

Flatfish Stock Assessments for the West Coast of Canada for 1996 and Recommended Yield Options for 1997

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by

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ABSTRACT

Fargo, J. J. and A. R. Kronlund. 1997. Flatfish stock assessments for the west coast of Canada for 1996 and recommended yield options for 1997. Can. Tech. Rep. Fish. Aquat. Sci. 2149: 124 p.

Interim assessments were prepared for Area 3C and 3D petrale sole, Area 5C-E Dover sole, Area 5A, 5B and 5C-D rock sole and Area 5C-D English sole. A detailed assessment was prepared for Area 3C-D Dover sole. Data analyzed for the interim assessments include: 1) catch-effort data from the commercial fishery and 2) length composition data from the commercial fishery. Information used for the detailed assessment for Area 3C-D Dover sole included 1) catch-effort data from the commercial fishery and 2) biological and catch-rate data from two biomass surveys.

Petrable sole stocks remain at a very low level. Recruitment for the 'southern' stock shows no sign of an increase in more than a decade. Recruitment for the 'northern' stock appears to be increasing based on length frequency anomalies but corroboration of this observation is necessary with additional year's data. The fishery for this species continues to be limited to incidental landings only. The fishery for Area 3C-D Dover sole continued to expand in 1995. CPUE indicators for the commercial fishery all indicate a decline since 1988. Both the number of vessels participating in the fishery and fishing effort have increased dramatically in recent years while CPUE has decreased. Accordingly, estimates of yield for 1997 have been revised downward from 1996. Area 5C-E Dover sole continued to be exploited above the high-risk level in 1995. Commercial CPUE has been in decline since 1993. Stock abundance as indicated by CPUE from the commercial fishery appears to be declining over the last three years although CPUE in 1995 is close to the longterm average. Rock sole landings declined for all areas of the coast and the contribution to the fishery of the strong year-classes in the late 1980s appears to be diminishing. The stock in Area 5A appears to be near the long term average abundance for the 1954 to 1995 period as indicated by CPUE from the commercial fishery. The stock in Area 5B is below the longterm average abundance as indicated by CPUE from the commercial fishery. Yield for Hecate Strait rock sole is based on the 1995 biomass estimate from catch-age analysis. The biomass estimate for 1995 was higher than that for 1994 and the yield options for 1997 have been raised from those for 1996. Yield for Hecate Strait English sole is based on the 1995 biomass estimate from catch-age analysis. The biomass estimate for 1995 was slightly higher than that for 1994 and the yield options for 1997 have been raised from those for 1996. However, the current estimate of fishing mortality for this stock is high and further analysis will be necessary to resolve this.

RÉSUMÉ

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Des évaluations provisoires ont été préparées pour la plie de Californie des zones 3C et 3D, de la limande-sole des zones 5C-E, de la fausse limande des zones 5A, 5B et 5C-D et du carlottin anglais des zones 5C-D. Une évaluation détaillée a été préparée pour la limande-sole des zones 3C-D. Les données analysées dans le cas de l'évaluation provisoire étaient : 1) les données sur les prises et l'effort de la pêche commerciale et 2) les données sur la composition selon la longueur des prises commerciales. Les données utilisées dans le cas de l'évaluation détaillée pour la limande-sole des zones 3C-D étaient : 1) les données sur les prises et l'effort de la pêche commerciale et 2) les données biologiques et les données sur les taux de prises de deux études sur la biomasse.

Les stocks de sole de Californie demeurent très faibles. Le recrutement du stock du «sud» ne montre aucun signe d'augmentation depuis plus d'une décennie. Le recrutement du stock du «nord» semble augmenter si l'on en juge par les anomalies relatives à la fréquence des longueurs, mais il faudra corroborer cette observation à l'aide de données obtenues au cours des années à venir. La pêche de cette espèce se limite toujours aux captures accessoires. La pêche de la limande-sole dans les zones 3C-D a continué d'augmenter en 1995. Les indicateurs relatifs aux CPUE dans le cas de la pêche commerciale indiquent tous une réduction depuis 1988. Le nombre de bateaux participant à la pêche ainsi que l'effort de pêche ont beaucoup augmenté ces dernières années, alors que les CPUE ont diminué. Par conséquent, les estimations de la production en 1997 ont été révisées à la baisse par rapport à celles de 1996. La limande-sole dans les zones 5C-E a continué d'être exploitée au dessus du niveau de risque élevé en 1995. Les CPUE commerciales diminuent depuis 1993. L'abondance des stocks d'après les CPUE de la pêche commerciale semble diminuer depuis les trois dernières années, mais les CPUE en 1995 se rapprochent de la moyenne à long terme. Les débarquements de fausse limande ont diminué dans toutes les zones de la côte et la contribution des fortes classes d'âge de la fin des années 80 semble diminuer. Le stock de la zone 5A semble se rapprocher de l'abondance moyenne à long terme pour la période de 1954 à 1995 comme l'indiquent les CPUE de la pêche commerciale. La production de fausse limande dans le détroit d'Hécate est basée sur l'estimation de la biomasse de 1995 d'après l'analyse de l'âge à la capture. L'estimation de la biomasse de 1995 était plus élevée que celle de 1994 et les options de production pour 1997 ont augmenté par rapport à celles

pour 1996. La production de carlottin anglais dans le détroit d'Hécate est basée sur l'estimation de la biomasse de 1995 d'après l'analyse de l'âge à la capture. L'estimation de la biomasse de 1995 était légèrement inférieure à celle de 1994 et les options de production pour 1997 ont été augmentées par rapport à celles pour 1996. Toutefois, l'estimation actuelle de la mortalité par pêche est élevée dans ce stock et une analyse plus poussée sera nécessaire pour élucider ce problème.

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4.0 FLATFISH

4.0.1. GENERAL INTRODUCTION

This year interim assessments have been prepared for all flatfish stocks except Area 3CD Dover sole. Catch and effort statistics have been updated for all stocks to include information from the 1995 fishery. In past assessments the CPUE index was adjusted to account for changes in vessel horsepower over time. This approach has not been used in this year's assessments in view of the marginal significance of that relationship. Vessel horsepower accounted for less than 10% of the variability in CPUE over time. The median 25% qualified statistic has been adopted as the index of CPUE for this year's assessments. Trimmed estimators (see Appendix 4.1) are a more appropriate measure of central tendency for the skewed distributions commonly encountered in fisheries catch-effort data (Richards and Schnute 1992). Catch-effort data from the commercial fishery forms the basis for the assessments for Dover sole and Area 5A-B rock sole. These analyses assume that CPUE is proportional to stock abundance. In recent years this has come under criticism and results from some analyses have indicated that a commercial CPUE index will not provide a signal of stock decline until the stock has been depleted (Walters and Hillborn 1992, Richards and Schnute 1986). The assessment for area 3CD Dover sole incorporates information from biomass surveys as well as commercial fishery data. Catch-age analysis has been updated for Hecate Strait English sole and rock sole and the yield options for 1997 are based on percentiles of the confidence region for the 1995 stock biomass estimates.

A new catch-age model has been used this year (Schnute and Richards 1995) for the assessments of Hecate Strait rock and English soles. Model residuals have been examined and results of this analysis are compared with last year's results. Yield estimates for these two stocks are produced by applying a target fishing mortality reference point to the 25th and 50th percentiles of the confidence region for the estimate of biomass for 1995.

Yield options for 1996-97 are summarized in Table 4.1. Petrale sole stocks remain low and the yield options for 1997 are the same as those in 1996. The yield options for Area 3CD Dover sole have been lowered reflecting a significant decline in CPUE for the last 5 years. The yield options for Area 5A rock sole remain the same as last year. The high-risk option for Area 5B rock sole has been lowered due to a decrease in commercial fishery CPUE for that stock in recent years. Yield options for Hecate Strait rock sole have been increased reflecting the increase in exploitable biomass between 1994 and 1995 determined from the catch-age analysis. Yield options for Hecate Strait English sole have been raised slightly reflecting the increase in

exploitable biomass between 1994 and 1995 determined from the catch-age analysis. However, the high level of fishing mortality for that species is a cause for concern and further analysis will be necessary to resolve this. Yield options for the Area 5CDE Dover sole stock remain the same as last year.

4.1. COASTWIDE

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. STRAIT OF GEORGIA

Yield options are not proposed for flatfish for this region.

4.3. WEST COAST OF VANCOUVER ISLAND (AREAS 3C AND 3D)

4.3.1. Petrable Sole

4.3.1.1. Introduction

The petrale sole (*Eopsetta jordani*) population off the west coast of Vancouver Island is thought to be composed of two stocks based on results from tagging experiments conducted in the 1960s (Ketchen and Forrester 1966) (Pedersen 1975a). The southern stock occupies both the Canadian and U.S. portions of Area 3C, while the northern stock is presumed to occupy Areas 3D-5D. Fishing effort data for the intensive fishery occurring from 1950 to 1970 is not available because the fishery was carried out largely by U.S. trawlers and no effort data was collected. Petrale sole recruit to the commercial fishery beginning at age four but recruitment is not knife-edged. They are not fully recruited until age 8. Length of 50% sexual maturity, L_{50} , is 38.1 cm (7 y) for males and 44.3 cm (8 y) for females (Ketchen and Forrester 1966). They are probably not fully recruited until age eight. Assessment of these stocks is limited by the lack of catch-effort time series data and a lack of age composition data after 1970. The backlog of age composition data is now being processed but it will take several more years to complete. Concern over the long term decline in landings for these stocks led managers to adopt an incidental trip limit of 2000 lb for petrale sole in 1995. The stock catch histories and all available biological data available are used as the basis for this assessment.

Previous catch-at-age analyses by Ketchen and Forrester (1966) and Pedersen (1975b) indicated that 'there appeared to be no need for regulation of the summer fishery and the effects of winter fishing on the spawning concentrations appeared to be overshadowed by environmentally induced variations in the production of recruits' (Ketchen 1979). More recently Castillo et al. (1994) showed that offshore Ekman transport at the egg and larval stage accounted for 55% and 65% of the variation in petrale sole year-class strength in PMFC Areas 2B and 3A, respectively. They concluded, as have previous investigators, that density-independent survival variation at the early life stages is significant compared to variation in spawning biomass; thus, environment regulates recruitment for this species. However, the spawning biomass of these stocks could now be so low that the effect of favourable environmental conditions is negated.

4.3.1.2 Landing statistics

Landings for the southern stock increased slightly to 353 t in 1995 from 328 t in 1994 while landings for the northern stock increased to 446 t in 1995 from 295 t in 1994, despite the incidental catch limit in effect (Tables 4.2-4.3). This was mainly due to catches in Area 5A-B. These catches represented trips where less than 3 t of petrale sole was caught and, in most cases, where it made up less than 10% of the total catch. This was probably a result of incidental catch in the fishery for rockfish in 5A-B. The time series of landings for this species shows cyclic trends with peaks occurring about once a decade (Figures 4.1 and 4.2). Landings fluctuations coincide with recruitment cycles for the species (Ketchen and Forrester 1966, Castillo et al. 1994). For both stocks, landings show an overall decline since the start of the fishery. The dotted line in each graph is the result of a loess smoother fit to each series. Regulatory measures for these stocks are in part, responsible for the decline since 1985. A trip limit of 40,000 lb was in effect for the first quarter from 1985 to 1991. From 1991 to 1995 a trip limit of 10,000 lb was in effect during the first quarter of the year while in 1996 incidental catches only are permitted.

Effort for the southern stock decreased to 2877 h in 1994 from 3223 h in 1993 while effort for the northern stock more than doubled to 2500 h in 1994 from 1131 h in 1993. Catch per unit effort for the southern stock declined to 0.114 t/h in 1994 from 0.139 t/h in 1993 while CPUE for the northern stock declined to 0.118 t/h in 1994 from 0.252 in 1993.

4.3.1.3. Biological data

Length frequency anomaly time series for the period 1956-94 for the 'southern' stock and 1956-94 for the 'northern'

stock are presented in Figures 4.3 and 4.4. The anomalies represent the annual deviations from the long term mean proportion at each 1 cm length interval. The negative (shaded) proportions represent deviations below the long term mean while the positive proportions represent deviations above the long term mean. The magnitude of the deviations are used solely for assessment of individual years and cannot be compared across years. There are positive anomalies between 30-40 cm for the 'southern' stock in each decade from the 1950s-1970s. Beginning in the early 1980s a series of negative anomalies is fairly continuous through 1994. We interpret this to mean that recruitment, as indicated by anomalies, has been below the long term average for more than a decade.

For the 'northern' stock, biological samples were combined across areas (3D-5D) to obtain the most continuous series available. Despite the pooling of samples there are many years without samples after 1970. There are positive anomalies between 30-40 cm in each decade sampled up to the 1980s and 1990s when negative anomalies dominate. In 1993 there is some evidence of an increase in recruitment and this carried through to 1994. Additional year's data are needed to confirm this.

4.3.1.4. Stock status

The loess smoother suggests a continuous decline in landings from the start of the series in 1942 for the 'southern' stock until about the mid 1970s when the decline slowed somewhat. Similarly, for the 'northern' stock a steady decline in landings is observed from 1944 until the mid 1970s. However, there is little evidence of a trend in subsequent years.

4.3.1.5. Yield Options

The catch histories for these stocks indicate that yield decreased substantially after heavy removals in the 1950s and 1960s. Recruitment has been low for more than a decade for the 'southern' stock and has only recently increased for the 'northern' stock. Age composition data are needed to reconstruct the stock history and examine the effect of spawning biomass and environment on recruitment for these stocks. This analysis is still several years away.

Precautionary yield option

Managers should continue in 1997, as in 1996, to permit incidental catches only from these stocks as a conservation measure.

4.3.2. Area 3CD Dover sole

4.3.2.1. Area 3CD Rationale and Introduction

In the most recent assessment for Area 3CD Dover sole, Fargo (1995) noted a decline in catch per unit effort (CPUE) in this fishery since 1989. In turn, the Groundfish Subcommittee of PSARC concluded that the recent decline in CPUE may be an indication that annual landings of approximately 1500 t represent the maximum sustained yield for this stock (Fargo 1995). This conclusion was based on the declining trend in the ratio of means CPUE estimator shown in Fig. 4.5c (solid, thick line). The primary objective of this assessment is to investigate the decline in CPUE in light of the all available commercial CPUE data, survey data, and biological data.

The Dover sole (*Microstomus pacificus*) is a right-eyed flounder that inhabits the Pacific coast of North America from California to the Bering Sea (Hart 1973). It occupies mud-bottom and feeds primarily on benthic invertebrates. Abundance has been shown to decrease with increasing latitude (Westrheim et al. 1992). Significant commercial quantities of this species occur only between California and British Columbia. Results of U.S. adult tagging studies indicate that a number of individual stocks exist along the Pacific coast and that there is minimal intermingling of adults among stocks (Westrheim et al. 1992). This suggests that the area 3CD population is probably a discrete stock rather than a trans-boundary stock. Dover sole are vulnerable to the commercial trawl fishery at about six years of age, although they are not fully recruited until age 10 (Fargo and Workman 1995). Length of 50% sexual maturity, L_{50} , is 37.1 cm (4 y) for males and 39.5 cm (8 y) for females. Little north-south movement of adults has been observed, although they do undertake bathymetric migrations from shallow (70-100 fa) to deep (200-400 fa) water in the fall and winter for spawning (Westrheim et al. 1992). Adults spawn over a six month season (December-May) and spawning is size-age specific with larger, older fish spawning earlier than younger fish (Hunter et al. 1992). In contrast to the adults, the larvae of this species undergo a prolonged pelagic phase offshore that can last up to two years. Thus, the larvae of different stocks could intermingle extensively. The growth rate for this species is relatively slow (von Bertalanffy $k=0.12$ for males and 0.09 for females (Fargo and Workman 1995)). Estimates of maximum age range between 36-52 years among all stocks (Westrheim et al. 1992); maximum age for Area 3CD Dover sole estimated from biological samples collected to date is 49 years (Fargo and Workman 1995).

4.3.2.2. Area 3CD Management History

The management history for the Area 3CD Dover sole fishery is summarized in Table 4.4. The fishery was unregulated

prior to 1992. In 1992 a 20,000 lb (9 t) trip limit was regulated (but not invoked) after 70% of the quota was caught. Since 1992, variable trip limits less than 50,000 lbs (23 t) have been used to manage the fishery within quota guidelines. Table 4.4 also shows the recommended yield, the landings actually achieved, and their difference. During the period from 1988 to 1995, trips where less than 50,000 lb (23 t) of Dover sole were landed accounted for 60%-95% of the total landings from this area (Table 4.5). Because of management regulations, trips greater than 50,000 lb (23 t) were not permitted after 1993.

The effect of management regulations on catch per trip is shown in Fig. 4.6a. In general, the distribution of catch per trip is highly skewed towards large landings; less than 25% of the trips landed more than 5 t of Dover sole. The largest landings occurred from 1989 to 1991. A distinct truncation of the landings attributable to the 50,000 lb (23 t) trip limit is shown by the boxplots for 1993 through 1995. A small overage in the trip limit was allowed in the landings of Dover sole, accounting for some landings greater than 23 t in 1993 through 1995. The same data are shown in Fig. 4.6b with CPUE log_e transformed to reduce the skewness. The solid line indicates the mean CPUE by year. There is no evidence of a trend in the catch per trip between 1988 and 1995.

4.3.2.3. Area 3CD Commercial Catch and Effort Data

Commercial catch and effort data have been the basis for assessments of Area 3CD Dover sole in the absence of a time series of biological data adequate for catch-at-age or length-based models (see, for example, Fargo 1995). Abundance surveys were conducted only in 1981 and 1995. In view of the paucity of alternative data sources, fishery managers and assessment biologists have relied on commercial CPUE data to indicate stock status; other investigators (Walters and Hillborn 1992, Richards and Schnute 1986) have advised caution in the use of CPUE as an indicator of stock abundance.

Annual catch and effort statistics for Area 3CD Dover sole are presented in Table 4.6, 4.7. The data used for examination were extracted from the groundfish database; individual observations corresponded to a fishing event defined by a unique depth range (20 fa) and fishing locality rather than tow by tow information. Tow by tow data are not available until 1991. Thus, post-1990 data were summarized by fishing event to provide comparable observations over the period from 1980 to 1995.

Landings of Area 3CD Dover sole first occurred in the early 1980s, however, annual tonnage did not exceed 400 t until 1988 and peaked at 2125 t in 1993 (Fig. 4.7a, Table 4.6). Note that two vessels with total catches of 369 t and 596 t were removed from the plot to enlarge the catch scale. This permits

closer examination of the region where most of the data are. Similarly, the time-series of effort increases from approximately 1660 h trawled in 1988 to over 7893 h trawled in 1995 (Fig 4.7b, Table 4.6). Again, one vessel with a total effort of 1072 h was removed from the panel to facilitate examination of the region where most of the data are. Vessel participation in the fishery has increased dramatically from less than 20 vessels in the period 1980 to 1987 to current levels of about 60 vessels (Fig. 4.7c). Correspondingly, the annual number of trips has also increased (Fig. 4.7d) as a result of greater participation in the fishery and due to the effect of trip limits beginning in 1993.

The data summarized in Fig. 4.7 and Table 4.6 demarcate two distinct periods in the exploitation history for area 3CD Dover sole: (1) 1980 to 1987, and (2) 1988 to 1995. The split is largely based on the relatively low levels of effort expended in the fishery during the earlier period. The increase in landings and vessel participation beginning in 1988 may be associated with increasing regulation of the trawl fishery in general. Some of the subsequent analyses are limited to the latter period because of the abrupt change in fishery characteristics.

4.3.2.4. Interaction between CPUE Estimates and Qualification in the Area 3CD Fishery

Figure 4.5. shows various CPUE series derived using four candidate estimators of CPUE at four levels of qualification ranging from 0 to 50 percent. The various methods of computing annual CPUE are described in Appendix 4.1. Qualification level, the proportion of the target species in the catch by weight, has been used in groundfish assessments in an attempt to identify fishing observations attributable to the "directed" fishery. Although 25 percent qualification has been used historically for area 3CD Dover sole, the choice of a qualification level is arbitrary.

A plot of cumulative Dover sole catch (scaled between 0 and 1) against qualification level (Figure 4.8.) shows no obvious inflection point that would suggest the level of the directed fishery. Inspection of the plot shows that about 0.15 of the catch is eliminated by a qualification level of 25 percent, while about 0.3 of the catch is removed using a 50 percent qualification level. One half of the catch is removed using a qualification level on the order of 70 percent. Thus, the area 3CD fishery for Dover sole is characterized by an extreme number of catch events in which Dover sole constitute a relatively small fraction by weight. A very high qualification level would be required to filter these "incidental" catch observations from the dataset. Because of the ambiguity in the choice of qualification level, we present CPUE series for several levels of qualification and look for differences. Other investigators have used an absolute criterion, eg. observations where the catch of a target species exceeds a specified weight (Richards 1988).

Inspection of Fig. 4.5 reveals that the ratio of means and mean of ratios estimators are at higher levels than the trimmed estimators (see Appendix 4.1) in the period from 1988 to 1995. This result is indicative of the extreme skewness of the observations during this period. For the case of 0% qualification (Fig. 4.5a), the removal of these outliers using a 10% or 50% trimmed mean of ratio estimator eliminates the downward trend in CPUE. However, very little qualification is required to produce a clear downward trend in the series for all four estimators (Fig. 4.5b). This phenomenon is exaggerated as the level of qualification increases (Fig. 4.5c,d).

The ratio of means estimator, shown as the long dash line, has been used historically to monitor Area 3CD Dover sole stock status. Inspection of the ratio of means estimates shows the declining trend in CPUE from approximately 0.313 t/h in 1989 at zero percent qualification to 0.234 t/h in 1995.

Estimates computed using the mean of ratios (equation 4.2, Appendix 4.1) are shown as a thin solid line. This estimator is more sensitive to extreme observations; the mean can be biased upwards by very few large catches. Although the trajectory is more erratic than for other CPUE estimators, the decline in CPUE from a estimate of 0.381 metric tonnes in 1989 can be seen.

The 50% trimmed mean (median) of ratios estimator (equation 4.3, Appendix 4.1) is shown as a short dash line. With the removal of each tail of the distribution, this series shows an increasing trend over the period from 1989 to 1995 for zero percent qualification. However, at positive qualification levels this CPUE series is in decline from 1989 to 1995.

One interpretation of Fig. 4.5a is that the recent decline in the CPUE series represents the effects of very few extreme catches; a more robust estimator of the series can be obtained by using a trimmed mean of ratios estimator. However, when qualification is used as a tactic to identify the directed component of the fishery, the conclusion is that CPUE is declining, rapidly in the case of 50% qualification, regardless of the form of the CPUE estimator. The rate of decline increases with increasing qualification level.

In summary, Fig. 4.5 demonstrates an interaction between qualification level and the form of the CPUE estimator. Other investigators (Quinn 1985, Richards and Schnute 1992) have examined the application of a variance stabilizing transformation coupled with mean and median estimators of CPUE. Pollock *et al.* (1994) examined the performance of CPUE estimators in the context of angler surveys. Their preferred estimator depends on the form of the angler survey, but they do recommend the use of trimmed mean of ratio estimators to achieve variance stabilization and robustness. We note that determining the best measure of CPUE in a given situation does not answer the question of whether the CPUE series is a reliable index of abundance.

Figure 4.9 shows a Trellis plot of Dover sole catch (t) as a function of effort (h trawled) given qualification level. A loess smooth of the relationship is shown as a solid line. For qualification levels less than about 40 percent, the relationship between catch and effort is negligible. For qualification levels greater than 40 percent there is a strong, positive, linear relationship. Note that all panels span approximately the same range of effort.

4.3.2.5. Area 3CD Fishery dynamics

Figure 4.7c demonstrated a dramatic increase in vessel participation for the area 3CD Dover sole fishery beginning in 1988. The behavior of individual vessels is examined on an annual basis in Fig. 4.10. Catch (Fig. 4.10a) and effort (Fig. 4.10b) per vessel have remained relatively constant since 1989, but at a level higher than in the period from 1980 to 1988. Trips per vessel (Fig. 4.10c) increased during 1993 to 1995 relative to earlier years, in part due to the imposition of trip limits. Figure 4.10d shows boxplots of the number of localities fished per vessel over time. Prior to 1991, the median number of localities fished ranged from 1-3. Since 1991, however, the number of localities fished per vessel shows an increase to the range 3-5. The increase may be attributable to (1) local depletion of Dover sole for some localities, (2) interaction with other target species, or (3) management effects.

In the period from 1987 to 1989, effort (h trawled) peaked during the summer months (June to July). In recent years (1990 to 1995) the intensity of the fishery has shifted to the first quarter of the year (March to April) by which time approximately 80 percent of the annual catch is landed. This is a response of the fleet to a target fishery for Dover sole.

Management area 23 yields the largest landings of Dover sole on an annual basis, but significant landings have been produced since 1988 from areas 24 and 25 (Table 4.8, Fig. 4.11). Figure 4.11 shows a Trellis plot of the relationship between catch and year given management area. The thin solid line in each panel represents \log_{10} annual landings of Dover sole (t). The mean landings from 1988 to 1995 is shown by the horizontal thick line within each panel. Landings are above average in recent years for all areas except 21, where a large decline in landings has occurred. This is probably related to the reduction in Pacific ocean perch quotas since 1991. Dover sole in this area were caught primarily as bycatch in that fishery.

Figure 4.12 shows annual landings ($\log_{10} t$) as a function of year given fishing locality. The strip label above each figure panel is a combination of major area, minor area, and fishing locality. For example, 32310 is major area 3, minor area 23, locality number 10. Area 23 is largely supported by landings from localities 10 and 13. The bulk of landings in area 24 are

due to catch taken in localities 6 and 7, while area 25 landings are for the most part from localities 1 and 2.

Between 1988 and 1995, the depth fished by vessels has increased (Fig. 4.13). This is presumably due to expansion of the fishery to the deeper depths (200-400 fa) where Dover sole are most abundant. Vessels have continued to fish deeper in each successive year beginning in 1992. Catches at depths greater than 400 fa may reflect the increasing emphasis of the fishery on thornyheads in recent years (Richards 1996). The loess trend line (solid line) within each panel of Fig. 4.13 reveals a seasonal pattern in the depth fished by vessels. Shallower depths are fished during the summer-fall months, while deeper depths are fished in the winter-spring months. This fishing pattern shows great stability for all years of data and is consistent with the life history for adult Dover sole (see Section 4.3.2.1).

4.3.2.6. Factors affecting CPUE for the Area 3CD Fishery

Catch per unit effort data for flatfish species contain more information and are more amenable for stock assessment analysis than that for many schooling species (Fargo and Tyler 1991). Each fishing event (catch by depth stratum and locality) can be associated with auxiliary data including vessel, gear, year, month, depth fished (fa), effort (h trawled) and catch by species (kg). Variability in catch per unit effort may be attributed to differences in the spatial/temporal pattern of fishing and changing technology. Assumptions regarding the distribution of fish over space and time must also be satisfied if CPUE is to serve as a reliable index of abundance. Various strategies have been suggested in the literature for adjusting CPUE in the presence of fishing fleet dynamics (eg. Gavaris 1980; Quinn 1985; Richards and Schnute 1986; Hilborn and Walters 1992). All methods rely on the removal of a systematic component from the observed CPUE series, often coupled with suitable transformation of the CPUE values in an attempt to satisfy normality assumptions. While we do not attempt to adjust the CPUE series in this assessment, this section provides exploratory analyses of the CPUE data for systematic relationships with auxiliary data.

The relationship between catch (t) and effort (h trawled) given year is shown using the Trellis plot in Fig. 4.14. The catch data shown in this figure is 25 percent qualified. Where sufficient data are available, a positive, often linear, relationship is indicated by the loess trend lines (the solid line within each panel). Extremely high catches are associated with moderate to high levels of effort in 1989 through 1991. The effects of trip limits can be detected beginning in 1993, when very large catches are no longer observed.

The relationship between catch (t) and effort (h trawled) given depth interval and qualification level was examined using the three Trellis plots shown in Fig. 4.15. There were positive relationships between catch and effort for all but the shallowest depths fished at 0 percent qualification. The exception may be reflective of the actual target fishery for Dover sole as opposed to the incidental catches allowed using 0 percent qualification.

A seasonal trend in depth fished was demonstrated in Fig. 4.13. This pattern is consistent with the bathymetric migration of Dover sole to deeper waters in the fall-winter period for spawning. If the change in depth fished is an attempt by fishers to maintain CPUEs, we expect at least constant CPUE as a function of month and depth. Figure 4.16 shows Trellis plots of the relationship between \log_e CPUE (t/h) and month given depth for three levels of qualification. A loess smooth of the trend appears as a solid line within each panel. Relatively high CPUEs are observed from December to May at all depth intervals with the exception of shallow depths at 0 percent qualification. Because of the extreme positive skewness of the CPUE distribution, the loess trend line shows little relationship between CPUE and month, ie. the effects of observations with high CPUE are overwhelmed by the majority of very small CPUE values.

Between 1988 and 1995, two depth modes for the fishery were apparent (Fig. 4.17). Over all fishing areas, the relationship between CPUE and depth fished shows little evidence of a trend for any year, again due to the extreme skewness of the CPUE distribution.

The minor management areas show the same general decline in \log_e CPUE over time (Fig. 4.18) as the aggregate data (Fig. 4.5). One management tactic might be to restrict fishing effort in highly productive areas to remain within quota guidelines for Dover sole, but allow harvest of other species. Similarly, indexing sites could be established for the different minor management areas to produce a more consistent CPUE series for the assessment of this stock.

4.3.2.7. Area 3CD Survey CPUE Data

Fishery-independent CPUE data are available from two research surveys conducted in Area 3CD in 1981 and 1995 (Fargo and Workman 1995). Although the stations occupied on each survey were similar, there were differences in vessels, skippers, and the fishing gear used. Comparable estimates of CPUE were computed by unit area (nm^2) to adjust for the differences in effective area swept. The mean CPUE by depth strata (100 fa intervals over 100-400 fa) and stratified mean and associated statistics are presented in Table 4.9. There was no measurable change in the stratified means for the two surveys, however, there were significant differences in CPUE among depth strata on

both surveys (Kruskal-Wallis test, $p < 0.0001$, Fargo and Workman 1995). Catch per unit effort was highest in the 200-299 fa interval for the 1981 survey and between 300-399 fa for the 1995 survey. These depth-dependent differences could be due to the variable spawning season of Dover sole rather than to differences in abundance between the two surveys (Fargo and Workman 1995).

4.3.2.8. Area 3CD Survey Biological Data

Most biological data for this stock results from the surveys conducted in 1981 and 1995; few biological measurements have been obtained from the commercial fishery. Fargo and Workman (1995) reported significant differences in size and age among depth strata (Mann-Whitney test, $p < 0.0001$), thus, a comparison of the data across the two surveys should be restricted to similar depth strata. In 1981, sampling was restricted to the 200-299 fa depth stratum so that similar stratification was applied to the 1995 survey data. Unfortunately, the resultant small sample size for the 1995 data precluded a valid comparison for male Dover sole.

In lieu of depth stratification, we applied the following logic: if the fishery effect on the stock has been significant between the surveys, then older fish should be under-represented in the 1995 samples. We deliberately biased the comparison against a fishery effect by including age data collected from all depth strata for males sampled on the 1995 survey. The comparison, shown in Fig. 4.19, shows that younger animals (age class 6-12) dominate the age distribution in 1995 with a relative lack of animals older than age class 12 in 1995. The percentage of males age class 10 and younger in 1981 was about 10% compared with almost 60% in 1995.

A similar analysis for the age distribution of females is shown in Fig. 4.20. In this case, a number of animals older than age class 32 are evident in 1995 that were not observed in 1981. However, these animals were trawled at depths greater than 299 fa.

This shift in the age and size structure of the stock could result from differences in recruitment between the 1981 and 1995 surveys, differences in the timing of spawning between the two surveys, fishery effects, or some combination of these factors.

4.3.2.9. Area 3CD Dover sole abundance

Important findings from the analysis of the area 3CD Dover sole data include the following:

- (1) estimated CPUE series show a decline since 1988 for the mean of ratios and ratio of means estimators regardless of qualification level;

- (2) estimates computed from the trimmed ratio of means estimator show a stable series since 1988 only for the 0 percent qualification level; the CPUE series are in decline for qualification levels above 15 percent;
- (3) participation has increased threefold to about 60 vessels in recent years from about 20 vessels prior to 1988;
- (4) the number of fishing localities visited per vessel has approximately doubled in recent years;
- (5) there is little evidence that adjusting the CPUE series for differences in time, depth and area will be beneficial;
- (6) significant differences in size and age distribution of the stock have occurred between 1981 and 1995.

Changes in size and age composition may be due to differences in the rate of recruitment between the two time periods, differences in spawning timing between the two survey periods, a fishery effect or some combination of these factors.

There are several possible scenarios for the stock based on the analysis. Recent work by Hunter et al. (1992) on the reproductive biology of Dover sole suggest that changes in spawning timing would probably not produce a major shift in the size/age composition of samples collected on the spawning ground unless the samples were collected months apart during the spawning season. In fact, the two surveys were conducted at close to the same period during the spawning season, February (1995) and February-March (1981).

In an effort to examine possible changes in recruitment over time, recruitment series were examined for U.S. stocks of Dover sole adjacent to Canadian waters. Recruitment for U.S. stocks of Dover sole has been declining irregularly since 1981 (Turnock et al. 1995). This is not consistent with the changes observed in age structure for the Area 3CD stock between 1981 and 1995. If recruitment for Area 3CD Dover sole was higher in 1981 than in 1995, then we expect proportionately more smaller, younger fish in the 1981 samples. In fact, the opposite was true.

If recruitment is in decline for the stock, then changes observed in age structure for the stock are consistent with the decline observed in the commercial CPUE index. However, there was no measurable difference in survey catch rates between the 1981 and 1995 surveys. Inspection of the stratified biomass estimates shows that it is unlikely any difference in CPUE between the two surveys could be detected. The fact that the 1981 and 1995 surveys are 15 years apart, and the lack of an intervening time series of survey catch rate estimates, means that the utility of the survey estimates as a relative index is poor.

Although the commercial CPUE has declined since 1989, part of that decline is attributable to regulations imposed on the fishery beginning in 1993. Prior to 1993, the commercial index had declined by approximately 30 percent. If this index is proportional to stock abundance, then a reduction in removals is necessary to arrest the recent trend in CPUE.

4.3.2.10. Recommendations and yield options

Recommendations based on the analyses performed in this assessment include:

- (1) Bio-sampling from the commercial fishery must be increased to improve the reliability of recruitment and mortality estimates for the stock.
- (2) Completion of age determinations of samples obtained from the 1995 survey, particularly from the 200-299 fa depth interval, will provide better comparison between size/age between the two surveys.
- 3) A set of index sites to be occupied seasonally by commercial trawlers may provide a better index of stock abundance in the face of increasing fishery regulation. Index sites could also provide information for monitoring the effect of regulations.

Low-risk yield option:

A yield of 1000 t, appears sustainable based on the trend in commercial CPUE between 1988 and 1990.

High-risk yield option:

Yields in excess of 1500 t observed from 1991 to 1995 are associated with a decline in the commercial CPUE index and a coincident increase in both effort and vessel participation. Continued removals at current levels may constitute a risk of overfishing the stock.

4.4. QUEEN CHARLOTTE SOUND (AREAS 5A and 5B)

4.4.1. Rock Sole

4.4.1.1. General Introduction

The rock sole (*Lepidopsetta bilineata*) is a minor component of the shelf, on-bottom trawl fishery in Queen

Charlotte Sound and Hecate Strait. Four discrete stocks have been identified based on results from numerous tagging experiments (Ketchen 1982, Fargo and Westrheim 1987). Landings of rock sole are coincidental with landings of lingcod (*Ophiodon elongatus*) and Pacific cod (*Gadus macrocephalus*) in Queen Charlotte Sound. Yield is dependent upon recruitment which has been highly variable over time (Fargo 1995). Rock sole recruit to the fishery at age 4 but recruitment is not knife-edged. Length of 50% maturity, L_{50} , is 32.4 cm (5 y) for females and 27.6 cm (4 y) for males. Managers have used a coastwide trip limit as a catch limitation measure for this species. This interim assessment of the Area 5A and 5B stocks is based on catch-effort data and size composition data collected from the commercial fishery.

The fishery in areas 5A and 5B was unregulated prior to 1986. During the period from 1986 to 1992 a 30,000 lb trip limit was regulated followed by a 20,000 lb trip limit in 1993. Various trip limits less than 20,000 lb were used by managers in recent years. For 1996, quotas have been specified by thirds (4 months each).

4.4.1.2. Area 5A Landing Statistics

Landing statistics for rock sole from the 5A trawl fishery are presented in Fig. 4.21 and Table 4.10. These landings include contributions from the U.S. fishery prior to 1978. Statistics are calculated directly from data observations corresponding to a discrete fishing event by gear, area and depth range (20 fa). Total catch (t), total effort (h trawled), and the number of Canadian vessels participating in the fishery are plotted against year in panels (a-c) of Fig. 4.21. U.S. landings from this area were prohibited after 1977 when Canada declared extended offshore jurisdiction. Fluctuations in the time series are approximately coincident, with a substantial increase in each series beginning in 1990. The increase was largely precipitated by a doubling of the number of vessels participating in the fishery in the period from 1990 to 1995. This may be partly an artifact of the small level for trip limits for other species of groundfish forcing vessels to fish more species to obtain a trip with significant economic value. Landings of rock sole in Area 5A decreased to 212 t in 1995 from 311 t in 1994. Effort decreased to 939 h in 1995 from 1399 h in 1994.

Annual CPUE (t/hr) series corresponding to various estimators (Appendix 4.1) are shown for 0 percent qualification in Fig. 4.22a and 25 percent qualification in Fig. 4.22b. At 0 percent qualification, the CPUE trajectories show good agreement regardless of the choice of estimator. However, the removal of fishing events falling below the 25 percent qualification level increases the variability of each CPUE series, in particular those computed using the mean of ratios estimator and 10 percent trimmed mean estimator (Appendix 4.2). All CPUE series show a

decline since 1992 regardless of estimation method and qualification level. The decline is not extraordinary in the context of historical fluctuations in CPUE for this stock.

The increased variability of the CPUE series at 25 percent qualification can be attributed to the strong relationship between catch and effort for area 5A rock sole (Fig. 4.23). At qualification levels less than approximately 10 percent there is little relationship; these events are associated with relatively low catches. However, a strong, approximately linear relationship between catch and effort emerges for qualification levels greater than 10 percent. Note the near absence of observations with low catch at high effort levels.

The distribution of catch events within each year is summarized by boxplots in Fig. 4.24a. The mean trend is shown by the solid thick line. The horizontal dotted lines are placed at the 20,000 lb and 30,000 lb trip limits. In years prior to the implementation of management actions, few catch events would be affected using these limits. The corresponding effort distributions are summarized in Fig. 4.24b.

Previous assessments of area 5A rock sole used a CPUE series standardized for year and vessel horsepower (Fargo 1995). The horsepower of vessels in the fishery increased by a factor of two in the early 1970's (Fig. 4.24c) but there appears to be little relationship between CPUE and horsepower over time (Fig. 4.25). The Trellis plot in Fig. 4.25 shows \log_e CPUE as a function of vessel horsepower given year. In general, the loess trend line shows little evidence of a relationship between CPUE and horsepower. Furthermore, there is little evidence of an interaction between horsepower and year since the trend line occurs at about the same CPUE in each year (if CPUE increased with horsepower, we would expect the CPUE to be higher in the period after about 1970). Possible explanations for the lack of the relationship between CPUE and vessel horsepower is that (1) larger vessels lack the maneuverability to set nets efficiently in the rather limited rock sole habitat in area 5A. (2) rock sole may be fished to try to "fill out" a trip primarily directed at rockfish spp. employing rockfish gear which is less efficient at catching flatfish species.

For this assessment the median CPUE for 25 percent qualified landings has been adopted as the CPUE index for the commercial fishery. The annual catch (t) series and annual effort (h) series corresponding to this index are plotted in Fig. 4.26a. Fluctuations in these two series are remarkably coincident. The median CPUE and the CPUE index adjusted for changes in vessel horsepower over time are plotted in Fig. 4.26b. The latter index has been replaced by the median 25% qualified index (see Section 4.0.1) and is included for comparison only.

4.4.1.3. Area 5A Fishery Dynamics

Catch as a function of year given fishing locality is shown in Fig. 4.27. Minor Area 11, locality 2 dominates the landings followed by localities 3 and 4. Other localities provide only minor contributions to the total landings. The distribution of annual CPUE (ln t/h) for these localities is shown in Fig. 4.28. Qualified CPUE observations exhibit clustering at three periods; the late 1960's, late 1970's, and early 1990's. These periods correspond to peaks in the annual catch and effort series (Fig. 4.21a,b).

Seasonal fluctuations in the depth fished occur within a narrow interval (40-70 fa) over all years (Fig. 4.29). The loess trend line in each panel provides some evidence that shallower depths are fished in the summer months.

4.4.1.4. Area 5A Recruitment

Since 1987, recruitment has increased for all rock sole stocks on the B.C. coast, although the increase has not been as dramatic for the stocks in Queen Charlotte Sound as it has for those in Hecate Strait (Fargo 1994). Recruitment overfishing has not been demonstrated for any of these stocks in studies to date despite their long (50 years) exploitation histories. The decline in CPUE in Area 5A since 1992 may be a result of the diminishing contribution to the fishery of the strong year-classes produced in the late 1980s and early 1990s.

In the absence of age composition data, size composition data has been used to track recruitment of B.C. flatfish species. Although not amenable to length-based models due to a lack of distinct modes in the size distribution, time series of length frequency anomalies computed from these data have been used in the past to assess annual recruitment for various flatfish stocks (Ketchen and Forrester 1966, Forrester and Thomson 1969, Fargo 1991). We have used anomaly plots to provide a qualitative assessment of possible recruitment patterns. The anomaly series in Fig. 4.30 show the deviation from the long term mean in the numbers of female fish at each centimetre length interval for annual samples. Data for male rock sole was not used due to small sample sizes; males are of smaller size than females and are underrepresented in the fishery samples. The long term mean proportion at length is computed from a weighted sum of the annual proportions at length, where the weighting is proportional to the size of each sample. The positive areas represent higher than average numbers-at-length while the shaded areas represent lower than average numbers. The shift of a positive anomaly to the right over time is interpreted as the passage of a strong year-class through the fishery. The peaks in the catch series (Fig. 4.21a) roughly correspond with increases in recruitment indicated by the anomaly plots for this

stock. The magnitude of the deviations are not comparable across years since the actual abundance is unknown.

The recruitment of strong year-classes for this stock is observed in the anomalies from the mid-late 1950s, mid-late 1960s, and less clearly in the mid 1970s. In more recent years, recruitment appears to have been below average, although caution is required in interpreting the deviations due to the small size ($n < 50$ fish) of the samples. Recruitment events interpreted from the anomaly plots for this stock coincide with those for rock sole in other areas (Fargo 1995). These recruitment events also coincide with the peaks in both the catch and effort time series (Fig. 4.21a,b)

4.4.1.5. Area 5A Recommendations and Yield Options

Interpretation of the catch-effort data for area 5A rock sole is complicated by the fact that this stock is a minor component of the Area 5A multispecies trawl fishery. In addition, indications of overfishing could be masked by the target preferences of the fleet, regulations, and market preferences. Future analyses should attempt to resolve these problems through multi-species analysis of the Area 5A fishery. In addition, the age composition time series for this stock should be updated to provide more reliable estimates of recruitment, stock abundance, and yield for this stock.

Although there is no single indicator that shows any long term trend, all CPUE series for area 5A rock sole have been in decline since 1992. This recent decline is coincident with a marked increase in the numbers of vessels participating in this fishery. Our interpretation of the length anomalies indicate that recruitment in the most recent years may be below average. If so, yield for this stock is expected to decrease. In aggregate, these results suggest that the current removals from the stock are not sustainable. We note that trip limits applied to this stock in the past have not been effective in restricting catch and effort.

Yield options for 1996 remain the same as those for 1995.

Pre-cautionary yield option:

A yield of 250 t, equivalent to the low-risk yield for last year's assessment, appears to be sustainable.

High risk yield option:

Yields greater than 500 t, the maximum for the 1954-95 period (Table 4.10) would constitute a greater risk to the stock.

4.4.1.6. Area 5B Landing Statistics

Landing statistics for rock sole from the 5B trawl fishery are presented in and Figure 4.31 and Table 4.11. Statistics are calculated directly from data observations corresponding to a discrete fishing event by vessel, gear, area and 20 fa depth interval. Total catch (t), total effort (h trawled), and the number of Canadian vessels participating in the fishery are plotted against year in panels (a-c) of Fig. 4.31. U.S. landings from this area were prohibited after 1977 when Canada declared extended offshore jurisdiction. As was the case for the Area 5A stock, fluctuations in the area 5B time series are approximately coincident, with a substantial increase in each series beginning in the late 1980's. The increase was largely precipitated by a doubling of the number of vessels participating in the fishery during recent years. This may be partly an artifact of the small level for trip limits for other species of groundfish forcing vessels to fish more species to obtain a trip with significant economic value. Landings in 1995 were 252 t, down from 323 t in 1994. Effort in 1994 was 848 h down from 1023 h in 1994. This may be the result of the fourth quarter closure of the trawl fishery in 1995.

Annual CPUE (t/hr) series corresponding to various estimators (Appendix 4.1) are shown for 0 percent qualification in Fig. 4.32a and 25 percent qualification in Fig. 4.32b. At 0 percent qualification, the CPUE trajectories show good agreement regardless of the choice of estimator. However, the removal of fishing events falling below the 25 percent qualification level increases the variability of each CPUE series, in particular those computed using the mean of ratios estimator and 10 percent trimmed mean of ratios estimator (Appendix 4.2). All CPUE series show a decline since 1991 regardless of estimation method and qualification level. This decline has reached historical lows in CPUE for the 25 percent qualified series, and is among the historic lows for the 0 percent qualified data.

The increased variability of the CPUE series at 25 percent qualification can be attributed to the strong relationship between catch and effort for area 5B rock sole (Fig. 4.33). At qualification levels less than approximately 10 percent there is little relationship; these events are associated with relatively low catches. However, a strong, approximately linear relationship between catch and effort emerges for qualification levels greater than 10 percent. Note the near absence of observations with low catch at high effort levels.

The distribution of catch events within each year is summarized by boxplots in Fig. 4.34a. The mean trend is shown by the solid thick line. The horizontal dotted lines are placed at the 20,000 lb and 30,000 lb trip limits. In years prior to the implementation of management actions, few catch events would be affected using these limits. The corresponding effort distributions are summarized in Fig. 4.34b.

Previous assessments of area 5B rock sole used a CPUE series standardized for year and vessel horsepower (Fargo 1995). The horsepower of vessels in the fishery increased by a factor of two in the early 1970's (Fig. 4.34c) but there appears to be little relationship between CPUE and horsepower over time (Fig. 4.35). There is a marked decrease in vessel horsepower in the early 1980's, perhaps explained by other species becoming more attractive to fishers during this period. With this exception, the trend in horsepower over time is similar to that in area 5A. The Trellis plot in Fig. 4.35 shows \log_e CPUE as a function of vessel horsepower given year. In general, the loess trend line shows little evidence of a relationship between CPUE and horsepower. Furthermore, there is little evidence of an interaction between horsepower and year since the trend line occurs at about the same CPUE in each year (if CPUE increased with horsepower, we would expect the CPUE to be higher in the period after about 1970). Possible explanations for the lack of the relationship between CPUE and vessel horsepower is that (1) larger vessels lack the maneuverability to tow nets efficiently in the rather limited rock sole habitat in area 5B. (2) rock sole may be fished to try to "fill out" a trip primarily directed at rockfish spp. employing gear which is less efficient at catching flatfish species.

For this assessment the median CPUE for 25 percent qualified landings has been adopted as the index for the commercial fishery. The annual catch (t) series and annual effort (h) series corresponding to this index are plotted in Fig. 4.36a,b. The two series are remarkably coincident. The median CPUE and the CPUE index adjusted for changes in vessel horsepower over time are plotted in Fig. 4.36c. The latter index is included for comparison only; the approach has been abandoned because of the lack of significance between vessel horsepower and CPUE. Trimmed estimators are a more appropriate measure of central tendency for the skewed distributions commonly encountered in fisheries catch-effort data (Richards and Schnute 1992).

4.4.1.7. Area 5B Fishery Dynamics

Catch as a function of year given fishing locality is shown in Fig. 4.37. Localities 2 and 4 in Minor Area 8 dominate the landings, followed by landings from localities 1 and 3. Landings from the latter locality have declined in the 1990's. Other localities provide negligible contributions to the total landings. The distributions of annual CPUE ($\ln t/h$) for the dominant localities are shown in Fig. 4.38. Qualified CPUE observations are clustered in the late 1960's, early 1980's, and early 1990's. These periods correspond with peaks in the annual catch and effort series (Fig. 4.31a,b), although the peaks are less well defined than for area 5A.

Seasonal fluctuations in the depth fished occur within a narrow interval (50-80 fa) over all years (Fig. 4.39). The loess trend line in each panel provides some evidence that deeper depths are fished in the summer months in recent years.

4.4.1.8. Area 5B Recruitment

Since 1987, recruitment has increased for all rock sole stocks on the B.C. coast, although the increase has not been as dramatic for the stocks in Queen Charlotte Sound as it has for those in Hecate Strait (Fargo 1994). Recruitment overfishing has not been demonstrated for any of these stocks in studies to date even though they have long (50 years) exploitation histories. The decline in CPUE since 1991 may be a result of the diminishing contribution to the fishery of the strong year-classes produced in the late 1980s.

In the absence of age composition data size composition data has been used in the past to track recruitment of B.C. flatfish species (Ketchen and Forrester 1966, Forrester and Thomson 1969, Fargo 1991). The length frequency data are not amenable to size-based models because of the lack of definite length modes. Anomalies were computed for the 5B stock using the same method as was used for the 5A stock (See Section 4.4.4.4).

The recruitment of strong year-classes for this stock is observed in the anomalies from length frequency data for females only from the mid-late 1950s, mid-late 1960s and, although less clearly, the mid 1970s (Figure 4.40). In the early to mid 1980s, recruitment was below the long term mean, but increased in the late 1980s and early 1990s. The plot for 1994 indicates that recruitment is declining though interpretation of the plots for recent years is hampered by the small sample size ($n < 50$ fish). Recruitment events interpreted from the anomaly plot for this stock roughly coincide with those for rock sole in other areas (Fargo 1995). Unlike the case in area 5A, recruitment events for the 5B stock do not correlate well with the peaks in the catch and effort time series.

4.4.1.9. Area 5B Recommendations and Yield Options

The catch-effort data is complicated by the fact that this stock is a minor component of the Area 5B trawl fishery. Future analyses should be directed at a thorough multi-species analysis of the Area 5B fishery. In addition, age composition time series for this stock should be updated so that more reliable estimation methods for recruitment, stock abundance, and yield can be applied to this stock.

