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Slope rockfish assessment for the west coast of Canada in 1999

J. T. Schnute, N. Olsen, and R. Haigh

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, BC V9R 5K6

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ABSTRACT

This year's report does not provide a new assessment, but rather a series of steps essential for future assessments, based on industry-sponsored surveys for slope rockfish. Our research follows a strategic plan for collaborative work with the groundfish industry. The report presents the latest available data and makes the following major advancements on past work. First, we have developed a bathymetric database, cross-referenced with the observer data, from which we can calculate bottom area available to fishing as well as actual bottom areas swept and impacted. We have also provided estimates of biomass for each slope rockfish species by extrapolating observed estimates of density at depth to all available coastal bathymetry. Second, in collaboration with the Canadian Groundfish Research and Conservation Society, we have initiated the development of an industry-sponsored slope rockfish survey, independent of the fishery. To date, we have developed maps that record fishermen's impressions of trawl characteristics of the ocean floor. These classifications and preliminary estimates of fish density provide essential prior information in designing a survey that minimizes the variance of biomass estimates for a given level of available resources. Third, we have used biological data to calculate rough estimates of key reference points for the slope rockfish species. The report presents the complete mathematical framework for calculating reference point values from underlying biological parameters.

Analyses extended from last year suggest a continuing decline in the density of longspine thornyheads in the most heavily fished blocks in assessment unit region 3C. Although these results are not definitive, they suggest a cautious approach to the development of a new fishery on this species.

In response to a request from industry and management, we examine the possible justification for shifting the 5CD/5ES boundary 20 minutes north of its present location at 52°N. If the quota remains unchanged in each area, the impact on quota holders would be minimal. Furthermore, fishing pressure on the Morseby Gully region would be somewhat alleviated if 5CD quota holders shift some of their effort to the region off the southwest Queen Charlotte Islands.

Although we have observed a number of significant trends in CPUE, we do not specifically recommend that current TAC levels be adjusted. CPUE trends may indicate changes in abundance; however, there are so many confounding factors that we can only advise managers to be aware of potential problems. Until controlled surveys are implemented and/or confounding factors are statistically incorporated in CPUE measurements, we cannot with any degree of confidence provide reliable measures of stock abundance at this time and recommend that the 1999 yield options be extended to 2000.

RÉSUMÉ

Le rapport de la présente année ne contient pas de nouvelle évaluation, mais plutôt une série d'étapes essentielles aux évaluations à venir, fondées sur les résultats de relevés sur le sébaste de la pente parrainés par l'industrie. Nos recherches sont conformes à un plan stratégique de collaboration avec l'industrie du poisson de fond. On trouve dans le rapport les dernières données disponibles et les progrès importants accomplis, qui sont présentés ci-après. Tout d'abord, nous avons créé une base de données bathymétriques, avec renvois aux données des observateurs, à partir desquelles nous pouvons calculer la superficie des fonds pouvant faire l'objet de pêche de même que les superficies réelles des fonds chalutés et perturbés. Nous avons aussi fourni des estimations de la biomasse du sébaste pour chaque espèce de la pente en extrapolant à tous les fonds côtiers de bathymétrie connue les estimations de la densité selon la profondeur. Deuxièmement, en collaboration avec la Canadian Groundfish Research and Conservation Society, nous avons amorcé la mise en œuvre d'un relevé sur le sébaste de la pente, indépendant de la pêche, parrainé par l'industrie. Jusqu'à maintenant, nous avons établi des cartes pour l'enregistrement des impressions des pêcheurs relativement aux caractéristiques de chalutage du plancher océanique. Cette catégorisation et les estimations préliminaires de la densité de poisson constituent des renseignements préalables essentiels à la conception d'un relevé réduisant la variance des estimations de biomasse pour un niveau donné de ressources exploitables. Troisièmement, nous avons utilisé des données biologiques pour le calcul d'estimations grossières de points de référence clés pour les espèces de sébaste de la pente. On trouve dans le rapport la démarche mathématique complète appliquée au calcul des valeurs des points de référence à partir des paramètres biologiques.

Des analyses remontant à l'an dernier portent à croire à un déclin constant de la densité du sébastolobe à longues épines dans les blocs les plus fortement pêchés de l'unité d'évaluation 3C. Bien que non définitifs, ces résultats indiquent qu'il y a lieu de faire preuve de prudence au moment du développement d'une nouvelle pêche de cette espèce.

Afin de donner suite à une demande de l'industrie et des gestionnaires, nous examinons la pertinence d'un déplacement de la limite entre 5CD et 5ES de 20 minutes vers le nord, à partir de son emplacement actuel, à 52°N. Si le quota demeure inchangé dans toutes les zones, l'incidence sur les détenteurs de quotas devrait être minime. En outre, la contrainte de pêche dans la région du ravin Morseby devrait quelque peu diminuer si les détenteurs de quotas en 5CD déplaçaient une partie de leur effort de pêche vers le sud-ouest des îles de la Reine-Charlotte.

Nous avons noté diverses tendances significatives du CPUE, mais nous ne recommandons pas de correctifs particuliers aux TAC actuels. Les tendances du CPUE peuvent indiquer des modifications de l'abondance, mais il y a tellement de facteurs sources de confusion que nous ne pouvons qu'aviser les gestionnaires d'être à l'affût de problèmes éventuels. Tant que des relevés contrôlés n'auront pas été effectués et/ou que ces facteurs n'auront pas été pris en compte de façon statistique dans la mesure du CPUE, nous ne pourrons donner, avec une certaine certitude, de mesures fiables de l'abondance du stock. Nous recommandons par conséquent que les options de rendement de 1999 soient maintenues pour 2000.

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SLOPE ROCKFISH
(Pacific ocean perch, yellowmouth rockfish, redstripe rockfish, rougheye rockfish, shortspine/longspine thornyheads, and shortraker rockfish)

1. Introduction

For assessment purposes, slope rockfish include Pacific ocean perch, yellowmouth rockfish, redstripe rockfish, rougheye rockfish, shortspine/longspine thornyheads (collectively termed “thornyheads”), and shortraker rockfish. In British Columbia (BC), these seven species are managed within six major areas (3C, 3D, 5AB, 5CD, 5ES, 5EN) for a total of 42 species-area combinations called *assessment units*. In recent years, slope rockfish have been managed with reference to a benchmark stock of Pacific ocean perch (POP) in area 5AB. For example, the 1997 report (Richards et al. 1998) presented a detailed catch-at-age analysis of this stock, along with a detailed risk analysis leading to quota recommendations. Quotas for the remaining 41 assessment units came from scale factors relating each unit to the benchmark stock. Diverse historical data from fisheries and research surveys provided guidelines for estimating the necessary scale factors, which also took account of differing biological characteristics for each species.

Assessment reports in 1997 (Richards et al. 1998) and 1998 (Schnute et al. 1999) took account of an important new database compiled from observers aboard trawl vessels since 1996. In particular, the 1998 report examined the possibility of using these data to obtain more rational estimates of relative scale factors among assessment units. Interviews with expert fishermen provided additional information. As an introduction to the analysis here, we cite four key conclusions from Schnute et al. (1999).

1. Trawl catch per unit effort (CPUE) for each species varied substantially with depth. Consequently, all analyses of CPUE data incorporated depth stratification.
2. Commercial slope rockfish tows that occurred in similar times and places as historical research survey tows revealed similar dependencies of CPUE on depth. For some species, however, a lower CPUE in commercial tows provided evidence of avoidance fishing, in which the aim is to capture a finite quota, rather than to optimize fishing efficiency.
3. Analysis of heavily fished blocks indicated little evidence of stock depletion, except for longspine thornyheads.
4. Industry opinions conformed more closely to recent yield and quota recommendations than to various computed CPUE abundance indices, based on effort qualified by species and depth.

It had been hoped that detailed CPUE data by species from tens of thousands of commercial tows would provide meaningful estimates of the scale factors relating assessment units to the benchmark stock. Conversations with fishermen, supported by the evidence in conclusion 2, indicated that CPUE in a quota fishery might fail to reflect stock abundance. In fact, historical quotas seemed in better agreement with industry opinions about relative stock abundance than any of several possible CPUE indices (conclusion 4).

Although the 1998 report (Schnute et al. 1999) recognized the key role of depth strata in a multispecies ecology, the assessment team did not have access to technology for a complete bathymetric analysis. During the last year, this problem has been rectified by developing a bathymetric database using the Geographic Information System (GIS) software package ArcView. In addition, staff members have collaborated with the Canadian Groundfish Research and Conservation Society (CGRCS), a non-profit organization funded entirely by the BC groundfish trawl fishery, on a project to develop an industry-sponsored survey of slope rockfish, independent of the fishery. (DFO and CGRCS entered into a collaborative agreement to fund one research biologist position for data analysis and preparation of the assessment.) This interim report presents results from these two exercises, along with other results of concern to DFO managers and the industry.

The new trawl observer database has developed at an opportune time, given a growing worldwide concern for the effects of fishing on marine ecosystems (Hall 1999). New approaches to management, including marine protected areas, have been proposed to address such concerns. Walters and Bonfil (1999) illustrate the potential for using observer data to investigate the multispecies spatial characteristics of the Pacific groundfish fishery, of which slope rockfish represent only one component. The previous two slope rockfish assessments (Richards et al. 1998, Schnute et al. 1999) similarly portray aspects of the fishery uniquely revealed by the observer database. The assessment team now routinely uses GIS tools to generate graphs and analyses that would have been impossible three years ago.

These developments have been accompanied by a management shift to an IVQ system in which fishermen have capital assets linked to long term prospects for commercial species. The CGRCS collaboration illustrates an emerging dialogue in which scientists and fishermen take advantage of each other’s knowledge. Although this dialogue cannot override the broader public interest in conservation, perhaps it can lead in the long run to more rational management with greater understanding shared among stakeholders. Knowledge of the fishery can come from many sources, and fishermen can certainly contribute to scientific interpretation of the observer data.

The changes cited above demonstrate a pressing need to move groundfish assessments in new directions. For slope rockfish, the benchmark assessment unit has not been surveyed since 1995. The remaining 41 units lack consistent time series of surveys adequate for a formal assessment. This report documents the work in progress to design industry-sponsored surveys that could make future assessments possible. As a starting point, we use current observer data and information about trawl grounds systematically compiled from experienced fishermen. We use spatial analysis to quantify the marine area by depth along the BC coast and to examine trawl activity and catch in recent years.

Sections 2 and 3 of this report describe the history of the fishery and various data sources used for stock assessment. In particular, section 3.6 presents the new bathymetric database. Section 4 follows the format of earlier reports in summarizing the historical catch, effort, and CPUE data for slope rockfish. Technical methods required to implement our analyses appear in section 5. These include a grid system for spatial analysis (section 5.1), a depth stratified method of biomass estimation (section 5.2), and biological models used to obtain reference points for slope rockfish stocks (section 5.3).

Our biological analysis consolidates and extends earlier work by Schnute and Richards (1998) and Walters and Bonfil (1999).

Section 6 applies the spatial methods of sections 5.1–5.2 to data from the groundfish trawl fishery. We examine the coastal distribution of trawl effort (section 6.1) and areas heavily fished (section 6.2), We also use CPUE data to estimate stock biomass in each assessment unit, although we recognize severe limitations in the relevance of these data. Our analyses at least offer prototypes for future biomass projections, based on data from a properly designed survey. In section 7, we estimate biological parameters for some slope rockfish species and, via the theory in section 5.3, obtain very rough estimates of certain key reference points. Section 8 addresses various industry concerns, including the use of expert fishermen knowledge on towable bottom (section 8.1), implications for future survey design (section 8.2), and possible consequences of moving an area boundary (section 8.3). We summarize our results in section 9.

2. History of the fishery

Table 2.1 lists recent yield options and quotas for the 42 assessment units. In some cases, yields or quotas have been applied to combined units; these appear as extra lines in the table. For example, assessment reports in 1997 and 1996 specified POP yield options in all six major areas. Corresponding POP quotas were set somewhat differently, with a quota in each of four areas and a fifth quota for two areas (5ES, 5EN) combined. Yields or quotas may also have been set on a coastwide basis, with additional restrictions in only some of the six areas or combinations of areas.

Table 2.1 has been designed to portray the actual history of yield options and quotas, but we have added a 'Total' summary line for each species. This repeats coastwide numbers, where appropriate, but otherwise gives totals calculated from the relevant areas or combinations of areas. In particular, yield ranges on the 'Total' line are obtained by summing low and high ends of the appropriate ranges. Historically, yield recommendations have sometimes been flexible about transferring yield among regions to achieve the appropriate combined yield. The 'Total' line serves to indicate overall productivity of each species on the BC coast.

A trawl fishery for slope rockfish has existed in BC since the 1940s. However, historical Canadian trawl catches were relatively minor. Between 1965–76, rockfish along the BC coast were targeted primarily by Soviet and Japanese vessels. Exact removals by foreign fisheries are unknown due to a lack of species composition and locality information, especially for Soviet vessels. Ketchen (1980) estimated the Soviet rockfish catch in BC to be between 29,000–63,000 tonnes in 1966, the year of the largest fishery.

No quotas were in effect for slope rockfish prior to 1977. For most subsequent years, rockfish management has involved a combination of species/area quotas, area/time closures, and trip limits on the major species (Table 2.2). Quotas were first introduced in 1979 for Pacific ocean perch (Table 2.3) and yellowmouth rockfish (Table 2.4), in 1982 for rougheye rockfish (Table 2.5), in 1993 for redstripe rockfish (Table 2.6), and in 1996 for shortraker rockfish and shortspine thornyheads.

In 1983, an open-fishing experiment was initiated in the Langara Spit area (north of 54ºN). Open fishing continued until 1991, when a trawl closure was established in the main region of the Pacific ocean perch fishery. The experimental design involved an open fishery, followed by a fishery closure, where open and closed periods were planned to extend for equivalent time periods, initially five years each (Leaman and Stanley 1993). This experiment is now complete and the area re-opened to fishing in 1997.

All slope rockfish assessments suffer from the lack of reliable time series on fishery catch. The port monitoring program initiated in 1994 and the at-sea observer program initiated in Oct 1995 have led to major improvements in data quality. We have no information on historical levels of dumping, discarding, or misreporting prior to the at-sea-observer program. Without a mechanism for reconstructing the actual historical catch, we have assumed that the reported landed catch represents the actual catch at-sea, except where explicitly stated, and we treat the term “catch” as synonymous with the term “landings”.

The trawl fishery underwent a major change in 1997 through the introduction of individual vessel quotas (IVQs). In addition, the schedule of management was changed from a calendar year basis to a fishing year that begins in April and ends the following March. For example, recent periods of fishery regulation include:

- 1995 fishing year (January 1, 1995, to September 29, 1995 for bottom trawls October 11, 1995 to December 31, 1995 for midwater trawls)
- 1996 fishing year (February 16, 1996, to December 31, 1996)
- 1997 first quarter (January 1, 1997, to March 31, 1997)
- 1997 fishing year (April 1, 1997 to March 31, 1998)
- 1998 fishing year (April 1, 1998 to March 31, 1999)
- 1999 fishing year (April 1, 1999 to March 31, 2000)

In this report, we refer to these regulatory periods as 1995, 1996, 1997a, 1997, 1998, and 1999, respectively. Each period had a distinct quota, with a lag of one quarter (1997a) before the introduction of IVQs in 1997.

3. Data sources

3.1. GFCATCH database: 1954–1995

The Department of Fisheries and Oceans (DFO) maintains detailed statistics of groundfish landings by trawl gear (1954–1995), longline gear (1979–1986), and trap gear (1979–1995). The database, called GFCATCH (Leaman and Hamer 1985), is currently housed on a networked computer at the Pacific Biological Station (PBS), Nanaimo, BC. Groundfish Division staff can access the data through a FORTRAN program called GFSEL.

There are three sources for historical groundfish catch data (details in Rutherford 1999): (i) trip reports/fisher logs, (ii) landing records (sales slips or validation records), and (iii) anecdotal evidence. Logbooks, kept by vessel captains, contain confidential fishing information – location, depth, effort, and estimates of weight by species or species groups. Until 1989, port liaison officers transcribed logbooks to trip reports. Processing plants and fishermen submitted sales slips, which record the reported catch weight by species and price paid. The two systems are complementary. Logbooks provide reasonable information on areas and effort, but only estimates of catch. By contrast, sales slips provide better estimates of weight, but give very little information on fishing area or effort. Recorded weights from sales slips were substituted monthly into trip reports and, where possible, prorated to replace estimates given by fishermen. Anecdotal information (viewing an offload or interviewing the vessel's crew) was used to supplement and, occasionally, override the data from the other two sources.

A data retrieval program called GFSEL (groundfish selection) was developed to gain access to the data files (Leaman and Hamer 1985). Based on user specifications, the program returns records of the corresponding catch and effort data. The user can also download these records to a text file. Catch and fishing event information in GFCATCH are available from 1954 to 1995, representing 66,327 landing records. Since 1996, an onboard observer program (Section 3.2) has taken the place of fisher logs. Sales slips were supplanted by 'validation records' from a mandatory dockside monitoring program, implemented in 1994 for trawl landings. Validation records provide greater species detail and accuracy than sales slips.

In 1998, a copy of the data in GFCATCH was transferred to a relational database on the SQL server PACSTAD within the Groundfish Unit. This database, called GFCatch, is available through a Microsoft Access 97 shell using ODBC. In accordance with the conventions set out in Schnute et al. (1996), there are six documentation tables (A Tables), three primary data tables (B Tables: *B1_Trips* – 66,327 records, 12 fields; *B2_Events* – 272,382 records, 32 fields; *B3_Catch* – 1,036,224 records, 5 fields), and 17 supplementary code tables (C Tables). Figure 3.1.1 shows the relational structure of the three primary data tables.

3.2. Observer trawl database: PacHarvest (1996–1999)

In 1996, a mandatory observer program for most Option A trips (bottom trawl) and some Option B trips became an important new data source for the groundfish fishery. Archipelago Marine Research (AMR) was contracted to provide trained observers, who record fishing event and catch information. AMR also converts observer logs to electronic format and performs quality control on the data. Captains of vessels not covered by the observer log program (Options A for hake and pollock, B and C) submit their own logbook records. In the past, fisher logs were computerized by AMR as a courtesy; however, in future this may be a requirement of the contract.

Originally, the Observer database was to be stored in Vancouver using the ORACLE database management system. For reasons beyond the scope of this report, the ORACLE project has failed to produce a data archive suitable for stock assessment work. As an interim measure, the slope rockfish assessment team developed an appropriate relational database, called PacHarvest, managed by Microsoft SQL Server 7.0. The system resides on the NT Server PACSTAD, which is also maintained by the slope rockfish assessment team at the Pacific Biological Station in Nanaimo. Currently, AMR supplies ASCII data files that can be loaded into a Microsoft Access 97 database, manipulated to create standardize fields, and transferred to the SQL Server database. The entire transformation from text files to a centralized SQL Server database has been automated using Visual Basic routines written by the student Mike Jensen during the summer of 1999. Documentation and Access database shells for connecting to the central database can be found on the DFO Intranet at http://pacstad/pacharvdb/Default.htm. Although this interim system has provided the basis for various groundfish assessments in the past two years, long term data integrity of the data system urgently requires a proper level of support beyond the context of one assessment team.

All groundfish analysts can connect to PacHarvest using Microsoft Access 97. The connection uses linked tables, whose names have prefixes *A*, *B*, and *C* to indicate documentation, primary data, and codes, respectively. In particular, the six primary data tables are named: *B1_Hails*, *B2_Trips*, *B3_Fishing_Events*, *B4_Catches*, *B5_Validation_Headers*, and *B6_Validation_Species*. Additionally, table *B4_Catches* has been condensed to *B4_Total_Catch* containing total retained and discarded catch to facilitate analysis. Table 3.2.1 lists the number of records in each of these tables at the time of writing this report. Note that the largest table currently includes over 830,000 records. Analysis in this report depends principally on the tables *B2_Trips*, *B3_Fishing_Events*, *B4_Catches*, and *B4_Total_Catch*. Figure 3.2.1 illustrates the links among these tables.

When a trawler leaves port for a fishing trip, the captain hails out to the nearest port authority and is subsequently assigned a hail-out number. Upon returning from a fishing trip, the vessel hails in and is assigned a hail-in number, which serves as a trip identifier in this database. *B1_Hails* contains information collected by the port authorities and is the most current record of fishing activity available. *B2_Trips* similarly contains information unique to each trip, identified by the hail-in number. However, this table includes records only for trips where either observer logs or fisher logs have been submitted to AMR and converted to electronic format.

