

9. Literature Cited

Archipelago Marine Research Ltd. 2000. A summary of the 2000 sablefish (*Anoplopoma fimbria*) survey conducted in British Columbia waters October 9 to November 13, 2000. Unpublished data report.

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.

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

Downes, A.J., Andrews, W.T., Smith, M.S., Saunders, M.W., and G.D. Jewsbury. 1997. Cruise details of sablefish (*Anoplopoma fimbria*) surveys conducted in B.C. waters, 1994-1995. Can. Data. Rep. Fish. Aquat. Sci. 1007: 106p.

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.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. Sablefish stock assessment for 2001 and advice to managers for 2002. Can. Sci. Advisory Res. Doc. 2001/135. 54p.

Heifetz, J. and J.T. Fujioka. 1991. Movement dynamics of tagged sablefish in the northeastern Pacific Ocean. Fish. Res. 11: 355-374.

Heifetz, J. and N.E. Maloney. 2001. Estimation of tag-reporting rates for sablefish in the Northeastern Pacific Ocean. Alaska Fishery Research Bulletin 8: 1-11.

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. 2001. Information on non-target species in the International Pacific Halibut Commission standardized stock assessment survey data. PSARC Working Paper G2001-07.

McFarlane, G.A., Saunders, M.W., Thomson, R.E. and R.I. Perry. 1997. Distribution and abundance of larval sablefish, *Anoplopoma fimbria*, off the west coast of Vancouver Island, and linkages to physical oceanography. *In* Biology and management of sablefish, *Anoplopoma fimbria*. p. 81-92. NOAA Technical Report NMFS 130.

Matteson, K. Hannah, R.W., and J.T. Golden. 2001. Evaluation of pot and longline gear as survey tools for sablefish. Oregon Dept. Fish Wildlife, Newport, Oregon. 63p.

Murie, D.J., Mitton, W., Saunders, M.W., and G.A. McFarlane. 1995. A summary of sablefish tagging and biological studies conducted during 1982-1987 by the Pacific Biological Station. Can. Data Rep. Fish. Aquat. Sci. 959: 84p.

Pacific Fishery Management Council. 2001. Pacific council news. Winter 2001, **25**:(3).

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: 66p.

Saunders, M.W., Leaman, B.M., and G.A. McFarlane. 1997. Influence of ontogeny and fishing mortality on the interpretation of sablefish, *Anoplopoma fimbria*, life history. *In* Biology and management of sablefish, *Anoplopoma fimbria*. p. 81-92. NOAA Technical Report NMFS 130.

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. and R. Methot. 2001. Status of the sablefish resource of the U.S. Pacific coast in 2001. National Marine Fisheries Service.

Sigler, M.F., Fujioka, J.T., and S.A. Lowe. 2000. Alaska sablefish assessment for 2001. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2001.

Sigler, M.F., Lunsford, C.R., Lowe, S.A., and J.T. Fujioka. 2001. Alaska sablefish assessment for 2002. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2002.

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: 129p.

Starr, P. 2002. Preliminary analysis of results: longspine thornyhead random stratified trawl survey west coast Vancouver Island, September-October 2001. Unpublished report.

Starr, P.J. and R. Haigh. 2000. Assessment of the Canadian longspine thornyhead (*Sebastolobus altivelis*) for 2000. Can. Stock Assess. Res. Doc. 2000/154. 66p.

Stocker, M. and A. Cass. 2001. Report of the Groundfish Subcommittee Meeting, November 13-16, 2001. Can. Sci. Advisory Sec., Proceedings Series 2001/034. 60p.

Workman, G.D., Boutillier, J.A., Philips, A.C., Gillespie, G.E., Park, W-G, Clark, D., and B. Pennell. 2001. Results from a bottom trawl survey of Grooved Tanner Crab, *Chionoecetes tanneri* Rathbun, stocks off the west coast of Vancouver Island, July 21-August 3, 1999. Can. Manuscr. Rep. Fish. Aquat. Sci. 2568. 79p.

Table 1. Depth strata definitions by 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	251 (458)	350 (641)
	3	351 (642)	450 (824)
	4	451 (825)	550 (1006)
	5	551 (1007)	Deeper

Table 2. Number of index sets conducted at offshore sablefish survey localities by depth stratum and year. Sets were assigned to depth strata based on the mean of depth observations taken at one minute intervals.

Location	**Stratum**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Barkley Canyon	1			1	1	1	1	1	1	1	1	2	1
	2	2	2	1	2	1	1	1	1	1	1		1
	3	2	2	1	2	1	1	1	1	1	1	1	1
	4	2	2	1	2	1	1	1	1	1	2	1	1
	5	2	2	1	2	1	1	1	1	1		1	1
Esperanza Inlet	1			1	1	1	1	1	1	2	1	1	1
	2	2		1	1	1	1	1	2		1	1	1
	3	2		1	1	1	1	1		1	1	1	1
	4	3		1	1	1	1	1	1	1	1	1	1
	5	1		1	1	1	1	1	1	1	1	1	1
Solander Island	1					1	1						
	2					1	1						
	3					3	1						
	4						1						
	5						1						
Quatsino Sound	1	1		1	1	1	1	1	1	1	1	1	1
	2	1	2	1	1	1	1	1	1	1	1	1	1
	3	2	2	1	1	2	1		1	1	1	1	1
	4	2	2	1	1	1	1	2	1	1	1	1	1
	5	2	2	1	1		1	1	1	1	1	1	1
Triangle Island	1			1		1	1	1	2	1	1	2	1
	2		1	1	1	1	1	1		1	1		1
	3		1	1	1	1	1	1	1	1	1	1	1
	4		1	1	1	1	1	1	1	1	1	1	1
	5		1	1	1	1	1	1	1	1	1	1	1

Table 2. continued.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cape St. James	1					1	1	1	2	1	1	1	1
	2					1	1	1		1	1	1	1
	3					1	1	1	1	1	1	1	1
	4					1	1	1	1		1	1	1
	5					1	1	1	1	2	1	1	1
Gowgaia Bay	1					1	1	1	1	1	1	1	1
	2			1	1	1	1	1	1	1	1	1	1
	3			1	2	1	1	1	1	1	1	1	1
	4			1	1	1	1	1	1	1	1	1	1
	5			1	1	1	1	1	1	1	1	1	1
Buck Point	1			1	1	1	1	1	1	1	1	1	1
	2		1	1	1	1	1	2	1	1	1	1	1
	3		1	1	1	1	1	1	1	1	1	1	1
	4		1	1	1	1	1		1	1	1	1	1
	5		1	1	1	1	1	1	1	1	1	1	1
Hippa Island	1				1	1	1	1		1	1	1	1
	2			1	1	1	1	1		1	1	1	1
	3			1	1	1	1	1		1	2	1	1
	4			1	2	1	1	1		1		1	1
	5			1		1	1	1		1	1	1	1
Langara Island-	1			1		1	1	1	2	1	1	1	1
North Frederick	2		1	1	1	1	1	1		1	1	2	1
	3		1	1	1	1	2	2	1	1	1	1	1
	4		1	1	1	1			1	1	1		1
	5		1	1	1	1	1	1	1	1	1	1	1

Table 3. Sablefish survey vessel, timing, and skipper for 1988 to 2001. Start Date is the date of the first survey set and End Date is the date of the last survey haul.

Year	Vessel	Skipper	Start Date	End Date
1988	F/V Vicious Fisher	Fletcher	October 31	November 23
1989	F/V La Porsche	Brynjolfsen	October 21	November 17
1990	F/V Viking Star	Farrington	November 09	November 20
1991	R/V W.E. Ricker	Farrington	October 10	October 28
1992	R/V W.E. Ricker	Roberts	October 15	November 03
1993	R/V W.E. Ricker	Farrington	October 23	November 10
1994	F/V La Porsche	Beauvais	October 15	October 25
1994	F/V Western Viking	Jones	October 19	November 07
1995	F/V Victor F	Derry	October 15	October 28
1995	F/V Viking Sunrise	Oslen	October 10	October 25
1995	F/V Ocean Pearl	Fraumeni/Gold	October 08	October 18
1996	F/V Viking Star	Elvan	October 08	October 20
1996	F/V Ocean Pearl	Derry	September 27	October 06
1997	F/V Ocean Pearl	Derry	September 27	October 14
1998	F/V Ocean Pearl	Derry	September 24	October 10
1999	F/V Ocean Pearl	Derry	September 29	October 17
2000	F/V Pacific Viking	Melnychuck	October 08	November 11
2001	F/V Ocean Pearl	Derry	October 07	October 29

Table 4. Sample mean catch rate (number fish per trap) of survey index sets by depth stratum, locality, stock, and year. Sets assigned to depth strata based on the mean of depth observations taken at one minute intervals. Fouled or holed traps excluded from summary.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barkley Canyon	1			13.76	23.04		7.92	3.12	7.52	1.46	2.15	2.78	0.16
	2	15.74	6.73	24.65	26.38	22.42	8.92	3.72	6.92	2.16	1.56		0.64
	3	7.36	9.50	18.92	16.78	7.84	6.40	6.08	6.88	2.36	1.87	13.28	2.64
	4	14.70	23.44	21.04	19.44	19.88	10.40	8.24	5.44	7.21	6.53	12.48	8.13
	5	11.72	15.60	19.16	12.88	17.20	7.92	9.68	6.64	8.76		11.04	5.28
	Mean	12.47	13.82	19.51	19.33	16.83	8.31	6.17	6.68	4.39	3.73	8.47	3.37
Esperanza Inlet	1			7.48	13.29	9.40	4.84	5.32	10.12	4.04	4.13	6.48	1.68
	2	8.04		12.40	16.76	8.64	8.17	2.40	4.28		2.67	5.00	0.29
	3	5.14		8.24	12.16	6.36	4.72	1.72		1.63	2.32	2.42	0.81
	4	10.33		10.60	20.48	3.52	13.45	2.72	1.58	1.52	2.04	7.33	0.96
	5	9.60		16.76	22.12	8.44	5.25	6.64	5.70	7.42	5.61	3.00	4.81
	Mean	8.37		11.10	16.96	7.27	7.29	3.76	5.19	3.65	3.35	4.85	1.71
Solander Island	1					0.68	5.68						
	2					5.48	3.72						
	3					3.52	2.96						
	4						4.08						
	5						3.52						
	Mean					3.34	3.99						
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
	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	3.30	2.76	7.08	10.24	3.20	2.16		0.21	5.68	3.32	3.84	5.76
	4	5.40	9.50	14.72	4.08	1.72	3.32	1.82	0.24	2.36	3.60	8.05	5.88
	5	6.90	5.94	9.32	5.32		4.52	2.52	0.52	2.12	4.88	2.24	1.64
	Mean	5.07	5.21	8.97	7.63	3.81	3.41	2.25	0.87	3.42	3.72	4.26	3.15
Triangle Island	1			5.44		3.52	4.48	5.08	2.30	1.64	2.68	4.36	0.96
	2		4.67	12.08	11.56	9.44	7.52	4.72		3.84	3.16		0.78
	3		1.33	10.36	9.20	4.42	7.76	2.84	3.56	2.36	2.67	5.12	0.48
	4		1.71	4.64	7.17	0.36	4.00	1.60	0.44	4.88	1.36	1.12	0.56
	5		1.13	4.32	6.76	0.36	4.28	2.40	1.37	6.28	1.14	1.21	0.44
	Mean		2.21	7.37	8.67	3.62	5.61	3.33	1.99	3.80	2.20	3.23	0.65
Southern Stock	**Mean**	8.47	8.05	11.74	14.42	7.41	6.15	3.88	3.68	3.82	3.25	5.20	2.22

Table 4. continued.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cape St. James	1					1.62	3.17	2.44	1.56	2.13	4.22	2.04	1.08
	2					3.32	2.08	3.52		3.80	5.74	4.95	2.72
	3					4.20		4.43	3.24	1.96	3.36	3.08	0.64
	4					3.91	0.88	1.80	1.52		1.71	1.74	0.17
	5						1.38	1.64	0.56	1.15	0.38	0.35	0.11
	Mean					3.26	1.88	2.77	1.69	2.04	3.08	2.43	0.95
Gowgaia Bay	1					1.81	3.48	3.67	3.48	3.00	0.68	0.58	0.36
	2		11.75	10.83	15.13		7.24	2.56	4.00	4.84	2.09	6.13	0.42
	3		4.33	8.71	13.81	9.17	6.40	2.76	1.36	4.72	1.50	2.61	0.69
	4		2.63	3.44	7.12	3.76	5.40	2.00	0.64	3.29	0.56	2.08	
	5		3.96	4.84	6.84		1.68	1.68	0.60	3.92	0.28	1.32	0.35
	Mean		5.67	6.96	11.34	4.91	4.84	2.53	2.02	3.95	1.02	2.54	0.45
Buck Point	1			3.12	9.32	2.00	2.40	2.62	0.64	3.85	2.09	2.96	0.44
	2		6.96	11.71	12.25	6.80	2.72	4.80	3.92	4.80	2.32	4.60	0.67
	3		2.13	10.32	5.00	4.09	3.92	1.60	0.96		2.04	1.20	0.24
	4		3.79	7.35	4.16	4.36	1.50		0.48	1.72	0.80	1.72	0.16
	5		2.29	4.92	3.36		1.40	3.54	0.60	4.52	0.31	1.24	0.40
	Mean		3.79	7.48	6.82	4.31	2.39	3.47	1.32	3.72	1.51	2.34	0.38
Hippa Island	1				1.09	2.96	1.80	2.27		1.96	0.88	1.56	0.56
	2			4.79	10.84	2.16	2.16	4.21		4.92	1.48	2.44	0.68
	3			3.76	8.36	2.88	4.40	6.38		6.60	0.84	1.96	0.08
	4			8.16	6.62	5.52	2.00	4.00		3.92		1.40	0.43
	5			4.44			2.24	5.13		0.58	2.64	0.52	0.28
	Mean			5.29	6.71	3.38	2.52	4.40		3.60	1.34	1.58	0.41
Langara Island-North Frederick	1			1.72		1.74	0.28	1.88	2.48	3.40	0.24	2.67	0.08
	2		10.29	4.16	10.43	3.96	2.71	2.52		6.29	6.44	1.50	0.36
	3		8.33	1.20	9.28	2.32	2.34	0.98	1.24	2.96	4.20	1.33	0.11
	4		8.96	4.20	6.04	3.16			1.12	4.76	3.08		0.16
	5		11.00	6.60	5.92		0.68	2.72	2.08	3.52	2.48	0.44	0.40
	Mean		9.65	3.58	7.92	2.79	1.67	1.82	1.88	4.19	3.29	1.49	0.22
Northern Stock	**Mean**		6.37	5.79	8.21	3.67	2.69	3.00	1.73	3.49	2.05	2.08	0.48

Table 5. Sample mean catch rate (kg/trap) of survey index sets by depth stratum, locality, stock and year. Sets assigned to depth strata based on the mean of depth observations taken at one minute intervals. Fouled or holed traps excluded from summary.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barkley Canyon	**1**			33.44	54.84		28.44	12.08	23.90	5.21	7.55	8.30	0.38
	2	39.86	12.65	74.00	65.62	58.54	26.33	13.04	20.76	5.84	4.91		1.53
	3	19.18	16.34	39.67	49.30	24.76	21.64	16.20	14.65	6.68	4.26	25.68	5.70
	4	29.76	41.26	42.60	46.64	38.56	26.76	21.28	13.13	14.63	15.14	25.60	17.97
	5	25.40	32.84	39.96	30.98	36.84	18.32	23.28	15.71	17.12		27.48	13.71
	Mean	29.00	25.77	45.93	48.88	39.68	24.30	17.18	17.63	9.89	9.40	19.07	7.86
Esperanza Inlet	**1**			25.48	50.13	24.84	15.08	19.04	28.92	13.00	14.02	20.92	5.84
	2	21.58		35.28	38.72	15.52	26.71	7.80	6.29		7.21	15.42	0.89
	3	13.12		24.16	39.80	15.68	13.60	4.52		4.67	5.90	5.21	1.60
	4	21.13		27.24	54.88	9.56	28.65	7.36	2.90	3.33	4.79	15.46	2.19
	5	18.28		36.20	60.12	21.60	14.55	14.00	10.84	16.23	14.29	7.80	11.50
	Mean	18.88		29.67	48.73	17.44	19.72	10.54	11.05	9.31	9.24	12.96	4.40
Solander Island	**1**					3.28	19.48						
	2					16.28	11.24						
	3					8.57	9.28						
	4						11.60						
	5						11.72						
	Mean					9.06	12.66						
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	12.00	5.92	27.52	34.93	19.20	12.04	8.60	2.72	13.36	9.62	10.00	2.20
	3	9.72	7.02	20.48	33.36	9.14	5.64		0.49	14.80	9.05	9.32	11.96
	4	15.76	18.79	34.24	16.08	3.96	8.68	5.44	0.41	8.00	12.58	15.41	10.57
	5	14.72	14.88	22.96	19.96		15.70	8.72	0.86	6.28	14.43	5.96	3.29
	Mean	13.12	11.65	25.10	26.26	11.83	10.62	7.25	2.24	10.64	12.02	9.84	6.52
Triangle Island	**1**			23.96		9.36	14.48	17.28	8.31	5.48	8.76	13.30	3.34
	2		13.79	32.04	36.04	22.60	24.61	14.92		11.32	8.26		2.06
	3		3.63	26.56	25.20	12.25	26.72	9.24	10.73	7.76	7.88	11.52	1.11
	4		6.96	18.04	33.29	0.76	15.96	7.52	1.25	16.56	4.08	4.12	1.78
	5		5.42	15.20	29.40	1.40	17.28	9.36	5.66	26.00	5.26	4.79	1.53
	Mean		7.45	23.16	30.98	9.27	19.81	11.66	6.85	13.42	6.85	9.41	1.97
Southern Stock	**Mean**	19.96	16.46	30.97	40.81	18.50	18.61	11.66	9.44	10.90	9.38	12.82	5.19

Table 5. continued.

Location	Stratum	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Cape St. James	**1**					6.88	11.42	8.11	5.40	7.22	13.67	6.54	3.14
	2					9.56	7.42	13.20		13.20	17.34	14.27	6.51
	3					13.20		14.57	8.86	5.58	9.32	8.79	1.49
	4					16.23	3.08	6.56	4.74		5.22	6.30	0.49
	5						6.54	8.32	2.37	4.73	1.53	1.22	0.42
	Mean					11.47	7.11	10.15	5.36	7.09	9.42	7.43	2.41
Gowgaia Bay	**1**					7.67	14.08	15.00	12.13	10.76	2.43	2.08	0.94
	2		47.21	37.17	62.21		24.88	8.72	12.22	18.20	5.30	17.63	1.35
	3		15.54	20.25	52.17	35.63	21.20	10.04	3.94	17.08	4.37	8.04	2.20
	4		11.58	11.52	29.56	17.44	19.96	7.52	2.30	13.25	2.54	6.36	
	5		17.25	18.60	31.64		6.96	6.60	2.78	16.75	1.20	4.52	0.97
	Mean		22.90	21.88	45.55	20.24	17.42	9.58	6.67	15.21	3.17	7.73	1.36
Buck Point	**1**			12.65	44.12	7.20	9.16	9.19	2.08	14.35	6.63	10.04	1.31
	2		25.83	40.46	33.00	20.28	9.20	13.84	11.05	16.12	5.86	13.24	1.74
	3		5.58	27.36	14.40	11.65	11.68	4.44	2.49		4.12	2.96	0.56
	4		11.33	24.30	15.56	15.84	4.29		1.55	6.20	2.50	5.00	0.49
	5		7.67	16.00	12.84		4.68	11.04	1.91	14.04	1.20	3.96	1.17
	Mean		12.60	24.15	23.98	13.74	7.80	10.47	3.82	12.68	4.06	7.04	1.06
Hippa Island	**1**				3.95	9.52	6.80	7.82		7.33	2.64	4.72	2.06
	2			18.46	30.68	9.68	6.76	18.25		17.50	4.12	9.68	1.65
	3			11.64	29.00	9.52	13.52	26.13		22.52	1.73	5.56	0.16
	4			24.64	24.54	13.40	6.77	15.72		15.80		5.08	1.49
	5			14.48			7.56	18.75		2.63	11.13	2.00	0.83
	Mean			17.30	22.54	10.53	8.28	17.33		13.16	4.27	5.41	1.24
Langara Island-North Frederick	**1**			6.68		7.91	0.84	7.67	12.99	17.16	0.78	9.75	0.44
	2		37.79	14.84	45.17	14.48	12.33	11.84		26.21	23.65	4.42	1.09
	3		30.00	4.64	32.20	7.96	8.64	3.74	4.48	11.88	13.29	3.58	0.17
	4		33.70	15.12	22.72	9.96			3.47	15.56	8.74		0.51
	5		42.92	24.92	27.12		2.60	8.80	6.91	11.80	8.82	1.76	1.12
	Mean		36.10	13.24	31.80	10.08	6.61	7.16	8.17	16.52	11.06	4.79	0.67
Northern Stock	**Mean**		23.87	19.10	30.93	12.84	9.54	10.94	6.00	12.94	6.39	6.48	1.35

Table 6. Sample means of commercial catch rates (kg retained per trap) by survey locality, outside of survey localities and by stock for annual period and September to November period.

Annual	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barkley Canyon	13.11	17.83					12.86	13.65	15.67	9.11	10.71	5.04
Buck Point	17.65	22.49	20.60	11.77	15.29	12.18	12.04	10.68	13.08	7.17	10.36	8.24
Cape St. James	15.75	16.50	22.19	23.07	19.58	17.38	11.66	9.43	16.19	13.19	9.09	10.16
Esperanza Inlet	11.39	9.27		16.88	19.58	17.51	12.11	12.76	9.83	11.83	13.58	8.56
Gowgaia Bay	31.67	31.25	26.18	18.67	19.19	15.26	13.04	10.82	13.05	11.62	12.90	7.21
Hippa Island	18.01	28.65	16.55	15.54	12.80	11.74	14.80	12.06	10.15	11.83	11.93	8.26
Langara Island-North Frederick	19.18	40.86	26.01	24.00	22.27	19.02	20.11	15.94	12.32	21.73	14.22	8.68
Quatsino Sound	16.33	15.35	21.76	17.65	17.83	8.37	10.14	12.13	12.17	7.93	8.27	8.99
Triangle Island	16.99	13.60	29.21	27.96	27.80	15.20	8.71	9.16	14.27	9.42	7.95	11.61
Outside of localities	23.08	26.09	23.17	20.43	18.43	15.19	14.80	12.58	12.08	13.38	12.45	9.65
North	19.37	24.92	22.99	20.11	18.75	15.17	14.01	12.44	12.56	12.98	11.90	9.44
South	13.95		52.84		33.91	9.62	11.55	9.30	8.50	5.59		4.54

September to November	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Barkley Canyon	13.50						17.30	14.88	15.01	14.03	14.20	3.82
Buck Point	15.17	20.61	22.88	12.56	15.63	14.60	12.57	12.00	21.08	7.83	10.70	5.43
Cape St. James	21.69	16.95	22.00	13.59	17.04	13.71	11.16	10.84	17.04	13.56	8.10	11.34
Esperanza Inlet	9.05	9.27		16.03	25.09	25.33	12.47	14.13	10.38	10.26	15.55	6.45
Gowgaia Bay	30.23	34.02	27.54	14.50	25.42	17.87	9.91	13.11	15.75	7.93	12.79	3.81
Hippa Island	15.46	22.61	12.88	14.53	14.87	7.09	12.93	9.07	12.66	5.02	7.44	6.85
Langara Island-North Frederick	18.70		27.14	23.04	15.18	15.78	27.94	12.64	16.77	20.61	7.57	8.21
Quatsino Sound	17.30	11.07	21.76	18.57	19.05		15.34	12.62	14.80	7.53	9.74	9.24
Triangle Island	14.58	12.55	29.20	20.44	15.87		12.31	11.20	16.04	10.97	10.37	3.97
Outside of localities	23.47	23.72	21.16	18.19	15.58	18.14	14.59	13.48	15.16	12.54	10.19	7.42
North	20.42	22.59	22.00	18.25	16.45	18.12	14.30	13.19	14.84	12.40	10.25	7.64
South	13.95						21.26	9.51		5.59		4.33

Table 7. Distribution of the proportion of trap gear sets by survey locality and year determined from commercial logbook data. Sets were defined as being in a locality if the start or end position of the set was included in the locality bounds. All other sets were designated as "Outside" locality bounds.

Year	Total Sets	Barkley Canyon	Quatsino Sound	Esperanza Inlet	Triangle Island	Cape St. James	Gowgaia Bay	Buck Point	Hippa Island	Langara Island-North Frederick	Outside
1990	1899	0.025	0.131	0.050	0.072	0.028	0.041	0.039	0.042	0.021	0.552
1991	1867	0.033	0.069	0.002	0.058	0.017	0.060	0.061	0.047	0.037	0.616
1992	1978		0.010	0.000	0.009	0.041	0.060	0.082	0.045	0.062	0.690
1993	2712		0.052	0.041	0.053	0.040	0.028	0.050	0.053	0.056	0.625
1994	3037		0.106	0.035	0.038	0.052	0.031	0.053	0.070	0.124	0.490
1995	2801		0.025	0.058	0.050	0.060	0.066	0.041	0.046	0.041	0.612
1996	3164	0.010	0.059	0.117	0.029	0.052	0.042	0.035	0.026	0.063	0.566
1997	4460	0.002	0.066	0.087	0.024	0.028	0.025	0.043	0.049	0.054	0.621
1998	4431	0.054	0.068	0.081	0.078	0.065	0.032	0.018	0.024	0.049	0.531
1999	4115	0.042	0.049	0.044	0.078	0.072	0.013	0.024	0.020	0.079	0.580
2000	3333	0.019	0.022	0.037	0.055	0.094	0.015	0.036	0.056	0.110	0.555
2001	3548	0.024	0.049	0.024	0.041	0.103	0.010	0.026	0.031	0.071	0.620
All	37345	0.019	0.058	0.053	0.050	0.058	0.032	0.039	0.041	0.066	0.584

Table 8. Summary of tagging information and estimates of stock size and exploitation rate.

Tagging year	Next year	Number tagged	Next year trap recoveries	Percent tags not usable	Expanded for non usable	Expanded to include shedding	Percent next year	Percent returned t+1	Trap catch including sorting	Total landings all gears	Implied abundance	Exploitation rate
1991	1992	2,430	70	0.131	81	96	0.10	39%	4,722	5,128	46,479	0.110
1992	1993	3,578	70	0.223	90	108	0.08	37%	5,449	5,088	67,006	0.076
1993	1994	7,004	261	0.188	321	384	0.10	53%	5,304	5,084	51,296	0.099
1994	1995	3,594	233	0.049	245	293	0.11	76%	4,337	4,007	40,452	0.099
1995	1996	12,653	860	0.032	888	1,061	0.11	74%	3,835	3,379	33,843	0.100
1996	1997	9,119	656	0.005	659	788	0.12	75%	4,613	4,178	40,041	0.104
1997	1998	7,117	753	0.007	758	906	0.17	75%	5,100	4,492	30,050	0.149
1998	1999	15,914	864	0.006	869	1,039	0.09	75%	3,698	4,717	42,503	0.111
1999	2000	17,763	993	0.015	1,009	1,205	0.09	75%	2,701	3,806	29,864	0.127
2000	2001	19,764	904	0.008	912	1,089	0.07	75%	2,738	3,559	37,253	0.096

Table 9. Number of tags returned from Alaskan tagging program by area of release and recovery.

	area recovered first row is area numbers 2nd row is latitude or longitude boundaries								
	13	14	15	16	17	18	19		
Area Released	155-160	150-155	145-150	140-145	135-140	52.50-60	50-52.5	Total over all areas	% to 19
13	157	103	111	56	89	75	41	764	0.054
14	38	284	139	87	114	72	57	909	0.063
15	22	76	297	93	82	57	43	762	0.056
16	26	26	79	241	99	39	19	603	0.032
17	30	60	109	99	796	181	71	1496	0.047
18	13	48	34	54	299	879	115	1579	0.073

Table 10. Sablefish biomass estimates from 2001 thornyhead survey by stratum.

Area stratum:Depth stratum (m)	Biomass (t)	Standard error (t)	Relative error (%)
A:500-800	2,912	1,582	54.3
B:500-800	1,593	765	48
C:500-800	376	134	35.7
D:500-800	881	357	40.5
E:500-800	1,453	616	42.4
A:800-1200	1,456	350	24
B:800-1200	860	160	18.5
C:800-1200	587	143	24.3
D:800-1200	809	231	28.5
E:800-1200	1,540	384	24.9
A:1200-1600	446	389	87.2
B:1200-1600	179	69	38.3
C:1200-1600	101	5	5.1
D:1200-1600	31	31	100
E:1200-1600	255	4	1.6
Total	13,479		

Estimates courtesy of Paul Starr

Table 11. Implications on total stock biomass of combinations of *q* and percent area surveyed.

	Proportion of stock surveyed			
q	0.3	0.5	0.7	1.0
0.3	149,761	89,857	64,183	44,928
0.4	112,321	67,393	48,138	33,696
0.5	89,857	53,914	38,510	26,957
0.6	74,881	44,928	32,092	22,464
0.7	64,183	38,510	27,507	19,255
0.8	56,160	33,696	24,069	16,848
0.9	49,920	29,952	21,394	14,976
1.0	44,928	26,957	19,255	13,479

Table 12. Implications on exploitation rate of combinations of *q* and percent area surveyed, given a total allowable catch of 4,000 t.