Although there is no single indicator that shows any longterm trend, all CPUE indicators for this stock have been in decline since 1991. The coincident increase in the numbers of

vessels and effort in this fishery distinguishes the current decline from those observed previously in the series. Interpretation of the length anomalies indicate that recruitment in the most recent years is declining. In aggregate, we expect that yield for area 5B rock sole will decrease. Furthermore, the current level of effort may increase the likelihood of overfishing the stock. In addition, the trip limit used for regulation in the past appears to have done little to restrict catch and effort for this stock.

The high-risk option for the 1997 fishery has been lowered to 400 t due to the low recruitment scenario for the stock.

Pre-cautionary yield option:

A yield of 250 t, is considered to be sustainable with low risk to the area 5B stock.

High risk yield option:

Based on declining trends in CPUE over time (Table 4.11) yields greater than 400 t, constitute a risk to the area 5B stock especially when recruitment is declining as it appears to be from this analysis.

4.5.1. Rock Sole -- Hecate Strait

4.5.1.1. Introduction

Stock delineation studies conducted by Ketchen (1982) and Fargo and Westrheim (1987) indicate that there are at least two stocks of rock sole in Hecate Strait. However, these stocks are treated as a single unit for this assessment. Past work has suggested that both density-dependent and density-independent factors regulate abundance for this species (Fargo and McKinnell 1989). Low production has been associated with low spawning biomass. Ocean temperature regime is also an important determinant of year-class production (Forrester and Thomson 1969, Fargo and McKinnell 1989). Recruitment has fluctuated greatly over time and the last significant increase occurred during the early 1990s and is now subsiding. Landing statistics have been updated with data from the 1995 fishery. The age composition data series has been updated with data for 1995. Catch-age analysis is the basis for this assessment.

4.5.1.2. Landing statistics

Landing statistics from the Hecate Strait trawl fishery are presented in Table 4.12 and Figure 4.41. Annual catch

statistics for the 1954-95 period are calculated directly from data observations. No detailed records exist for the pre-1954 data and historical catch indices were used (Fargo 1995). For this assessment the median CPUE for 25% qualified landings has been estimated for the commercial fishery. The GLM CPUE series used for previous assessments is also presented for comparison with the new index (See Section 4.0.1 for explanation). Fishing effort has estimated directly as the total (summed) effort for 25% qualified landings.

Landings decreased in 1995 to 1294 t from 1384 t in 1994 while effort decreased to 3538 h from 4282 h. Effort is still among the highest on record. The fourth quarter closure of the trawl fishery in 1995 is likely responsible for some of the decline in landings and effort in 1995. Median CPUE increased to 0.322 t/h in 1995 from 0.275 t/h in 1994 but is currently below the long term average. Since the early 1980s there is little contrast in the commercial CPUE series although stock abundance has fluctuated dramatically (Fargo 1995). One reason for this is the increasing regulation of the B.C. groundfish fishery. Area-specific trip limits have doubtlessly influenced the commercial CPUE index and for the most recent years it has failed to track changes in abundance altogether (Fargo 1995).

4.5.1.3. Catch-age Analysis

The age composition time series for this species was updated with age determinations for samples collected during the 1995 commercial trawl fishery. The series covers the period 1945-95 and includes a range of ages from 3 to 21 (Figure 4.42). The range of ages used for catch-age analysis was 4 to 12 with the last age group representing fish aged 12 years or older (12+). Three year olds are not fully recruited and older fish were grouped together because of the bias in surface readings (early years) compared to determinations made from burnt cross-sections (later years). The entire range of years was analysed.

The state space model of Schnute and Richards (1995) was used for the catch-age analysis (see Appendix A in the slope rockfish assessment document (Richards and Olsen 1996)). This model differs from the catch-age model used for the last two assessments (Fournier and Archibald 1982) in the specification of model error structure. Parameters in the model likelihood of the include standard deviations σ_1 , τ_1 , and τ_2 corresponding to the error in the recruitment, biomass index and proportions-at-age. The variance ratio $\rho = \sigma_1^2 / (\sigma_1^2 + \tau_1^2)$ relates process error in the recruitment series to measurement error. This ratio is specified in the likelihood calculation, analogous to emphasis factors in the stock synthesis model of Methot (1989,1990).

Input data for the model included landed catch, proportions at age in the catch, weight at age and CPUE estimates

for rock sole from the Hecate Strait surveys conducted between 1984 and 1995. For this year's assessment the model was tuned with the survey CPUE index for rock sole. Problems with the commercial index are discussed in Section 4.5.1.2.

Because the variance ratio, ρ , must be specified we first explored the sensitivity of the model biomass estimates to different choices for ρ . For the first model run, model a, the error in the recruitment index was assumed to be the dominant source of model variability ($\rho=0.9$). An alternate model run, model b, was done with the assumption that the variability in the recruitment index was equal to that in the survey CPUE index ($\rho=0.5$). The instantaneous rate of natural mortality, M , was assumed to be constant at 0.25 for all runs as in last year's assessment. This value falls within the range of estimates reported in previous assessments (Fargo 1995). The model also assumes a time-invariant fishery selectivity which increases asymptotically to 1 for the final age-group. Results from both model runs are presented in Table 4.13.

Residuals from the two models were examined for indications of problems with the model fit. The pattern of residuals was similar for both models and we have used those from model a to illustrate the model fit. There was no trend in the residuals for any of the years with respect to age (Figure 4.43). Similarly, there was no trend in the residuals for any of the age groups with respect to time (Figure 4.44). The model fit was poorest (largest residuals) for the 1960 to 1980 period and the younger, 4-6, age groups (Figure 4.45). As well, there were negative residuals for the 12+ age group for nearly all years.

The biomass trajectories for the two models in this year's assessments and that from the model used in last year's assessment are presented in Figure 4.46. Results from all models indicate that exploitable biomass for this stock increased dramatically in the late 1980s and has been decreasing since 1990. Recruitment has been declining since 1990 as well (Table 4.13) (Fargo 1995). The decline in recruitment appears to be due to environmental influence (Fargo 1995). The estimate of exploitable biomass in 1994 from last year's assessment was 5522 t while the estimates for 1994 from models a and b were 7707 t and 6355 t respectively. Exploitable biomass in 1995 for both models from this year's analysis is approximately 75% of that in 1991 while recruitment in 1995 is approximately 42% of that in 1991. The estimate of exploitable biomass in 1995, B_{95} , from model a was 6670t (2846t, 10494t) for the 95% confidence interval (Table 4.13). The comparable figures for 1995 from model b were: 5963t (3175t, 8751t) for B_{95} .

Estimates of fishing mortality in 1995 for models a and b were 0.26, 0.21, respectively. Some of the reference points of fishing mortality used for stock assessment by others are: $F_{0.1}$ (Anthony 1982), $F_{35\%}$ (Clark 1991) and F_{med} . Estimates of these points for rock in Hecate Strait are 0.25, 0.27 and 0.21, respectively. $F_{0.1}$ and $F_{35\%}$ are points on the yield per recruit

and spawning biomass per recruit curves, respectively. F_{med} is the fishing rate on an equilibrium population with a spawner per recruit ratio equal to the inverse of the median observed ratio of recruits to spawners. The latter reference point has been suggested by the ICES Comprehensive Fishery Evaluation Working Group as an alternative to F_{max} for ICES stock assessment work.

4.5.1.4. Survey catch-rate index

Biannual trawl surveys for indexing the abundance of marine fish species in Hecate Strait have been conducted since 1984. The design of the survey is based on an allocation of fixed stations for each 10 fa depth interval and has not changed over time. The 1996 survey was conducted in an 'off' year at the request of industry. Mean CPUE and the associated 90 percent confidence interval were estimated for the exploitable proportion of the rock sole catch (fish ≥ 35 cm) for each survey. Between 1984 and 1989 mean CPUE increased from 14.8 kg/h to 52.2 kg/h (Figure 4.47). It then declined to 37.3 kg/h between 1989 and 1996. The rate of decline in mean CPUE since 1989 does not appear to be as dramatic as that indicated in last year's assessment. Because of the large amount of uncertainty in the survey index, the trend in mean CPUE can only be interpreted over a period of several surveys rather than on a survey to survey basis.

4.5.1.5. Yield Options

The results of the catch-age analysis indicate a decline in the contribution of the strong year-classes which recruited in the late 1980s. CPUE from the commercial fishery and independent trawl surveys conducted in Hecate Strait both show a decline over this period although fishing regulations have doubtlessly biased the commercial index. As well, the El Nino event along the B.C. coast in 1994-95 should produce unfavourable conditions for year-class production for Hecate Strait rock sole (Fargo and McKinnell 1989). Thus, yield from this stock should continue to decrease over the next 2-3 years. The 1996 trawl survey suggests that abundance is not dropping as dramatically as thought in last year's assessment.

The yield options for 1997 have been increased from those in 1996. The discrepancy between yield options in last year's and this year's assessments was due mainly to differences in the use of the survey data. For last year's assessment the biomass estimate in 1994, B_{94} , from catch-age analysis was multiplied by the ratio of survey CPUE in 1995 to that in 1993 to produce an estimate of biomass for 1995 that was 76% lower than the lowest catch-age analysis estimate for 1995 biomass for this year's assessment. However, as a precautionary strategy this year, the estimate of biomass from model a, the lower of the two

model estimates, was used to estimate yield. Yield was estimated using the 95% confidence interval for B_{95} , 5963 t (3175-8751t). The F_{med} yield associated with the 25th percentile of the confidence region for B_{95} , 4042 t, is 766 t. The F_{med} yield corresponding to the 50th percentile of the confidence region for B_{95} , 5963 t, is 1129 t. Note that F_{med} is the most conservative of all the F reference points for this stock.

Low risk yield option:

A yield of 800 t, is the low-risk sustainable option for these stocks.

High risk yield option:

A yield of 1100 t, is the high-risk sustainable option for these stocks.

4.5.2. English Sole -- Hecate Strait

4.5.2.1. Introduction

Stock delineation studies conducted by Ketchen (1956) and Fargo et al. (1984) indicate that a single stock of English sole exists in Hecate Strait. The stock was probably near the pristine level in the 1940s, declined after large removals in the 1950s and has remained fairly stable since the late 1960s (Fargo 1995). There is evidence that both density dependent and density independent factors exert an influence on recruitment for this stock (Fargo 1994). Spawning stock biomass and Ekman transport during the egg and larval stages both influence year-class production. The stock has produced strong year-classes about once a decade with the latest increase in recruitment occurring in the early 1990s. Age of recruitment is 4 years for both males and females although recruitment is not knife-edged. Length of 50% maturity, L_{50} , is 25.5 cm (3 y) for males and 35.1 cm (4 y) for females (Foucher et al. 1989). The contribution of strong year-classes to the fishery usually lasts about 4-5 years. The series of annual landing statistics has been updated with results for the 1995 fishery. The age composition data series has been updated with data for 1995 as well. Catch-age analysis has been used to produce an estimate of the current stock biomass and fishing mortality sustained by the stock.

4.5.2.2. Landing statistics

Annual landing statistics are presented in Table 4.14 and Figure 4.48. Statistics from 1954-95 are calculated directly from data observations. No detailed records exist for the pre-1954 data and historical catch indices have been used (Fargo

1995). The median CPUE for 25% qualified landings has been used as an index for the commercial fishery. The GLM CPUE series used for previous assessments is also presented for comparison with the new index (See Section 4.0.1 for explanation). The median 25% qualified CPUE showed no trend over the last three years while the GLM CPUE increased slightly over that period. The median CPUE showed more contrast over time than the GLM CPUE. However the effect of management regulations embedded in both these statistics may prevent detection of real trends in the later years (1980-95). Fishing effort was estimated as the total (summed) annual effort for 25% qualified landings. Effort increased in the early 1990s and is currently above the longterm average.

English sole landings increased to 1190 t in 1995 from 1000 t in 1994 while effort increased to 2321 h from 1860 h over the same period. These increases occurred despite the fourth quarter closure of the trawl fishery in 1995. CPUE in 1995 decreased slightly to 0.320 t/h from 0.343 t/h in 1994. CPUE shows a declining trend since 1988 and is below the long term average, 0.363, for the 1944-95 period.

4.5.2.3. Catch-age Analysis

The age composition data series for this stock was updated with age determinations made from samples collected during the 1995 trawl fishery. The data series spans the period 1944-95 over an age range of 3 to 23 years (Figure 4.49). For the catch-age analysis, the full compliment of years was analysed with a range of ages of 4 to 12+. Three year olds are not fully recruited while the last age groups were combined because of the bias in age determinations made from otolith surface readings as compared to determinations made from burnt cross-sections (Figure 4.50).

The state space model of Schnute and Richards (1995) was used for the catch-age analysis (see Section 4.5.1.3 and Appendix A in (Richards and Olsen 1996)). Input data for the model included landed catch, proportions at age in the catch, weight at age and CPUE estimates for English sole from the Hecate Strait surveys conducted between 1984 and 1995. For last year's assessment the catch-age model was tuned with the commercial CPUE series rather than the survey CPUE series.

For the first model run, model a, the error in the recruitment index was assumed to be the dominant source of model variability ($\rho=0.9$). An alternate run, model b, was done with the assumption that the variability in the recruitment index was equal to that in the survey CPUE index ($\rho=0.5$). The instantaneous rate of natural mortality, M , was assumed to be constant at 0.25 for all runs as in last year's assessment. This value falls within the range of estimates reported in previous

assessments (Fargo 1995). The model also assumes a time-invariant fishery selectivity which increases asymptotically to 1 for the final age-group. Results from both model runs are presented in Table 4.13. Results from the two models are presented in Table 4.15.

Residuals from the two models were examined for indications of problems with the model fit. The pattern of the residuals was similar for both models and the residuals from model a are used for the discussion that follows. Residuals showed positive trends for the early years, 1944 to 1952 with respect to age (Figure 4.51) while residuals were for the period 1968-83 were cyclic with respect to age. This indicates that some systematic component in these data was not accounted for by the model for these years. There was, however no trend in the residuals for the later years, (1984-95) with respect to age.

The residuals showed no trend with respect to time for any of the age groups analysed except the 12+ group where there was a positive trend (Figure 4.52). This may reflect the difference in ageing technique (otolith surface) used for the early years or ageing error. The model fit was poorest for the early years and older age groups (Figure 4.53). There were large negative residuals for the age group 12+ for the early years and for the 9 to 11 age groups for the later years. There were large positive residuals for the age 8 to 10 groups for the earlier years and for the 4-5 age groups for the mid 1970s to the mid 1980s.

The patterns in the residuals from this analysis suggest that bias is present in the model estimates. In the future the data time series used for the analysis will be examined in more detail. If there are inconsistencies in the data series over time, the model cannot be expected to fit the data well. It may be possible to improve the overall model fit by dropping the early years from the analysis, where the fit was most problematic.

The biomass trajectory for the early years from this analysis differs markedly from that presented in last year's assessment (Figure 4.54). A discrepancy in the proportions-at-age for the early years was discovered. When this was corrected the estimate of pristine biomass for the stock was greatly reduced. The revised data contain more information than the previous data with the result that model residuals were considerably reduced. Although the biomass trajectory for the early years differed that for the later years is similar for all three models.

The estimate of exploitable biomass in 1994, B_{94} , from last year's assessment was 2482 t while the estimates for B_{94} for models a and b were 3522 t and 3740 t, respectively. The estimate of B_{95} from model a was 3151 t while the corresponding estimate from model b was 3177 t. Exploitable biomass for this

stock has been declining since 1993 while the level of recruitment has been declining since 1991 (Table 4.15). A slight declining trend in biomass is apparent over the period from the mid 1970s to the present as well. The smooth trends in recruitment over time are believed to result from ageing error \pm one year where the largest year-classes are displaced to the adjacent years.

Estimates of fishing mortality in 1995 for models a and b were 0.63 and 0.47, respectively. The reference points of fishing mortality for the stock for $F_{0.1}$ (Anthony 1982) $F_{35\%}$ (Clark 1991) and F_{med} , are 0.25, 0.28 and 0.19, respectively. $F_{0.1}$ and $F_{35\%}$ are points on the yield per recruit and spawning biomass per recruit curves, respectively. F_{med} is the fishing rate on an equilibrium population with a spawner per recruit ratio equal to the inverse of the median observed ratio of recruits to spawners. The latter reference point has been suggested by the ICES Comprehensive Fishery Evaluation Working Group as an alternative to F_{max} for ICES stock assessment work. The current high level of fishing mortality estimated for the stock is more than double most of the estimates of F associated with sustainable yield.

4.5.2.4. Survey catch-rate index

Biannual trawl surveys for indexing the abundance of marine fish species have been conducted in this region since 1984. Mean CPUE and the associated 90 percent confidence interval was estimated for the exploitable proportion of the English sole catch (fish \geq 35 cm) for each survey. Over this time period English sole survey CPUE increased from 27.7 kg/h in 1987 to 45.7 kg/h in 1993. It then declined to 29.7 kg/h in 1995 (Figure 4.55). Mean CPUE for the 1996 survey was slightly less than for the 1995 survey.

4.5.2.5. Yield Options

The same approach was used for estimation of yield for Hecate Strait English sole as that used for Hecate Strait rock sole. The survey index indicates that the level of exploitable biomass in 1996 is slightly lower than the level in 1995. Biomass declined significantly between 1944 and 1962 then slowly increased from 1963 to 1974 and has remained fairly stable since then. All indicators for this stock suggest a decline in abundance in recent years. Both the survey and commercial CPUE indices are declining in recent years while recruitment is also declining over the same period. Estimates of F for the stock from the catch-age analysis are very high as well. As a precautionary strategy the lower of the two model estimates of B_{95} , 3177 t (3588-2766t) has been used to estimate yield. The fishing rate of F_{med} , 0.19, was applied the 25th and 50th

percentiles of the confidence region for B_{95} to produce a range of yield of 500 t-600 t.

Low risk yield option:

A yield of 500t t, is the low-risk option.

High risk yield option:

A yield of 600 t, is the high-risk option.

4.5.3. Dover Sole

4.5.3.1. Introduction

The fishery for Dover sole in Areas 5C-E takes place in northern Hecate Strait at 50 to 80 fathom depths between May-October, and off the west coast of the Queen Charlotte Islands from December-April at 200 to 400 fathom depths. The seasonal shift in the fishery is related to the bathymetric migration for the species. The fishery off the west coast of the Queen Charlotte Islands takes place on a spawning population. Dover sole in this area recruit to the fishery at age 5 years of age but recruitment is not knife-edged. Length of 50% maturity, L_{50} , is 37.1 cm (6 y) for males and 39.5 cm (6-7 y) for females.

The Dover sole fishery in area 5C-E was unregulated prior to 1981. Beginning in 1981, annual quotas were applied: 300t from 1981 to 1984, 500 t from 1985 to 1990, 1000 t from 1991 to 1994, and 1100 t in 1995.

4.5.3.2. Area 5CDE Landing Statistics

Landing statistics for Dover sole from the Area 5C-E trawl fishery for 1970-94 are presented in Table 4.16. Statistics are computed directly from observations corresponding to a discrete fishing event by vessel, gear, area and depth range (20 fa). Total catch (t), total effort (h), and the number of vessels participating in the fishery are plotted in panels (a) to (c) of Fig. 4.56. Effort increased markedly in the late 1960s and again in the early 1990s. Coincident increases in catch ensued; a historical high catch of 1587 t was landed in 1995. The current level of effort is more than three times the long term mean for the 1970 to 1995 period.

Annual CPUE (t/h) series corresponding to various estimators (Appendix 4.1) are shown for 0 percent and 25 percent qualification levels in Fig. 4.57a,b. The trajectories show good

agreement, particularly since 1970. For the case of 0 percent qualification (Fig. 4.57a), the CPUE series show little trend over the period from 1985 to 1995. However, the CPUE series are in decline over the same period for 25 percent qualified observations (Figure 4.57b).

Figure 4.58 is a Trellis plot of catch (t) as a function of effort (h) given qualification level. A positive, linear trend in the catch-effort relationship is evident at qualification levels as low as about 10 percent.

The intra-annual catch distribution for fishing events is shown by the boxplots in Fig. 4.59a. The annual mean is shown as the thick, solid line within the panel. Note the reduction in variance of the catches in the 1990s. Similarly, plots for effort and horsepower are shown in Fig. 4.59b and 4.59c, respectively. Vessel horsepower increased markedly in the mid 1970s, approximately doubling over previous years. However, this increase in horsepower has had little effect on fishing power. Figure 4.60 shows \log_e transformed CPUE as a function of vessel horsepower given year. Years have been pooled to provide equal weighting of observations within each panel. During the first half of the time series there are few vessels exceeding 400 hp. Beginning in the mid-1970s, the introduction of vessels exceeding 600 hp to the fishery seems not to have increased fishing power (the loess trend line within each panel is horizontal). In the late 1970s there is some evidence of an increasing trend in CPUE that completely vanishes by the mid-1980s. Note that the level of CPUE has stayed at about the same level since the mid-1980s. We produced the same plot for 25 percent qualified data with similar results except that the level of the trend line was lower in top half of the plot (mid-1980s to 1995), a result consistent with the decline in CPUE shown by Fig. 4.57b.

For this assessment, the median of ratios CPUE for 25 percent qualified observations has been adopted as the CPUE index for the commercial fishery. The annual catch (t) and annual effort (h) series corresponding to this index are plotted in Fig. 4.61a. Peaks in the catch series correspond well with peaks in the effort series, a result consistent with the strong catch-effort relationship shown in Fig. 4.58. The median CPUE and the GLM CPUE index used for previous assessments are shown in Fig. 4.61b (See Section 4.0.1. for explanation).

4.5.3.3. Area 5CDE Fishery Dynamics

Figure 4.62 shows \log_e transformed catch as a function of year given fishing locality. The locality label within each given strip is a combination of major area, minor area and locality number, eg. 70201 is major area 7 (5D), minor area 02, locality 01. Localities 70204, 70601 and 70701 dominate the

catch in area 5C. Major contributions to the total landings are derived from localities 80401, 80402, 80405 over the history of the fishery. Locality 80501 has experienced steadily increasing levels of catch since 1970. The major removals from the area 5E have been fished from localities 93012 and 93502. For many localities in all areas, fishing has resumed in the 1990s after years of negligible or sporadic catches.

The relationship between CPUE (log_e transformed, 25 percent qualified) and year for selected localities is shown in Fig. 4.63. These localities provide major contributions to catch in their respective areas. A decline in the CPUE index is suggested by the loess trend line within each panel for localities in area 5D and localities 93102 and 93502. Insufficient qualified observations exist to define trends in area 5C.

Depth fished as a function of month given year is shown for areas 5C and 5D combined in Figure 4.64, and for area 5E in Figure 4.65. In the early years the fishery in Area 5CD took place at shallower depths (50-250 fa) off of Dundas Island and Two Peaks and Butterworth grounds. However, observations at depths deeper than 150 fa occur only for the later years. This may represent expansion of the fishery to new depths due to declining catch-rates in recent years. It may also represent bycatch in the rockfish fishery in the southern part of Hecate Strait. The fishery in Area 5E concentrates on 200-400 fa depths. This occurs mainly in the fall and winter months and this fishery has involved progressively more effort (number of observations) in the most recent years.

4.5.3.4. Area 5CDE Recommendations and Yield Options

A maximum sustained yield (MSY) range of 800-1000 t was estimated for this stock using surplus production analysis and the commercial catch-effort data for the period 1970 to 1994 (Fargo 1995). Results from a length-based simulation model (Fargo 1991) indicated that the MSY could be as high as 1200 t and this was set as the high-risk option for the stock. A marked increase in effort beginning in the late 1980s has produced a corresponding increase in catch. Landings for the period from 1993 to 1995 were the highest recorded for the area 5CDE Dover sole fishery. Catch per unit effort has been in decline in recent years for 25 percent qualified observations, regardless of the CPUE estimator (Fig. 4.57b).

The high-risk yield option was exceeded by 18 to 32 percent during 1993 to 1995. Current trends in catch, effort, and CPUE suggest that recent yields greater than 1200 t may lead to overfishing of this stock. Biological samples obtained from the commercial fishery should be processed and age determinations made for samples collected in recent years. The age structure of

the stock should be examined to determine the total mortality rate for the stock in light of the recent decline in CPUE.

Low risk yield option:

A yield of 800 t, equivalent to the MSY estimated using surplus production analysis.

High risk yield option:

A yield of 1200 t is suggested as an upper limit for the area 5CDE Dover sole stock.

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Table 4.1. Yield options for British Columbia flatfish species/stocks
1996-97

| Species | Area | 1996 | | 1997 | |
|--------------|-----------|-----------------------------------|-----------|----------|-----------|
| | | low risk | high risk | low risk | high risk |
| Petrale sole | | Coastwide incidental catches only | | | |
| Dover sole | Area 3C-D | 1300 t | 2000 t | 1000 t | 1500 t |
| | Area 5C-E | 800 t | 1200 t | 800 t | 1200 t |
| Rock sole | Area 5A | 250 t | 500 t | 250 t | 500 t |
| | Area 5B | 250 t | 600 t | 250 t | 400 t |
| | Area 5C-D | 350 t | 700 t | 800 t | 1100 t |
| English sole | Area 5CD | 300 t | 500 t | 500 t | 600 t |

Table 4.2. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock" 1942-95.

| Year | Flattery Spit | Area 3C north | Total Area 3C | Total Canadian | Year | Flattery Spit | Area 3C north | Total Area 3C | Total Canadian | CPUE ^a (t/h) | Effort ^b (h) |
|------|---------------|---------------|---------------|----------------|------|---------------|---------------|---------------|----------------|-------------------------|-------------------------|
| 1942 | - | - | 1561 | ? | 1969 | 255 | 142 | 397 | 52 | | |
| 1943 | - | - | 2264 | ? | 1970 | 80 | 198 | 278 | 142 | | |
| 1944 | - | - | 1489 | ? | 1971 | 74 | 523 | 597 | 366 | | |
| 1945 | - | - | 718 | ? | 1972 | 22 | 561 | 583 | 426 | | |
| 1946 | - | - | 906 | ? | 1973 | 211 | 452 | 663 | 328 | | |
| 1947 | - | - | 627 | ? | 1974 | 230 | 684 | 914 | 466 | | |
| 1948 | - | - | 1321 | ? | 1975 | 474 | 465 | 939 | 295 | | |
| 1949 | - | - | 1178 | ? | 1976 | 304 | 453 | 757 | 172 | | |
| 1950 | - | - | 854 | 362 | 1977 | 157 | 311 | 468 | 311 | | |
| 1951 | - | - | 794 | 293 | 1978 | 287 | 126 | 413 | 126 | | |
| 1952 | - | - | 948 | 419 | 1979 | 256 | 92 | 348 | 92 | | |
| 1953 | - | - | 748 | 367 | 1980 | 147 | 115 | 262 | 115 | | |
| 1954 | - | - | 664 | 279 | 1981 | 125 | 180 | 305 | 180 | | |
| 1955 | - | - | 415 | 142 | 1982 | 45 | 232 | 277 | 232 | | |
| 1956 | 40 | 585 | 625 | 173 | 1983 | 179 | 183 | 362 | 183 | | |
| 1957 | 9 | 629 | 638 | 200 | 1984 | 237 | 218 | 455 | 218 | | |
| 1958 | 19 | 609 | 628 | 144 | 1985 | 122 | 147 | 269 | 147 | | |
| 1959 | 33 | 1072 | 1105 | 159 | 1986 | 75 | 197 | 272 | 197 | | |
| 1960 | 233 | 974 | 1207 | 174 | 1987 | 113 | 123 | 236 | 123 | 0.392 | 12 |
| 1961 | 375 | 1109 | 1484 | 156 | 1988 | 185 | 183 | 368 | 183 | 0.420 | 102 |
| 1962 | 215 | 850 | 1065 | 135 | 1989 | 191 | 386 | 587 | 386 | 0.352 | 450 |
| 1963 | 90 | 658 | 748 | 66 | 1990 | 134 | 478 | 612 | 478 | 0.316 | 599 |
| 1964 | 71 | 530 | 601 | 141 | 1991 | 106 | 408 | 514 | 408 | 0.217 | 1026 |
| 1965 | 140 | 658 | 798 | 118 | 1992 | 260 | 128 | 388 | 128 | 0.180 | 548 |
| 1966 | 118 | 512 | 630 | 90 | 1993 | 200 | 248 | 448 | 248 | 0.139 | 926 |
| 1967 | 106 | 259 | 365 | 104 | 1994 | 189 | 139 | 328 | 139 | 0.114 | 453 |
| 1968 | 114 | 233 | 347 | 110 | 1995 | 195 | 158 | 353 | 158 | 0.120 | 414 |

^a Area 3C north 25% qualified (Jan. - Mar.)

^b Effort = Area 3C north 25% qualified Effort (Jan-Mar)

Table 4.3. Canada-U.S. landings (t) of petrale sole from the "northern stock" Areas 3D,5A-5D, 1942-95.

| Year | Area 3D | Areas 5A-5B | Areas 5C-5D | Total | Total Canadian | Year | Area 3D | Areas 5A-5B | Areas 5C-5D | Total | Total Canadian | CPUE ^a (t/h) | Effort ^b (h) |
|------|---------|-------------|-------------|-------|----------------|------|---------|-------------|-------------|-------|----------------|-------------------------|-------------------------|
| 1942 | - | - | - | - | ? | 1969 | 262 | 114 | 22 | 398 | 101 | - | |
| 1943 | - | - | - | - | ? | 1970 | 136 | 56 | 22 | 214 | 65 | - | |
| 1944 | 499 | 303 | - | 802 | ? | 1971 | 127 | 97 | 55 | 280 | 118 | - | |
| 1945 | 270 | 1535 | 193 | 1998 | ? | 1972 | 50 | 154 | 33 | 237 | 102 | - | |
| 1946 | 623 | 1258 | 494 | 2375 | ? | 1973 | 197 | 211 | 24 | 432 | 78 | - | |
| 1947 | 469 | 986 | 769 | 2224 | ? | 1974 | 196 | 283 | 14 | 493 | 85 | - | |
| 1948 | 943 | 920 | 3011 | 4874 | ? | 1975 | 234 | 156 | 27 | 417 | 99 | - | |
| 1949 | 316 | 429 | 1644 | 2390 | ? | 1976 | 153 | 132 | 30 | 315 | 118 | - | |
| 1950 | 694 | 569 | 700 | 1963 | 435 | 1977 | 58 | 73 | 24 | 155 | 155 | - | |
| 1951 | 305 | 326 | 642 | 1273 | 426 | 1978 | 21 | 63 | 13 | 97 | 97 | - | |
| 1952 | 265 | 305 | 574 | 1144 | 249 | 1979 | 10 | 57 | 39 | 106 | 106 | - | |
| 1953 | 235 | 450 | 46 | 731 | 92 | 1980 | 31 | 40 | 33 | 104 | 104 | - | |
| 1954 | 712 | 234 | 300 | 1237 | 96 | 1981 | 15 | 41 | 42 | 98 | 98 | - | |
| 1955 | 452 | 462 | 94 | 1008 | 118 | 1982 | 30 | 61 | 16 | 107 | 107 | - | |
| 1956 | 291 | 528 | 53 | 872 | 68 | 1983 | 29 | 161 | 35 | 225 | 225 | - | |
| 1957 | 1320 | 333 | 216 | 1869 | 198 | 1984 | 77 | 79 | 24 | 180 | 180 | - | |
| 1958 | 174 | 227 | 171 | 572 | 205 | 1985 | 50 | 81 | 22 | 153 | 153 | - | |
| 1959 | 227 | 160 | 216 | 603 | 175 | 1986 | 24 | 120 | 25 | 169 | 169 | - | |
| 1960 | 93 | 212 | 120 | 425 | 238 | 1987 | 37 | 165 | 101 | 303 | 303 | - | |
| 1961 | 277 | 171 | 102 | 550 | 192 | 1988 | 276 | 167 | 133 | 576 | 576 | 0.552 | 233 |
| 1962 | 295 | 343 | 165 | 803 | 331 | 1989 | 178 | 220 | 151 | 549 | 549 | 0.357 | 258 |
| 1963 | 202 | 537 | 82 | 821 | 329 | 1990 | 249 | 148 | 142 | 539 | 539 | 0.383 | 425 |
| 1964 | 183 | 421 | 163 | 767 | 359 | 1991 | 137 | 143 | 85 | 365 | 365 | 0.313 | 217 |
| 1965 | 300 | 418 | 202 | 920 | 363 | 1992 | 133 | 93 | 72 | 298 | 298 | 0.252 | 154 |
| 1966 | 264 | 469 | 260 | 993 | 465 | 1993 | 117 | 105 | 63 | 285 | 285 | 0.252 | 146 |
| 1967 | 169 | 485 | 176 | 830 | 350 | 1994 | 53 | 197 | 45 | 295 | 295 | 0.118 | 34 |
| 1968 | 293 | 266 | 137 | 696 | 257 | 1995 | 77 | 327 | 42 | 446 | 446 | 0.126 | 8 |

^a Area 3D 25% qualified CPUE (Jan. - Mar.)

^b Effort = Area 3D 25% qualified Effort (Jan-Mar)

Table 4.4. Management history for Area 3CD Dover sole (1990-1996). All numbers in metric tonnes unless noted.

| Year | Trip Limit (1000's lbs) | Condition | Assessment | TAC | Catch | Overage |
|-------------|----------------------------|---|------------|------|--------------|---------|
| pre 1990 | None | | None | None | Table 4.5 | |
| 1990 | None | | 1000-2000 | None | 1497 | |
| 1991 | None | | 500-2000 | 1300 | 1433 | 133 |
| 1992 | 20 | After 70% quota | 500-2000 | 1300 | 1644 | 344 |
| 1993 | 50 | Invoked Q1 only | 500-2000 | 1300 | 2167 | 867 |
| 1994 | 50, 25, 6.25 | Selected trip option | 1300-2000 | 1650 | 1751 | 100 |
| 1995 | 40, 20, 5 | Selected trip option, invoked Q1 only | 1300-2000 | 1650 | 1860 | 210 |
| 1996 | | | 1300-2000 | 1813 | | |

Table 4.5. Annual area 3CD Dover sole landings by trip (weight), 0% qualified, 1980-95.

| YEAR | Weight of landing (lb) | | | | | | | | | | TOTAL (t) | ≥ 50000 (lb) | |
|------|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------|--------------|------|
| | 1- 9999 | 10000- 19999 | 20000- 29999 | 30000- 39999 | 40000- 49999 | 50000- 59999 | 60000- 69999 | 70000- 79999 | 80000- 89999 | 90000- 99999 | | | |
| 80 | 26 | 1 | 2 | 2 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 218 | 171 |
| 81 | 28 | 4 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 208 | 187 |
| 82 | 46 | 5 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 191 | 177 |
| 83 | 45 | 2 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 82 | 80 |
| 84 | 34 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | 42 |
| 85 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 24 |
| 86 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 26 |
| 87 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 32 |
| 88 | 140 | 6 | 2 | 5 | 4 | 3 | 0 | 2 | 0 | 0 | 0 | 468 | 443 |
| 89 | 203 | 18 | 13 | 3 | 5 | 1 | 1 | 1 | 0 | 0 | 8 | 1314 | 826 |
| 90 | 182 | 18 | 12 | 4 | 5 | 4 | 3 | 2 | 2 | 1 | 5 | 1267 | 972 |
| 91 | 249 | 26 | 16 | 4 | 6 | 8 | 2 | 0 | 1 | 1 | 5 | 1404 | 1151 |
| 92 | 377 | 38 | 14 | 9 | 6 | 4 | 2 | 3 | 1 | 0 | 6 | 1613 | 1374 |
| 93 | 603 | 29 | 19 | 23 | 35 | 5 | 2 | 0 | 0 | 0 | 0 | 2129 | 2110 |
| 94 | 451 | 68 | 26 | 22 | 5 | 4 | 1 | 0 | 0 | 0 | 0 | 1726 | 1712 |
| 95 | 442 | 53 | 29 | 15 | 15 | 6 | 1 | 0 | 0 | 0 | 0 | 1860 | 1845 |

Table 4.6. Annual catch statistics and CPUE estimates at 0 percent qualification. Catch per unit effort estimates are in units of (t/h) where CPUE denotes the mean of ratios estimate, CPUE₁₀ denotes the 10% trimmed mean of ratios estimate, CPUE₅₀ denotes the median of ratios estimate, and CPUE_R denotes the ratio of means estimate.

| Year | n | Catch (t) | Effort (h) | CPUE | CPUE ₁₀ | CPUE ₅₀ | CPUE _R |
|------|-----|--------------|---------------|-------|--------------------|--------------------|-------------------|
| 1980 | 31 | 224 | 760 | 0.366 | 0.292 | 0.219 | 0.295 |
| 1981 | 66 | 210 | 849 | 0.337 | 0.269 | 0.215 | 0.248 |
| 1982 | 55 | 191 | 1026 | 0.319 | 0.229 | 0.161 | 0.186 |
| 1983 | 36 | 82 | 682 | 0.216 | 0.193 | 0.156 | 0.120 |
| 1984 | 22 | 42 | 429 | 0.185 | 0.118 | 0.109 | 0.097 |
| 1985 | 19 | 25 | 511 | 0.096 | 0.091 | 0.077 | 0.048 |
| 1986 | 24 | 26 | 322 | 0.167 | 0.135 | 0.108 | 0.082 |
| 1987 | 31 | 32 | 444 | 0.130 | 0.086 | 0.074 | 0.071 |
| 1988 | 114 | 478 | 1660 | 0.333 | 0.252 | 0.192 | 0.288 |
| 1989 | 231 | 1297 | 4149 | 0.381 | 0.233 | 0.142 | 0.313 |
| 1990 | 226 | 1273 | 3951 | 0.352 | 0.256 | 0.170 | 0.322 |
| 1991 | 325 | 1408 | 5321 | 0.296 | 0.238 | 0.193 | 0.265 |
| 1992 | 507 | 1613 | 5565 | 0.328 | 0.275 | 0.239 | 0.290 |
| 1993 | 760 | 2125 | 7708 | 0.353 | 0.255 | 0.218 | 0.276 |
| 1994 | 741 | 1714 | 6763 | 0.288 | 0.245 | 0.217 | 0.253 |
| 1995 | 740 | 1850 | 7893 | 0.294 | 0.238 | 0.207 | 0.234 |

Table 4.7. Annual catch statistics and CPUE estimates at 25 percent qualification. Catch per unit effort estimates are in units of (t/h) where CPUE denotes the mean of ratios estimate, $CPUE_{10}$ denotes the 10% trimmed mean of ratios estimate, $CPUE_{50}$ denotes the median of ratios estimate, and $CPUE_R$ denotes the ratio of means estimate.

| Year | n | Catch (t) | Effort (h) | CPUE | $CPUE_{10}$ | $CPUE_{50}$ | $CPUE_R$ |
|------|-----|--------------|---------------|-------|-------------|-------------|----------|
| 1980 | 13 | 184 | 306 | 0.657 | 0.547 | 0.556 | 0.604 |
| 1981 | 36 | 171 | 461 | 0.458 | 0.382 | 0.339 | 0.371 |
| 1982 | 21 | 129 | 281 | 0.516 | 0.447 | 0.361 | 0.461 |
| 1983 | 9 | 22 | 84 | 0.383 | 0.383 | 0.389 | 0.261 |
| 1984 | 5 | 24 | 79 | 0.505 | 0.505 | 0.256 | 0.300 |
| 1985 | 1 | 3 | 9 | 0.280 | 0.280 | 0.280 | 0.280 |
| 1986 | 2 | 2 | 8 | 0.321 | 0.321 | 0.321 | 0.230 |
| 1987 | 1 | 1 | 4 | 0.143 | 0.143 | 0.143 | 0.143 |
| 1988 | 48 | 371 | 620 | 0.586 | 0.509 | 0.426 | 0.598 |
| 1989 | 105 | 1115 | 1754 | 0.699 | 0.524 | 0.415 | 0.636 |
| 1990 | 115 | 1122 | 1882 | 0.571 | 0.479 | 0.402 | 0.596 |
| 1991 | 181 | 1222 | 2572 | 0.434 | 0.373 | 0.316 | 0.475 |
| 1992 | 290 | 1382 | 3034 | 0.438 | 0.382 | 0.357 | 0.456 |
| 1993 | 424 | 1785 | 4459 | 0.491 | 0.365 | 0.318 | 0.400 |
| 1994 | 519 | 1492 | 4626 | 0.345 | 0.298 | 0.267 | 0.323 |
| 1995 | 511 | 1630 | 5352 | 0.350 | 0.287 | 0.259 | 0.305 |

Table 4.8. Annual catch (t) by minor area for the area 3CD Dover sole fishery, 1980-95.

| Year | 21 | 23 | 24 | 25 | 26 | 27 | Total |
|------|----|------|-----|-----|----|-----|-------|
| 1980 | 2 | 73 | 36 | 107 | 1 | 4 | 224 |
| 1981 | 1 | 129 | 31 | 43 | 1 | 4 | 210 |
| 1982 | 7 | 121 | 43 | 13 | 0 | 8 | 191 |
| 1983 | 6 | 15 | 38 | 14 | 1 | 8 | 82 |
| 1984 | 3 | 8 | 11 | 17 | 1 | 3 | 42 |
| 1985 | 2 | 16 | 1 | 3 | 0 | 2 | 25 |
| 1986 | 0 | 18 | 3 | 0 | 1 | 4 | 26 |
| 1987 | 5 | 10 | 6 | 6 | 1 | 5 | 32 |
| 1988 | 4 | 253 | 102 | 107 | 5 | 9 | 478 |
| 1989 | 11 | 337 | 547 | 357 | 30 | 15 | 1297 |
| 1990 | 20 | 752 | 280 | 152 | 48 | 21 | 1273 |
| 1991 | 17 | 665 | 268 | 356 | 41 | 61 | 1408 |
| 1992 | 9 | 820 | 393 | 317 | 30 | 45 | 1613 |
| 1993 | 9 | 1115 | 447 | 467 | 25 | 63 | 2125 |
| 1994 | 2 | 854 | 329 | 452 | 24 | 53 | 1714 |
| 1995 | 2 | 957 | 324 | 427 | 31 | 109 | 1850 |

Table 4.9. CPUEs by depth for the 1981 and 1995 Dover sole biomass surveys conducted off the west coast of Vancouver Island.

| Year | Depth interval (fa) | n | mean (t/nm ²) | s.d. | 95% c.i. |
|------|------------------------|----|------------------------------|--------|-------------------|
| 1981 | 100 - 199 | 1 | 0.416 | NA | NA |
| 1981 | 200 - 299 | 25 | 17.740 | 29.040 | (6.124, 29.356) |
| 1981 | 300 - 399 | 11 | 1.536 | 1.989 | (0.337, 2.735) |
| 1981 | 400 - 499 | 5 | 0.127 | 0.240 | (-0.088, 0.342) |
| 1981 | stratified mean | 42 | 6.453 | 46.260 | (-28.102, 41.008) |
| 1995 | 100 - 199 | 6 | 0.640 | 1.108 | (-0.265, 1.545) |
| 1995 | 200 - 299 | 17 | 1.909 | 3.292 | (0.312, 3.506) |
| 1995 | 300 - 399 | 17 | 32.346 | 70.944 | (0.619, 64.073) |
| 1995 | 400 - 499 | 7 | 2.177 | 2.623 | (0.194, 4.160) |
| 1995 | stratified mean | 50 | 9.466 | 89.744 | (-48.827, 67.759) |

Table 4.10. Canada-U.S. landing statistics for rock sole in Area 5A, 1954-95.

| Year | Landings (t) | Effort (h) ^a | CPUE (t/h) ^b | CPUE (t/h) ^c |
|------|--------------|-------------------------|-------------------------|-------------------------|
| 54 | 52 | 175 | 0.189 | 0.216 |
| 55 | 119 | 274 | 0.279 | 0.287 |
| 56 | 551 | 1441 | 0.309 | 0.241 |
| 57 | 511 | 1633 | 0.234 | 0.219 |
| 58 | 501 | 2204 | 0.223 | 0.181 |
| 59 | 212 | 834 | 0.168 | 0.162 |
| 60 | 397 | 1588 | 0.211 | 0.148 |
| 61 | 237 | 757 | 0.188 | 0.212 |
| 62 | 196 | 910 | 0.111 | 0.120 |
| 63 | 161 | 456 | 0.133 | 0.170 |
| 64 | 156 | 346 | 0.128 | 0.195 |
| 65 | 157 | 350 | 0.169 | 0.203 |
| 66 | 330 | 651 | 0.273 | 0.283 |
| 67 | 252 | 822 | 0.206 | 0.233 |
| 68 | 435 | 1224 | 0.224 | 0.233 |
| 69 | 293 | 1230 | 0.133 | 0.115 |
| 70 | 167 | 566 | 0.153 | 0.159 |
| 71 | 135 | 392 | 0.165 | 0.162 |
| 72 | 58 | 117 | 0.111 | 0.168 |
| 73 | 57 | 68 | 0.109 | 0.352 |
| 74 | 74 | 50 | 0.085 | 0.351 |
| 75 | 37 | 191 | 0.077 | 0.111 |
| 76 | 182 | 466 | 0.115 | 0.185 |
| 77 | 83 | 197 | 0.089 | 0.209 |
| 78 | 79 | 230 | 0.106 | 0.134 |
| 79 | 202 | 526 | 0.202 | 0.216 |
| 80 | 238 | 810 | 0.194 | 0.206 |
| 81 | 114 | 404 | 0.152 | 0.181 |
| 82 | 189 | 548 | 0.208 | 0.261 |
| 83 | 124 | 195 | 0.147 | 0.266 |
| 84 | 142 | 348 | 0.149 | 0.217 |
| 85 | 56 | 115 | 0.108 | 0.156 |
| 86 | 23 | 12 | 0.027 | 0.112 |
| 87 | 80 | 74 | 0.105 | 0.249 |
| 88 | 128 | 330 | 0.113 | 0.180 |
| 89 | 143 | 425 | 0.119 | 0.164 |
| 90 | 190 | 554 | 0.140 | 0.134 |
| 91 | 200 | 608 | 0.126 | 0.159 |
| 92 | 290 | 731 | 0.210 | 0.231 |
| 93 | 462 | 1864 | 0.185 | 0.199 |
| 94 | 311 | 1399 | 0.131 | 0.150 |
| 95 | 212 | 939 | 0.127 | 0.138 |

^a Effort - Annual effort for 25% qualified landings.

^b CPUE - Adjusted for changes in vessel horsepower class over time.

^c CPUE - Median CPUE for 25% qualified landings.

Table 4.11. Canada-U.S. landing statistics for rock sole in Area 5B, 1954.

| Year | Landings (t) | Effort (h) ^a | CPUE (t/h) ^b | CPUE (t/h) ^c |
|------|--------------|-------------------------|-------------------------|-------------------------|
| 54 | 203 | 133 | 0.463 | 0.295 |
| 55 | 267 | 259 | 0.322 | 0.247 |
| 56 | 307 | 614 | 0.313 | 0.270 |
| 57 | 206 | 531 | 0.240 | 0.302 |
| 58 | 379 | 1338 | 0.206 | 0.206 |
| 59 | 344 | 945 | 0.249 | 0.213 |
| 60 | 503 | 1444 | 0.242 | 0.203 |
| 61 | 416 | 1167 | 0.205 | 0.189 |
| 62 | 531 | 1345 | 0.235 | 0.227 |
| 63 | 517 | 947 | 0.234 | 0.225 |
| 64 | 482 | 559 | 0.202 | 0.193 |
| 65 | 568 | 729 | 0.231 | 0.226 |
| 66 | 772 | 794 | 0.276 | 0.253 |
| 67 | 741 | 423 | 0.322 | 0.280 |
| 68 | 392 | 492 | 0.240 | 0.246 |
| 69 | 652 | 1028 | 0.217 | 0.211 |
| 70 | 245 | 319 | 0.235 | 0.192 |
| 71 | 368 | 790 | 0.214 | 0.203 |
| 72 | 382 | 518 | 0.195 | 0.189 |
| 73 | 324 | 245 | 0.291 | 0.238 |
| 74 | 371 | 165 | 0.167 | 0.232 |
| 75 | 408 | 497 | 0.163 | 0.276 |
| 76 | 368 | 879 | 0.187 | 0.218 |
| 77 | 188 | 351 | 0.133 | 0.182 |
| 78 | 217 | 279 | 0.202 | 0.265 |
| 79 | 208 | 425 | 0.168 | 0.209 |
| 80 | 410 | 846 | 0.373 | 0.263 |
| 81 | 220 | 570 | 0.184 | 0.211 |
| 82 | 155 | 314 | 0.195 | 0.287 |
| 83 | 206 | 447 | 0.231 | 0.245 |
| 84 | 87 | 116 | 0.124 | 0.238 |
| 85 | 170 | 358 | 0.156 | 0.269 |
| 86 | 135 | 178 | 0.121 | 0.171 |
| 87 | 205 | 165 | 0.207 | 0.295 |
| 88 | 272 | 302 | 0.198 | 0.329 |
| 89 | 260 | 520 | 0.173 | 0.269 |
| 90 | 419 | 843 | 0.175 | 0.217 |
| 91 | 437 | 922 | 0.205 | 0.284 |
| 92 | 416 | 1203 | 0.212 | 0.227 |
| 93 | 343 | 1155 | 0.175 | 0.224 |
| 94 | 323 | 1023 | 0.181 | 0.215 |
| 95 | 252 | 848 | 0.155 | 0.150 |

^a Effort = Landings/CPUE.

^b CPUE - Adjusted for changes in vessel horsepower class over time.

^c CPUE - Median CPUE for 25% qualified landings.