Table *B3_Fishing_Events* contains information unique to each tow within a trip. A tow is identified by combinations of hail number and set number. The fishing event table contains observer logs from January, 1996, to March, 1999, and fisher logs from 1996. By giving preference to observer logs over fisher logs, duplicate records have been eliminated when both were computerized for any given tow. In the SQL database, we have also converted latitude and longitude fields to decimals from degrees/minutes, converted depths from fathoms to metres, and added fields to describe fishing year, slope rockfish (SRF) assessment areas, mean latitude/longitude, and mean fishing depth. New date fields were created to unify separate date and time fields. Additionally, there is a Visual Basic algorithm to convert LORAN C values to latitudes and longitudes and to derive groundfish statistical areas and Pacific Marine Fisheries Commission (PMFC) areas from latitudes and longitudes. These area conversions were originally performed by obsolete FORTRAN code that could not be easily updated. Most records in the fishing events table correspond to bottom trawls, although 5,595 records (~7.8%) describe midwater trawls.

Table *B4_Catches* documents the catch of each species (in kg) within a tow. Unique catches are identified by combinations of hail number, set number, species code and utilization code, where the latter documents the fate of the catch (e.g., retained or discarded). In the current database, over 53.9% of the records document discarded catch, accounting for 19.9% of the total captured biomass. There are catch records available from 69,113 tows described in *B3_Fishing_Events*. Since 1996, the trawl fishery has captured 351 species, including invertebrates. Of these, 224 were fish species, 64 of which were sold commercially (Table 3.2.2).

Table *B4_Total_Catch* is a condensed version of *B4_Catches* where catch records are summarized to give total and discarded catch concurrently. Other than utilization code 1 for retained catch, *B4_Catches* contains catch coded 4 (dumped), 22 (discarded, marketable, dead), 23 (discarded, marketable, live), 24 (discarded, unmarketable), 27 (halibut, discarded, live), and 28 (halibut, discarded, dead). Therefore, the assumption made is that all catch records with utilization codes greater than 1 can be considered discarded catch. Unique records are identified by combinations of hail number, set number, and species code. This new arrangement of catch records greatly facilitates further analyses.

Table *B5_Validation_Headers* describes trawl landings recorded by the dockside monitoring program. The catch composition and weight of these landings are detailed in *B6_Validation_Species*. Note that validated landings do not provide estimates of discarded catch.

3.3. Hook and line rockfish logbook database: RockfishLogs (1986–1998)

Data from the commercial hook and line rockfish fishery are entered in a relational database, called RockfishLogs, on the Microsoft SQL server PACSTAD. The table structures and relationships are identical to those outlined in (Haigh and Richards 1997) with the exception that separate annual tables are no longer used. There are three primary data tables called *B1_Trip*, *B2_Set*, and *B3_Catch*. On a spatial scale, the inshore rockfish fishery is divided into management areas that are approximate subareas of the PMFC areas. Thus, both temporal and spatial categories for the hook and line data require translation into a slope rockfish context. First, calendar fishing years must be divided into the regulatory periods identified here (1996, 1997a, 1997, 1998). This is a straightforward calculation, given the dates of fishing events. Second, inshore rockfish areas must be combined to give catch estimates within the six SRF areas. This calculation depends on rather extensive definitions of DFO management areas and subareas that correspond to the SRF areas (Table 3.3.1).

3.4. Survey data

DFO has conducted independent and joint surveys to investigate the distribution, abundance, and biology of rockfish in the northeast Pacific Ocean since 1963. The main objective of these swept-area trawl surveys is to provide a fishery-independent index of abundance and to collect synoptic biological samples of rockfish caught in the survey area. Biological sampling provides representative size, age, sex, and maturity data for commercially important rockfish species. Sampling also provides information from areas that have experienced different exploitation histories.

Information collected during surveys is similar to that collected by observers of the commercial fishery. Survey tow data include date, latitude, longitude, duration, depth, distance trawled, and the catch of each species. It is therefore possible to compare survey and commercial tows in areas of overlap. For example, the last report (Schnute et al. 1999, section 4.2) compared commercial data with data from two research surveys:

- in 1996, off the west coast of Vancouver Island (Area 3C), and
- in 1997, off the west coast of the Queen Charlotte Islands (Areas 5ES, 5EN).

Extensive historical data from surveys have not been archived in the official GFBIO database (section 3.5 below). This limitation has constrained our analysis of biological parameters in section 7.

3.5. GFBIO database

GFBIO is a relational database system for storing, maintaining, and gaining access to groundfish biological data. The database was developed in 1993–1994 by DFO staff in the Stock Assessment Division and the Informatics Systems Division. Currently, it exists as an ORACLE database on a VAX computer at Regional Headquarters in Vancouver. GFBIO primarily archives data collected from individual fish samples. These data have been collected since the 1940s from waterfront, observer, charter, and research trip sampling activities. Records include information on species, length, sex, and age, linked with background information such as location and collection methodology.

To facilitate analysis of biological data, we have created a mirror of the sample and specimen data in a relational database, called GFBio, on the Microsoft SQL server PACSTAD. There are only two tables in this database. *Z_Sample_Details* contains information relevant at the sample level (latitude, longitude, depth, date, major area, minor area, locality, slope rockfish assessment area, trip type) and *Z_Specimen_Details* contains information relevant at the specimen level (species, sex, length, weight, age). The specimen table is cross-referenced to the sample table by a sample ID number. As the ORACLE GFBIO database changes continually, the SQL mirror is updated before any analysis.

Previous slope rockfish assessments (Richards and Olsen 1996; Richards et al. 1998) used age structure data from this database in the benchmark analysis of Pacific ocean perch in area 5AB. This report does not revise the 1996 analysis, partly because recent age data from commercial samples have not been archived in GFBIO. We do, however, use historical biological data to estimate biological parameters and associated reference points for some slope rockfish stocks (section 7 below).

3.6. Bathymetry Database

Our analysis uses depth contour data for coastal British Columbia from digital natural resource maps produced by the Canadian Hydrographic Service (Fig. 3.6.1). From these data, we calculate a Triangulated Irregular Network (ESRI 1999) and interpolate depth values over a rectangular region of coastal British Columbia. The best interpolation algorithm for contour data is not immediately obvious. ArcView GIS 3.1 offers several interpolators, including Inverse Distance Weighted (IDW), Kriging, Spline, Trend Surface, and Triangulated Irregular Network (TIN). After much exploratory analysis, we decided that the most satisfactory results were obtained with the TIN algorithm. For example, the IDW algorithm produces a surface that resembles stacked layers while the TIN algorithm produces a smoother, presumably more natural surface (Fig. 3.6.2).

For spatial reference, we use a rectangle large enough to ensure coverage of all coastal regions relevant to the trawl observer database. This rectangle necessarily includes areas with no available bathymetric data, such as land forms, US waters, and offshore waters. We divide the large rectangle into blocks of size 2 km $\times$ 2 km. Each block has the following associated attributes:

- Universal Transverse Mercator (UTM) coordinates (x, y) in zone 9 to locate the block on the earth's surface, as described further in section 5.1 below;
- the same coordinates expressed as longitude and latitude;
- integer coordinates (i, j) to specify the block position in a grid;
- an index *k* that assigns a unique integer to each block;
- mean depth of the block, where -999 indicates missing data;
- the block's geographic feature (0 = Canadian ocean, 1 = US ocean, 2 = Canadian inlet, 3 = land)
- the groundfish major statistical area in which the block lies.

Our large rectangle has its lower left corner at UTM coordinates

(x, y) = (151,653 m East, 5,317,991 m North),

that is, longitude -133.66318º and latitude 47.920455º. It extends east of this point for 848 km and north for 780 km, thus giving a grid of 424 $\times$ 390 = 165,360 blocks, each with area 4 km^2.

We have devised an Access database *BCBathymetry.mdb* in which the table *B2_Bathymetry* contains the information listed above for all 165,360 blocks. Another table *B1_Bathymetry* similarly documents blocks on a finer 1 km $\times$ 1 km scale. Spatial analysis in this report deals primarily with 2 km $\times$ 2 km blocks that have been accessed by the trawl fleet since 1996. These include all Canadian ocean blocks with depths less than or equal to 1,700 m, excluding inlets and near-shore regions (Fig. 3.6.3).

The observer database PacHarvest includes depth information for most tows (Section 3.2, Fig. 3.2.1). Thus, within blocks impacted by the fishery, each bottom tow gives a depth d_1 that can be compared with the depth d_2 from the corresponding block in the bathymetric database. Differences between these two measurements can sometimes be large, as portrayed in Fig. 3.6.4. Currently, of bottom tows with depth information, the following table ranks the percentage of tows with a maximum specified difference:

$\max\|d_1 - d_2\|$	Percentage
500 m	99.6%
200 m	95.1%
100 m	87.2%
50 m	78.0%

4. Catch, effort, and CPUE summaries

4.1. Historical data (1967–1999)

Catch data by species, area, and fishing year can be obtained from the three databases discussed in Section 3.1–3.3: GFCATCH, the trawl observer database, and the hook and line database. For this report, we have devised a system to render the hook and line data compatible with trawl data. Table 4.1.1 gives a compilation of available hook and line data, based on the area translations defined in Table 3.3.1. Of the seven slope rockfish species, rougheye and shortraker are most affected by the hook and line fishery.

Tables 4.1.2 to 4.1.8 present catch (excluding discards) and median CPUE from the slope rockfish (SRF) trawl fishery. Six tables correspond to the six SRF areas (Tables 4.1.2–4.1.7) and a final table gives statistics for the entire coast (Table 4.1.8). Catches of shortspine and longspine thornyheads have been combined to match historical data limitations. Each table includes information on Canadian trawl catch, species proportions, CPUE, and effort. Catch prior to 1996 is the Canadian trawl landed catch from the GFCATCH database. From 1996 on, catch is obtained from the trawl observer database, in which data by tow (from *B2_Trips*, *B3_Fishing_Events*, and *B4_Catches*) have not been rectified with landed weights (from *B5_Validation_Headers* and *B6_Validation_Species)*. Results presented here may differ somewhat from those in earlier reports, due to the dynamic nature of observer data obtained from AMR. The contractor continually updates and corrects observer records as needed. Additionally, our change in identifying groundfish statistical areas (Section 3.2) has redefined slope rockfish assessment areas for a number of records. We hope that the new method more accurately places tows in the correct areas.

For consistency with past reports, we calculate the median CPUE by a 20% qualification rule within suitably defined trips. First, for a given area or the entire coast, we screen the data for all records with a slope rockfish catch. Next, catch and effort are summed across the selected records for a given trip. From 1996 on, a trip is defined as the portion of a "hail-in" trip where tows occurred in one SRF assessment area. Thus, each record in the analysis represents one trip (or a portion of a "hail-in" trip) with a slope rockfish catch in a given area. Trip records are considered "qualified" if the total slope rockfish catch accounts for at least 20% of the total fish catch (all fish species) for that trip. Although a qualification method based on individual tows rather than trips might be preferable, tow-by-tow data are not available in the GFCATCH database prior to 1991.

Again, we have maintained this CPUE calculation solely for historical purposes. Some obvious problems are (i) a change to observers on board since 1996, (ii) changes in discrimination of species identification, and (iii) behavioural changes by fishermen, specifically avoidance fishing.

Species proportions in Tables 4.1.2–4.1.8 are computed from qualified records only. Thus, the reported proportion p_s of species *s* is the ratio

$$p_s = \frac{\text{total catch of species } s}{\text{total fish catch}},$$

where totals apply to qualified records in the given area. Following Richards and Schnute (1992), CPUE is calculated as the median CPUE value (ratio of catch to effort) across qualified records. Estimated effort on slope rockfish is then the ratio of total SRF catch (qualified or not) to qualified CPUE. For comparison, we define nominal effort as the total effort from all SRF trips (qualified or not). The number of qualified trips gives the sample size used to calculate CPUE.

The observer database includes information on both kept and discarded catch. Table 4.1.9 summarizes this information by species, area, and fishing year. In particular, beginning in 1996, total catch can be distinguished from the landed catch reported in Tables 4.1.2–4.1.8. Generally, discard rates are well below 10% for all slope rockfish species, except redstripe rockfish and longspine thornyheads. Redstripe rockfish are often caught at sizes below those that are marketable; consequently, about 25% of the redstripe catch is discarded. Discard rates for both thornyhead species have been increasing since the observer program was started. At present, we are not sure why this might be.

Tables 4.1.2–4.1.8 focus on catch by species and CPUE for the entire complex of slope rockfish. Figures 4.1.1 to 4.1.7 portray catch and CPUE graphically, where the CPUE is now computed individually for each species. The 20% qualification rule still applies, but in this case the catch of a given species must be at least 20% of the total fish catch. The catch portrayed in these figures represents the total trawl catch including discards in 1996–97 (Table 4.1.9), as well as the hook and line catch in 1993–97 (Table 4.1.1). In Figs. 4.1.6–4.1.7, we treat all thornyheads as shortspine prior to the development of the observer database in 1996. Although we recognize that observers may have difficulty distinguishing between the two thornyhead species, we simply portray the data in the current database. To maintain a consistent series of annual catches in these figures, we do *not* include data for the fishing period 1997a (Section 1.1).

Figures 4.1.1 to 4.1.7 also indicate quotas for each assessment unit, in cases where such quotas have been imposed historically. Thus, the figures can be used to assess whether or not shifts in catch have resulted from changing (or newly imposed) quotas. In cases where quotas have been assigned to combined assessment units, we compute a quota retrospectively for each assessment unit by allocating the combined quota in proportion to the historical catch.

Slope rockfish effort has been expanding since the mid-1980s. In 1996, both estimated and nominal effort increased to the highest values ever recorded, followed by an apparent reduction in 1997 (Table 4.1.8). Nominal effort in 1998 climbed again to reach 90% of the peak in 1996.

Overall, the historical CPUE data are considered to have little value in interpreting recent stock abundance trends, because of restrictive trip limits, unknown levels of dumping, discarding and misreporting, and frequent changes to the management plan. The new observer database resolves at least some of these issues by providing more precise records of effort and catch, including discards.

4.2. Recent data from the observer program (1996–1999)

The observer database provides highly detailed information on the characteristics of the trawl fishery. We begin with figures that portray the effort and corresponding catch of slope rockfish species. Figure 4.2.1 shows tow locations for the calendar years 1996–1999 by depth strata on a map of the BC coast, where each point has been plotted at the midpoint of a tow. Boundary lines for major statistical areas (3C, 3D, 5AB, 5CD, 5ES, 5EN) are also shown. The shallowest depth interval (0–100 m) has been chosen to include most catch of flatfish species, which are not part of this assessment. Thereafter, the depth intervals increase by 50, 100, 200, 400, and 800 m. Typically, shelf rockfish are found down to 150 m, and slope rockfish are harvested in the four depth intervals below 150 m.

Figure 4.2.2 extends the spatial analysis of Fig. 4.2.1 by including a temporal component of the fishery. Here tows by depth are grouped by month and latitude intervals of ½°; for example, the label "48" denotes the latitude interval from 48° to 48°30′. Circles in this figure represent the number of tows in each latitude-month-depth stratum, where circular area is proportional to the total hours towed. Most effort was expended in the 150–450 m depth range, with shallow fisheries (0–150 m) primarily in the north, and deep water fisheries (below 450 m) primarily in the south, off the west coast of Vancouver Island. The figure also shows some seasonal patterns in the effort, where vertical dotted lines indicate boundaries between fishing years. We examined another figure similar to Fig. 4.2.2, depicting the number of tows, rather than the number of hours towed. Patterns of effort by tow are very similar to those of effort by hours, except that the very deep tows (below 850 m) represent disproportionately larger amounts of time. Thus, fishermen tend to extend tow duration for nets dropped to depths near 1 km.

The effort patterns in Figs. 4.2.1–4.2.2 produced a catch of 351 species over the period Jan 1996 to Mar 1999 (Table 3.2.2), as mentioned earlier. Figure 4.2.3 presents the catch, including discards, of Pacific Ocean perch, yellowmouth rockfish, redstripe rockfish, rougheye rockfish, shortspine thornyhead, and longspine thornyhead. The seventh SRF species, shortraker rockfish, has been excluded for lack of space. In panels of this figure, circles indicate the catch biomass within a stratum defined by species, month, and latitude, where circular area is proportional to biomass. Circle shading portrays catch depth, using the shadings introduced in Fig. 4.2.2. Because a species-month-latitude stratum can include catches at various depths, the shading indicates mean fishing depth d weighted by catch:

$$d = \frac{\sum_i c_i d_i}{\sum_i c_i}$$

where c_i and d_i denote the catch and depth of the ith tow in the stratum. The six species in Fig. 4.2.3 occur almost entirely in the four deepest strata of Figs. 4.2.1–4.2.2. Ideally, all circles in Fig. 4.2.3 should be comparable to each other; however, this would leave nothing but circles reduced to invisible dots for the minor species. To avoid this problem, maximum circle sizes correspond to the biomass scale of 64, 128, 256, or 512 t, where factors of 2 allow easy comparison among panels. For each species, the maximum circle size has been chosen to best reveal the catch distribution among strata. As in Fig. 4.2.2, fishing years are delimited by vertical dotted lines.

From Fig. 4.2.3, Pacific ocean perch catch was greatest between latitudes 51½° and 52° N (Area 5AB) at depths of 250–400 m. Just to the south (51°–51½° N), fishing occurred at shallower depths (150–250 m). During certain periods (e.g., Jul–Aug, 1996) an apparent lull in catch corresponds to (i) a switch of effort by Option A vessels to the offshore joint-venture hake fishery and (ii) management limits aimed at redirecting effort. Since the implementation of the IVQ system in 1997, fishermen can fish when they want. Under this new management regime, there was a tendency to catch most of the quota in the first half of the fishing year. Noticeable overlap by season and depth occurred between the yellowmouth rockfish and Pacific Ocean perch fisheries, although yellowmouth rockfish tended to be caught a bit further south.

Redstripe rockfish were consistently caught at 150–250 m, predominantly at 51–51½° N, and the catch was spread fairly evenly throughout the fishing year. Rougheye rockfish catch occurred at depths of 250–450 m along the northwest coast of the Queen Charlotte Islands, predominantly in the spring and fall of 1996 and towards the end of the 1997 and 1998 fishing years. Shortspine thornyheads were harvested along the west coast of Vancouver Island at depths greater than 450 m, where they appear to co-occur with longspine thornyheads. Further north, shortspine thornyheads were caught at 250–450 m in Moresby Gully and off the northwest coast of the Queen Charlotte Islands in spring and autumn. Longspine thornyhead catch exhibited separation by depth from most other slope rockfish, except shortspine thornyheads. They were typically caught at depths greater than 850 m along the west coast of Vancouver Island. In 1998, there was a notable tendency to catch the quota during the first half of the fishing year. Communications with industry indicate that this would have happened in 1997 also; however, fishermen were slowly adjusting to the IVQ system.

5. Analytical methods

5.1. Spatial analysis

To examine trawl catch and effort in relation to BC coastal bathymetry, we consider a three-dimensional coordinate system (x, y, z), where z denotes the ocean depth at a point (x, y) on the earth's surface. In general, x and y represent coordinates in easterly and northerly directions, respectively. For example, last year's report (Schnute et al. 1999) used (x, y) to denote longitude and latitude, respectively. This projection visually exaggerates the relative size of northern areas because northerly convergent longitude lines on the earth's surface appear as parallel lines with constant x-values.

The Universal Transverse Mercator (UTM) projection gives a more realistic portrayal of the earth's surface within standardized zones of longitude. Complex formulas relating UTM coordinates to longitude and latitude take account of the earth's ellipsoidal shape, with a wider diameter at the equator than at the poles. Most of the BC trawl fishery takes place in UTM zone 9, which has a central meridian at -129° longitude (i.e., 129° W) and extends 3º in longitude to the east and west. The UTM projection scales distances exactly along two great circles – the equator and the central meridan, which act as *x* and *y* axes, respectively. The ‘easting’ coordinate *x* and ‘northing’ coordinate y specify distances in metres. Along the equator, $y = 0$ by definition; however, the central meridian is assigned the standard easting $x = 500{,}000$ m, rather than the usual value $x = 0$. This ensures that $x > 0$ throughout the zone. In effect, the difference $x - 500{,}000$ m represents the number of meters east of the central meridian, with the obvious interpretation that a negative difference corresponds to a westward displacement. The northing *y* coordinate measures distance from the equator. These interpretations of *x* and *y*, however, are exact only along the equator and central meridian. Distances are approximate elsewhere. From our perspective, the UTM system offers convenient coordinates for the earth’s surface in a two-dimensional projection that nearly preserves distance measurements. Modern software for Geographic Information Systems, such as ArcView, supports the use of UTM.