	Proportion of stock surveyed			
q	0.3	0.5	0.7	1.0
0.3	0.03	0.04	0.06	0.09
0.4	0.04	0.06	0.08	0.12
0.5	0.04	0.07	0.10	0.15
0.6	0.05	0.09	0.12	0.18
0.7	0.06	0.10	0.15	0.21
0.8	0.07	0.12	0.17	0.24
0.9	0.08	0.13	0.19	0.27
1.0	0.09	0.15	0.21	0.30

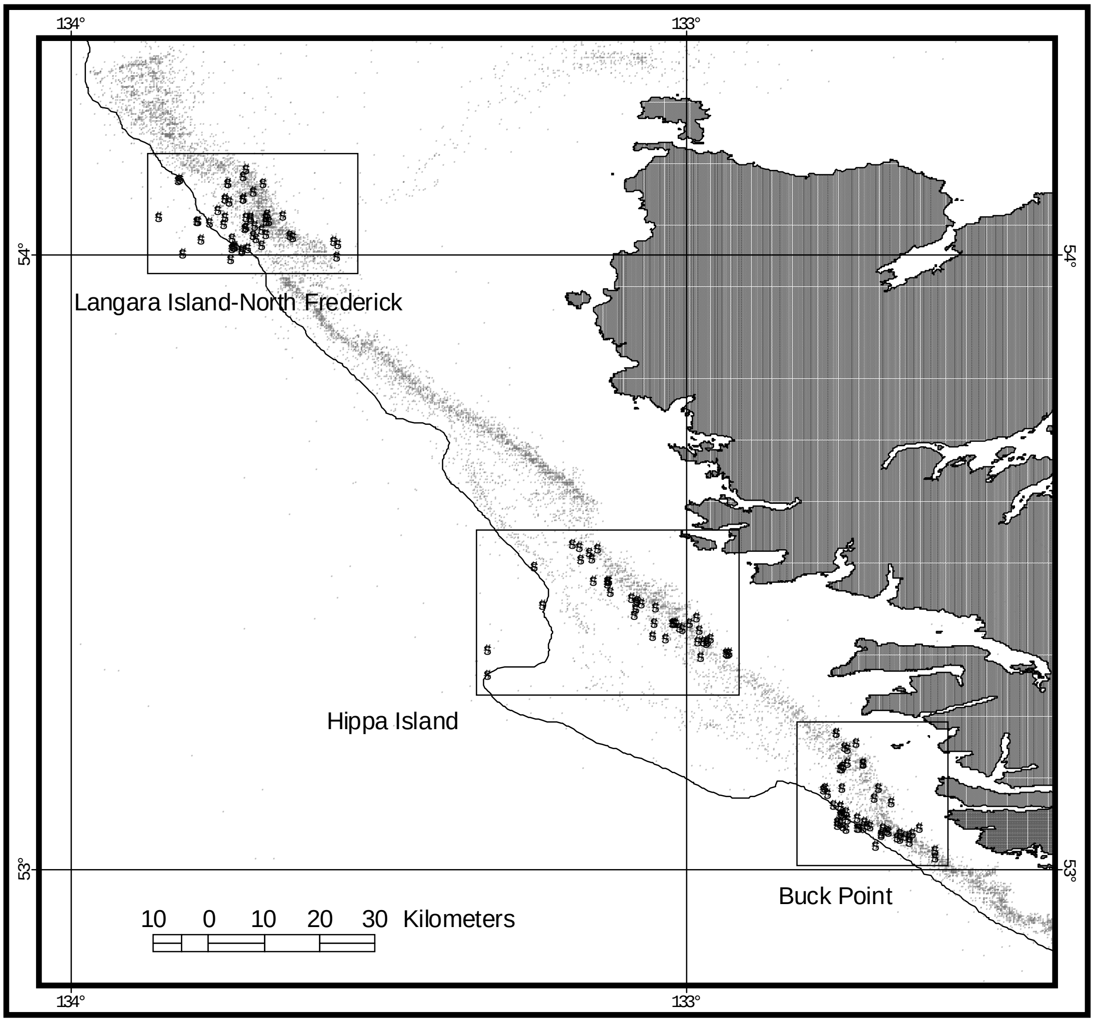

Figure 1. Sablefish survey localities at Langara-Frederick Island, Hippa Island, and Buck Point. The rectangles indicate a bounding box that includes all survey sets from 1990 to 2001. Large filled circles indicate the start position of each index survey set. Small gray circles indicate the start position of commercial sets. The 1000 m contour is shown as a curved solid line.

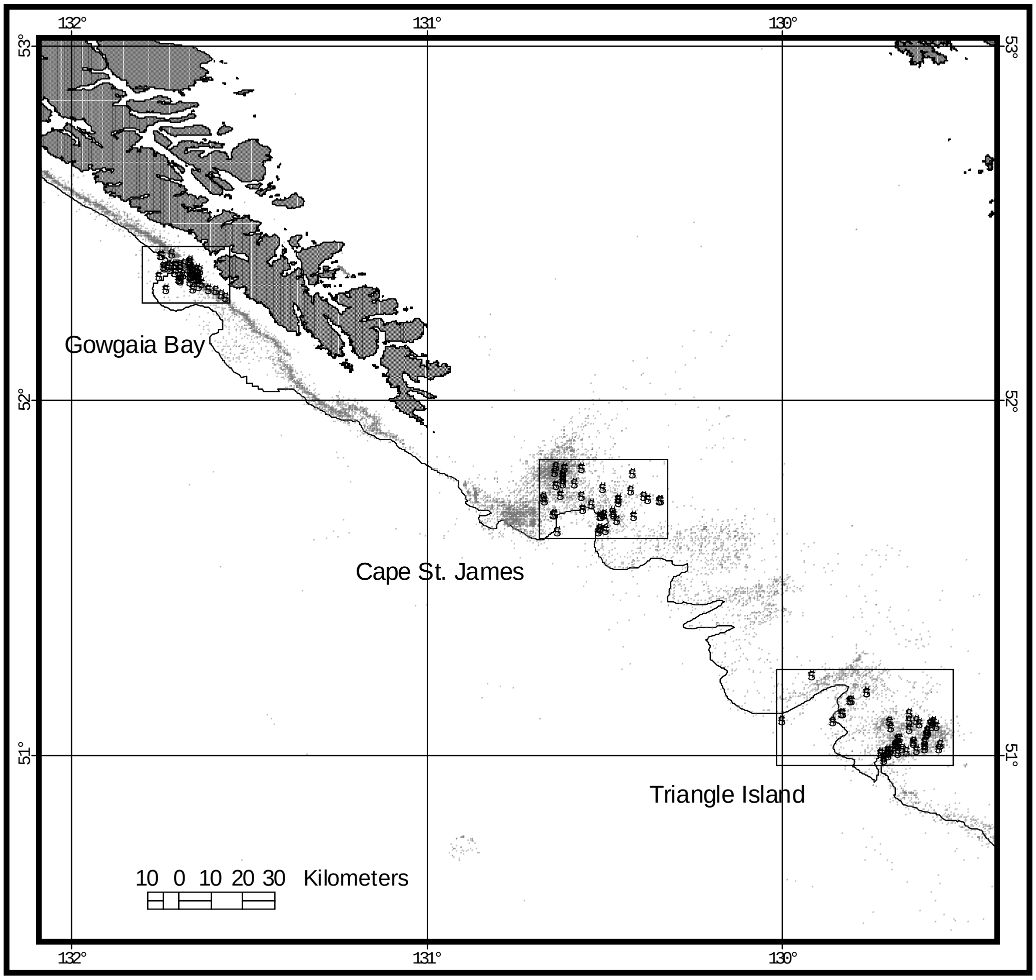

Figure 2. Sablefish survey localities at Gowgaia Bay, Cape St. James, and Triangle Island. The rectangles indicate a bounding box that includes all survey sets from 1990 to 2001. Large filled circles indicate the start position of each index survey set. Small gray circles indicate the start position of commercial sets. The 1000 m contour is shown as a curved solid line.

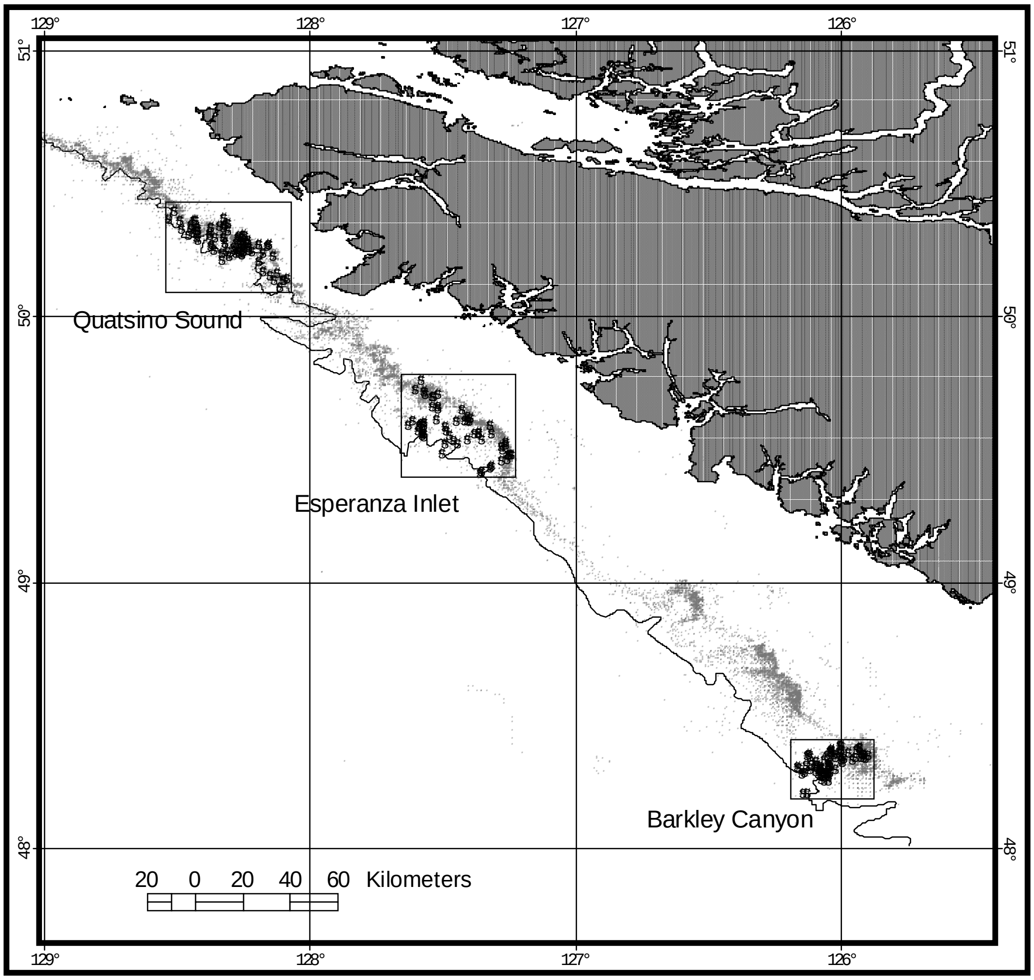

Figure 3. Sablefish survey localities at Esperanza Inlet, Quatsino Sound, and Barkley Canyon. The rectangles indicate a bounding box that includes all survey sets from 1990 to 2001. Large filled circles indicate the start position of each index survey set. Small gray circles indicate the start position of commercial sets. The 1000 m contour is shown as a curved solid line.

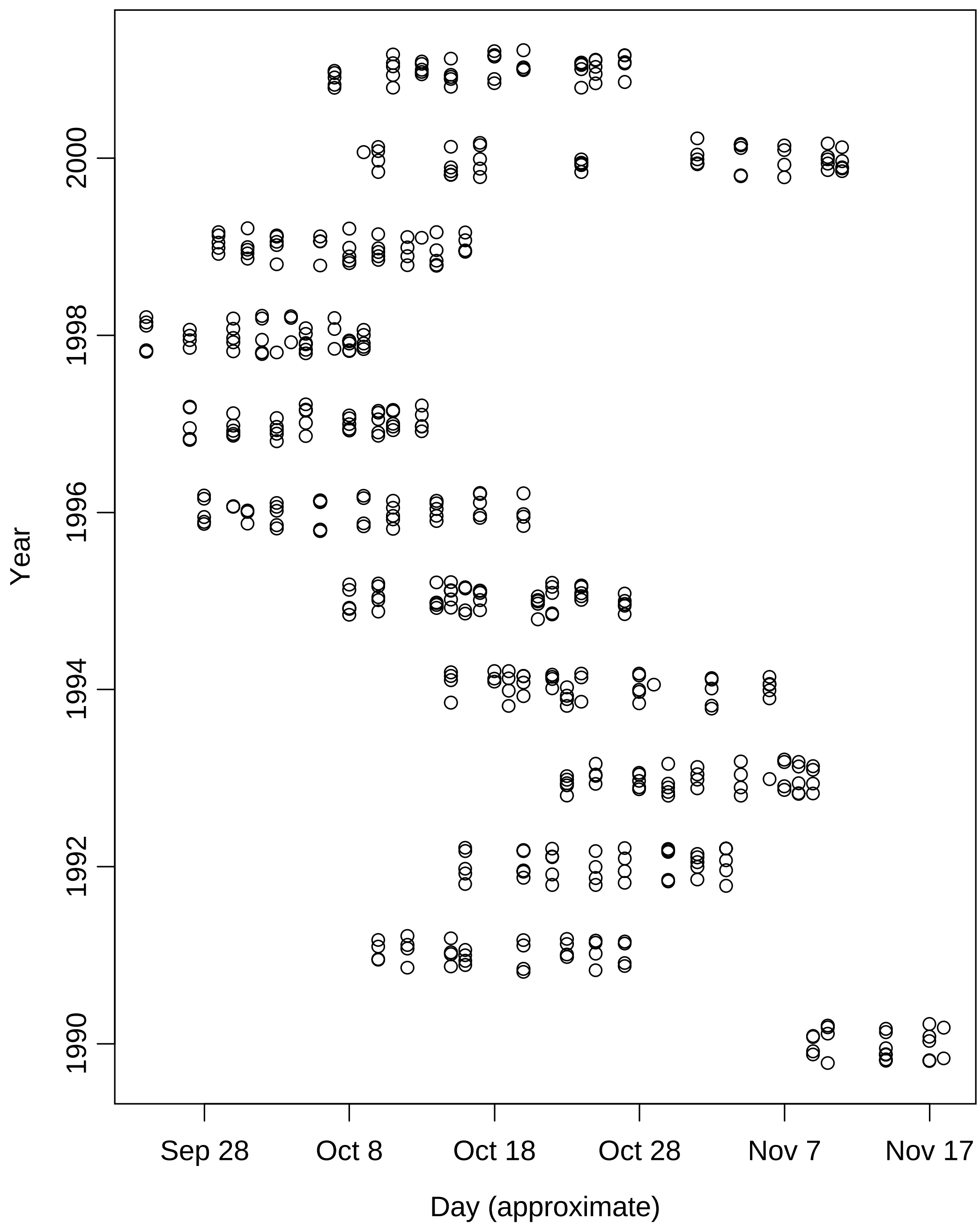

Figure 4. Timing of sablefish survey sets by year. Each circle represents the set date of a survey set. Circles have been jittered along the y-axis to expose sets conducted the same day. Dates indicated are not adjusted for leap years.

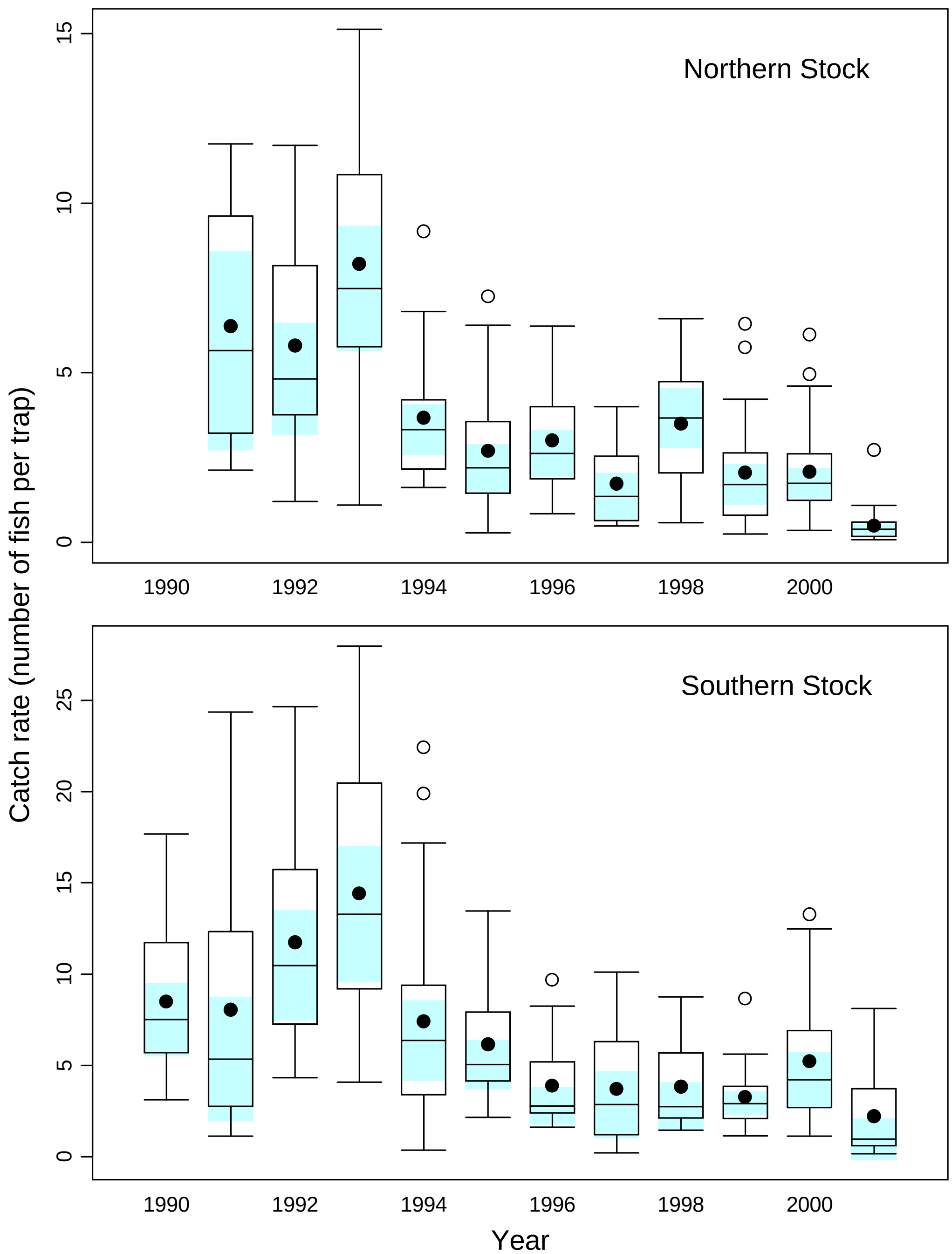

Figure 5. Distribution of sablefish survey catch rates (number of fish per trap) for each set by year and stock. Boxplots show the distribution of catch rates observed on each set. The filled circles show the mean annual catch rate. The lightly shaded rectangle indicates an approximate 95 percent confidence interval on the median annual catch rate.

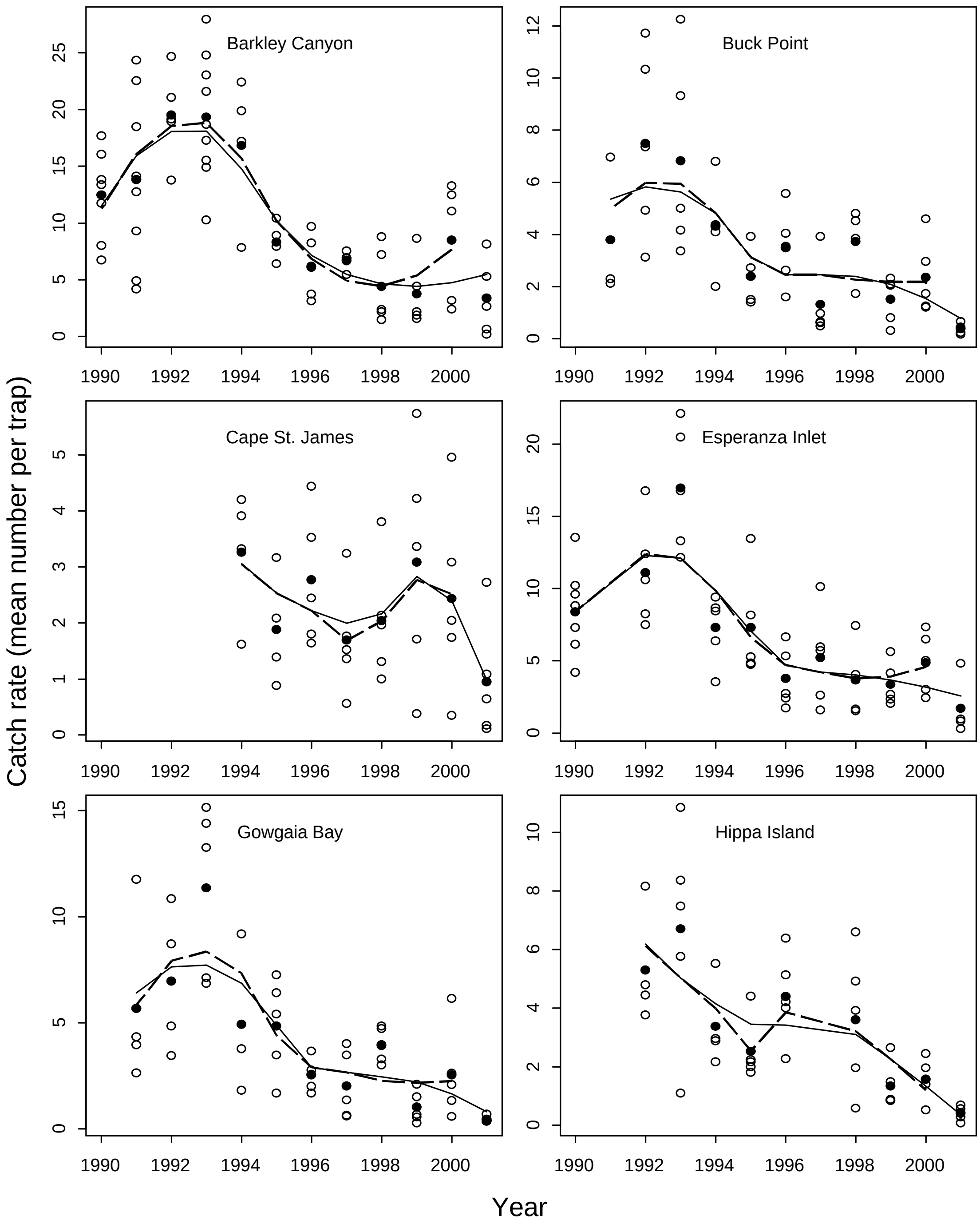

Figure 6. Survey catch rates (number of fish per trap) per set by year and locality. Open circles represent the mean number of fish per trap for each survey index set. The filled circle is the annual mean of the catch rate per set observations. The solid curve is the result of a loess smooth to the time trend in each locality.

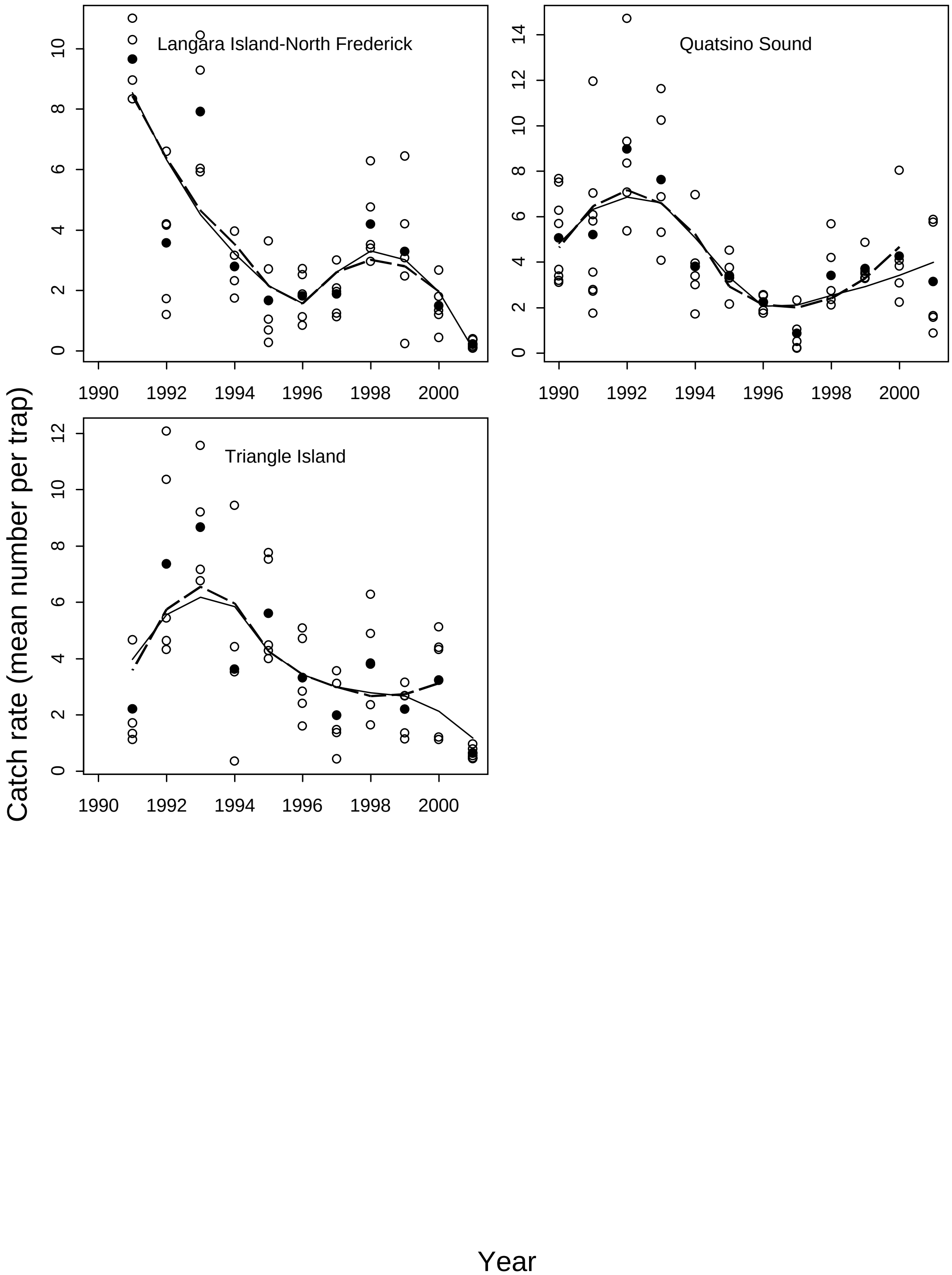

Figure 6. continued.

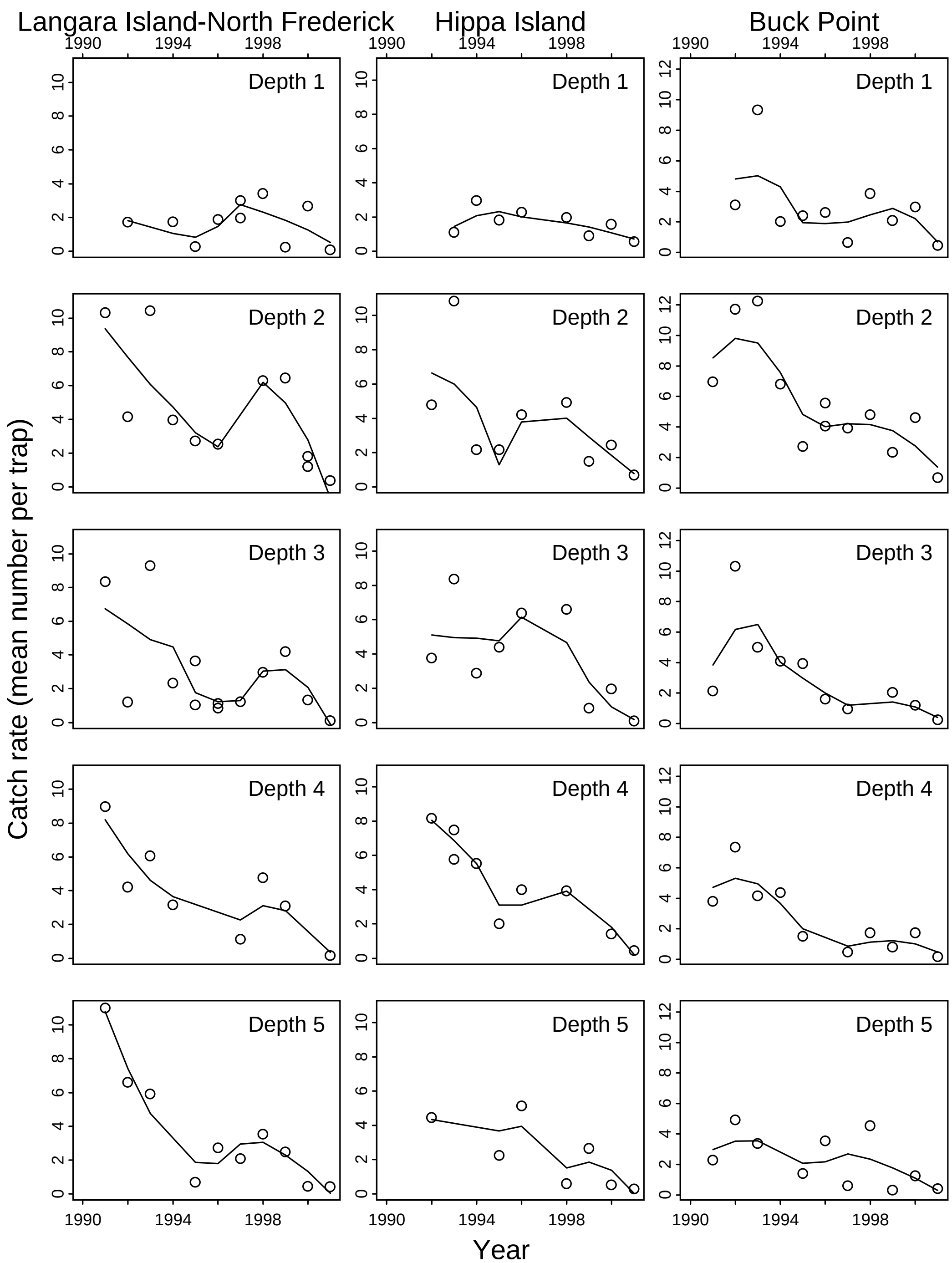

Figure 7. Survey catch rates (number of fish per trap) for each set by year, depth stratum and locality. The solid curve represents a loess regression through the observations.

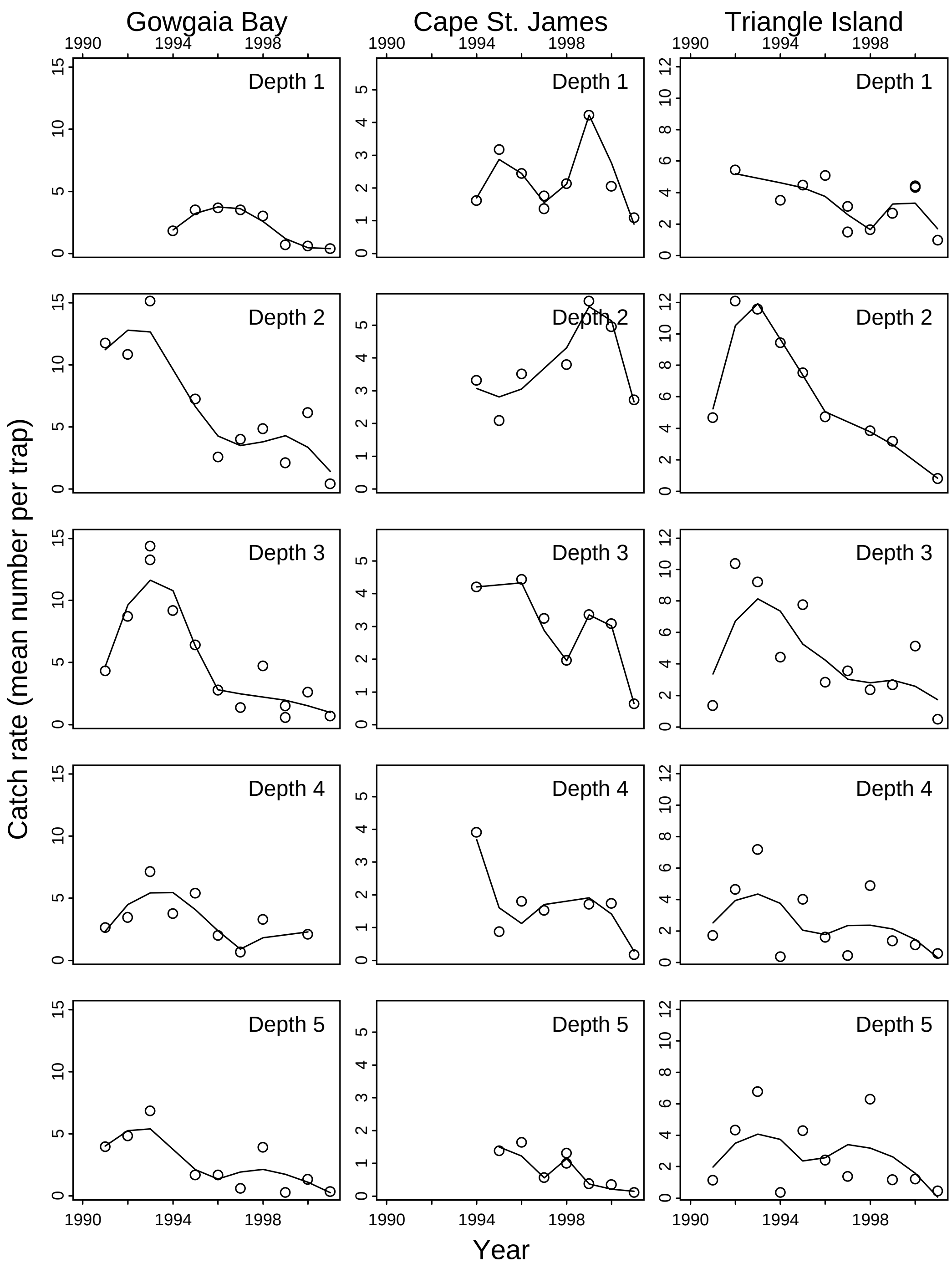

Figure 7. continued.