Table 4.12. U.S.-Canada landing statistics for Hecate Strait rock sole, 1944-95.

| Year | Landings (t) | Effort (h) ^a | CPUE(t/h) ^b | CPUE(t/h) ^b |
|------|--------------|-------------------------|------------------------|------------------------|
| 45 | 121 | 434 | 0.279 | 0.279 |
| 46 | 410 | 2228 | 0.184 | 0.184 |
| 47 | 1181 | 1946 | 0.607 | 0.607 |
| 48 | 901 | 1753 | 0.514 | 0.514 |
| 49 | 657 | 1352 | 0.486 | 0.486 |
| 50 | 784 | 1452 | 0.540 | 0.540 |
| 51 | 1024 | 944 | 1.085 | 1.085 |
| 52 | 2292 | 2014 | 1.138 | 1.138 |
| 53 | 779 | 1227 | 0.635 | 0.635 |
| 54 | 926 | 840 | 1.106 | 0.938 |
| 55 | 1560 | 1558 | 0.807 | 0.680 |
| 56 | 1160 | 1484 | 0.691 | 0.644 |
| 57 | 1151 | 2019 | 0.506 | 0.443 |
| 58 | 1256 | 1331 | 0.946 | 0.650 |
| 59 | 416 | 636 | 0.581 | 0.403 |
| 60 | 1127 | 1100 | 1.010 | 0.680 |
| 61 | 744 | 694 | 1.340 | 0.900 |
| 62 | 829 | 849 | 0.832 | 0.735 |
| 63 | 881 | 735 | 0.781 | 0.737 |
| 64 | 743 | 835 | 0.467 | 0.531 |
| 65 | 879 | 629 | 0.644 | 0.545 |
| 66 | 2544 | 2491 | 0.693 | 0.598 |
| 67 | 2162 | 2324 | 0.801 | 0.511 |
| 68 | 2366 | 4209 | 0.431 | 0.386 |
| 69 | 1461 | 4485 | 0.480 | 0.314 |
| 70 | 1403 | 3660 | 0.320 | 0.326 |
| 71 | 1503 | 3587 | 0.315 | 0.255 |
| 72 | 515 | 650 | 0.279 | 0.337 |
| 73 | 507 | 619 | 0.273 | 0.435 |
| 74 | 622 | 603 | 0.310 | 0.475 |
| 75 | 1204 | 1912 | 0.319 | 0.360 |
| 76 | 1438 | 1830 | 0.480 | 0.402 |
| 77 | 846 | 1896 | 0.240 | 0.285 |
| 78 | 874 | 1662 | 0.324 | 0.336 |
| 79 | 1313 | 1943 | 0.341 | 0.330 |
| 80 | 977 | 2420 | 0.189 | 0.254 |
| 81 | 584 | 806 | 0.196 | 0.287 |
| 82 | 291 | 841 | 0.172 | 0.209 |
| 83 | 247 | 499 | 0.166 | 0.286 |
| 84 | 188 | 573 | 0.126 | 0.188 |
| 85 | 112 | 276 | 0.174 | 0.242 |
| 86 | 219 | 470 | 0.248 | 0.345 |
| 87 | 536 | 577 | 0.278 | 0.389 |
| 88 | 1402 | 2520 | 0.377 | 0.410 |
| 89 | 1422 | 3757 | 0.281 | 0.288 |
| 90 | 1519 | 3948 | 0.303 | 0.319 |
| 91 | 2666 | 6552 | 0.261 | 0.295 |
| 92 | 2226 | 5777 | 0.294 | 0.289 |
| 93 | 2080 | 5851 | 0.289 | 0.301 |
| 94 | 1384 | 4282 | 0.264 | 0.275 |
| 95 | 1294 | 3538 | 0.303 | 0.322 |

^a Effort = Annual effort for 25% qualified landings

^b CPUE - Adjusted for changes in vessel horsepower class over time.

^c CPUE - Median CPUE for 25% qualified landings

Table 4.13. Results of catch-age analysis for Hecate Strait rock sole, 1945-95.¹

| Year | Recruitment (000,000's fish) | | Exploitable population (000,000's fish) | | Exploitable biomass (000's t) | | Fishing mortality (F) | |
|------|---------------------------------|---------|---|----------|-------------------------------------|---------|-----------------------------|----------|
| | model a | model b | model a | model b | model a | model b | model a | model b |
| 45 | 0.99860 | 1.13889 | 1.61404 | 2.33065 | 1.33943 | 2.04017 | 0.094681 | 0.061140 |
| 46 | 1.85619 | 1.53685 | 2.03943 | 2.65941 | 1.67969 | 2.38043 | 0.279837 | 0.189029 |
| 47 | 2.64574 | 1.94170 | 2.59886 | 2.94249 | 1.91824 | 2.38820 | 0.956249 | 0.682235 |
| 48 | 2.12069 | 2.13599 | 2.58032 | 2.69680 | 1.86550 | 2.08581 | 0.659676 | 0.565574 |
| 49 | 1.92613 | 2.32660 | 2.72097 | 2.85706 | 2.10178 | 2.26376 | 0.374828 | 0.342807 |
| 50 | 2.65639 | 2.68168 | 3.16083 | 3.39947 | 2.49654 | 2.68402 | 0.376927 | 0.345452 |
| 51 | 3.75410 | 3.00152 | 3.84505 | 3.96420 | 2.66284 | 2.80559 | 0.485405 | 0.454109 |
| 52 | 3.40528 | 2.91205 | 4.42906 | 4.25624 | 3.39665 | 3.34207 | 1.123260 | 1.157740 |
| 53 | 2.53584 | 2.60397 | 3.78728 | 3.44676 | 2.71270 | 2.49941 | 0.338509 | 0.373493 |
| 54 | 1.93318 | 2.32525 | 4.09519 | 3.83288 | 3.16300 | 2.90203 | 0.346385 | 0.384320 |
| 55 | 1.50846 | 2.16127 | 3.94853 | 3.94533 | 3.03036 | 2.92036 | 0.723174 | 0.763958 |
| 56 | 1.62047 | 2.21878 | 3.00454 | 3.34132 | 2.42623 | 2.56205 | 0.650296 | 0.602871 |
| 57 | 2.55756 | 2.54366 | 2.74968 | 3.27882 | 2.01043 | 2.32518 | 0.849836 | 0.683226 |
| 58 | 3.37609 | 2.87282 | 2.90242 | 3.32912 | 1.99237 | 2.34089 | 0.995345 | 0.769055 |
| 59 | 3.71501 | 3.03033 | 3.32457 | 3.44147 | 1.95702 | 2.18786 | 0.238978 | 0.210895 |
| 60 | 2.69783 | 2.88040 | 4.42336 | 4.35026 | 2.47904 | 2.52071 | 0.606255 | 0.592570 |
| 61 | 2.21595 | 2.78054 | 4.22375 | 4.25866 | 2.54459 | 2.59781 | 0.345856 | 0.337426 |
| 62 | 2.16747 | 2.83584 | 4.26947 | 4.60986 | 3.02981 | 3.23997 | 0.319675 | 0.295535 |
| 63 | 2.61947 | 3.09155 | 4.33586 | 4.99686 | 3.38242 | 3.81414 | 0.301733 | 0.262642 |
| 64 | 3.70842 | 3.50461 | 4.73276 | 5.50484 | 3.79582 | 4.38620 | 0.217835 | 0.185601 |
| 65 | 4.25873 | 3.75839 | 5.68862 | 6.29166 | 4.17536 | 4.70548 | 0.236382 | 0.206783 |
| 66 | 4.22729 | 3.77161 | 6.63155 | 6.92947 | 4.52848 | 4.83270 | 0.825029 | 0.747420 |
| 67 | 3.65059 | 3.48840 | 5.67525 | 5.71409 | 4.50305 | 4.62651 | 0.654156 | 0.629809 |
| 68 | 3.20815 | 3.10534 | 5.27000 | 5.18493 | 4.30005 | 4.28832 | 0.799011 | 0.802362 |
| 69 | 2.58356 | 2.67309 | 4.48601 | 4.38450 | 3.86235 | 3.77202 | 0.475244 | 0.489922 |
| 70 | 1.83936 | 2.27315 | 4.23956 | 4.24575 | 2.9807 | 2.93935 | 0.636191 | 0.648780 |
| 71 | 1.42644 | 2.03097 | 3.43832 | 3.68672 | 3.00149 | 3.08507 | 0.694652 | 0.667841 |
| 72 | 1.80392 | 2.09320 | 2.77381 | 3.24504 | 2.60523 | 2.94120 | 0.220247 | 0.192492 |
| 73 | 2.49613 | 2.27450 | 3.21439 | 3.73908 | 3.19207 | 3.71999 | 0.172963 | 0.146519 |
| 74 | 2.63061 | 2.35186 | 3.89210 | 4.29402 | 3.75717 | 4.23740 | 0.180983 | 0.158747 |
| 75 | 2.16247 | 2.30251 | 4.42868 | 4.72132 | 3.23071 | 3.51056 | 0.466288 | 0.420019 |
| 76 | 2.12262 | 2.32785 | 4.08142 | 4.38288 | 4.43644 | 4.81880 | 0.391760 | 0.354413 |
| 77 | 2.14354 | 2.38567 | 3.93040 | 4.31131 | 3.48542 | 3.82434 | 0.278030 | 0.250020 |
| 78 | 2.40449 | 2.49471 | 4.09870 | 4.54523 | 3.39339 | 3.78123 | 0.297812 | 0.262848 |
| 79 | 2.09403 | 2.47213 | 4.18724 | 4.71784 | 3.48900 | 3.93459 | 0.472127 | 0.406026 |
| 80 | 2.49479 | 2.56426 | 3.91746 | 4.52212 | 3.80358 | 4.42630 | 0.296875 | 0.249393 |
| 81 | 2.02871 | 2.42832 | 4.07614 | 4.75211 | 3.36533 | 3.95887 | 0.190597 | 0.159602 |
| 82 | 1.60431 | 2.28921 | 4.25384 | 5.11119 | 3.61326 | 4.33952 | 0.083965 | 0.069412 |
| 83 | 1.52822 | 2.30577 | 4.49233 | 5.63167 | 4.00430 | 4.93706 | 0.063668 | 0.051325 |
| 84 | 1.81253 | 2.52617 | 4.71143 | 6.15290 | 4.13254 | 5.31207 | 0.046560 | 0.036033 |
| 85 | 2.18797 | 2.88203 | 5.05826 | 6.76777 | 4.54617 | 5.99527 | 0.024944 | 0.018858 |
| 86 | 2.80989 | 3.38557 | 5.66965 | 7.58092 | 5.44444 | 7.20641 | 0.041056 | 0.030861 |
| 87 | 4.77552 | 4.12684 | 6.74067 | 8.54140 | 5.83090 | 7.47824 | 0.096427 | 0.074373 |
| 88 | 5.54908 | 4.61156 | 8.17857 | 9.46229 | 6.55430 | 7.83908 | 0.240678 | 0.197046 |
| 89 | 3.91802 | 4.58749 | 8.78699 | 9.70456 | 7.60622 | 8.89760 | 0.206965 | 0.174137 |
| 90 | 4.32511 | 4.74009 | 9.16617 | 10.12100 | 7.61769 | 8.64307 | 0.222399 | 0.193279 |
| 91 | 4.79351 | 4.77116 | 9.39826 | 10.38610 | 7.80290 | 8.87253 | 0.418045 | 0.357358 |
| 92 | 4.30897 | 4.53673 | 8.61381 | 9.62106 | 7.78804 | 8.85277 | 0.336624 | 0.289613 |
| 93 | 3.35915 | 4.16857 | 8.19405 | 9.32208 | 7.46656 | 8.62793 | 0.326527 | 0.275855 |
| 94 | 2.49961 | 3.82149 | 7.48572 | 8.99690 | 6.35534 | 7.70739 | 0.245606 | 0.197924 |
| 95 | 2.02094 | 3.63234 | 6.87336 | 8.98731 | 5.59630 | 6.67000 | 0.264584 | 0.197246 |

¹ See Section 4.5.1.3 for explanation of models a and b.

Table 4.14. Landing statistics for Hecate Strait English sole, 1944-95.

| Year | Landings (t) | Effort (h) ^a | CPUE (t/h) ^b | CPUE (t/h) ^c |
|------|--------------|-------------------------|-------------------------|-------------------------|
| 44 | 152 | 215 | 0.707 | 0.707 |
| 45 | 304 | 365 | 0.832 | 0.832 |
| 46 | 470 | 809 | 0.581 | 0.581 |
| 47 | 350 | 538 | 0.651 | 0.651 |
| 48 | 937 | 2740 | 0.342 | 0.342 |
| 49 | 795 | 1893 | 0.420 | 0.420 |
| 50 | 2622 | 4910 | 0.534 | 0.534 |
| 51 | 1024 | 2142 | 0.478 | 0.478 |
| 52 | 1347 | 3293 | 0.409 | 0.409 |
| 53 | 871 | 2084 | 0.418 | 0.418 |
| 54 | 455 | 563 | 0.354 | 0.362 |
| 55 | 875 | 744 | 0.494 | 0.401 |
| 56 | 956 | 1344 | 0.477 | 0.349 |
| 57 | 552 | 640 | 0.238 | 0.244 |
| 58 | 693 | 617 | 0.308 | 0.337 |
| 59 | 940 | 772 | 0.330 | 0.315 |
| 60 | 1147 | 1058 | 0.387 | 0.333 |
| 61 | 871 | 1615 | 0.316 | 0.298 |
| 62 | 459 | 903 | 0.231 | 0.247 |
| 63 | 408 | 568 | 0.158 | 0.207 |
| 64 | 436 | 441 | 0.210 | 0.272 |
| 65 | 414 | 326 | 0.154 | 0.317 |
| 66 | 362 | 354 | 0.165 | 0.302 |
| 67 | 534 | 535 | 0.343 | 0.411 |
| 68 | 671 | 844 | 0.305 | 0.302 |
| 69 | 819 | 1314 | 0.358 | 0.390 |
| 70 | 1002 | 2042 | 0.371 | 0.312 |
| 71 | 488 | 1585 | 0.219 | 0.192 |
| 72 | 371 | 550 | 0.196 | 0.230 |
| 73 | 667 | 514 | 0.272 | 0.411 |
| 74 | 500 | 519 | 0.333 | 0.519 |
| 75 | 938 | 1015 | 0.439 | 0.466 |
| 76 | 1133 | 1627 | 0.265 | 0.275 |
| 77 | 1179 | 2201 | 0.248 | 0.310 |
| 78 | 559 | 944 | 0.169 | 0.246 |
| 79 | 864 | 980 | 0.206 | 0.337 |
| 80 | 995 | 1105 | 0.204 | 0.327 |
| 81 | 1327 | 2149 | 0.250 | 0.249 |
| 82 | 428 | 1062 | 0.183 | 0.219 |
| 83 | 430 | 834 | 0.193 | 0.240 |
| 84 | 658 | 1129 | 0.253 | 0.290 |
| 85 | 585 | 1520 | 0.230 | 0.226 |
| 86 | 335 | 469 | 0.247 | 0.365 |
| 87 | 630 | 396 | 0.210 | 0.347 |
| 88 | 688 | 540 | 0.263 | 0.493 |
| 89 | 826 | 925 | 0.334 | 0.385 |
| 90 | 992 | 1335 | 0.248 | 0.383 |
| 91 | 913 | 940 | 0.185 | 0.308 |
| 92 | 987 | 1602 | 0.256 | 0.307 |
| 93 | 1421 | 2636 | 0.244 | 0.295 |
| 94 | 1000 | 1860 | 0.275 | 0.343 |
| 95 | 1190 | 2321 | 0.297 | 0.320 |

^a Effort = Annual effort for 25% qualified landings

^b CPUE - Adjusted for changes in vessel horsepower class over time.

^c CPUE - Median CPUE for 25% qualified landings

Table 4.15 Results of catch-age analyses for Hecate Strait English sole, 1944-95.¹

| Year | Recruitment (000,000's fish) | | Exploitable population (000,000's fish) | | Exploitable biomass (000's t) | | Fishing mortality (F) | |
|------|---------------------------------|---------|---|----------|-------------------------------------|---------|-----------------------------|----------|
| | model a | model b | model a | model b | model a | model b | model a | model b |
| 44 | 3.87862 | 3.75681 | 11.07060 | 11.19520 | 6.69848 | 6.89380 | 0.022953 | 0.022296 |
| 45 | 3.84356 | 3.71712 | 11.12840 | 11.13000 | 7.26361 | 7.36922 | 0.042754 | 0.042128 |
| 46 | 3.79143 | 3.65879 | 10.98960 | 10.89710 | 6.79512 | 6.80766 | 0.071676 | 0.071539 |
| 47 | 3.66142 | 3.56029 | 10.61240 | 10.45740 | 6.37755 | 6.33067 | 0.056443 | 0.056874 |
| 48 | 3.45556 | 3.42474 | 10.33340 | 10.15490 | 6.06028 | 5.98079 | 0.167960 | 0.170400 |
| 49 | 3.24795 | 3.28386 | 9.28632 | 9.13660 | 5.52616 | 5.44365 | 0.155323 | 0.157873 |
| 50 | 3.09279 | 3.16366 | 8.51115 | 8.41531 | 4.88401 | 4.81544 | 0.769713 | 0.786357 |
| 51 | 2.98990 | 3.06688 | 5.57945 | 5.56075 | 3.13722 | 3.09907 | 0.395124 | 0.401108 |
| 52 | 2.92277 | 2.98904 | 5.08481 | 5.10757 | 2.66803 | 2.65355 | 0.702928 | 0.708509 |
| 53 | 2.90538 | 2.93330 | 4.21579 | 4.26096 | 2.22337 | 2.23222 | 0.497165 | 0.494615 |
| 54 | 2.93945 | 2.89638 | 4.13782 | 4.16953 | 1.94333 | 1.95420 | 0.266748 | 0.265049 |
| 55 | 2.95278 | 2.84612 | 4.54305 | 4.52465 | 2.20648 | 2.20112 | 0.505107 | 0.506708 |
| 56 | 2.81487 | 2.73311 | 4.31710 | 4.25236 | 2.16977 | 2.14098 | 0.580890 | 0.591539 |
| 57 | 2.66927 | 2.61421 | 3.98227 | 3.88810 | 2.15277 | 2.10200 | 0.296270 | 0.304634 |
| 58 | 2.50334 | 2.49203 | 4.17911 | 4.07380 | 1.99884 | 1.94501 | 0.425721 | 0.440517 |
| 59 | 2.32398 | 2.37604 | 3.96849 | 3.88957 | 1.86886 | 1.82011 | 0.699123 | 0.726607 |
| 60 | 2.18398 | 2.29363 | 3.33242 | 3.31323 | 1.60230 | 1.57224 | 1.258230 | 1.307610 |
| 61 | 2.07657 | 2.24792 | 2.48545 | 2.54823 | 1.17051 | 1.18134 | 1.363050 | 1.336730 |
| 62 | 2.07151 | 2.27172 | 2.12904 | 2.28299 | 0.99188 | 1.05298 | 0.621304 | 0.572531 |
| 63 | 2.29196 | 2.41258 | 2.44662 | 2.66250 | 1.11464 | 1.20969 | 0.455764 | 0.411397 |
| 64 | 2.62353 | 2.60629 | 2.92488 | 3.13997 | 1.37077 | 1.48187 | 0.382827 | 0.348455 |
| 65 | 2.98317 | 2.80373 | 3.49641 | 3.62979 | 1.70070 | 1.78893 | 0.278959 | 0.263215 |
| 66 | 3.19062 | 2.93184 | 4.18102 | 4.17451 | 1.90733 | 1.93878 | 0.210466 | 0.206674 |
| 67 | 2.98180 | 2.89640 | 4.79129 | 4.68663 | 2.40587 | 2.38300 | 0.250974 | 0.253715 |
| 68 | 2.75489 | 2.84046 | 5.01852 | 4.91446 | 2.59347 | 2.55455 | 0.299386 | 0.304718 |
| 69 | 2.61536 | 2.81629 | 4.92448 | 4.90983 | 2.70125 | 2.67888 | 0.361247 | 0.364887 |
| 70 | 2.72549 | 2.90186 | 4.68028 | 4.77395 | 2.66682 | 2.69075 | 0.471170 | 0.465830 |
| 71 | 2.96157 | 3.04549 | 4.38074 | 4.54088 | 2.39721 | 2.46457 | 0.227616 | 0.220654 |
| 72 | 3.24157 | 3.20516 | 4.85024 | 5.00261 | 2.59280 | 2.66973 | 0.154420 | 0.149621 |
| 73 | 3.49006 | 3.34229 | 5.53523 | 5.61366 | 3.71322 | 3.78066 | 0.197998 | 0.194100 |
| 74 | 3.75272 | 3.46431 | 6.06607 | 6.00776 | 4.04906 | 4.03299 | 0.131802 | 0.132364 |
| 75 | 3.76657 | 3.47161 | 6.73736 | 6.51811 | 3.62818 | 3.53650 | 0.299123 | 0.308203 |
| 76 | 3.48232 | 3.34639 | 6.57438 | 6.26197 | 4.23396 | 4.04844 | 0.311426 | 0.328311 |
| 77 | 3.17188 | 3.19171 | 6.25648 | 5.94734 | 3.94679 | 3.73988 | 0.354854 | 0.378703 |
| 78 | 2.92344 | 3.05852 | 5.74966 | 5.52541 | 3.79543 | 3.60896 | 0.159327 | 0.168291 |
| 79 | 2.90467 | 3.02509 | 5.91870 | 5.79474 | 4.06264 | 3.92066 | 0.239107 | 0.248937 |
| 80 | 2.95662 | 3.03500 | 5.77504 | 5.73428 | 2.84714 | 2.81166 | 0.429972 | 0.436775 |
| 81 | 2.93574 | 3.02799 | 5.14476 | 5.18020 | 2.86708 | 2.85652 | 0.621461 | 0.624652 |
| 82 | 2.73869 | 2.96998 | 4.33924 | 4.46612 | 2.90446 | 2.96163 | 0.159418 | 0.156087 |
| 83 | 2.41574 | 2.86411 | 4.69307 | 4.98128 | 3.06372 | 3.20818 | 0.151233 | 0.143908 |
| 84 | 2.01202 | 2.71500 | 4.78752 | 5.34445 | 2.69557 | 2.96425 | 0.279852 | 0.251001 |
| 85 | 1.84039 | 2.67958 | 4.34551 | 5.24881 | 2.04067 | 2.41409 | 0.337812 | 0.277504 |
| 86 | 1.97100 | 2.82712 | 3.87502 | 5.12157 | 2.07611 | 2.68475 | 0.175973 | 0.133279 |
| 87 | 2.43276 | 3.16379 | 4.05332 | 5.55711 | 2.23508 | 3.02493 | 0.331103 | 0.233534 |
| 88 | 3.32159 | 3.68902 | 4.24396 | 5.82601 | 1.93762 | 2.68294 | 0.438620 | 0.296299 |
| 89 | 4.28730 | 4.19716 | 4.71086 | 6.12502 | 2.49382 | 3.35751 | 0.402298 | 0.282384 |
| 90 | 5.16077 | 4.62659 | 5.63974 | 6.65519 | 2.83195 | 3.47873 | 0.431227 | 0.335699 |
| 91 | 5.18048 | 4.81442 | 6.44932 | 7.04685 | 2.95367 | 3.36672 | 0.369771 | 0.316334 |
| 92 | 4.62453 | 4.77002 | 7.01392 | 7.42578 | 3.20986 | 3.48512 | 0.367433 | 0.332964 |
| 93 | 3.86162 | 4.54747 | 7.01894 | 7.55386 | 3.49807 | 3.81322 | 0.521252 | 0.466252 |
| 94 | 3.26218 | 4.28453 | 6.14797 | 7.06335 | 2.86173 | 3.28723 | 0.429919 | 0.362703 |
| 95 | 3.06797 | 4.16830 | 5.59816 | 6.96519 | 2.55243 | 3.15692 | 0.627777 | 0.473129 |

¹ See Section 4.5.1.3 for explanation of models a and b.

Table 4.16. Canada-U.S. landing statistics for Dover sole, Areas 5C,D,E, 1970-95

| Year | Landings (t) | Effort (h) ^a | CPUE (t/h) ^b | CPUE (t/h) ^c |
|------|--------------|-------------------------|-------------------------|-------------------------|
| 70 | 965 | 1324 | 1.001 | 0.590 |
| 71 | 903 | 1367 | 0.933 | 0.556 |
| 72 | 922 | 1495 | 0.832 | 0.543 |
| 73 | 768 | 910 | 1.063 | 0.679 |
| 74 | 767 | 878 | 1.157 | 0.687 |
| 75 | 882 | 1135 | 0.749 | 0.573 |
| 76 | 1022 | 1465 | 0.651 | 0.440 |
| 77 | 577 | 900 | 0.505 | 0.319 |
| 78 | 483 | 650 | 0.568 | 0.497 |
| 79 | 697 | 1057 | 0.524 | 0.333 |
| 80 | 807 | 724 | 0.562 | 0.416 |
| 81 | 840 | 1079 | 0.543 | 0.428 |
| 82 | 512 | 894 | 0.561 | 0.433 |
| 83 | 693 | 544 | 1.268 | 0.568 |
| 84 | 953 | 1526 | 0.698 | 0.448 |
| 85 | 830 | 1039 | 0.512 | 0.485 |
| 86 | 1040 | 931 | 0.739 | 0.562 |
| 87 | 503 | 432 | 0.548 | 0.549 |
| 88 | 649 | 652 | 0.540 | 0.594 |
| 89 | 696 | 775 | 0.733 | 0.567 |
| 90 | 787 | 1181 | 0.631 | 0.542 |
| 91 | 649 | 1041 | 0.595 | 0.428 |
| 92 | 883 | 1444 | 0.556 | 0.381 |
| 93 | 1508 | 2767 | 0.558 | 0.414 |
| 94 | 1418 | 3117 | 0.522 | 0.371 |
| 95 | 1587 | 4220 | 0.439 | 0.320 |

^a Effort = Total effort for 25% qualified landings

^b CPUE - Adjusted for changes in vessel horsepower class over time.

^c CPUE - Median CPUE (25% qualified landings)

Appendix 4.1 - CPUE estimators

Ratio of means estimator

The ratio of means (pooled) estimator is computed by dividing the total observed catch by the total observed effort

$$R_t = \frac{\sum_{i=1}^{n_t} C_{ti}}{\sum_{i=1}^{n_t} E_{ti}}, \quad t=1, \dots, T.$$

(4. (1))

Mean of ratios estimator

The mean of ratios estimator is formed by computing the average of individual CPUEs for each year

$$R_{\mu t} = \frac{1}{n_t} \sum_{i=1}^{n_t} \frac{C_i}{E_i}, \quad t=1, \dots, T.$$

(4. (2))

Trimmed mean of ratios estimator

In the presence of skewed observations, both the mean of ratios estimator and the ratio of means estimator can perform badly; they are sensitive to a small number of outliers. A family of robust alternatives can be derived by trimming a fraction of the observations at each tail of their distribution. For example, the median is a 50 percent trimmed mean. Removing 15 percent from each end of the ordered observations is a 15 percent trimmed mean. A trimming proportion of 10% to 20% produces reasonably behaved estimators over a wide range of conditions. We define the trimmed mean of ratios estimator with trimming proportion α by

$$R_{tr(\alpha), t} = \frac{1}{n_t} \sum_{i=1}^{n_t} \frac{C_{ti}}{E_{ti}}, \quad t=1, \dots, T.$$

(4. (3))

Note that the mean of ratio estimator is a 0% trimmed mean estimator.

Appendix 4.2 - Graphical methods: Boxplots and trellis plots

Boxplots:

Boxplots are a useful technique for summarizing the distribution of a set of data, showing not only the location and spread of data but also skewness. Usually the vertical axis of a figure containing a boxplot is in the scale of the variable of interest. The graph consists of a box with a lower bound and upper bounds specified by the first quartile (25th percentile) and third quartile (75th percentile) of the data, respectively. The box shows the limits of the middle half of the data; the line inside the box represents the median (50th percentile). The box is bounded by "whiskers" drawn to the nearest data value not exceeding the standard span from the quartiles. The span for boxplots in this paper is 1.5 times the inter-quartile range. Data values beyond the bounds of the span are plotted using a circle and are considered outliers.

Trellis Plots:

Trellis plots are a recent innovation in graphical data analysis implemented in the S-Plus statistical software package (Mathsoft 1995). The salient feature of a Trellis plot is that it consists of a rectangular array of panels with columns, rows, and pages. Each panel of a Trellis plot is formed by subsetting, or *conditioning*, the data by the values of additional variables. For example, each panel might consist of an x versus y scatterplot for data corresponding to the level of a third variable, z. The variables x and y are referred to as the *panel variables*, while z is called the *conditioning* or *given variable*. Each panel of the Trellis plot is read in the usual manner for a graph: left to right and bottom to top. The panels should be read in the same order since the value of the conditioning variable increases from left to right and from bottom to top.

The top of each panel consists of a *strip label* that indicates the value of the given variable. For a discrete factor, such as fishing locality, the strip label might contain the name or code for each locality. A dark bar within each strip indicates the ordering of the given variable. In the case of a continuous conditioning variable there are too many unique values at which to plot a graph. Instead, the data are grouped by intervals of the conditioning variable. The proportion of data included within each group is indicated by the darkened strip within each strip label. Usually there is some degree of overlap of data between adjacent panels to provide a smooth transition over the range of the given variable. The size of each group is chosen to provide approximately the same number of observations within each panel, thus, the visual weighting of the panels is similar. The groups are ordered from low to high so that the value of the conditioning variable increase as the panels go from left to right and bottom to top.

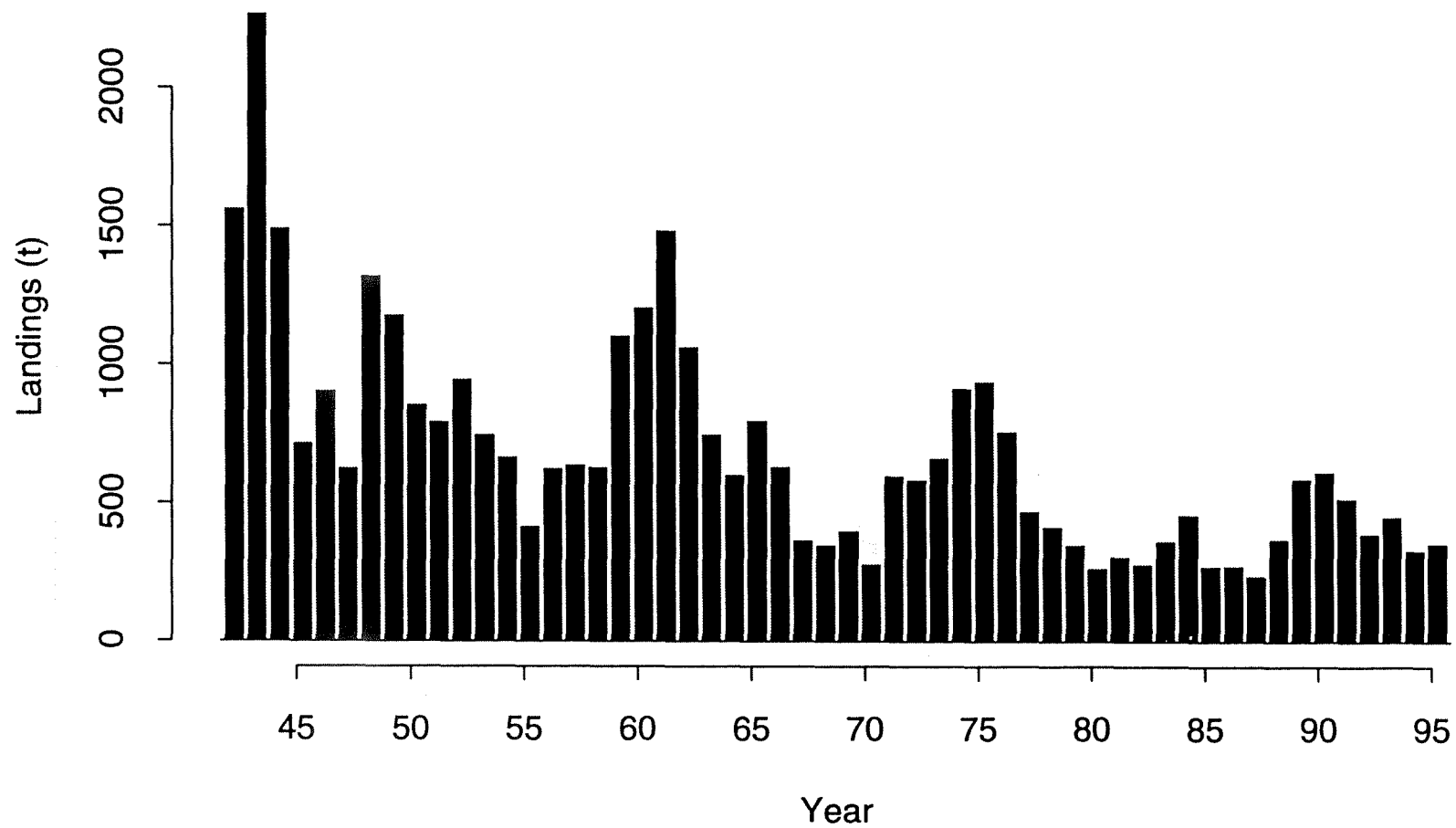


Fig. 4.1. Landings from the 'southern' stock of petrale sole in British Columbia, 1942-95.

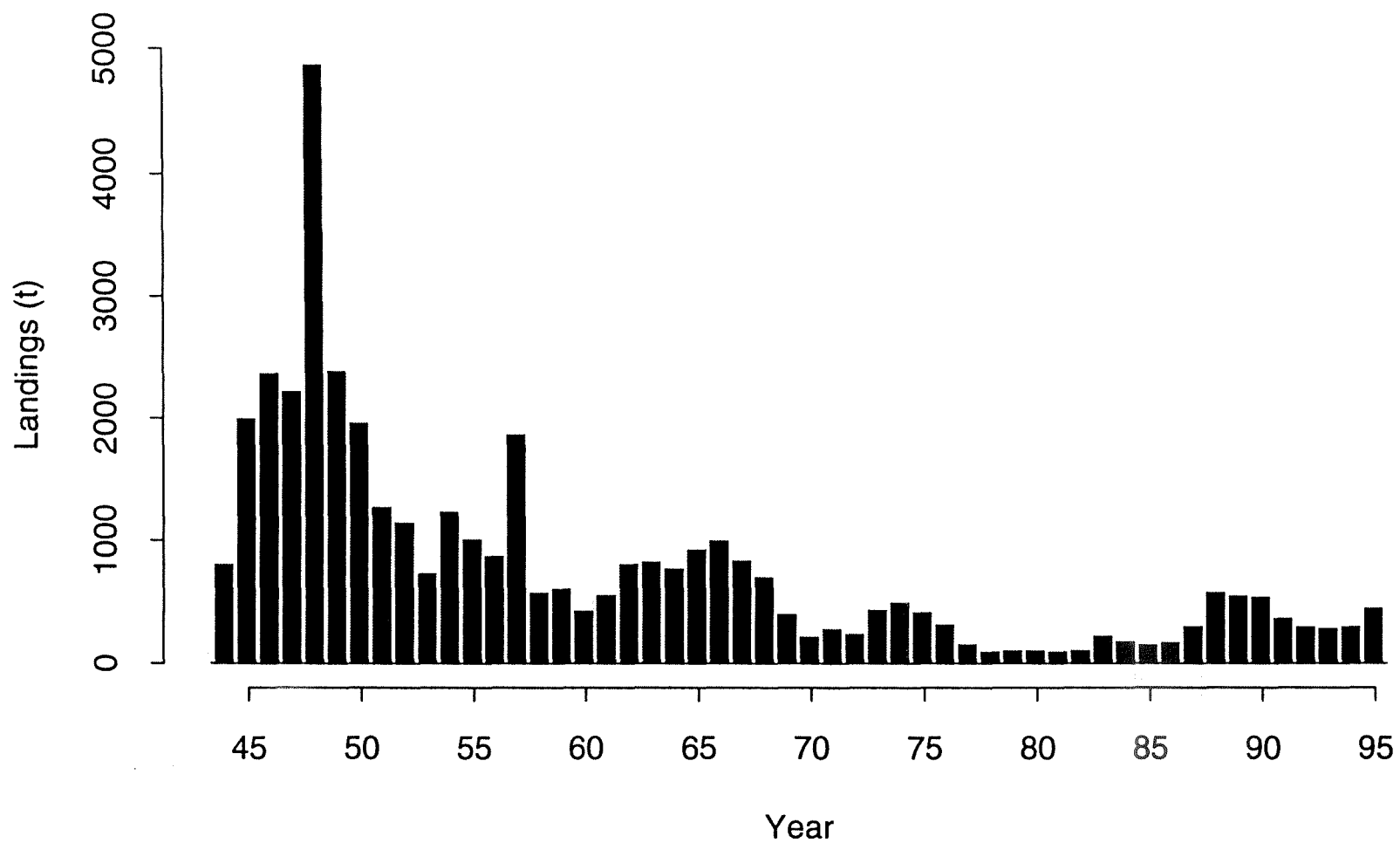


Fig. 4.2. Landings from the 'northern' stock of petrale sole in British Columbia, 1944-95.

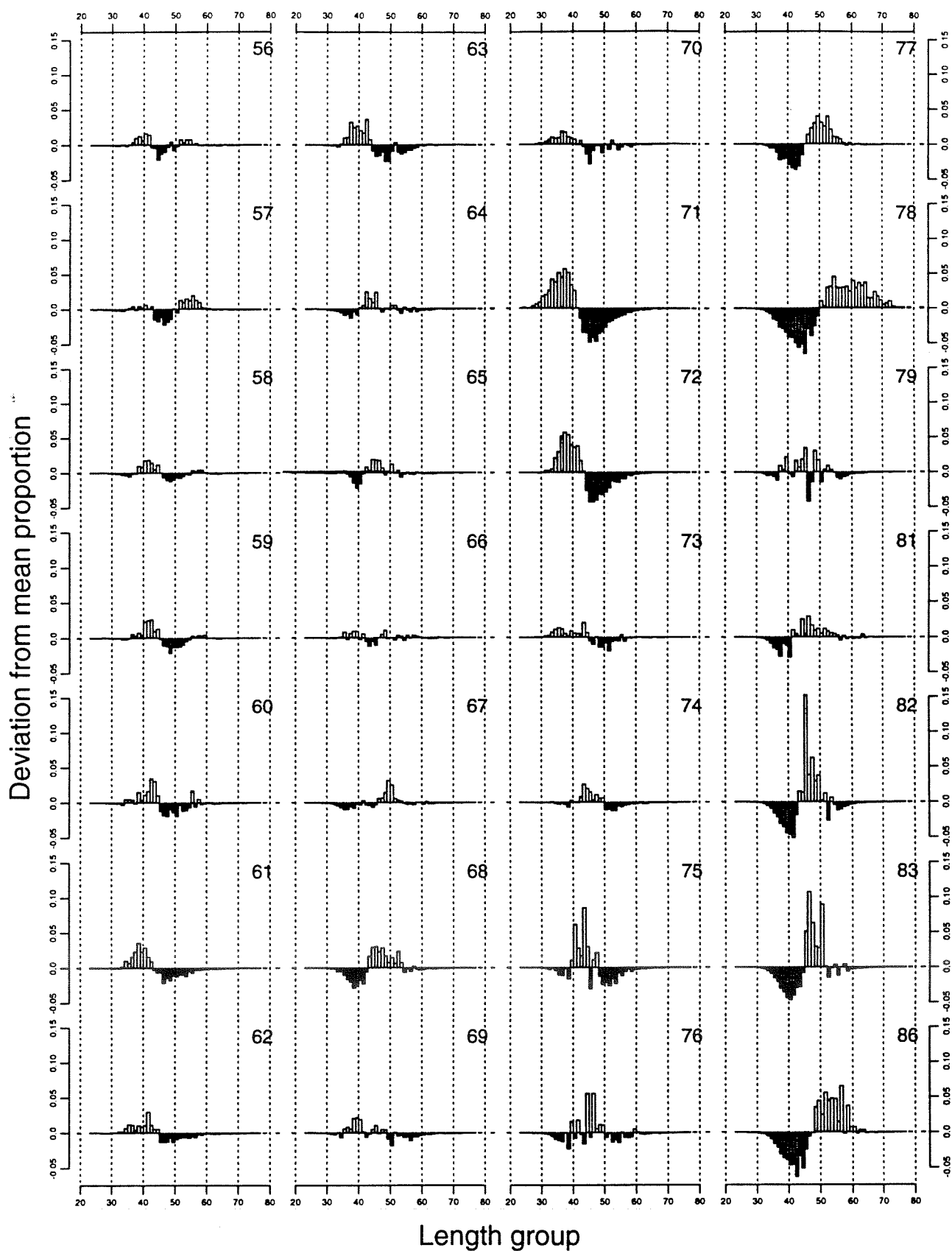


Fig. 4.3. Length frequency deviations from the long-term mean for the 'southern' stock of petrale sole, 1956-94.

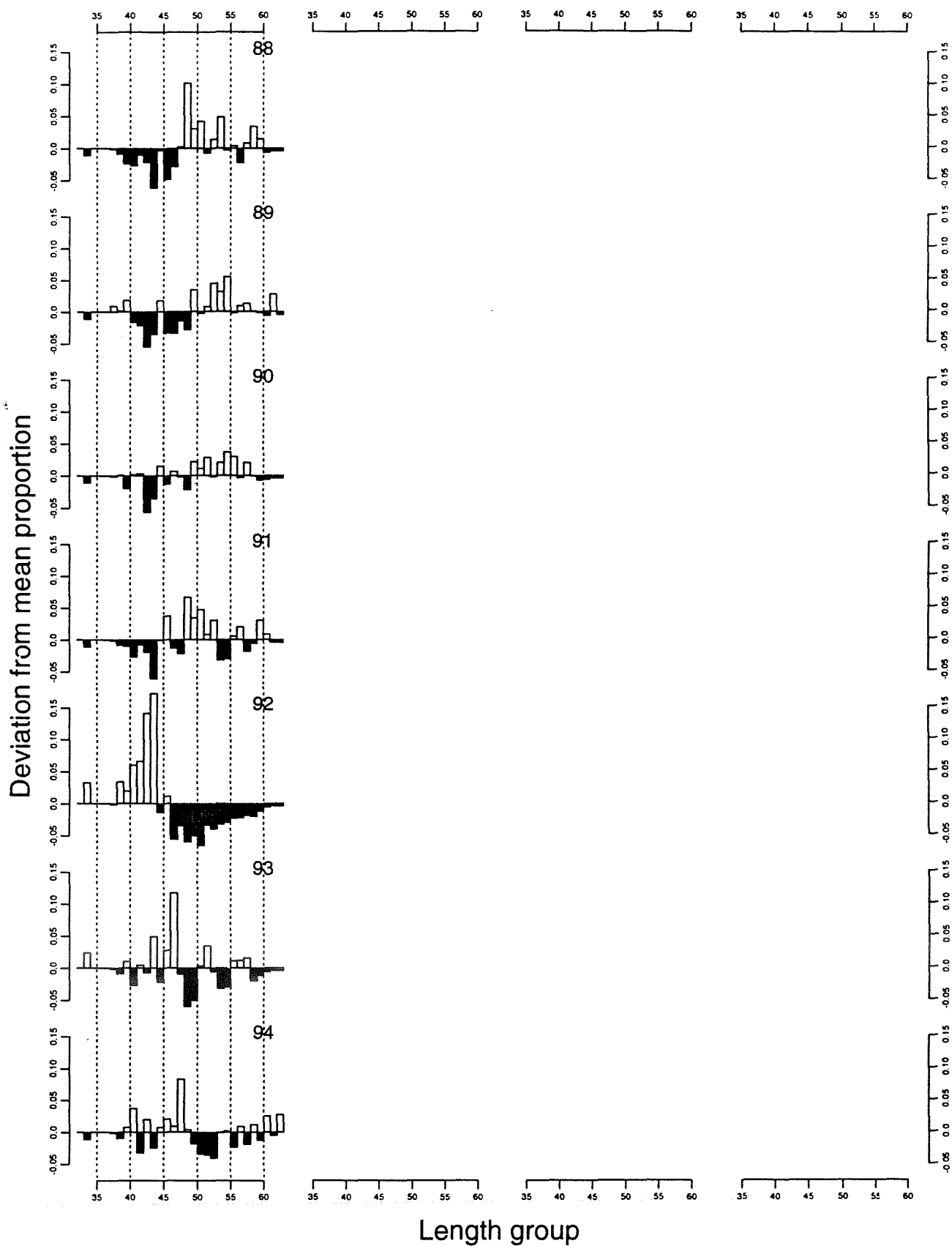


Fig. 4.3 - con't. Length frequency deviations from the long-term mean for the 'southern' stock of petrale sole, 1956-94.

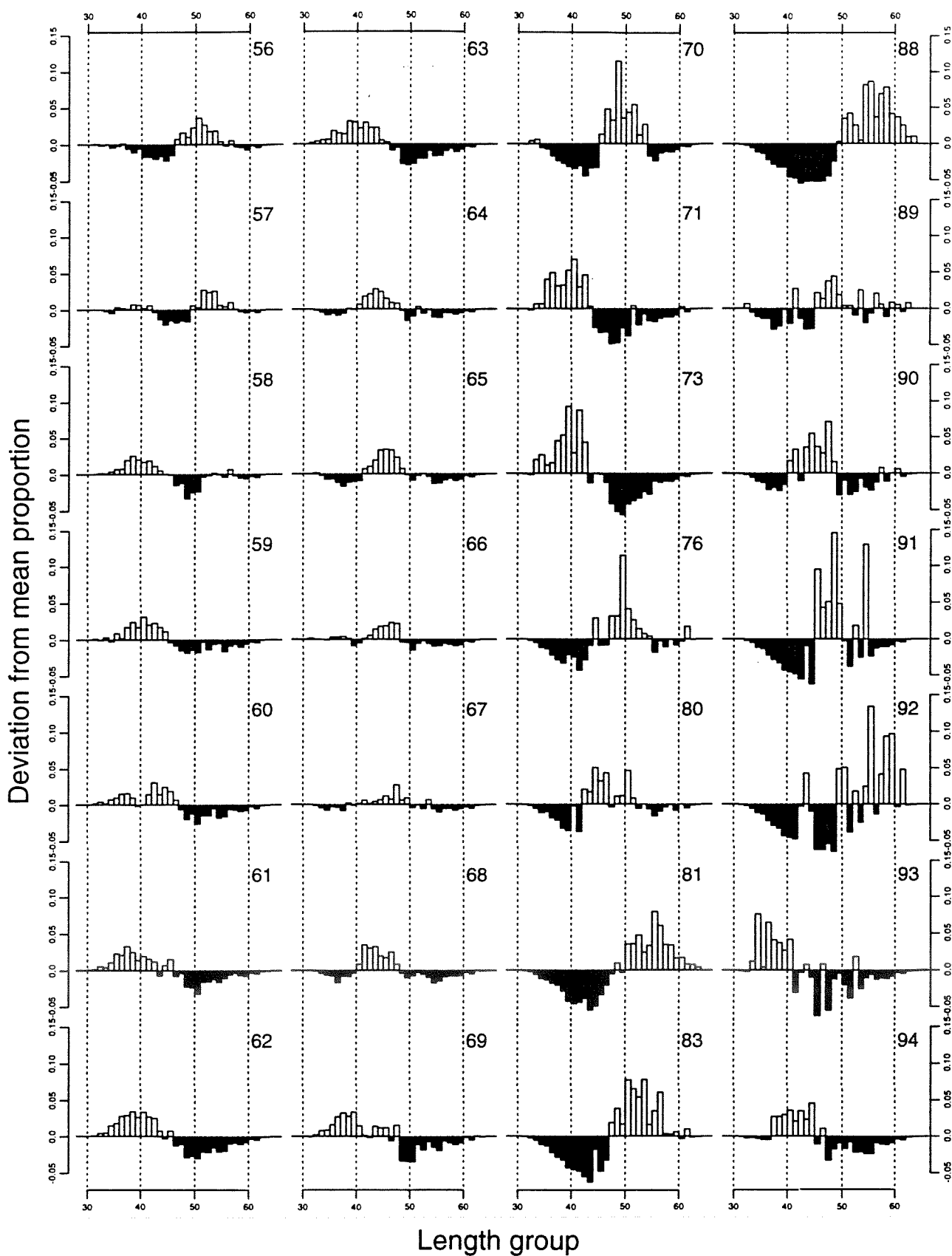


Fig. 4.4. Length frequency deviations from the long-term mean for the 'northern' stock of petrale sole, 1956-94.

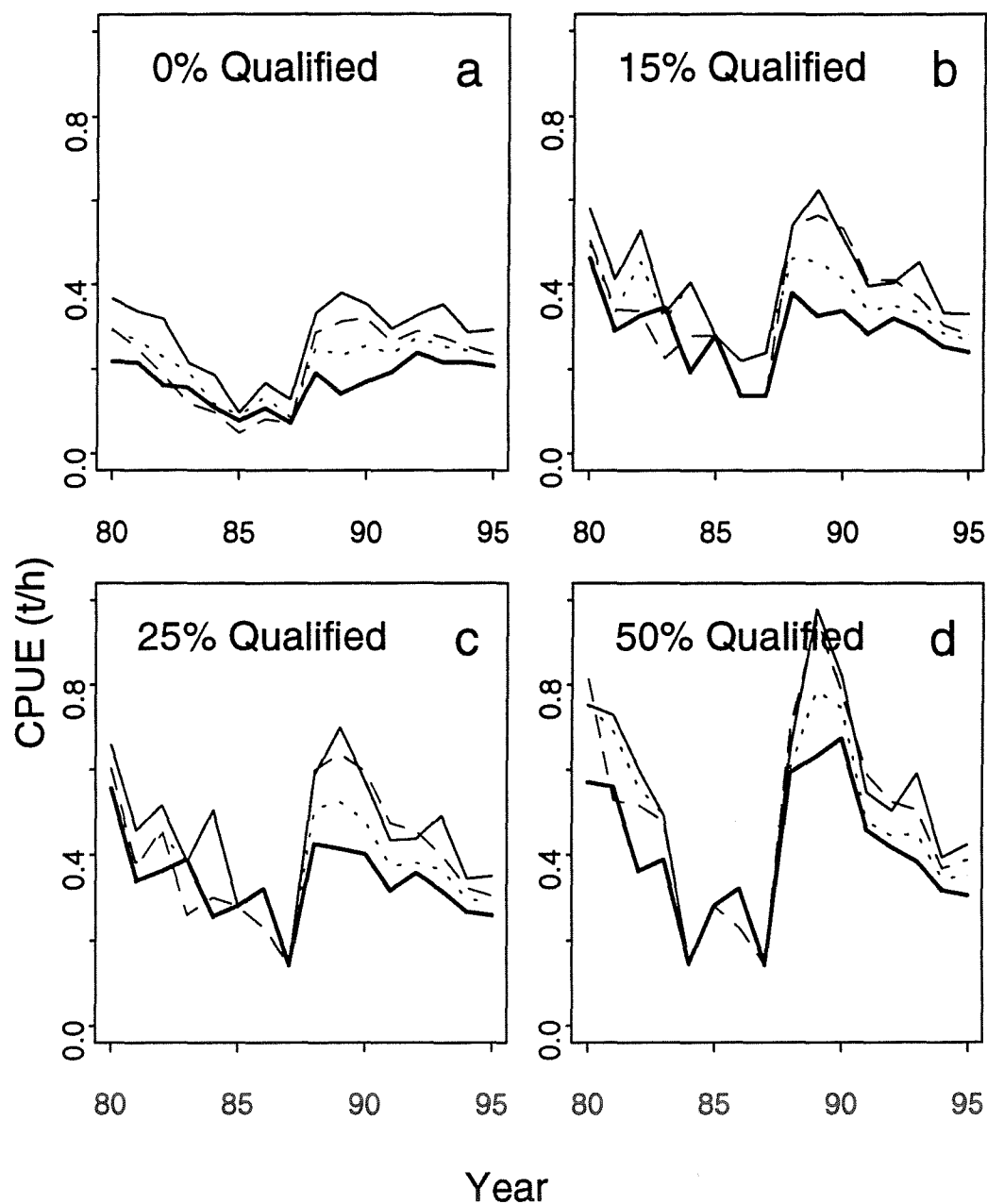


Fig. 4.5. Area 3CD Dover sole CPUE series (t/h) by year for four levels of qualification ranging from 0% to 50%. Within each panel (a-d) CPUE is computed using four estimators (see Appendix 4.1): ratio of means (long dash line), mean of ratios (solid thin line), 10% trimmed mean of ratios (short dash line), and 50% mean of ratios (solid thick line).