Our detailed study of the trawl fishery requires the use of a spatial grid defined by coordinates (x_i, y_j) with $i = 0, \cdots, m$ and $j = 0, \cdots, n$, where

(5.1.1) $$x_i = x_0 + i\,\Delta x\,,\ \ y_j = y_0 + j\,\Delta y\,.$$

The coordinate lines $x = x_i$ and $y = y_j$ define mn rectangular blocks b_{ij} of dimension $\Delta x \times \Delta y$ with reference to a base point (x_0, y_0). Each block b_{ij} has the lower left corner (x_{i-1}, y_{j-1}), upper right corner (x_i, y_j), and centre point

(5.1.2) $$(\dot{x}_i, \dot{y}_j) = (x_{i-1} + \frac{\Delta x}{2},\ y_{j-1} + \frac{\Delta y}{2})\,.$$

We enumerate blocks within the grid by the single index

(5.1.3) $$k = i + (j-1)\,m\,,$$

where $k = 1, \cdots, mn$. Thus, depending on the context, we may refer to block b_{ij} in the grid or block b_k in the enumerated list.

A tow centered at location (x, y) lies in the block b_{ij} specified by the integer coordinates

(5.1.4) $$i = 1 + \mathrm{int}\left(\frac{x - x_0}{\Delta x}\right),\quad j = 1 + \mathrm{int}\left(\frac{y - y_0}{\Delta y}\right),$$

where the function ‘int’ extracts the integer part of a real number. For example, $\mathrm{int}(5.83) = 5$. The block index *k* similarly determines integer coordinates

(5.1.5) $$j = 1 + \mathrm{int}\left(\frac{k-1}{m}\right),\quad i = k - (j-1)\,m\,,$$

of the corresponding block b_{ij} .

Following our definition of a three-dimensional coordinate system (x, y, z), we let z_{ij} denote ocean depth at the centre point $(\dot{x}_i, \dot{y}_j)$ of block b_{ij} . By convention, $z_{ij} < 0$ on land, and we consider primarily marine blocks with $z_{ij} > 0$. The area a_{ij} of block b_{ij} depends on the chosen coordinate system. For example, if *x* and *y* are longitude and latitude measured in degrees, then to a high degree of approximation

(5.1.6) $$a_{ij} = 3600\,\Delta x\,\Delta y\,\cos y_j \text{ nm}^2.$$

By definition, a nautical mile corresponds to a movement of 1'= (1/60)º at the equator. The factor $\cos y_j$ in (5.1.6) adjusts for shorter distances along latitude lines as the latitude y_j increases. For UTM coordinates (x, y), all blocks have the same approximate rectangular area

(5.1.7) $$a_{ij} = \Delta x\,\Delta y \text{ m}^2.$$

5.2. Biomass estimation

The annual trawl fishery includes tens of thousands of tows. If these all came from a designed survey, they would provide the raw data for detailed stock abundance estimates. Unfortunately, commercial tow data differ in many respects from rigorous survey data. For example, last year's report (Schnute et al. 1999, Section 4.2 and Fig. 4.2.10) showed that commercial catch per unit effort (CPUE) can actually be less than survey CPUE in similar circumstances, due to avoidance fishing in a commercial quota fishery. For four reasons, however, we temporarily ignore these problems and examine the current trawl data as if the fishery were a survey. First, due to the lack of surveys, these data offer the best information currently available. Second, the commercial data at least provide a starting point for survey design. The industry collaboration begins with commercial CPUE as an indicator of relative abundance, as described below in sections 8.1–8.2. Third, the calculation here serves as a prototype for future analyses of industry-sponsored survey data. Finally, the stratified survey approach offers a point of comparison and contrast with earlier work of Walters and Bonfil (1999).

Last year's report (Schnute et al. 1999, Section 4.2 and Figs. 4.2.1–4.2.9) also demonstrated a strong relationship between species abundance and depth. This association suggests using a depth-stratified approach to the analysis of CPUE data. Consider a given assessment unit (species and management region) and time period, which might be an entire fishing year. The management region consists of a particular set of blocks b_k from the list of mn blocks in the entire grid (5.1.1). Let *S* denote the set of indices *k* that define the management area, so that the complete region is the union of blocks $\bigcup_{k \in S} b_k$.

These blocks can be stratified by depth category *h* associated with the depth interval

(5.2.1) $$d_h = \{z \mid (h-1)\,\Delta z \le z < h\,\Delta z\}$$

for a specified depth increment Δz. The centre depth z_k of each block b_k places the block in a particular depth interval d_h. For example, if $z_k = 378$ m and $\Delta z = 100$ m, then block b_k belongs to the fourth depth interval d_4, between 300 m and 400 m. Thus, the set S of blocks in the management area can be divided into subsets S_h associated with depth intervals d_h. The complete management region now becomes the union of blocks $\bigcup_h \bigcup_{k \in S_h} b_k$. If a_k is the area of block b_k, then depth stratum h has total area

(5.2.2) $$A_h = \sum_{k \in S_h} a_k$$

and the management region occupies the total area

(5.2.3) $$A = \sum_h A_h = \sum_h \sum_{k \in S_h} a_k \ .$$

During the given time period, fishing effort need not occur in every block b_k with $k \in S$. Let S^* be the subset of indices $k \in S$ corresponding to blocks actually fished. Similarly, let S_h^* denote the subset of indices $k \in S_h$ that correspond to fished blocks in depth stratum h. These determine depth-stratified areas

(5.2.4) $$A_h^* = \sum_{k \in S_h^*} a_k$$

impacted by the fishery and the total impacted area

(5.2.5) $$A^* = \sum_h A_h^* \ .$$

Consider a single tow with effort E in block b_k, where E is measured in units of time. Suppose that the boat moves with speed v and that the net opening spans a width w. Then the net sweeps a total bottom area vwE, which represents the fraction vwE / a_k of the total area a_k in the block. If the tow randomly samples the block and produces a catch C of the given species, then an expanded estimate of biomass in the block is

(5.2.6) $$B_k = \frac{a_k}{vwE} C = \frac{a_k}{vw} U = q_k U \ ,$$

where $U = C / E$ denotes catch per unit effort and

(5.2.7) $$q_k = a_k / (vw)$$

is a catchability coefficient for block b_k. From this point of view, each tow produces a CPUE measurement U that indexes abundance in the block by coefficient q_k.

During the given time period, many tows may occur in block b_k. We compute the total effort E_k and catch C_k from all tows. We also compute the CPUE U_k as the median catch per unit effort from all tows within the block. We choose the median, rather than the mean or the ratio C_k / E_k, as more resistant to outliers and other anomalous effects (Richards and Schnute 1992). The median calculation includes tows with catch $C = 0$, so that U_k may be 0 in some blocks b_k. Formula (5.2.6) with $U = U_k$ then gives an estimate of total biomass B_k for every block $k \in S^*$. These blocks represent different proportions of area within each depth stratum. A stratified estimate of total biomass in all depth strata is

(5.2.8) $$B = \sum_h \frac{A_h}{A_h^*} \sum_{k \in S_h^*} q_k U_k$$

In (5.2.8), the factor A_h / A_h^* expands the total biomass estimated in fished blocks of depth stratum *h* to the entire area available in the stratum.

The estimate *B* in (5.2.8) represents a statistic derived from numerous tow data. Bootstrap methods could be used to assess the variance of this estimator. For example, each bootstrap estimate could be obtained by sampling tows with replacement from the original population of tows.

5.3. Population dynamics and reference points

Fish populations develop in response to recruitment, growth, mortality, and fishing. The parameters governing these processes determine various reference points, commonly used in precautionary management strategies. For most slope rockfish stocks, we lack sufficient data to estimate all the necessary parameters. However, some biological data do exist, and these provide at least rough estimates of certain key reference points.

We adopt a model similar to that proposed by Schnute and Richards (1998), although we extend their analysis slightly. For each year *t*, we consider the eight state variables listed in the following table:

Quantity	Meaning	Units
R_t	recruitment at the start of year t	number of fish
P_t	population at the start of year t	number of fish
B_t	biomass at the start of year t	weight
W_t	mean weight in year t	weight
A_t	mean age in year t	years
h_t	harvest rate in year t	dimensionless
C_t	catch biomass in year t	weight
S_t	spawning biomass at the end of year t	weight

We assume that fish recruit at age *r*, when the fish weight is w_r. After this, the weight w_a at age *a* develops recursively by the Brody relationship

(5.3.1a) $$w_{a+1} = l + k\, w_a \,.$$

The difference equation (5.3.1a) with the initial weight w_r implies the growth law

(5.3.1b) $$w_a = \begin{cases} \dfrac{l}{1-k} + \left(w_r - \dfrac{l}{1-k} \right) k^{\,a-r}, & k \neq 1; \\ w_r + (a-r)\, l\,, & k = 1. \end{cases}$$

The three growth parameters (w_r, l, k) in (5.3.1b) are equivalent to (w_∞, K, a_0) in the more common von Bertalanffy formulation

(5.3.2) $$w_a = w_\infty \left[1 - e^{-K(a-a_0)} \right]$$

via the transformations

(5.3.3) $$w_r = w_\infty \left[1 - e^{-K(r-a_0)} \right], \;\; l = (1-e^{-K})\, w_\infty, \;\; k = e^{-K} \,.$$

Among the state variables listed above, the harvest rate h_t acts as a control. We assume that the remaining seven states are governed by the recursive dynamic equations

(5.3.4a) $$R_t = a\, S_{t-r} \left(1 - bg\, S_{t-r} \right)^{1/g}$$

(5.3.4b) $$P_t = R_t + (1-d)(1-h_{t-1})\, P_{t-1}$$

(5.3.4c) $$B_t = w_r R_t + (\, l + k W_{t-1})(\, P_t - R_t\,)$$

(5.3.4d) $$A_t = \frac{rR_t + (1+A_{t-1})(P_t - R_t)}{P_t}$$

(5.3.4e) $$W_t = \frac{B_t}{P_t}$$

(5.3.4f) $$C_t = h_t B_t$$

(5.3.4g) $$S_t = B_t - C_t \,.$$

Schnute and Richards (1998), using somewhat different notation, derived equations (5.3.4) from a catch-age model with knife-edged selectivity to the fishery at age *r*. These equations can, however, be given a direct interpretation. Recruitment (5.3.4a) follows a flexible rule that includes the special cases of Beverton-Holt $(g = -1)$ and Ricker $(g = 0)$. The current population (5.3.4b) includes new recruits and survivors from the previous year $t-1$, reduced by fractions $1-d$ and $1-h_t$ that result from natural mortality and fishing, respectively. The death rate d and harvest rate h_t can be expressed in terms of the natural mortality *M* and fishing mortality F_t as

(5.3.5) $$d = 1-e^{-M}, \; h_t = 1-e^{-F_t}.$$

Thus, for small mortalities *M* and F_t, $d \approx M$ and $h_t \approx F_t$. The current biomass (5.3.4c) results from new recruits at weight w_r and the remaining population at a weight determined by Brody growth (5.3.1a) of the previous mean weight W_{t-1}. Similarly, the mean age (5.3.4d) comes from recruits at age *r* and the remaining population whose mean age has advance by one year. The mean weight (5.3.4e) now can be expressed simply as total biomass divided by total population. Finally, in biomass units, the catch (5.3.4f) and surviving spawning stock (5.3.4g) result from the harvest rate h_t.

Equations (5.3.4) must be applied in the order shown. For example, R_t from (5.3.4a) is used in (5.3.4b), P_t from (5.3.4b) is used in (5.3.4c), and so on. Collectively, these equations update seven state variables in year *t* from values in previous years. If h_t is held at a constant value *h* for many iterations, the equations converge to equilibrium values dependent on *h*. These can be computed sequentially from

(5.3.5a) $$s(h) = (1-d)(1-h)$$

(5.3.5b) $$A(h) = r + \frac{s}{1-s}$$

(5.3.5c) $$W(h) = \frac{(1-s)w_r + s\,l}{1-ks}$$

(5.3.5d) $$r(h) = \frac{1-s}{(1-h)W}$$

(5.3.5e) $$R(h) = \frac{r}{bg}\left[1-\left(\frac{r}{a}\right)^g\right]$$

(5.3.5f) $$P(h) = \frac{R}{1-s}$$

(5.3.5g) $B(h) = WP$

(5.3.5h) $C(h) = hB$

(5.3.5i) $S(h) = B - C$

Two new quantities appear in this list: the overall survival $s(h) = (1-d)(1-h)$ from fishing and natural mortality and the ratio of recruits to spawning biomass

(5.3.6) $$r(h) = \frac{R(h)}{S(h)}$$

For a given recruitment age *r*, the calculation (5.3.5) depends only on the fixed harvest rate *h* and the vector

(5.3.7) $$q = (a, b, g, d, w_r, l, k)$$

of seven biological parameters, associated with recruitment (a, b, g), natural mortality (d), and growth (w_r, l, k). Thus, if a few key biological parameters are known, (5.3.5) gives an algorithm for evaluating the long-term consequences of operating a fishery at a specified harvest rate. In particular, the first four quantities (5.3.5a)–(5.3.5d) depend only on the survival and growth parameters, independent of the recruitment function (5.3.4a).

With no harvest $(h = 0)$, we obtain the conditions associated with a pristine stock:

(5.3.8a) $$s_0 = 1 - d$$

(5.3.8b) $$A_0 = r - 1 + \frac{1}{d}$$

(5.3.8c) $$W_0 = \frac{d\, w_r + (1-d)\, l}{1 - k(1-d)}$$

(5.3.8d) $$r_0 = \frac{d\,(1 - k + kd)}{d\, w_r + (1-d)\, l} = \frac{d}{W_0},$$

where additional calculations from (5.3.5e)–(5.3.5i) give R_0, P_0, and $B_0 = S_0$. We can use these quantities to formulate biologically meaningful surrogates for the recruitment parameters (a, b).

The pristine recruit-spawner ratio $r_0 = R_0 / S_0$ represents inherent recruitment productivity for the stock. As the stock size *S* decreases toward zero, model (5.3.4a) predicts that this ratio should approach a, that is, $r = R/S \rightarrow a$ as $S \rightarrow 0$. In a viable stock, productivity must be larger at small stock sizes than under pristine conditions, that is $a > r_0$. By (5.3.8d), this implies that model parameters must satisfy the condition

$$a > \frac{d\,(1-k+kd)}{d\,w_r + (1-d)\,l}. \qquad (5.3.9)$$

Let $f = a / r_0 > 1$ be the factor that represents the increase in productivity from a pristine stock S_0 to a small stock $S \approx 0$. Then a can be expressed in terms of f and other model parameters as

$$a = \frac{f\,d\,(1-k+kd)}{d\,w_r + (1-d)\,l}. \qquad (5.3.10)$$

Furthermore, a short calculation shows that

$$B_0 = W_0 P_0 = \frac{W_0}{d} R_0 = \frac{1}{r_0} R_0 = \frac{1}{bg}\left(1 - f^{-g}\right);$$

consequently,

$$b = \frac{1}{g\,B_0}\left(1 - f^{-g}\right). \qquad (5.3.11)$$

Equations (5.3.10)–(5.3.11) allow us to replace the model parameter vector q in (5.3.7) with the equivalent vector

$$q' = (f, B_0, g, d, w_r, l, k) \qquad (5.3.7)$$

Figure 5.3.1 shows plots of *B, C, C/R, S/R, A,* and *W* in relation to *h* generated from (5.3.5) with parameter values:

r	f	B_0	g	d	w_r	l	k
9 yr	5	100 t	-1	0.05	0.590 kg	0.105 kg	0.911

These correspond to parameters discussed in section 7 for Pacific ocean perch, where the value B_0 merely sets a convenient scale and $g = -1$ specifies a Beverton-Holt curve. The curve $C(h)$ achieves a maximum $C = 1.55$ t when $h = 0.045$, so that a harvest rate h slightly less than the death rate d produces maximum sustained yield (MSY) in the long run. Figure 5.3.2 illustrates similar results for a Ricker recruitment model with $g = 0$, where other parameters take the same values shown above. This model predicts a higher MSY $C = 2.59$ t at a higher harvest rate $h = 0.060$. Both models predict stock extinction at a steady harvest rate $h = 0.129$.

These examples illustrate a few of many common reference points that can be determined from the curves in Figs. 5.3.1–5.3.2. Mean age and mean weight can also serve as indicators of stock status. In this paper, we adopt the following conventions:

- a subscript 0 indicates the pristine equilibrium value associated with no harvesting, as in B_0, R_0, P_0, S_0, and r_0.
- a superscript asterisk denotes a value associated with MSY, such as C^*, h^*, B^*, A^*, and W^*;
- a superscript pound sign indicates extinction, as in the extinction harvest rate $h^\#$;
- a subscript percentage indicates the value associated with that percentage reduction of the value S/R from the pristine value S_0/R_0.

For example, $h_{50\%}$ denotes the value of *h* for which $S/R = 0.5 S_0/R_0$. Dotted lines indicate this reference point in the S/R panels of Figs. 5.3.1–5.3.2.

6. Spatial analysis

6.1. Coastal distribution of trawl effort and analysis of swept-area

For our spatial analysis of trawl effort, we use observer data from all bottom trawls during the period from February 16, 1996, to December 31, 1998. In particular, we use the following information from available records:

1. mean trawl location, calculated from start and end locations;
2. trawl duration (h);
3. recorded trawl depth (m);
4. major statistical area of trawl;
5. vessel code.

The mean location (x, y) of each trawl places it within a specific bathymetric block *k*, given by (5.1.3)–(5.1.4). Thus, trawl data and bathymetric data can be linked by the block index *k*. These geo-referenced data are stored as the table *B3_Trawls* in the access database *BCBathymetry.mdb* (section 3.6). Tables 3.6.1 and 6.1.1 show the formats of bathymetric and trawl records, respectively.

We calculate the area impacted by the net during each trawl from the trawl duration and estimates of vessel speed *v* and doorspread net width *w*. Historical surveys performed with commercial trawl vessels (Yamanaka et al. 1996) suggest the minimal values

(6.1.1a) $v = 4.8 \text{ km}\cdot\text{h}^{-1} = 2.6 \text{ nm h}^{-1}$, $w = 43$ m.

From (5.2.7) applied to a 2 km $\times$ 2 km block with area $a = 4 \text{ km}^2$, these correspond to the catchability

(6.1.1b) $q = 19.4$ h,

which can be interpreted as the tow time required to sweep the entire block. We consider doorspread to be a reasonable measure of net size in calculating the impacted area of ocean floor. For swept area biomass calculations, however, we recognize that smaller wingtip to wingtip measurements might be considered more appropriate. Last year's report (Schnute et al. 1999, p. 14) cited the most conservative estimates of fishermen

(6.1.2a) $v = 4.6\ \text{km}\cdot\text{h}^{-1} = 2.5\ \text{nm h}^{-1}$, $w = 16.8$ m,

which correspond to the time

(6.1.2b) $q = 51.8$ h

required to sweep an entire block. The estimates (6.1.1b) and (6.1.2b) differ by the factor

(6.1.3) $f = 2.7$.

Thus, biomass calculations from (6.1.1) would be increased by the factor *f* if (6.1.2) were used instead. Similarly, impacted area calculations would be decreased by *f*. For consistency in this report, we use (6.1.1) in all calculations. Our results, however, contain high uncertainty, and a suitable adjustment factor *f* can always be introduced to account for a specific bias, such as the shift from (6.1.1) to (6.1.2).

The trawl data indicate that tows are not distributed evenly over the coast but are highly clustered along bathymetric contours (Fig. 6.1.1). This pattern reflects the occurrence of commercial groundfish species, which are themselves distributed in relation to depth. We stratify our analysis of trawl effort by depth and groundfish major statistical area to account for species biology and the constraints imposed by quota management. We examine three aspects of the relationship between trawl effort and the underlying bathymetry:

1. What is the total area of sea floor available to the trawl fleet?
2. How much area has the trawl fleet swept during the study period?
3. How much area of the sea floor has the trawl fleet impacted during the study period?

We define “impacted area” as the total area of sea floor affected by one or more trawl events. By contrast, “swept area” refers to the sum of areas swept by all tows, without regard to recurrence over the same portion of sea floor. Thus, a given block can contribute a maximum of its physical area ($4\ \text{km}^2$) to the calculation of impacted area, but tows within it might contribute many times this amount in the calculation of swept area.

The area of sea floor available to the trawl fleet varies considerably among depth and major area strata (Table 6.1.2, Fig. 6.1.2). In general, the largest area of sea floor occurs between the depths of 0 m and 400 m. However, some statistical areas, such as 3D and 5ES, include substantial regions in deeper waters. A major thornyhead fishery occurs in the deep water portion of area 3C.

The amount of swept area similarly varies substantially among strata. In a few cases, the swept area greatly exceeds the available sea floor area (e.g., 700 m – 800 m, Area 3C), indicating a great deal of trawl effort in these regions. By definition the impacted area cannot exceed the available sea floor area. Even heavily trawled strata always include blocks not affected by trawl gear.

Within strata, swept area values per block are generally less than $4\ \text{km}^2$ (Fig. 6.1.3). Thus, most blocks have not been completely swept during the study period. Coastwide, over 70% of impacted blocks have not been completely swept, and over 35%

have had less than ¼ of their area swept. The table below summarizes by depth range the available area of sea floor in coastal BC down to 1,700 m and the corresponding percentage impacted by the bottom trawl fishery during the study period (1996–1998).