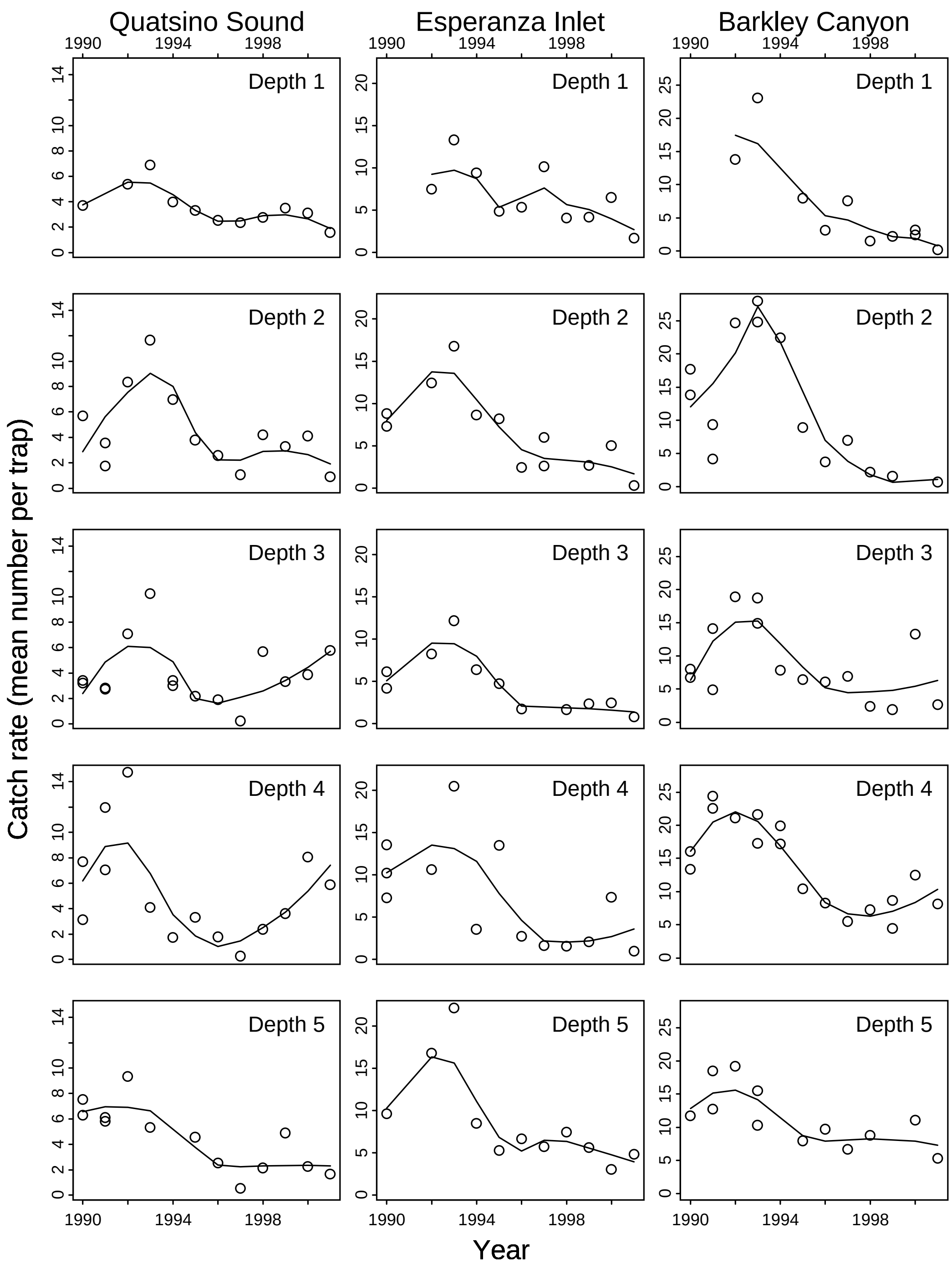

Figure 7. continued.

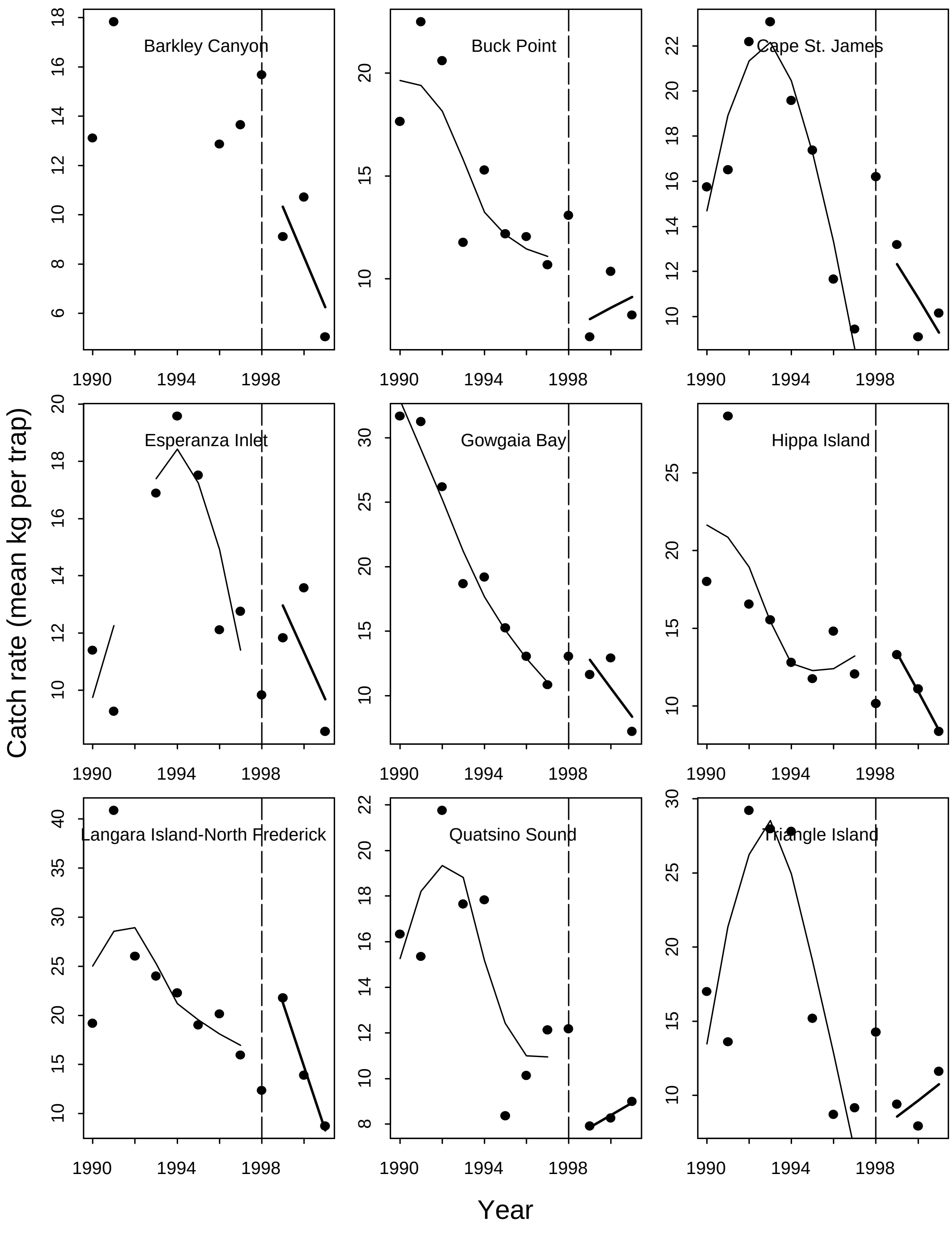

Figure 8. Mean annual commercial trap catch rates per set (kg per trap) by locality. The solid curve represents a loess smooth of the trend from 1990 to 1997. The trend from 1999 to 2001 is fit with a simple linear regression. The adoption of escape rings in the trap fishery is indicated by the vertical dashed line at 1998.

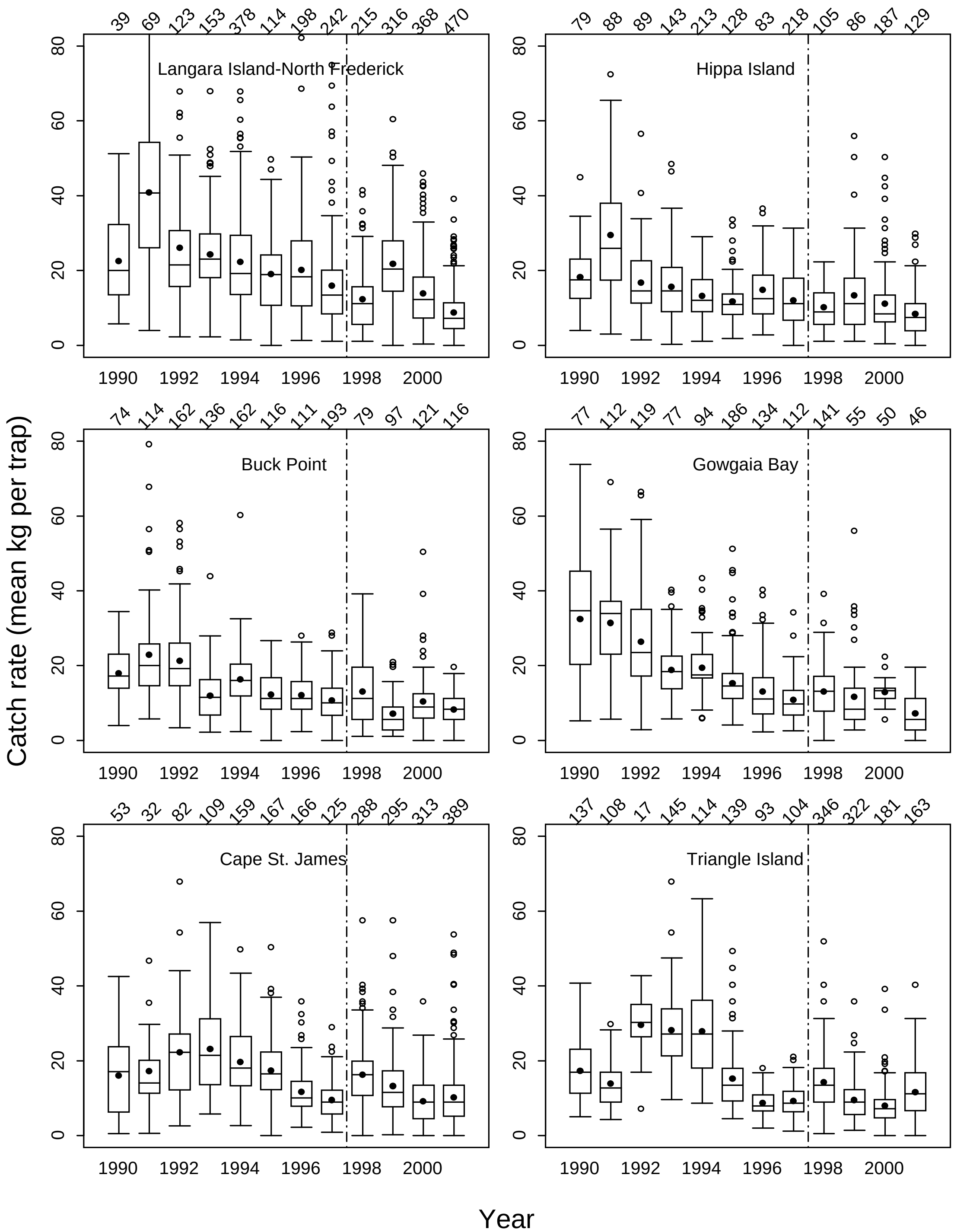

Figure 9. Distribution of annual commercial catch rates (mean kg per trap) by year and survey locality. Filled circles represent the mean annual catch rate. A vertical dot-dash line at 1998 indicates the adoption of escape rings. The number of sets represented is listed above each boxplot.

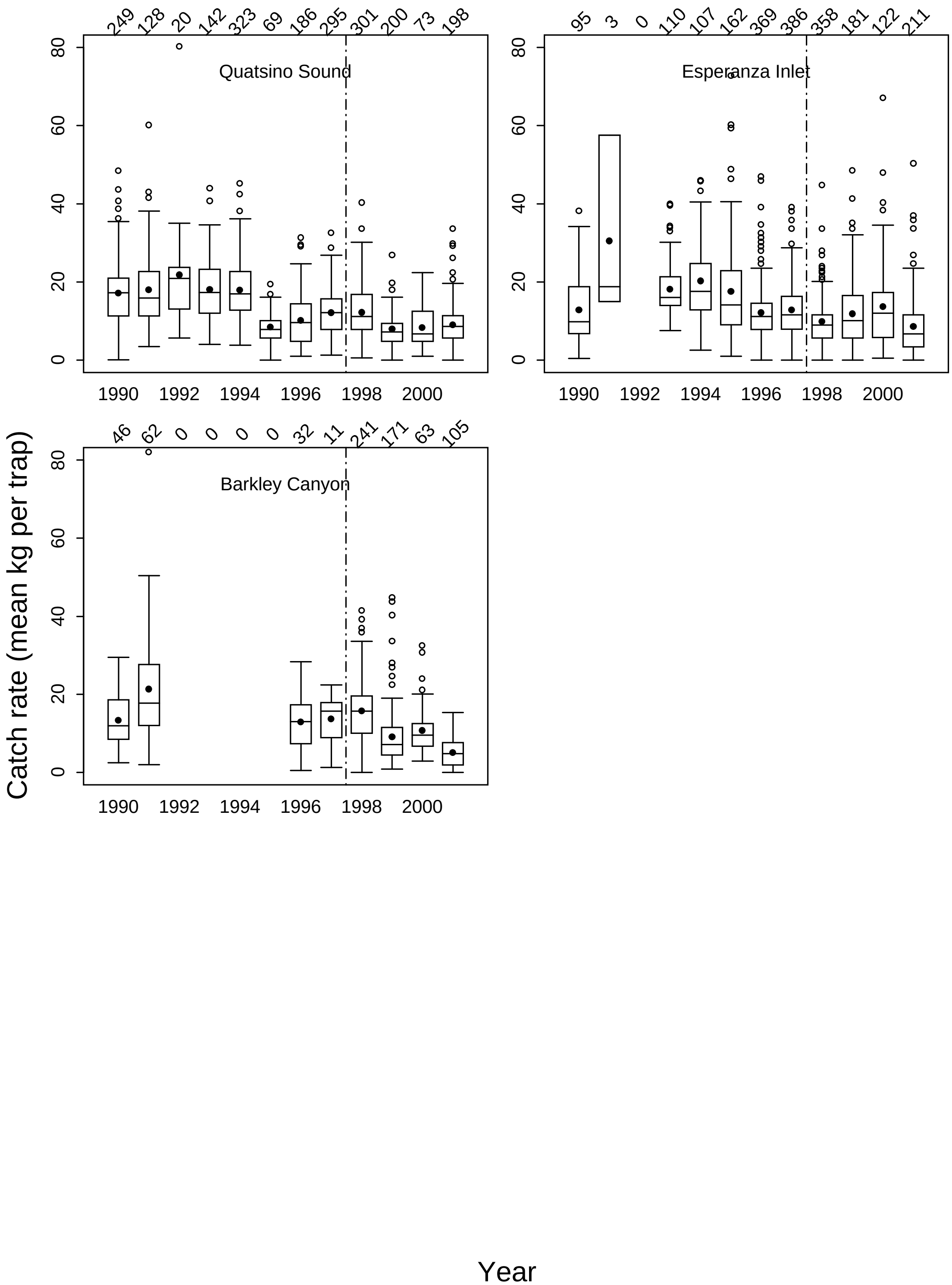

Figure 9. continued.

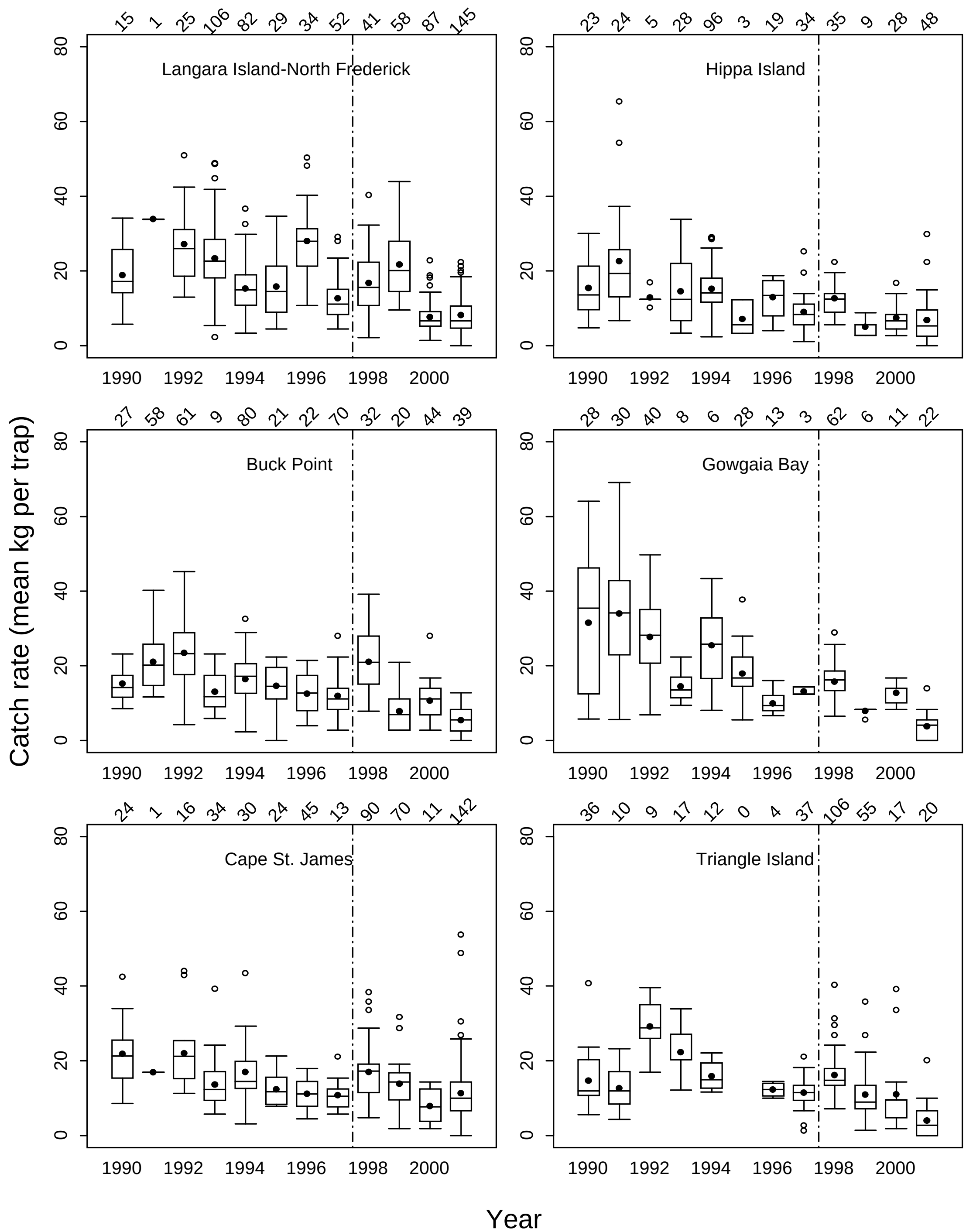

Figure 10. Distribution of September to November commercial catch rates (mean kg per trap) by year and survey locality. Filled circles represent the mean annual catch rate. A vertical dot-dash line at 1998 indicates the adoption of escape rings. The number of sets represented is listed above each boxplot.

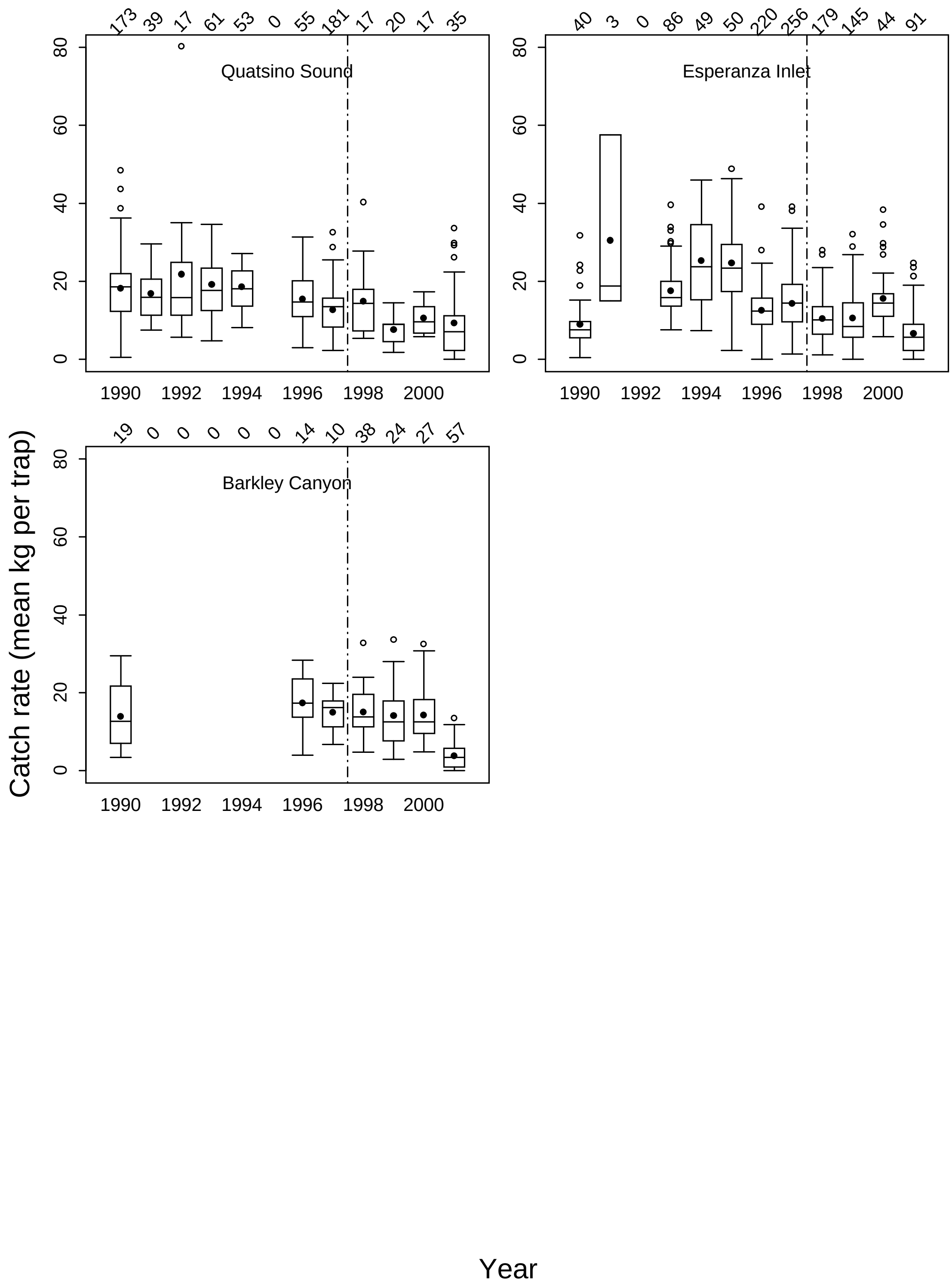

Figure 10. continued.

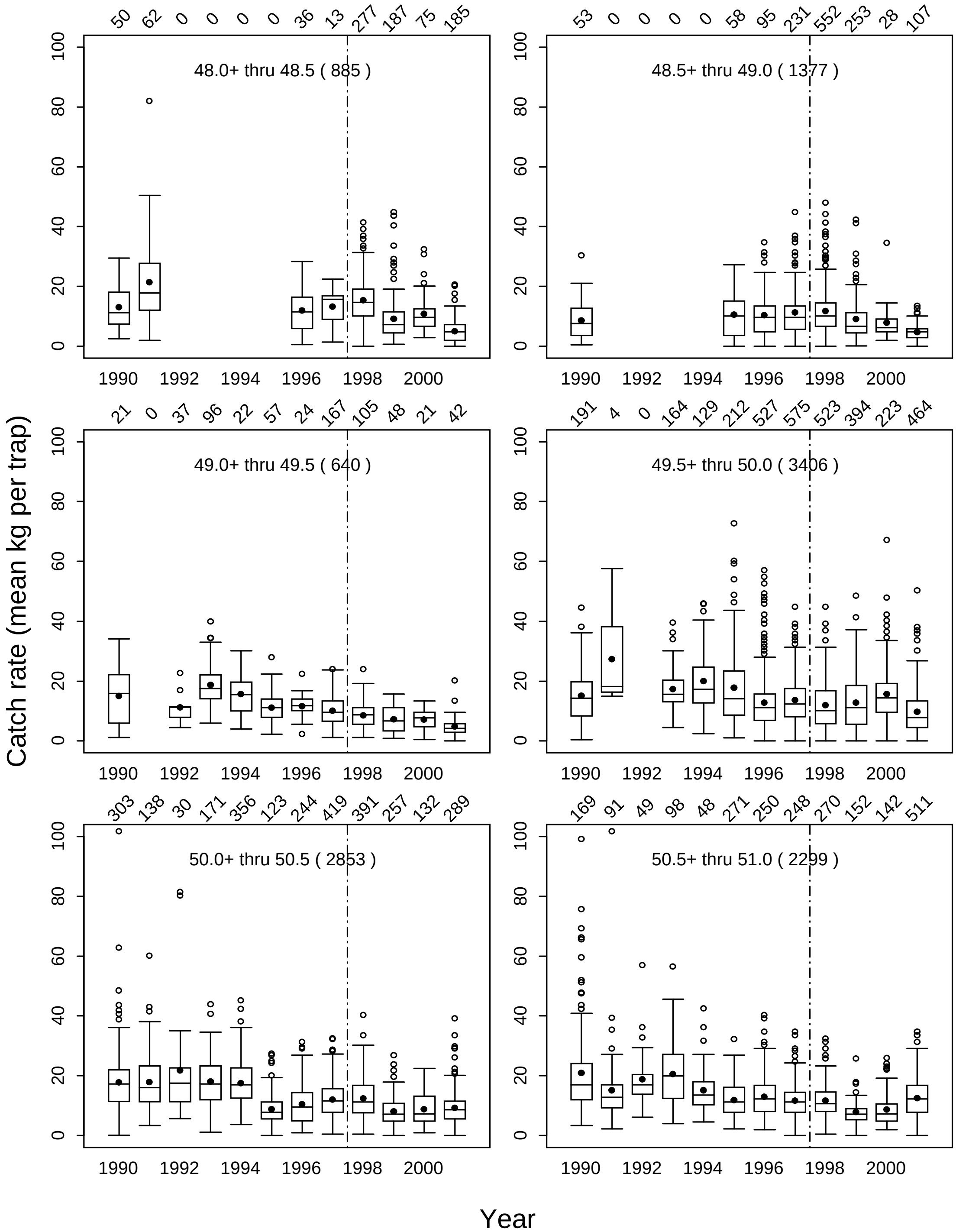

Figure 11. Distribution of annual commercial catch rates (mean kg per trap) by year and latitude band. Filled circles represent the mean annual catch rate. A vertical dash dot line at 1998 indicates the adoption of escape rings in the trap fishery. The sample size (number of sets) is listed above each boxplot.

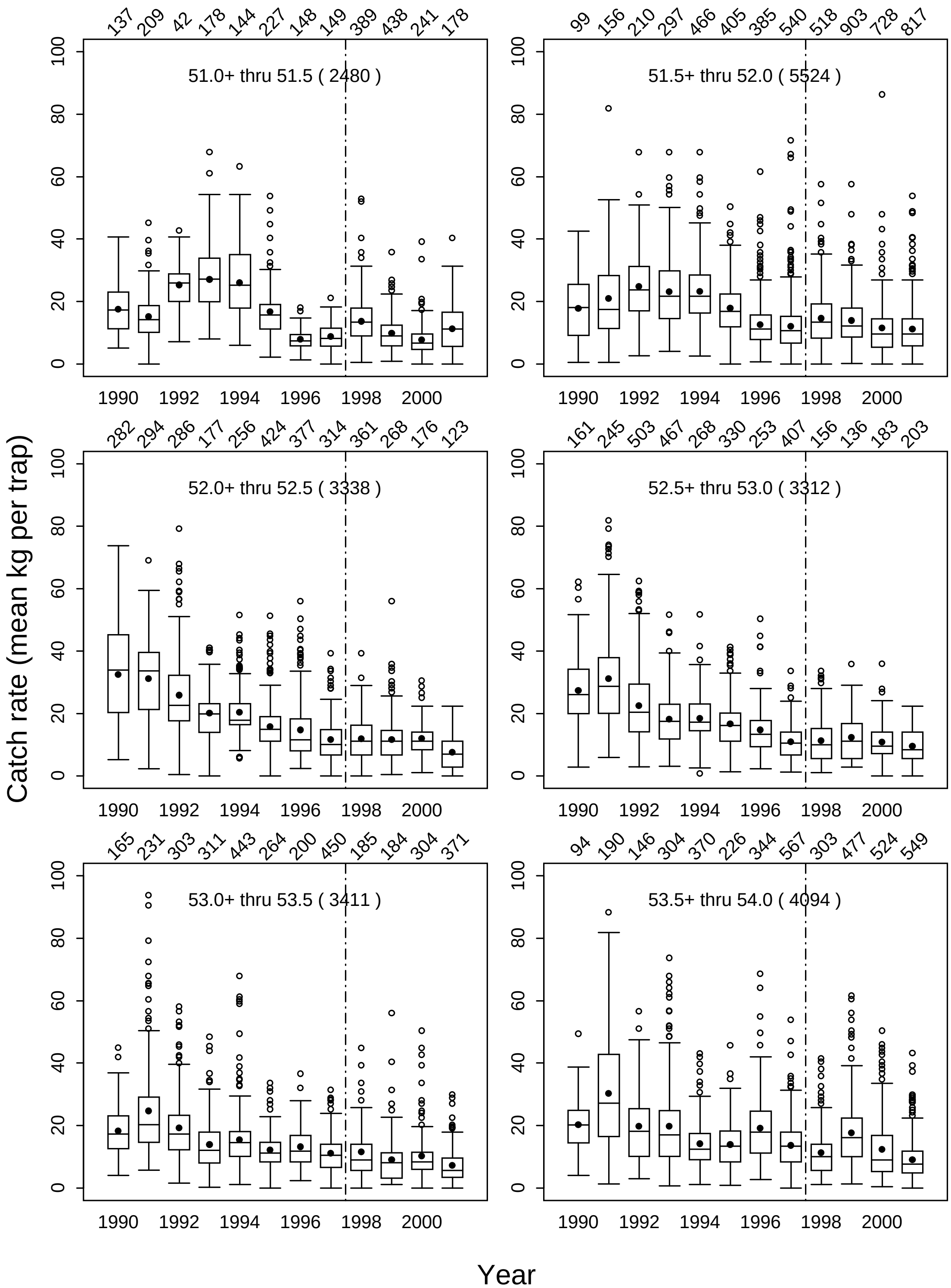

Figure 11. continued.