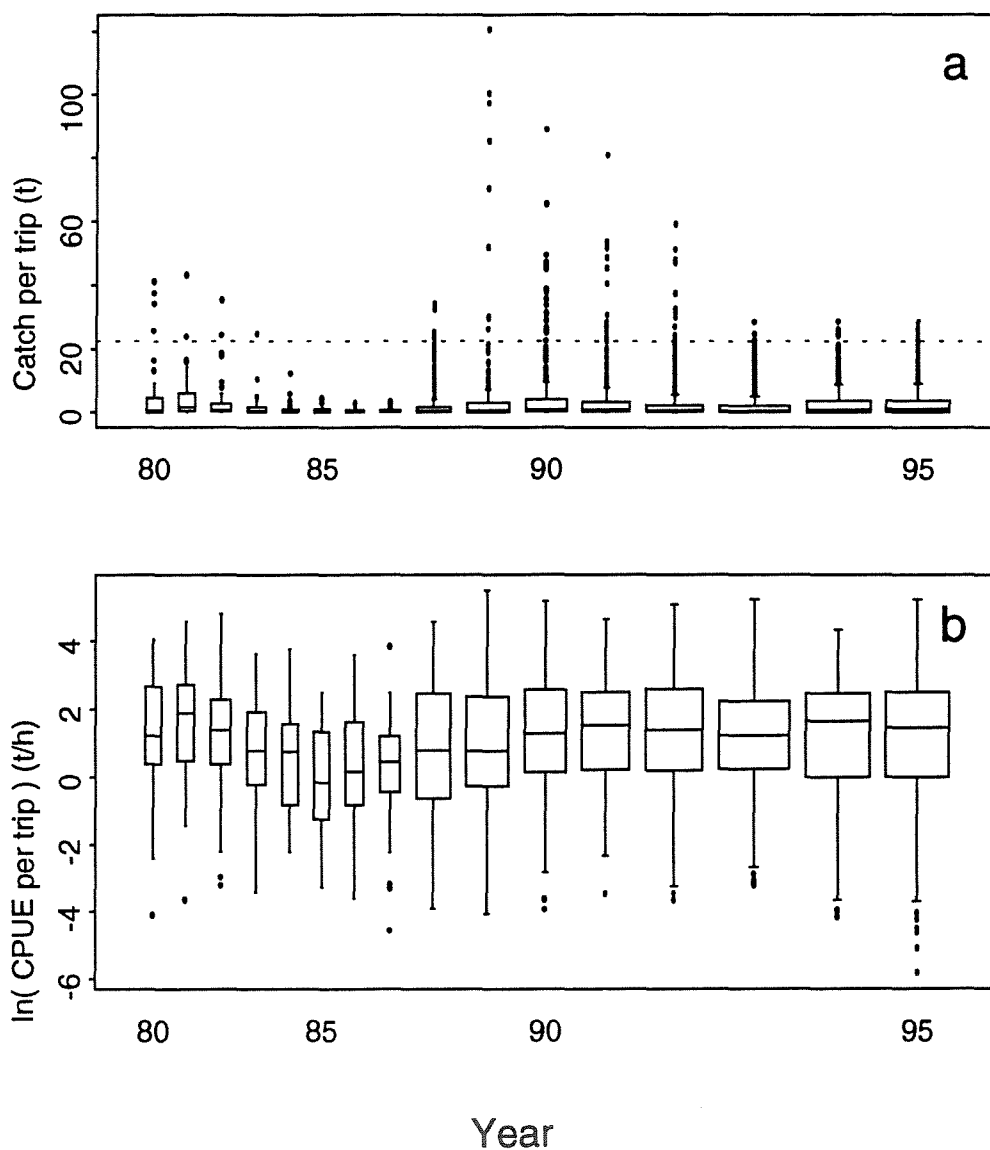


Fig. 4.6. Boxplots of Area 3CD Dover sole catch per trip (t) by year. Box plot width is proportional to the number of observations within each year. The horizontal dotted line represents the maximum trip limit of 50,000 lb (23t) applied to the fishery beginning in 1993. A clear truncation of extreme landings from highs in 1989 to 1992 can be seen.

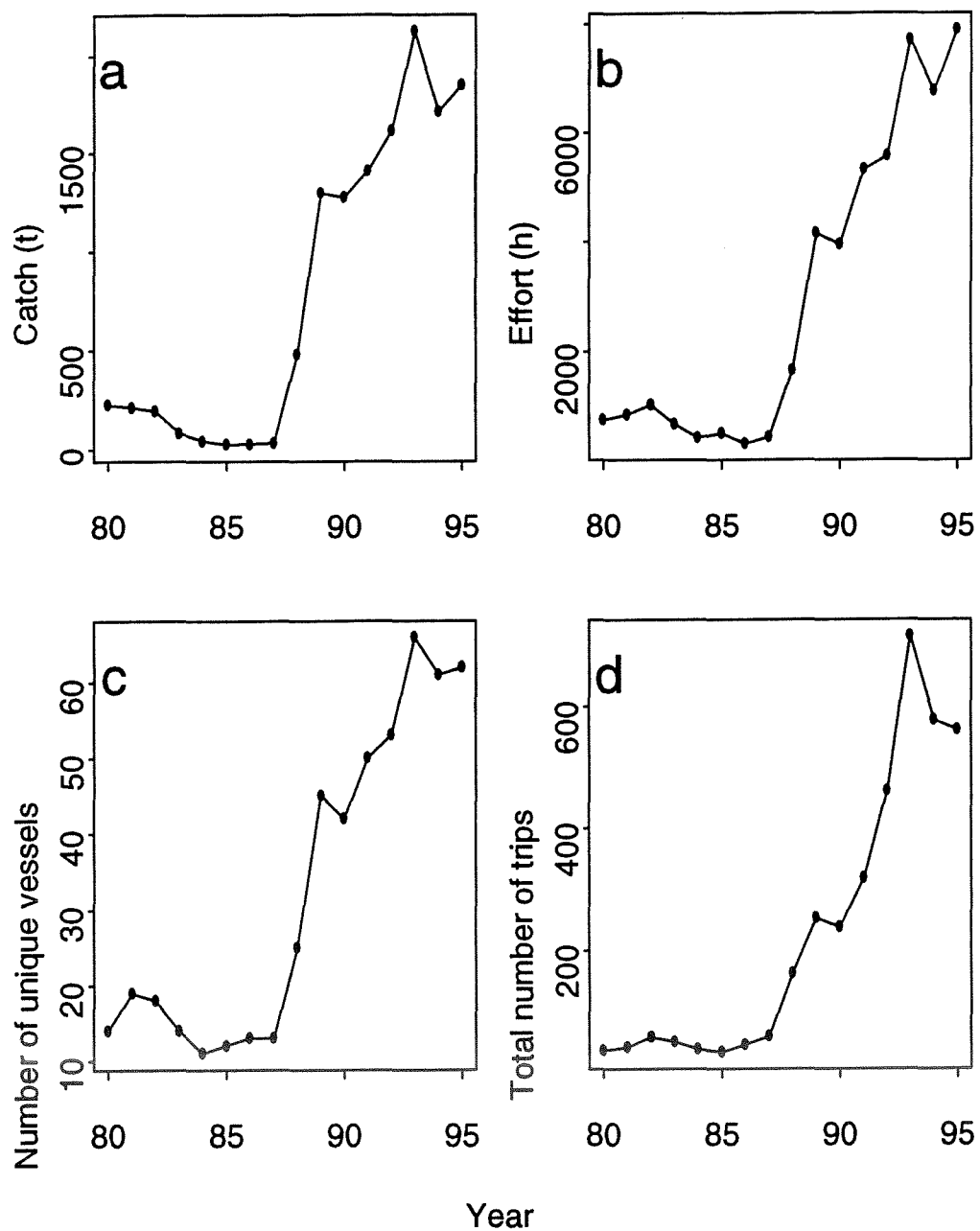


Fig. 4.7. Panels (a-d) depict catch (t), effort (h trawled), the number of unique vessels, and the total number of trips by year, respectively.

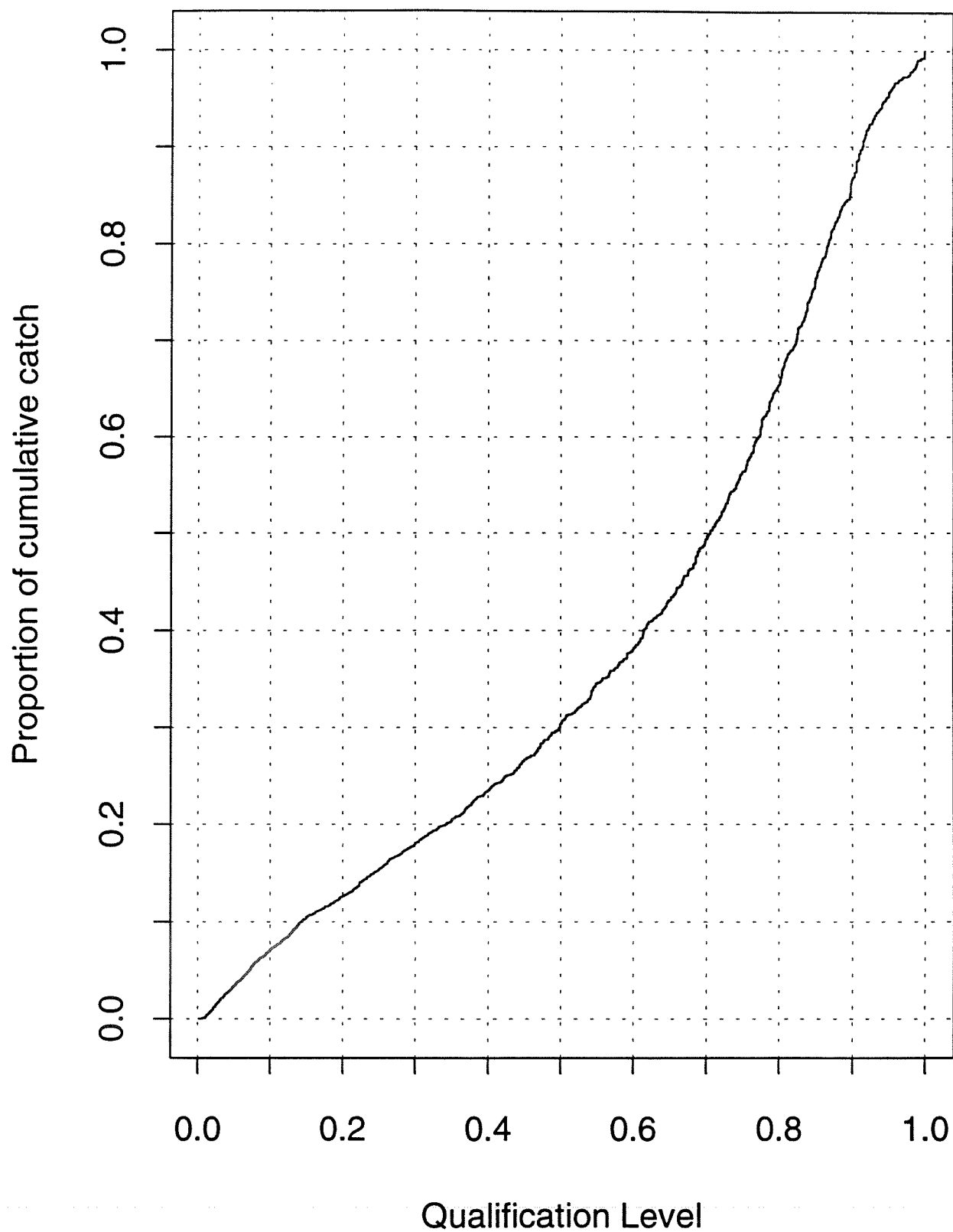


Fig. 4.8. Plot of cumulative percent catch as a function of qualification level for the period 1988 to 1995.

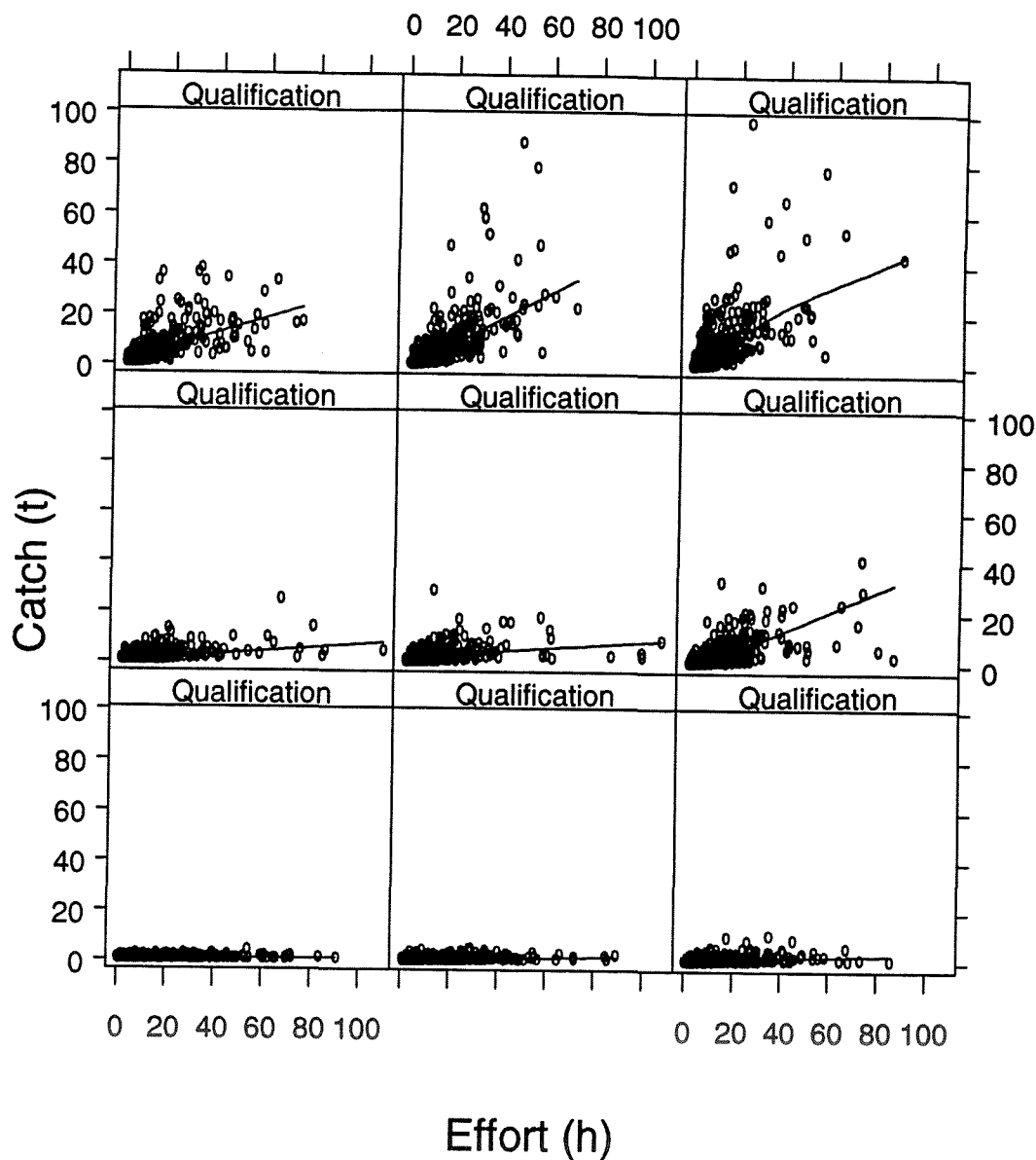


Fig. 4.9. Trellis plot of area 3CD Dover sole catch (t) as a function of effort (h trawled) given qualification level. Qualification consists of nine ranges with each range containing a similar number of observations (allowing for an overlap of approximately 12%): 0.002-0.004, 0.039-0.088, 0.081-0.165, 0.153-0.284, 0.270-0.430, 0.411-0.594, 0.575-0.731, 0.722-0.849 and 0.838-1.000. A lowess smooth of the trend line is shown as a solid line within each panel. No relationship between catch and effort is apparent below qualification levels of about 0.4.

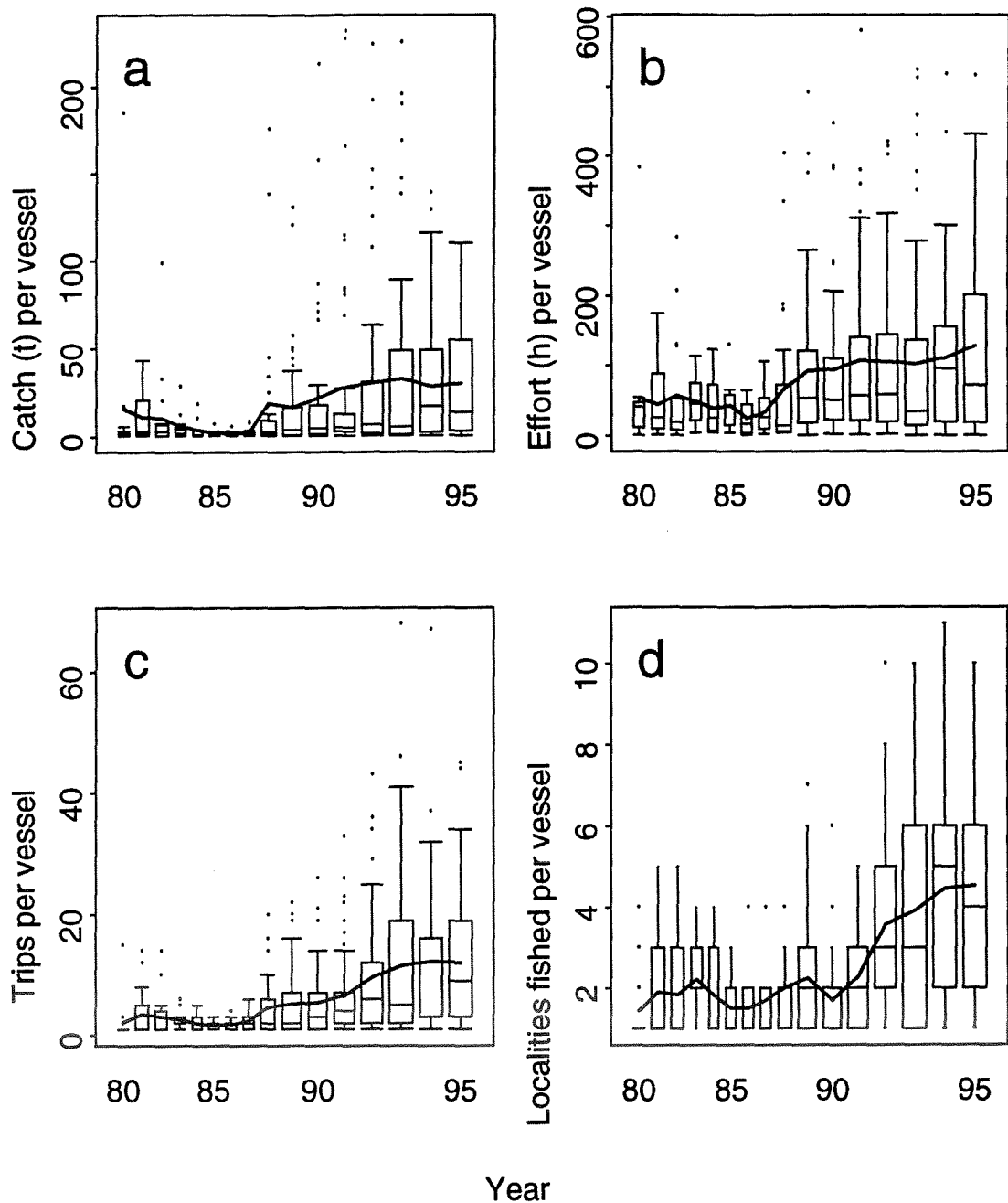


Fig. 4.10. Panels (a-d) show fleet dynamics on a vessel basis. Panel (a) shows boxplots of the catch (t) per vessel over time (years). Similarly, panels (b-d) show the annual distributions of effort (h trawled) per vessel, trips per vessel, and the number of unique localities fished per vessel. The width of the boxplots is proportional to the number of observations in each year.

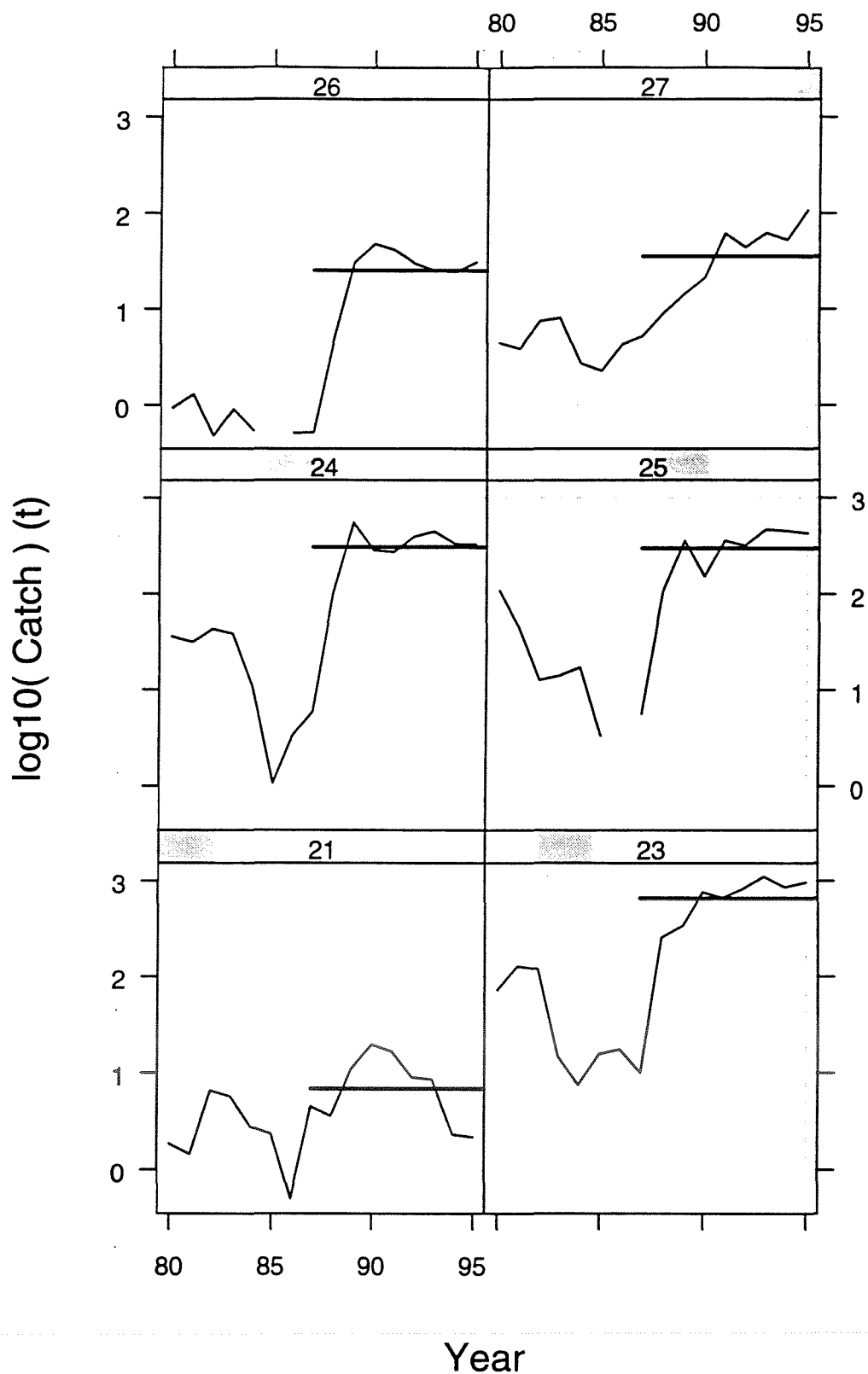


Fig. 4.11. Trellis plot of $\log_{10} (t)$ catch as a function of year given minor fishing area. The solid horizontal line in each panel represents the mean catch in the period from 1988 to 1995.

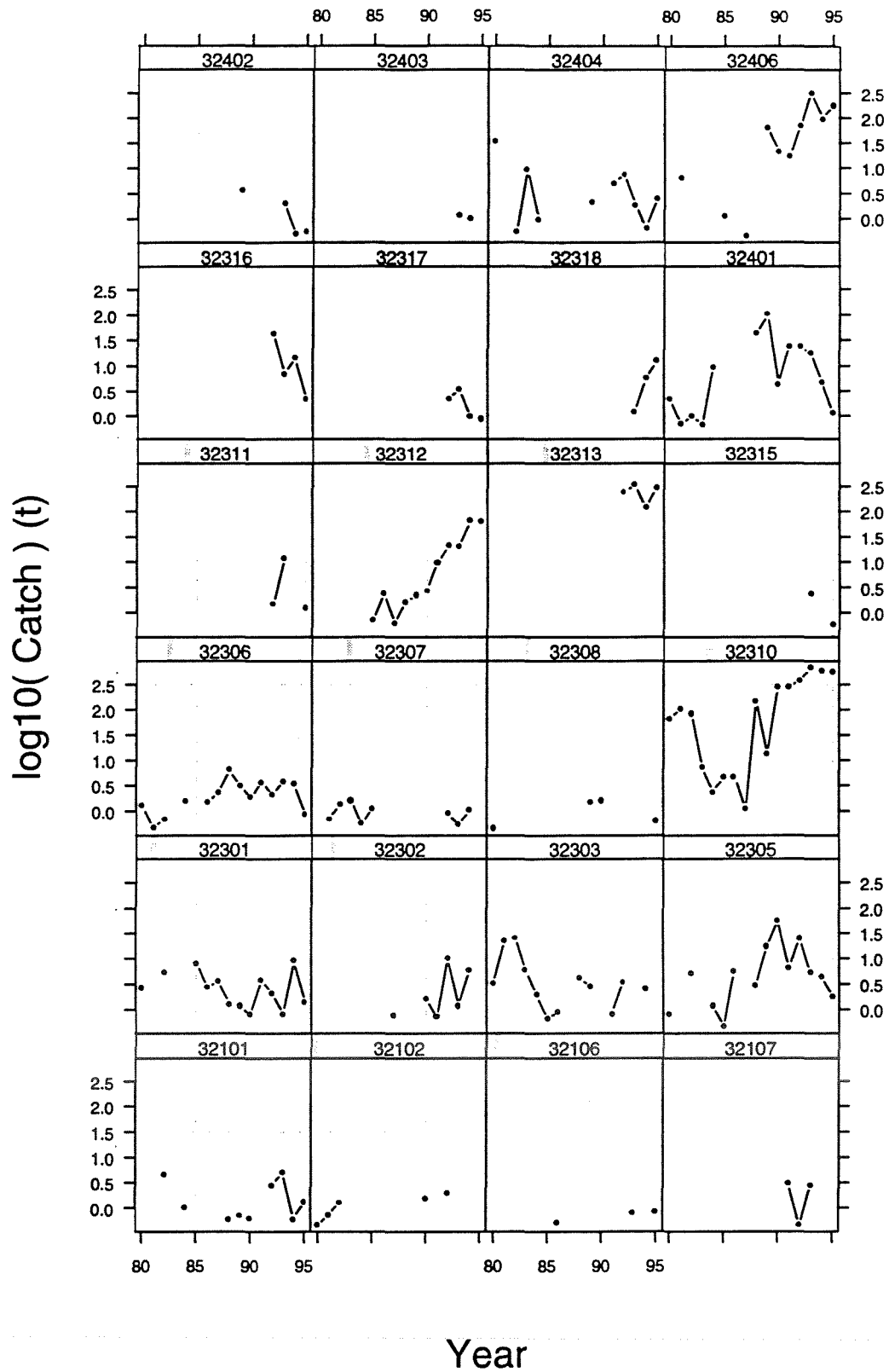


Fig. 4.12. Trellis plot of \log_{10} (t) catch as a function of year given fishing locality. The given label for each panel consists of the major area, minor area, and locality codes.

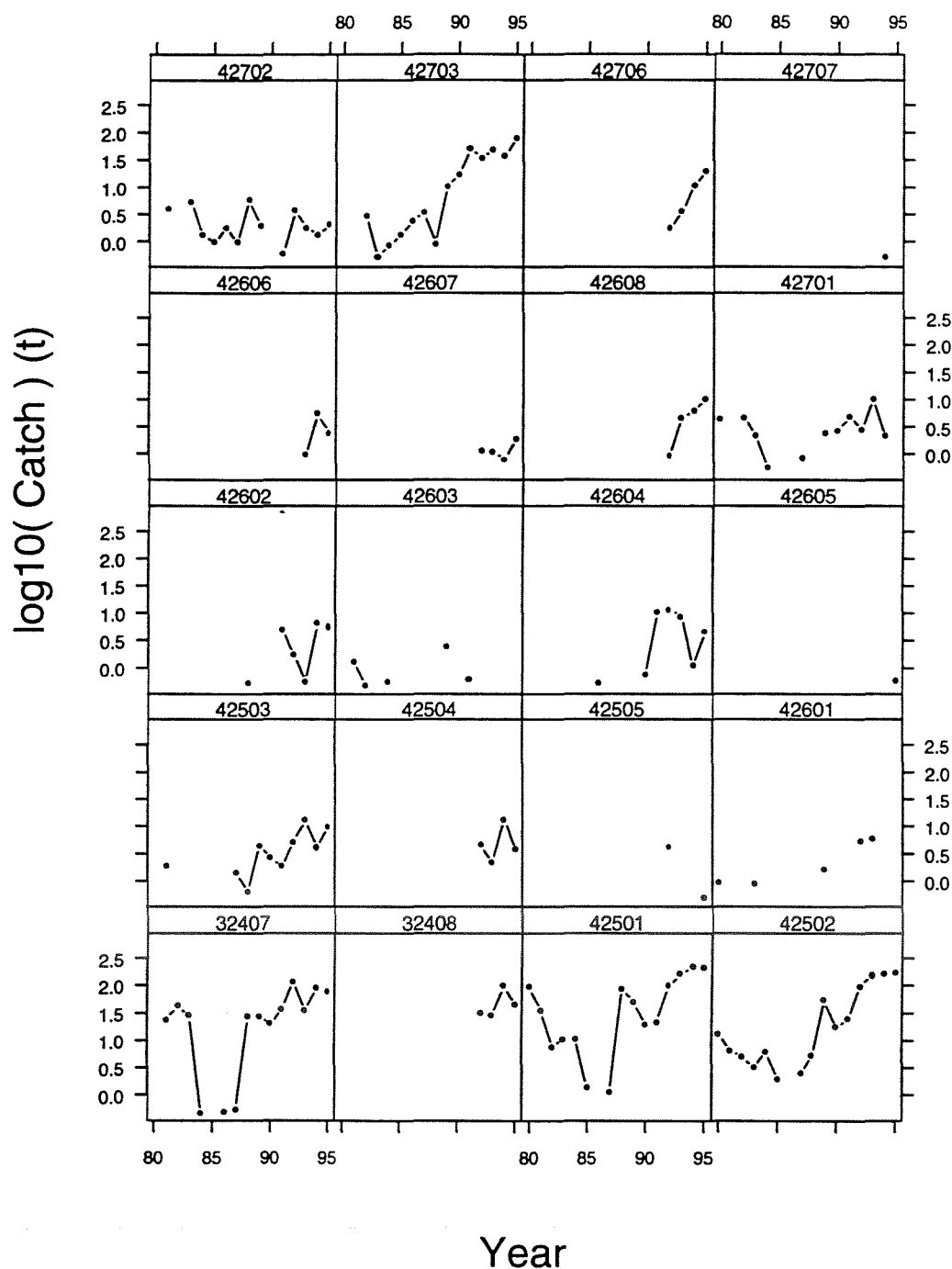


Fig. 4.12 - con't. Trellis plot of $\log_{10} (t)$ catch as a function of year given fishing locality. The given label for each panel consists of the major area, minor area, and locality codes.

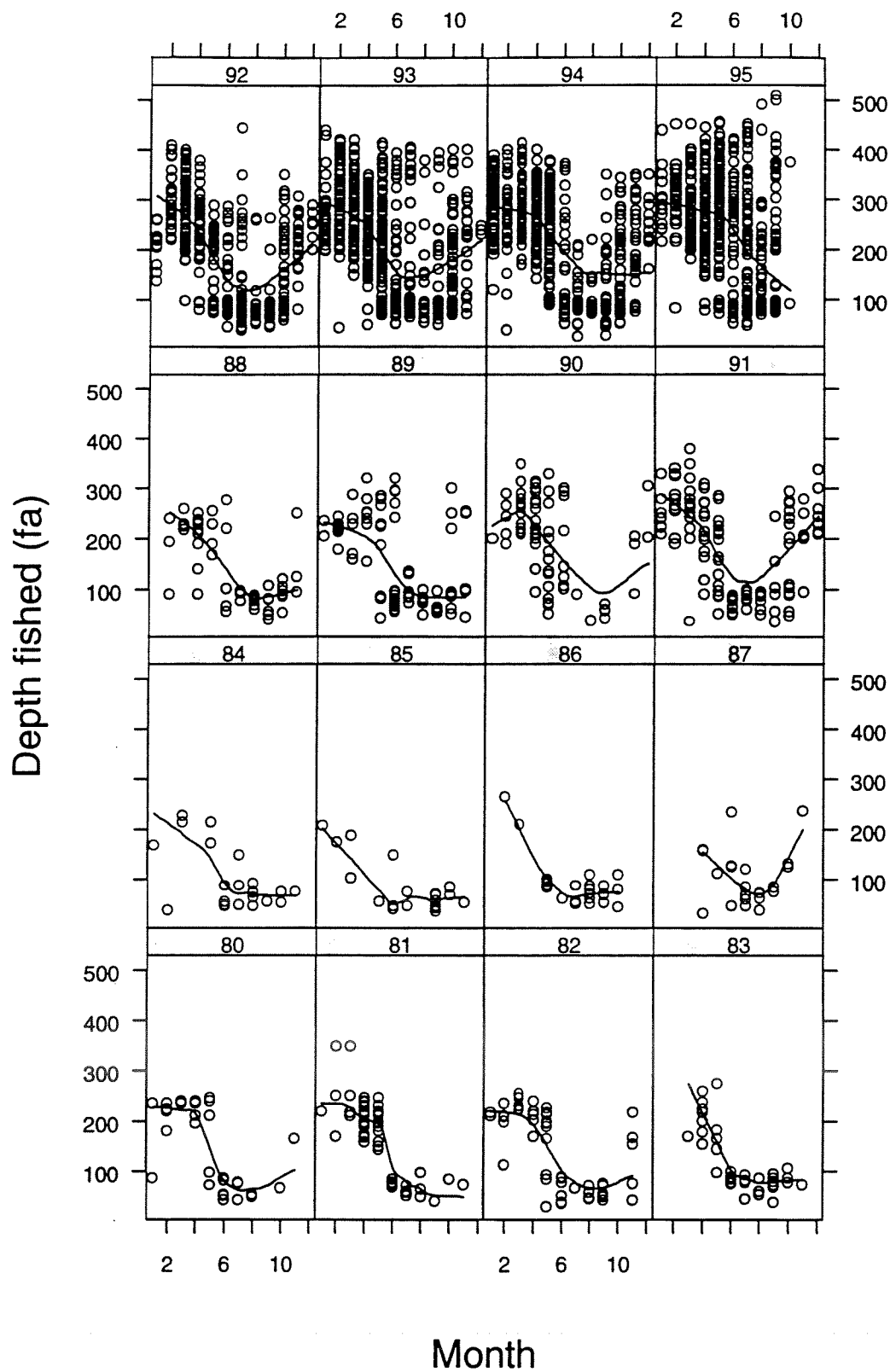


Fig. 4.13. Depth fished (fa) as a function of month given year. A cyclical pattern of deeper fishing (200-399 fa) in winter months is shown by the loess smooth (solid line).

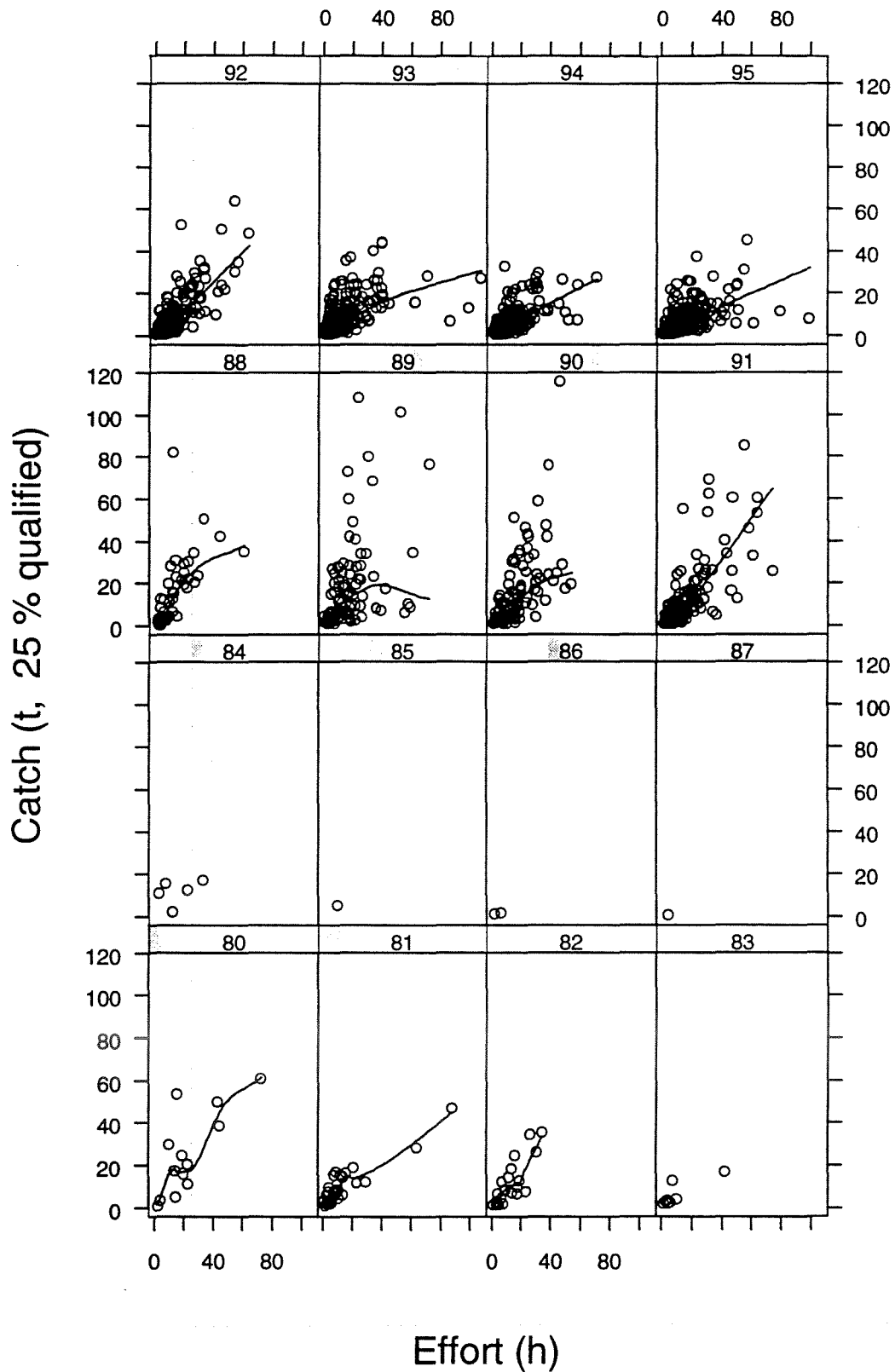


Fig. 4.14. Trellis plot of area 3CD Dover sole catch (t) as a function of effort (h trawled) given year. The catch is 25% qualified. Within each panel, the solid line represents a loess smooth of the trend.

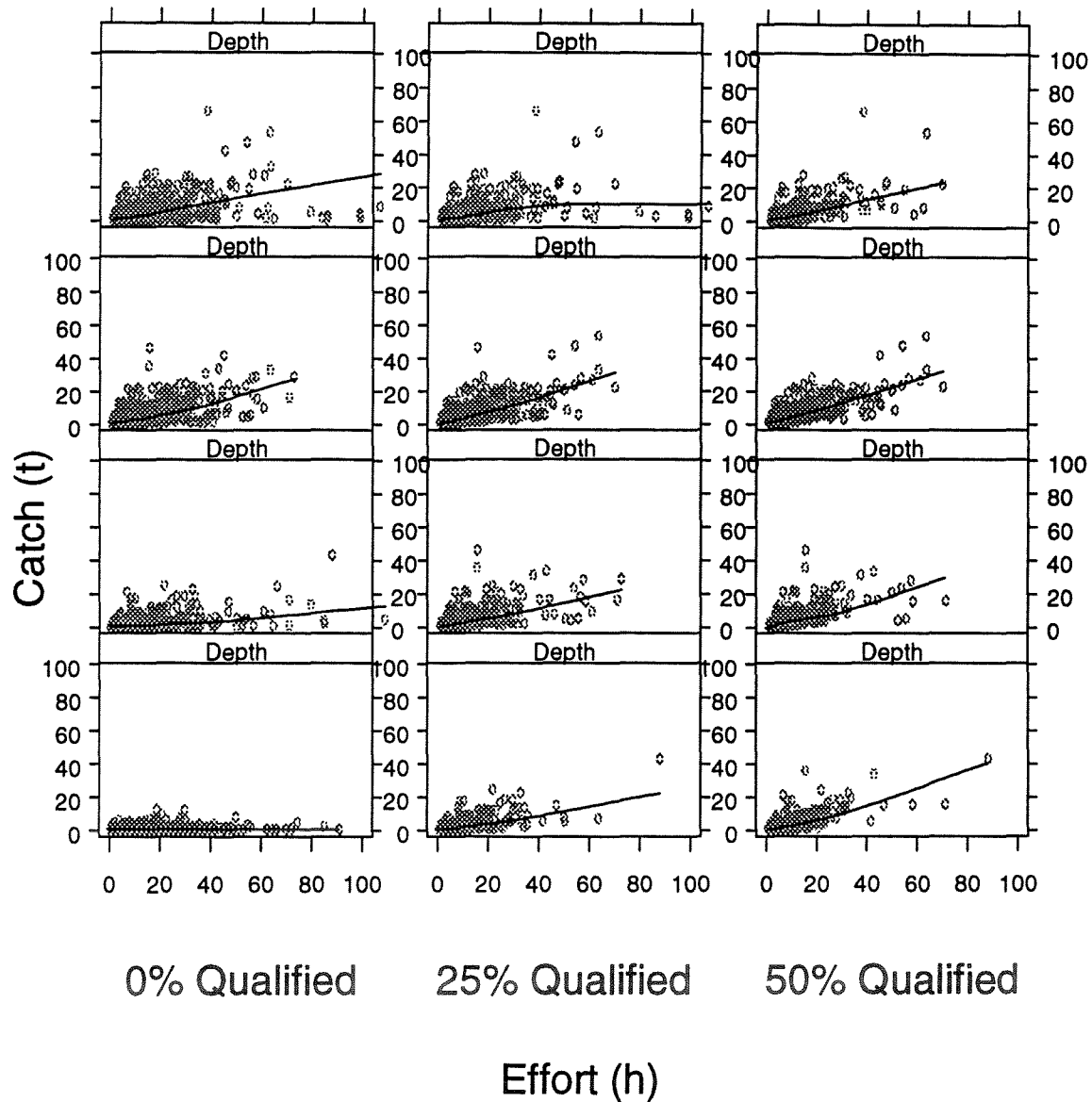


Fig. 4.15. Trellis plot of Area 3CD Dover sole catch (t) as a function of effort given depth. Depth consists of four ranges with each range containing a similar number of observations (allowing for an overlap of approximately 12%): 25-135 fa, 100-230 fa, 225-293 fa and 285-510 fa. The catch is 25% qualified. Within each panel, the solid line represents a loess smooth of the trend.

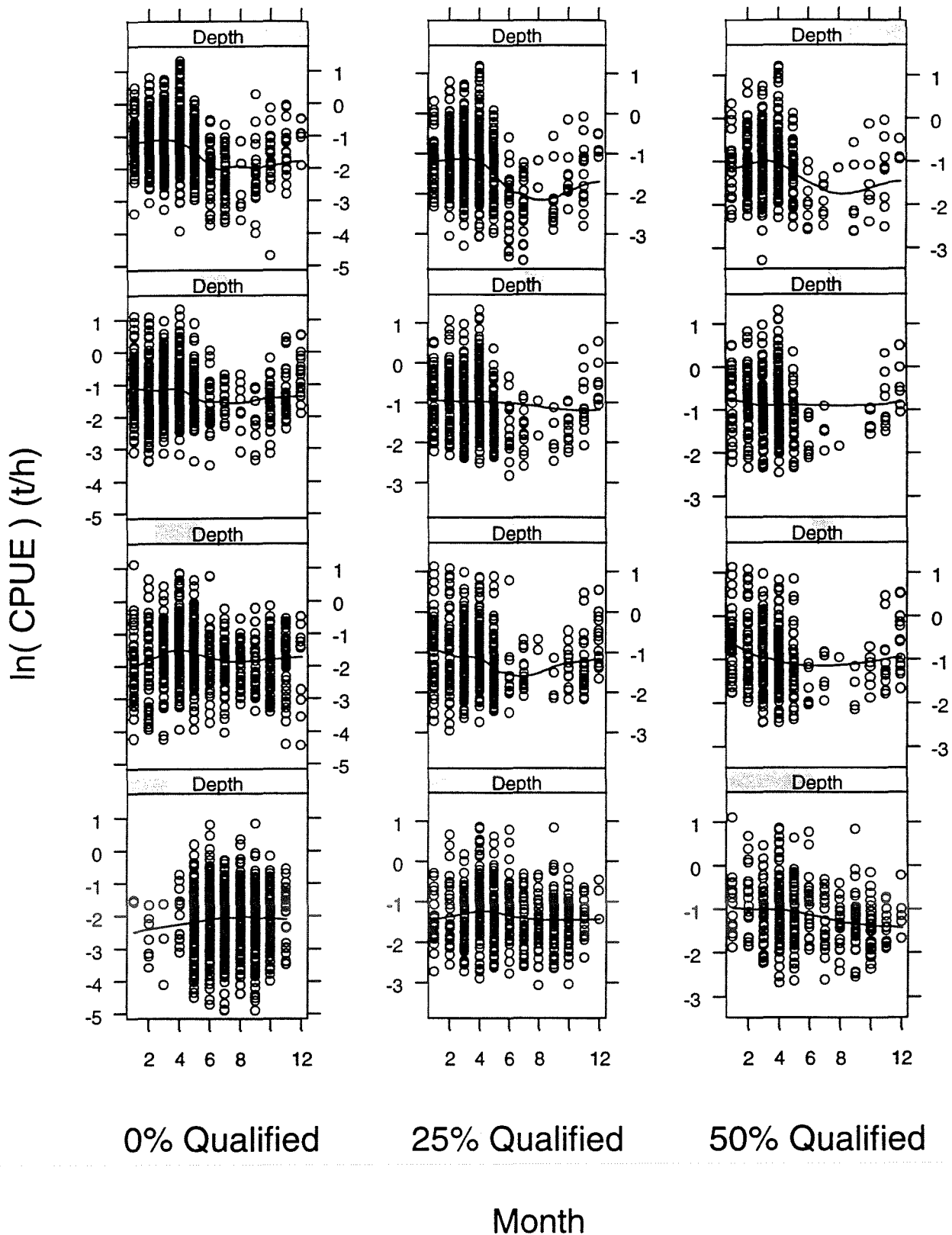


Fig. 4.16. Trellis plots of area 3CD Dover sole of log_e CPUE (t/h) as a function of month given depth (fa) for three levels of qualification. Within each panel, the solid line represents a loess smooth of the trend.

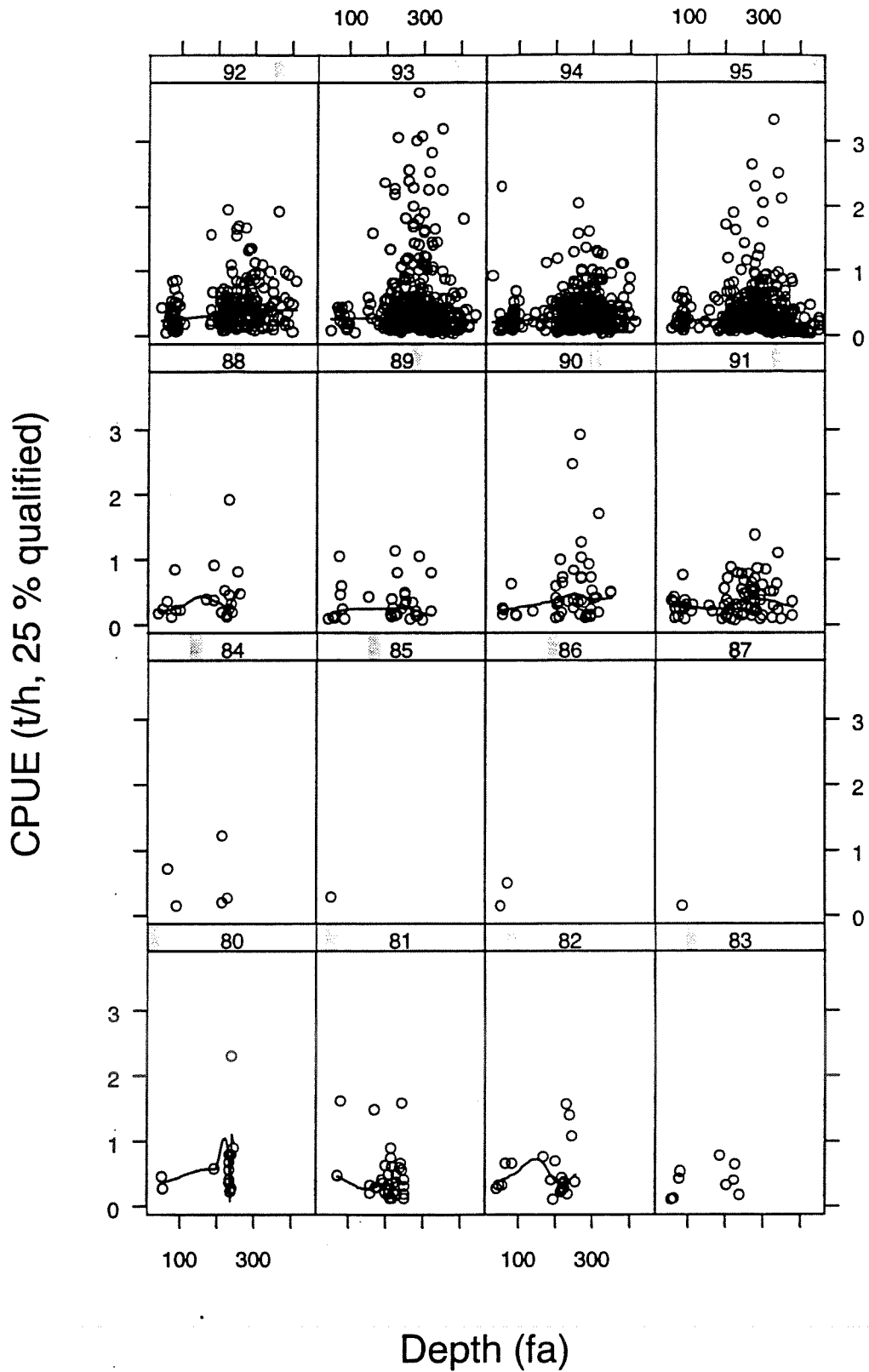


Fig. 4.17. Trellis plot of CPUE (t/h) as a function of depth (fa) given year. The CPUE index is 25 percent qualified. The solid trend line within each panel is produced using a loess smooth.