Depth Range	Area (km^2)	Percent Impacted
0–399	87,912	11.7%
400–999	9,272	25.1%
1000–1700	12,524	2.9%
Total	109,708	11.8%

6.2. Heavily fished blocks

Of the 165,360 blocks in the UTM spatial grid, 84,853 blocks (~51.3%) occur in the ocean. The number of blocks in which slope rockfish were harvested is remarkably small (Table 6.2.1). During the period from January, 1996, to March, 1999, 4,604 blocks (~5.4% of the ocean blocks) were accessed at some point for at least one of the seven slope rockfish. This activity comprised 35,254 tows. Tows catching individual species occurred in smaller areas, ranging from 1,185 blocks for longspine thornyheads to 3,073 for POP. It is interesting to note that since the introduction of the IVQ system in fishing year 1997, the number of blocks accessed has declined. There is, however, a tendency to try new blocks as indicated by the ratio of blocks accessed in any one fishing year to those accessed over the entire time period.

Table 6.2.2 gives the number of blocks in which pairs of species were caught together. The highest co-occurrence was between POP and shortspine thornyheads (2,152 blocks) and the lowest between longspine thornyheads and redstripe rockfish (317 blocks). The latter number reflects the fact that longspines generally live quite deep on the bottom, whereas redstripes are predominantly midwater fish.

Fishing effort varies considerably among blocks. Table 6.2.3 shows data from the ten blocks with highest catch for each species, based again on all observer logs in the current database. These “hot” blocks provide an indication of local high abundance and/or where the net works well. Fishermen are clearly going to fish where they catch fish. Many of these hot blocks have experienced high levels of effort, measured in hundreds of hours since 1996. The estimates (6.1.1)–(6.1.2) suggest that a block should be more than completely swept after 60 h fishing. If only parts of a block constitute trawlable grounds, then effort becomes more concentrated on the trawlable portion.

If fish were confined to blocks and consistently available to the gear, such high effort levels would reduce abundance rapidly. Figures 6.2.1 to 6.2.8 investigate possible depletion evidenced by the CPUE history in the top six hot blocks (with at least 5 tows) during the time period available in the database. Plots in these figures also show a linear trend regression line. Similarly, Table 6.2.3 lists the regression slope for each of the top 10 blocks, along with a confidence level for the hypothesis of no trend (slope = 0). Of the 70 SRF blocks in Table 6.2.3, 16 appear to show depletion, that is, a significant negative trend. Another 12 blocks suggest a positive trend. Despite the different grid system used by Schnute et al. (1999), the number of significant trends has roughly doubled since the last assessment. This is partly due to the fact that there are more data points over time, thereby clarifying trends and lowering the threshold for statistical significance. We particularly note the highly significant negative trends for longspine thornyheads.

In spite of large catch removals, 54 of the 70 'hot' blocks show no statistical evidence of depletion during the time period available in the database. We conjecture that fishing in the 'hot' blocks is typically directed at migrant fish from surrounding regions when schooling behaviour makes them available to the gear. Thus, swept area biomass estimates provide at best an abundance index of surrounding populations. Possible explanations for the absence of a negative trend include the following:

- The surrounding population is large enough not to show serious depletion from the removals.
- The time frame of 3¼ years is too short to show changes in abundance, given highly variable CPUE.
- CPUE cannot be used to detect abundance changes. In a worst case scenario, fish would persist in the areas of greatest vulnerability, even while donor populations of migrant fish declined. This could create an illusion of security when populations are actually at risk.

The longspine thornyhead statistics provide a warning of possible depletion in the hot blocks. This caution is reinforced by the belief that CPUE is a relatively reliable indicator of thornyhead abundance (see Section 8.1, Table 8.1). However, we must examine possible depth-dependent effort changes over time. According to the CGRCS, there has been increased effort in deeper areas, and a cursory look at the data reveals that effort increases with fishing depth for the thornyheads. Additionally, fishermen have been changing their harvest strategy to slower tows for higher quality, frozen-at-sea product. Thus, both deeper tows and slower tows would increase the apparent effort and, by themselves, could drag down the CPUE over time.

Thornyheads are know to migrate to deeper depths as they develop, and the spawning biomass occurs for both species in the oxygen minimum zone between 600 and 1000 m (Jacobson and Vetter 1996). All observed negative trends occurred in blocks with an average depth less than 800 m (Table 6.2.3). Despite a presumed influx of individuals from shallower depths, depletion seems to be occurring at a faster rate than replacement. As these fish might assume a greater role in perpetuating future generations, we would be wise to manage this resource in a precautionary manner.

6.3. Biomass estimation

We use the algorithms in section 5.2 to produce biomass estimates B for each slope rockfish species in each statistical area. From these and the known historical catches C, we then estimate the corresponding harvest rates $h = C / B$ (Tables 6.3.1–6.3.7, Fig. 6.3.1–6.3.2). In general, biomass estimates vary widely across years for a given species and statistical area. Most species appear to have the highest biomass in Areas 5AB and 5CD and lowest in Areas 3C, 3D, and 5EN. Exploitation rates are often extremely high in Areas 3C and 3D and generally lowest in Area 5CD.

We have several reasons to suspect the accuracy of these estimates. They probably depend highly on management strategies and quotas that influence the behaviour of fishermen. For example, avoidance fishing may have a significant effect on biomass estimates, particularly in areas such as 3C where quotas are relatively low. If fishermen avoid a species to stay within quota limitations, we would expect to see a corresponding low biomass estimate and high exploitation rate. Such an effect may be manifest across species if fishermen avoid certain depth ranges in an effort to reduce the catch of a particular species. For example, this may explain some of the low biomass estimates and high exploitation rates in Area 3C. On the other hand, we suspect that the biomass estimates of longspine thornyheads in Area 3C may be more accurate than estimates for other species. The deep-water thornyhead fishery in Area 3C is known to be particularly “clean”, i.e., to have a low incidence of by-catch. This would preclude the need for avoidance fishing. Furthermore, this species is distributed relatively uniformly over the sea floor. Given these factors, we would expect commercial trawls to exhibit CPUE values similar to those from research surveys. Thus, biomass estimates based on commercial data would be comparable to estimates from surveys.

If recruitment and growth precisely compensate for natural mortality, then a simplistic population model would reflect only losses due to catch, that is,

(6.3.1) $$B_{t+1} = B_t - C_t \, .$$

This pattern implies overexploitation, because the fishery continually reduces abundance. Ideally, recruitment and growth should also replace the catch, leading to a sustainable stock size. In table 6.3.6, however, the longspine thornyhead population in Area 3C seems to obey (6.3.1) fairly closely, again suggesting a steady depletion of the stock.

Historically, the biomass of the benchmark Pacific ocean perch stock in Area 5AB has been estimated at approximately 40,000 t (Richards et al. 1997, Fig. 4.3, p. 59). The analysis in Table 6.3.1 indicates a current biomass around 24,000 t. Given a bias factor, such as f in (6.1.3), this estimate can easily be rationalized as comparable to the historical value. Conversely, the historical estimate might be used to estimate the bias factor

$$f = \frac{40{,}000}{24{,}000} = 1.7 \ .$$

Despite potential difficulties with commercial catch data, the technique illustrated here offers a useful framework for future analyses. In particular, the ability to expand catch densities over actual bathymetric areas considerably advances the prospects for producing realistic slope rockfish biomass estimates. Stocks must be limited by their finite habitat, and we now have preliminary estimates of habitat size. If industry sponsors future rockfish surveys, then the resulting analyses must have elements in common with those proposed here. For example, an annual survey of 500 tows could be simulated by bootstrap samples of size 500 from existing commercial data. Such an exercise would give prior estimates of variability and highlight potential problems that must be addressed in a rational survey design.

7. Species biology and reference points

Biological data (lengths, weights, and ages) are available in the GFBio database for Pacific ocean perch and yellowmouth, redstripe, and rougheye rockfish. Age data are most complete for POP, spanning the years 1978 to 1997. Sporadic data exist for other rockfish species. Rougheye rockfish have been sampled consistently since 1990 due to the efforts of the hook and line group. Considerable data from recent years; however, remain to be rendered in electronic form.

We compute age proportions within a given stratum by averaging across samples. Thus, if sample *k* in year *t* includes n_{atk} fish at age *a*, we estimate the proportion at age *a* in year *t* as

$$p_{at} = \frac{1}{K_t} \sum_{k=1}^{K_t} \frac{n_{atk}}{\sum_a n_{atk}} \ , \qquad (7.1)$$

where K_t denotes the number of samples in year *t*. Thus, each sample counts equally, regardless of sample size. Bubble plots of proportion-at-age provide a convenient method of visualizing recruitment strength, where a strong cohort appears as a diagonal of relatively large bubbles (Fig. 7.1). For example, Pacific ocean perch show a strong cohort starting with age-9 fish in 1985. This cohort, which can easily be followed diagonally to the right, remained one of the strongest year classes until 1996. Other cohorts visible in the diagram are not as strong (e.g., age-9 perch in 1989). For yellowmouth rockfish, an age-9 cohort appeared in 1991, but there is a large gap in the data from 1980 to 1989, where a larger recruitment event might have occurred. For redstripe rockfish, there are only three successive years of age data, but these give some indication of two recruitment events where age-18 fish and age-20 fish were cohorts in 1990. The rougheye rockfish plot gives no clear recruitment event but there does seem to be a cohort of age-35 fish in 1990.

Bubble plots in Fig. 7.1 also serve to estimate the age *r* of full recruitment and the death rate d , as shown in Table 7.1. We estimate both parameters informally, partly with reference to historical literature.

In Figs. 7.2 to 7.5, the age data have been divided among slope rockfish assessment areas to yield area-specific proportion-at-age bubble plots. For Pacific ocean perch (Fig. 7.2), the data do not span enough years in areas 3C and 3D to give any meaningful insight. In the remaining areas, the large recruitment in the coastwide bubble plots, mentioned above, is very evident with age-9 fish dominating in 1985. For yellowmouth rockfish (Fig. 7.3), the bubble plots are only meaningful for areas 5AB where age-9 fish formed the dominant cohort in 1991. Redstripe rockfish (Fig. 7.4) show the same trend in 5AB as they did coastwide. Nearly all the age data for rougheye rockfish (Fig. 7.5) come from 5ES.

Figure 7.6 provides a rough visualization of when major spawning events might have taken place, based on the proportion-at-age bubble plots. The most obvious features of this representation are

1. within any species, important spawning/recruitment events tend to occur coastwide;
2. these events do not seem to occur at the same time for the different species.

Figure 7.7 shows relationships between weight and age for the four slope rockfish species. Because GFBIO currently contains no perch weight data, we used mean weight data from Richards (1994). For yellowmouth, redstripe, and rougheye rockfish, GBBIO similarly contains almost no age-weight data, but does include some age-length and length-weight data. We used these to estimate the following regression models predicting weight from length:

(7.2) Yellowmouth: $w = -2188.138 + 7.987997 \cdot l$, n = 74;

(7.3) Redstripe: $w = -102.4288 + 0.9853546 \cdot l$, n = 218;

(7.4) Rougheye: $w = -2592.892 + 9.258157 \cdot l$, n = 1392;

where weights w and lengths l are expressed as g and mm, respectively. Then we used predicted weights from the age-length data to obtain the scatter plots in Fig. 7.7. The figure shows least squares fits to growth curves (5.3.1b) with the parameters (w_r, l, k) listed in Table 7.1. All weight data shown in Fig. 7.7 were derived from length data via (7.2)–(7.4), except for about 3% true weight data for rougheye rockfish.

Estimates of reference points require recruitment parameters (f, B_0, g), in addition to the mortality and growth parameters (w_r, l, k) discussed above. Following Walters and Bonfil (1999), we choose $f = 5$ as a reasonable estimate for rockfish species. We give the problem a convenient scale by setting $B_0 = 100$ t and examine the recruitment models of Beverton-Holt $(g = -1)$ and Ricker $(g = 0)$. Table 7.1 includes the parameters estimated above from the biological data for Pacific ocean perch, yellowmouth, redstripe, and rougheye rockfish, plus parameters for the thornyhead species taken directly from Walters and Bonfil (1999, Table 1, p. 604). The latter parameters seem slightly suspect; for example, they imply that a 60 year old shortspine thornyhead would weigh more than 18 kg.

The results in Table 7.1 serve as 'back of the envelope' estimates of overall productivity for slope rockfish. The MSY biomass B^* lies in the range of 1/3 to 1/2 of the pristine biomass B_0, with corresponding MSY harvest rates h^* of 3%–7%. The Ricker model indicates higher rates h^* and yields C^* than the Beverton-Holt model. Figure 5.3.2 (upper left panel) offers an intuitive reason for this. Recruitment initially increases with harvest rates $h > 0$, a phenomenon that might be consistent with cannibalism by adults on young fish. In general, healthy slope rockfish stocks must be abundant relative to the catch. This could be deceptive in a new fishery. For example, a pristine Pacific ocean perch stock of 100 t with Beverton-Holt recruitment (Table 7.1, column 1) could be fished down to 34 t before an annual quota $C^* = 1.5$ t would need to be imposed. If fishermen become accustomed to large catches during the initial period of fishing down the pristine stock, they might have difficulty adjusting to a quota that is only 1.5% of the initial biomass B_0. We fear that such a phenomenon could actually occur for longspine thornyhead stocks, with no clear understanding of an appropriate point to stop the initial phase.

Obviously, the results in Table 7.1 are highly speculative. In fact, they offer a precise technology for speculation. For example, we have set the parameters f and g quite arbitrarily and used death rates d that are rather poorly defined. We make these choices in the absence of more solid data, but the process at least provides focus for exploring questions about slope rockfish productivity.

8. Industry concerns

During 1999, the Canadian Groundfish Research and Conservation Society (CGRCS) became increasingly involved with the assessment process through collaborative agreements and the sponsorship of various workshops to implement a comprehensive, industry-led, fisheries independent survey program to assess stocks of the major slope rockfish.

In May, 1999, members of the CGRCS, stock assessment staff from the Pacific Biological Station (PBS), US representatives of NOAA's National Marine Fisheries Service (NMFS), and various consultants met to discuss the reliability of bottom trawl surveys to estimate the abundance of the major BC rockfish species. The conclusion of the workshop was that indices of abundance from bottom trawl surveys would be most effective for Pacific ocean perch, yellowmouth rockfish, the rougheye-shortraker rockfish complex, and the thornyheads (Table 8.1).

Participants at the meeting identified five steps toward developing trawl surveys for these species:

1. Use fishermen to develop a map of areas along the BC coast that vary in trawlability given current technology and experience. Exact definitions of such areas can be quite formal and rely on criteria relevant to survey work rather than harvest practise.
2. Develop maps showing our current knowledge of species density. This would come primarily from the observer database. A first approximation can be as simple as calculating catch per unit effort (e.g., kg/h). Additionally, explore density variation with time (monthly, seasonally, time of day, etc.) and depth.
3. Evaluate various survey designs based on the coefficient of variation of the biomass index. Stratify effort amongst the area types identified in Point 1.
4. Implement the designed survey on a trial basis and refine where necessary.
5. Results of surveys can be used in stock assessments and quota recommendations.

Subsequent workshops in August and September, 1999, solicited the opinions of fishermen on what constituted trawlable bottom. Their knowledge of the sea floor has accrued after years, if not decades, of fishing along the BC coast. As a starting point we chose the central coast (CC) because this area hosts some of the highest trawling activity

(Fig. 8.1). Fishermen with extensive experience in the CC, along with representatives of the CGRCS and DFO, participated in the exercise.

8.1. Expert knowledge of towable bottom

Taking into account the protocols used by NMFS for their triennial surveys of rockfish along the western US coast, the workshop group discussed appropriate measures for the BC coast and settled on the definitions of trawlable in Table 8.1.1. Using these definitions, several fishermen drew clearly delineated, colour-coded polygons on bathymetric charts outlining areas of the sea floor that, to the best of their knowledge, satisfied the four conditions in Table 8.1.1.

The results were presented at a subsequent meeting with the CGRCS, and members in attendance chose the chart of one fisherman as being most representative of bottom trawlability with respect to the design of slope rockfish surveys (Fig. 8.1.1). It should be noted that within any one of these polygons, there may be small areas of trawl type other than that indicated. Additionally, an area's trawl classification may vary depending on the vessel master's experience, the vessel's technology, and the type of gear and vessel.

Another set of fishermen has coded the bottom along the west coast of the Queen Charlotte Islands using the same classification scheme. The CGRCS plans to develop similar maps of the entire BC coast.

8.2. Survey design

This report illustrates biomass calculations from groundfish trawl data. Sections 5.2 and 6.1 highlight features of the analysis that could be used in survey design. For example, bootstraps from the existing database could be used to obtain prior variance estimates. Generally, the surveys will standardize trawling methodology and minimize confounding effects (e.g., avoidance fishing, harvest policy changes, management restrictions, depth-dependent effort effects, skipper experience, gear efficiencies, diurnal and seasonal effects, tidal states, fish life cycles).

8.3. Boundary between 5CD and 5ES

An issue that has arisen at industry meetings is the existing boundary between 5CD and 5ES. The fishermen propose that the boundary be shifted north from its current location at 52° N to 52° 20' N (Fig. 8.3.1). The rationale is that if quotas remain the same in 5CD and 5ES, fishing pressure in 5CD can be alleviated somewhat. Relatively little fishing activity occurs in the southern part of 5ES, because license holders for 5ES concentrate their fishing effort along the NW section of the Queen Charlotte Islands (Fig. 8.3.1). The proposed addition to 5CD makes sense to the fishermen from a logistical point of view.

Although the current observer database does not identify a vessel's port of origin, it does identify its offload port. Since 1996, vessels fishing in the combined area of 5CD, 5ES, and 5EN have offloaded at 14 different ports (Fig. 8.3.1). For illustrative purposes, we classified Masset, Port Edward, Prince Rupert, and Port Hardy as northern ports, and the remaining as southern ports. Unknown ports were given no designation. We also chose three new boundaries at 52.1° N, 52.3° N (boundary proposed by fishermen), and 53° N and plotted the catch of each slope rockfish species in the fishing years 1996 to 1998 for the area of 5ES that would theoretically become part of 5CD (Fig. 8.3.2). For example, if the boundary were shifted to 52.3° N for POP, the area catch in 1996 would have been 44.7 t by northern vessels and 23.9 t by southern ones. Similarly, in 1997 and 1998, the catch would have been: N = 5.7 t, S = 11.7 t and N = 7.7 t, S = 0 t, respectively. Obviously, fishermen were less inclined to fish this area for POP after 1996 (when IVQs were in place). In general, it appears that northern ports would be more affected by a change in boundary than southern ones. Also, as a percentage of the catch in 5CD or 5E, the catch in this area, at least during 1997 and 1998, was small, and a shift from 5ES to 5CD would not adversely affect quota holders. The same can be said about all other slope rockfish species with the exception of longspine thornyheads in 1996. A boundary shift for this species before the IVQ system affected only northern vessels where ~15% of the 5E catch would have transferred to 5CD. In subsequent years, however, there was no longspine catch in the affected area. In general, there appears to be no real concern, from a quota holder's point of view, in shifting the boundary.

Another issue is whether the existing boundary makes sense with respect to stocks. A preliminary, CGRCS-funded study by Withler et al. (1998) suggests that there are two separate Pacific ocean perch stocks in Moresby Gully, based on DNA differences at microsatellite loci. These stocks are not currently managed separately. Additionally, the DNA study found that the POP samples in south Moresby were genetically identical to those off the southwest coast of the Queen Charlotte Islands, perhaps up to Rennel Sound (~53° 20' N). This provides an additional reason for extending the 5CD boundary further north, at least for Pacific ocean perch.

9. Summary

This year's report does not provide a new assessment, but rather a series of steps essential for future assessments, based on industry-sponsored surveys for slope rockfish. Our research follows a strategic plan for collaborative work with industry, initiated at a workshop in May, 1998. The report presents the latest available data and makes the following major advancements on past work.

1. Although the 1998 report recognized the key role of depth strata in a multispecies ecology, the assessment team did not have access to technology for a complete bathymetric analysis. We have now rectified this problem by developing a bathymetric database using the Geographic Information System (GIS) software package ArcView. The coastal bathymetry was partitioned into blocks that are cross-referenced with the observer data. For each 100 m depth interval, we calculated bottom area available to fishing as well as actual bottom areas swept and impacted. We have also provided estimates of biomass for each SRF species by extrapolating observed estimates of density (CPUE) at depth to all available coastal bathymetry.

2. Staff members collaborated with the Canadian Groundfish Research and Conservation Society (CGRCS) on a project to develop an industry-sponsored survey of SRF, independent of the fishery. To date, we have developed maps that record

fishermen’s impressions of trawl characteristics of the ocean floor. These classifications and preliminary estimates of fish density provide essential prior information in designing a survey that minimizes the variance of biomass estimates for a given level of available resources.