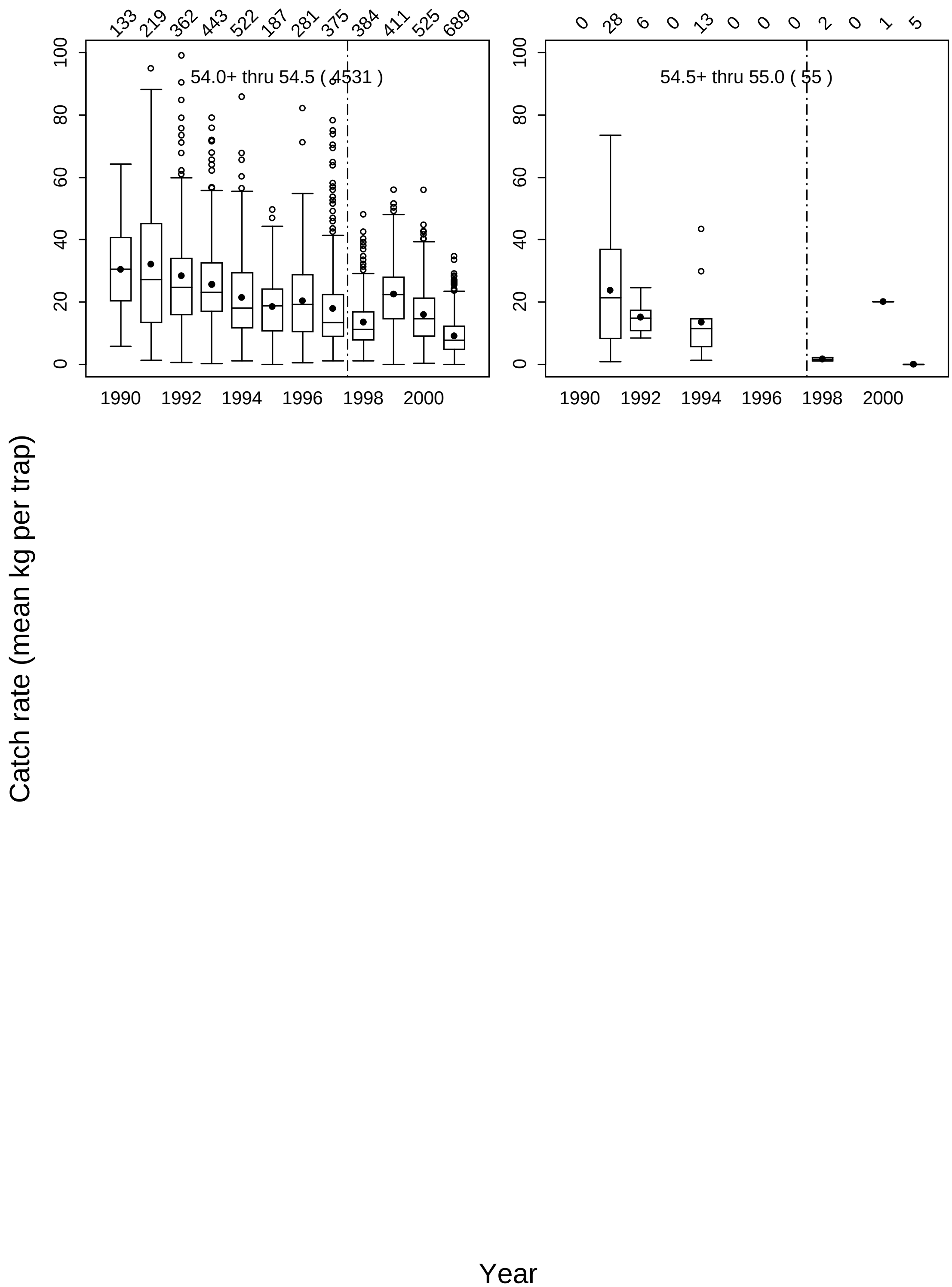

Figure 11. continued.

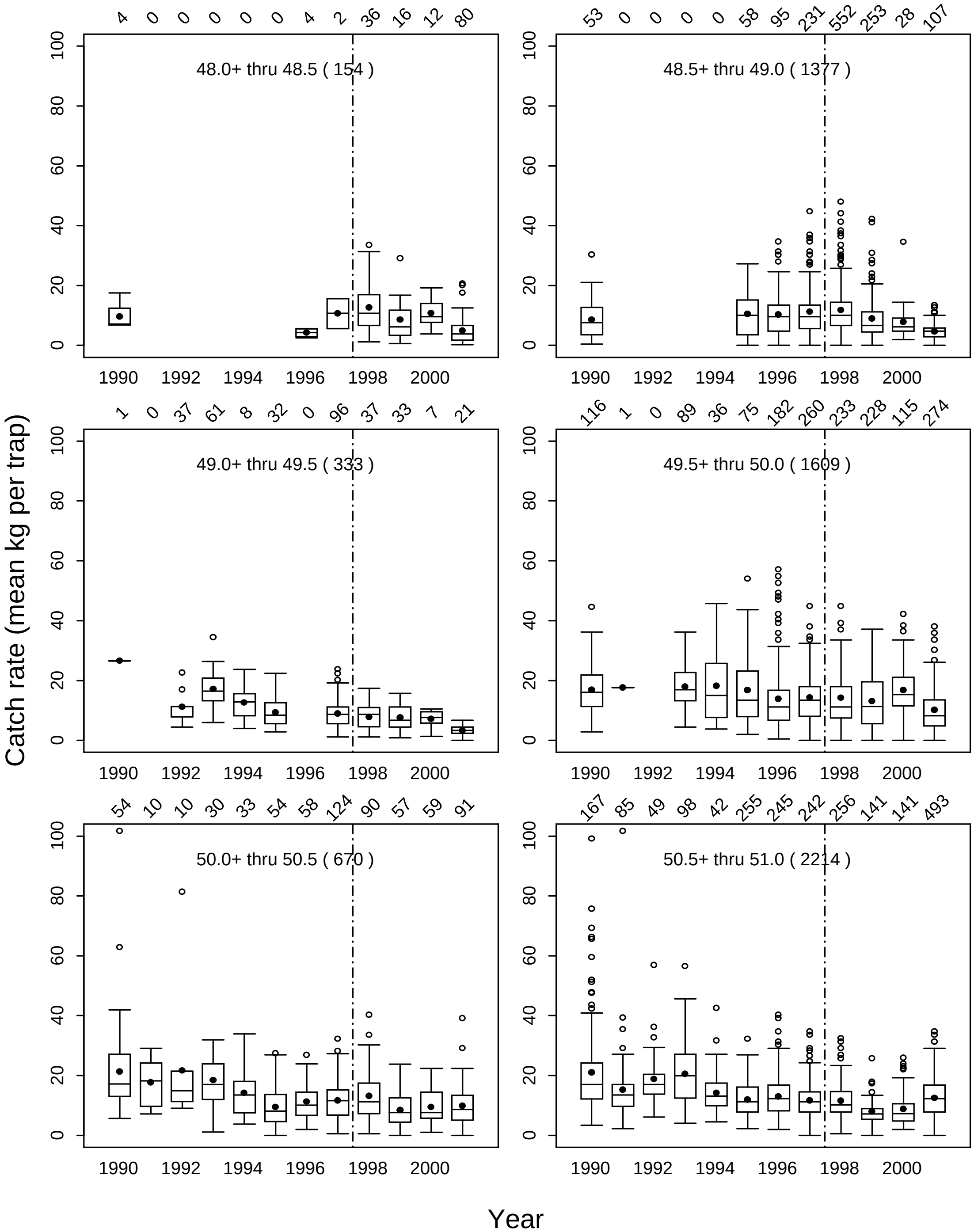

Figure 12. Distribution of commercial catch rates (mean kg per trap) by year and latitude band for sets outside of survey localities. Filled circles represent the mean annual catch rate. A vertical dash-dot line at 1998 indicates the adoption of escape rings in the trap fishery. The sample size (number of sets) is listed above each boxplot.

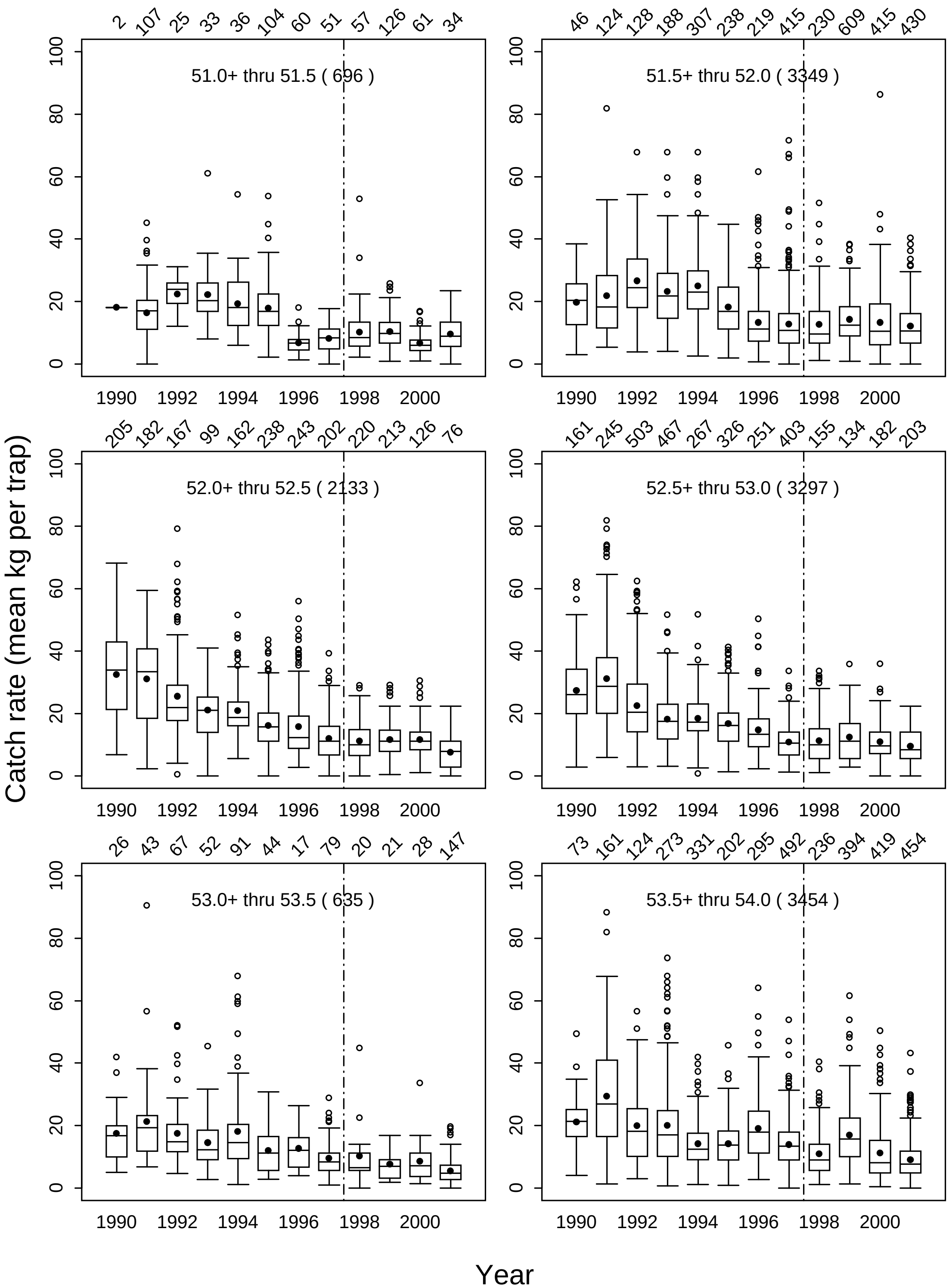

Figure 12. continued.

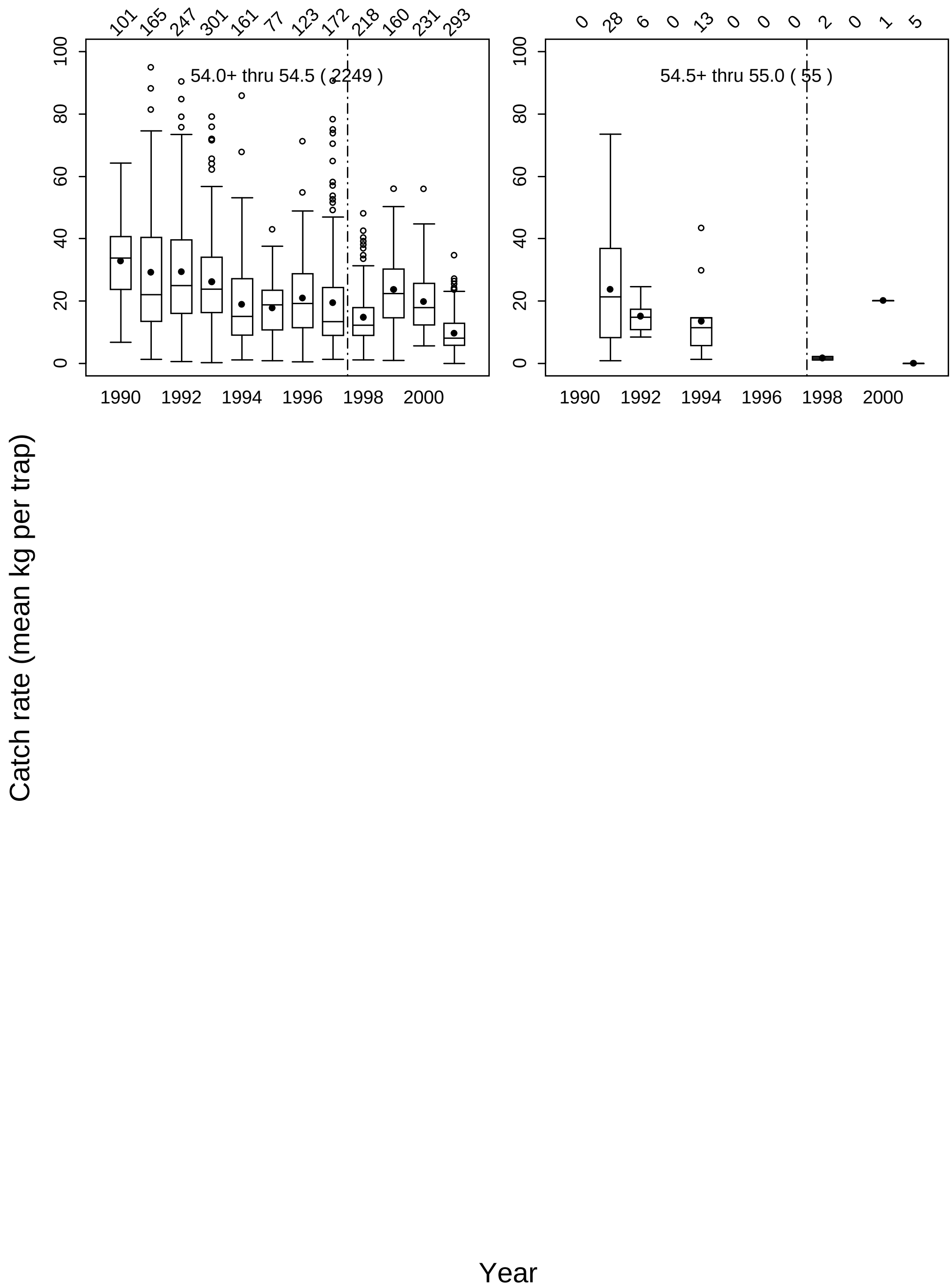

Figure 12. continued.

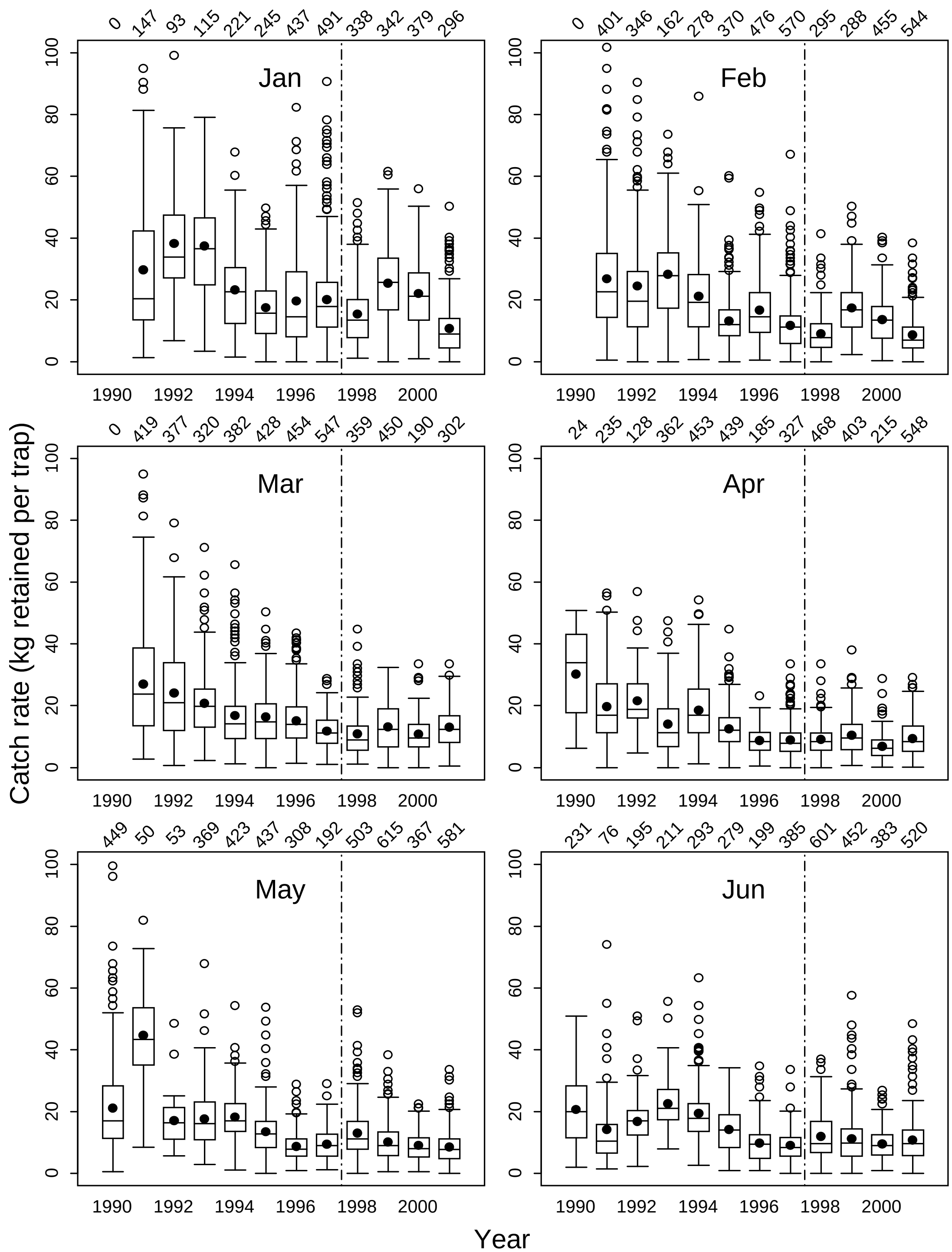

Figure 13. Distribution of commercial catch rates (retained kg per trap) by year and month. Filled circles represent the mean annual catch rate. A vertical dash-dot line at 1998 indicates the adoption of escape rings in the trap fishery. The sample size (number of sets) is listed above each boxplot.

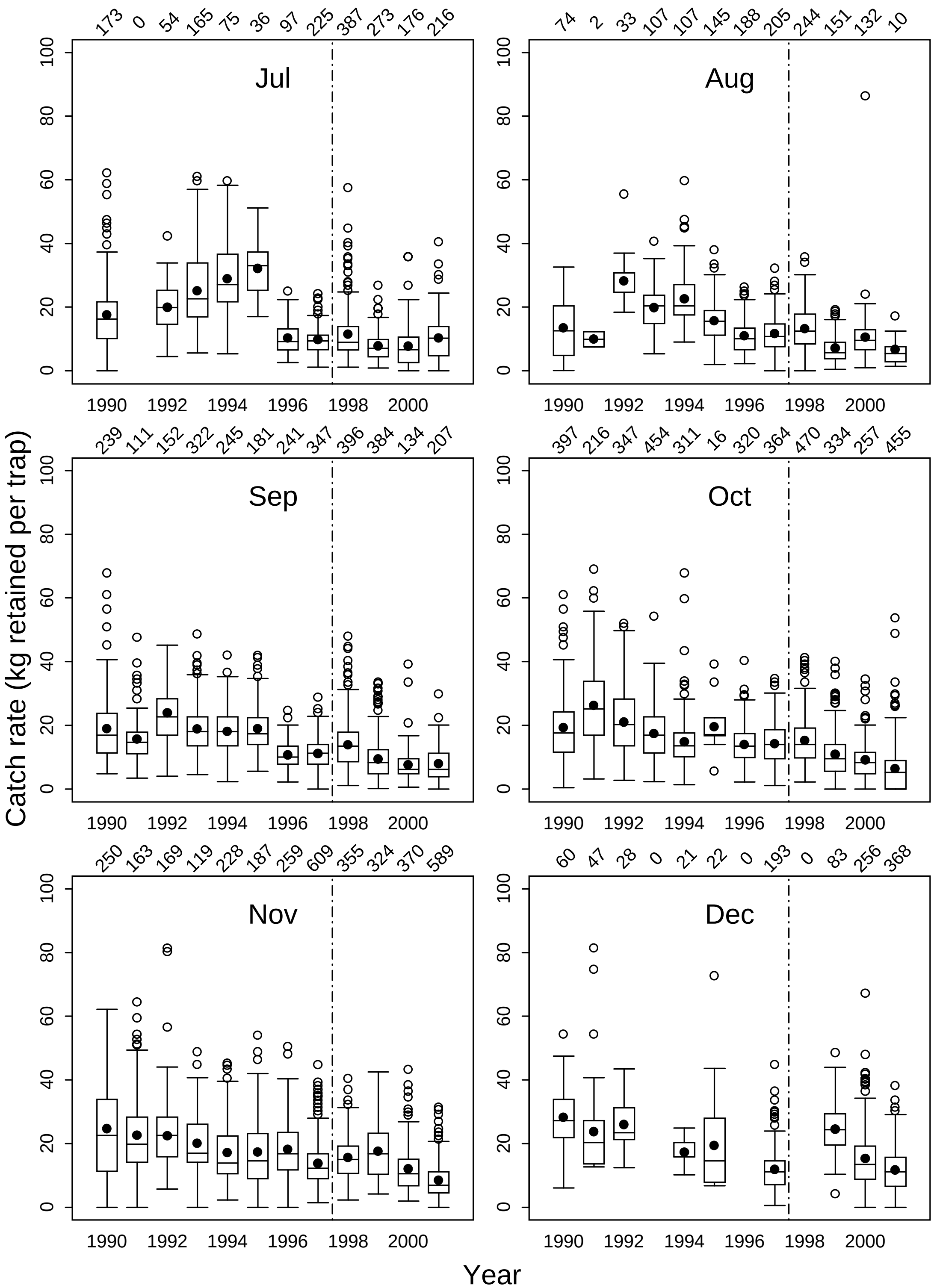

Figure 13. continued.

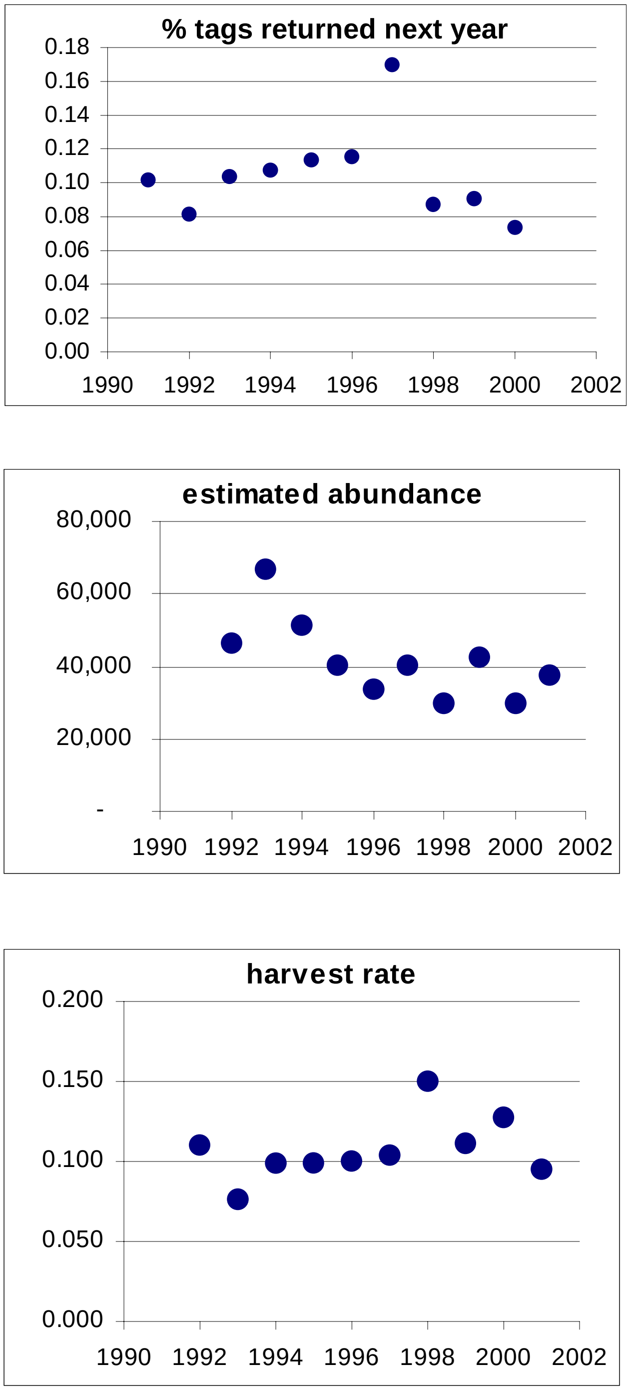

Figure 14. Percent tags returned the next year, total harvest rate, and implied abundance trends.

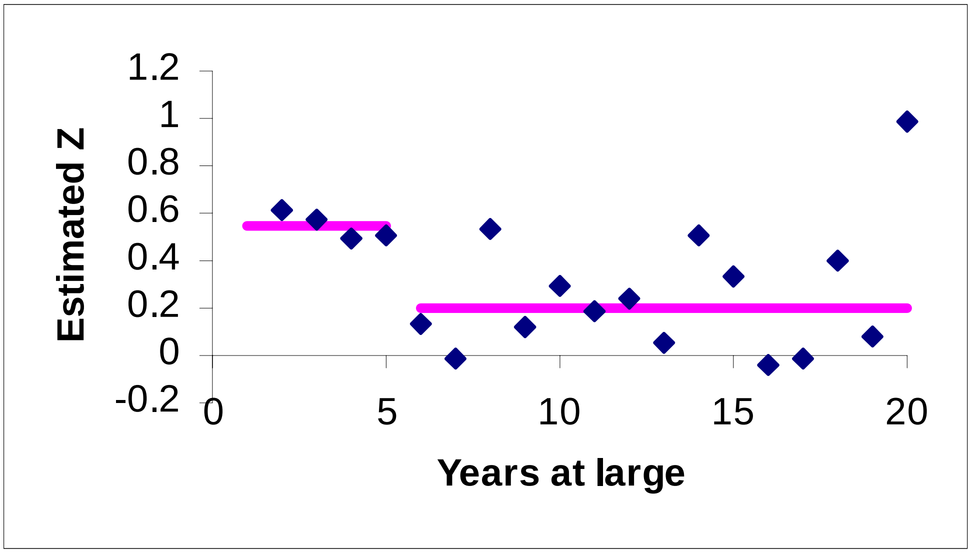

Figure 15. Estimated Z as a function of years at large for results from B.C. tagging studies.

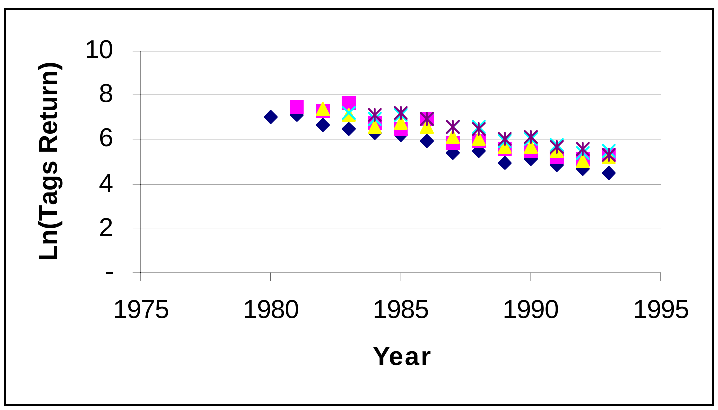

Figure 16. Tags returned by year for four years of large release in Alaska. Data adjusted by increasing tag return rates from Heifetz and Maloney (2001). Estimated Z for all groups is 0.2.

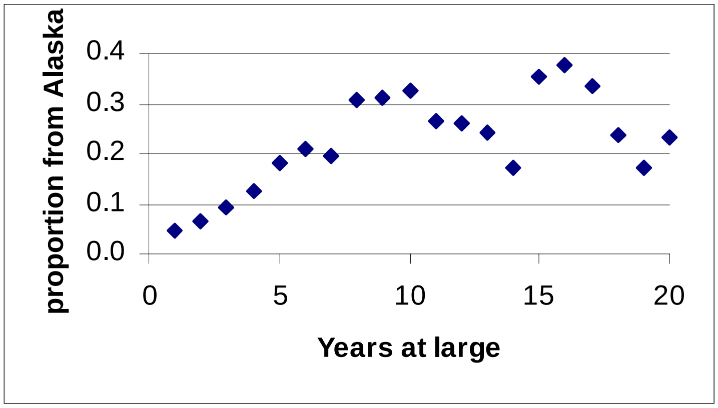

Figure 17. Proportion of all tag returns from B.C. releases that come from Alaska.

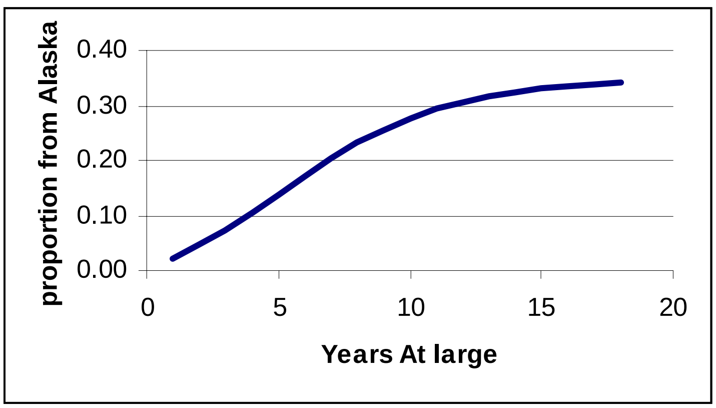

Figure 18. Proportion of B.C. tags returned from Alaska.