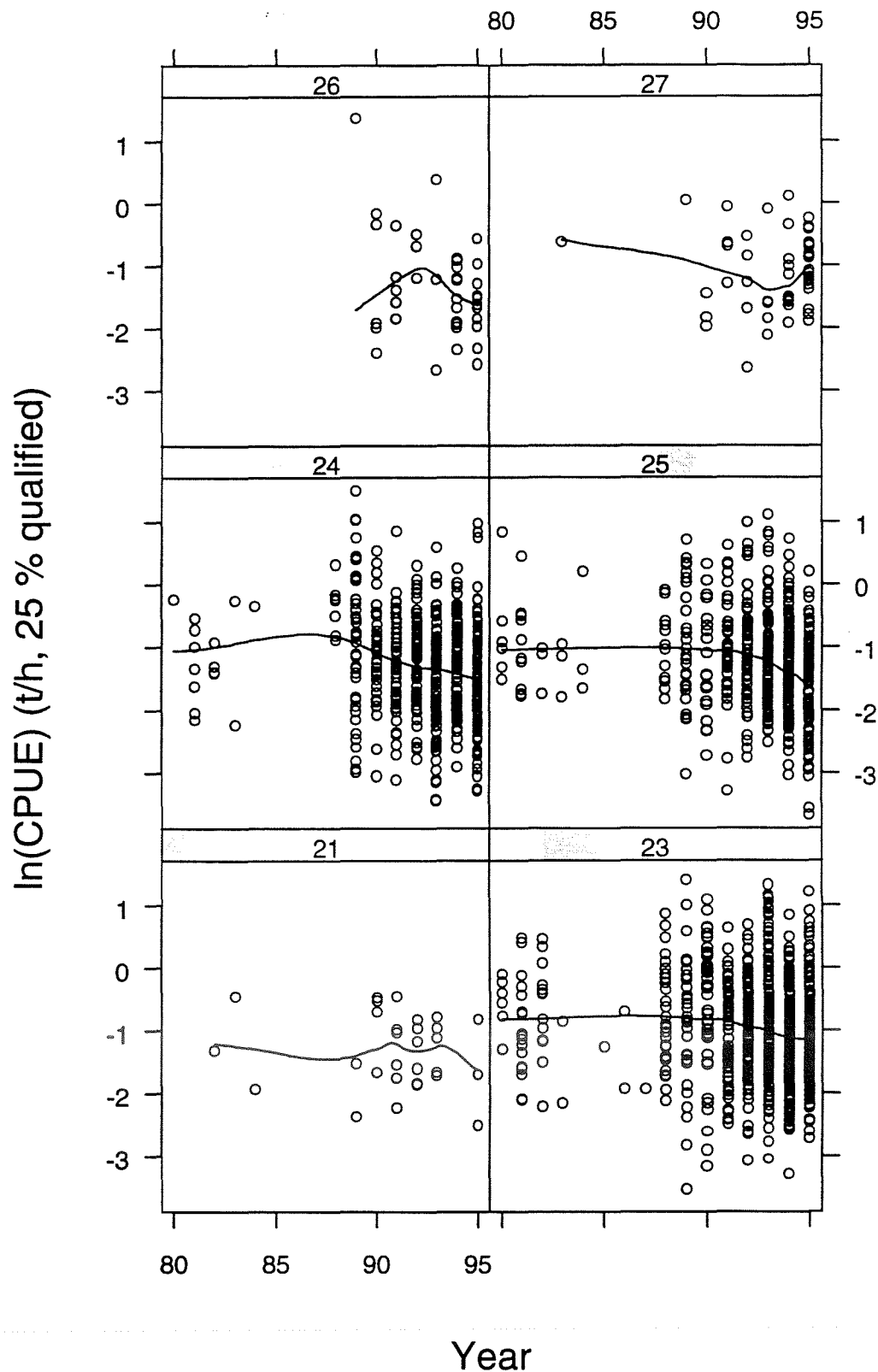


Fig. 4.18. Relationship between \log_e CPUE (t/h) and year for each minor area within area 3CD. The CPUE index is 25 percent qualified. The solid line within each panel is a loess smooth of the relationship between the CPUE index and year.

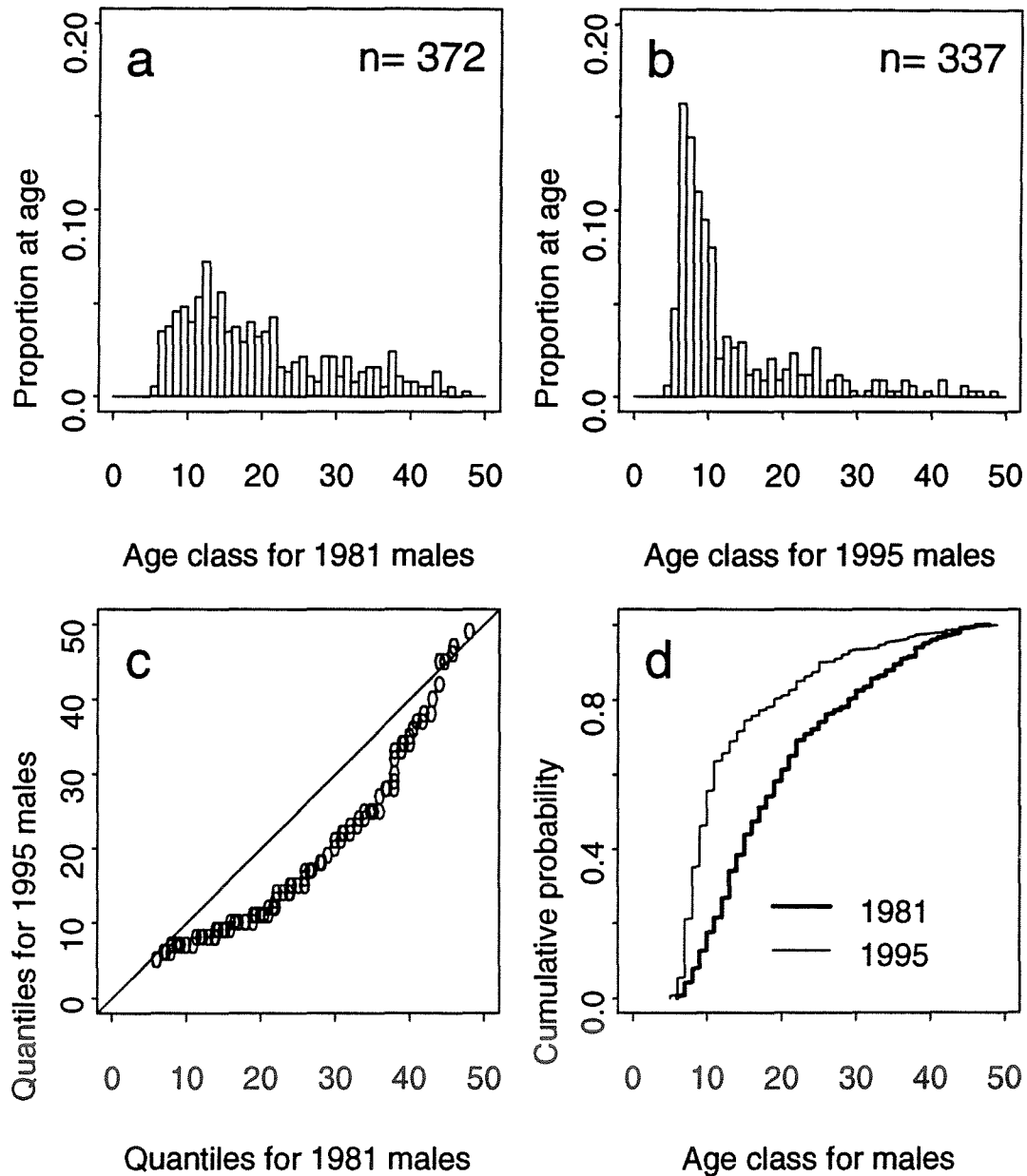


Fig. 4.19. Comparison of age distributions of male Dover sole between the 1981 and 1995 surveys. Panels (a) and (b) show histograms of the distribution of age classes for the 1981 and 1995 surveys, respectively. The distributions are directly compared using a quantile-quantile plot (panel c) and a cumulative probability plots (panel d).

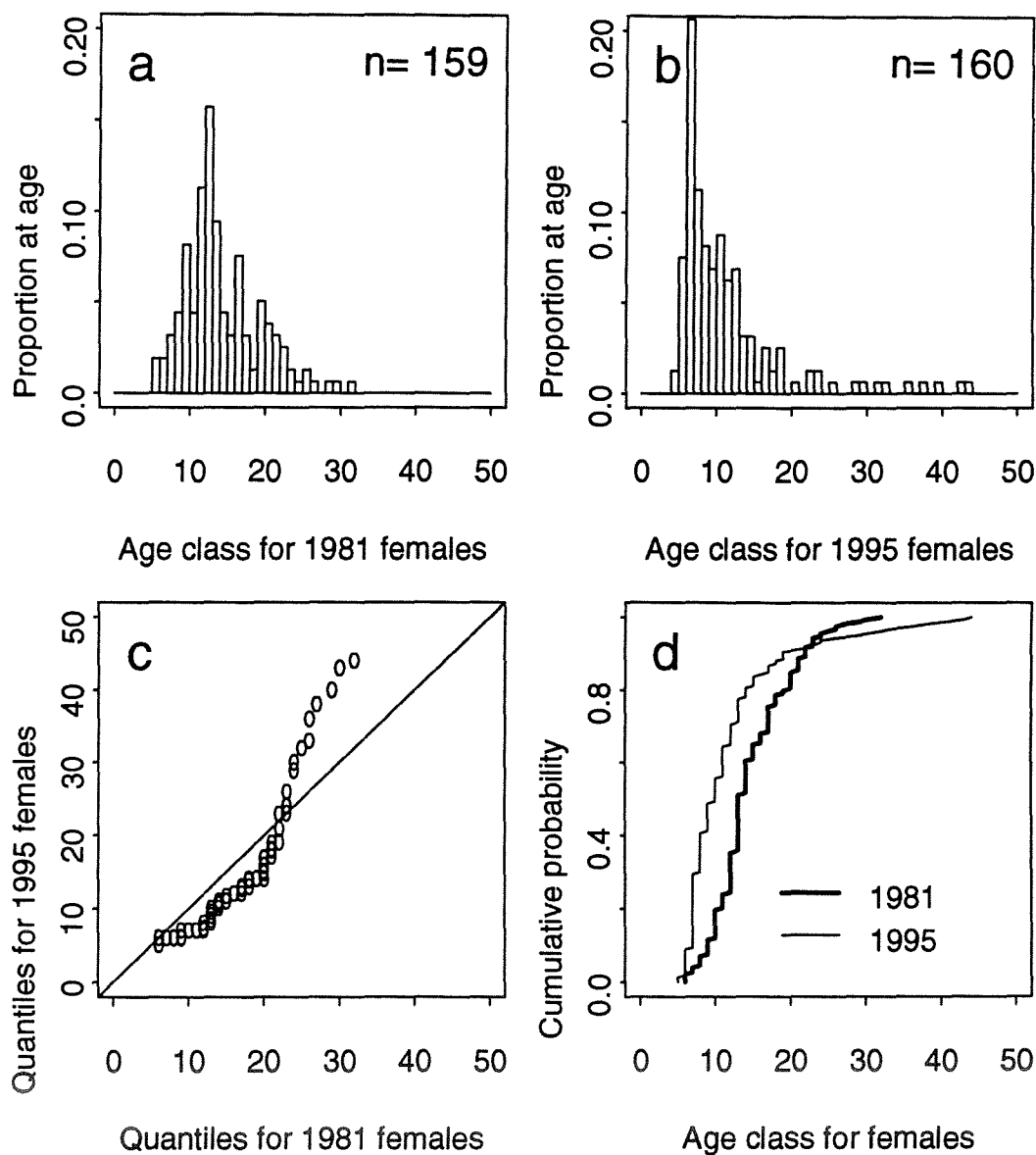


Fig. 4.20. Comparison of age distributions of female Dover sole between the 1981 and 1995 surveys. Panels (a) and (b) show histograms of the distribution of age classes for the 1981 and 1995 surveys, respectively. The distributions are directly compared using a quantile-quantile plot (panel c) and a cumulative probability plots (panel d).

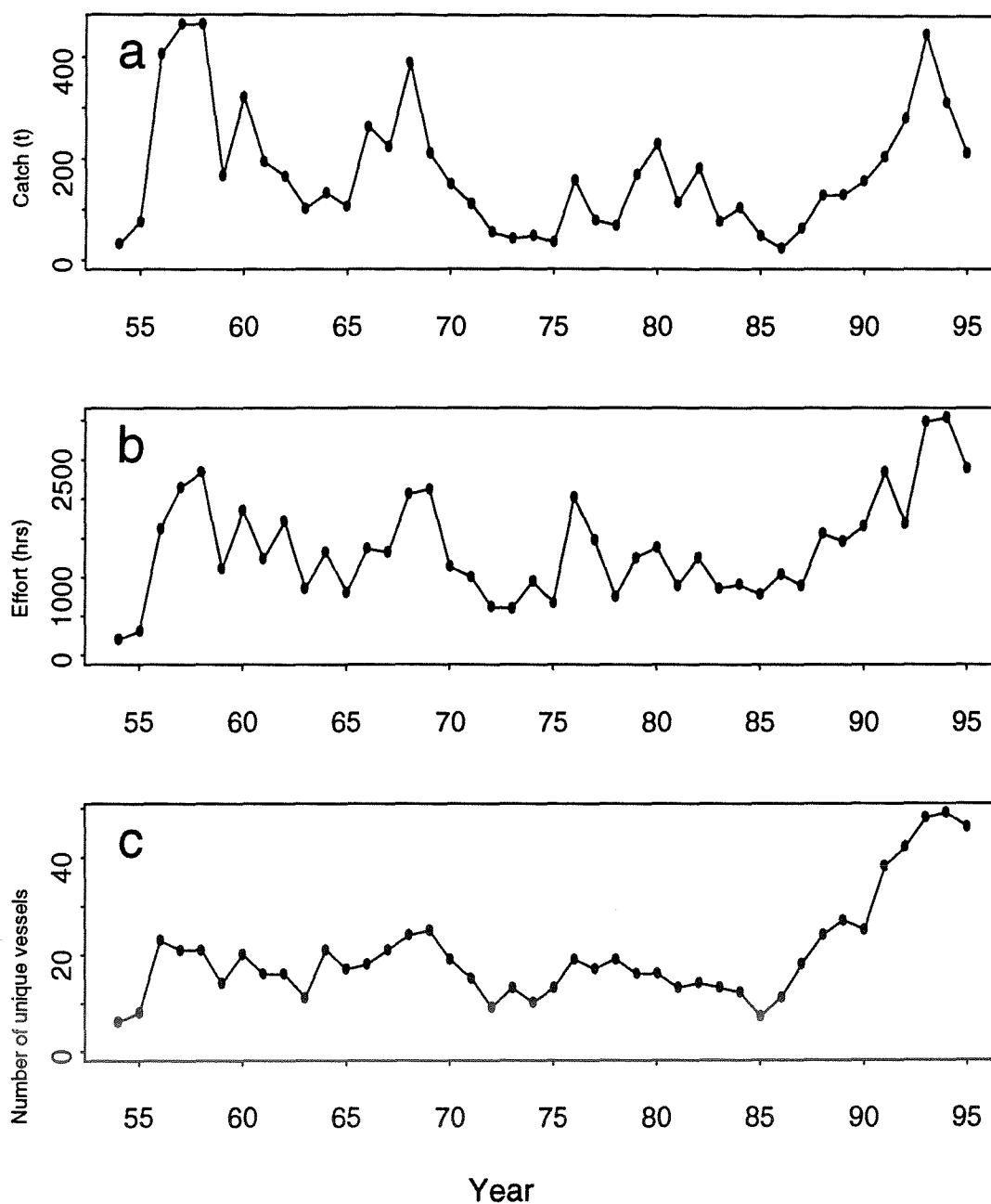


Fig. 4.21. Area 5A rock sole catch (panel a), effort (Panel b), and vessel participation (panel c) plotted against year. These series include data from the Canadian fishery only.

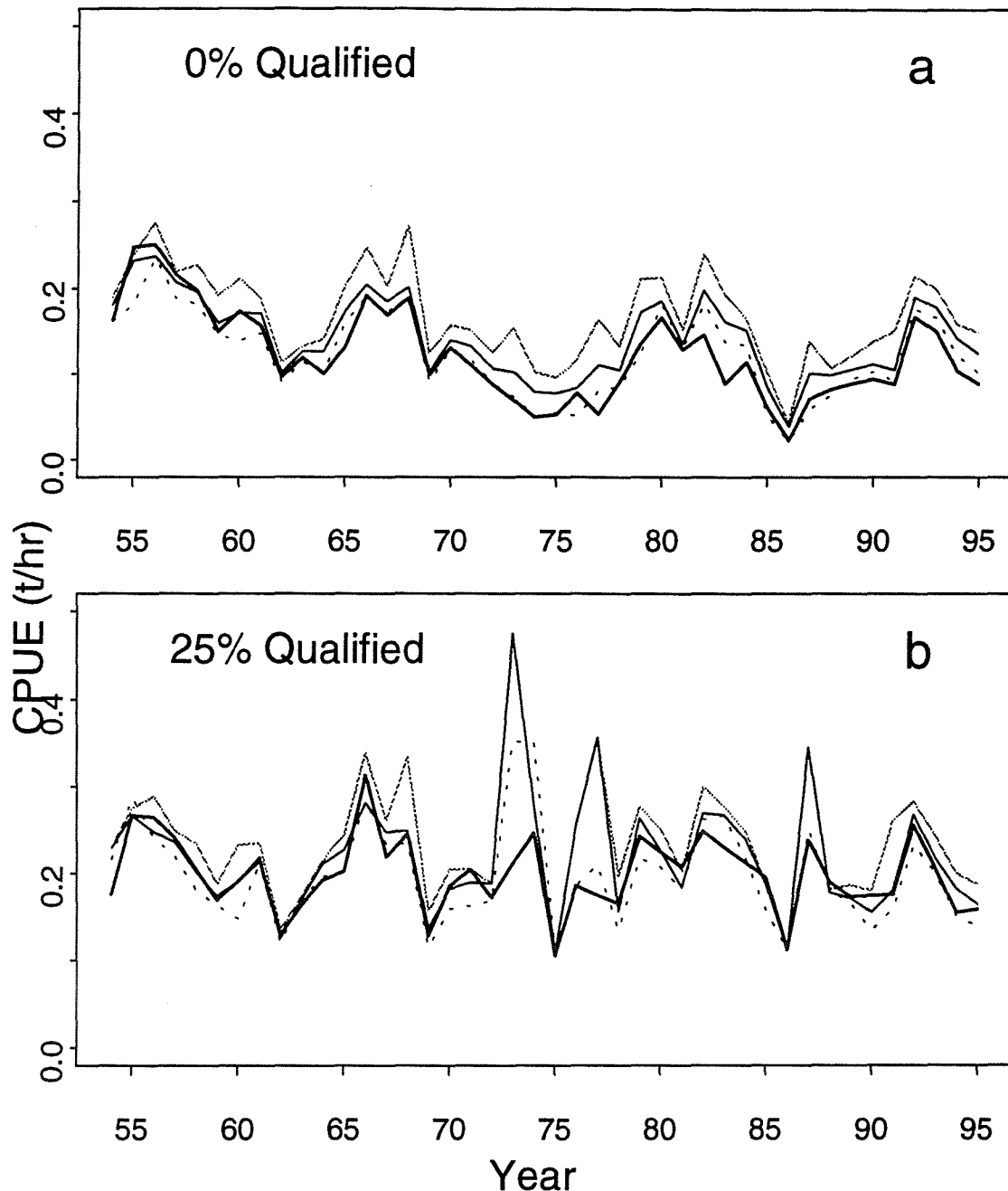


Fig. 4.22. Area 5A rock sole annual catch per unit effort series at 0% (panel a) and 25% (panel b) qualification levels. Series using four estimators of CPUE are plotted: ratio of means (gray, thick line), mean of ratios (solid, thin line), 10% trimmed mean of ratios (dotted line), and 50% trimmed mean (median) of ratios.

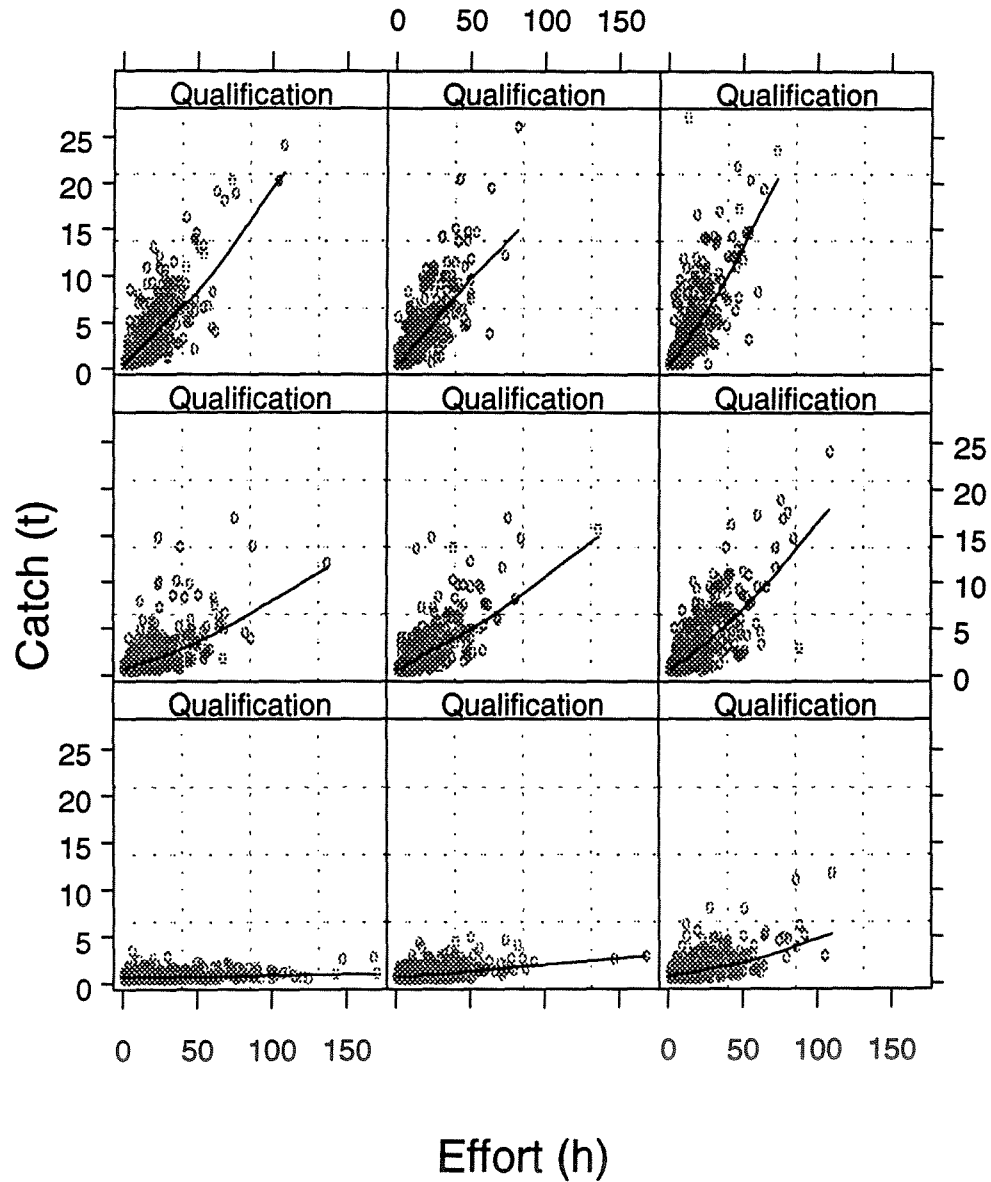


Fig. 4.23. Trellis plot of area 5A rock sole catch as a function off effort given qualification level. Qualification consists of nine ranges with each range containing a similar number of observations (allowing for overlap of approximately 12%): 0.003-0.045, 0.040-0.088, 0.082-0.162, 0.150-0.254, 0.242-0.383, 0.367-0.532, 0.507-0.722, 0.699-0.913 and 0.891-1.000. A loess trend line is shown as a solid line within each panel.

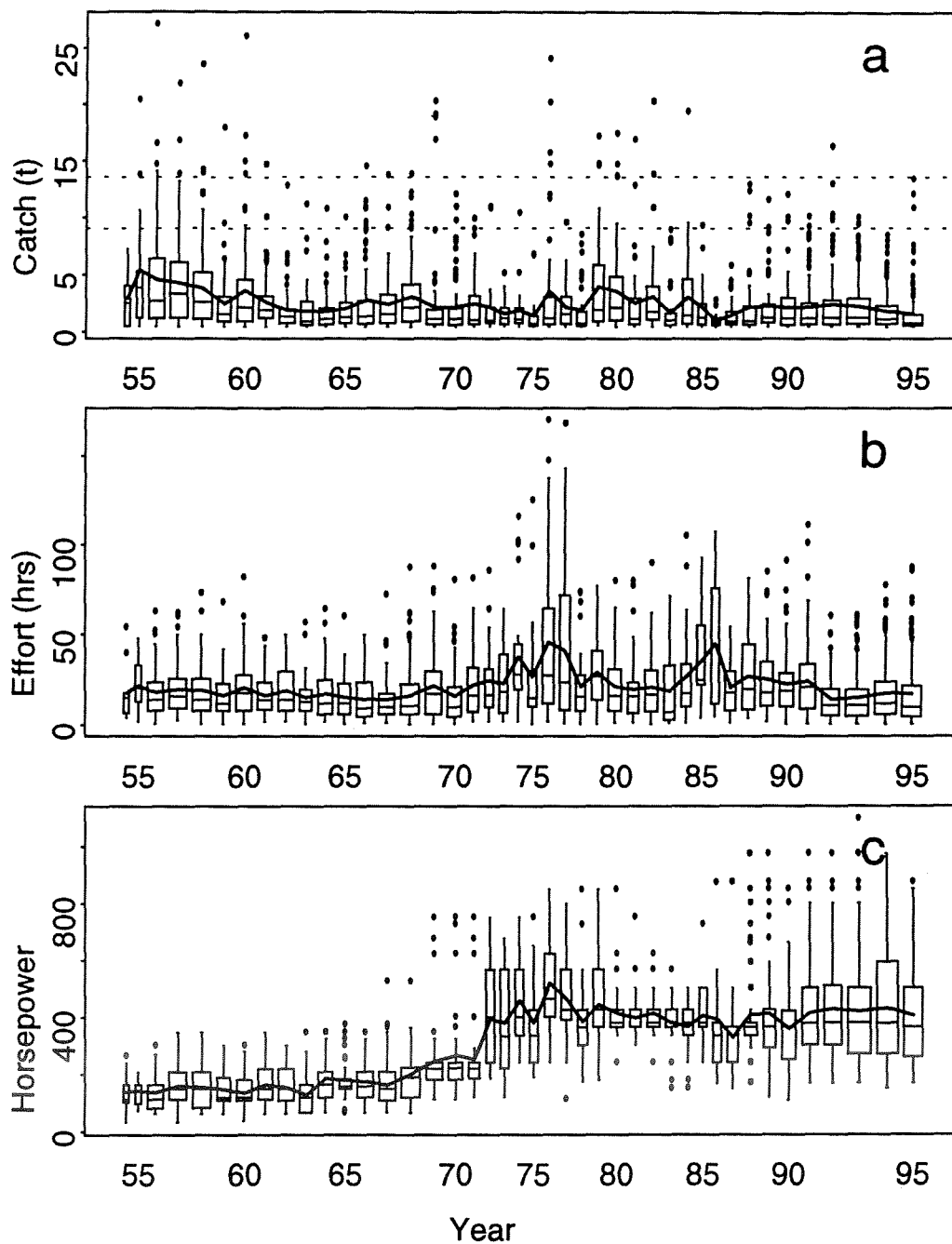


Fig. 4.24. Boxplots showing the annual distribution of catch (panel a), effort (panel b), and vessel horsepower (panel c) derived from the fishing event data for area 5A rock sole. The annual mean is shown as a thick solid line overlaid on the boxplots.

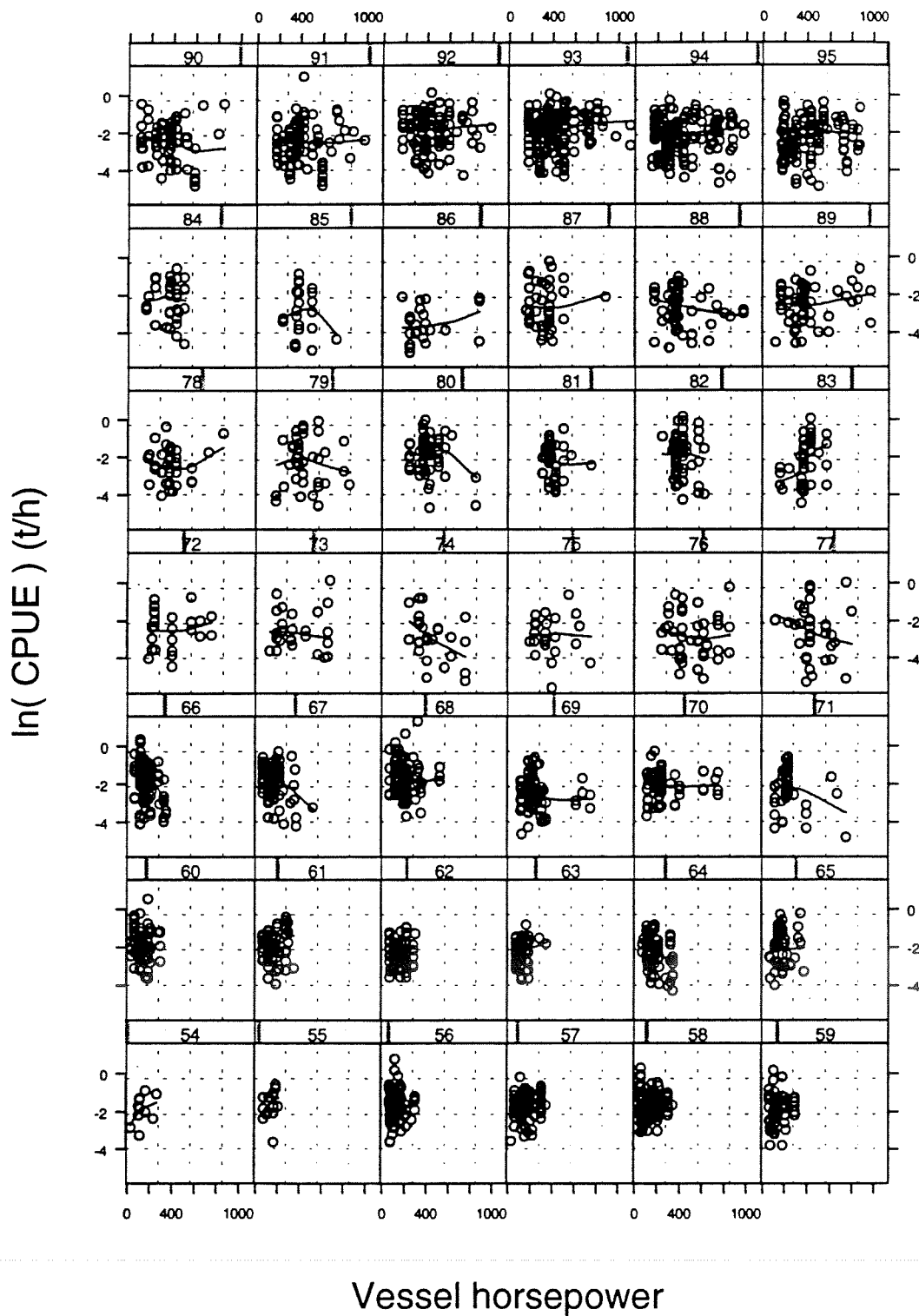


Fig. 4.25. Trellis plot of area 5A rock sole CPUE (\log_e transformed) as a function of vessel horsepower given year. A loess trend line is shown as a solid line within each panel.

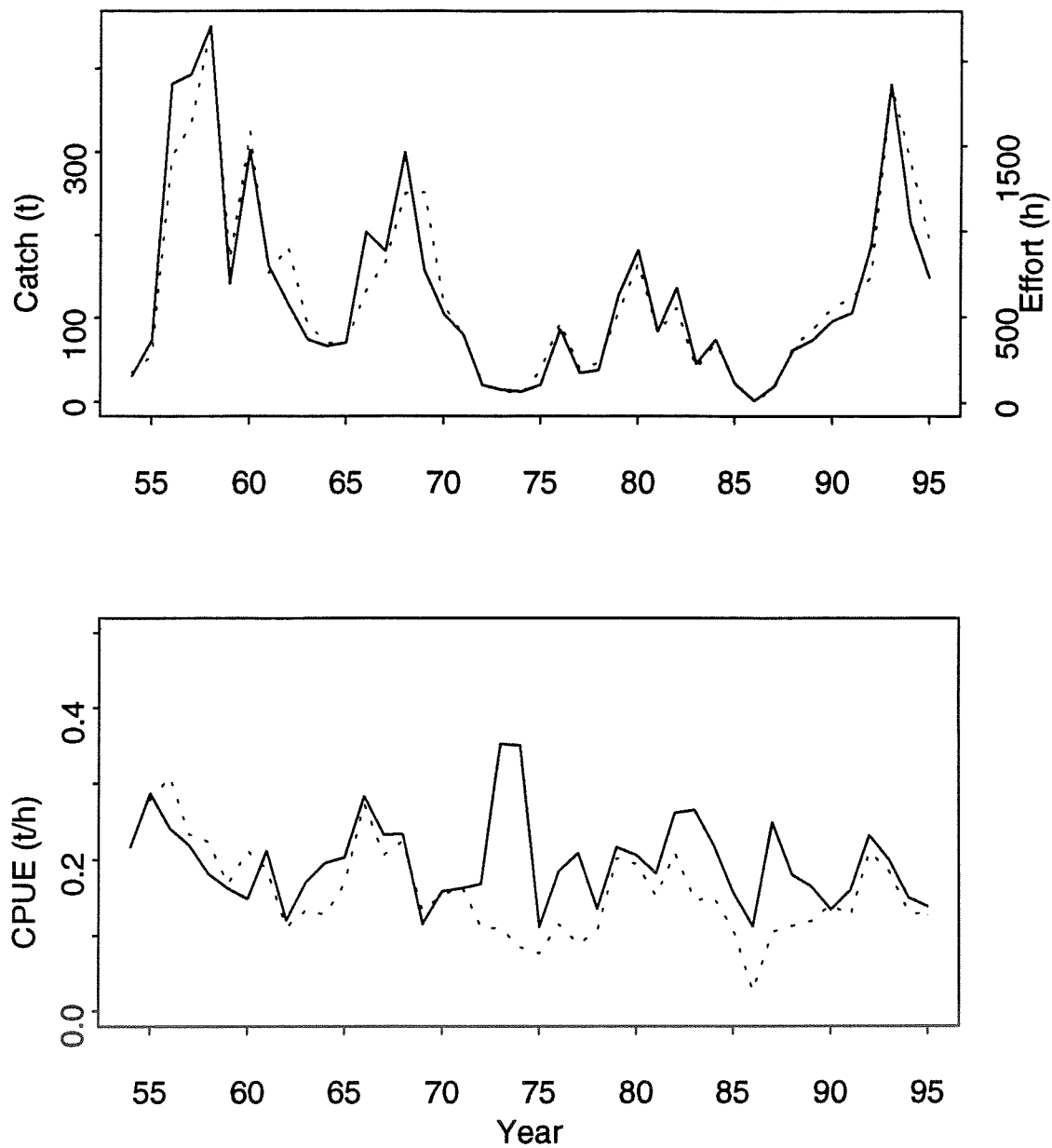


Fig. 4.26. Area 5A rock sole catch and effort series (panel a) and CPUE series (panel b) for 25% qualified fishing events. Note the coincidence of fluctuations in the catch series (solid line, panel a) with the effort series (dotted line, panel a). In panel (b) the median of ratios CPUE series is plotted as the solid line, while the CPUE adjusted for year and vessel horsepower is shown as a dotted line.

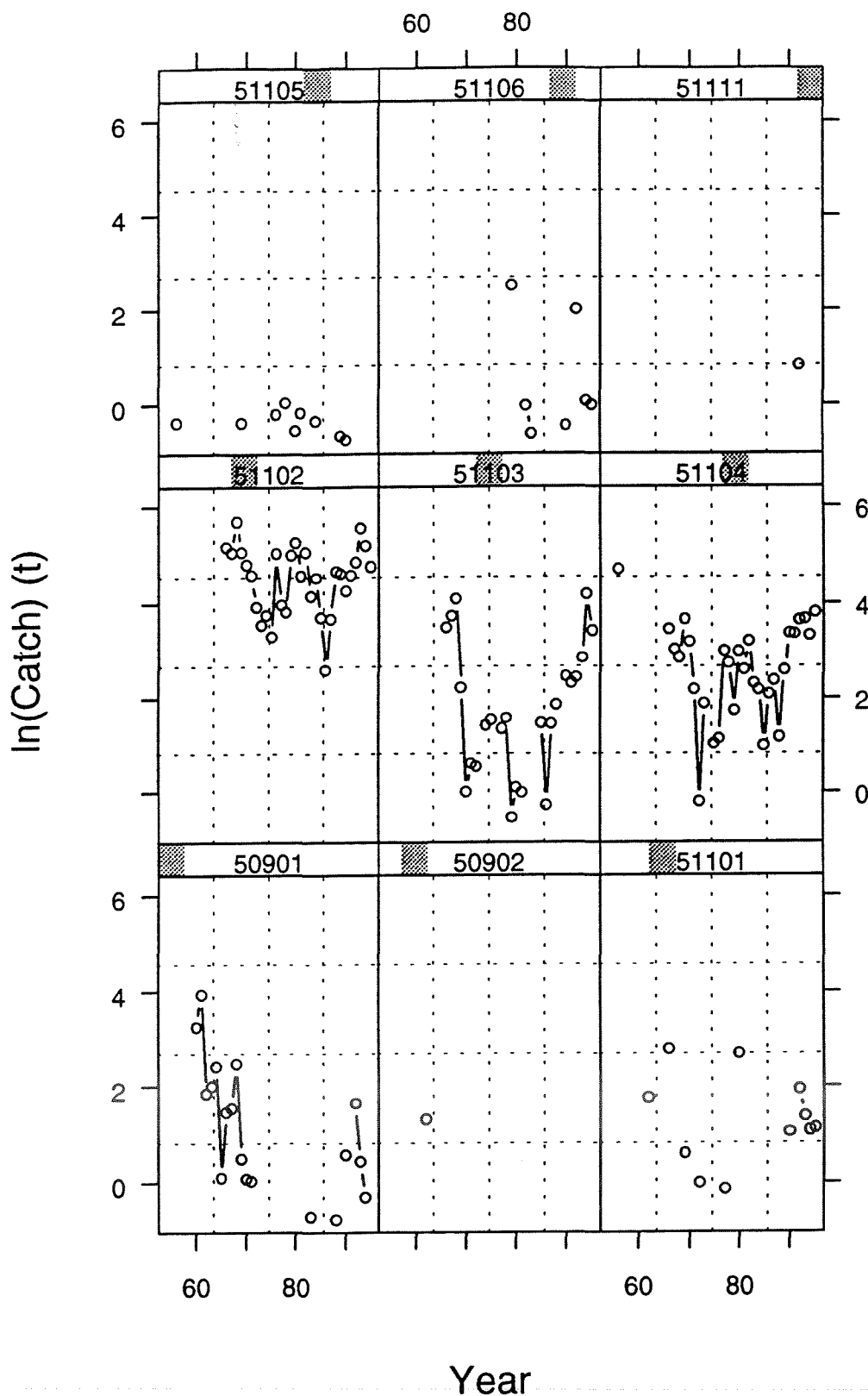


Fig. 4.27. Trellis plot of area 5A rock sole catch (t) \log_e transformed) as a function of year given fishing locality. The given strip label is a combination of major area, minor area, and fishing locality. For example, 51102 is major area 5 (5A), minor area 11, locality 02.

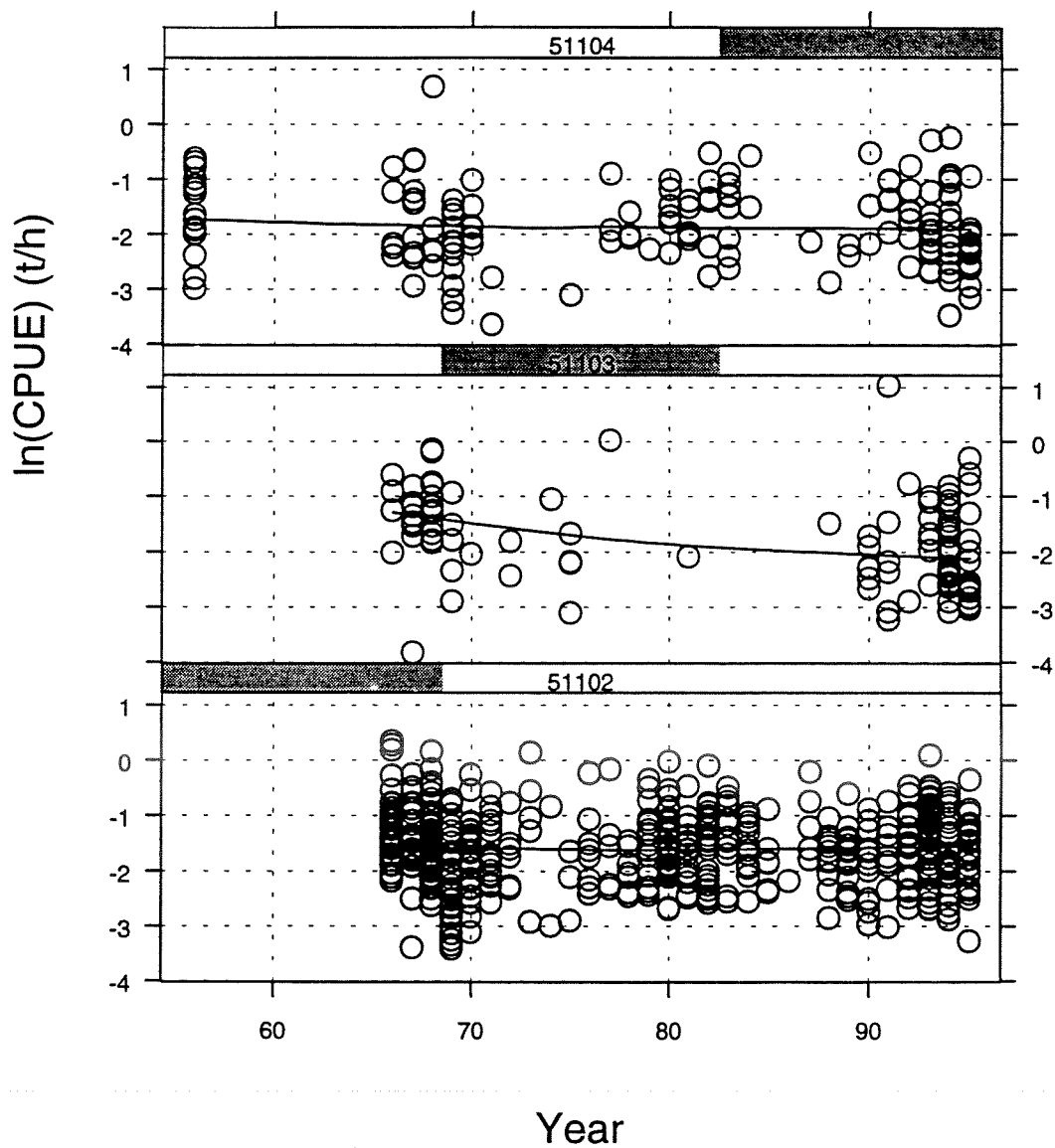


Fig. 4.28. Trellis plot of area 5A rock sole CPUE series (\log_e transformed, 25% qualified) for three fishing localities. A loess trend line is shown as a solid line within each panel.

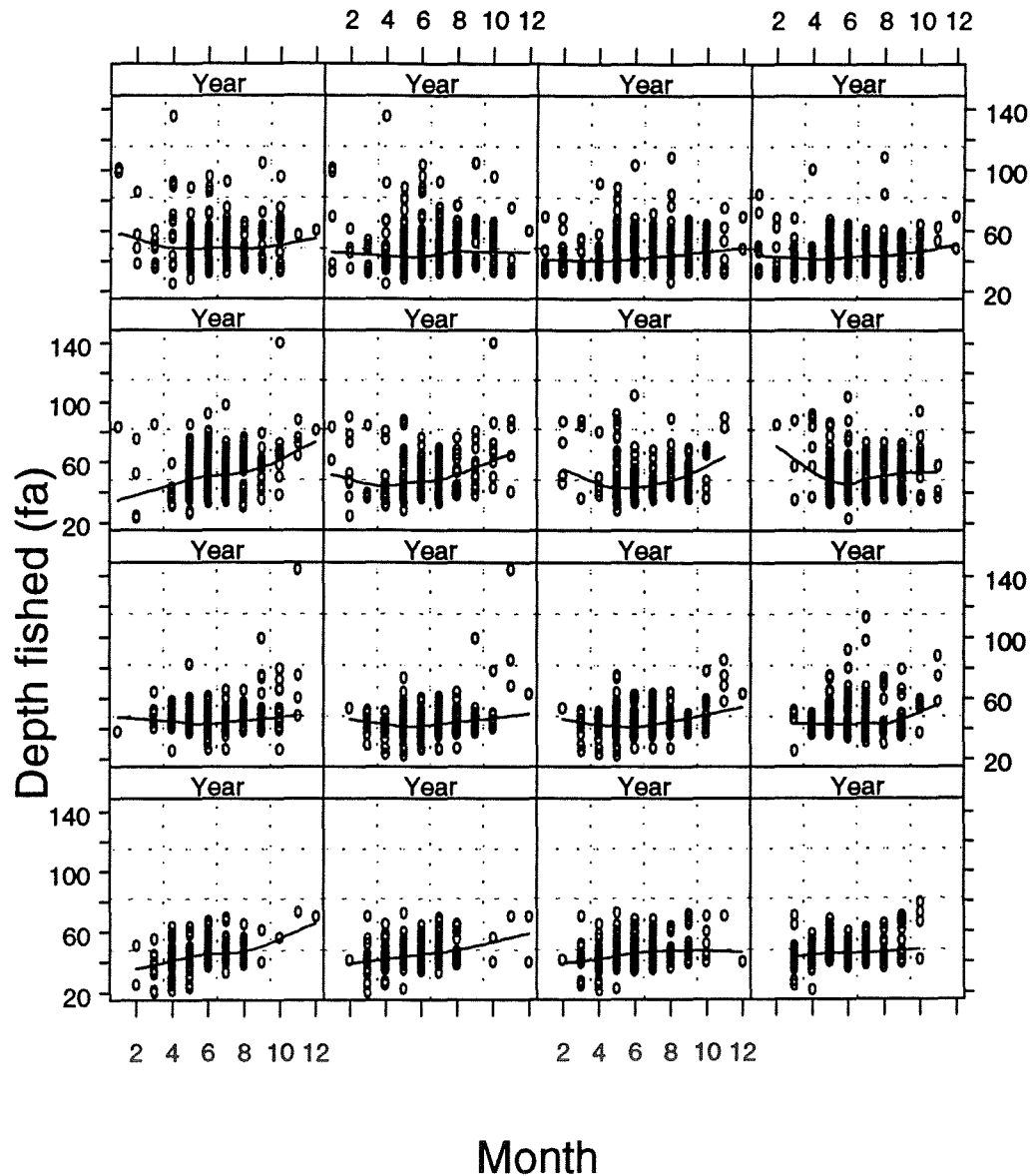


Fig. 4.29. Depth fished as a function of month given year for area 5A rock sole. Year consists of sixteen ranges with each range containing a similar number of observations (allowing for an overlap of approximately 12%): 54-57, 57-59, 59-61, 61-64, 63-66, 66-68, 68-70, 69-75, 74-79, 79-83, 82-88, 87-91, 90-92, 92-93, 93-94 and 94-95. The loess trend line (solid line within each panel) suggests shallower depths are fished in summer months.