3. We have used biological data (length, weight, age) to calculate rough estimates of key reference points for the slope rockfish species. For example, proportion-at-age bubble plots indicate recruitment information and population structure. The report presents the complete mathematical framework for calculating reference point values from underlying biological parameters.

Analyses extended from last year suggest a continuing decline in the density of longspine thornyheads in the most heavily fished blocks in assessment unit region 3C. Although these results are not definitive, they suggest a cautious approach to the development of a new fishery on this species. In some cases, avoidance fishing or changes among vessels may explain negative CPUE trends in heavily fished blocks.

In response to a request from industry and management, we examine the possible justification for shifting the 5CD/5ES boundary 20 minutes north of its present location at 52°N. If the quota remains unchanged in each area, the impact on quota holders would be minimal. Furthermore, fishing pressure on the Morseby Gully region would be somewhat alleviated if 5CD quota holders shift some of their effort to the region off the southwest Queen Charlotte Islands.

Any stock assessment must address two questions: (1) how many fish are out there? and (2) how many can safely be caught? This report documents the data available and suggests protocols for dealing with each question. Our analysis extends work from the previous report (Schnute et al. 1999) by including coastal bathymetry data and biological data for estimating reference points. The bathymetry data give more precise definition to the phrase ‘out there’ in question 1. Together with the analytical framework in section 5.3, the biological data help define ‘safely’ in question 2. We have emphasized the need to move groundfish assessments in new directions, and this report offers a bridge between past methods and future analyses supported by industry-sponsored surveys. We also continue to support cooperation by all parties in collecting information and improving assessments.

The following table summarizes coastwide mean yield recommendations, quotas, kept catch, and total catch (tonnes) by slope rockfish species for the 1997 and 1998 fishing years. Symbols indicate statistically significant negative (-) or positive (+) CPUE trends among the 10 most heavily fished blocks for each species.

Species	1997 Yield	1997 Quota	1997 Kept	1997 Total	1997 Trends	1998 Yield	1998 Quota	1998 Kept	1998 Total	1998 Trends
	Coastwide Fishery									
POP	5,635	6,481	5,602	5,765	-	5,180	6,147	5,552	5,688	- - - - +
Yellowmouth	2,140	2,430	2,201	2,216	- +	2,125	2,385	2,087	2,101	+ + +
Redstripe	1,410	1,623	890	1,186	+	1,360	1,564	857	1,168	+ + + +
Rougheye	700	380	484	486	+ +	735	549	596	597	+ + +
Shortspine	680	748	506	541	-	670	749	513	548	- - -
Longspine	345	860	514	588	- - - -	335	861	743	862	- - - - - +
Shortraker	140	77	58	59	- -	155	117	41	41	- - - -

We do not specifically recommend that current TAC levels be adjusted based on the above table. CPUE trends may indicate changes in abundance; however, there are so many confounding factors that we can only advise managers to be aware of potential problems. Until controlled surveys are implemented and/or confounding factors are statistically incorporated in CPUE measurements, we cannot with any degree of confidence provide reliable measures of stock abundance at this time.

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Table 2.1. Recent history of yield options and quotas (tonnes) for slope rockfish species.

Species	Area	1997 Yield Option	1997 Quota	1998-2000 Yield Option	1998 Quota	1999 Quota
POP	3C	250 - 500	431	80 - 110	300	300
	3D	100 - 300	230	100 - 300	230	230
	5AB	1760 - 2340	2358	1200 - 2400	2070	2070
	5CD	1500 - 3400	2818	1500 - 3400	2817	2817
	5EN	150 - 170		280 - 520		
	5ES	300 - 500		170 - 300		
	5ES/5EN		644		730	730
	total	**4060 - 7210**	**6481**	**3330 - 7030**	**6147**	**6147**
YelMth	3C		100	130 - 260	221	223
	3D			190 - 390		
	5AB			460 - 980		
	5CD		360	390 - 830	691	697
	5EN			110 - 200		
	5ES			100 - 210		
	3D/5AB	710 - 1000	1866		1145	1156
	5ES/5EN		104		328	331
	Coastwide	1540 - 2740	2430		2385	2407
	total	**1540 - 2740**	**2430**	**1380 - 2870**	**2385**	**2407**
RedStr	3C		150	120 - 190	178	178
	3D			70 - 150		
	5AB			370 - 790		
	5CD		49	190 - 400	339	339
	5EN			20 - 80		
	5ES			140 - 200		
	3D/5AB	470 - 660	1198		794	794
	5ES/5EN		226		253	253
	Coastwide	1020 - 1800	1623		1564	1564
	total	**1020 - 1800**	**1623**	**910 - 1810**	**1564**	**1564**
RghEye	3C			70 - 130		
	3D			40 - 70		
	5AB			60 - 110		
	5CD			90 - 160		
	5EN			50 - 100		
	5ES			210 - 380		
	Coastwide	500 - 900	380		549	433
	total	**500 - 900**	**380**	**520 - 950**	**549**	**433**
Sthorn	3C			310 - 540		
	3D			80 - 140		
	5AB			20 - 30		
	5CD			50 - 90		
	5EN			20 - 30		
	5ES			10 - 20		
	Coastwide	490 - 870	748		749	732
	total	**490 - 870**	**748**	**490 - 850**	**749**	**732**
Lthorn	3C					
	3D					
	5AB					
	5CD					
	5EN					
	5ES					
	Coastwide	250 - 440	860	245 - 425	861	855
	total	**250 - 440**	**860**	**245 - 425**	**861**	**855**
SrtRak	3C			20 - 40		
	3D			20 - 40		
	5AB			10 - 20		
	5CD			30 - 50		
	5EN			10 - 20		
	5ES			20 - 30		
	Coastwide	100 - 180	77		117	92
	total	**100 - 180**	**77**	**110 - 200**	**117**	**92**

Table 2.2. Outline of historic fishery management practices and participating countries in the slope rockfish fishery off the BC coast between 1965–99.

	Management Practice	**Participants**
1965-76	None.	Soviet, Japanese, US, Canadian
1977-85	Species/area quotas, area/time closures, trip limits.	US until 1980, Canadian
1986	Coastwide quotas and trip limits.	Canadian
1987-88	Species/area quotas, area/time closures, trip limits.	Canadian
1989-93	Coastwide quotas and trip limits.	Canadian
1994-95	Aggregate rockfish mgmt, trip limits, coastwide quotas.	Canadian
1995-96	Aggregate rockfish management.	Canadian
1996-97	Species/area quotas, area/time closures, trip/monthly limits.	Canadian
1997-98	Species/area quotas, IVQs, area/time closures.	Canadian
1998-99	Species/area quotas, IVQs, area/time closures.	Canadian

Table 2.3. History of recommended yield options (low to high risk), assigned quotas, and commercial trawl catch for Pacific ocean perch stocks. Area 5ES was managed on the basis of the slope rockfish aggregate (Pacific ocean perch, yellowmouth rockfish, and rougheye rockfish) between 1983–1988. An open fishing experiment was conducted in Area 5EN between 1983–90; the area was closed from 1991–97 and yields were given for reference only. In 1986, coastwide aggregate quotas were assigned to the slope aggregate. In 1989–93 species quotas were assigned on a coastwide basis and area-specific quotas reflect the contribution in the coastwide quota. Coastwide aggregate quotas were again assigned in 1994–96. Quotas listed for years in which aggregates were assigned include other species in addition to Pacific ocean perch.

	Area 3C			Area 3D			Area 5AB			Area 5CD			Area 5ES			Area 5EN			Area 3C-5E		
Year	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch
1979	50	50	125	10		-	2000	2000	1257			370	600	600	839			227	2670		2818
1980	600	600	430			-	2000	2200	1387			2545	600	600	877		200	85	3200		5324
1981	500	500	547			-	1500	1500	1621	1600	1800	2217	600	600	599	200	200	109	4400		5094
1982	500	500	508		250	-	1000	1000	913	1600	2000	3626	600	600	614	200	200	342	3900		6003
1983	500	500	752	250	250	86	1100-2000	1000	1485	2000-2800	2000	2220	agg	agg	835	open	open	292			5670
1984	150-500	500	551	250	250	193	1100-2000	800	937	1900-2800	2000	2055	agg	agg	841	open	open	2186			6763
1985	0-500	300	243	250-500	350	313	850-1300	850	823	1700-2500	2000	1967	400-1000	agg	829	0-200	open	1921			6096
1986	0-350	100	242	175-350	350	1046	595-910	500	644	1190-1750	2000	629	280-700	agg	642	0-140	open	2725	2550-3800	5000	5928
1987	0-200	100	542	250-500	350	450	400-650	500	1646	1700-2500	2000	1911	400-1000	agg	661	open	open	1130			6340
1988	100-200	100	307	200-600	350	492	700-1000	700	1198	1900-3000	3000	3105	400-700	agg	766	150-170	open	1089			6957
1989	100-200	150	278	200-600	400	994	700-1000	850	1179	1900-3000	3000	1498	300-500	400	571	150-170	open	1525		4650	6045
1990	100-200	150	278	200-600	400	919	700-1000	850	1391	1900-3000	2450	1410	300-500	400	605	150-170	open	1154		4100	5757
1991	100-200	0	22	200-600	400	807	700-1000	850	865	1900-3000	2150	2019	300-500	400	635	150-170	0	-		3800	4349
1992	100-200	0	390	200-600	400	681	700-1000	850	949	1900-3000	2400	1699	300-500	400	374	150-170	0	-		4050	4093
1993	100-200	150	970	200-600	400	667	700-1000	850	895	1900-3000	2400	1556	300-500	400	477	150-170	0	19		4200	4584
1994	*		1365	*		233	350-1800		2428	1500-3400		1270	*		287	*	0	28	3400-5700	4917	5613
1995	*		789	*		102	350-1800		2600	1500-3400		1539	*		802	*	0	48	3400-5700	4234	5880
1996	*		402	*		132	350-1800		1227	1500-3400		3743	*		613	*	0	21	3400-5700	6884	6138
1997	250-500	431	455	100-300	230	77	1760-2340	2358	2063	1500-3400	2818	2402	300-500	644 (5E)	401	150-170	0	203	4060-7210	6481	5602
1998	80-110	300	374	100-300	230	42	1200-2400	2070	1822	1500-3400	2817	2576	170-300	730 (5E)	608	280-520	0	130	3330-7030	6147	5552
1999	80-110	300		100-300	230		1200-2400	2070		1500-3400	2817		170-300	730 (5E)		280-520			3330-7030	6147	

Table 2.4. History of recommended yield options (low to high risk), assigned quotas, and commercial trawl catch for yellowmouth rockfish stocks. Area 5ES was managed on the basis of the slope rockfish aggregate (Pacific ocean perch, yellowmouth rockfish, and rougheye rockfish) between 1983–1988. An open fishing experiment was conducted in Area 5EN between 1983–90; the area was closed from 1991–97 and yields were given for reference only. In 1986, coastwide aggregate quotas were assigned to the slope aggregate. In 1989–93 species quotas were assigned on a coastwide basis and area-specific quotas reflect the contribution in the coastwide quota. Coastwide aggregate quotas were again assigned in 1994–96. Quotas listed for years in which aggregates were assigned include other species in addition to yellowmouth rockfish. The quota for 1996 is included in the Pacific ocean perch quota (Table 2.3).

	Area 3C			Area 3D			Area 3D/5AB			Area 5CD			Area 5ES			Area 5EN			Area 3C-5E		
Year	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch
1979	*		2	*		-	100	50	17	50		20	750	750	389			17	950		438
1980	*		-	*		-	100	250	10	50		20	800	800	500			-	1200		548
1981	*		-	*		-	250		28	50		110	600	800	922	200		2	1200		1039
1982	*		7	*		-	250	250	5			442	600	100	414	100	600	68	950		1159
1983	*		52	*		20	200-500	250	228			204	agg	agg	588	open	open	52			1524
1984	*		12	*		114	200-500	250	628	300	300	338	agg	agg	441	open	open	73			1322
1985	*		4	*		412	200-500	350	458	200-300	250	232	400-1000	agg	496		open	180			1628
1986	*		3	*		980	140-350		716	140-210	250	100	280-700	agg	564		open	615	400-800		2491
1987	*		11	*		699	200-500	350	1208	200-300	250	116	400-1000	agg	451		open	109			1857
1988	*		14	*		161	250-750	375	1170	160-500	250	323	400-700	agg	289	350-500	open	107			1307
1989	*		56	*		299	250-750	500	574	160-500	350	176	400-700	600	228	350-500	open	158		1450	1602
1990	*		67	*		253	250-750	500	983	160-500	330	141	400-700	550	299	350-500	open	178		1380	1659
1991	*		52	*		201	250-750	500	974	160-500	330	169	400-700	550	121	350-500	0	-		1380	1204
1992	*		87	*		245	250-750	500	862	160-500	330	316	400-700	550	123	350-500	0	1		1380	1464
1993	*		73	*		276	250-750	500	937	160-500	330	156	400-700	550	144	350-500	0	4		1380	1119
1994	*		124	*		330	*		741	*		62	*		44	*	0	-	1100-1850	1593	1219
1995	*		92	*		231	*		989	*		119	*		72	*		-	1100-1850	1465	1310
1996	*		158	*		223	*		1027	*		497	*		127	*		-	1100-1850		1635
1997	*	100	62	*		367	710-1000	1866	853	*	360	216	*	104 (5E)	38	*		5	1540-2740	2430	2201
1998	130-260	221	76	190-390		200	460-980 (5A/B)	1145	1879	390-830	691	549	100-210	328 (5E)	205	110-200		4	1380-2870	2385	2087
1999	130-260	223		190-390			460-980 (5A/B)	1156	1253	390-830	697		100-210	331 (5E)		110-200			1380-2870	2407	

Table 2.5. History of recommended yield options (low to high risk), assigned quotas, and commercial trawl catch for rougheye rockfish stocks. Area 5ES was managed on the basis of the slope rockfish aggregate (Pacific ocean perch, yellowmouth rockfish, and rougheye rockfish) between 1983–1988. An open fishing experiment was conducted in Area 5EN between 1983–90; the area was closed from 1991–97 and yields were given for reference only. In 1986, coastwide aggregate quotas were assigned to the slope aggregate. In 1989–93 species quotas were assigned on a coastwide basis and area-specific quotas reflect the contribution in the coastwide quota. Coastwide aggregate quotas were again assigned in 1994–96.

	Area 3C			Area 3D			Area 5A/B			Area 5C/D			Area 5ES			Area 5EN			Area 3C-5E		
Year	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch
1979	*		3	*		-	*		5	*		4	150		192			14	150		218
1980	*		27	*		-	*		-	*		1	150		51			3	150		82
1981	*		7	*		-	*		1	*		-	250		10	200		98	450		116
1982	*		5	*		-	*		-	*		38	250	250	274	250		69	500		386
1983	*		2	*		-	*		5	*		6	agg	agg	74	open	open	127			214
1984	*		-	*		-	*		11	*		7	agg	agg	101	open	open	227			346
1985	*		1	*		-	*		-	*		3	100-500	agg	158	0-250	open	454			616
1986	*		1	*		12	*		14	*		3	70-350	agg	269	0-175	open	461	100-500		758
1987	*		3	*		2	*		3	*		6	100-500	agg	296	open	open	180	100-400		490
1988	*		49	*		22	*		106	*		95	200-300	200	353	50-100	open	467			1092
1989	*		140	*		17	*		57	*		28	200-300	250	251	50-100	open	511			1003
1990	*		106	*		19	*		89	*		17	200-300		470	50-100	open	494			1195
1991	*		171	*		52	*		103	*		31	200-300		607	50-100	0	1			964
1992	*		302	*		99	*		144	*		29	200-300		1061	50-100	0	7			1641
1993	*		403	*		98	*		167	*		27	200-300		1126	50-100	0	54			1874
1994	*		156	*		13	*		118	*		20	*		946	*	0	80	500-900	796	1333
1995	*		241	*		17	*		159	*		77	*		567	*		41	500-900	735	1101
1996	*		172	*		36	*		119	*		209	*		465	*		49	500-900	**1311	1050
1997	*		98	*		3	*		45	*		45	*		263	*		29	500-900	380	484
1998	70-130		127	40-70		8	60-110		37	90-160		35	210-380		357	50-100		32	520-950	549	596
1999	70-130			40-70			60-110			90-160			210-380			50-100			520-950	549	

** includes rougheye and shortraker rockfish quotas

Table 2.6. History of recommended yield options (low to high risk), assigned quotas, and commercial trawl catch for redstripe rockfish stocks. No quotas were assigned prior to the coastwide quota in 1993.

	Area 3C			Area 3D		Area 3D/5AB			Area 5CD			Area 5ES			Area 5EN			Area 3C-5E		
Year	Yield	Quota	Catch	Yield	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch	Yield	Quota	Catch
1988	200-1000		393	*	285	350-900		678	350-570		199	100-200		517	500-700		114	*		1824
1989	200-1000		288	*	311	350-900		599	350-570		234	50-100		154	500-700		151	*		1616
1990	200-1000		343	*	218	350-900		561	350-570		321	50-100		199	500-700		69	*		1970
1991	200-1000		251	*	238	350-900		489	350-570		120	50-100		245	500-700		4	*		1600
1992	200-1000		271	*	237	350-900		508	350-570		266	50-100		388	500-700		1	*		3051
1993	200-1000		349	*	198	350-900		547	350-570		95	50-100		330	500-700		12	*	2200	1912
1994	*		435	*	96	*		531	*		153	*		226	*		1	950-2570	1840	1397
1995	*		193	*	300	*		493	*		93	*		99	*		6	950-2570	1755	1282
1996	*		100	*	75	*		175	*		207	*		114	*		1	950-2570	2024	916
1997	*	150	128	*	82	470-660	1198	210		49	139		226 (5E)	89			5	1020-1800	1623	890
1998	120-190	178	107	70-150	58	370-790 (5A/B)	794	165	190-400	339	102	140-200	253 (5E)	154	20-80		0	910-1810	1564	857
1999	120-190	178		70-150		370-790 (5A/B)	794		190-400	339		140-200	253 (5E)		20-80			910-1810	1564	

Table 3.2.1. Current number of fields and records in the seven primary tables of the observer database (to July 1999).

Table	Fields	Records
B1_Hails	26	7,983
B2_Trips	20	4,279
B3_Fishing_Events	60	72,017
B4_Catches	13	831,758
B4_Total_Catch	6	665,714
B5_Validation_Headers	28	8,106
B6_Validation_Species	10	101,517

Table 3.2.2. Number of tows and species captured, as recorded by observers, in each fishing year, . Species = all species, Fish = all fish, CFish = commercial fish, RFish = rockfish species. Mean and standard deviation (SD) refer to the number of species per tow.

Year	Tows	Species	Fish	CFish	RFish	Mean	SD
1996	25,774	278	181	63	37	8.0	4.9
1997a	5,241	198	128	59	33	9.5	4.6
1997	17,106	249	168	63	35	10.7	4.8
1998	17,396	232	163	61	35	10.6	5.1
Total	65,517	351	224	64	37	9.5	5.1

Table 3.3.1. Approximation of slope rockfish assessment areas based on combinations of DFO management areas and subareas. The conversions are used to estimate hook and line catch of the SRF species.

SRF Area	DFO areas-subareas
3C	21, 23, 23-1:23-11, 24, 24-1:24-10, 25, 25-1:25-16
3D	26, 26-1:26-11, 27, 27-2:27-7
5AB	7, 7-1:7-30, 8, 8-1:8-16, 9, 9-1:9-12, 10, 10-1:10-12, 11, 11-1:11-2, 12-12, 27-1, 107, 107-1:107-3, 108, 108-1:108-16, 109, 109-1:109-12, 110, 110-1:110-13, 111, 111-1:111-5, 130, 130-1:130-2
5CD	1, 1-2:1-7, 2-1:2-19, 3, 3-1:3-4, 4, 4-1:4-15, 5, 5-1:5-24, 6, 6-1:6-25, 101, 101-4:101-10, 102, 102-1:102-3, 103, 103-1:103-7, 104, 104-1:104-13, 105, 105-1:105-2, 106, 106-1:106-26, 130-3:130-4
5ES	2, 2-31:2-100, 101-1, 142, 142-1:142-2
5EN	1-1, 101-2:101-3

Table 3.6.1. Structure of the *B2_Bathymetry* table from the database *BCBathymetry.mdb*.

Field Name	**Data Type**	**Description**
index	Integer	Block unique index
i	Integer	Block row index
j	Integer	Block column index
lat	Real	Latititude at block centre
lon	Real	Longitude at block centre
x	Real	UTM Easting at block centre
y	Real	UTM Northing at block centre
ma	Integer	Groundfish major statistical area
geocode	Integer	Geographic feature code
depth	Real	Bathymetric depth

Table 4.1.1. Hook and line catch (kg) of Pacific ocean perch, yellowmouth rockfish, redstripe rockfish, rougheye rockfish, shortspine thornyhead, and shortraker rockfish for the fishing years 1993 to 1998.