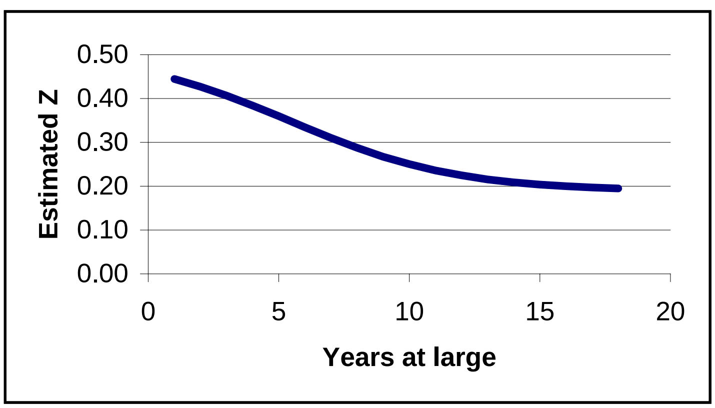

Figure 19. Estimated Z as a function of years at large.

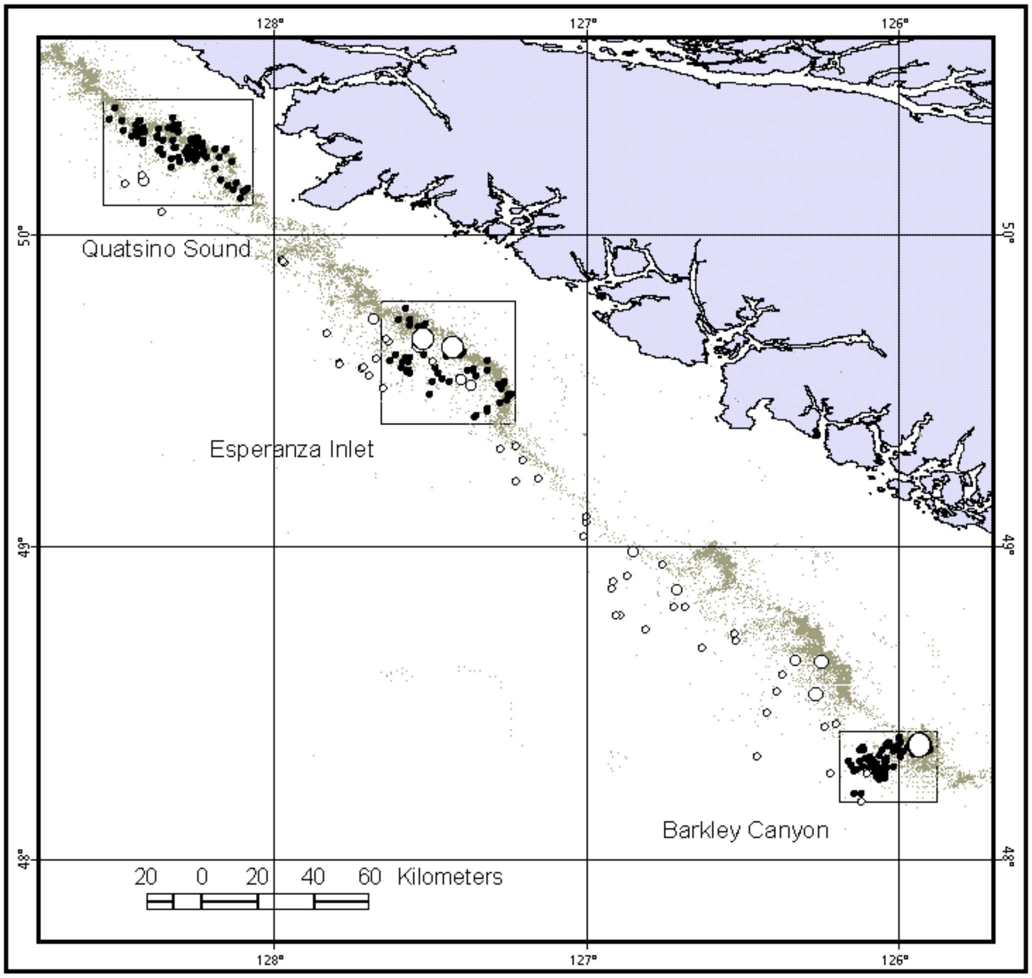

Figure 20. Set locations for the 2001 longspine thornyhead survey compared to sablefish survey sets and commercial sablefish sets. Open circles are sized proportional to sablefish catch weight observed on the thornyhead survey. Sablefish survey sets are indicated by filled circles and grey dots show locations of sablefish commercial fishing sets. All positions shown are the start position of the set. Maximum sablefish catch observed on the thornyhead survey was 528 kg.

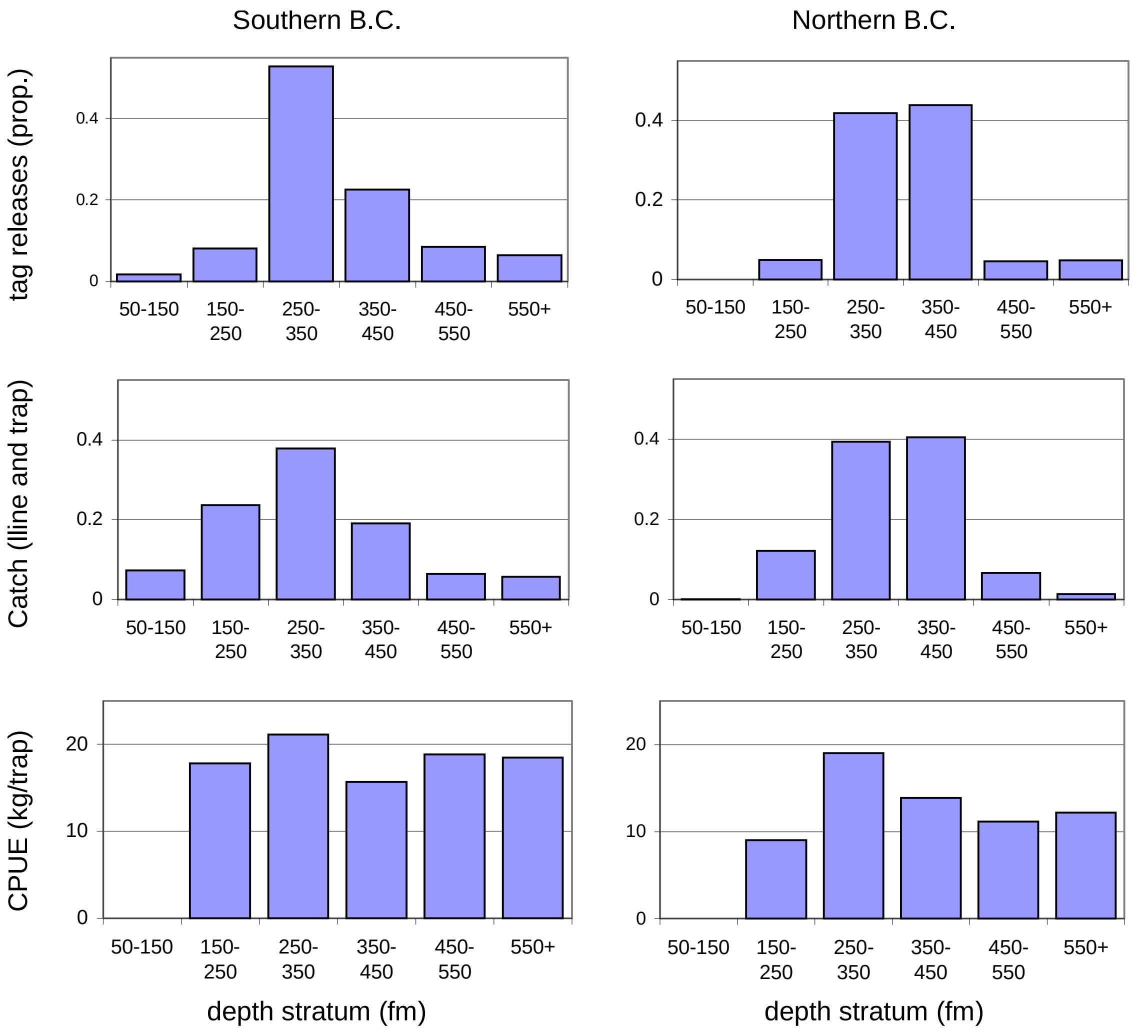

Figure 21. Distribution of tag releases, commercial catch, and sablefish survey catch rate in 2000.

Appendix A. PSARC Groundfish Subcommittee Request for Working Paper

Date Submitted: January 18, 2002

Individual or group requesting advice: Groundfish Management Unit

Proposed PSARC Presentation Date: January 29, 2002

Subject of Paper (title if developed):

Evaluation of survey and commercial catch per unit effort for sablefish (*Anoplopoma fimbria*) in British Columbia: supplement to the November 2001 sablefish assessment.

Stock Assessment Lead Author: A.R. Kronlund

Fisheries Management Author/Reviewer: C. Eros/Al Macdonald

Rational for request:

New 2001 survey information suggested that the December 2001 PSARC recommendation to maintain the current 4000t TAC for the 2002/03 fishing season may be inappropriately high. The 2001 PSARC advice was reviewed at RMEC December 13, 2001, accompanied by a memo from Science indicating that new and contrary survey information was available. It was determined that the new data would be reviewed by a special meeting of PSARC on January 29.

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

1. What are appropriate harvest levels for the remainder of the 2001/02 fishery and for the 2002/03 fishery?
2. Are there any biological concerns regarding the temporal distribution of catch between now and July 31, 2003?
3. Is a carryforward/overage policy over and above the TAC consistent with the stock assessment advice?

Objective of Working Paper: *(StAD staff to develop jointly with management)*

1. To review the 2001 survey results in the context of the historical survey data, identifying changes in survey conduct that influences interpretation of results;
2. To review commercial catch and effort data for sablefish, comparing trends derived from these data to those obtained from the sablefish survey data;
3. To update the tagging analysis used to compute exploitation rates of sablefish;
4. To provide a supplement to the November 2001 assessment of sablefish stock status, and provide yield options for the remainder of the 2001/2002 fishery and for the 2002/2003 fishery.

Appendix B Sablefish survey data: preparation

Survey data were assembled from 1990 to 2001. Data were included in analyses if the gear was set for the standard index survey and the trap usability code was 1, indicating that the gear was fishing correctly and not snarled or holed. Specific sets were excluded from the analysis as identified in Appendix Table B.1.

Table B.1. List of 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	Buck Point	12	5	report says extra traps for vessel, but not on bridge log, baiting unclear
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

For this working paper, the geographic extent of each locality was defined by drawing a rectangle that contained the start and end positions of all survey sets conducted from 1990 to 2001 (Figs. 1-3, Appendix Table B.2).

Table B.2. Geographic boundaries of the standard survey locations.

	Latitude		Longitude	
Location	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Barkley Canyon	48.4102	48.1861	126.189	125.878
Esperanza Inlet	49.7849	49.3955	127.653	127.222
Quatsino Sound	50.4327	50.0924	128.544	128.067
Triangle Island	51.2416	50.9683	130.014	129.515
Cape St. James	51.8361	51.6092	130.684	130.32
Gowgaia Bay	52.4346	52.2761	131.800	131.554
Buck Point	53.2422	53.0072	132.821	132.576
Hippa Island	53.5538	53.2846	133.342	132.914
Langara Island-North Frederick	54.1660	53.9706	133.875	133.534

Appendix C. Survey data: differences from Haist et al. (2001)

Survey data used in this working paper differs from that used by Haist et al. (2001). The differences relate to corrections to the historical data, new electronic availability of detailed data, and the selection of data for analysis. First, only sets that were made as part of the standard index survey were included; some tagging and deep-water sets that were used in the past were excluded. Second, sets were assigned to depth strata based on the modal bottom depth of the set, as opposed to the intended depth stratum. Recorded depth was considered to a more appropriate indicator of where the gear was fishing than intended depth. Third, traps were included only if they were recorded as fishing correctly. Traps that were fouled or holed in any way were excluded, whereas the data used by Haist et al. (2001) included some traps that were holed but still caught fish. Fourth, only traps that were baited with 1.0 to 1.5 kg of squid were included for analysis. Specific sets were excluded for the reasons outlined in Appendix Table A.1.

Actual differences between data used here and data used in Haist et al. (2001) varied from –4.21 to +1.593 fish per trap. Most differences were zero or minor (absolute value less than 0.1 fish per trap). Major differences are listed in Appendix Table B.1 and a description of the difference provided.

Appendix Table C.1. Explanations of survey data differences between Kronlund et al. (2002) and Haist et al. (2001).

Year	Location	Depth Stratum	Difference	Reason
1990	Quatsino Sound	2	+1.24	set 1 intended as stratum 2 but modal depth was in 1
1990	Esperanza Inlet	4, 5	+1.59, -1.96	set 5 was intended as stratum 5 but modal depth was in 4
1994	Quatsino Sound	4	-1.3	set 8 intended as stratum 4 but modal depth was in 3 set 9 intended as stratum 5 but modal depth was in 4
	Gowgaia Bay	3	+ 1.52	set 9 excluded, baited with hake and squid
	Hippa Island	3	-1.2	set 23 excluded, baited with hake and squid
	Langara Island-North Frederick	3	-1.1	set 29 excluded, baited with hake and squid
1995	Gowgaia Bay	3	+2.13	sets 14-17 excluded as they were "tagging sets"
1997	Triangle Island	1	+0.94	set 23 intended as stratum 2 but the modal depth was in 1
1998	Esperanza Inlet	1	-1.91	set 14 intended as stratum 2 but the modal depth was in 1 and set 13 in stratum 1 was excluded because of uncertainty concerning the number of traps
1999	Buck Point	5	-4.21	set 67 excluded due to baiting with hake
	Langara Island-North Frederick	5	-3.38	set 88 excluded due to baiting with hake
2000	Barkley Canyon	1	-0.86	set 8 intended as stratum 2 but the modal depth was in 1

Appendix D. Commercial logbook data: preparation

Commercial logbook data from the sablefish fishery are stored in a Microsoft Access database called **LogBooks.MDB** at the Pacific Biological Station, Nanaimo, British Columbia. Fishing event and catch data obtained from commercial logbooks are stored in tables ***87-94_Logs_Sites_Import*** and ***87-94_catch***, respectively for the 1987 to 1994 period. Due to a change in logbook format, the fishing event and catch data for 1995 to 2001 are stored in tables ***Commercial_Logs*** and ***Commercial_Catch***, respectively.

For this working paper, logbook data were filtered for analysis by excluding sets:

1. where the gear type was not trap;
2. that occurred as part of a fishing charter (**Commercial_Logs**:*Flag* like "*T*");
3. where the set number was described as 999 (**Commercial_Logs**: *SetNum*=999), indicating a dummy record;
4. where the location indicated a seamount.

For some analyses, logbook data were extracted that corresponded to fishing in the vicinity of survey localities. An arbitrary "bounding box" was defined for each survey locality by drawing a rectangle that contained the start and end positions of all survey sets from 1990 to 2001 (Figs. 1-3, Appendix Table B.2). Sets from commercial logbook data were assigned to each survey locality if either the start or end position of a set fell within the locality's bounding box. Thus, the entire set need not be contained in the bounding rectangle to be assigned to the locality.

Catch is reported as a visual estimate of the weight in pounds of product. All product weights were converted to round weight (kg) using the conversion factors listed in Appendix Table D.1. Round weight in pounds was converted to kilograms by multiplication by 0.4536. Although logbooks allow for recording of retained and discarded catch, only retained catch was used in the analysis due to sparse reporting of discards.

Table D.1. Conversion factors applied to sablefish products to estimate round weight.

Product	Conversion Factor
J-cut frozen	1.48
J-cut fresh	1.5108
J-cut unknown condition	1.495
Round unknown condition	0.97
Round fresh	0.98
Round frozen	0.96
Live	0.98

Appendix E. Spatio-temporal distribution of survey sets by locality

This appendix contains a collection of figures that illustrate the spatial and temporal distribution of survey sets, and commercial sets of sablefish trap gear coincident with the survey. An explanation of each figure is listed below:

Figure E.1. Timing of survey sets by year and locality. Each open circle represents a survey set. Positions of the plotted points have been randomly perturbed along the y-axis to expose sets deployed on the same date.

Figure E.2. Spatial position of survey sets by year for each locality. The relative placement of each survey set by year and locality is plotted using the start and end position of the set. The start position is recorded when the first anchor is attached, while the end position is recorded when the second anchor is attached.

Figure E.3. Spatial position of commercial sablefish sets of trap gear in September through November. The relative placement of each survey set by year and locality is plotted using the start and end position of the set. The number in brackets beside the year label indicates the number of sets plotted. Axis scales have been removed for reasons of confidentiality of logbook information.

Figure E.4. Sablefish commercial trap effort by week by year and locality. The week that survey sets were conducted is indicated by the shaded rectangle in each panel.

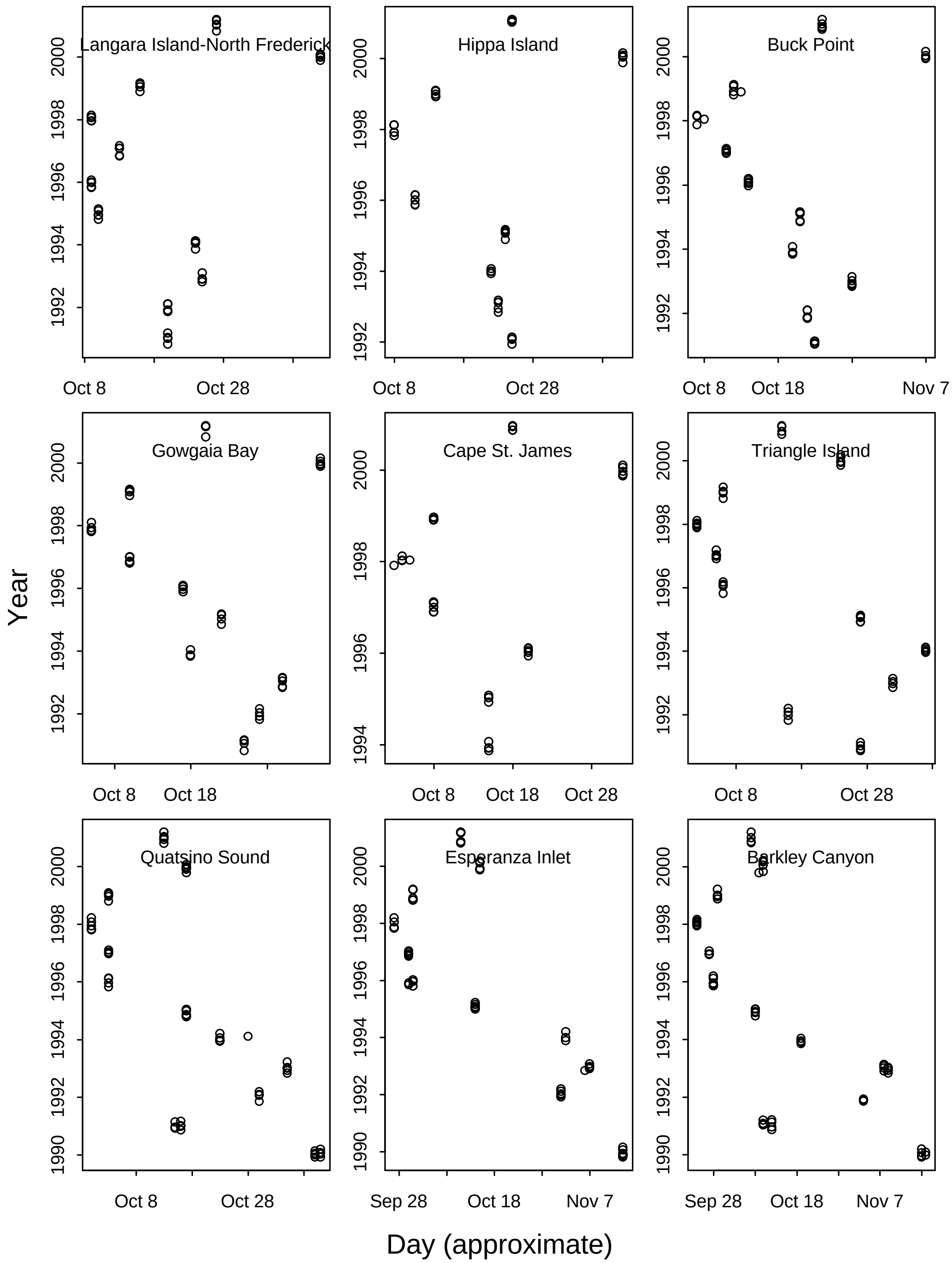

Figure E.1. Timing of survey sets by year and locality. Each circle represents a survey set, and circles have been jittered along the y-axis to expose sets conducted the same day.

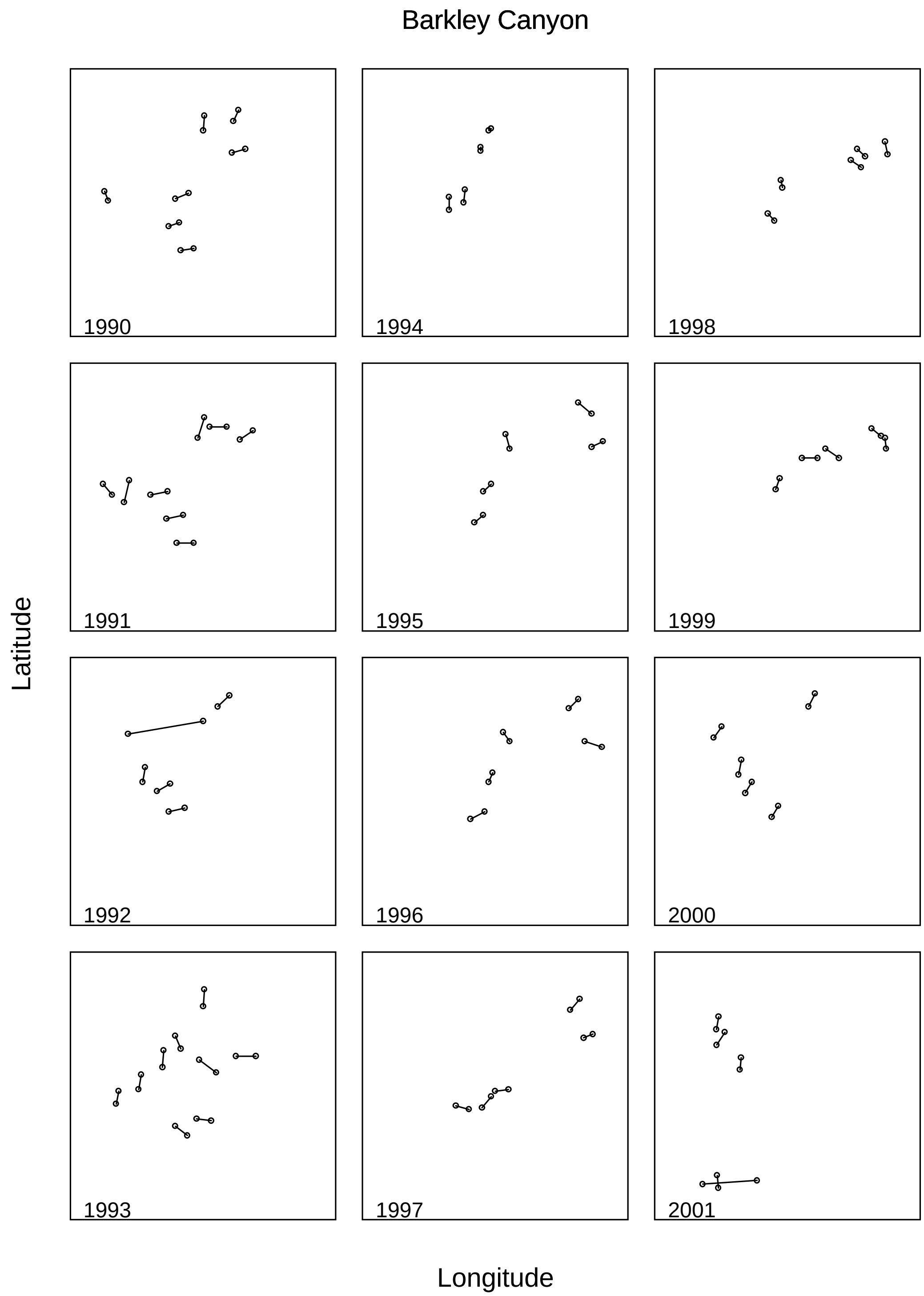

Figure E2. Relative spatial position of survey sets by year and survey locality.

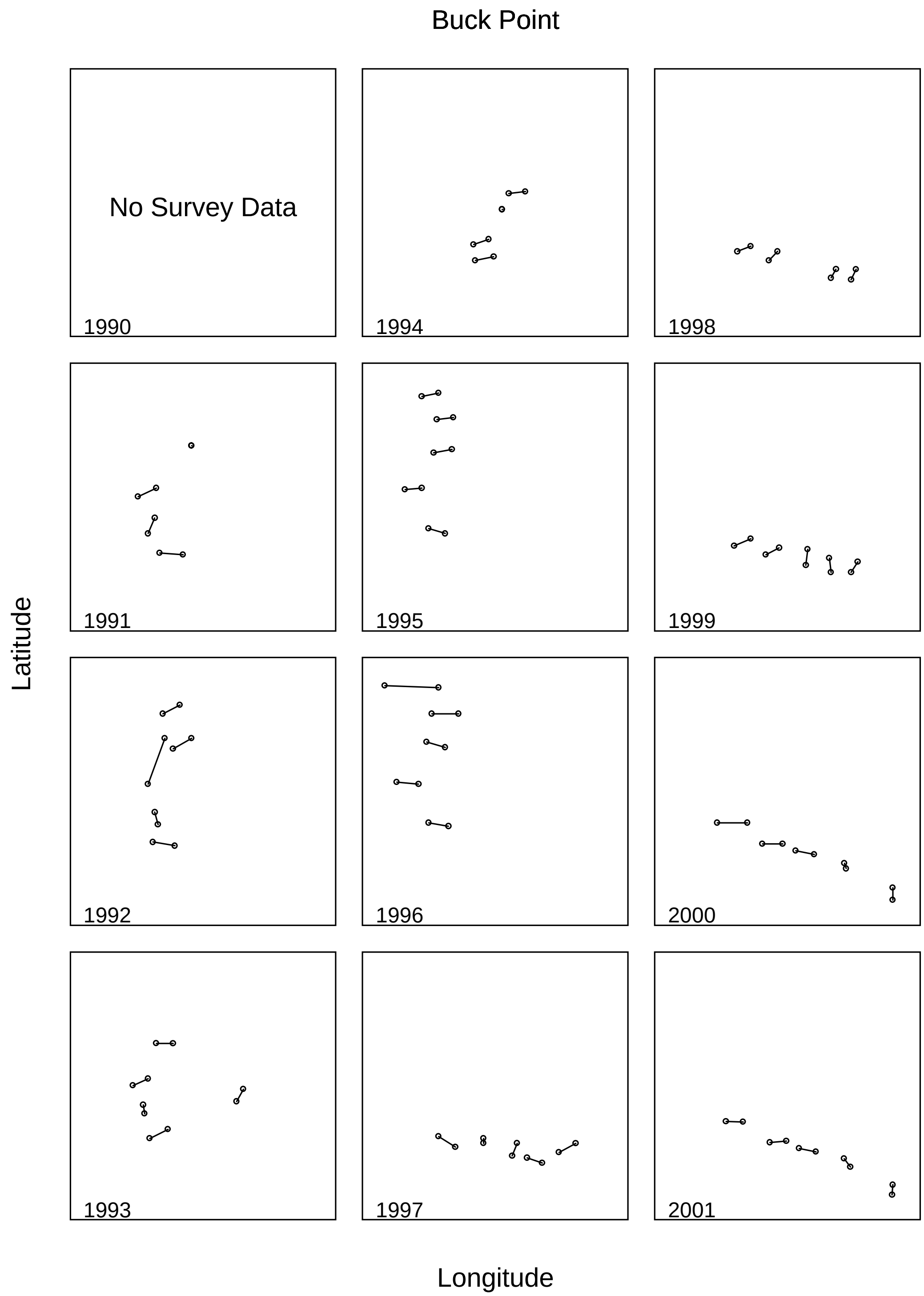

Figure E2. continued.

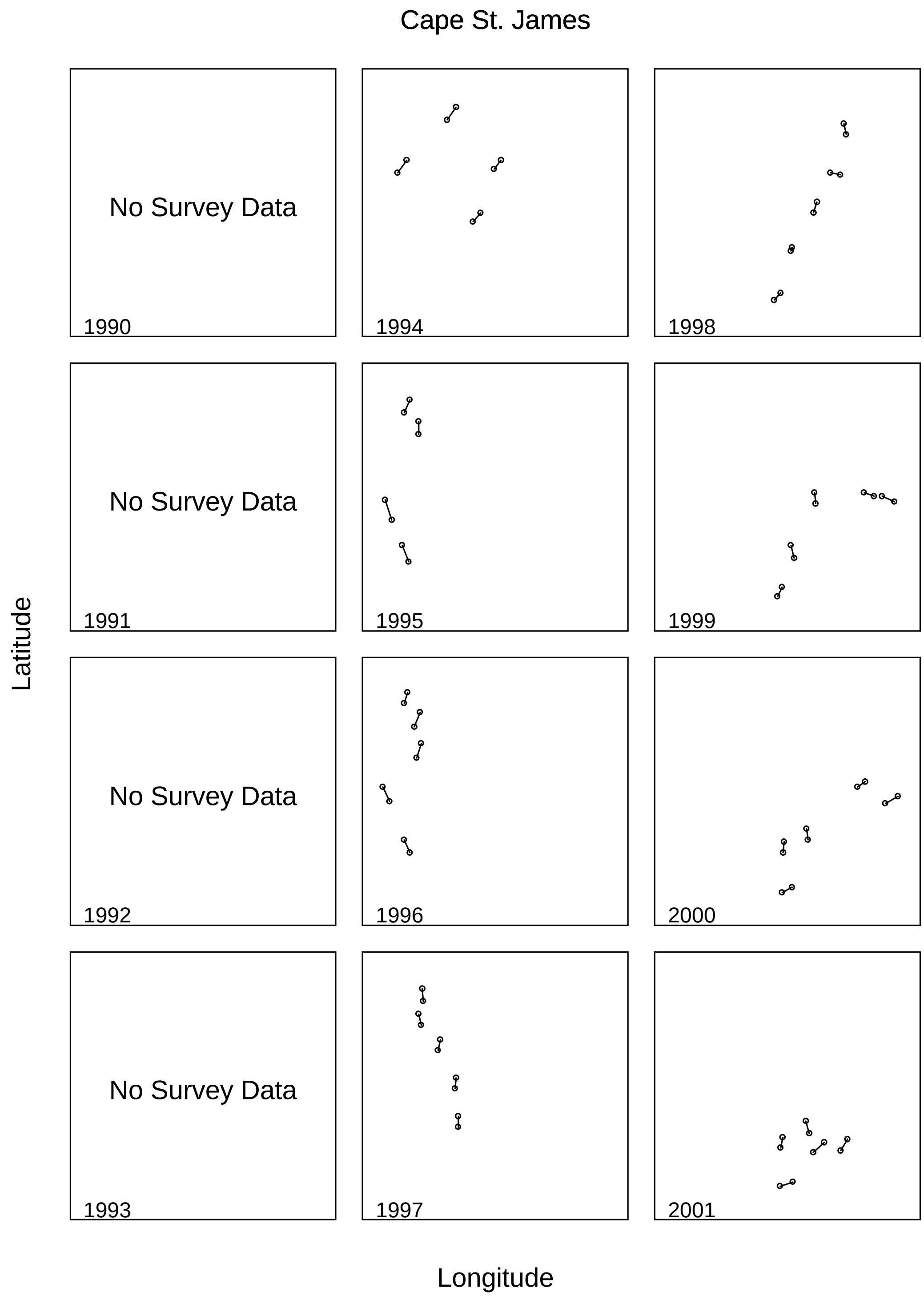

Figure E2. continued.