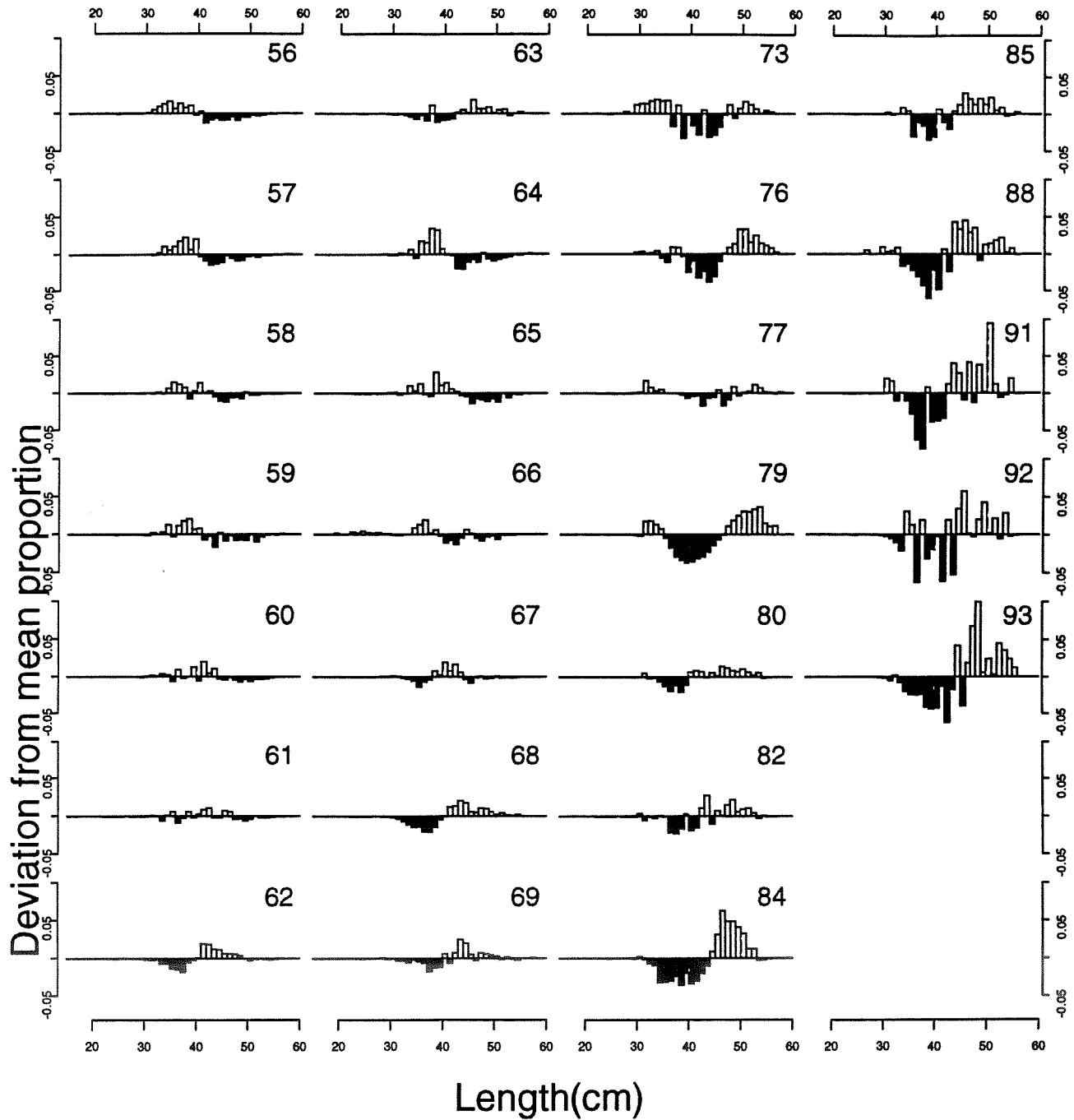


Fig. 4.30. Anomaly plots for area 5A female rock sole. Deviations from the long-term proportion at length are plotted, negative deviations are shaded. See text for interpretation.

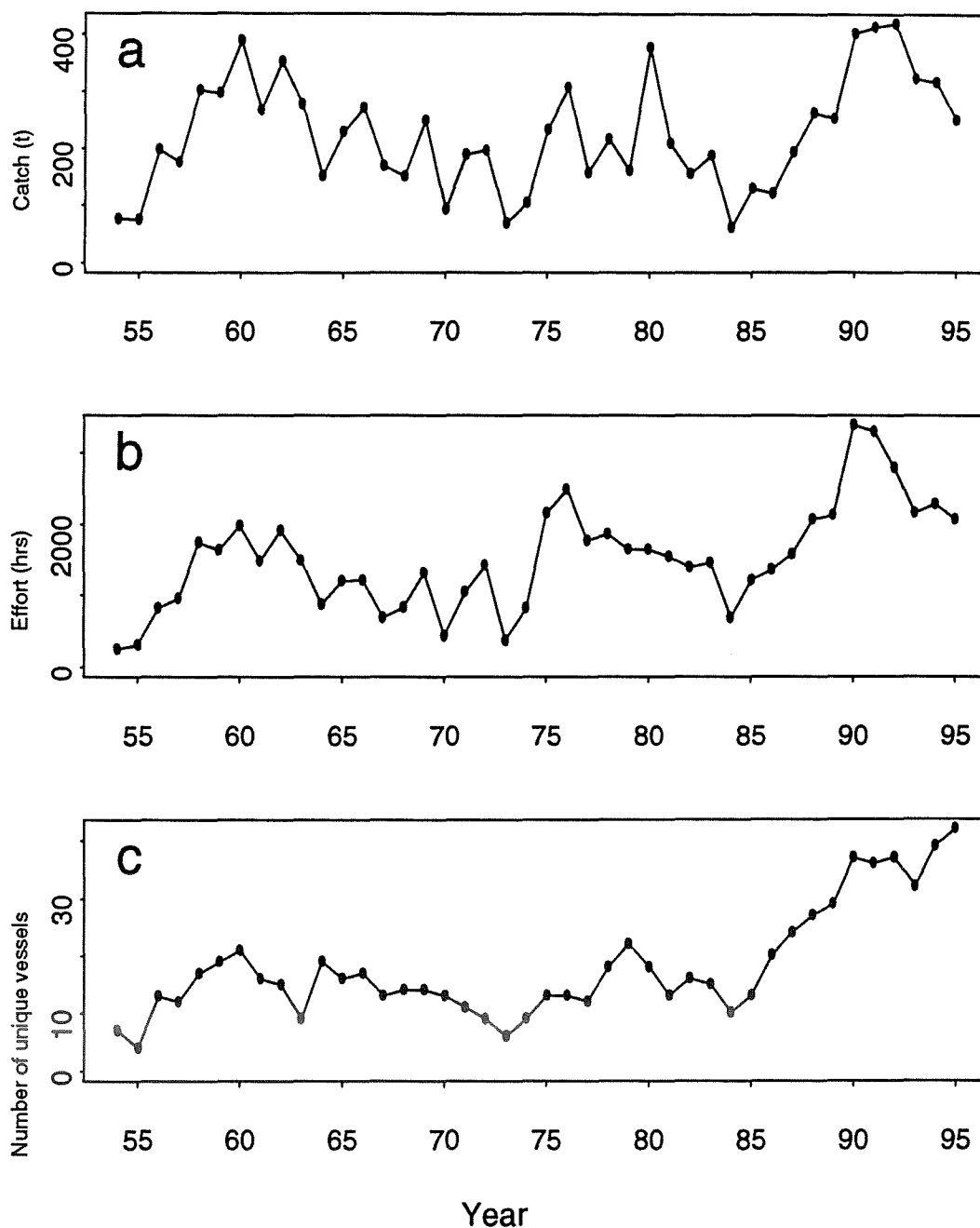


Fig. 4.31. Area 5B rock sole catch (panel a), effort (panel b), and vessel participation (panel c) plotted against year. These series include data from the Canadian fishery only.

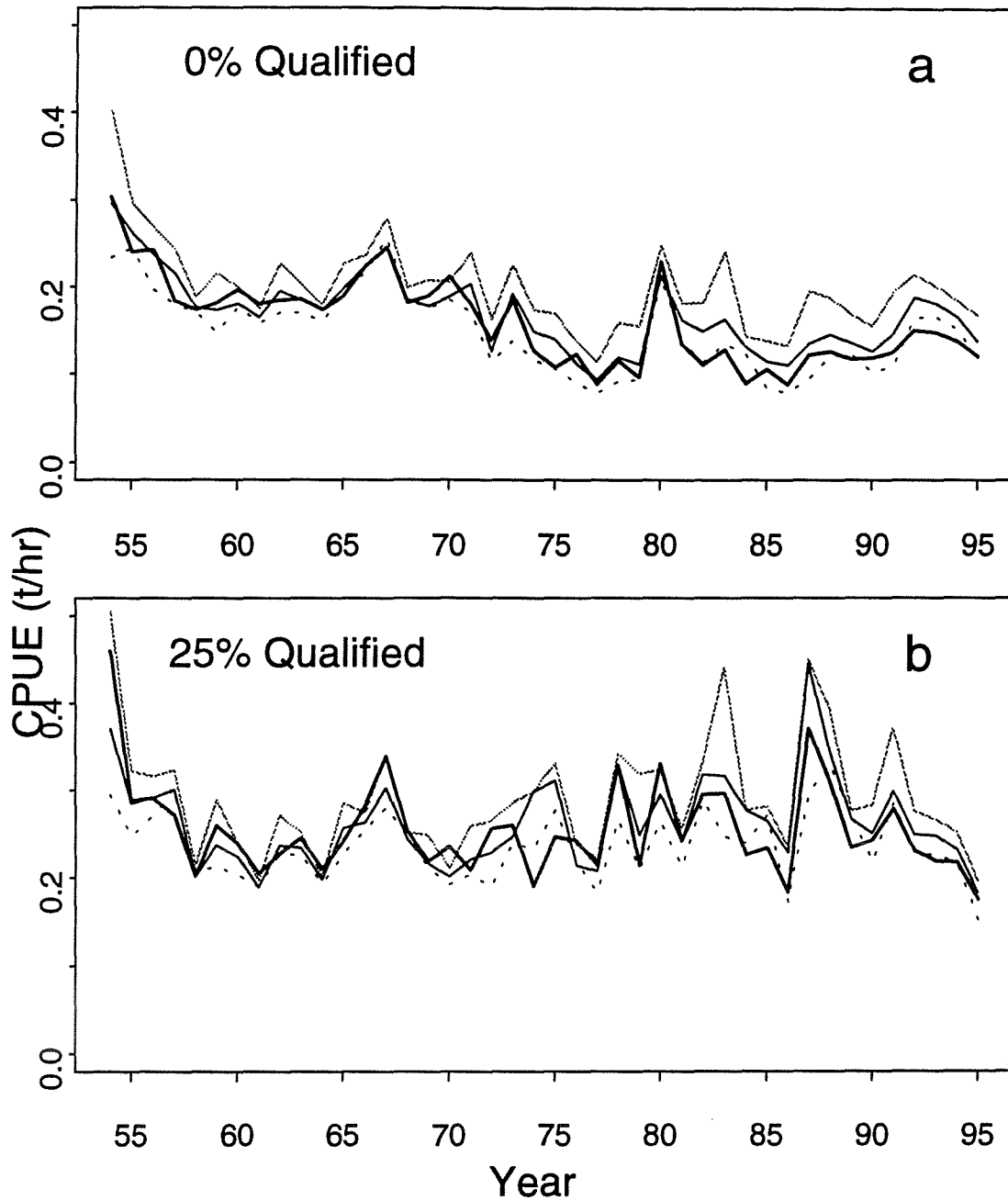


Fig. 4.32. Area 5B rock sole annual catch per unit effort series at 0% (panel a) and 25% (panel b) qualification levels. Series using four estimators of CPUE are plotted: ratio of means (gray, thick line), mean of ratios (solid, thin line), 10% trimmed mean of ratios (dotted line), and 50% trimmed mean (median) of ratios.

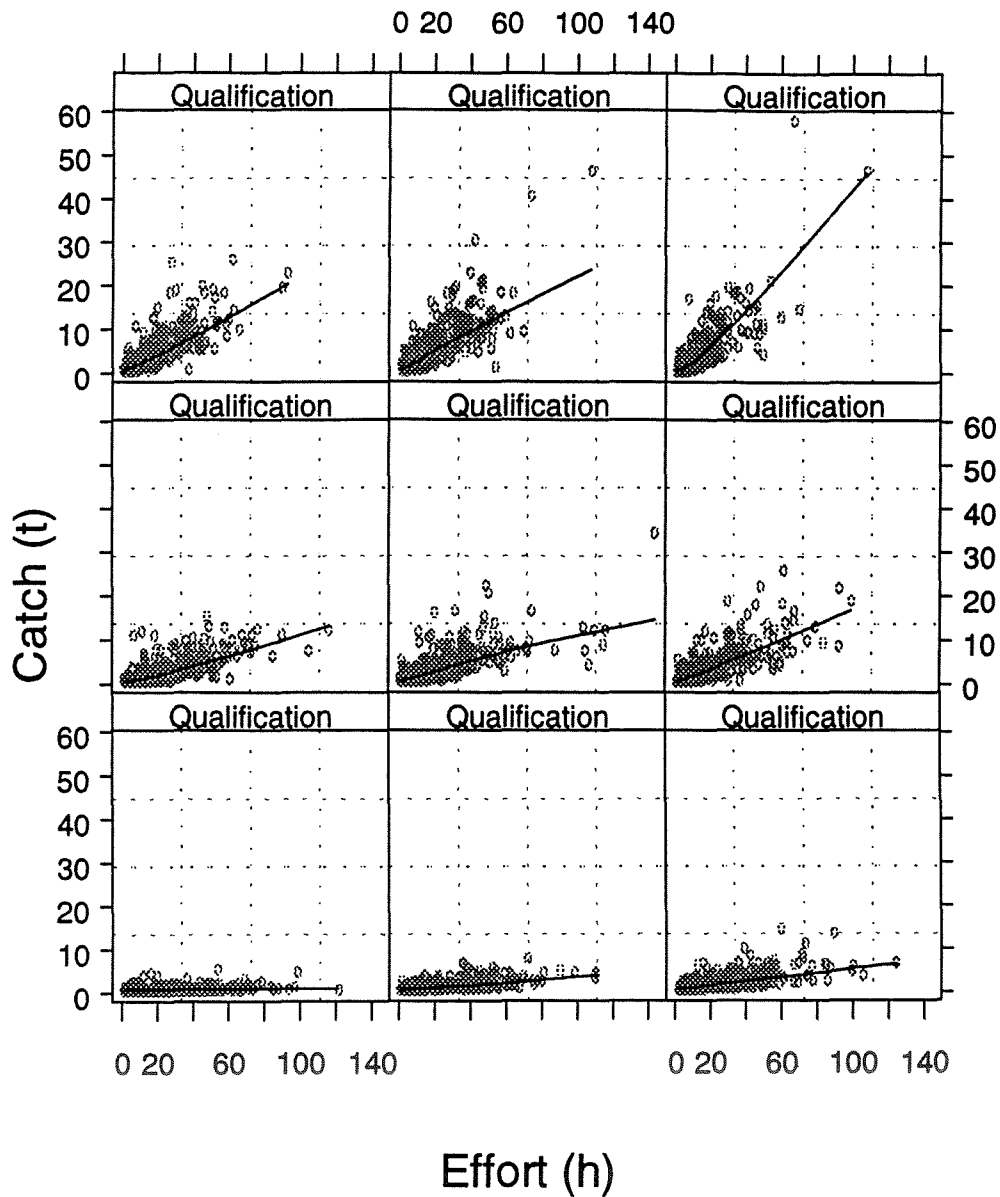


Fig. 4.33. Trellis plot of area 5B rock sole catch as a function of effort given qualification level. Qualification consists of nine ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 0.003-0.043, 0.039-0.086, 0.080-0.140, 0.133-0.220, 0.209-0.326, 0.313-0.464, 0.441-0.637, 0.611-0.851 and 0.826-1.000. A loess trend line is shown as a solid line within each panel.

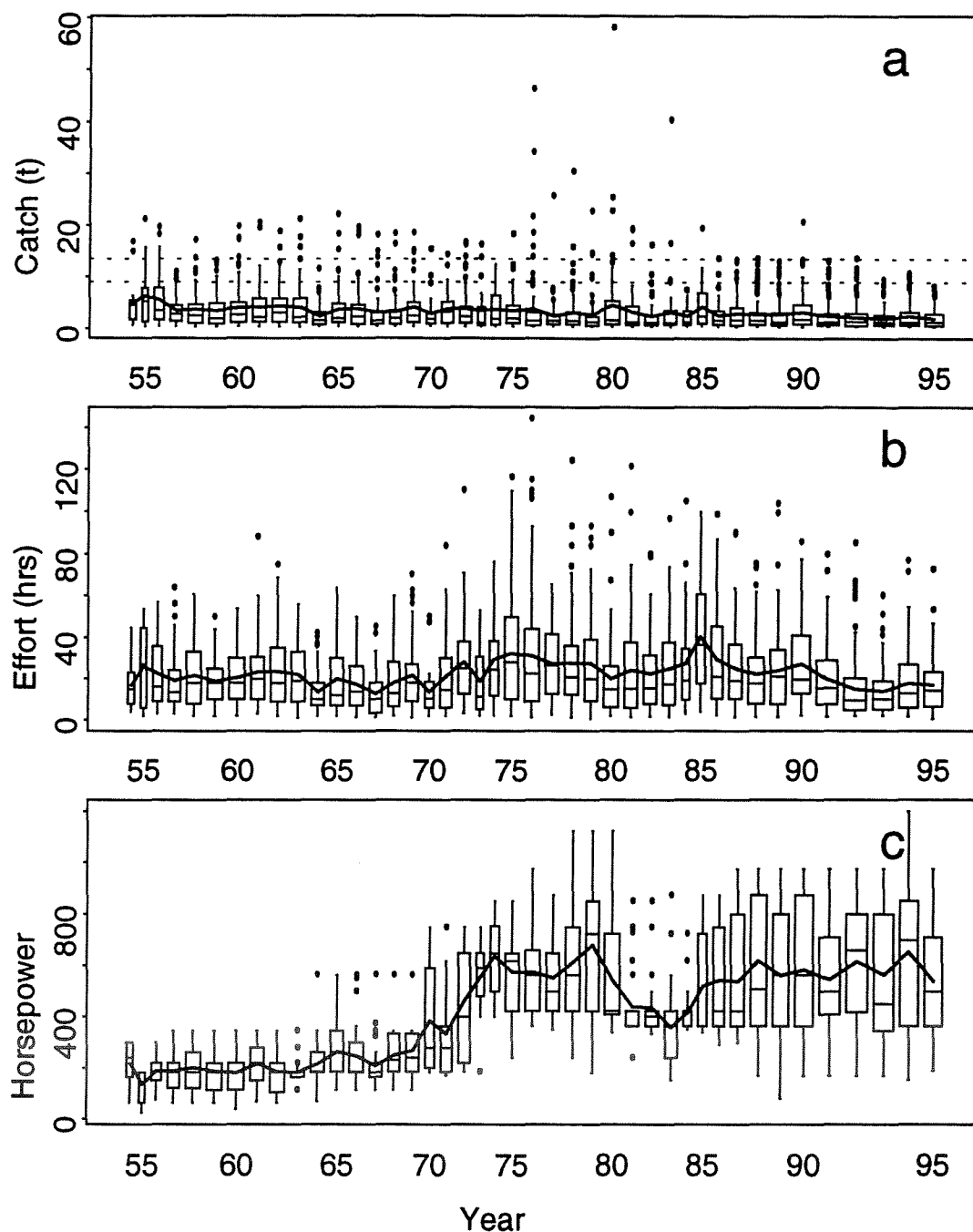


Fig. 4.34. Boxplots showing the annual distribution of catch (panel a), effort (panel b), and vessel horsepower (panel c) derived from the fishing event data for area 5B rock sole. The annual mean is shown as a thick solid line overlaid on the boxplots.

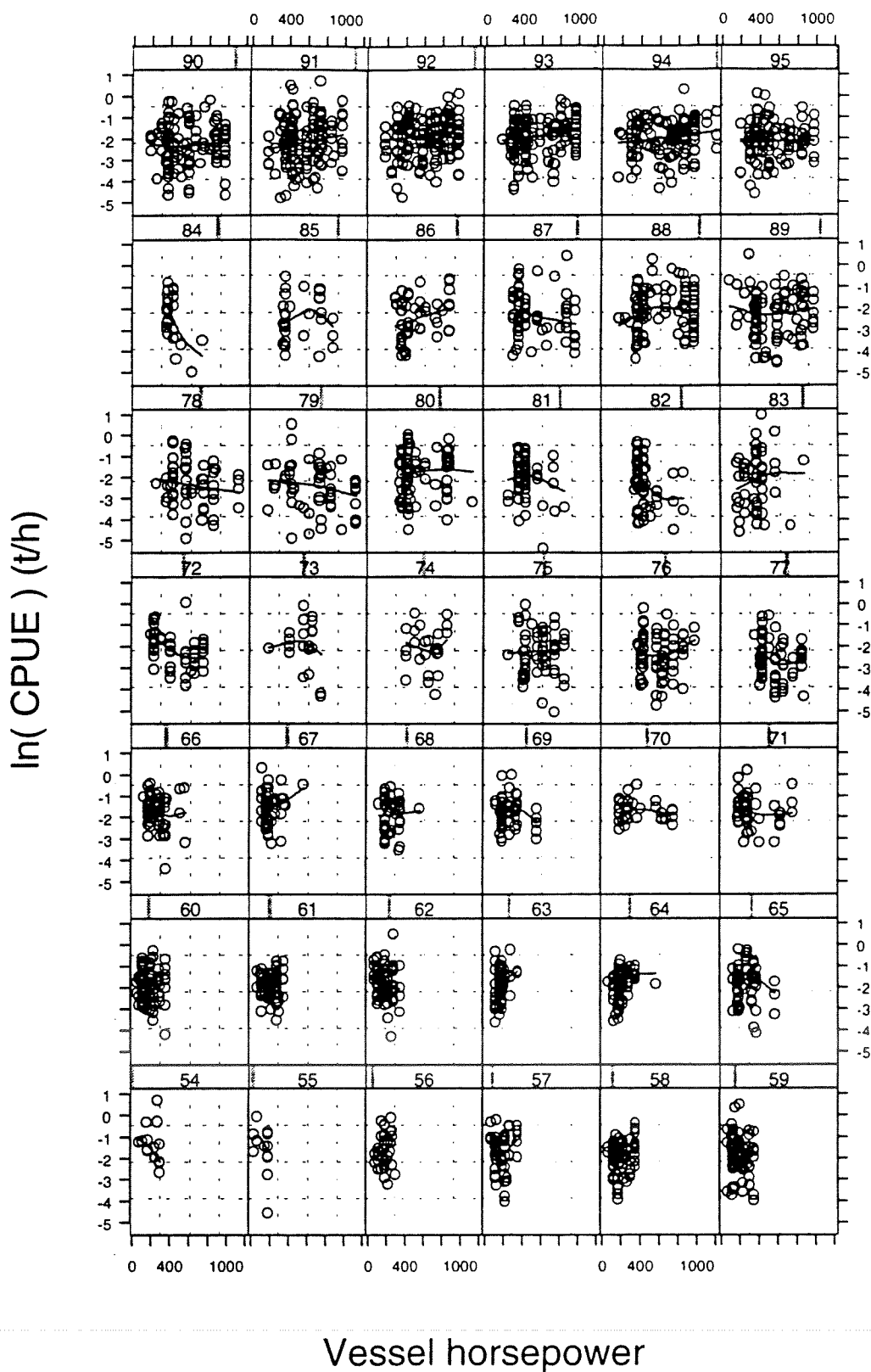


Fig. 4.35. Trellis plot of area 5B rock sole CPUE (\log_e transformed) as a function of vessel horsepower given year. A loess trend line is shown as a solid line within each panel.

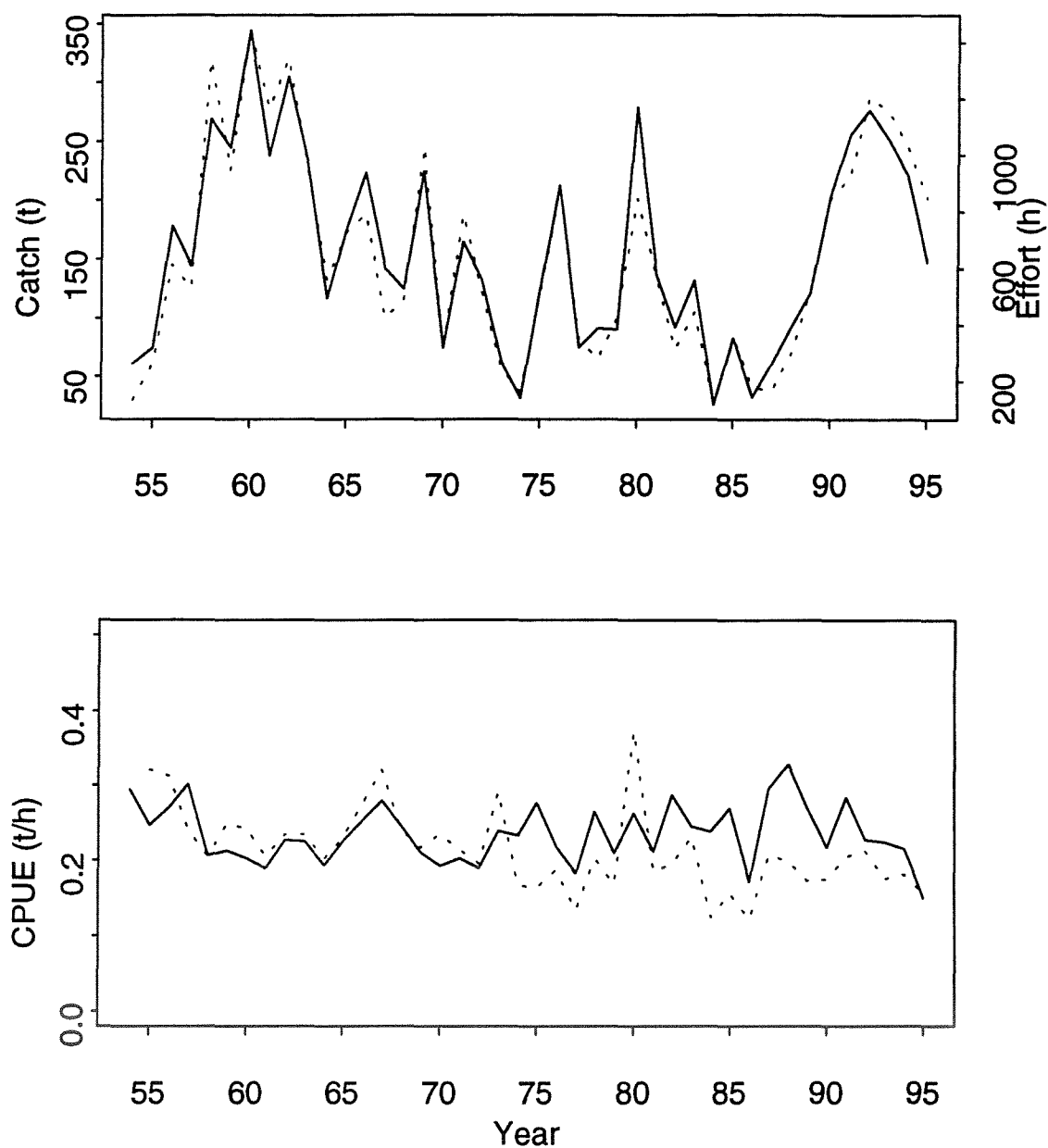


Fig. 4.36. Area 5B rock sole catch and effort series (panel a) and CPUE series (panel b) for 25% qualified fishing events. Note the coincidence of fluctuations in the catch series (solid line, panel a) with the effort series (dotted line, panel a). In panel (b) the median of ratios CPUE series is plotted as the solid line, while the CPUE adjusted for year and vessel horsepower is shown as a dotted line.

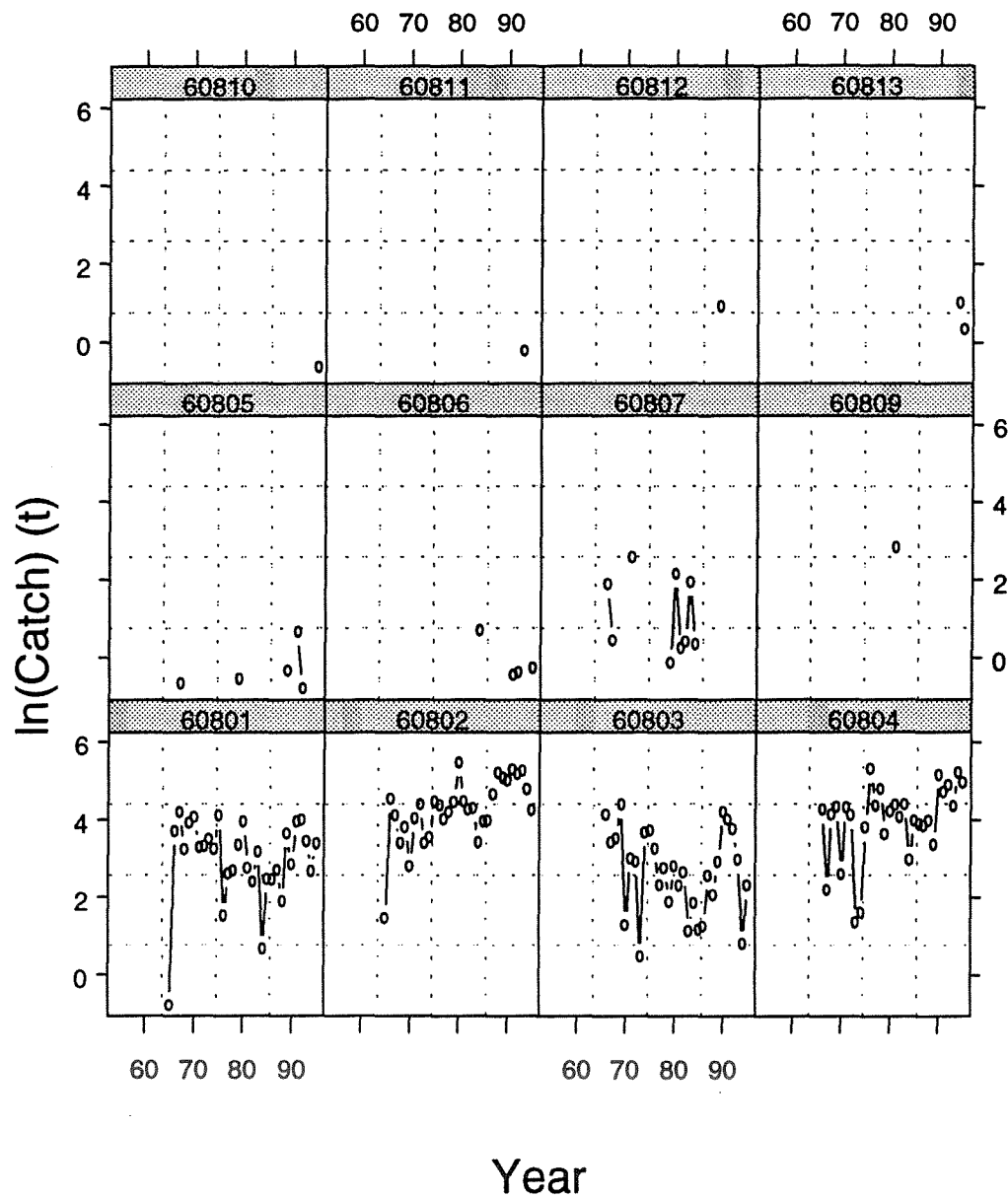


Fig. 4.37. Trellis plot of area 5B rock sole catch (\log_e transformed) as a function of year given fishing locality. The given strip label is a combination of major area, minor area, and fishing locality. For example, 60802 is major area 6 (5B), minor area 08, locality 02.

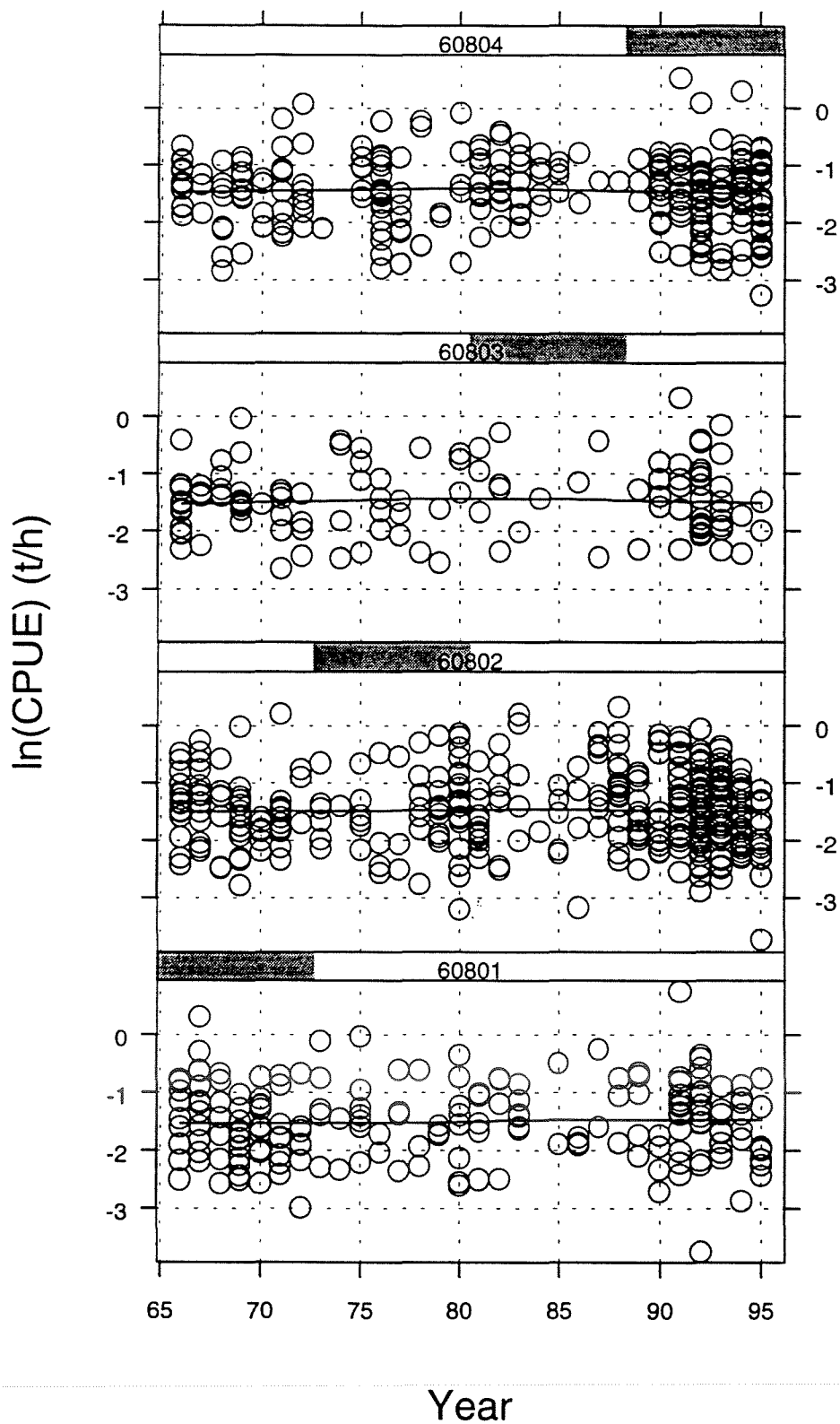


Fig. 4.38. Trellis plot of area 5B rock sole CPUE series (\log_e transformed, 25% qualified) for four fishing localities. A loess trend line is shown as a solid line within each panel.

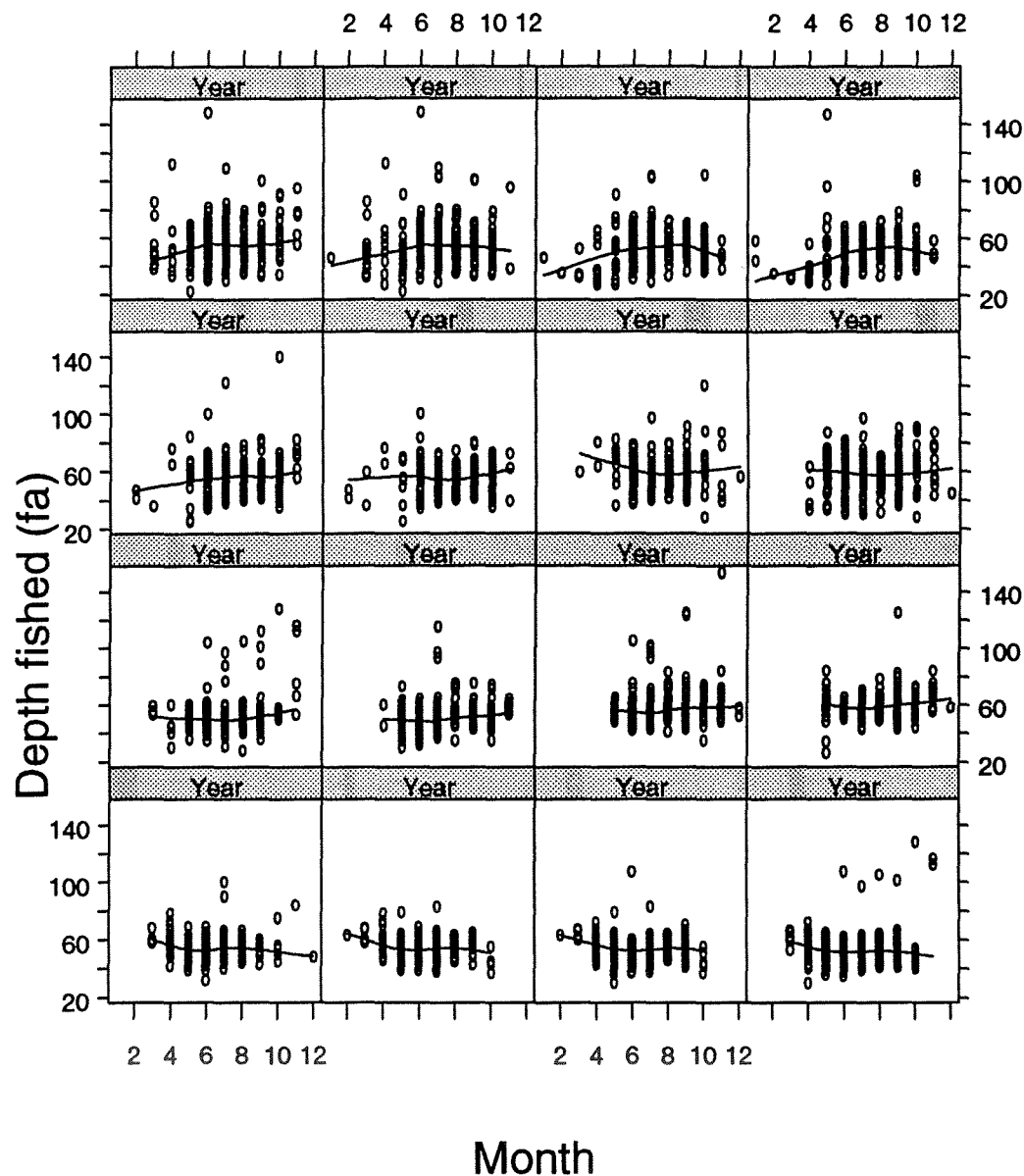


Fig. 4.39. Depth fished as a function of month given year for area 5B rock sole. Year consists of sixteen ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 54-59, 58-61, 60-63, 63-66, 66-69, 69-75, 74-77, 77-80, 80-83, 82-87, 87-89, 89-91, 91-92, 93-94 and 94-95. The loess trend line (solid line within each panel) suggests deeper depths are fished in summer months.

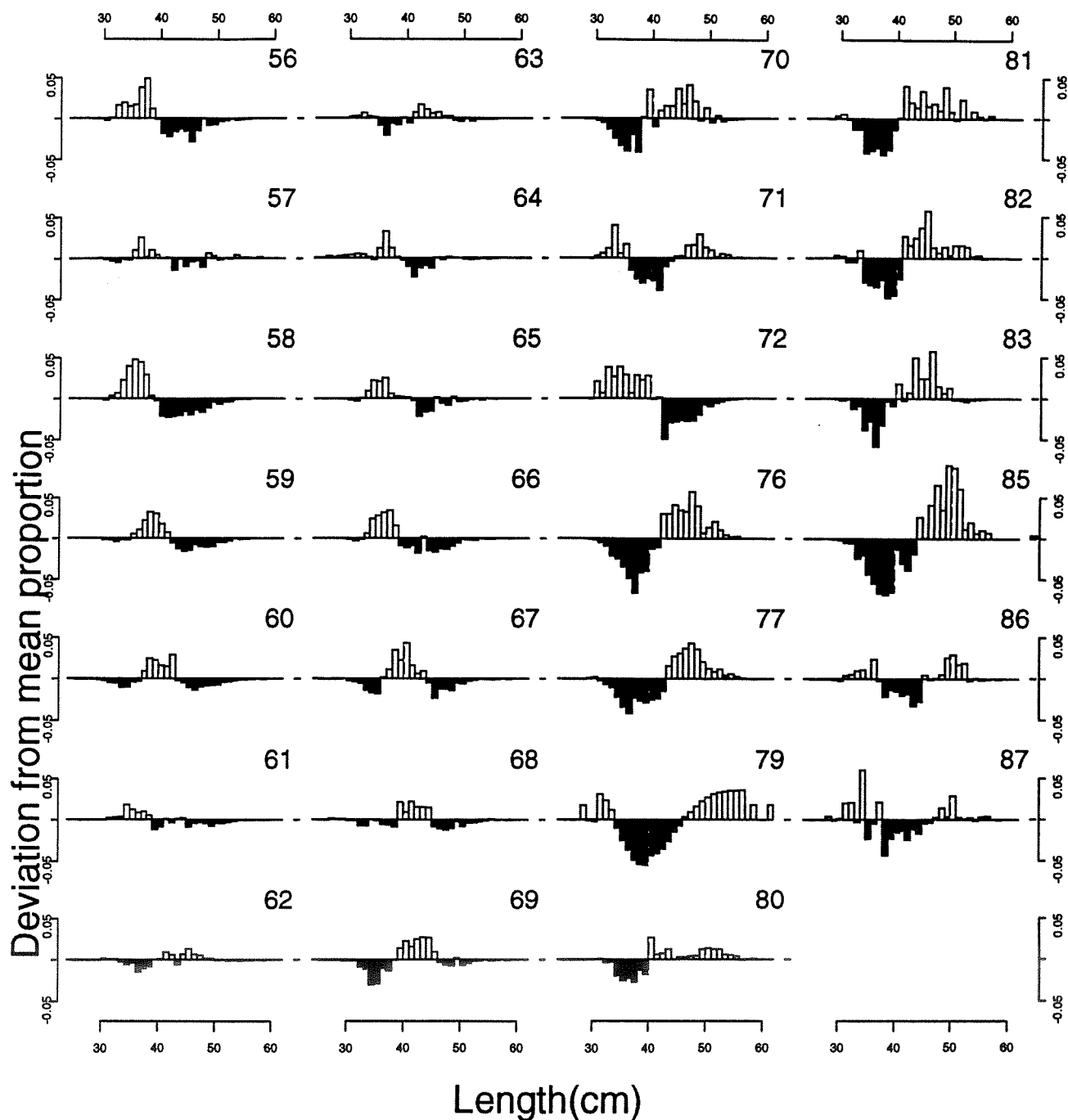


Fig. 4.40. Anomaly plots for area 5B female rock sole. Deviations from the long-term proportion at length are plotted, negative deviations are shaded. See text for interpretation.

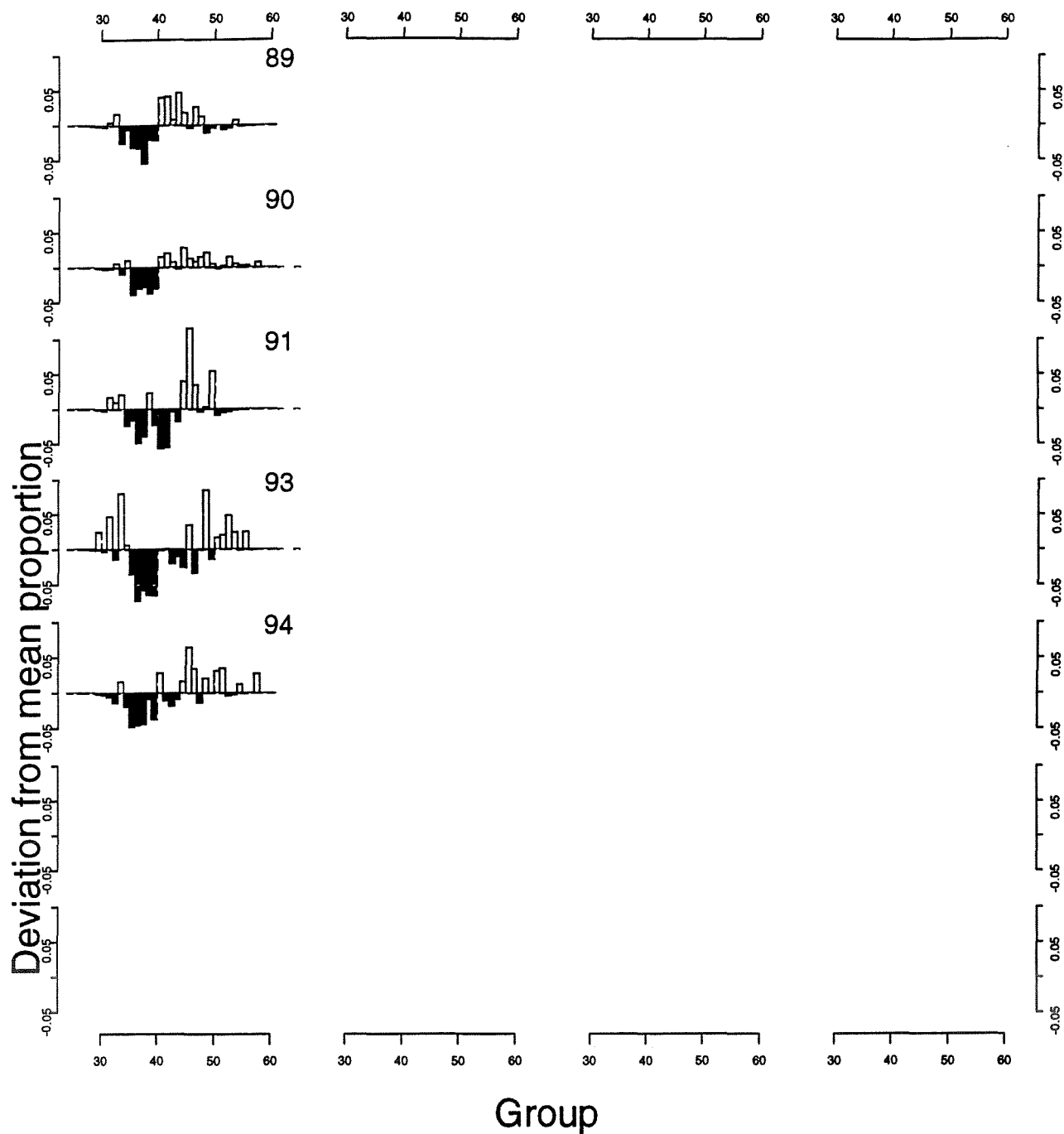


Fig. 4.40 - con't. Anomaly plots for area 5B female rock sole. Deviations from the long-term proportion at length are plotted, negative deviations are shaded. See text for interpretation.

Hecate Strait Rock sole standardized landing statistics, 1945-95

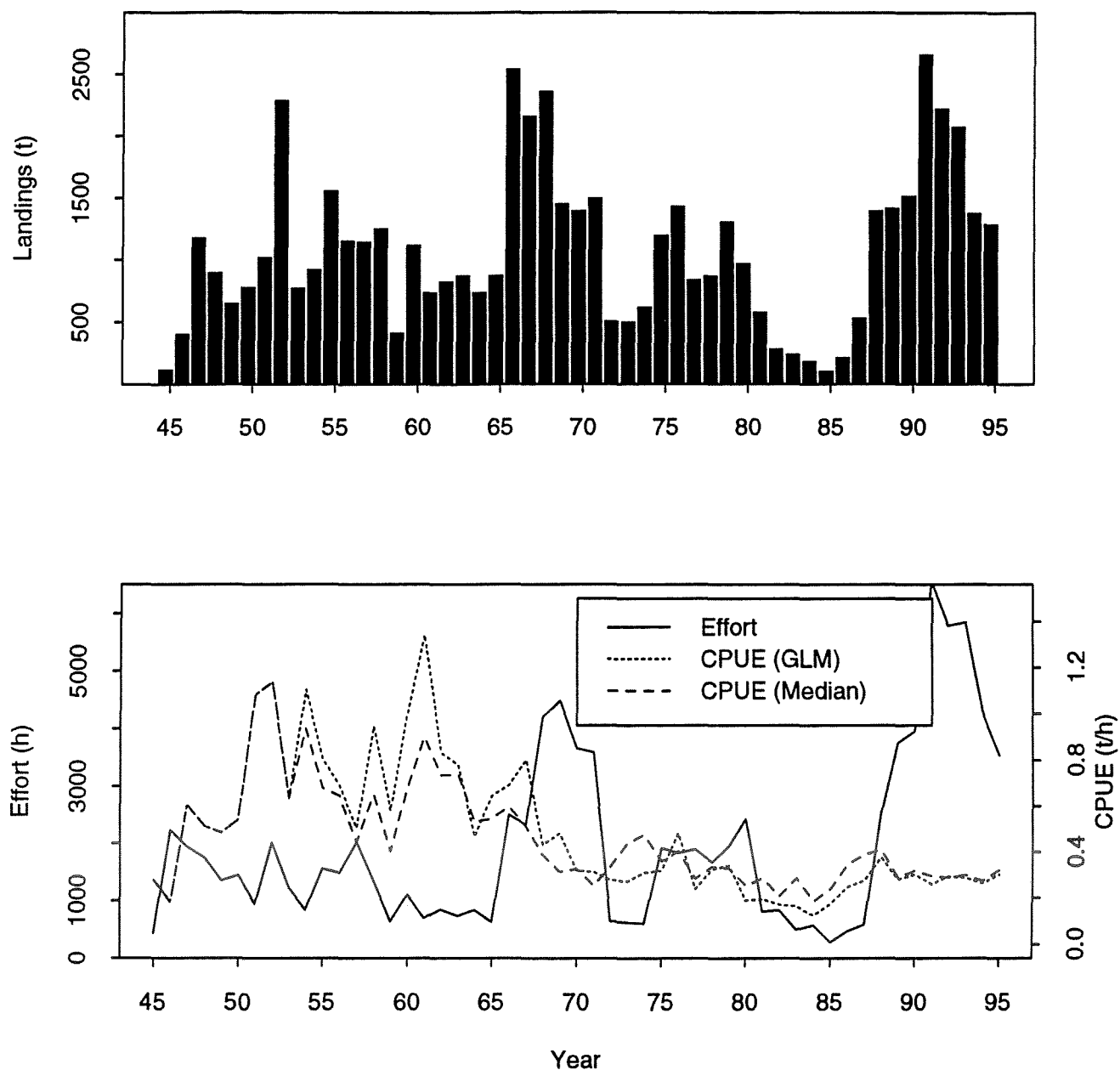


Fig. 4.41. Landing statistics for rock sole in Hecate Strait: top panel - landings in tonnes; bottom panel - effort and median and standardized CPUE series.