					Area				
Year	**Species**	**3C**	**3D**	**5AB**	**5CD**	**5EN**	**5ES**	**Total**	**Fishery Types**
1993	POP	9	10	14	200		277	509	longline
	Yellowmouth	1,519	431	386	63	544	39	2,982	longline, handline
	Redstripe	31	56	150	288	142	227	894	longline
	Rougheye	636	2,952	417	1,472	5,453	5,077	16,007	longline, handline
	Shortspine	181			9		5	195	longline
	Shortraker			23		18	10,126	10,167	longline
1994	POP	569	265					835	longline
	Yellowmouth			11,685			13	11,698	longline
	Redstripe	15	940	559	72	4	239	1,829	longline, handline
	Rougheye	795	270	14,887	710	435	101,627	118,725	longline
	Shortspine	23	42	614	74		946	1,699	longline, handline
	Shortraker			3,794	1,017		34,010	38,821	longline
1995	POP	57	17	238	2		617	930	longline
	Yellowmouth	10	13	11,570	151		4,649	16,394	longline
	Redstripe	6	1	58	55		190	310	longline, handline
	Rougheye	1,490	8,650	40,684	5,521	849	413,724	470,917	longline, handline
	Shortspine	294	1,066	2,762	319	37	11,706	16,183	longline, handline
	Shortraker	589	9,017	14,457	819	138	62,794	87,814	longline
1996	POP		110	499			362	971	longline, handline
	Yellowmouth		675	7,044			1,848	9,566	longline
	Redstripe		38	49	58	29	65	239	longline, handline
	Rougheye	1,568	47,985	29,101	461	541	52,063	131,718	longline, handline
	Shortspine	167	3,089	1,674	1		953	5,884	longline, handline
	Shortraker	1,084	30,385	17,972			10,631	60,073	longline, handline
1997a	POP						5	5	longline, handline
	Yellowmouth							0	
	Redstripe			106	70			177	longline, handline
	Rougheye						15,599	15,599	longline
	Shortspine			1			613	614	longline, handline
	Shortraker						2,408	2,408	longline
1997	POP		31	654	4	58	392	1,138	longline, handline
	Yellowmouth		220	2,669			344	3,232	longline
	Redstripe			76	229		195	500	longline, handline
	Rougheye	1	19,893	18,255	8		178,476	216,634	longline, handline
	Shortspine	90	1,828	1,158	10		1,824	4,909	longline
	Shortraker	10	18,121	20,252	26		30,024	68,433	longline, handline
1998*	POP		6	12			1,251	1,268	longline, handline
	Yellowmouth		272	3,197			1,857	5,326	longline, handline
	Redstripe		12	80	15		11	119	longline, handline
	Rougheye	1,331	2,025	4,350	168	1,889	168,771	178,534	longline, handline
	Shortspine	799	174	557	15		5,617	7,162	longline, handline
	Shortraker	294	1,627	1,723			24,593	28,237	longline, handline

* Apr-Dec

Table 4.1.2. Area 3C (including statistical areas 25 and 125) Canadian trawl catch (tonnes) of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the 20% qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1967	7	-	-	-	-	-	0.85	-	-	-	-	-	0.255	27	17	3
1968	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-
1969	2	-	-	-	-	-	0.26	-	-	-	-	-	0.101	20	41	1
1970	304	-	-	-	-	-	0.66	-	-	-	-	-	0.739	411	580	12
1971	218	-	-	9	-	-	0.52	-	-	0.02	-	-	0.245	928	717	16
1972	117	-	-	-	-	-	0.87	-	-	-	-	-	0.502	233	21	2
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	5	-	-	-	-	-	0.52	-	0.17	-	-	-	0.274	18	167	2
1976	1	-	-	-	-	-	1.00	-	-	-	-	-	0.869	1	5	1
1977	16	-	-	-	-	-	0.32	-	-	-	-	-	0.188	85	467	3
1978	53	1	-	-	-	-	0.49	-	-	-	-	-	0.499	108	78	3
1979	125	2	2	3	5	1	0.41	0.02	0.01	0.01	0.02	0.02	1.241	111	213	4
1980	430	-	-	27	16	-	0.61	-	-	0.03	0.01	-	0.681	694	765	13
1981	547	13	-	7	3	-	0.58	0.01	-	0.01	-	0.01	0.634	899	1095	22
1982	508	3	7	5	3	-	0.63	-	0.01	0.01	-	-	0.565	931	916	17
1983	752	30	52	2	-	2	0.50	0.03	0.05	-	-	-	0.874	959	916	21
1984	551	35	12	-	-	-	0.75	0.01	0.01	-	-	-	0.555	1078	1043	21
1985	243	61	4	1	1	2	0.37	0.08	0.01	-	-	-	0.340	918	1409	28
1986	242	515	3	1	-	1	0.16	0.31	-	-	-	-	0.711	1071	1895	44
1987	542	377	11	3	1	3	0.32	0.21	0.01	-	-	-	0.727	1289	1921	66
1988	307	393	14	49	7	14	0.14	0.25	0.01	0.02	-	0.01	0.381	2057	3022	74
1989	278	288	56	140	19	27	0.13	0.15	0.03	0.05	0.01	0.01	0.304	2661	4622	100
1990	278	343	67	106	23	73	0.14	0.20	0.04	0.04	-	0.01	0.294	3029	4359	115
1991	22	251	52	171	18	75	0.02	0.20	0.04	0.11	0.01	0.01	0.257	2296	2670	113
1992	390	271	87	302	92	114	0.17	0.11	0.04	0.12	0.04	0.01	0.399	3148	3943	235
1993	970	349	73	403	27	215	0.24	0.09	0.02	0.10	-	0.01	0.347	5865	7138	402
1994	1365	435	124	156	70	177	0.37	0.11	0.03	0.04	0.01	0.01	0.337	6903	7580	357
1995	789	193	92	241	78	446	0.28	0.07	0.03	0.08	0.02	0.03	0.280	6576	6763	339
1996	402	158	100	172	41	970	0.12	0.05	0.02	0.05	0.01	0.32	0.136	13592	14404	267
1997a	58	9	29	57	11	308	0.06	0.01	0.02	0.05	0.01	0.38	0.114	4133	4666	73
1997	455	62	128	98	25	678	0.15	0.02	0.02	0.02	0.01	0.26	0.126	11475	12431	159
1998	374	76	107	127	20	951	0.11	0.02	0.03	0.02	0.00	0.34	0.110	14978	15113	169

Table 4.1.3. Area 3D Canadian trawl catch (tonnes) of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1974	3	-	-	-	-	-	-	-	-	-	-	-	-	-	59	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	3	6	-	-	-	-	-	0.23	-	-	-	-	0.193	47	36	1
1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	-
1982	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	-
1983	86	4	20	-	-	-	0.34	-	0.04	-	-	-	1.127	98	115	2
1984	193	9	114	-	-	-	0.50	0.02	0.39	-	-	-	1.671	189	122	5
1985	313	43	412	-	-	4	0.36	0.04	0.42	-	-	0.01	0.943	818	529	19
1986	1046	678	980	12	-	10	0.25	0.22	0.29	-	-	-	1.287	2117	1388	93
1987	450	696	699	2	2	3	0.17	0.26	0.26	-	-	-	1.649	1123	904	73
1988	492	285	161	22	1	4	0.37	0.21	0.12	0.02	-	-	1.061	910	1094	82
1989	994	311	299	17	3	8	0.42	0.13	0.13	0.01	-	-	1.129	1445	1467	114
1990	919	218	253	19	5	13	0.42	0.11	0.13	0.01	-	-	1.002	1424	1665	129
1991	807	238	201	52	-	10	0.47	0.15	0.12	0.03	-	-	0.946	1383	1326	155
1992	681	237	245	99	54	11	0.37	0.13	0.14	0.06	0.02	0.01	0.788	1684	1567	217
1993	667	198	276	98	16	17	0.33	0.11	0.15	0.05	0.01	-	0.626	2030	1972	313
1994	233	96	330	13	12	18	0.23	0.08	0.33	0.01	0.01	0.01	0.577	1217	1263	145
1995	102	300	231	17	11	56	0.10	0.30	0.23	0.02	-	0.01	0.499	1437	1363	169
1996	132	223	75	36	7	252	0.13	0.22	0.07	0.03	0.01	0.24	0.262	2771	2937	139
1997a	20	141	37	10	3	70	0.06	0.39	0.08	0.03	0.01	0.20	0.275	1025	1071	56
1997	77	367	82	3	1	126	0.08	0.40	0.07	0.00	0.00	0.14	0.376	1749	2332	101
1998	42	200	58	8	5	140	0.06	0.30	0.07	0.01	0.01	0.20	0.283	1600	2033	80

Table 4.1.4. Area 5AB (Goose Island and Mitchell's Gullies) Canadian trawl catch (tonnes) of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1967	399	-	-	-	-	-	0.79	-	-	-	-	-	0.758	526	449	33
1968	881	-	-	-	-	-	0.87	-	-	-	-	-	0.655	1345	1048	42
1969	1539	-	-	-	-	-	0.80	-	-	-	-	-	0.639	2408	2319	59
1970	1767	-	-	-	-	-	0.83	-	-	-	-	-	0.604	2925	2814	53
1971	1116	-	5	-	-	-	0.77	-	-	-	-	-	0.450	2488	2317	35
1972	2196	-	-	8	-	-	0.73	-	-	-	-	-	0.739	2982	2944	44
1973	1360	-	177	-	-	-	0.74	-	0.10	-	-	-	1.195	1286	1446	33
1974	1513	-	79	-	-	-	0.79	-	0.04	-	-	-	0.866	1838	1688	43
1975	1911	13	1	-	-	-	0.83	0.01	-	-	-	-	0.775	2483	2520	63
1976	1518	12	12	14	-	-	0.69	0.01	0.01	0.01	-	-	0.696	2236	2428	63
1977	1074	34	336	-	-	-	0.58	0.02	0.15	-	-	-	0.597	2420	2339	57
1978	1203	18	17	1	-	-	0.53	0.01	0.01	-	-	-	0.704	1760	2525	59
1979	1257	8	10	5	-	-	0.77	-	0.01	-	-	-	0.707	1811	2069	57
1980	1387	-	28	-	-	-	0.74	-	0.02	-	-	-	0.876	1616	1556	64
1981	1621	-	5	1	2	-	0.85	-	-	-	-	-	0.903	1804	1256	35
1982	913	3	228	-	5	-	0.62	-	0.17	-	-	-	0.663	1734	1572	30
1983	1485	37	608	5	-	2	0.53	0.01	0.29	-	-	-	2.033	1051	626	26
1984	937	40	344	11	-	-	0.64	0.02	0.16	-	-	-	0.806	1652	795	30
1985	823	117	304	-	-	4	0.34	0.11	0.07	-	-	0.01	0.733	1703	1491	42
1986	644	395	228	14	5	2	0.27	0.25	0.11	0.01	-	-	0.889	1450	1692	73
1987	1646	649	471	3	1	3	0.35	0.16	0.13	-	-	-	0.719	3855	3798	180
1988	1198	316	413	106	4	4	0.33	0.09	0.13	0.03	-	-	0.616	3313	4457	197
1989	1179	477	684	57	1	1	0.26	0.12	0.17	0.01	-	-	0.737	3257	4218	193
1990	1391	821	721	89	1	5	0.25	0.13	0.12	0.01	-	-	0.735	4117	5998	232
1991	865	742	661	103	3	2	0.22	0.20	0.19	0.03	-	-	0.724	3282	4018	275
1992	949	1889	692	144	7	16	0.15	0.26	0.12	0.02	-	-	0.760	4864	4679	395
1993	895	928	465	167	14	50	0.19	0.20	0.11	0.04	-	0.01	0.741	3399	3812	430
1994	2428	485	659	118	63	282	0.41	0.07	0.11	0.02	0.01	0.04	0.752	5365	5469	397
1995	2600	591	796	159	21	169	0.40	0.09	0.12	0.02	-	0.02	0.814	5329	6150	587
1996	1227	629	419	119	4	63	0.31	0.16	0.10	0.03	0.00	0.01	0.373	6591	5717	331
1997a	336	371	168	18	2	6	0.22	0.25	0.10	0.01	0.00	0.00	0.601	1501	1452	113
1997	2063	1512	447	45	5	65	0.31	0.23	0.06	0.01	0.00	0.01	0.687	6019	6404	330
1998	1822	1054	437	37	1	44	0.32	0.18	0.07	0.01	0.00	0.01	0.566	5996	6657	285

Table 4.1.5. Area 5CD (Moresby Gully) Canadian trawl catch (tonnes) of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1968	-	-	-	-	-	-	-	-	-	-	-	-	-	-	44	-
1969	1	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-
1970	27	-	-	-	-	-	-	-	-	-	-	-	-	-	594	-
1971	10	-	-	-	-	-	0.90	-	-	-	-	-	0.055	181	346	3
1972	13	-	-	-	-	-	-	-	-	-	-	-	-	-	567	-
1973	38	-	-	-	-	-	0.79	-	-	-	-	-	0.763	50	673	2
1974	36	-	-	-	-	-	0.67	-	-	-	-	-	1.051	34	596	4
1975	117	-	-	-	-	-	0.79	-	-	-	-	-	0.804	146	1024	8
1976	86	-	-	-	-	-	0.68	-	-	-	-	-	0.233	368	2185	8
1977	74	1	4	-	-	-	0.31	0.01	0.10	-	0.01	-	0.198	399	1793	8
1978	174	4	92	-	-	-	0.46	0.01	0.26	-	-	-	1.272	212	979	11
1979	370	1	20	4	-	-	0.44	-	0.03	-	-	0.01	0.426	926	2086	36
1980	2545	19	20	1	2	-	0.76	0.01	0.01	-	-	-	1.019	2539	2282	78
1981	2217	5	110	-	2	4	0.73	-	0.02	-	-	-	1.062	2202	1807	45
1982	3626	23	442	38	29	9	0.79	-	0.10	0.01	0.01	-	1.797	2318	1860	62
1983	2220	20	204	6	11	5	0.83	0.01	0.04	-	0.01	-	1.865	1322	866	38
1984	2055	71	338	7	2	6	0.72	0.02	0.07	-	-	-	1.472	1684	1636	39
1985	1967	181	232	3	9	17	0.65	0.07	0.09	-	-	-	1.615	1491	1667	49
1986	629	110	100	3	2	8	0.46	0.08	0.08	-	-	-	0.805	1058	1369	50
1987	1911	307	116	6	2	7	0.66	0.11	0.03	-	-	-	1.342	1750	1845	104
1988	3105	199	323	95	29	19	0.66	0.04	0.07	0.02	0.01	-	1.429	2637	2954	199
1989	1498	234	176	28	4	7	0.49	0.07	0.06	0.01	-	-	1.124	1733	2209	123
1990	1410	321	141	17	3	13	0.51	0.12	0.05	0.01	-	-	0.967	1970	2247	110
1991	2019	120	169	31	12	13	0.68	0.04	0.06	0.01	-	-	1.264	1870	1890	158
1992	1699	266	316	29	7	21	0.57	0.10	0.12	0.01	-	-	0.954	2451	1908	166
1993	1556	95	156	27	6	61	0.60	0.04	0.07	0.01	-	0.01	0.729	2607	2368	217
1994	1270	153	62	20	18	85	0.51	0.06	0.03	0.01	0.01	0.02	0.530	3032	2856	152
1995	1539	93	119	77	60	262	0.52	0.03	0.04	0.03	0.02	0.05	0.463	4641	3792	221
1996	3743	497	207	209	55	164	0.60	0.08	0.03	0.03	0.01	0.02	0.741	6579	7118	327
1997a	279	31	26	6	3	19	0.48	0.05	0.04	0.01	0.01	0.03	0.509	714	607	42
1997	2402	216	139	45	15	89	0.67	0.06	0.04	0.01	0.00	0.02	0.880	3305	3342	190
1998	2576	549	102	35	10	66	0.57	0.12	0.02	0.01	0.00	0.01	0.916	3642	3975	200

Table 4.1.6. Area 5ES Canadian trawl catch (tonnes) of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1976	79	-	-	-	-	-	0.99	-	-	-	-	-	1.339	59	59	2
1977	1549	156	1257	76	10	-	0.46	0.05	0.39	0.02	-	-	2.411	1264	1061	66
1978	2414	231	1105	139	25	1	0.56	0.05	0.26	0.03	0.01	-	3.201	1223	1140	64
1979	839	73	389	192	11	1	0.50	0.04	0.23	0.11	0.01	-	1.936	778	644	38
1980	877	111	500	51	1	-	0.37	0.09	0.38	0.04	-	-	1.465	1051	595	42
1981	599	133	922	10	4	4	0.45	0.08	0.39	0.01	-	-	2.019	828	295	23
1982	614	34	414	274	3	1	0.42	0.02	0.25	0.20	-	-	2.212	606	481	33
1983	835	143	588	74	17	10	0.42	0.07	0.30	0.03	0.01	0.01	2.186	762	717	37
1984	841	148	441	101	11	4	0.46	0.09	0.21	0.07	-	-	2.351	658	389	24
1985	829	919	496	158	1	4	0.29	0.37	0.17	0.06	-	-	1.828	1316	913	50
1986	642	728	564	269	4	14	0.19	0.26	0.22	0.07	-	-	2.107	1054	840	43
1987	661	629	451	296	8	25	0.25	0.28	0.18	0.12	-	0.01	1.990	1040	1044	41
1988	766	517	289	353	5	11	0.30	0.20	0.12	0.15	-	-	1.967	987	1257	54
1989	571	154	228	251	6	6	0.36	0.10	0.15	0.17	-	-	1.294	940	799	35
1990	605	199	299	470	21	25	0.29	0.09	0.15	0.23	0.01	0.01	1.354	1196	1120	44
1991	635	245	121	607	15	17	0.31	0.12	0.06	0.29	0.01	0.01	1.523	1077	1119	74
1992	374	388	123	1061	61	48	0.14	0.14	0.05	0.41	0.02	0.01	0.920	2234	2410	181
1993	477	330	144	1126	218	93	0.14	0.11	0.05	0.36	0.04	0.02	0.859	2781	2541	225
1994	287	226	44	946	292	99	0.13	0.09	0.02	0.40	0.09	0.03	0.864	2193	1972	129
1995	802	99	72	567	72	61	0.39	0.05	0.03	0.27	0.03	0.02	1.012	1653	1708	114
1996	613	127	114	465	30	35	0.37	0.08	0.07	0.28	0.02	0.02	0.951	1455	1364	111
1997a	353	20	100	39	5	3	0.58	0.03	0.16	0.06	0.01	0.01	1.607	323	305	33
1997	401	38	89	263	5	8	0.39	0.04	0.09	0.26	0.00	0.01	1.368	588	593	50
1998	608	205	154	357	2	27	0.37	0.12	0.09	0.21	0.00	0.02	1.825	740	937	61

Table 4.1.7. Area 5EN Canadian trawl catch (tonnes) of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1977	1	-	-	-	-	-	1.00	-	-	-	-	-	0.328	3	20	1
1978	22	-	-	-	1	-	0.65	-	-	-	0.13	-	0.337	68	151	5
1979	227	5	17	14	2	-	0.63	0.01	0.05	0.04	0.01	0.01	0.576	460	204	9
1980	85	-	-	3	-	-	0.71	-	-	0.02	-	0.01	0.314	280	130	7
1981	109	-	2	98	-	-	0.30	-	0.01	0.47	-	-	3.134	67	44	4
1982	342	13	68	69	1	3	0.49	0.01	0.13	0.16	-	0.01	2.467	201	145	14
1983	292	18	52	127	3	36	0.37	0.01	0.03	0.13	-	0.03	1.162	454	402	15
1984	2186	111	73	227	8	41	0.63	0.04	0.02	0.07	-	0.01	1.639	1615	1227	42
1985	1921	259	180	454	12	30	0.52	0.07	0.05	0.13	-	0.01	1.224	2334	1917	56
1986	2725	717	615	461	6	51	0.52	0.12	0.12	0.08	-	0.01	1.387	3299	3036	65
1987	1130	224	109	180	3	25	0.55	0.11	0.06	0.09	-	0.01	1.120	1492	1325	28
1988	1089	114	107	467	13	73	0.44	0.05	0.04	0.20	0.01	0.03	1.077	1730	1802	34
1989	1525	151	158	511	10	66	0.47	0.04	0.05	0.16	-	0.02	1.188	2038	2238	43
1990	1154	69	178	494	52	81	0.46	0.03	0.07	0.20	0.02	0.03	0.706	2872	2551	30
1991	-	4	-	1	30	39	0.01	0.36	-	0.03	0.03	0.31	0.247	300	67	6
1992	-	1	1	7	21	9	0.01	0.06	0.06	0.24	0.07	0.10	0.211	184	29	9
1993	19	12	4	54	63	77	0.09	0.07	0.02	0.27	0.04	0.05	0.361	634	376	29
1994	28	1	-	80	94	151	0.06	-	-	0.20	0.09	0.17	0.346	1023	818	50
1995	48	6	-	41	93	176	0.12	0.01	-	0.09	0.07	0.15	0.176	2070	899	40
1996	21	0	1	49	6	55	0.07	0.00	0.00	0.14	0.02	0.17	0.132	1001	1006	46
1997a	10	0	0	10	1	12	0.18	0.00	0.00	0.12	0.01	0.13	0.197	165	166	11
1997	203	5	5	29	7	55	0.43	0.01	0.01	0.05	0.01	0.11	0.302	1006	843	41
1998	130	4	0	32	4	28	0.42	0.01	0.00	0.09	0.01	0.09	0.653	304	606	29

Table 4.1.8. Coastwide Canadian trawl catch (tonnes) of Pacific ocean perch, redstripe, yellowmouth, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads, the proportions of Pacific ocean perch, yellowmouth, redstripe, rougheye, and shortraker rockfish, and longspine and shortspine thornyheads constituting the qualified catch, 20% qualified median CPUE, estimated effort, nominal effort, and the number of vessel trips used to calculate CPUE.