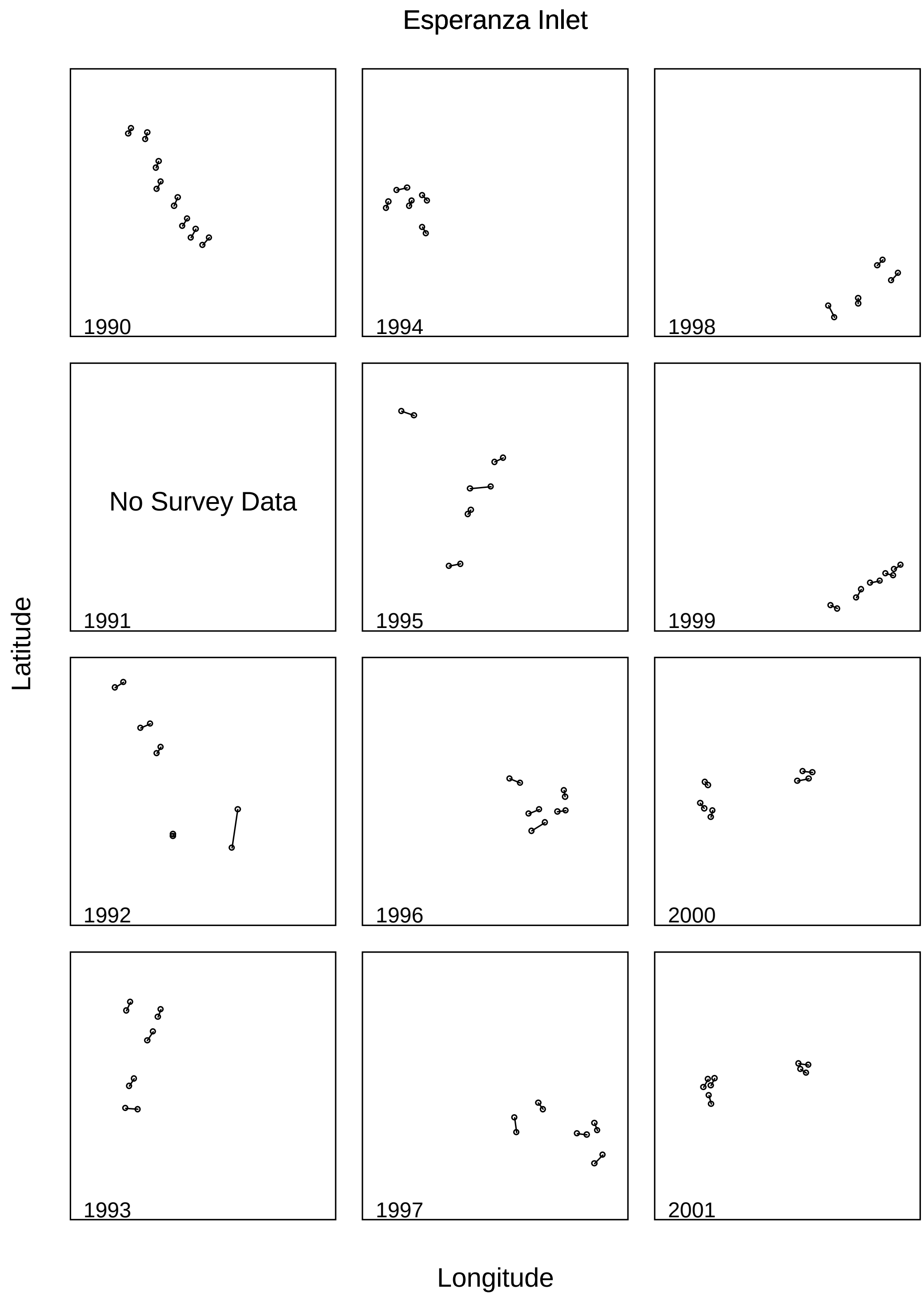

Figure E2. continued.

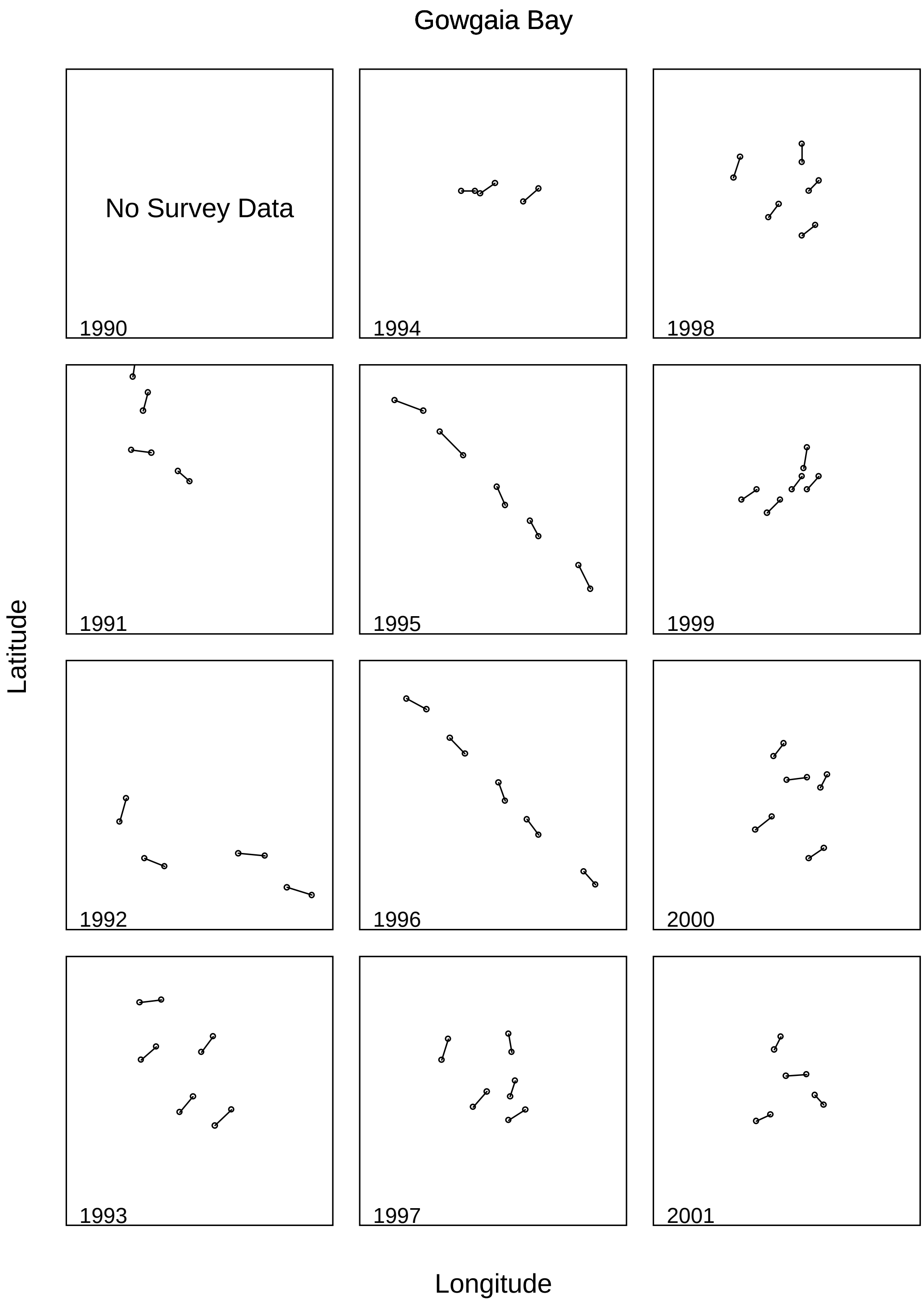

Figure E2. continued.

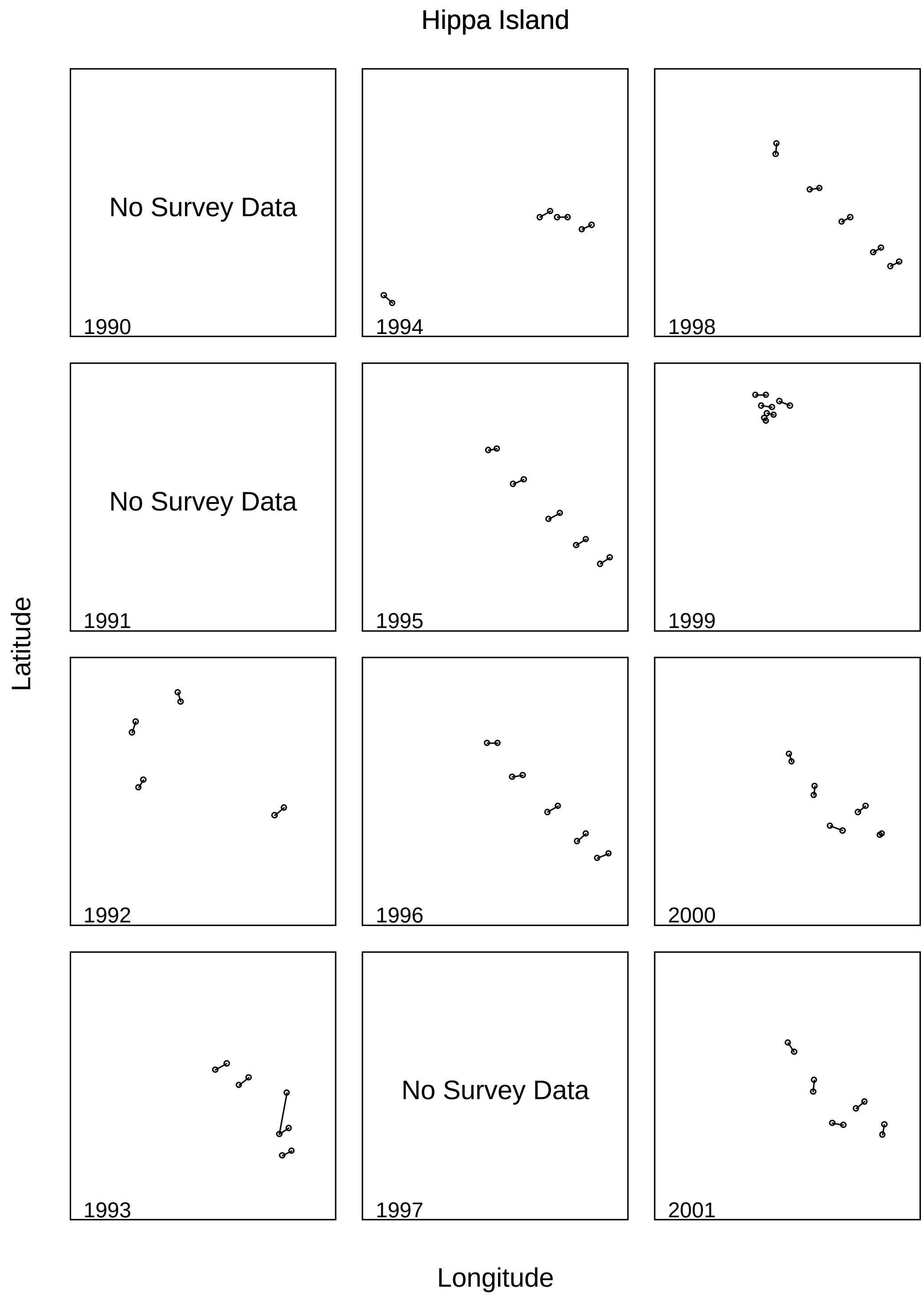

Figure E2. continued.

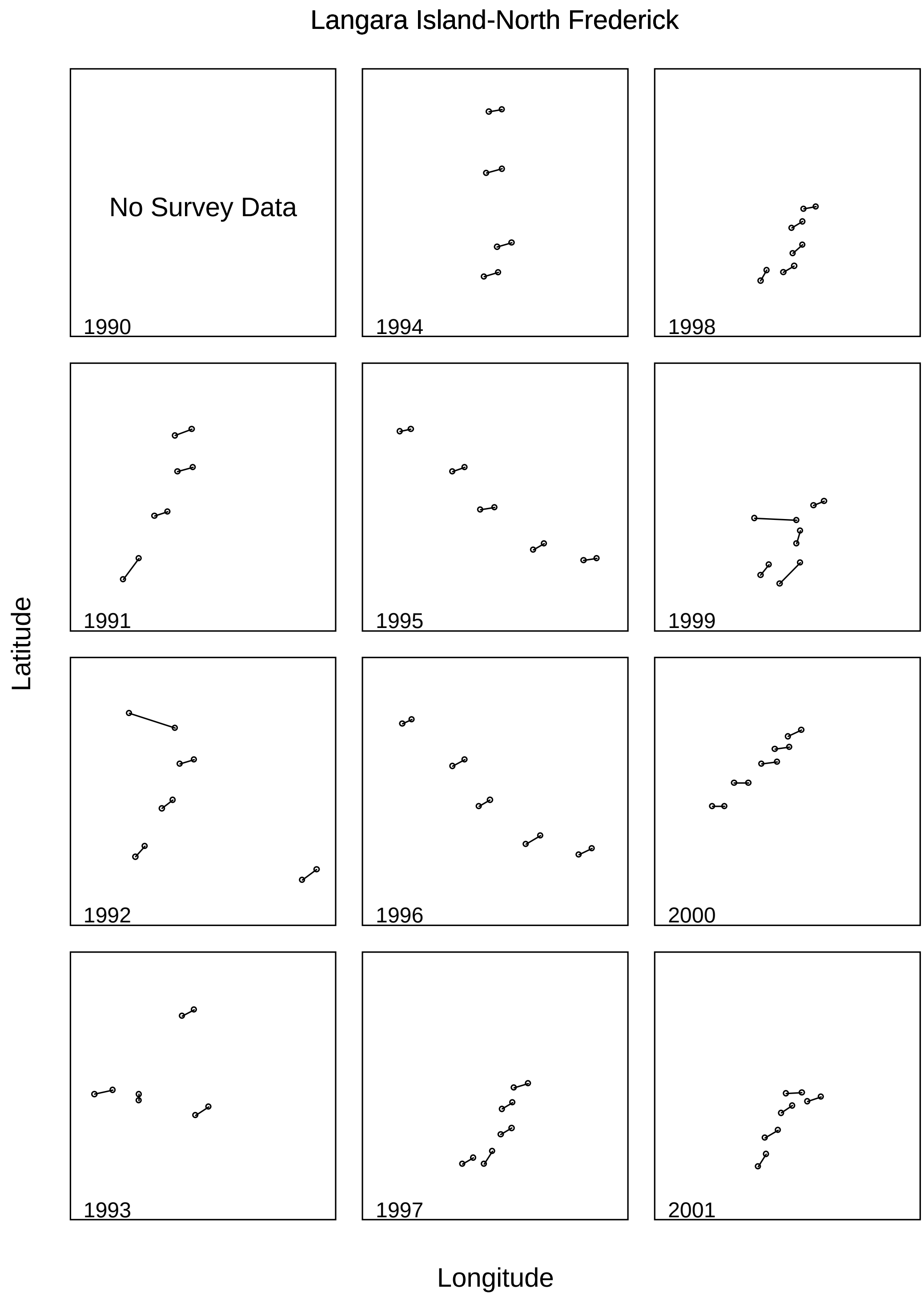

Figure E2. continued.

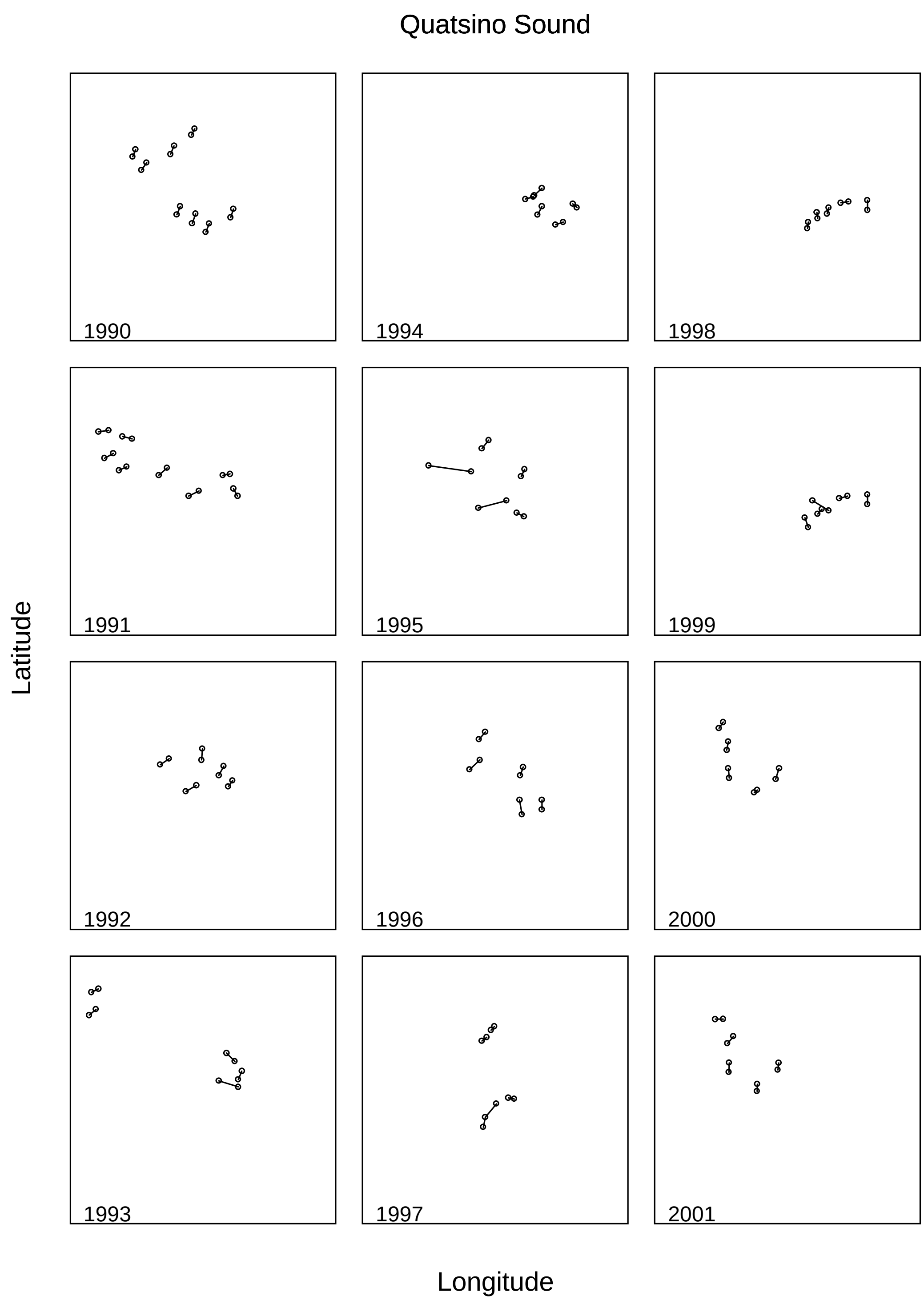

Figure E2. continued.

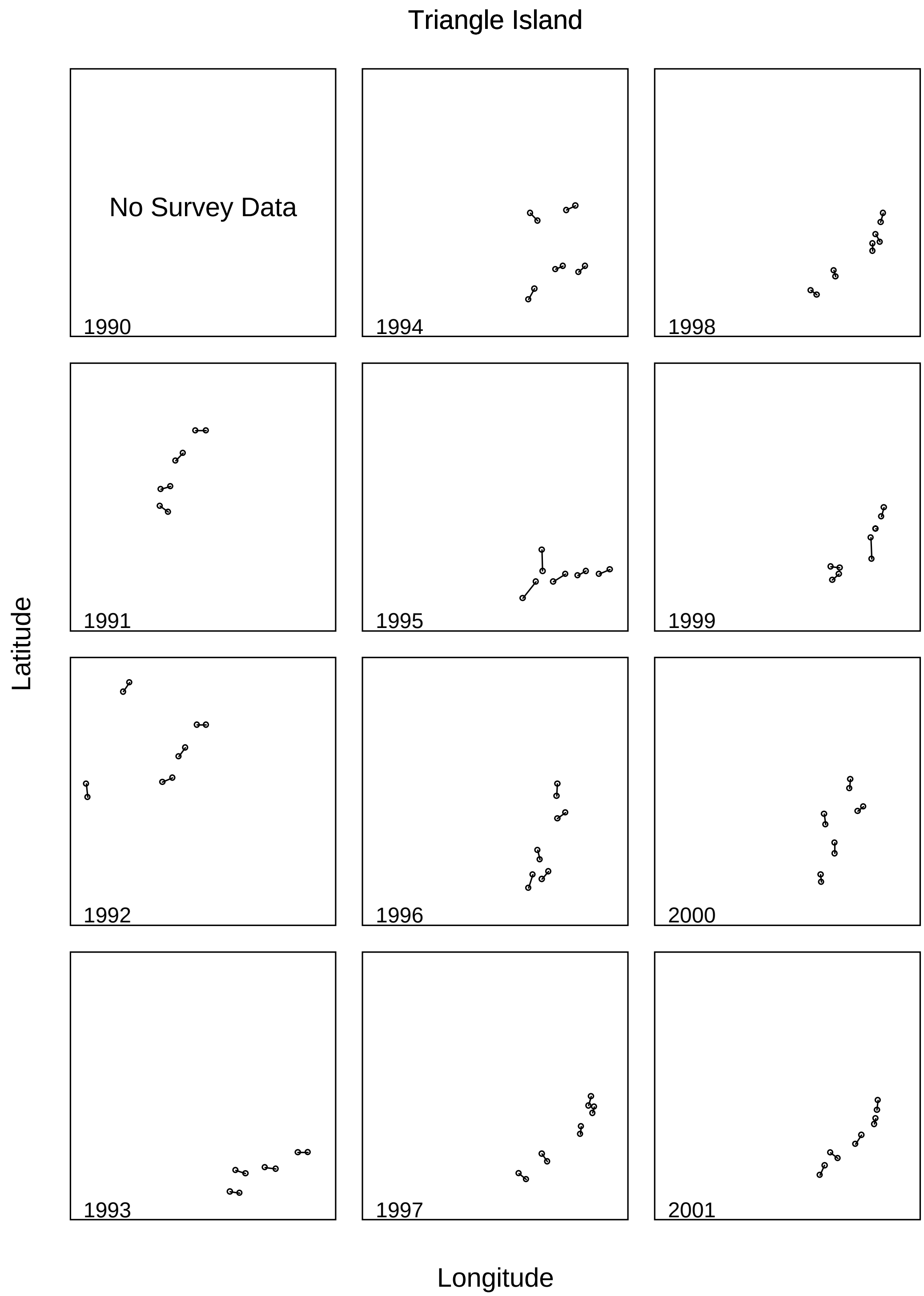

Figure E2. continued.

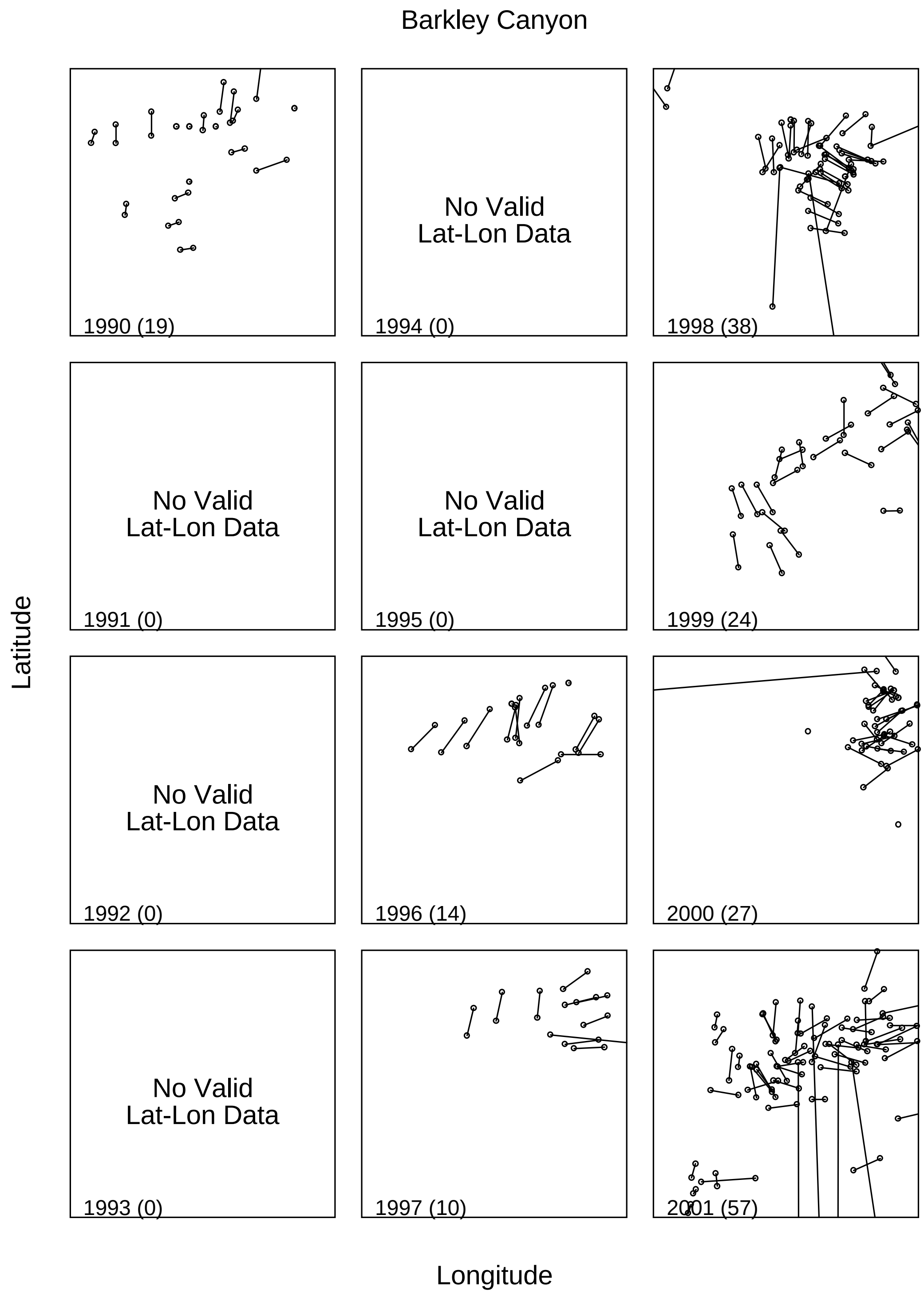

Figure E3. Relative spatial position of commercial sablefish sets of trap gear in September through November.

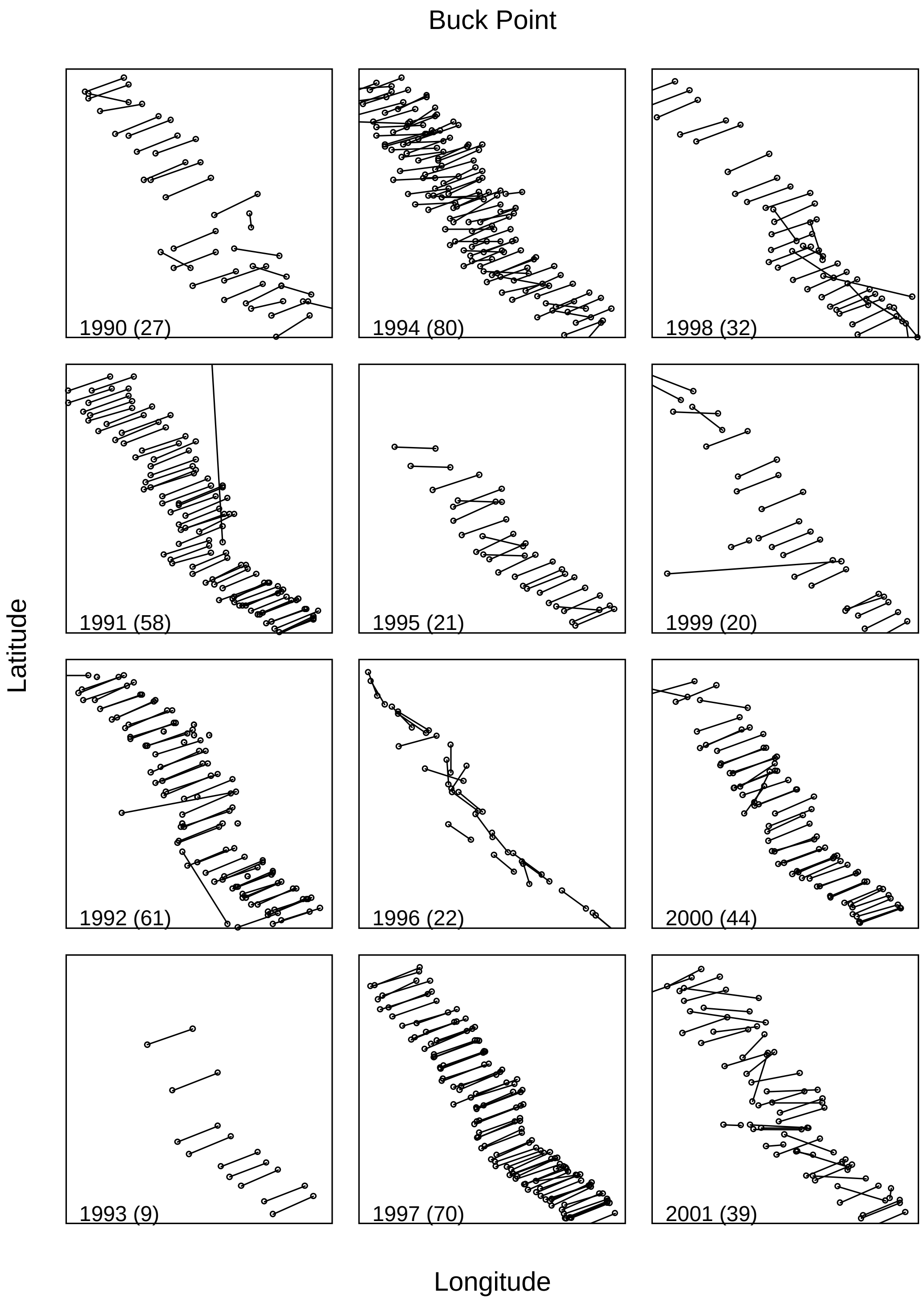

Figure E3. continued.