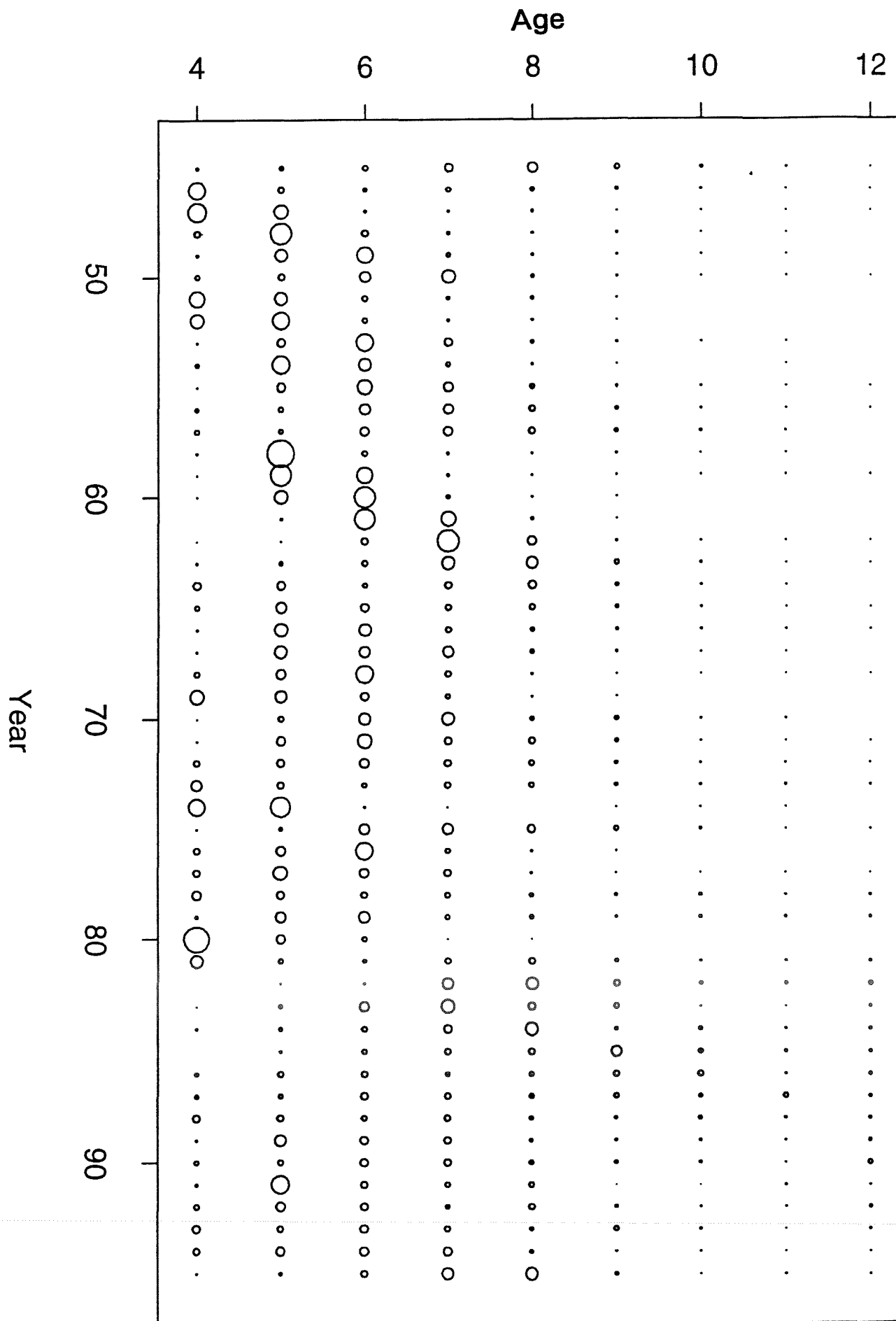


Fig. 4.42. Age proportion data by year for Hecate Strait rock sole, ages 4-12+, years 1945-95.

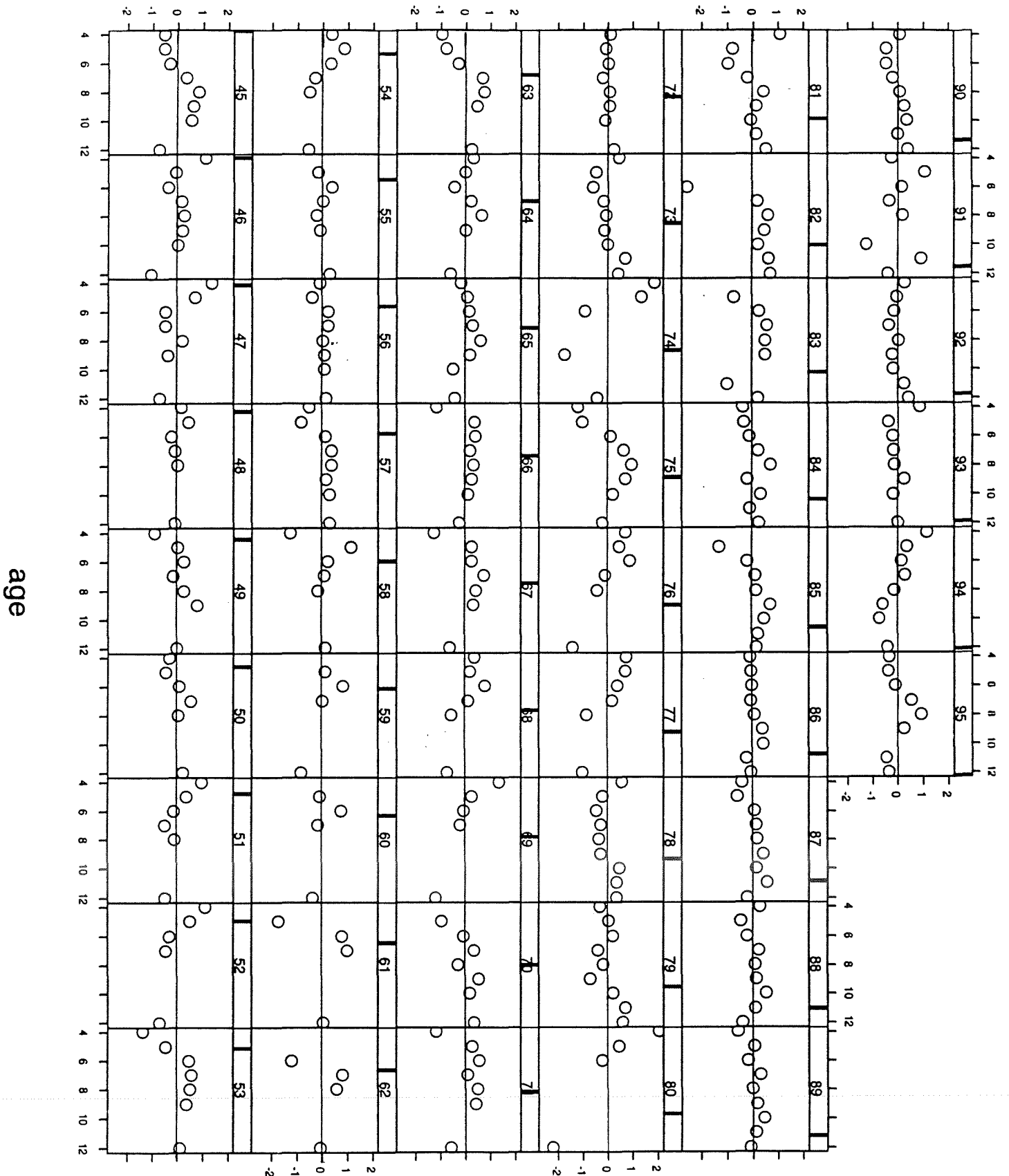


Fig. 4.43. Residual plots for the catch-age model results by age group by year, 1944-95.

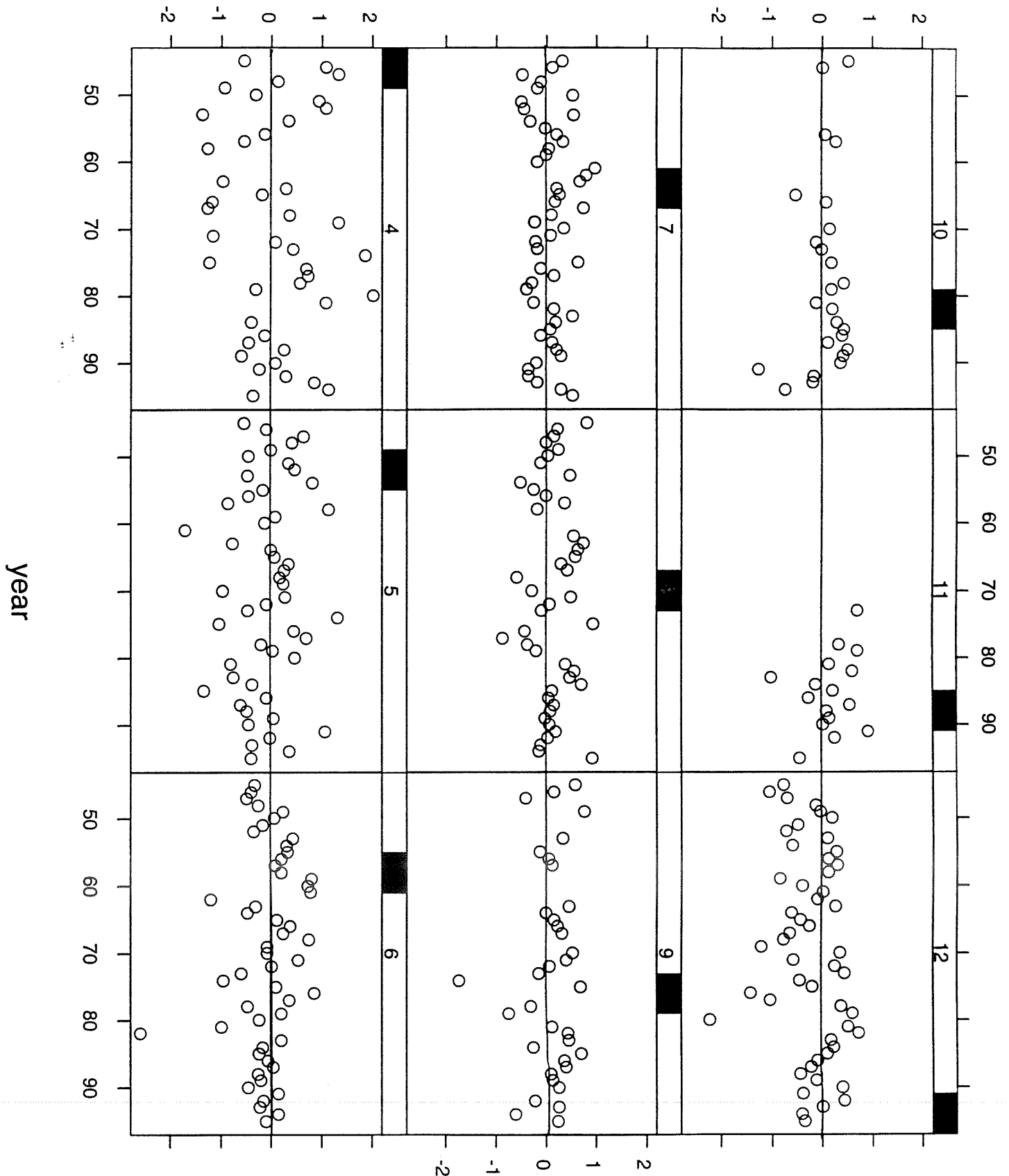


Fig. 4.44. Residual plots for the catch-age model results by year by age group, ages 4-12.

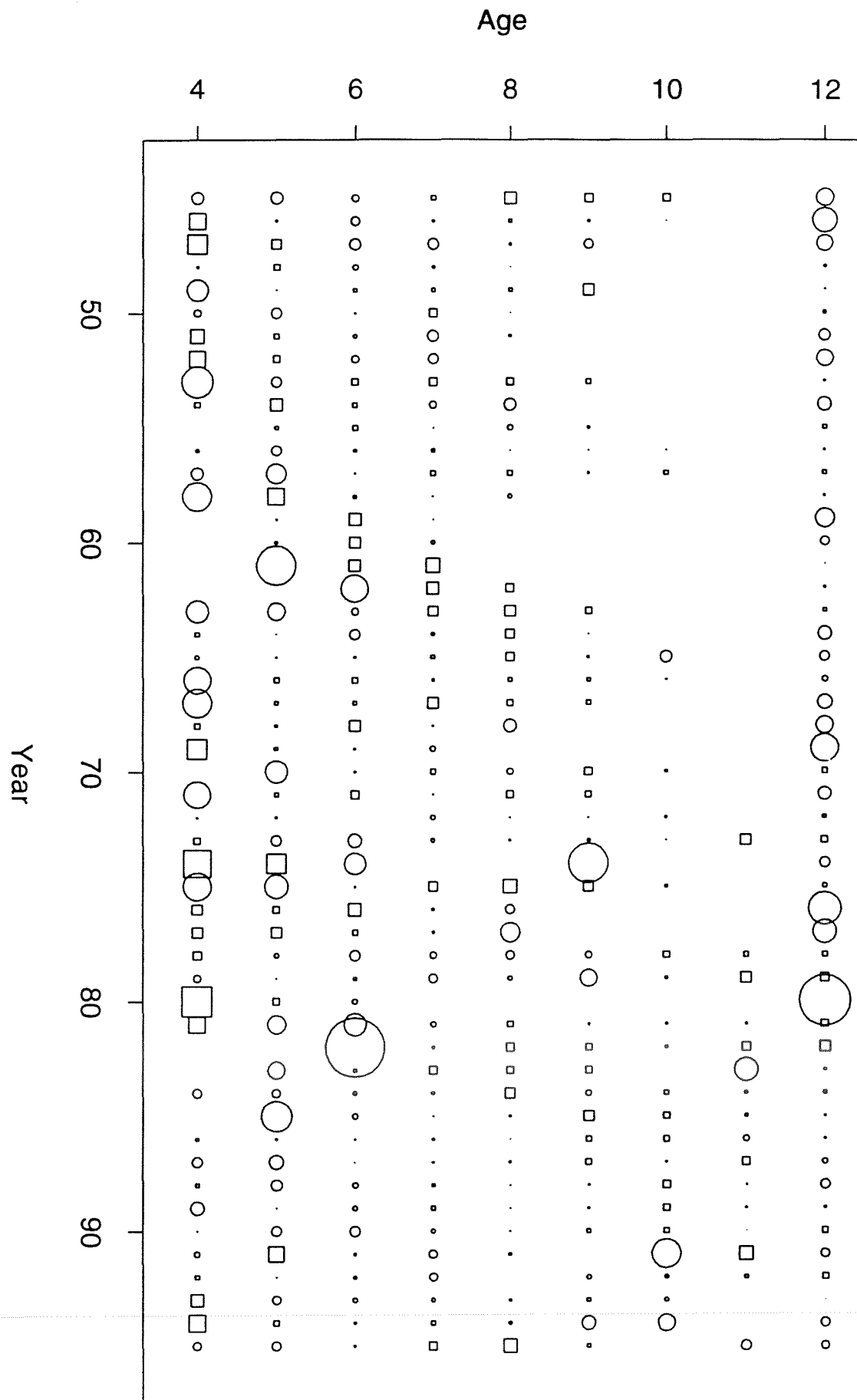


Fig. 4.45. Residual plot for the catch-age model results by year and age group: squares = positive residuals, circles = negative residuals.

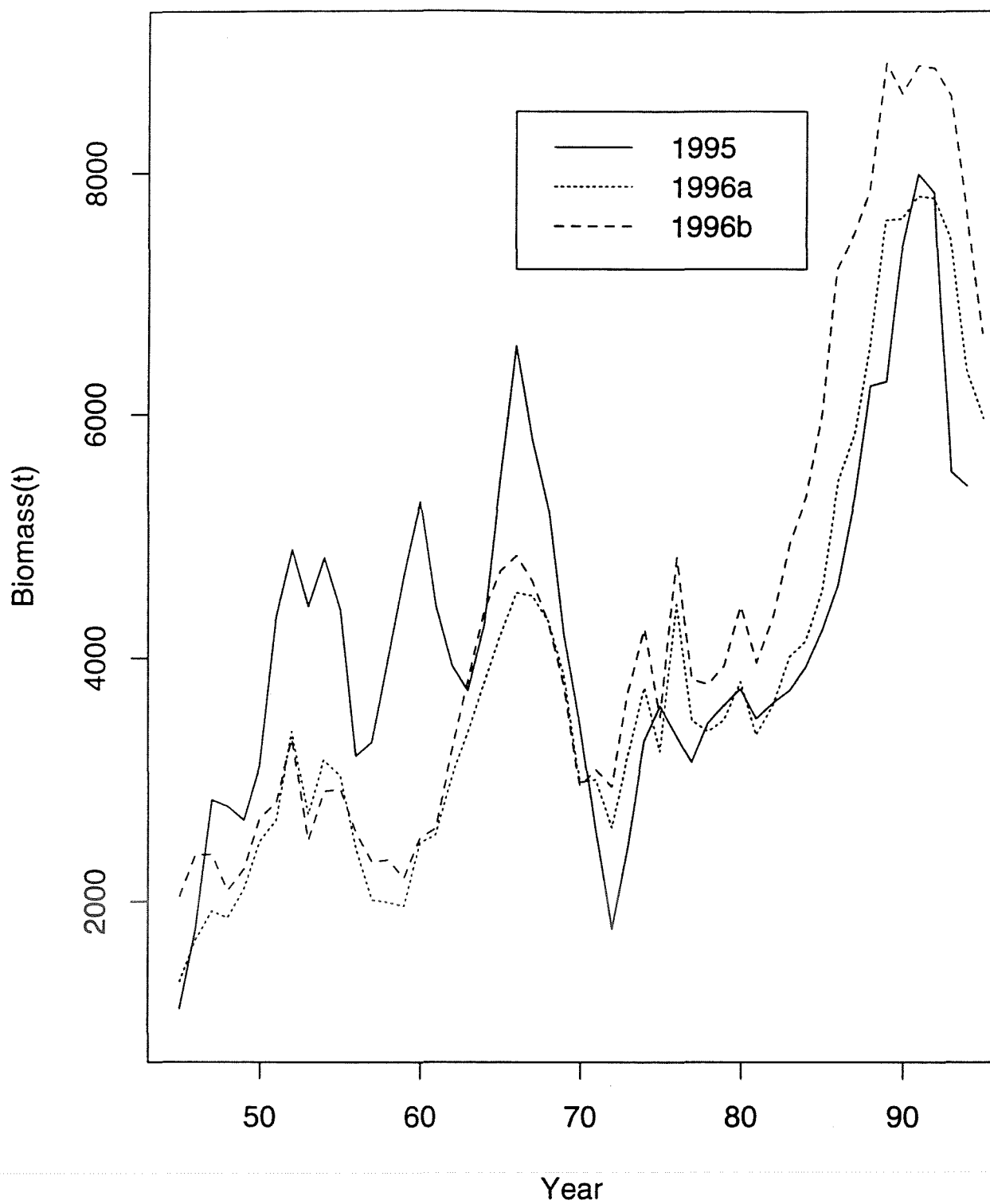


Fig. 4.46. biomass trajectories from the catch-age analyses for Hecate Strait rock sole, 1945-95.

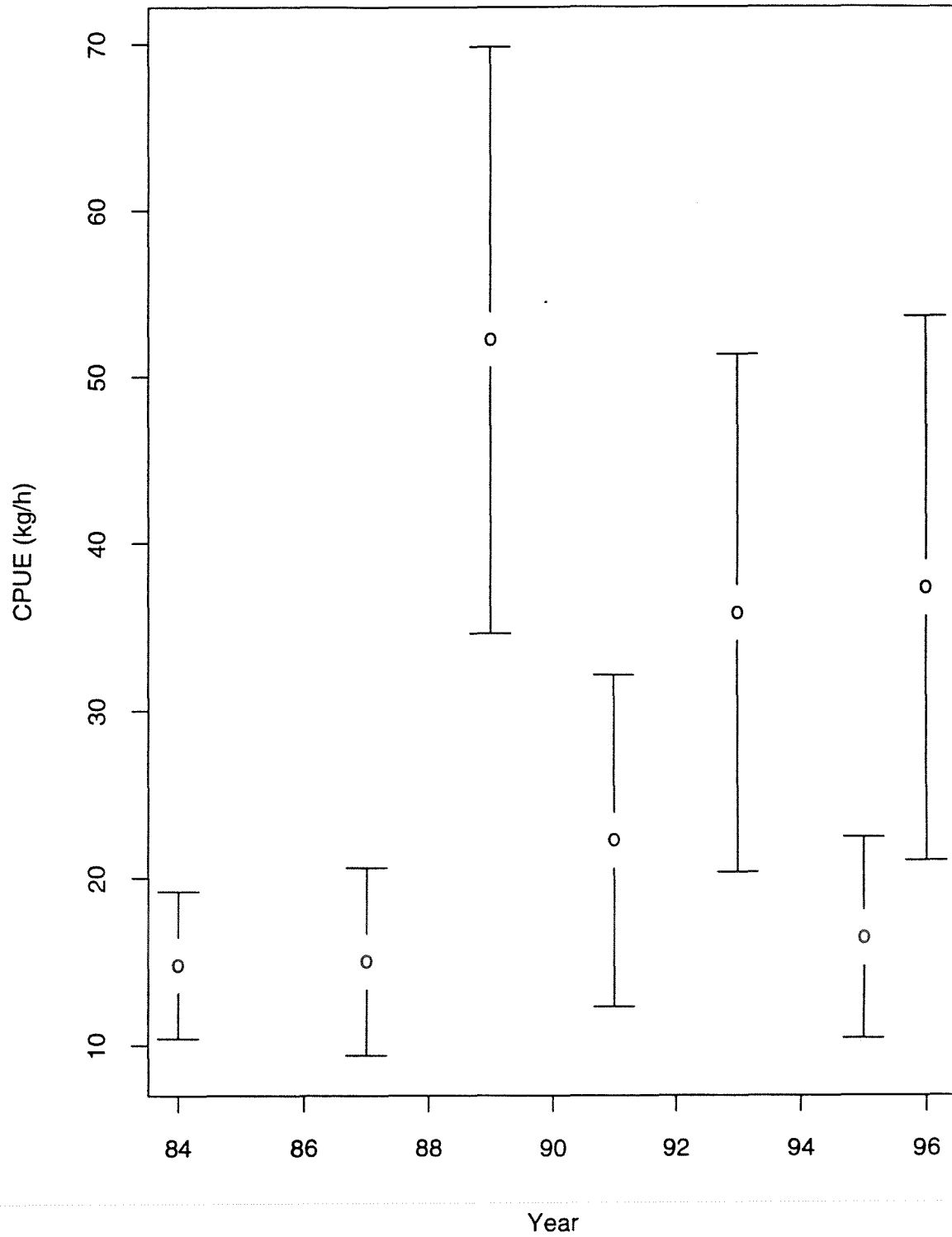


Fig. 4.47. Rock sole mean CPUE and 90% confidence interval from trawl surveys of Hecate Strait, 1984-96.

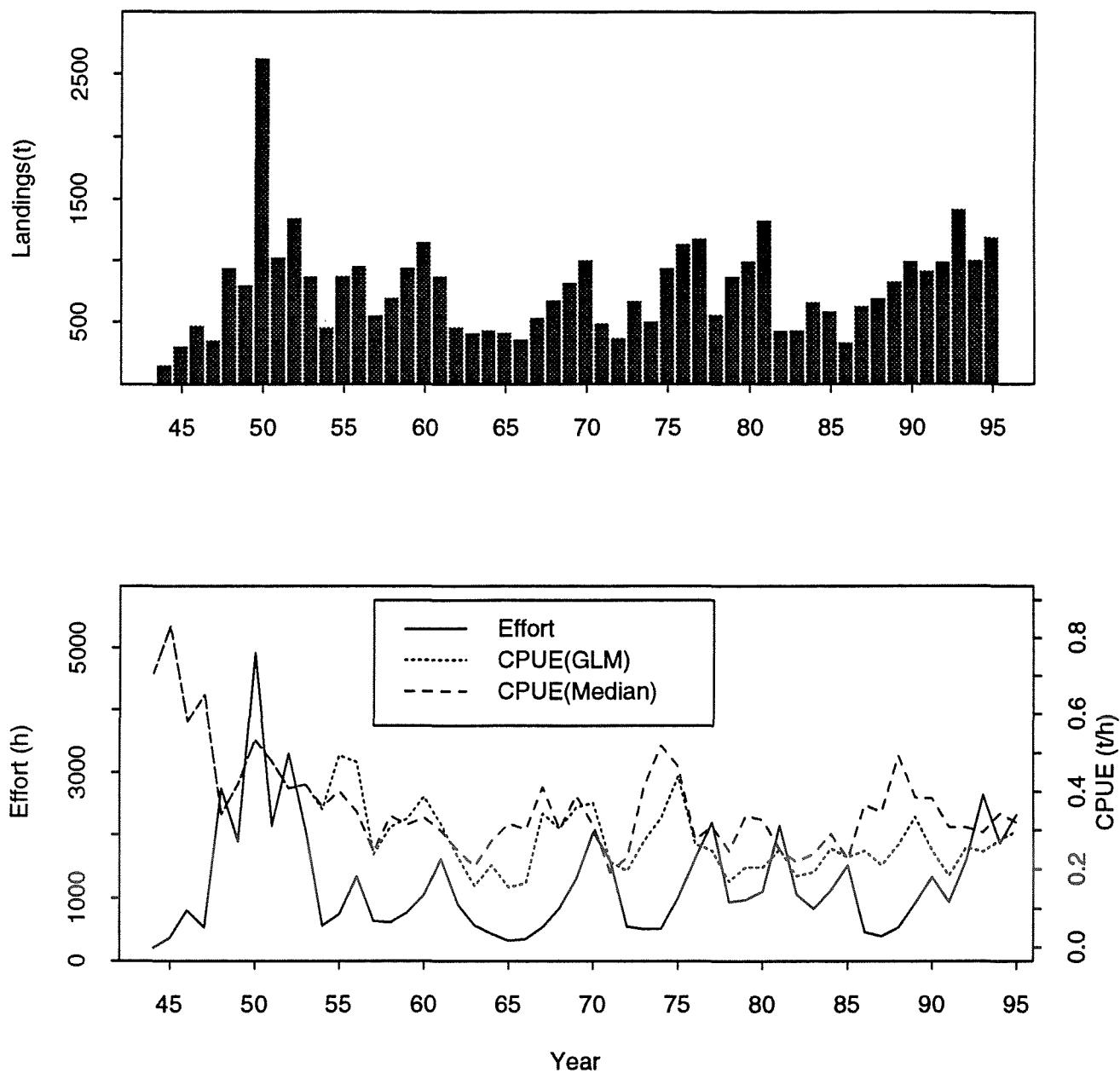


Fig. 4.48. Landing statistics for English sole in Hecate Strait: top panel landings in tonnes; bottom panel - effort and median and standardized CPUE series.

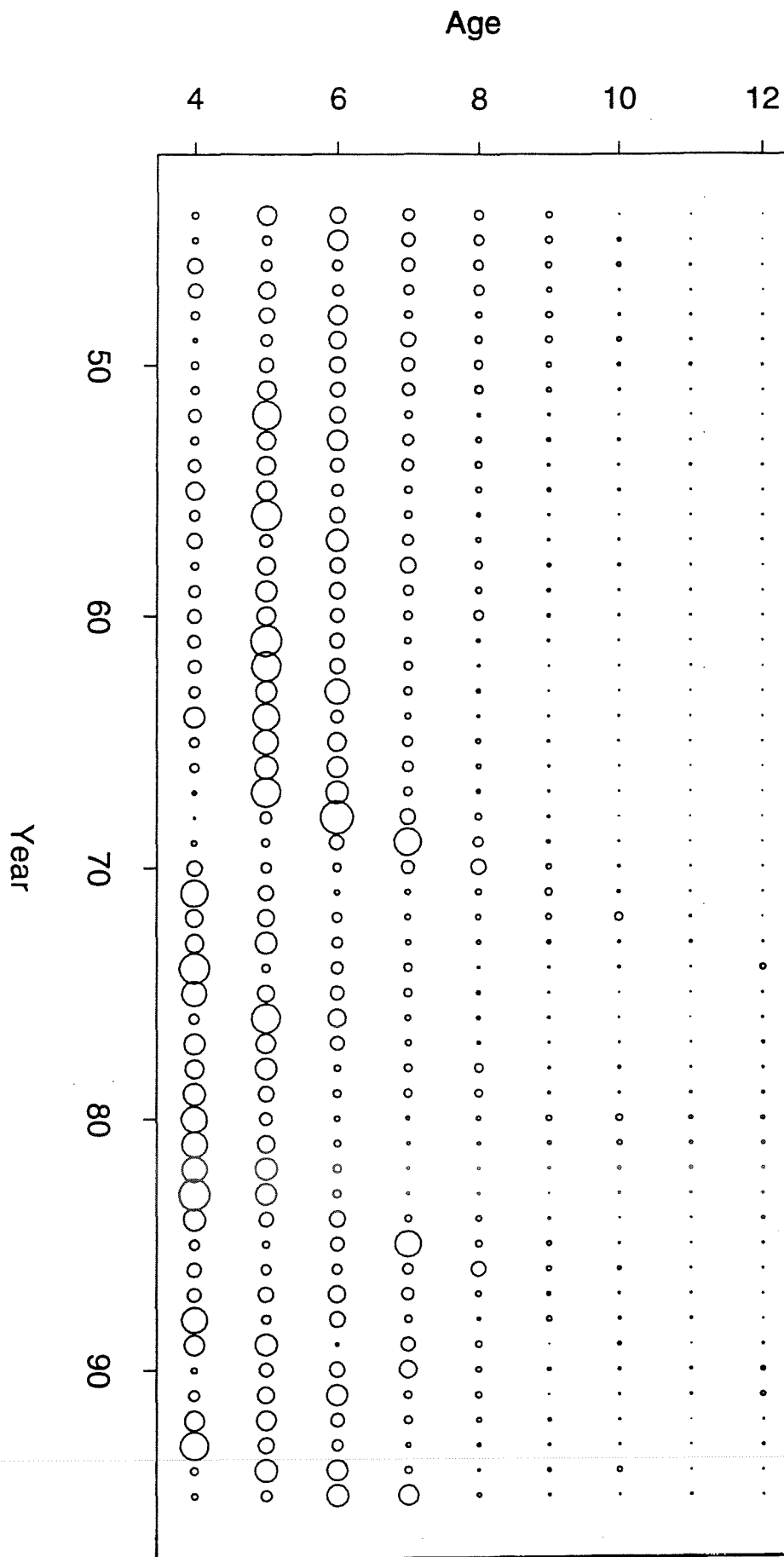


Fig. 4.49. Age proportion data by year for Hecate Strait English sole, ages 4-12+, years 1944-95.

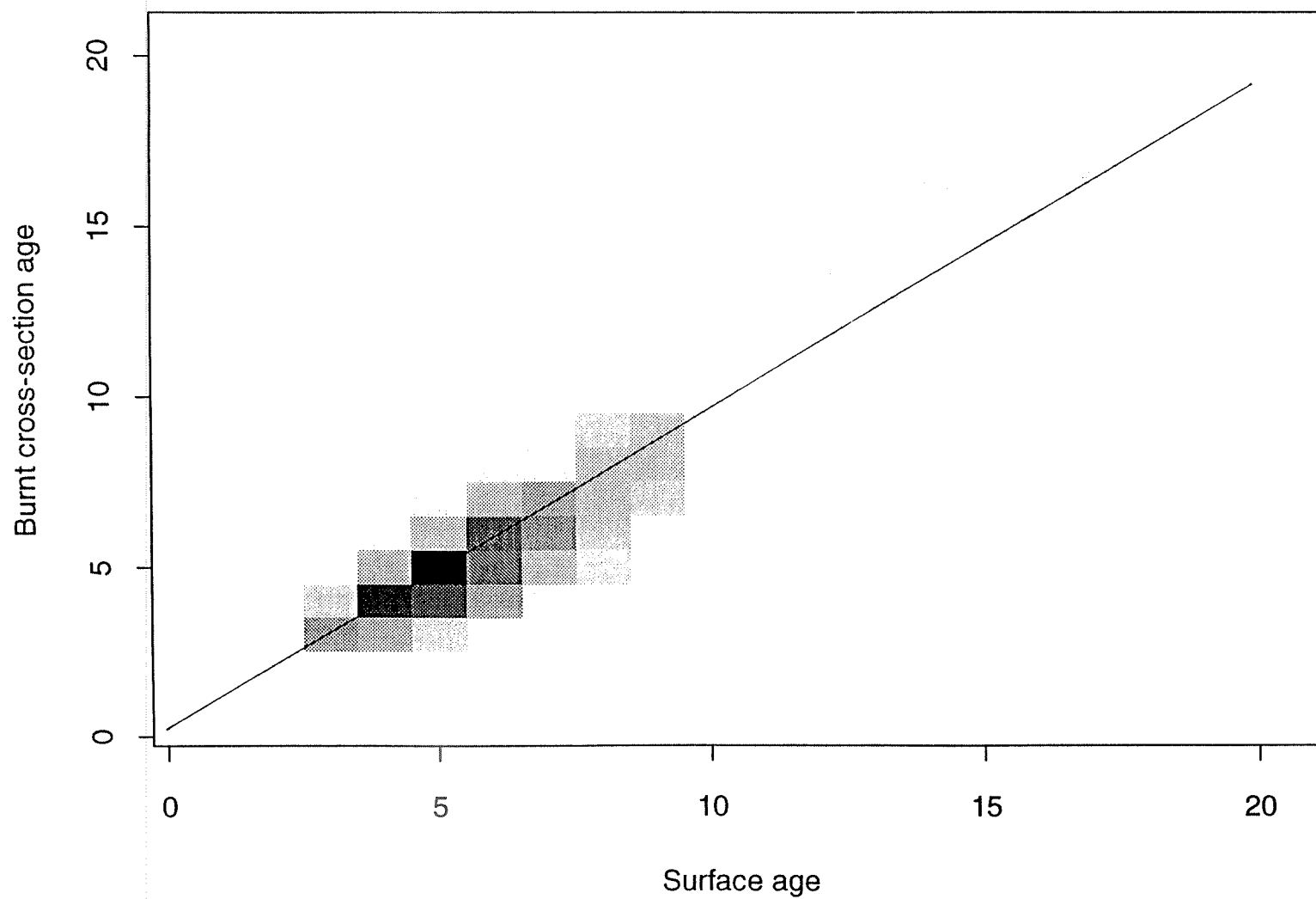


Fig. 4.50. Comparison of age determinations derived from otolith surfaces and burnt cross-sections for English sole. The diagonal line indicates 1:1 correspondence.

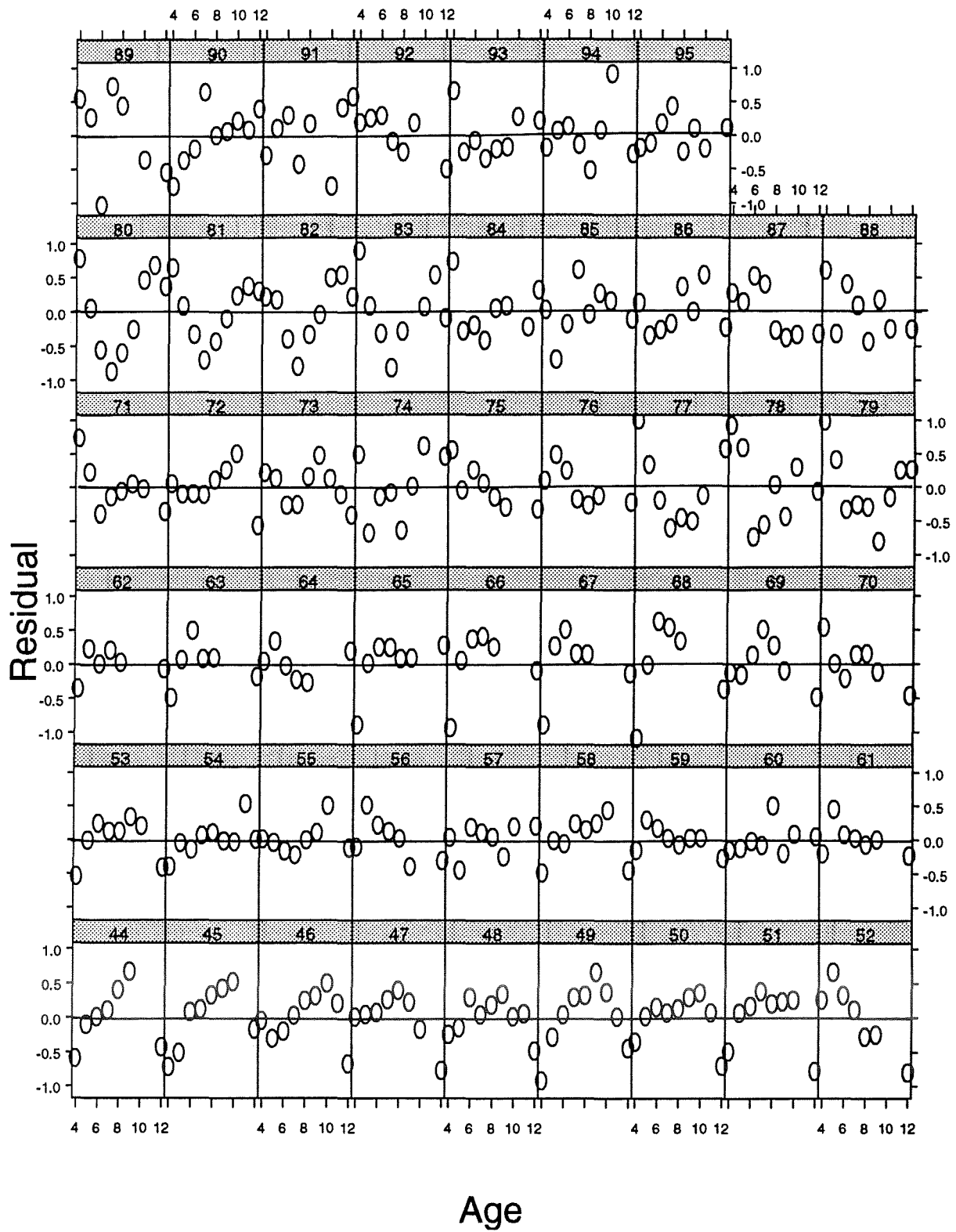


Fig. 4.51. Residual plots for the catch-age model results by age group by year, 1944-95.

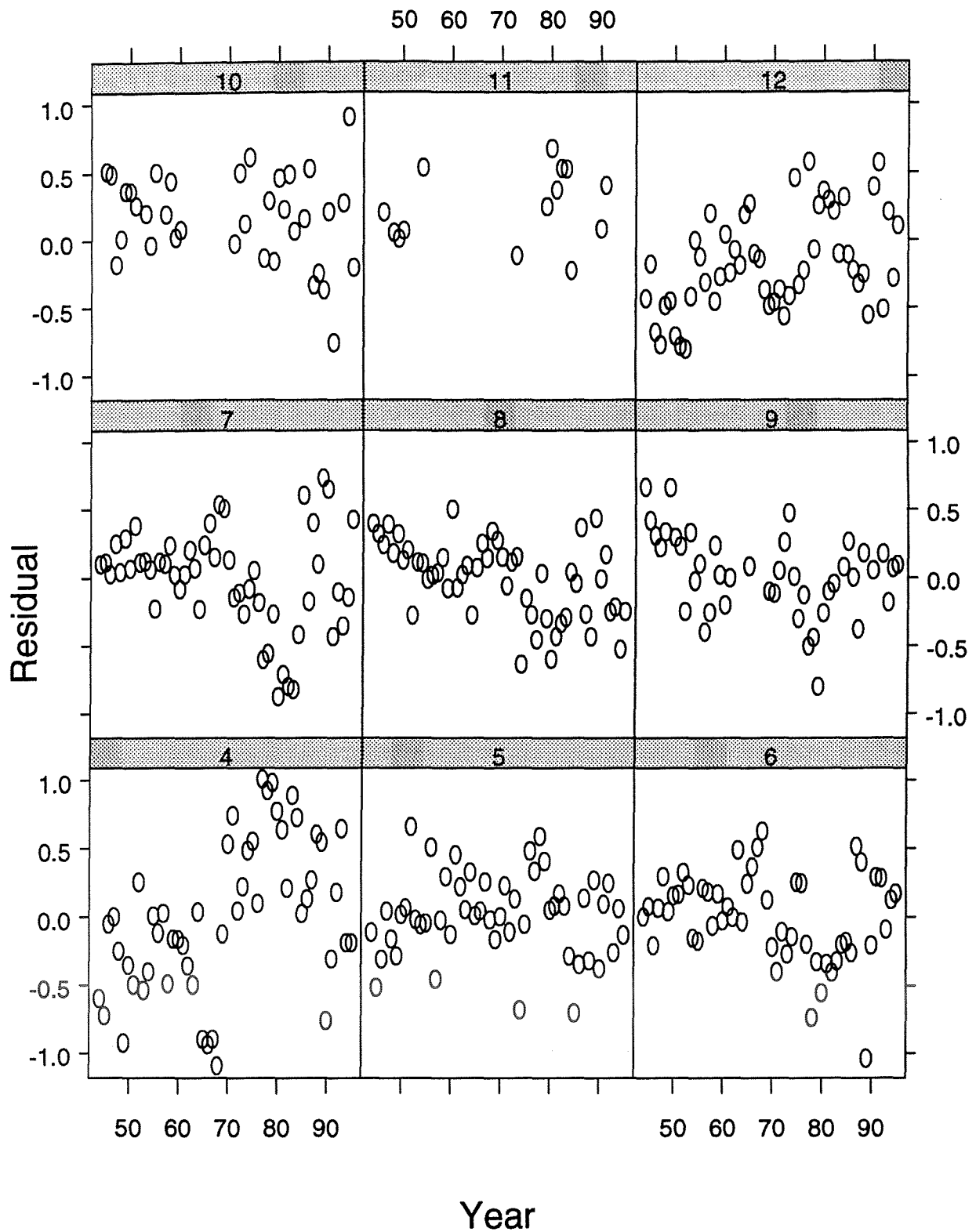


Fig. 4.52. Residual plots for the catch-age model results by year by age group, ages 4-12.

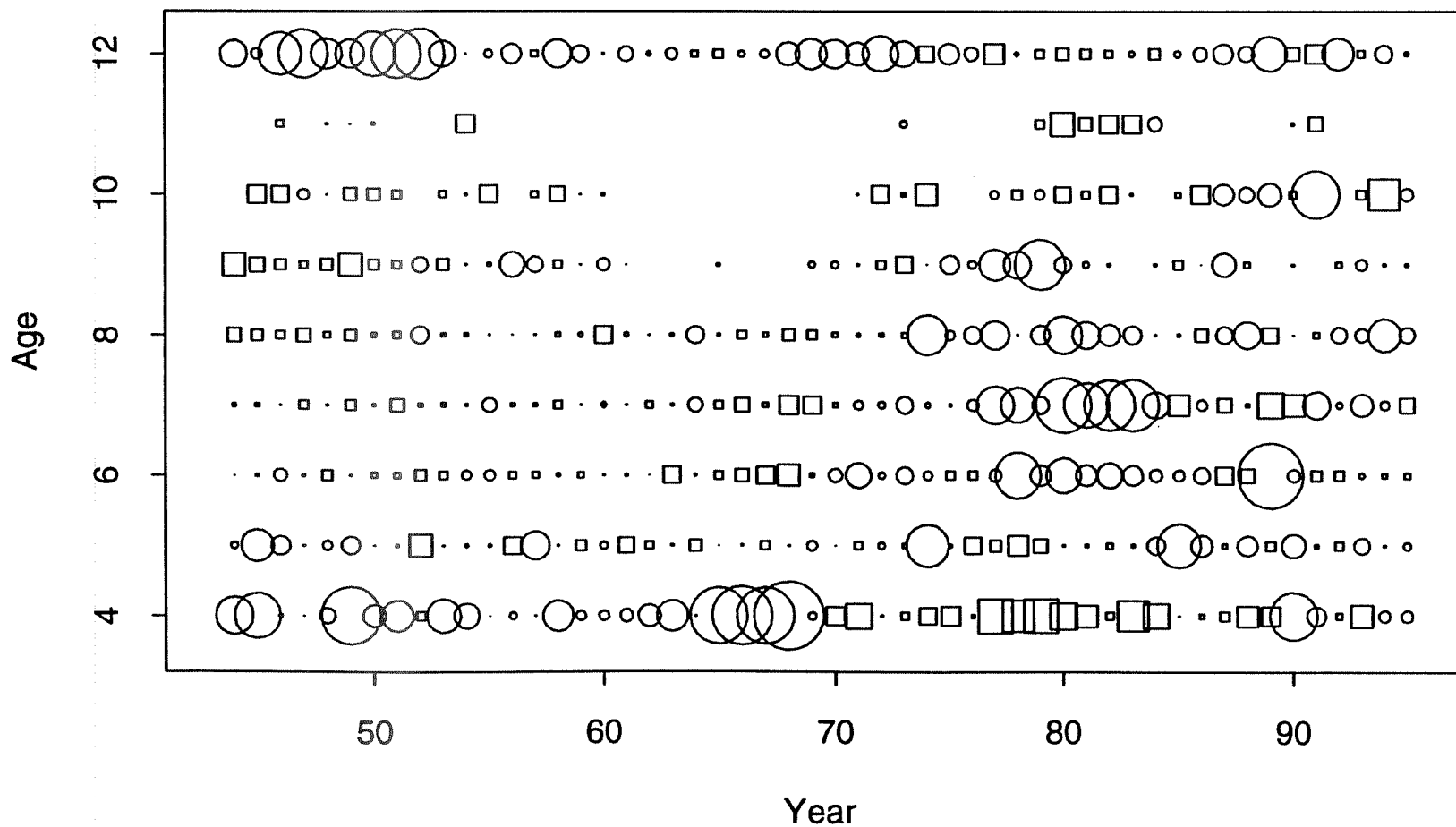


Fig. 4.53. Residual plot for the catch-age model results by year and age group: squares = positive residuals, circles = negative residuals.

English sole biomass trajectories from catch-age analysis

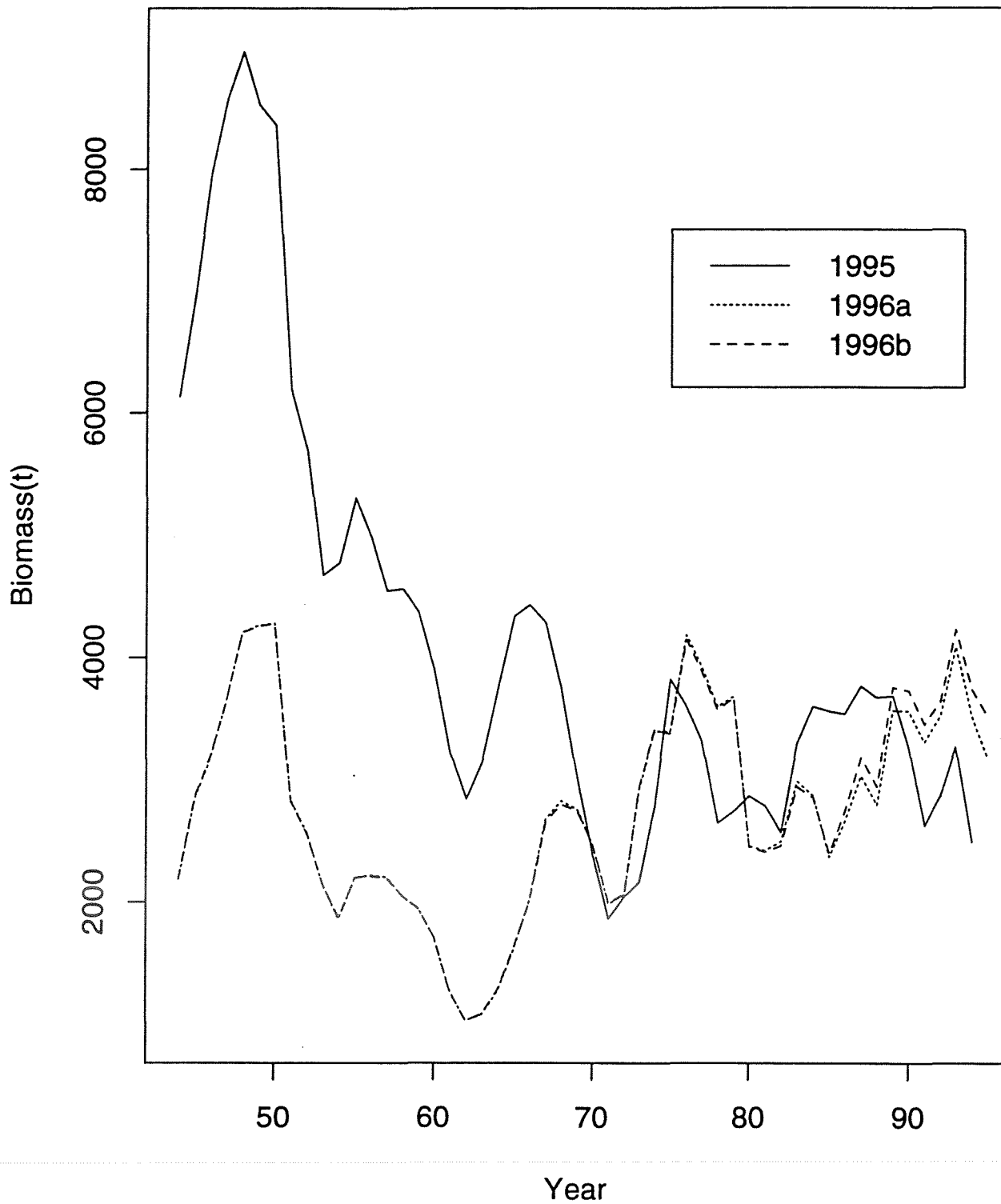


Fig. 4.54. Biomass trajectories for the catch-age analyses for Hecate Strait English sole, 1944-95.