	Catch (tonnes)						Proportion of qualified catch						CPUE	E. Eff	N. Eff	No.
Year	POP	YelM	Reds	Reye	Sraker	Thorny	POP	YelM	Reds	Reye	Sraker	Thorny	(tonnes/h)	(h)	(h)	trips
1967	406	-	-	-	-	-	0.79	-	-	-	-	-	0.757	536	465	36
1968	882	-	-	-	-	-	0.87	-	-	-	-	-	0.655	1346	1185	42
1969	1542	-	-	-	-	-	0.80	-	-	-	-	-	0.638	2416	2384	60
1970	2098	-	-	-	-	-	0.80	-	-	-	-	-	0.606	3464	4004	64
1971	1344	-	5	9	-	-	0.72	-	-	-	-	-	0.440	3085	3380	51
1972	2327	-	-	8	-	-	0.73	-	-	-	-	-	0.739	3159	3532	46
1973	1398	-	177	-	-	-	0.74	-	0.10	-	-	-	1.085	1451	2119	34
1974	1552	-	79	-	-	-	0.79	-	0.04	-	-	-	0.879	1855	2343	44
1975	2033	13	2	-	-	-	0.81	0.01	0.00	-	-	-	0.775	2642	3710	71
1976	1684	12	12	14	-	-	0.69	0.01	0.01	0.01	-	-	0.695	2479	4677	67
1977	2715	191	1596	77	10	-	0.50	0.04	0.30	0.02	-	-	0.959	4784	5679	127
1978	3869	261	1213	140	27	1	0.53	0.04	0.17	0.02	-	-	1.166	4727	4909	131
1979	2818	89	438	218	18	2	0.58	0.02	0.09	0.05	-	-	0.758	4725	5216	130
1980	5324	131	548	82	19	1	0.66	0.02	0.08	0.01	-	-	1.063	5744	5332	176
1981	5094	151	1039	116	11	9	0.67	0.02	0.08	0.02	-	-	0.979	6555	4514	113
1982	6003	75	1159	386	41	14	0.65	0.01	0.13	0.05	0.01	-	1.268	6057	5002	120
1983	5670	252	1524	214	30	55	0.55	0.03	0.17	0.02	-	0.01	1.614	4798	3641	110
1984	6763	414	1322	346	22	52	0.63	0.04	0.09	0.04	-	0.01	1.240	7194	5211	124
1985	6096	1579	1628	616	22	61	0.46	0.14	0.11	0.06	-	0.01	1.083	9235	7926	170
1986	5928	3142	2491	758	17	85	0.35	0.19	0.15	0.04	-	-	1.215	10220	10220	308
1987	6340	2882	1857	490	16	66	0.38	0.18	0.12	0.03	-	-	1.074	10852	10836	387
1988	6957	1824	1307	1092	58	125	0.41	0.11	0.08	0.07	-	0.01	0.900	12624	14586	459
1989	6045	1616	1602	1003	44	115	0.35	0.09	0.10	0.06	-	0.01	0.762	13687	15553	433
1990	5757	1970	1659	1195	105	209	0.31	0.10	0.09	0.07	0.01	0.01	0.634	17175	17939	489
1991	4349	1600	1204	964	78	156	0.35	0.13	0.10	0.08	-	-	0.776	10758	11089	557
1992	4093	3051	1464	1641	242	219	0.24	0.17	0.09	0.11	0.01	0.01	0.719	14896	14537	921
1993	4584	1912	1119	1874	345	512	0.25	0.11	0.07	0.11	0.01	0.01	0.571	18115	18206	1217
1994	5613	1397	1219	1333	549	812	0.34	0.08	0.08	0.08	0.02	0.03	0.536	20395	19957	949
1995	5880	1282	1310	1101	334	1171	0.35	0.08	0.08	0.07	0.01	0.03	0.527	21017	20715	1093
1996	6138	1635	916	1050	143	1539	0.38	0.10	0.05	0.06	0.01	0.09	0.341	33499	32546	1221
1997a	1056	573	360	140	24	419	0.27	0.15	0.09	0.03	0.01	0.10	0.387	6646	8267	328
1997	5602	2201	890	484	58	1020	0.37	0.15	0.05	0.03	0.00	0.06	0.555	18490	25945	871
1998	5552	2087	857	596	41	1256	0.35	0.13	0.05	0.03	0.00	0.08	0.506	20532	29321	824

Table 4.1.9. Observer reported catches and discards (tonnes) and the percent discarded of Pacific ocean perch, yellowmouth rockfish, redstripe rockfish, rougheye rockfish, shortspine thornyhead, longspine thornyhead, and shortraker rockfish.

		POP			Yellowmouth			Redstripe			Rougheye			Shortspine			Longspine			Shortraker		
Year	**Area**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**	**Total**	**Disc**	**%**
1996	3C	419.6	17.4	4.2	160.4	2.4	1.5	137.0	37.5	27.3	172.0	0.3	0.2	331.6	13.1	4.0	716.6	65.2	9.1	42.0	0.7	1.7
	3D	134.3	2.7	2.0	228.7	5.2	2.3	95.1	20.3	21.3	36.3	0.1	0.2	106.1	6.9	6.5	163.7	10.9	6.7	6.8	0.0	0.5
	5A/B	1,282.2	55.2	4.3	645.8	16.4	2.5	507.0	87.6	17.3	119.7	0.6	0.5	62.5	1.8	2.8	2.3	0.4	18.6	4.3	0.0	0.2
	5C/D	3,882.3	139.7	3.6	502.3	5.4	1.1	227.7	20.3	8.9	210.0	0.7	0.3	167.3	6.3	3.8	3.7	0.6	16.7	55.4	0.2	0.4
	5E-S	617.3	3.8	0.6	126.9	0.3	0.2	121.3	7.2	6.0	468.1	2.9	0.6	37.5	3.2	8.6	0.6	0.1	8.8	29.9	0.0	0.0
	5E-N	21.8	0.5	2.3	0.2	0.0	1.6	1.0	0.2	22.7	49.0	0.3	0.6	56.0	1.4	2.6	0.8	0.1	8.4	5.6	0.1	0.9
	Coast	6,357.5	219.3	3.4	1,664.3	29.6	1.8	1,089.1	173.1	15.9	1,055.1	4.8	0.5	761.0	32.7	4.3	887.8	77.2	8.7	144.0	1.0	0.7
1997a	3C	61.4	3.9	6.4	8.9	0.1	1.6	46.9	17.4	37.2	57.4	0.7	1.1	101.2	2.4	2.3	233.1	23.5	10.1	10.8	0.2	1.6
	3D	22.0	2.0	9.2	142.8	1.4	1.0	54.3	17.5	32.1	10.6	0.2	2.1	20.8	0.9	4.4	58.8	8.3	14.1	3.2	0.0	0.0
	5A/B	345.9	9.4	2.7	375.9	4.7	1.2	247.0	79.2	32.0	17.8	0.1	0.5	6.9	1.0	14.5	0.4	0.0	0.6	1.9	0.0	0.1
	5C/D	304.3	25.8	8.5	32.1	1.2	3.7	38.1	12.6	32.9	6.3	0.1	1.7	18.7	0.4	1.9	1.0	0.1	5.2	3.5	0.0	1.3
	5E-S	355.9	2.5	0.7	20.0	0.0	0.1	103.7	3.8	3.6	38.6	0.0	0.0	3.0	0.5	15.4	0.6	0.0	8.2	4.8	0.0	0.0
	5E-N	10.9	1.1	10.3	0.2	0.0	0.0	0.3	0.0	0.0	10.1	0.0	0.4	11.4	0.8	7.0	1.1	0.1	6.3	0.5	0.0	0.0
	Coast	1,100.4	44.7	4.1	579.9	7.4	1.3	490.3	130.4	26.6	140.9	1.1	0.8	161.9	5.9	3.6	295.0	32.0	10.8	24.6	0.2	0.9
1997	3C	474.1	19.0	4.0	62.3	0.6	0.9	198.9	70.7	35.6	98.8	0.3	0.3	265.5	16.4	6.2	492.7	64.1	13.0	25.0	0.0	0.0
	3D	80.0	2.5	3.2	368.5	1.0	0.3	120.9	38.8	32.1	3.0	0.0	0.0	54.2	3.8	6.9	83.2	8.0	9.6	1.3	0.0	2.9
	5A/B	2,134.7	71.5	3.3	1,522.5	10.6	0.7	603.7	157.0	26.0	45.6	0.1	0.3	63.8	6.3	9.9	9.3	1.7	18.8	4.8	0.0	0.4
	5C/D	2,467.8	66.0	2.7	219.3	2.8	1.3	165.1	26.0	15.8	45.6	0.4	0.8	92.9	4.8	5.2	1.5	0.3	18.0	14.7	0.1	0.4
	5E-S	403.1	2.2	0.5	38.7	0.2	0.5	92.6	3.2	3.5	263.2	0.3	0.1	9.4	1.8	19.0	0.5	0.1	16.1	5.5	0.1	1.2
	5E-N	205.5	2.2	1.1	4.7	0.0	0.1	4.7	0.1	2.1	29.5	0.2	0.8	55.1	1.7	3.1	1.2	0.1	4.2	7.5	0.0	0.5
	Coast	5,765.2	163.4	2.8	2,216.0	15.2	0.7	1,185.8	295.9	24.9	485.7	1.3	0.3	541.0	34.8	6.4	588.4	74.2	12.6	58.6	0.2	0.4
1998	3C	390.3	15.9	4.1	76.8	0.4	0.5	184.1	77.6	42.2	127.4	0.8	0.6	321.1	16.6	5.2	746.1	99.4	13.3	19.8	0.2	1.2
	3D	43.9	2.1	4.9	200.0	0.1	0.1	77.7	19.3	24.8	7.9	0.0	0.0	62.9	4.7	7.5	99.1	17.3	17.5	5.0	0.0	0.0
	5A/B	1,873.4	51.3	2.7	1,058.2	4.6	0.4	600.1	163.3	27.2	37.6	0.1	0.2	43.3	4.5	10.3	6.6	1.9	29.0	0.7	0.0	0.7
	5C/D	2,642.1	66.0	2.5	556.8	8.0	1.4	150.0	48.4	32.3	34.9	0.1	0.3	70.7	6.1	8.7	1.7	0.2	13.7	9.6	0.0	0.3
	5E-S	608.7	1.2	0.2	205.0	0.2	0.1	155.6	2.0	1.3	357.0	0.4	0.1	23.9	1.9	7.9	5.0	0.1	3.0	1.6	0.0	1.2
	5E-N	130.1	0.3	0.2	3.7	0.2	5.4	0.4	0.1	25.8	32.3	0.1	0.4	26.1	0.8	3.2	3.1	0.0	0.4	4.2	0.0	0.4
	Coast	5,688.5	136.7	2.4	2,100.6	13.5	0.6	1,167.9	310.7	26.6	597.2	1.5	0.2	548.1	34.6	6.3	861.6	119.1	13.8	40.8	0.3	0.8

Table 6.1.1. Structure of the *B3_Trawls* table from the database *BCBathymetry.mdb*.

Field Name	Data Type	Description
index	Integer	Unique block index identifying the block in which the trawl occurred
i	Integer	Block row index
j	Integer	Block column index
lat	Real	Mean latitude of trawl
lon	Real	Mean longitude of trawl
x	Real	Mean UTM Easting of trawl
y	Real	Mean UTM Northing of trawl
vessel	Integer	Groundfish major statistical area where trawl occured
date	date	Date of trawl
duration	Integer	Duration of trawl in minutes
depth	Real	Fishing depth of trawl
area	Real	Estimated area swept by trawl net in square km

Table 6.1.2. Bottom area (BA), swept area (SA) and impacted area (IA) in each depth and statistical area stratum.

Depth	3C			3D			4B			5AB			5CD			5EN			5ES			Coastwide		
Interval	BA	SA	IA	BA	SA	IA	BA	SA	IA	BA	SA	IA	BA	SA	IA	BA	SA	IA	BA	SA	IA	BA	SA	IA
100	5280	521	392	1428	20	20	2148	26	26	6880	1638	708	17072	3632	1403	424	3	3	572			33804	5841	2552
200	5628	1920	942	676	231	144	3080	33	33	9192	4417	1823	13632	2408	1324	228	6	6	708	27	18	33144	9043	4290
300	488	1080	353	156	340	85	1248	39	22	3812	1459	883	7796	1890	964	816	53	50	396	145	67	14712	5007	2423
400	336	969	244	116	85	32	960	99	91	476	51	35	3380	632	362	636	192	140	348	261	102	6252	2289	1006
500	332	768	229	152	79	24	96	0	0	236	97	30	504	202	94	384	272	169	372	97	65	2076	1514	610
600	424	931	242	240	135	69				264	65	33	168	9	8	56	32	21	312	49	39	1464	1221	413
700	424	901	221	276	203	62				248	16	16	144	7	7	72	7	7	380	49	36	1544	1183	349
800	344	1584	228	252	315	32				208	10	6	168	2	2	32	3	3	344	23	21	1348	1936	291
900	372	1161	242	212	466	45				176	3	3	168	1	1	44	1	1	292	32	18	1264	1663	311
1000	464	1005	306	276	125	41				192			156	0	0	48	1	1	440	2	2	1576	1133	349
1100	436	507	184	264	4	4				152	0	0	148	0	0	136	0	0	496	1	1	1632	512	189
1200	460	201	83	296	4	4				208			140			148			608	4	4	1860	209	90
1300	564	161	42	336	5	5				176			144			48			540	2	2	1808	168	49
1400	716	25	16	276						220			104			24			456	0	0	1796	25	17
1500	568	4	4	424	3	3				272			148	1	1	20			424			1856	8	8
1600	380	1	1	528	1	1				384	1	1	72						392			1756	3	3
1700	360	1	1	640	1	1				432			12						372			1816	3	3
Total	**17576**	**11740**	**3731**	**6548**	**2017**	**571**	**7532**	**197**	**171**	**23528**	**7758**	**3539**	**43956**	**8783**	**4166**	**3116**	**571**	**402**	**7452**	**693**	**375**	**109708**	**31758**	**12954**

Table 6.2.1. Count of UTM blocks in which various slope rockfish species were caught in each fishing year and the number of tows in those blocks.

Fishing Year	1996	1997a	1997	1998	All
Number of Blocks					
POP	1,896	545	1,592	1,502	3,073
Yellowmouth	981	326	941	890	1,796
Redstripe	1,154	457	1,071	1,024	2,148
Rougheye	917	371	695	655	1,575
Shortspine	1,903	703	1,642	1,570	3,068
Longspine	591	305	592	587	1,185
Shortraker	736	239	546	438	1,211
Slope Rockfish	2,966	1,101	2,555	2,469	4,604
Number of Tows					
POP	6,312	1,129	4,797	4,917	17,155
Yellowmouth	2,821	768	3,109	3,126	9,824
Redstripe	2,743	1,027	3,094	3,169	10,033
Rougheye	2,668	797	1,809	1,784	7,058
Shortspine	7,505	1,794	5,477	5,387	20,163
Longspine	2,309	807	1,980	2,240	7,336
Shortraker	1,851	416	1,181	943	4,391
Slope Rockfish	12,200	3,097	9,939	10,018	35,254

Table 6.2.2. Count of UTM blocks in which slope rockfish species co-occurred (Jan 1996 – Mar 1999).

Slope Rockfish	POP	YM	RS	RE	ST	LT	SR
POP	3,073						
Yellowmouth	1,592	1,796					
Redstripe	1,532	1,263	2,148				
Rougheye	1,308	753	647	1,575			
Shortspine	2,152	1,270	1,149	1,414	3,068		
Longspine	565	337	317	586	1,164	1,185	
Shortraker	997	601	514	933	1,112	522	1,211

Table 6.2.3. Data from the top ten UTM blocks determined by catch of Pacific ocean perch, yellowmouth rockfish, redstripe rockfish, and rougheye rockfish. Block number is defined by coordinates [i, j] with a mean Easting (UTME) and Northing (UTMN) in area SRF. Effort is defined by the number of tows and hours towed. D is the mean fishing depth. Catches (t) associated with tows in hot blocks are given for POP, yellowmouth (YM), redstripe (RS), rougheye (RE), and shortraker (SR) rockfish, shortspine (ST) and longspine (LT) thornyheads, and other commercial fish species (OTH). Regression line through CPUE vs time data yields change in CPUE per year (b) and its significance (p). The direction of significant trends is indicated by + or - symbol.

Block	i	j	UTME	UTMN	SRF	Tows	Hrs	D	POP	YM	RS	RE	ST	LT	SR	OTH	b	p	+/-
Pacific ocean perch																			
140,369	25	332	814653	5366991	5ES	113	112	329	414	4	2	154	3	<1	<1	42	-0.0138	0.754	
90,007	119	213	576653	5554991	5CD	142	158	316	322	28	<1	4	4	<1	1	149	-0.1788	0.000	-
140,793	25	333	816653	5366991	5ES	104	120	330	302	2	4	99	1	<1	<1	29	0.1615	0.003	+
90,858	122	215	580653	5560991	5CD	158	246	294	290	31	<1	1	3	<1	<1	78	-0.1160	0.045	-
88,306	114	209	568653	5544991	5CD	120	160	278	272	99	<1	<1	2	<1	1	94	-0.1221	0.009	-
90,431	119	214	578653	5554991	5CD	128	154	313	239	31	<1	2	4	<1	<1	516	0.0584	0.252	
87,458	114	207	564653	5544991	5CD	78	72	298	223	11	<1	2	1	<1	2	117	0.0698	0.401	
88,731	115	210	570653	5546991	5CD	80	96	293	207	25	<1	2	1	<1	1	25	-0.1795	0.037	-
87,034	114	206	562653	5544991	5CD	67	84	320	159	2	0	5	4	<1	5	140	0.1338	0.354	
87,457	113	207	564653	5542991	5CD	42	47	299	154	10	<1	1	1	0	1	48	0.0155	0.883	
Yellowmouth rockfish																			
60,395	187	143	436653	5690991	5AB	156	196	239	24	266	23	0	1	<1	<1	112	-0.0560	0.243	
57,008	192	135	420653	5700991	3D	73	191	247	38	144	10	<1	1	<1	<1	64	0.0685	0.236	
56,586	194	134	418653	5704991	3D	83	212	231	21	123	21	<1	<1	<1	<1	73	0.3048	0.000	+
60,819	187	144	438653	5690991	5AB	68	107	218	6	114	8	0	<1	<1	<1	96	-0.0873	0.233	
88,306	114	209	568653	5544991	5CD	103	138	276	222	106	<1	<1	2	<1	1	92	0.2760	0.002	+
56,585	193	134	418653	5702991	3D	79	199	234	38	101	16	<1	1	<1	<1	70	0.1971	0.004	+
57,432	192	136	422653	5700991	3D	74	171	235	43	99	12	<1	1	0	<1	53	0.0288	0.717	
61,240	184	145	440653	5684991	5AB	63	54	231	15	98	8	0	<1	<1	0	40	-0.0039	0.966	
59,971	187	142	434653	5690991	5AB	71	83	242	9	93	3	0	<1	<1	0	33	-0.0243	0.742	
88,731	115	210	570653	5546991	5CD	71	77	290	171	81	<1	<1	<1	<1	<1	21	-0.1416	0.218	
Redstripe rockfish																			
90,031	143	213	576653	5602991	5CD	26	29	160	<1	3	86	0	0	0	0	41	-0.1199	0.220	
76,501	181	181	512653	5678991	5AB	69	102	193	8	12	78	0	<1	0	0	138	0.0977	0.371	
76,924	180	182	514653	5676991	5AB	59	85	196	2	8	64	<1	<1	0	0	142	0.2997	0.013	+
119,199	55	282	714653	5426991	5ES	44	56	234	5	<1	61	<1	<1	0	<1	35	0.0346	0.712	
126,391	39	299	748653	5394991	5ES	48	78	235	24	66	60	<1	<1	<1	0	43	0.3149	0.027	+
119,622	54	283	716653	5424991	5ES	76	170	258	61	6	55	3	<1	<1	1	95	0.2119	0.041	+
90,032	144	213	576653	5604991	5CD	13	22	158	1	6	43	0	0	0	0	25	0.0707	0.676	
126,392	40	299	748653	5396991	5ES	27	42	225	10	34	38	<1	<1	0	<1	32	0.2572	0.008	+
93,020	164	220	590653	5644991	5AB	19	18	185	<1	0	37	<1	0	0	0	41	-0.0056	0.950	
79,449	161	188	526653	5638991	5AB	24	31	146	<1	15	36	0	<1	0	0	29	0.6808	0.383	
Rougheye rockfish																			
140,369	25	332	814653	5366991	5ES	107	114	339	389	4	2	158	3	<1	<1	47	0.2144	0.004	+
140,793	25	333	816653	5366991	5ES	98	114	332	285	2	2	102	1	<1	<1	31	0.1789	0.036	+
125,121	41	296	742653	5398991		30	57	383	29	1	<1	93	1	0	<1	3	0.0150	0.849	
75,612	140	179	508653	5596991	0	67	117	428	7	<1	<1	90	3	<1	<1	14	-0.0298	0.817	
141,639	23	335	820653	5362991	5ES	43	45	422	5	<1	<1	71	1	0	<1	40	0.0552	0.724	
125,122	42	296	742653	5400991	5ES	21	35	344	9	5	<1	45	1	0	<1	3	0.2286	0.020	+
140,792	24	333	816653	5364991	5ES	42	58	386	58	<1	<1	44	<1	0	1	30	-0.0810	0.487	
125,544	40	297	744653	5396991	5ES	13	27	382	7	3	0	35	<1	<1	1	4	0.2018	0.294	
75,613	141	179	508653	5598991	5AB	24	42	423	4	<1	0	35	<1	<1	<1	9	0.0956	0.611	
141,640	24	335	820653	5364991	5ES	18	32	426	4	<1	0	30	<1	0	<1	4	-0.0180	0.861	

Table 6.2.3 cont'd. Data from the top ten UTM blocks determined by catch of shortspine thornyhead, longspine thornyhead, shortraker rockfish, and other commercial fish species. Block number is defined by coordinates [i, j] with a mean Easting (UTME) and Northing (UTMN) in area SRF. Effort is defined by the number of tows and hours towed. D is the mean fishing depth. Catches (t) associated with tows in hot blocks are given for POP, yellowmouth (YM), redstripe (RS), rougheye (RE), and shortraker (SR) rockfish, shortspine (ST) and longspine (LT) thornyheads, and other commercial fish species (OTH). Regression line through CPUE vs time data yields change in CPUE per year (b) and its significance (p). The direction of significant trends is indicated by + or - symbol.