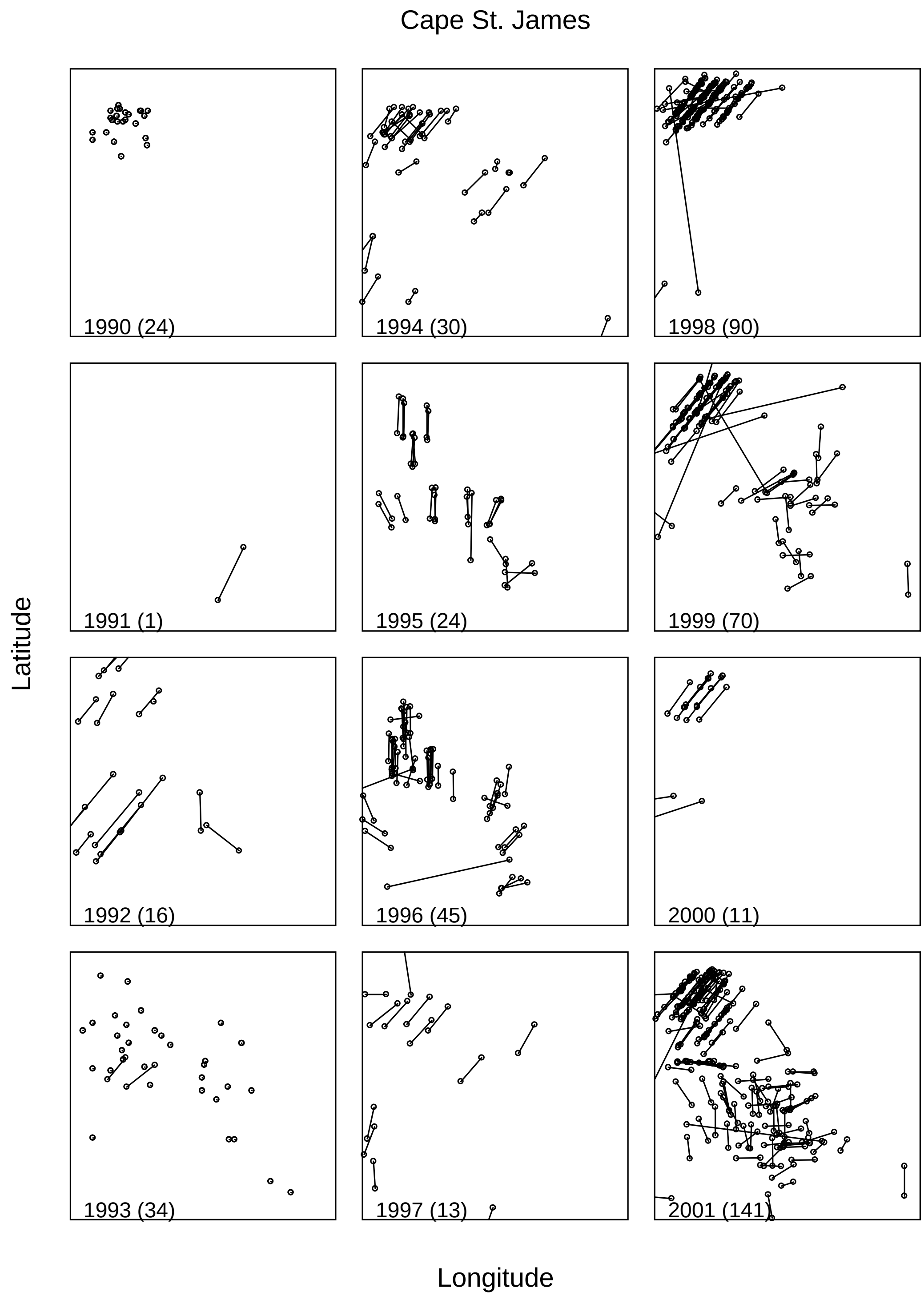

Figure E3. continued.

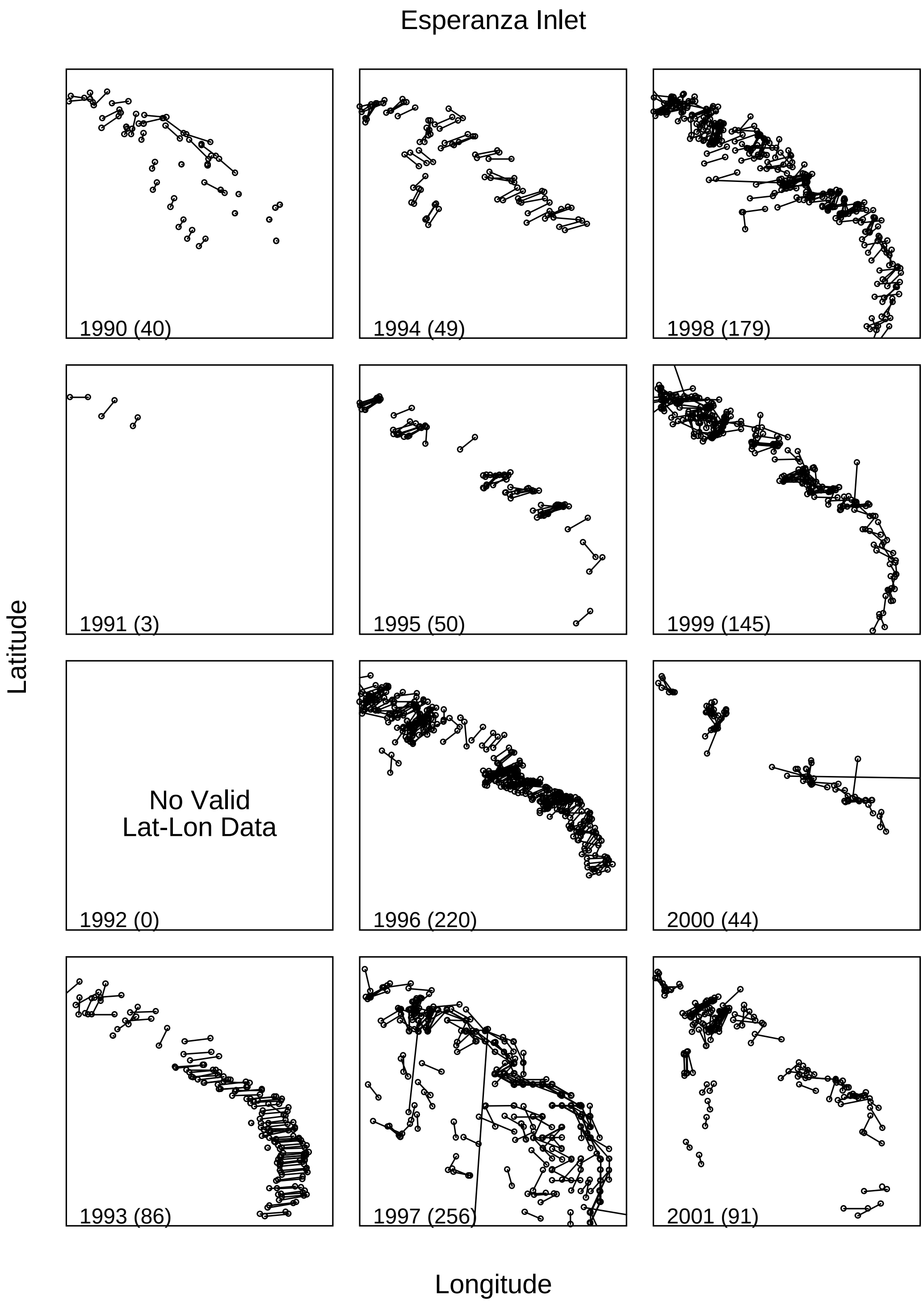

Figure E3. continued.

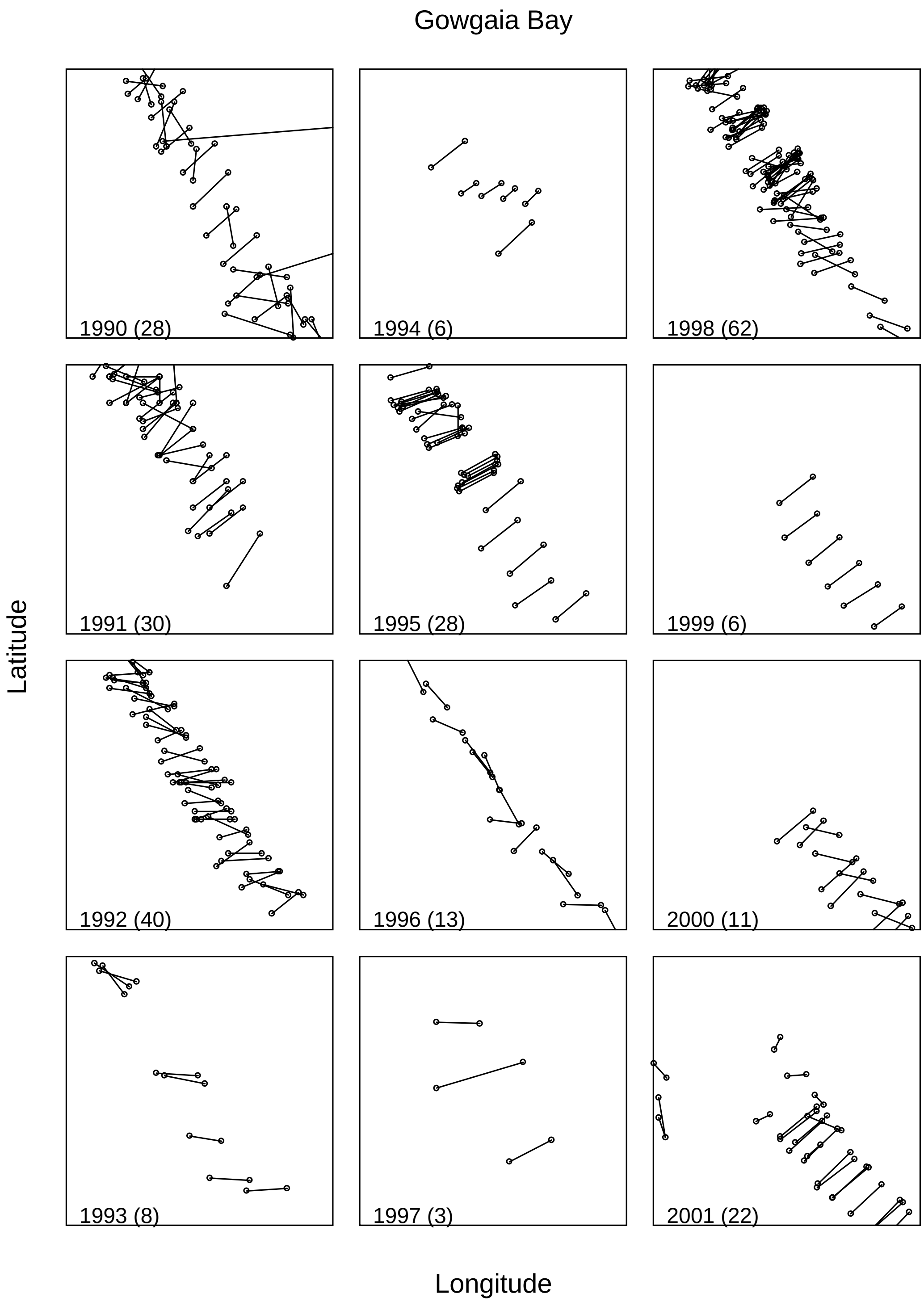

Figure E3. continued.

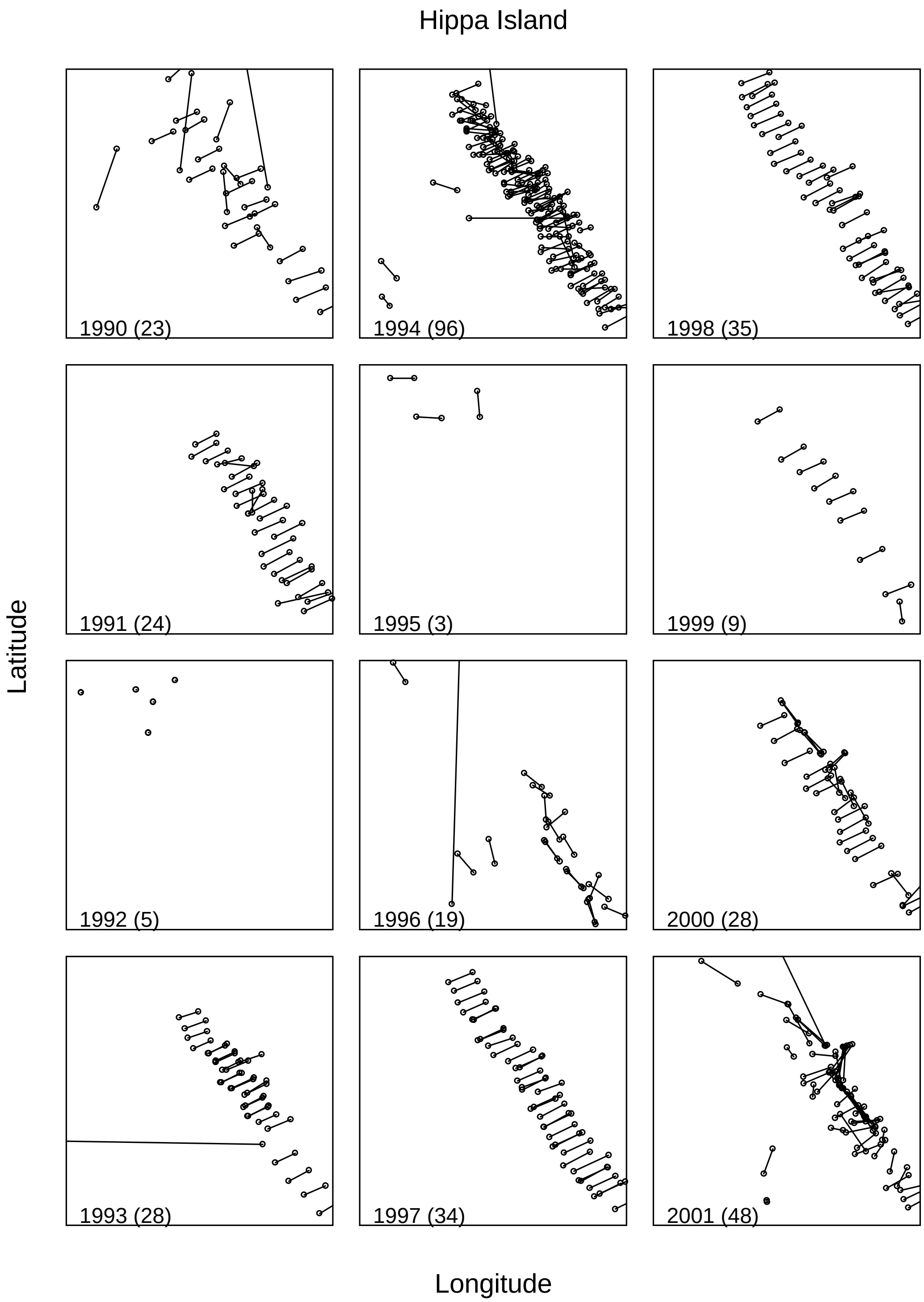

Figure E3. continued.

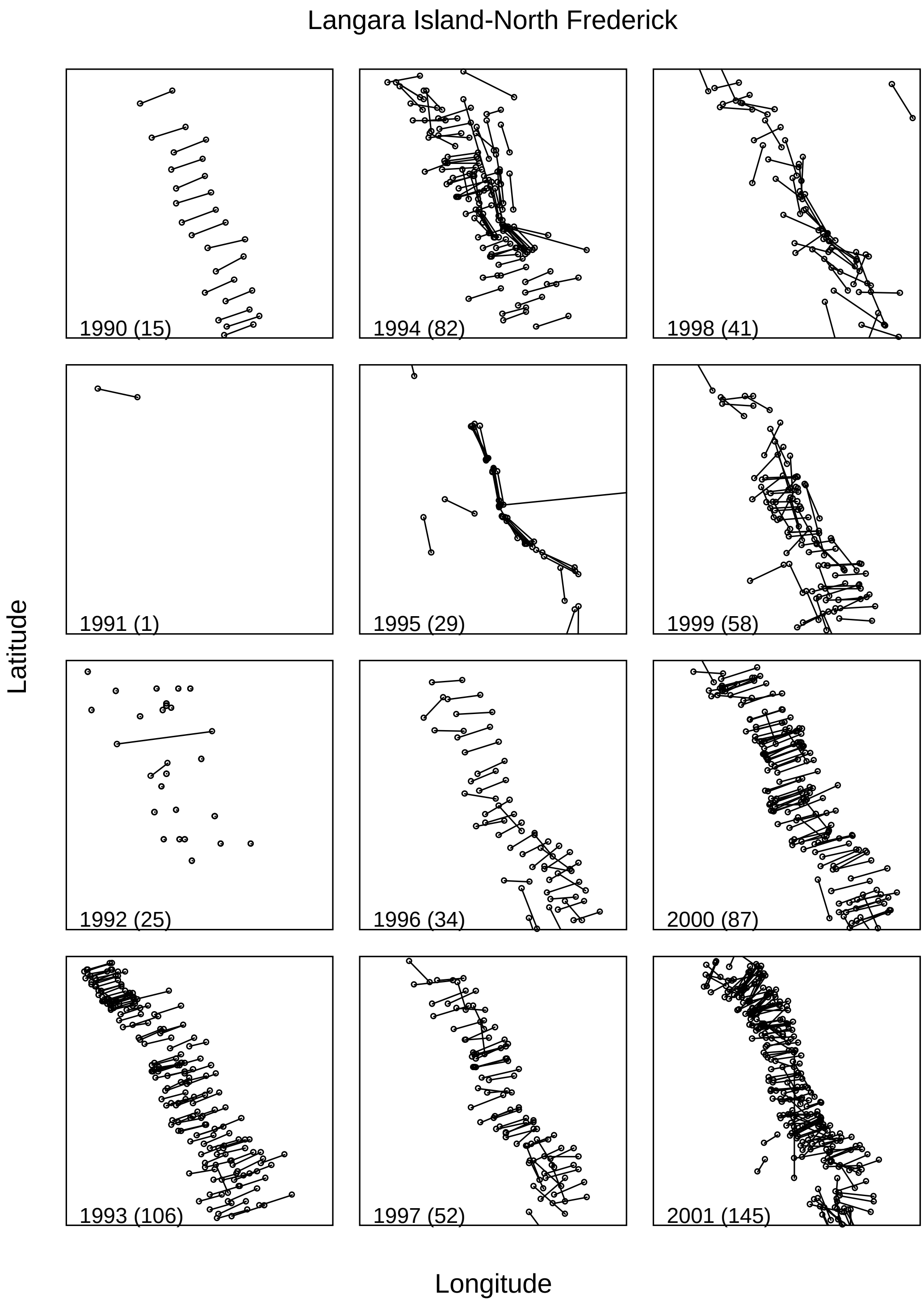

Figure E3. continued.

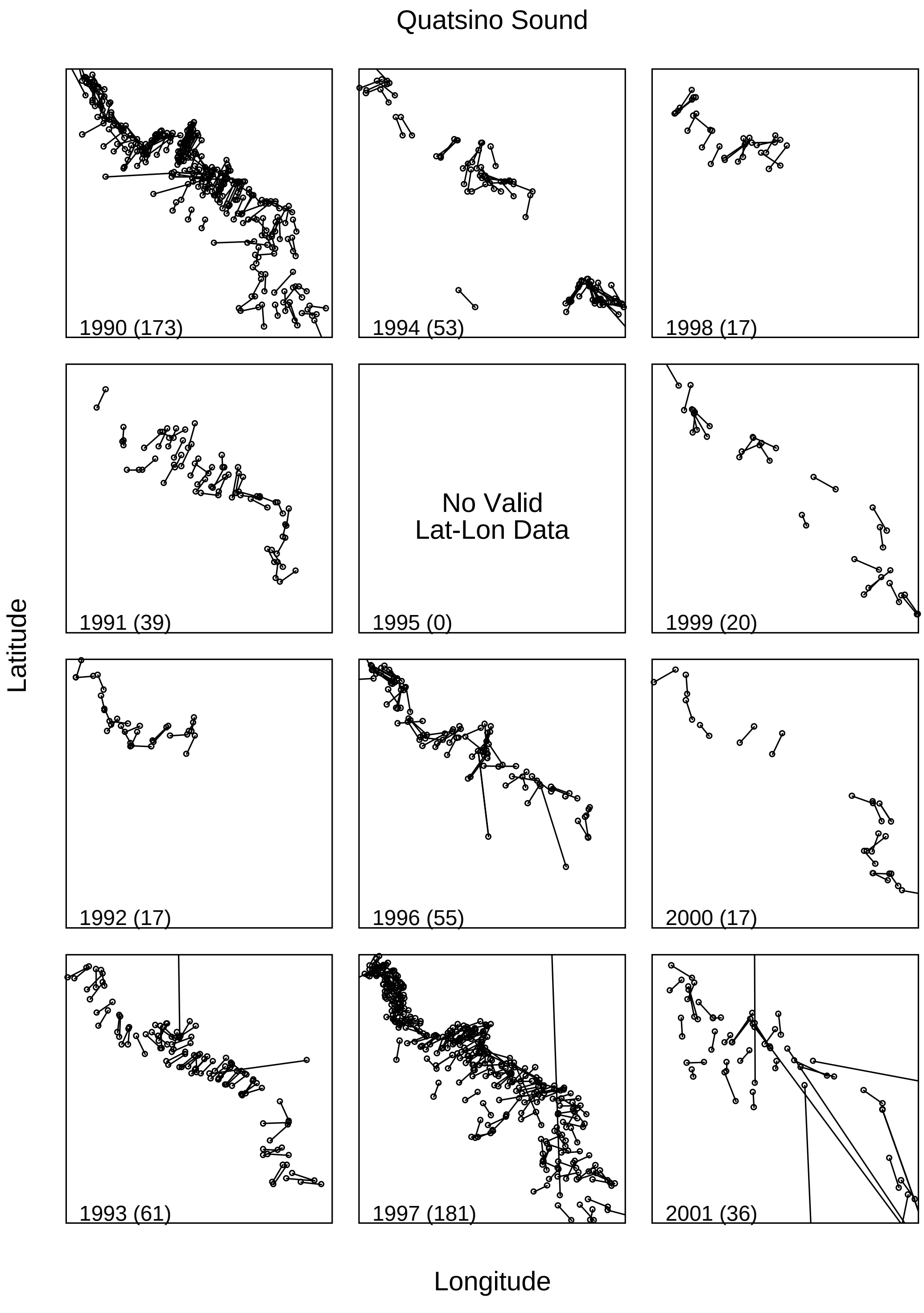

Figure E3. continued.

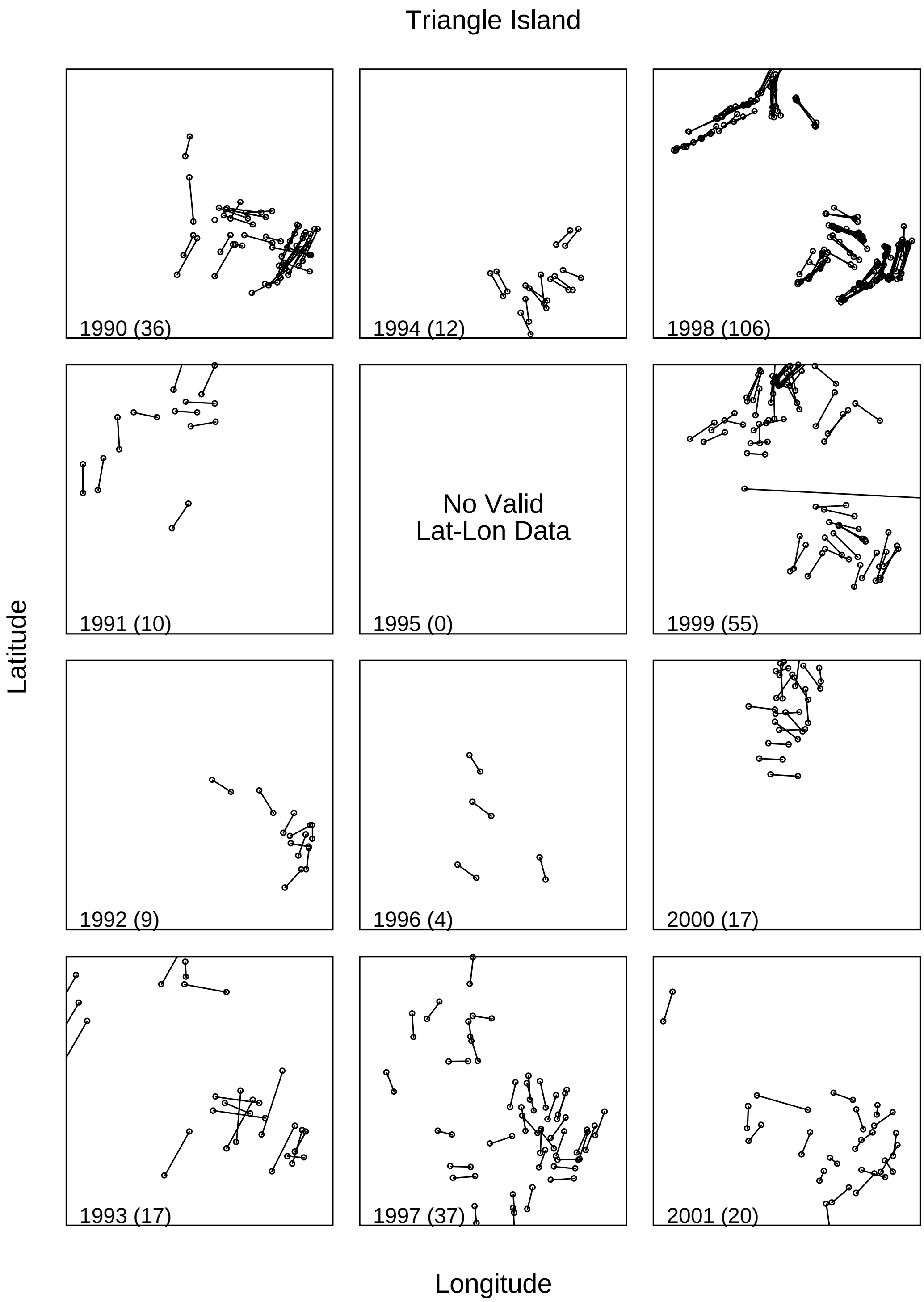

Figure E3. continued.

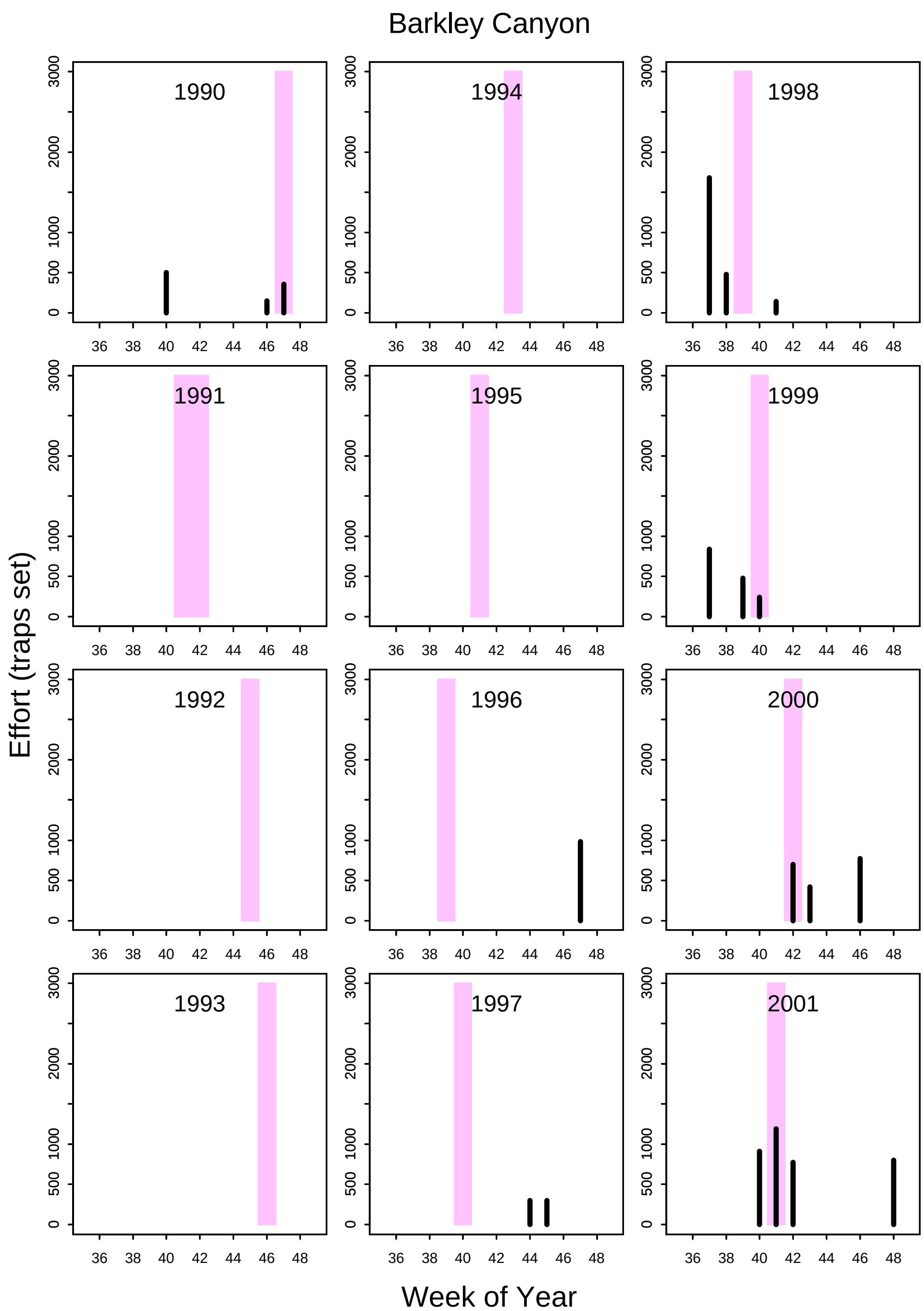

Figure E4. Sablefish commercial trap effort by week, year, and locality.

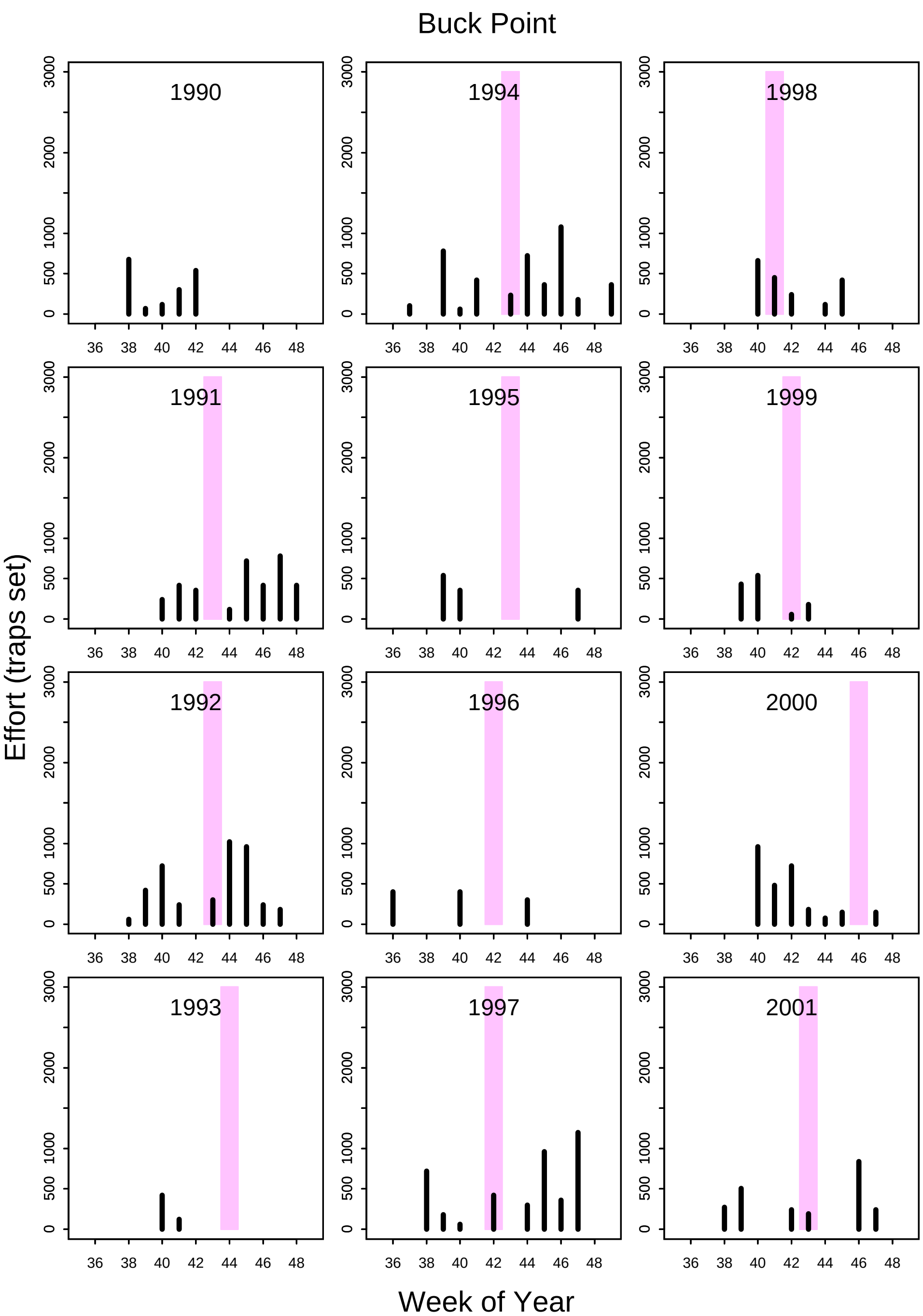

Figure E4. continued.