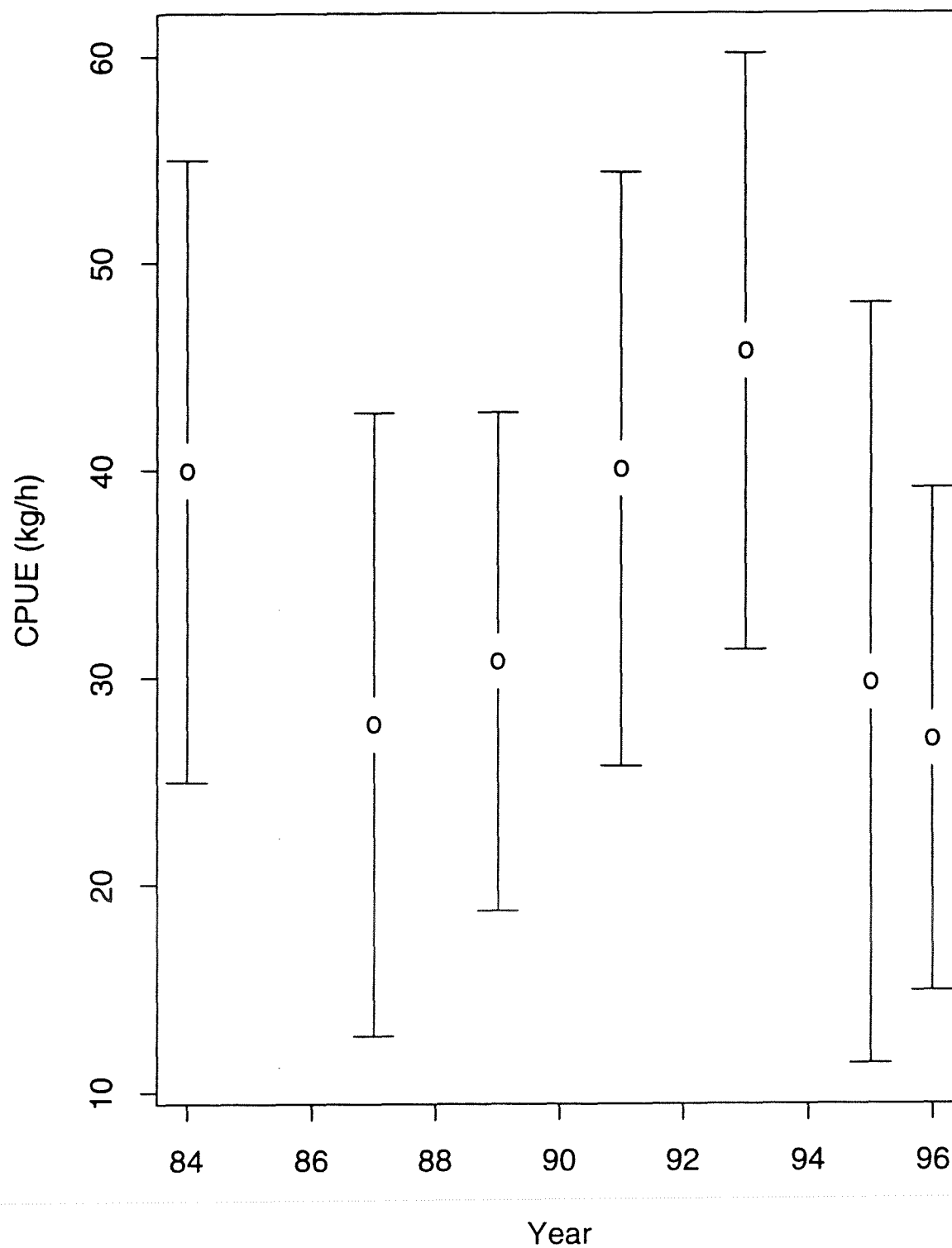


Fig. 4.55. English sole mean CPUE and 90% confidence interval for the Hecate Strait trawl survey, 1984-96.

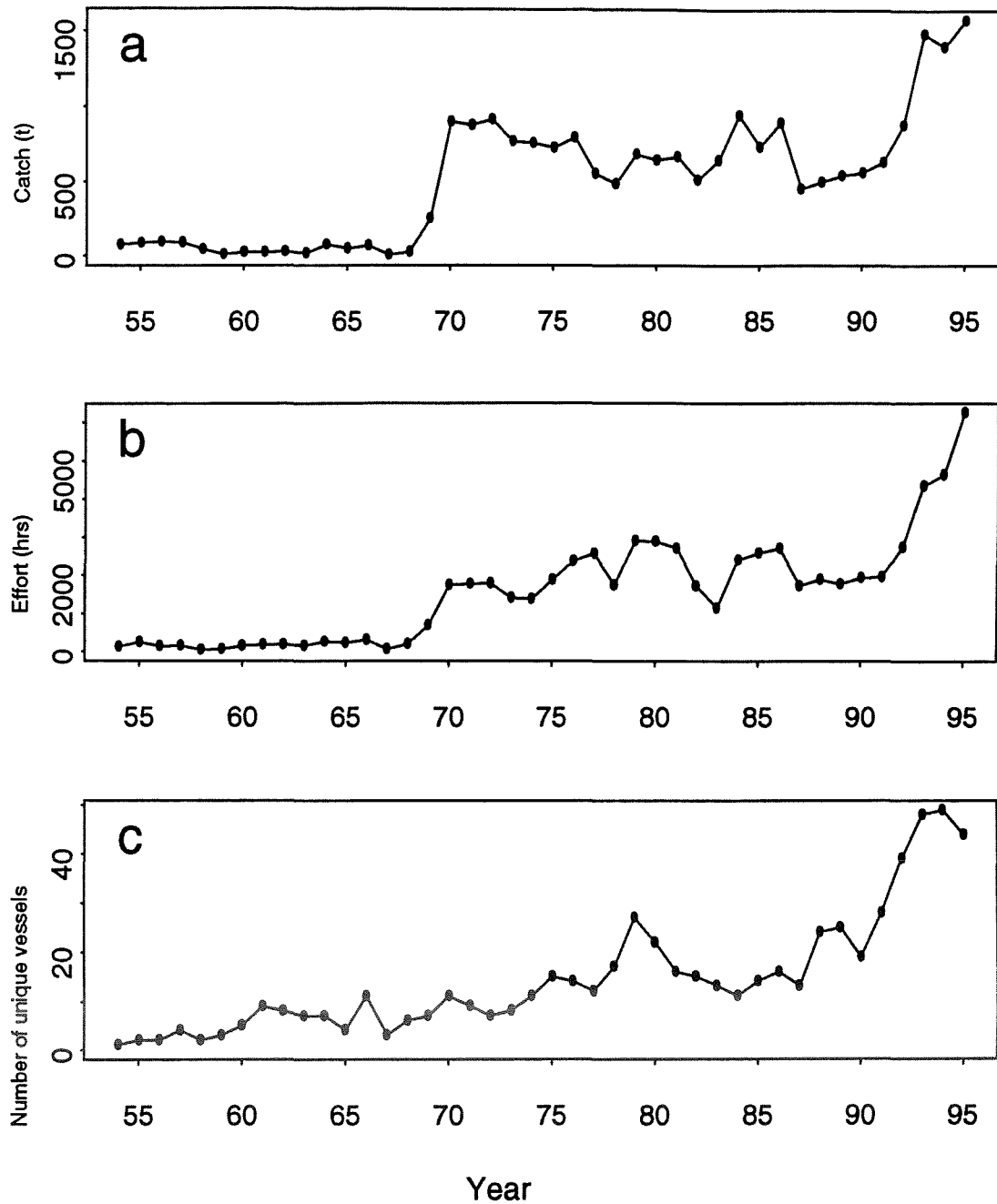


Fig. 4.56. Area 5CDE Dover sole catch (panel a), effort (panel b), and vessel participation (panel c) plotted against year.

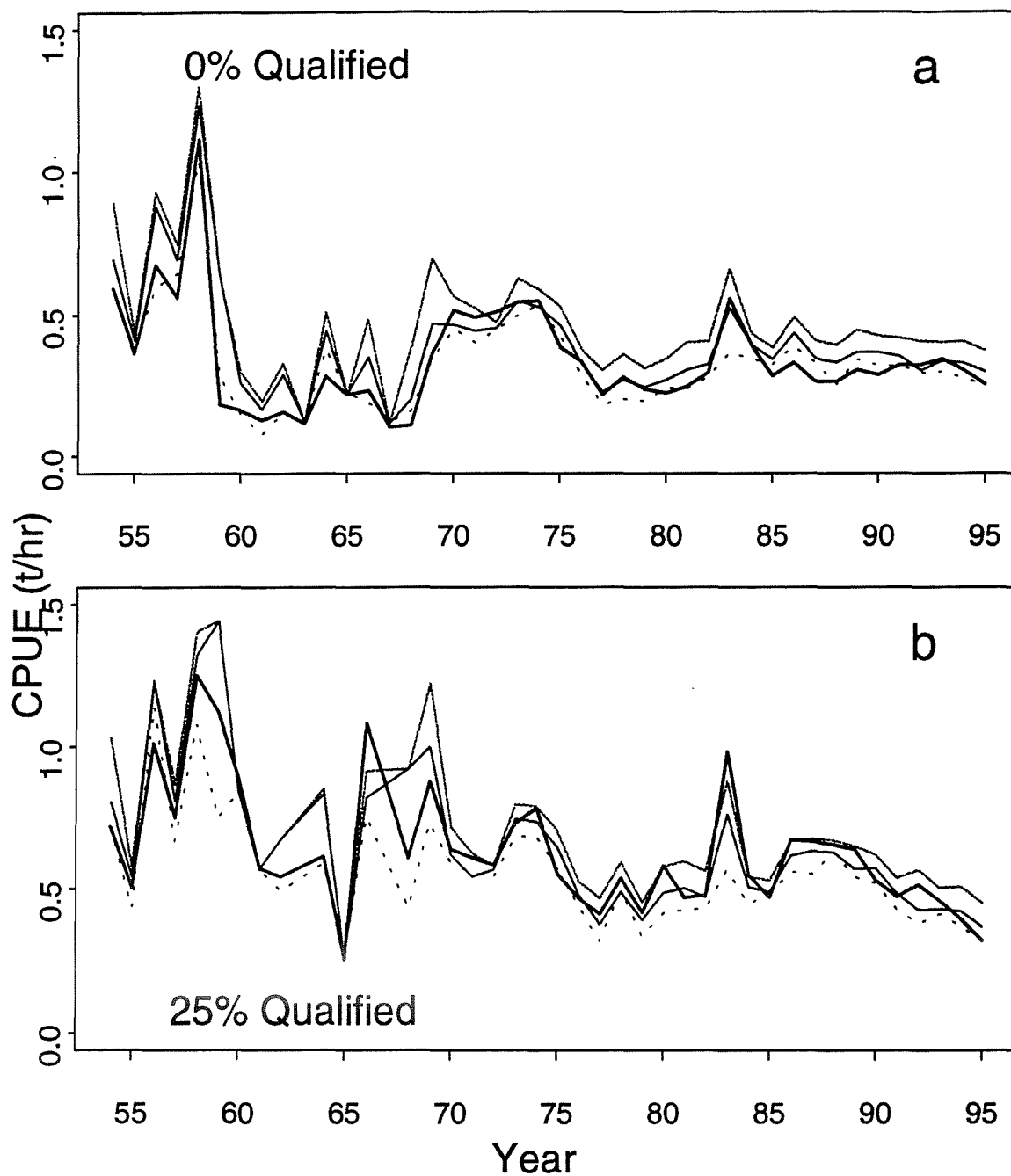


Fig. 4.57. Area 5CDE Dover sole annual catch per unit effort series at 0% (panel a) and 25% (panel b) qualification levels. Series using four estimators of CPUE are plotted: ratio of means (gray, thick line), mean of ratios (solid, thin line), 10% trimmed mean of ratios (dotted line), and 50% trimmed mean (median) of ratios.

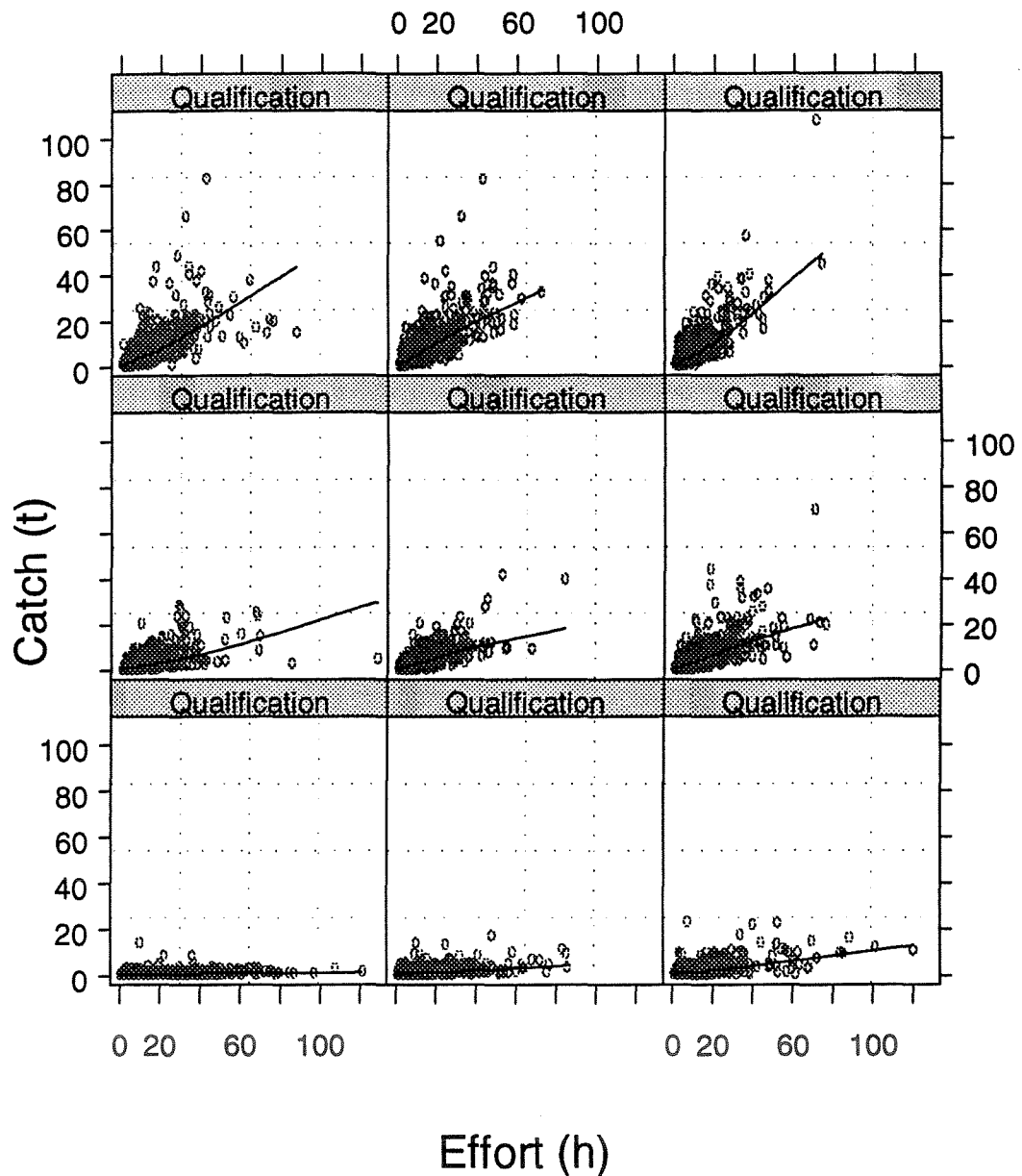


Fig. 4.58. Trellis plot of area 5CDE Dover sole catch as a function of effort given qualification level. Qualification consists of nine ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 0.001-0.043, 0.037-0.095, 0.088-0.178, 0.164-0.295, 0.278-0.431, 0.415-0.592, 0.570-0.731, 0.711-0.862 and 0.846-1.000. A loess trend line is shown as a solid line within each panel.

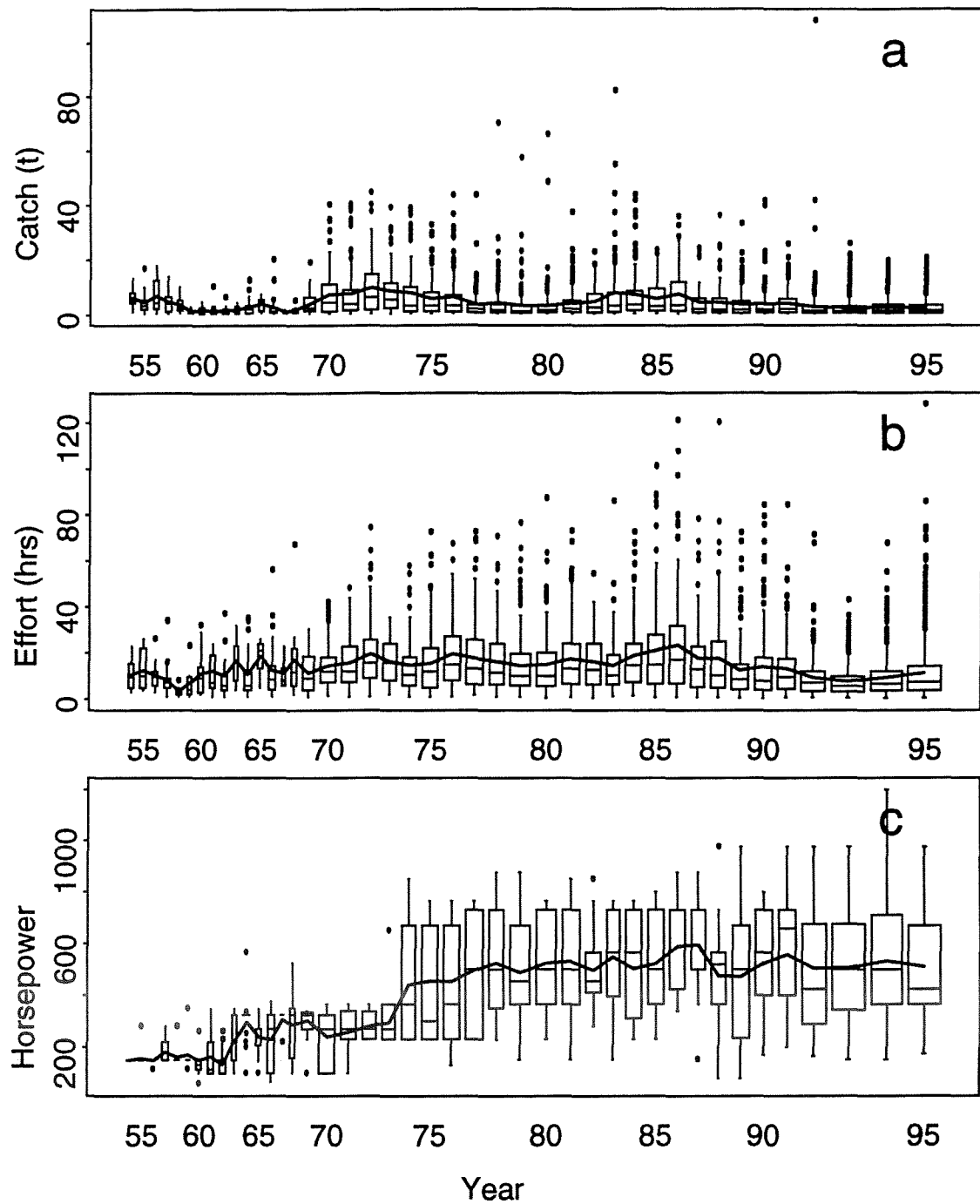


Fig. 4.59. Boxplots showing the annual distribution of catch (panel a), effort (panel b), and vessel horsepower (panel c) derived from the fishing event data for area 5CDE Dover sole. The annual mean is shown as a thick solid line overlaid on the boxplots.

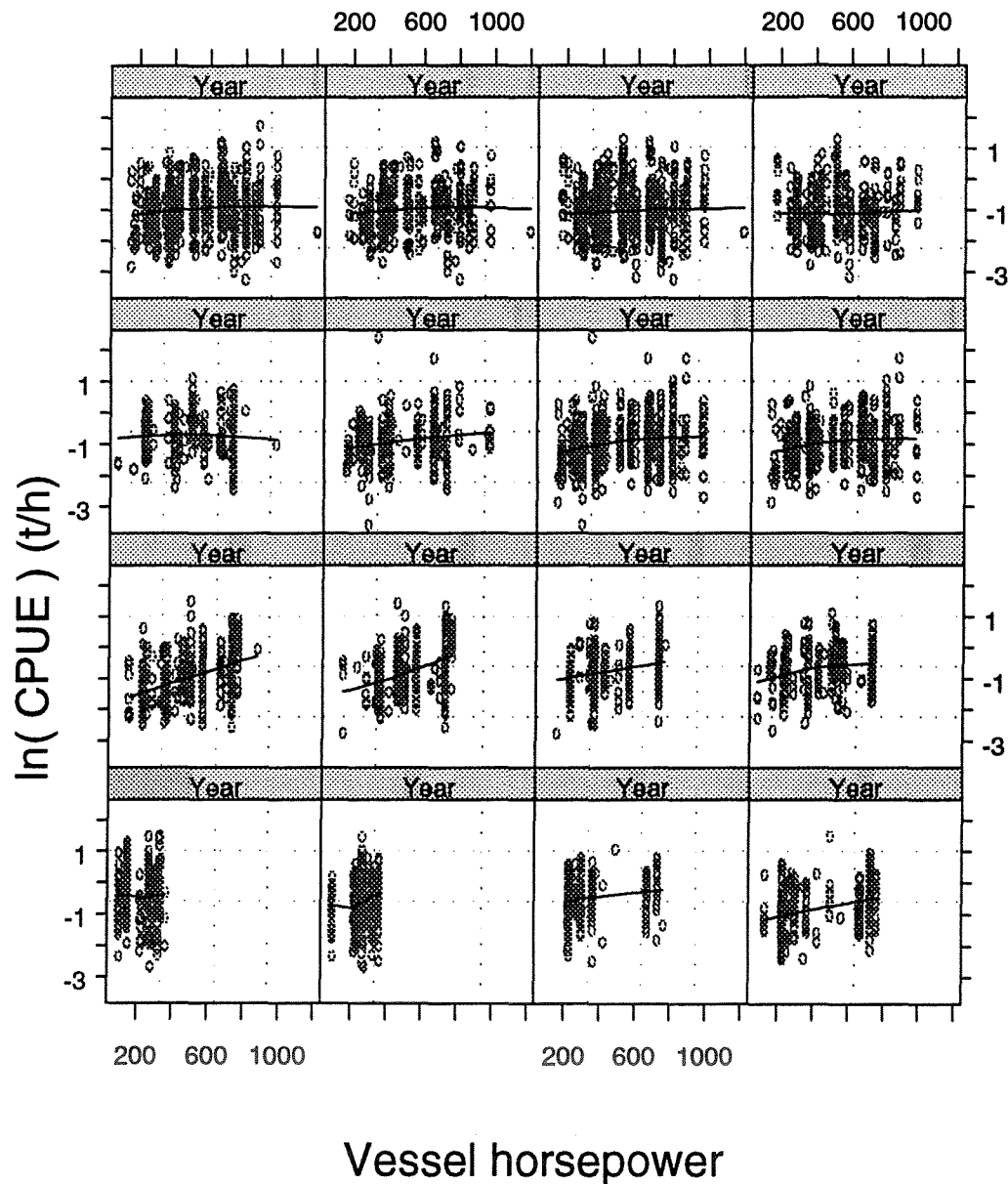


Fig. 4.60. Trellis plots of area 5CDE Dover sole CPUE (\log_e transformed) as a function of vessel horsepower given year. Year consists of sixteen ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 54-70, 70-73, 72-75, 75-78, 77-81, 80-83, 83-86, 85-89, 89-91, 91-92, 92-93, 93-93, 93-94, 94-94, 94-95 and 95-95. A loess trend line is shown as a solid line within each panel.

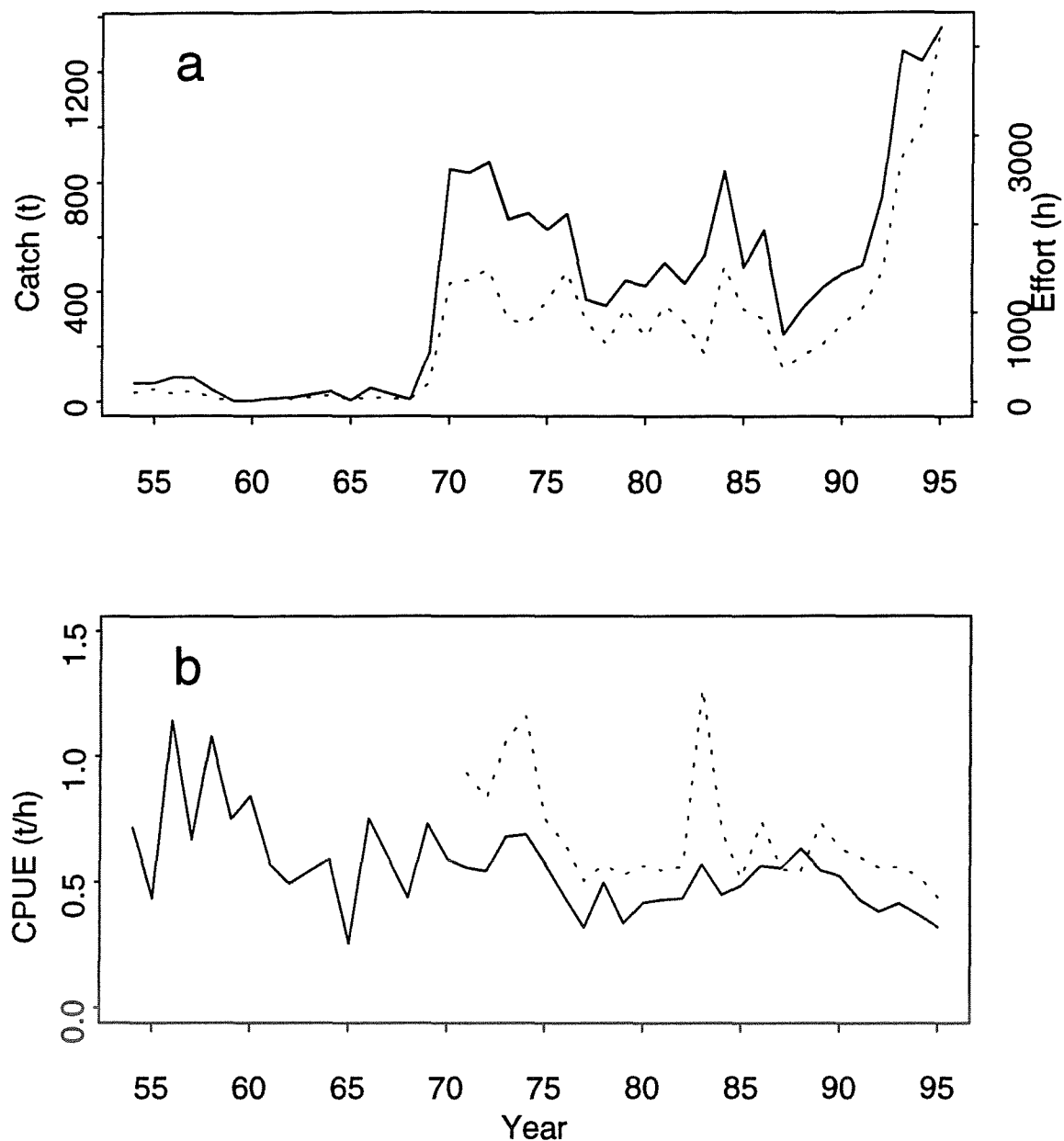


Fig. 4.61. Area 5CDE Dover sole catch and effort series (panel a) and CPUE series (panel b) for 25% qualified fishing events. Note the coincidence of fluctuations in the catch series (solid line, panel a) with the effort series (dotted line, panel a). In panel (b) the median of ratios CPUE series is plotted at the solid line, while the CPUE adjusted for year and vessel horsepower is shown as a dotted line.

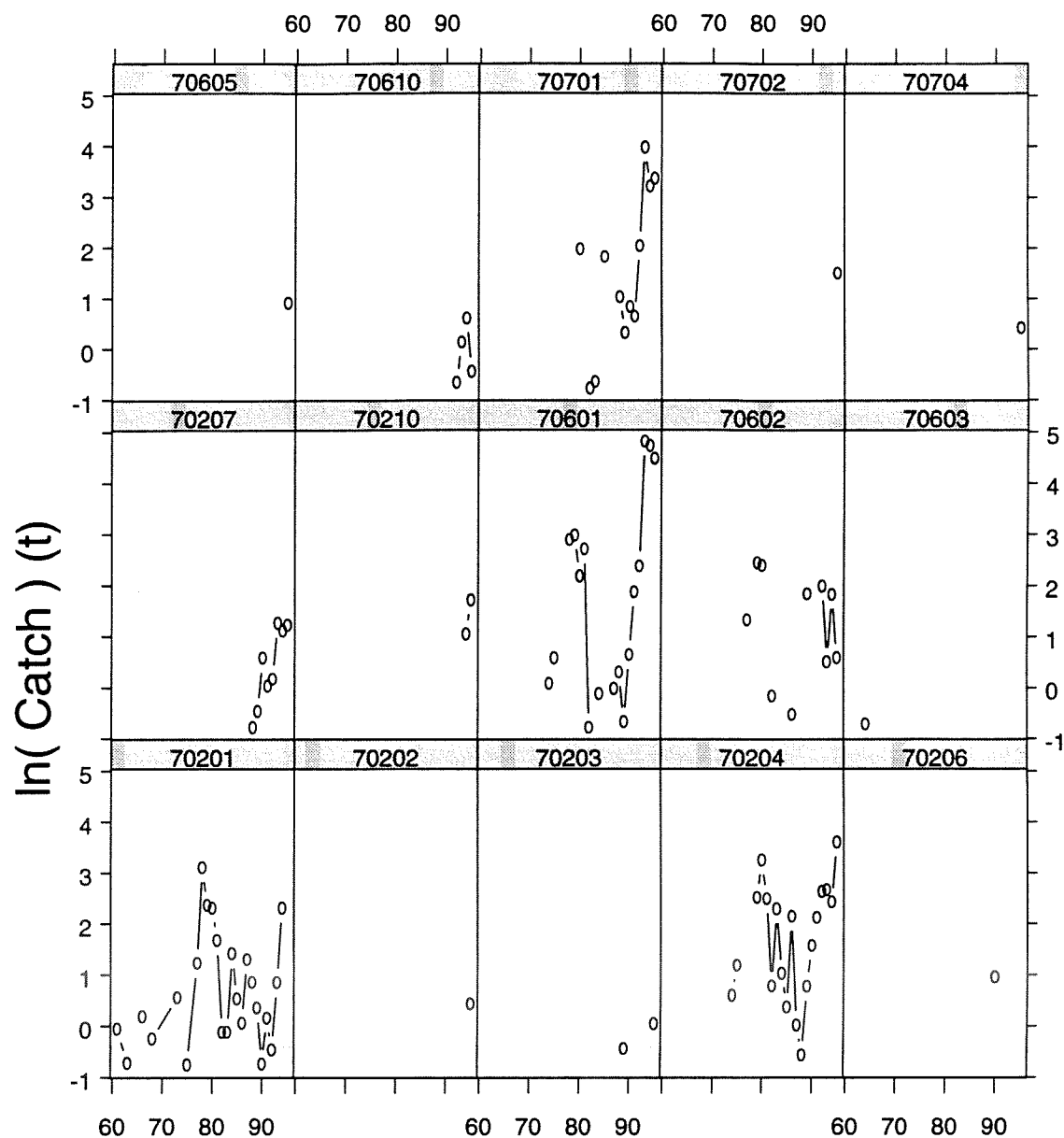


Fig. 4.62. Trellis plot of area 5CDE Dover sole catch (\log_e transformed) as a function of year given fishing locality. The given strip label is a combination of major area, minor area, and fishing locality. For example, 80401 is major area 8 (5D), minor area 04, locality 01.

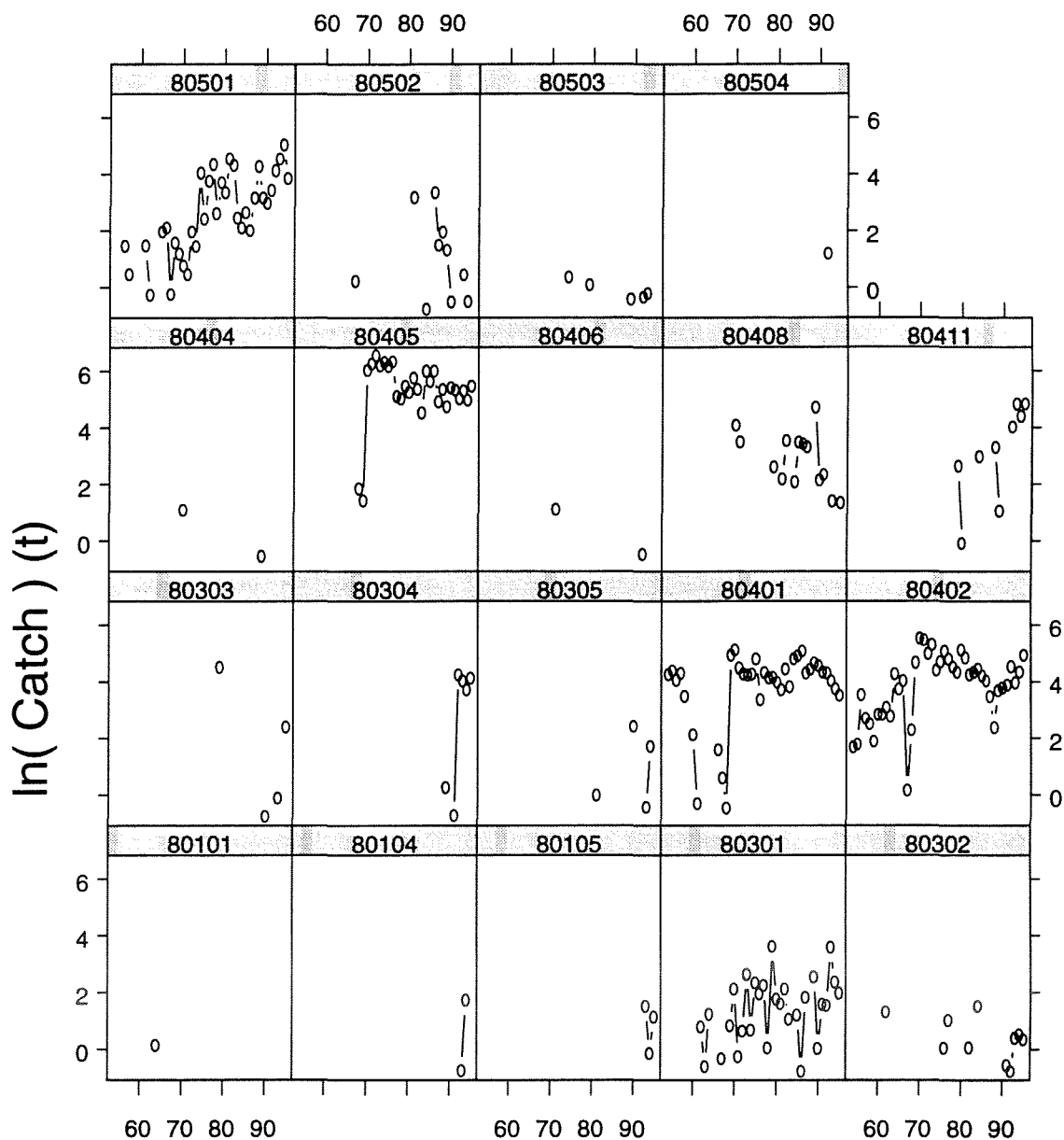


Fig. 4.62 - con't. Trellis plot of ^{Year} area 5CDE Dover sole catch (\log_e transformed) as a function of year given fishing locality. The given strip label is a combination of major area, minor area, and fishing locality. For example, 80401 is major area 8 (5D), minor area 04, locality 01.

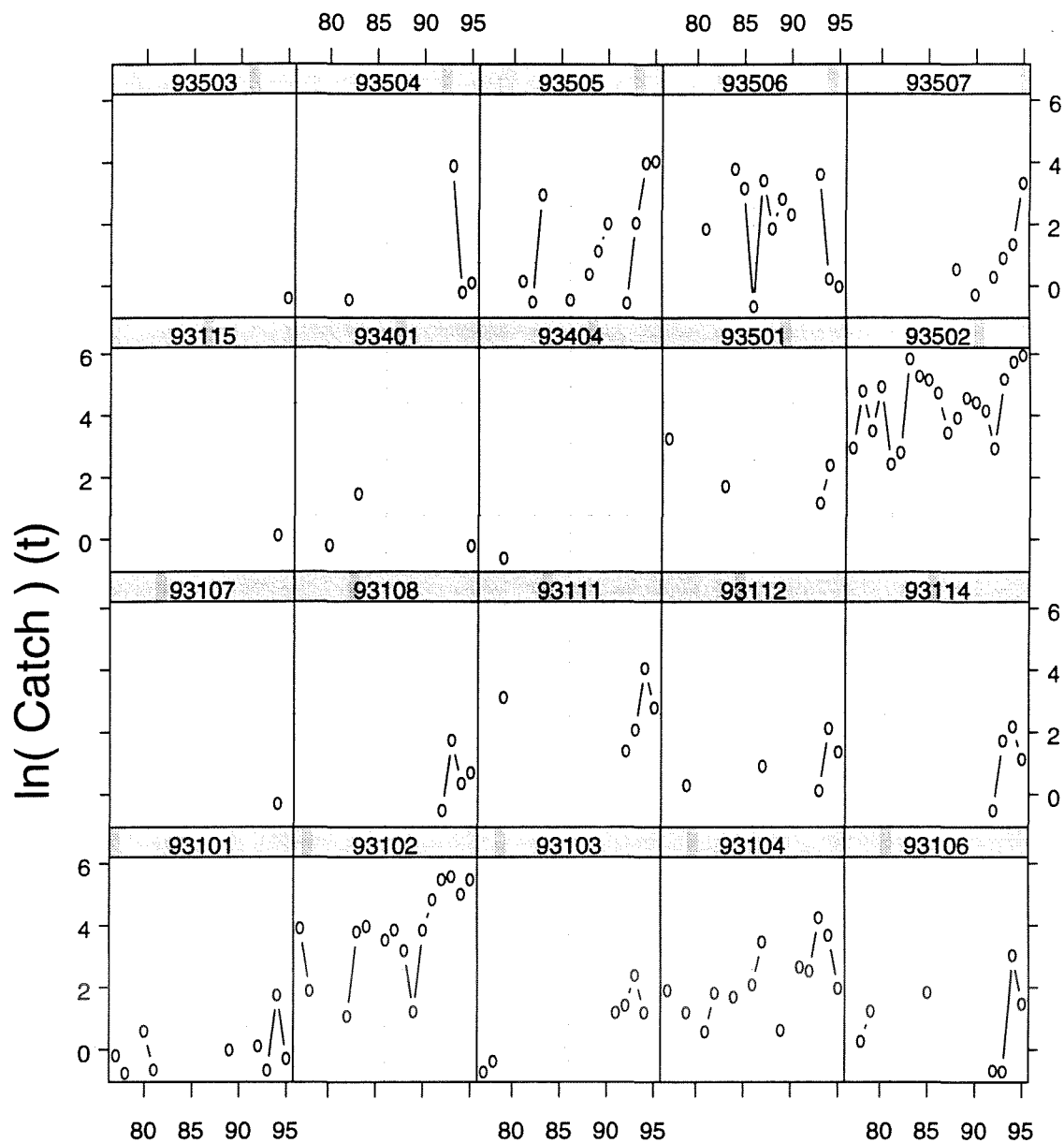


Fig. 4.62 - con't. Trellis plot of area 5CDE Dover sole catch (\log_e transformed) as a function of year given fishing locality. The given strip label is a combination of major area, minor area, and fishing locality. For example, 80401 is major area 8 (5D), minor area 04, locality 01.

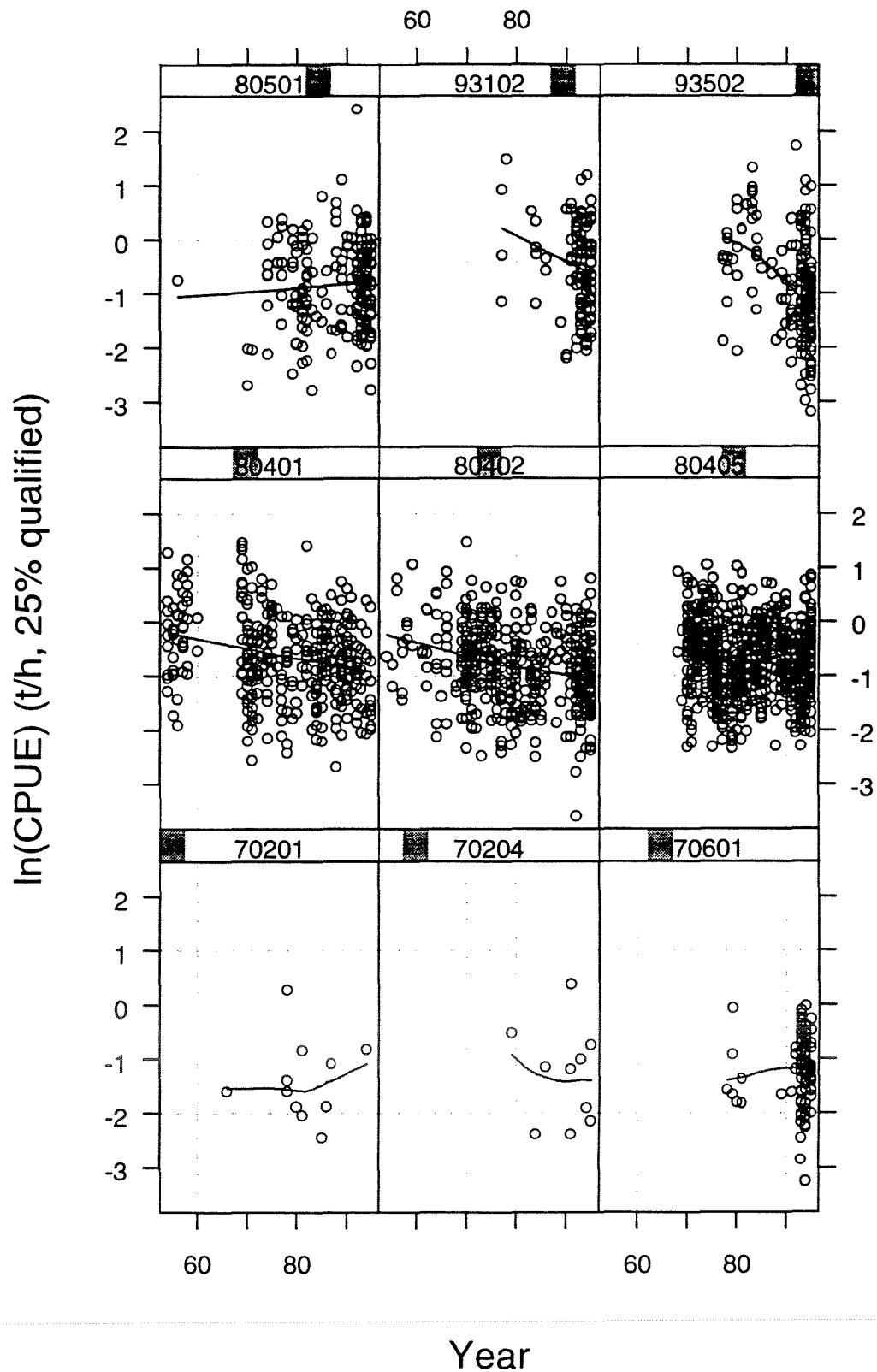


Fig. 4.63. Trellis plot of area 5CDE Dover sole CPUE series (\log_e transformed, 25% qualified) for selected fishing localities. A loess trend line is shown as a solid line within each panel.

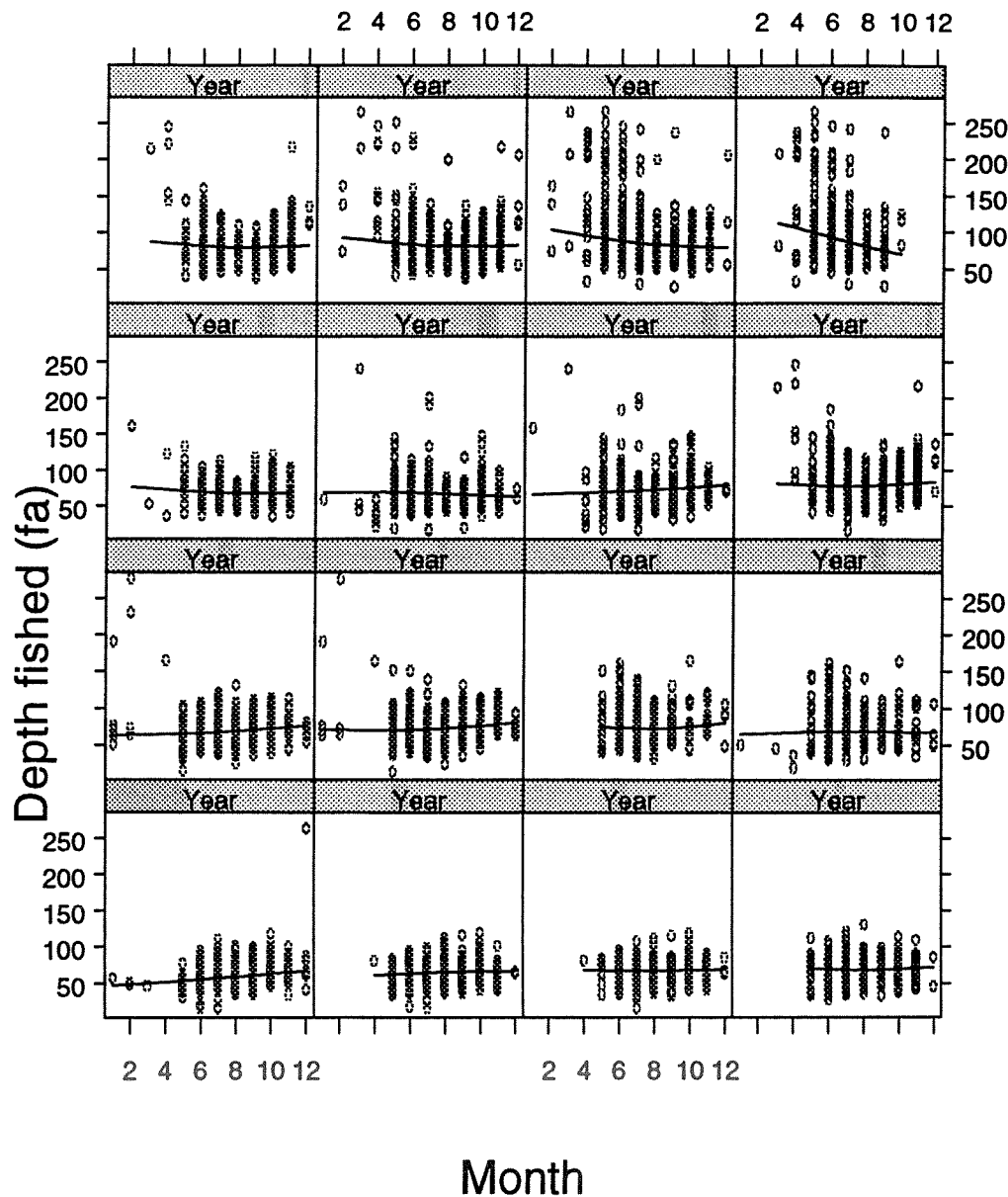


Fig. 4.64. Depth fished as a function of month given year for area 5C and 5D combined Dover sole. Year consists of sixteen ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 54-70, 69-72, 71-75, 74-77, 76-79, 78-80, 80-82, 81-84, 84-87, 87-90, 90-92, 92-93, 93-93, 93-94, 94-95 and 95-95. A loess smooth of the trend appears as a solid line within each panel.

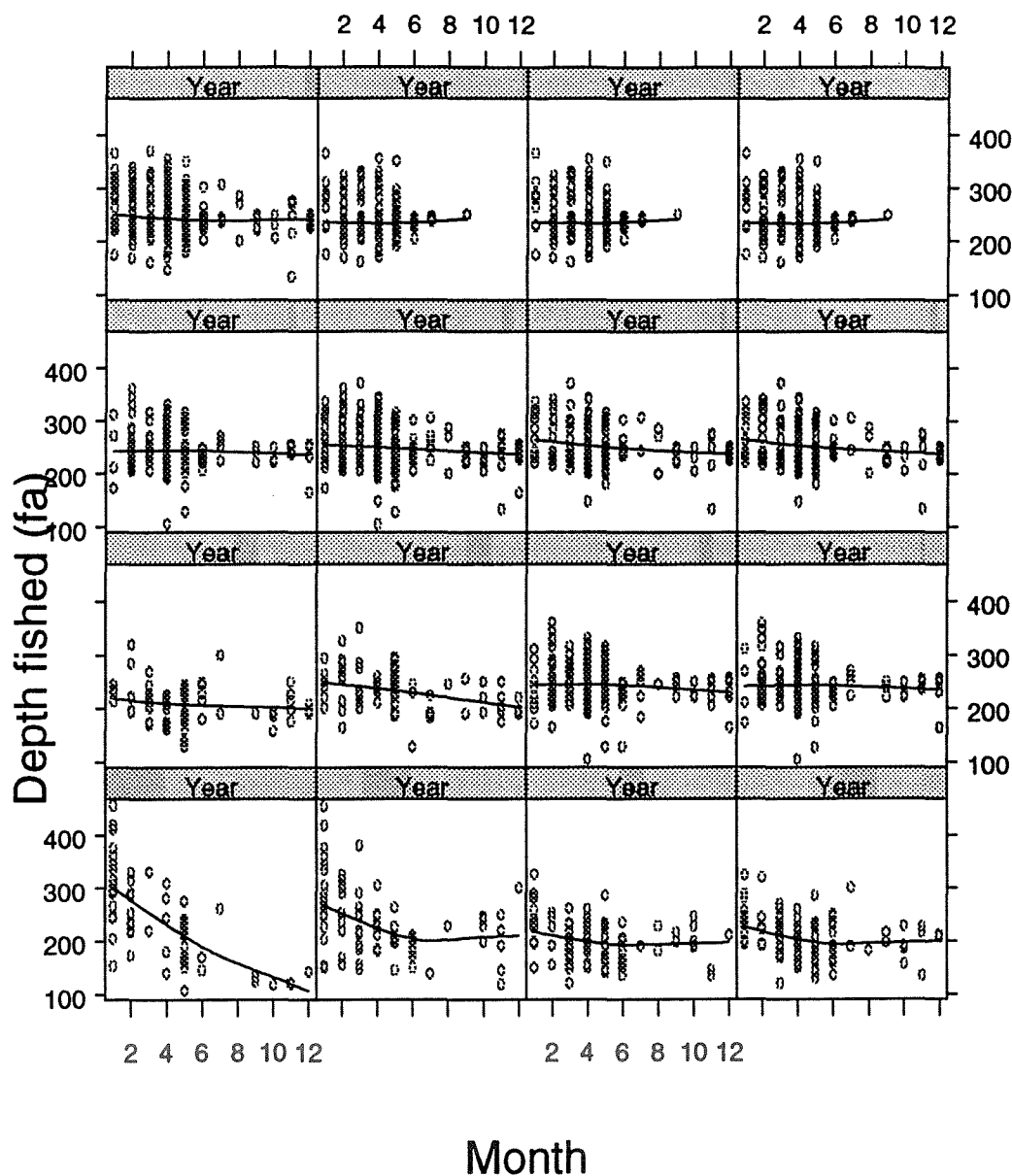


Fig. 4.65. Depth fished as a function of month given year for area 5E Dover sole. Year consists of sixteen ranges, with each range containing a similar number of observations (allowing for overlap of approximately 12%): 77-82, 81-85, 85-87, 87-89, 89-91, 91-92, 92-93, 93-93, 93-94, 94-94, 94-95, 95-95 and 95-95. A loess smooth of the trend appears as a solid line within each panel.