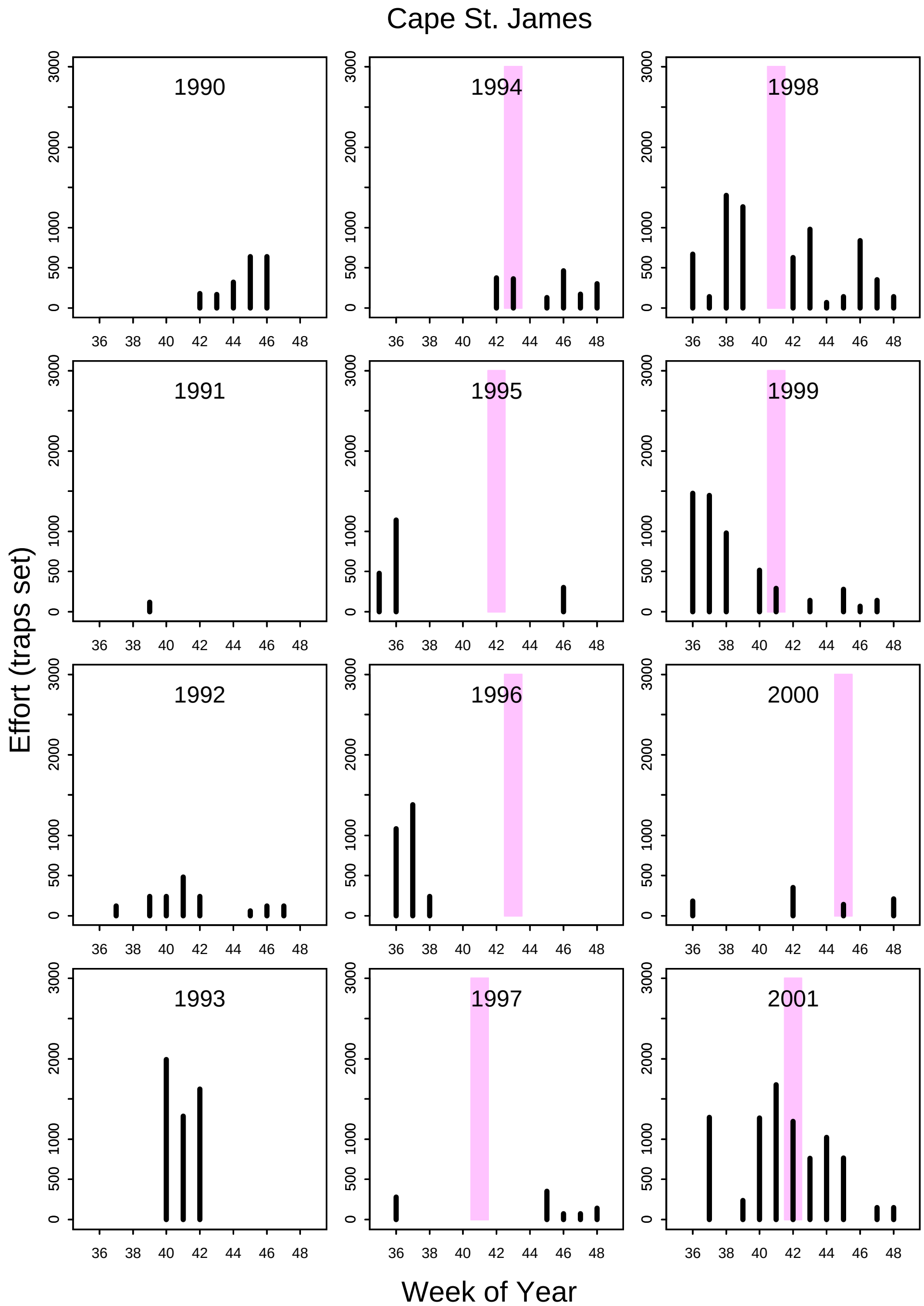

Figure E4. continued.

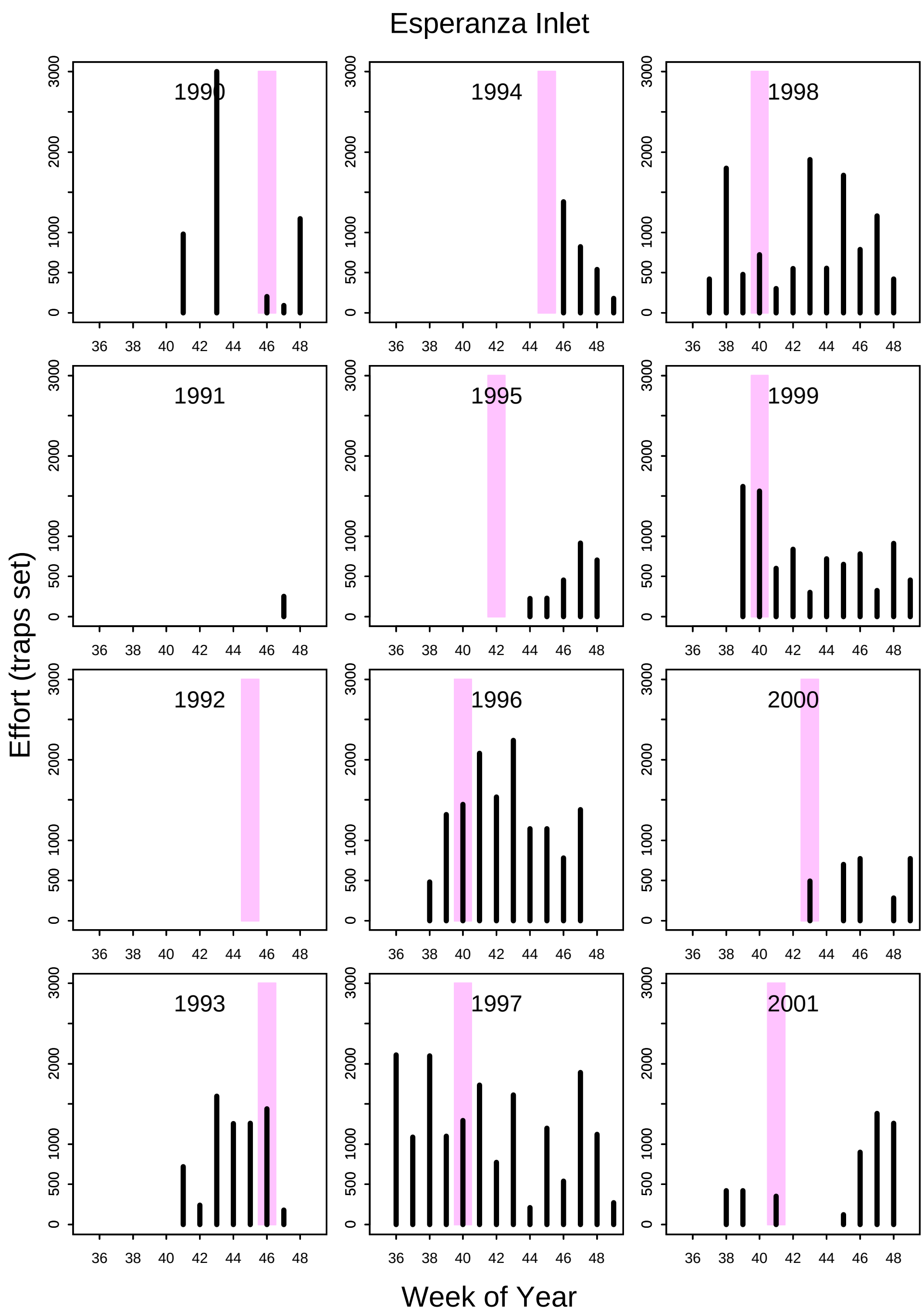

Figure E4. continued.

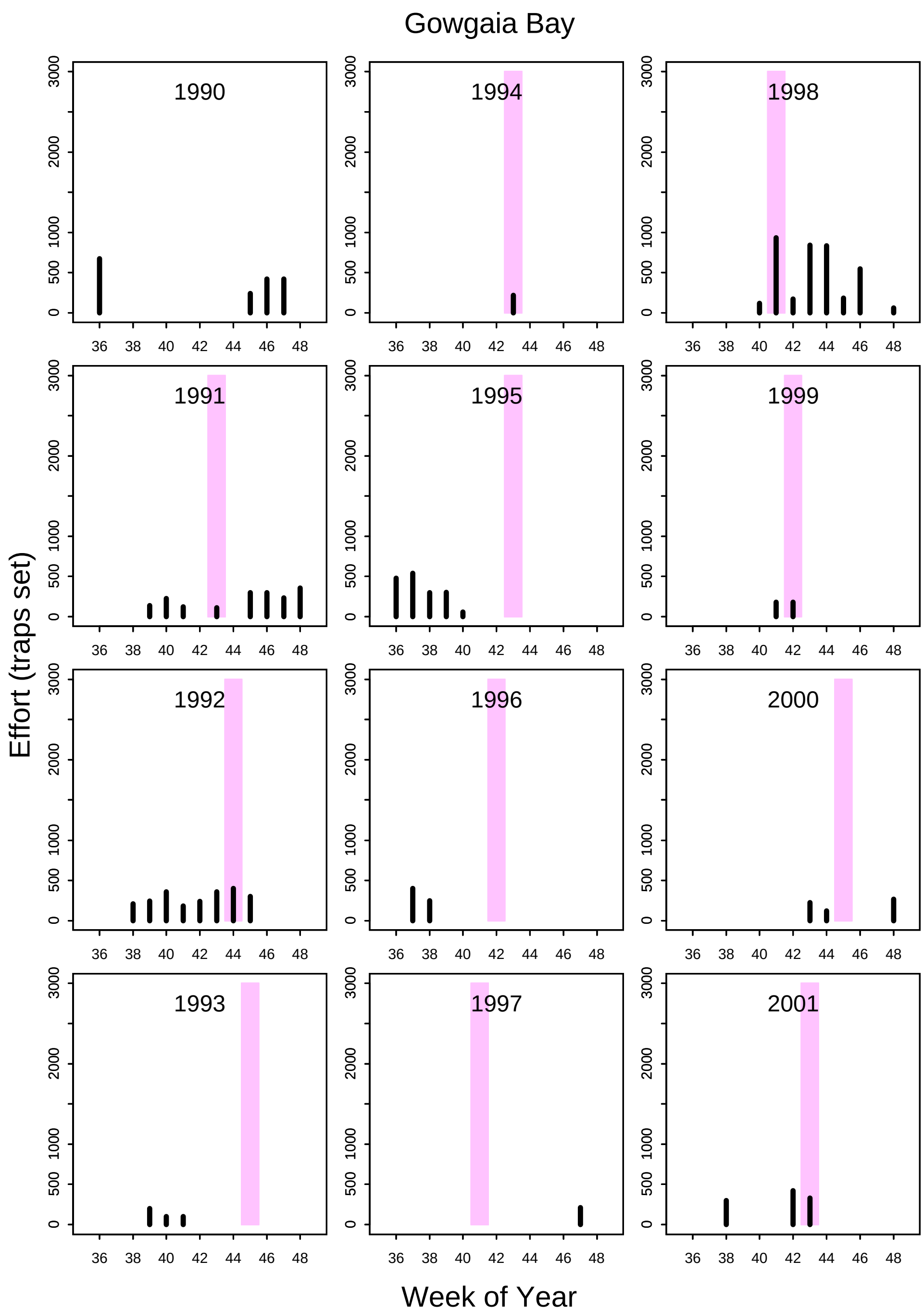

Figure E4. continued.

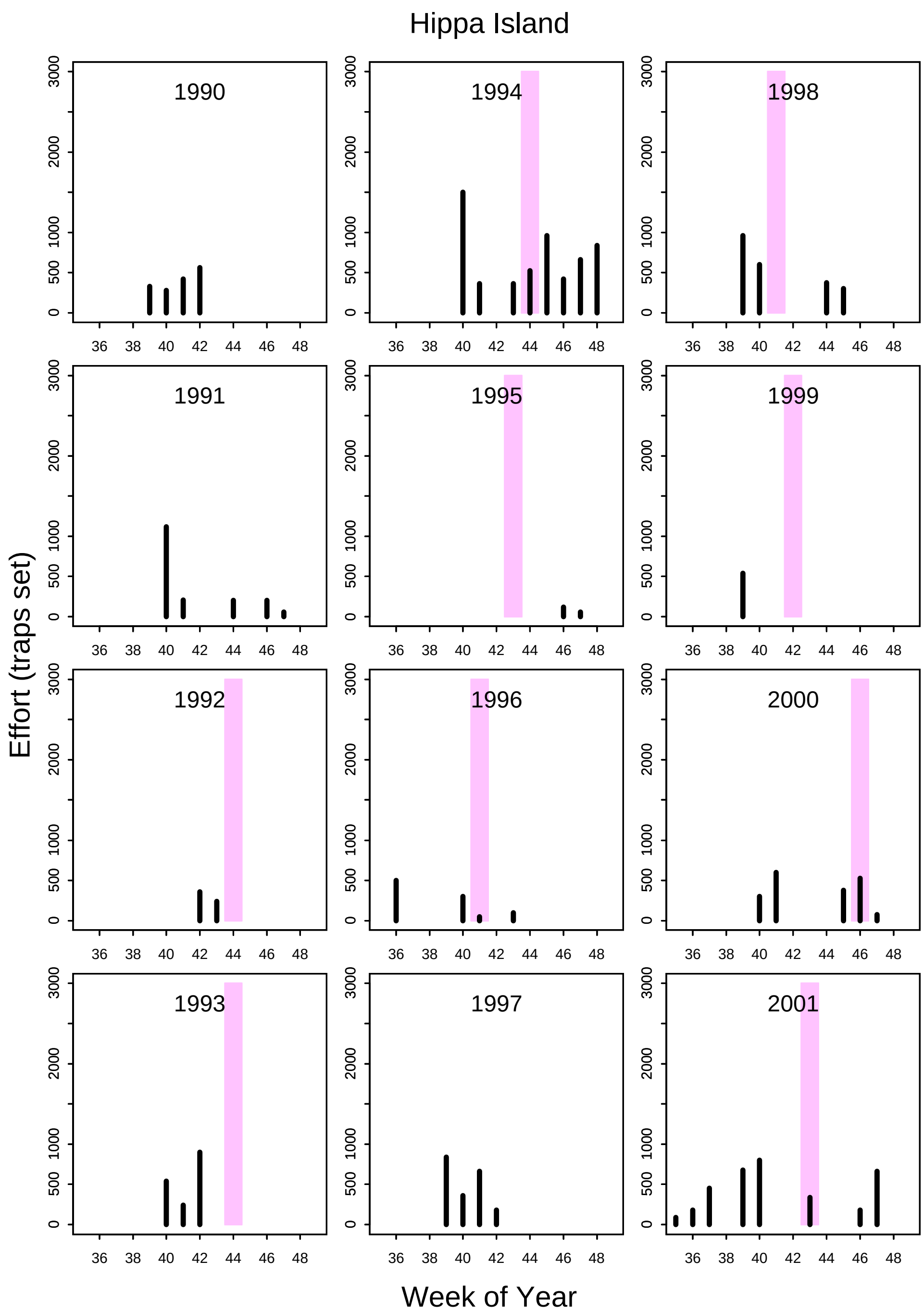

Figure E4. continued.

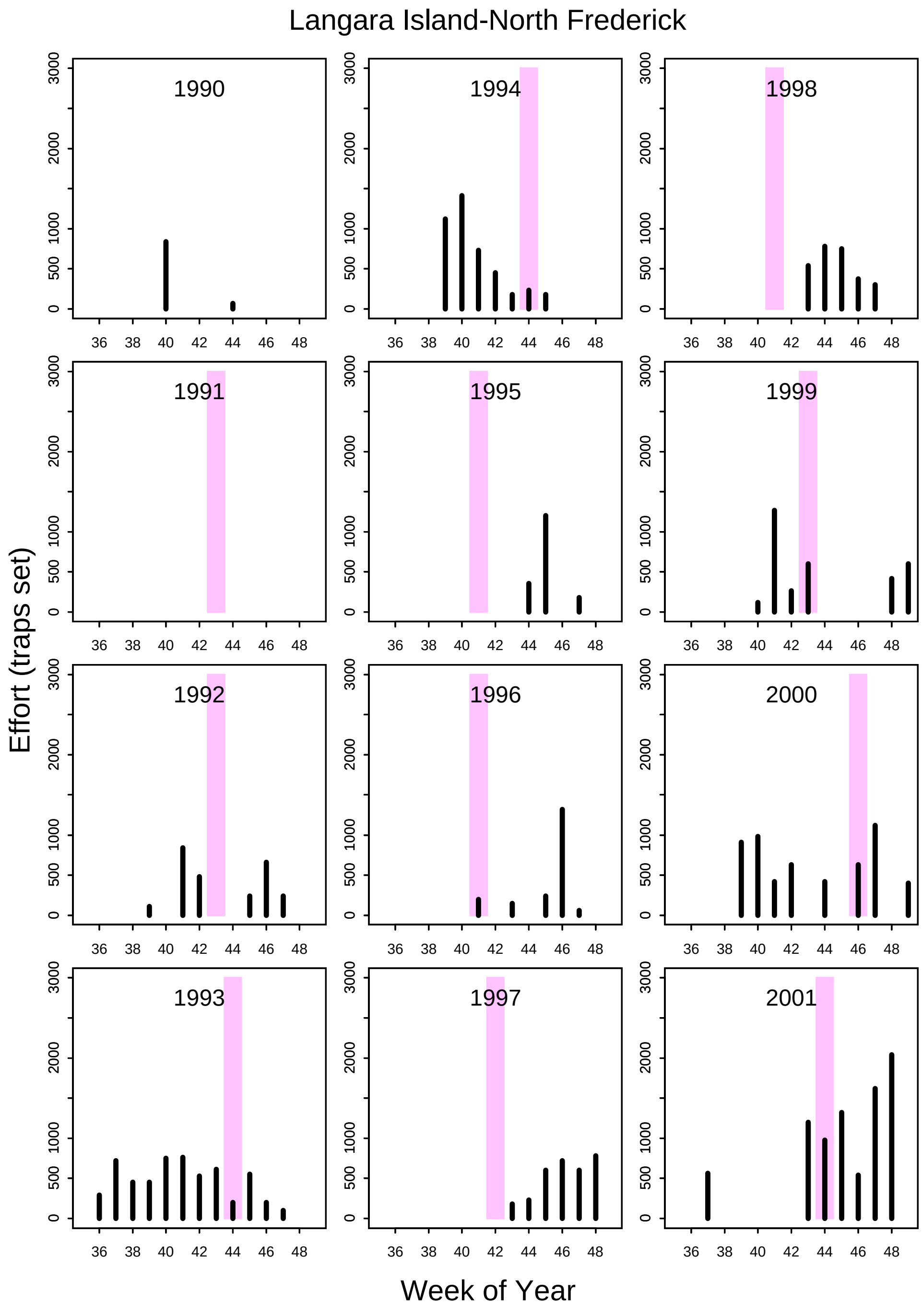

Figure E4. continued.

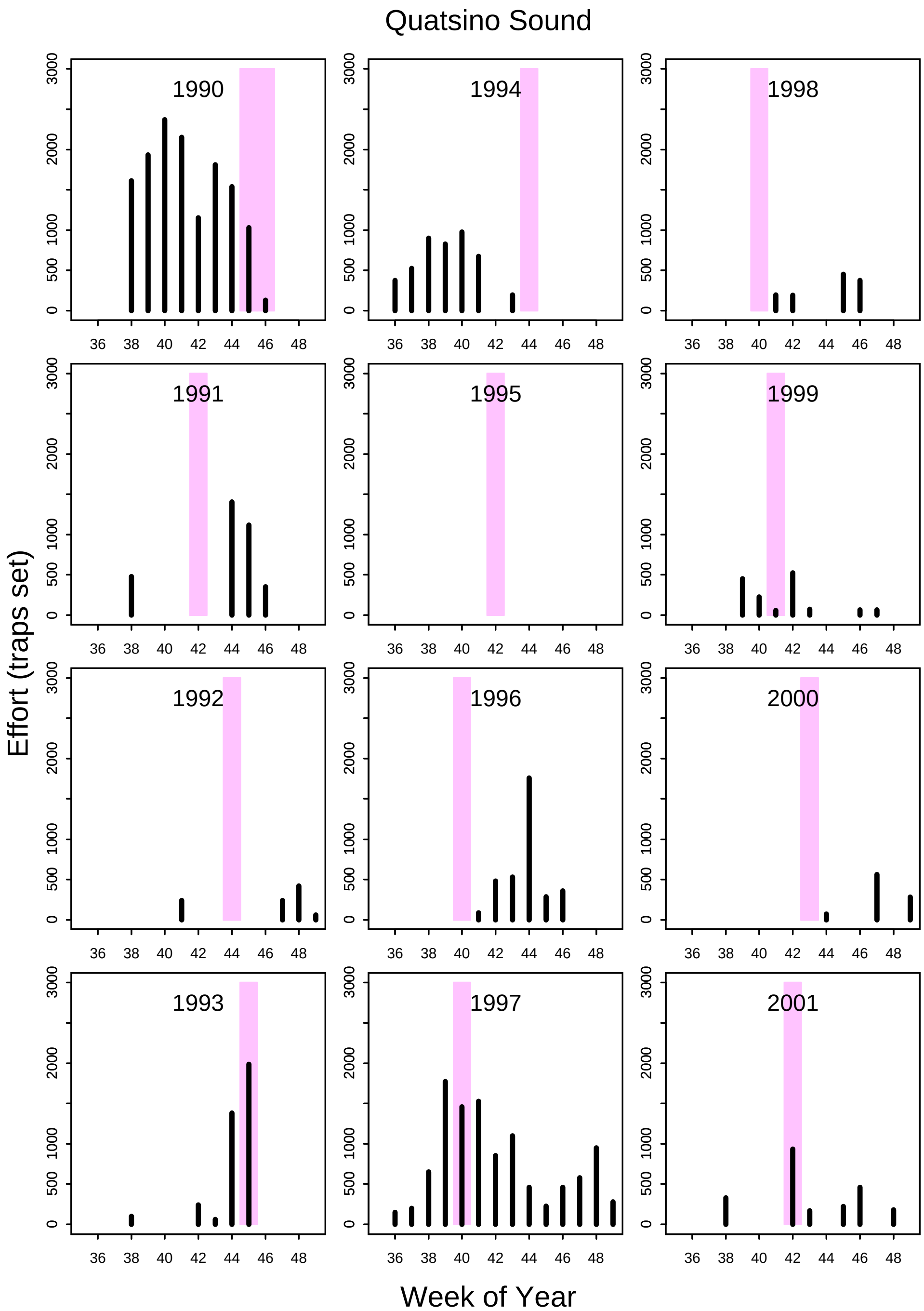

Figure E4. continued.

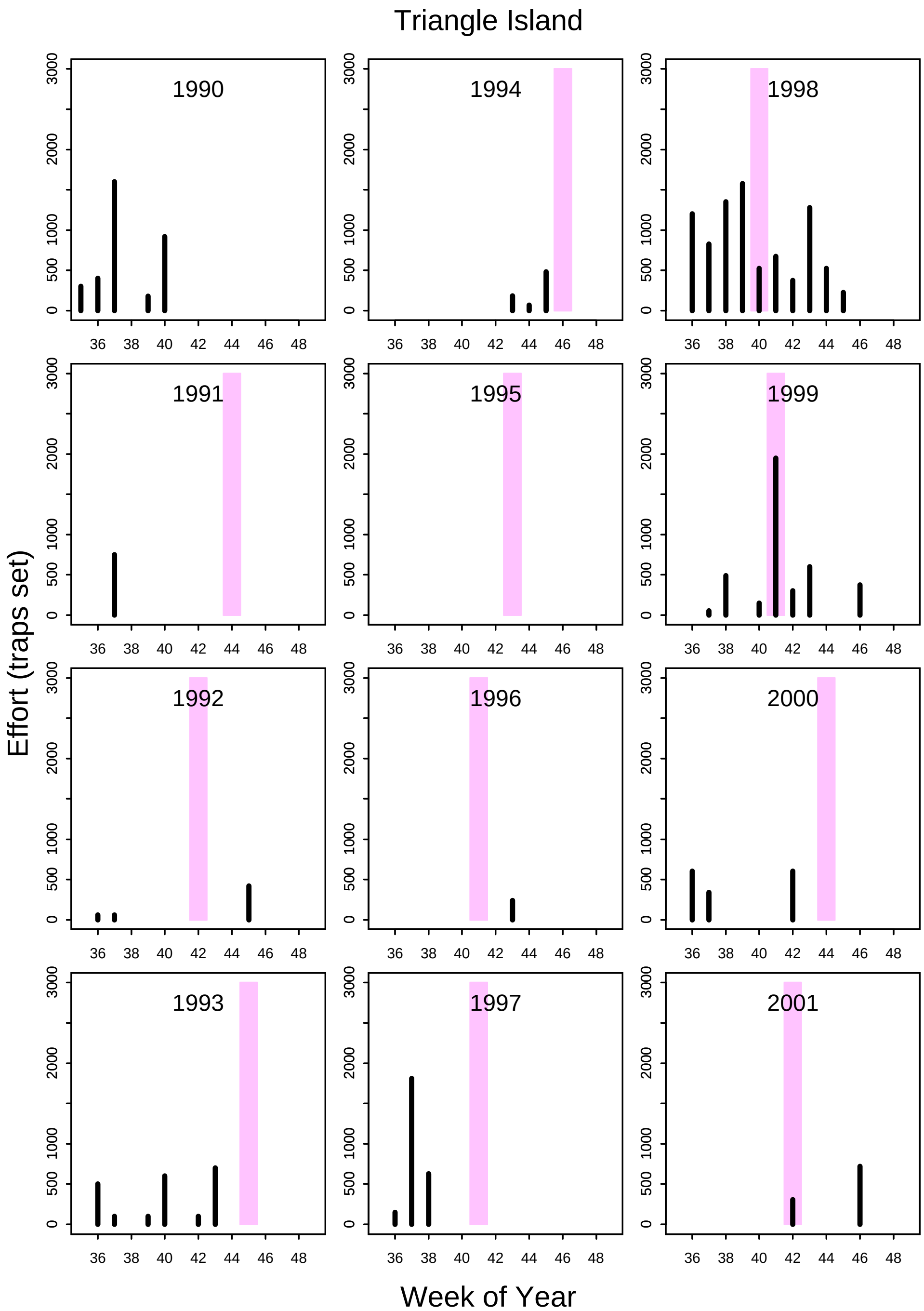

Figure E4. continued.

Appendix F. 2001 survey data

Table F.1 2001 survey data for southern index survey localities.

Location	Depth Stratum	Set Number	Traps Fished	Sablefish Sampled	Tagged	Recovered	Total	Total Weight	Fish/ Trap	kg/ Trap
Barkley Canyon	**1**	9	25	3	0	0	4	9.4	0.16	0.38
	2	10	25	16	0	0	16	38.3	0.64	1.53
	3	8	25	32	33	1	66	142.6	2.64	5.70
	4	7	25	54	144	0	198	436.3	7.92	17.45
	5	6	25	55	77	0	132	342.8	5.28	13.71
Esperanza Inlet	**1**	29	25	44	0	0	42	145.9	1.68	5.84
	2	28	25	6	0	0	6	18.7	0.24	0.75
	3	27	26	21	0	0	21	41.7	0.81	1.60
	4	26	23	22	0	0	22	50.3	0.96	2.19
	5	25	21	55	45	1	101	241.4	4.81	11.50
Quatsino Sound	**1**	34	25	35	0	0	35	104.7	1.40	4.19
	2	33	25	22	0	0	22	55.1	0.88	2.20
	3	30	25	52	92	0	144	298.9	5.76	11.96
	4	31	26	50	96	1	147	264.3	5.65	10.17
	5	32	25	41	0	0	41	82.2	1.64	3.29
Triangle Island	**1**	50	25	23	0	1	24	83.6	0.96	3.34
	2	49	25	18	0	0	18	47.4	0.72	1.90
	3	48	25	13	0	0	13	29	0.52	1.16
	4	47	25	15	0	0	14	44.5	0.56	1.78
	5	46	27	12	0	0	12	41.3	0.44	1.53

Table F.2 2001 survey data for northern index survey localities.

Location	Depth Stratum	Set Number	Traps Fished	Sablefish Sampled	Tagged	Recovered	Total	Total Weight	Fish/ Trap	kg/ Trap
Cape St. James	**1**	61	25	26	0	0	26	75.4	1.04	3.02
	2	60	25	43	26	0	68	162.7	2.72	6.51
	3	58	25	16	0	0	16	37.3	0.64	1.49
	4	57	25	4	0	0	4	11.3	0.16	0.45
	5	59	27	3	0	0	3	11.3	0.11	0.42
Gowgaia Bay	**1**	69	25	9	0	0	9	23.6	0.36	0.94
	2	71	24	11	0	0	10	32.3	0.42	1.35
	3	70	26	17	0	1	18	57.2	0.69	2.20
	4	66	26	1	0	0	1	2.2	0.04	0.08
	5	68	26	9	0	0	9	25.2	0.35	0.97
Buck Point	**1**	85	25	11	0	0	11	32.8	0.44	1.31
	2	86	25	15	0	1	16	41.7	0.64	1.67
	3	87	25	6	0	0	6	14.1	0.24	0.56
	4	88	25	4	0	0	4	12.3	0.16	0.49
	5	89	25	10	0	0	10	29.3	0.40	1.17
Hippa Island	**1**	101	27	15	0	0	15	55.7	0.56	2.06
	2	100	25	15	0	0	16	41.2	0.64	1.65
	3	99	25	2	0	0	2	4	0.08	0.16
	4	97	25	10	0	0	10	34.2	0.40	1.37
	5	96	25	7	0	0	7	20.7	0.28	0.83
Langara Island-	**1**	114	25	2	0	0	2	11.1	0.08	0.44
North Frederick	**2**	113	25	9	0	0	9	25.8	0.36	1.03
	3	112	25	2	0	0	2	3.3	0.08	0.13
	4	111	25	4	0	0	4	12.8	0.16	0.51
	5	110	25	10	0	0	10	28	0.40	1.12