Block	i	j	UTME	UTMN	SRF	Tows	Hrs	D	POP	YM	RS	RE	ST	LT	SR	OTH	b	p	+/-
Shortspine thornyhead																			
37,110	222	88	326653	5760991	3D	174	1,095	936	0	<1	<1	<1	39	120	0	61	-0.0779	0.038	-
37,958	222	90	330653	5760991	3D	115	635	898	0	0	0	0	27	45	0	32	0.0094	0.752	
31,615	239	75	300653	5794991	3C	150	630	594	4	<1	<1	18	24	23	5	232	0.0094	0.819	
31,191	239	74	298653	5794991	3C	86	407	703	<1	0	0	3	22	15	1	67	-0.0745	0.162	
22,725	253	54	258653	5822991	3C	103	593	852	0	0	0	0	19	44	0	18	0.0371	0.340	
150,567	47	356	862653	5410991	5CD	52	139	421	<1	0	0	<1	18	<1	1	35	0.0077	0.913	
11,723	275	28	206653	5866991	3C	109	506	857	0	0	0	<1	18	44	0	32	-0.0384	0.386	
31,614	238	75	300653	5792991	3C	104	559	869	0	0	0	<1	17	43	<1	55	-0.1187	0.011	-
26,109	245	62	274653	5806991	3C	75	435	935	0	0	0	<1	17	33	0	18	-0.0936	0.079	
10,876	276	26	202653	5868991	3C	93	518	883	0	0	0	0	15	44	0	21	-0.0995	0.039	-
Longspine thornyhead																			
37,110	222	88	326653	5760991	3D	174	1,099	936	0	<1	<1	<1	38	122	0	61	-0.0734	0.053	
36,686	222	87	324653	5760991	3D	95	574	952	0	0	0	0	15	49	0	35	-0.0115	0.739	
15,111	271	36	222653	5858991	3C	93	414	940	0	0	0	0	10	46	0	17	-0.0411	0.241	
37,958	222	90	330653	5760991	3D	108	611	905	0	0	0	0	24	45	0	29	-0.1174	0.000	-
22,725	253	54	258653	5822991	3C	104	598	853	0	0	0	0	19	45	0	18	-0.1187	0.006	-
11,723	275	28	206653	5866991	3C	107	498	857	0	0	0	<1	17	44	0	31	-0.1170	0.002	-
10,876	276	26	202653	5868991	3C	90	509	891	0	0	0	0	14	44	0	19	-0.1407	0.001	-
31,614	238	75	300653	5792991	3C	96	535	895	0	0	0	0	16	43	<1	39	0.1179	0.005	+
18,495	263	44	238653	5842991	3C	70	451	891	0	0	0	0	14	34	0	25	-0.0675	0.076	
26,109	245	62	274653	5806991	3C	75	439	937	0	0	0	<1	17	33	0	16	-0.1493	0.000	-
Shortraker rockfish																			
87,034	114	206	562653	5544991	5CD	54	72	346	110	<1	0	8	4	<1	8	149	-0.3802	0.000	-
31,615	239	75	300653	5794991	3C	59	168	444	4	<1	<1	15	4	<1	6	124	0.0850	0.235	
55,315	195	131	412653	5706991	3D	60	139	442	9	<1	2	16	2	0	6	88	-0.0470	0.506	
131,477	37	311	772653	5390991	5ES	6	15	508	<1	<1	0	6	1	0	4	4	-0.3317	0.302	
89,581	117	212	574653	5550991	5CD	7	12	360	30	4	0	1	<1	0	4	4	-0.5009	0.194	
103,162	130	244	638653	5576991	5CD	37	103	337	21	<1	0	4	8	<1	4	26	-0.0300	0.755	
18,497	265	44	238653	5846991	3C	19	58	470	<1	0	0	6	1	<1	3	34	-0.0067	0.967	
19,345	265	46	242653	5846991	3C	26	81	394	11	<1	<1	8	2	<1	3	43	-0.3246	0.001	-
31,616	240	75	300653	5796991	3C	27	81	373	4	<1	0	11	1	<1	3	90	-0.3076	0.011	-
87,035	115	206	562653	5546991	5CD	15	26	388	13	<1	0	2	1	0	3	26	-0.4286	0.010	-
Other commercial fish																			
148,083	107	350	850653	5530991	5CD	251	383	95	<1	0	0	0	<1	0	0	839	-0.0656	0.045	-
147,659	107	349	848653	5530991	5CD	260	440	93	<1	0	0	0	<1	0	0	820	-0.0914	0.002	-
65,457	161	155	460653	5638991	5AB	110	311	144	<1	6	35	0	0	0	<1	711	0.0150	0.782	
35,007	239	83	316653	5794991	3C	119	297	163	4	<1	<1	<1	<1	<1	<1	611	-0.0584	0.188	
34,583	239	82	314653	5794991	3C	102	222	167	4	<1	<1	<1	<1	<1	0	596	0.0052	0.929	
35,854	238	85	320653	5792991	3C	123	414	150	5	<1	6	<1	<1	0	0	587	-0.1044	0.015	-
90,431	119	214	578653	5554991	5CD	129	154	313	236	28	<1	2	4	<1	<1	520	0.0401	0.600	
34,159	239	81	312653	5794991	3C	76	154	174	<1	0	<1	<1	0	0	0	509	-0.2068	0.001	-
35,430	238	84	318653	5792991	3C	97	301	166	1	<1	1	0	<1	0	<1	490	-0.0478	0.299	
32,039	239	76	302653	5794991	3C	113	261	373	23	<1	<1	18	3	4	<1	450	0.3337	0.000	+

Table 6.3.1. Estimated Pacific ocean perch biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	32	6	311	0	0	0	514	1355	1468	607	1409	3150	-	-	-	-	-	-
200	514	619	281	23	154	125	5474	11430	9951	6037	7733	7849	94	-	-	990	425	1801
300	197	547	369	54	30	22	7386	11988	11852	25447	36583	40884	54	3081	5293	466	716	281
400	86	307	203	68	9	70	949	194	164	6644	13685	23425	193	2899	922	725	1126	854
500	85	10	134	1	30	10	35	3	203	483	1789	905	2	38	191	1069	6433	1130
600	15	22	62	1	25	6	4	40	84	190	-	-	0	159	1	165	76	441
700	14	1	0	0	0	0	5	0	248	817	48	119	-	0	0	887	4242	896
800	16	0	0	2	0	0	0	0	0	0	-	4609	-	0	0	10	349	5
900	0	0	0	2	12	0	0	0	176	14	-	-	-	0	-	444	2077	160
1000	0	11	0	0	0	41	-	-	0	0	-	-	-	0	-	688	3471	0
1100	0	0	0	0	0	0	-	0	-	53	-	-	-	-	-	6229	-	-
1200	0	4	0	-	446	0	-	-	-	-	-	-	-	-	-	138	875	-
1300	0	0	0	0	0	0	-	-	0	-	-	-	-	-	-	1639	6388	-
1400	0	22	0	-	-	-	-	-	-	-	-	-	-	-	-	642	-	-
1500	0	0	580	-	0	349	-	-	-	0	-	-	-	-	-	-	-	-
1600	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	0	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**960**	**1549**	**1940**	**150**	**707**	**623**	**14367**	**25010**	**24146**	**40293**	**61247**	**80941**	**343**	**6177**	**6407**	**14093**	**26177**	**5567**
Catch	**420**	**331**	**456**	**134**	**56**	**68**	**1282**	**2365**	**1940**	**3882**	**2308**	**2861**	**22**	**92**	**228**	**617**	**572**	**532**
Expl.	**0.4372**	**0.2137**	**0.2348**	**0.8942**	**0.0793**	**0.1093**	**0.0892**	**0.0946**	**0.0803**	**0.0964**	**0.0377**	**0.0353**	**0.0634**	**0.0149**	**0.0356**	**0.0438**	**0.0219**	**0.0955**

Table 6.3.2. Estimated yellowmouth rockfish biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	169	0	0	9	0	0	144	1107	56	23	3071	0	-	-	-	-	-	-
200	174	51	123	197	199	291	2508	7944	4786	146	1395	631	0	-	-	112	86	9
300	135	42	3	76	171	168	4403	4022	2321	2750	3294	4783	22	0	370	345	130	573
400	30	34	22	7	14	61	196	713	1056	163	206	489	1	15	14	10	58	90
500	12	1	37	89	78	97	128	61	257	1	29	60	0	1	1	136	118	232
600	5	1	1	0	16	0	538	139	49	41	-	-	0	0	0	116	0	24
700	19	0	0	0	0	0	160	286	1206	123	0	15	-	0	0	88	0	252
800	2	0	0	57	0	0	41	0	0	0	-	0	-	0	0	0	1	0
900	0	0	0	51	5	108	374	222	34	0	-	-	-	0	-	0	1	0
1000	2	0	0	0	0	273	-	-	43	0	-	-	-	0	-	16	0	0
1100	0	0	0	0	0	0	-	386	-	0	-	-	-	-	-	0	-	-
1200	0	0	0	-	506	0	-	-	-	-	-	-	-	-	-	110	0	-
1300	0	0	0	0	0	0	-	-	0	-	-	-	-	-	-	0	32	-
1400	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-
1500	0	0	48	-	0	2324	-	-	-	0	-	-	-	-	-	-	-	-
1600	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	0	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**547**	**130**	**233**	**486**	**990**	**3323**	**8492**	**14879**	**9809**	**3246**	**7995**	**5979**	**23**	**17**	**384**	**933**	**425**	**1180**
Catch	**160**	**47**	**70**	**229**	**229**	**327**	**646**	**1712**	**1094**	**502**	**211**	**484**	**0**	**1**	**8**	**127**	**48**	**167**
Expl.	**0.2931**	**0.3615**	**0.2998**	**0.4704**	**0.2314**	**0.0984**	**0.0761**	**0.1151**	**0.1115**	**0.1547**	**0.0263**	**0.0810**	**0.0086**	**0.0412**	**0.0201**	**0.1360**	**0.1138**	**0.1418**

Table 6.3.3. Estimated redstripe rockfish biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	98	1378	40	35	40	3	444	551	120	226	5397	74	-	-	-	-	-	-
200	1607	2700	2844	334	417	294	7245	4644	4645	6453	9794	5930	2	-	-	197	39	993
300	85	59	90	214	36	130	1200	656	1035	2395	4956	1496	210	102	314	599	212	487
400	15	20	11	3	14	49	24	58	301	6	149	1047	1	0	29	35	98	166
500	10	25	5	0	47	4	3	0	16	0	3	1	0	0	6	31	145	385
600	7	5	4	0	1	0	95	4	37	0	-	-	0	0	0	38	0	1
700	9	1	4	1	0	33	25	0	19	0	0	0	-	0	0	28	101	3
800	0	1	0	25	23	0	0	0	0	0	-	0	-	0	0	0	0	0
900	0	0	0	3	0	0	69	0	84	0	-	-	-	0	-	0	0	0
1000	0	0	0	0	0	21	-	-	52	0	-	-	-	0	-	448	0	0
1100	0	0	0	0	0	0	-	24	-	0	-	-	-	-	-	0	-	-
1200	0	0	0	-	29	0	-	-	-	-	-	-	-	-	-	83	0	-
1300	0	0	0	0	0	0	-	-	70	-	-	-	-	-	-	0	0	-
1400	0	2	0	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-
1500	0	0	0	-	0	8	-	-	-	0	-	-	-	-	-	-	-	-
1600	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	0	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**1831**	**4190**	**2998**	**617**	**607**	**542**	**9104**	**5937**	**6379**	**9081**	**20299**	**8548**	**213**	**102**	**349**	**1473**	**595**	**2034**
Catch	**137**	**118**	**238**	**95**	**92**	**135**	**507**	**628**	**631**	**228**	**161**	**124**	**1**	**0**	**5**	**121**	**122**	**141**
Expl.	**0.0748**	**0.0283**	**0.0793**	**0.1543**	**0.1523**	**0.2484**	**0.0557**	**0.1058**	**0.0990**	**0.0251**	**0.0079**	**0.0145**	**0.0045**	**0.0039**	**0.0134**	**0.0823**	**0.2048**	**0.0693**

Table 6.3.4. Estimated rougheye rockfish biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	46	2	6	0	0	3	79	170	0	15	229	9	-	-	-	-	-	-
200	53	7	13	22	0	0	11	19	85	21	42	17	379	-	-	10	77	156
300	26	13	30	6	8	2	99	201	146	216	44	764	73	1	276	89	69	48
400	51	20	54	11	23	0	340	447	436	3722	514	2244	100	106	61	471	843	1202
500	16	59	49	27	45	6	169	103	172	306	43	48	49	53	63	560	392	724
600	25	12	7	1	11	2	93	1	7	102	-	-	27	33	22	454	248	875
700	14	1	2	0	0	0	8	0	0	0	22	24	-	15	18	634	274	1183
800	3	1	1	1	0	0	0	0	0	100	-	917	-	4	15	987	346	169
900	1	0	1	15	0	0	0	0	0	92	-	-	-	3	-	395	409	605
1000	0	7	0	0	0	0	-	-	0	0	-	-	-	9	-	90	0	11
1100	0	0	0	0	0	0	-	0	-	93	-	-	-	-	-	6229	-	-
1200	2	4	0	-	29	0	-	-	-	-	-	-	-	-	-	3930	0	-
1300	0	0	0	0	0	0	-	-	0	-	-	-	-	-	-	9603	10	-
1400	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	107	-	-
1500	0	0	483	-	0	0	-	-	-	41	-	-	-	-	-	-	-	-
1600	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	0	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**238**	**127**	**647**	**83**	**115**	**12**	**799**	**942**	**845**	**4709**	**893**	**4023**	**628**	**225**	**455**	**23560**	**2670**	**4973**
Catch	**172**	**97**	**137**	**36**	**13**	**4**	**120**	**60**	**39**	**210**	**29**	**45**	**49**	**18**	**29**	**468**	**169**	**324**
Expl.	**0.7221**	**0.7630**	**0.2116**	**0.4394**	**0.1095**	**0.3508**	**0.1497**	**0.0638**	**0.0459**	**0.0446**	**0.0327**	**0.0112**	**0.0781**	**0.0792**	**0.0632**	**0.0199**	**0.0632**	**0.0651**

Table 6.3.5. Estimated shortspine thornyhead biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	30	39	43	0	0	0	4	18	35	31	252	55	-	-	-	-	-	-
200	30	35	64	3	4	1	115	118	235	557	453	346	9	-	-	28	16	13
300	13	11	9	3	2	8	250	212	214	727	555	498	148	178	34	14	23	17
400	22	20	25	2	3	6	52	32	46	636	915	584	184	176	129	53	39	27
500	24	31	43	27	17	29	28	75	35	121	162	169	110	133	122	54	59	52
600	46	59	62	101	38	59	54	58	54	56	-	-	12	6	14	44	21	56
700	65	65	49	99	78	68	40	94	10	30	41	41	-	7	28	48	20	71
800	44	55	39	41	39	40	3	84	50	77	-	147	-	18	7	34	56	103
900	44	50	42	43	24	36	5	30	11	80	-	-	-	5	-	28	6	32
1000	55	52	51	73	38	28	-	-	0	14	-	-	-	9	-	28	0	0
1100	66	50	47	26	59	42	-	0	-	28	-	-	-	-	-	114	-	-
1200	44	51	51	-	0	35	-	-	-	-	-	-	-	-	-	22	39	-
1300	56	58	44	47	29	84	-	-	0	-	-	-	-	-	-	10	64	-
1400	174	46	97	-	-	-	-	-	-	-	-	-	-	-	-	315	-	-
1500	98	33	6	-	77	6	-	-	-	0	-	-	-	-	-	-	-	-
1600	33	-	-	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	87	-	-	-	104	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**930**	**656**	**671**	**493**	**511**	**442**	**550**	**720**	**691**	**2357**	**2378**	**1840**	**463**	**531**	**334**	**791**	**343**	**369**
Catch	**332**	**280**	**344**	**106**	**59**	**59**	**62**	**68**	**45**	**167**	**91**	**75**	**56**	**39**	**49**	**38**	**8**	**19**
Expl.	**0.3567**	**0.4271**	**0.5132**	**0.2152**	**0.1147**	**0.1337**	**0.1136**	**0.0937**	**0.0649**	**0.071**	**0.0383**	**0.0405**	**0.1211**	**0.0737**	**0.1451**	**0.0474**	**0.0239**	**0.0528**

Table 6.3.6. Estimated longspine thornyhead biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	252	151	90	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
200	27	16	4	0	0	0	2	5	0	9	4	2	0	-	-	0	0	0
300	2	2	1	0	0	0	5	5	0	13	13	7	11	0	1	0	4	0
400	9	4	8	0	0	1	1	0	0	2	24	12	0	5	4	0	1	1
500	13	17	10	1	0	13	0	12	6	1	0	5	0	1	17	1	0	16
600	42	50	37	29	50	42	4	13	24	0	-	-	0	0	0	0	0	1
700	75	85	72	40	105	52	0	18	0	5	0	0	-	1	2	5	0	9
800	92	121	102	81	73	95	0	19	47	44	-	0	-	0	0	1	17	58
900	148	137	118	77	65	64	0	18	0	2	-	-	-	1	-	0	1	13
1000	194	195	167	139	95	84	-	-	0	5	-	-	-	1	-	0	0	0
1100	186	164	166	97	137	125	-	0	-	0	-	-	-	-	-	18	-	-
1200	181	183	174	-	7	155	-	-	-	-	-	-	-	-	-	0	42	-
1300	231	236	203	159	44	133	-	-	0	-	-	-	-	-	-	0	0	-
1400	253	175	118	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-
1500	430	228	0	-	70	0	-	-	-	0	-	-	-	-	-	-	-	-
1600	250	-	-	336	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	135	-	-	-	392	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**2521**	**1762**	**1271**	**958**	**1038**	**766**	**12**	**88**	**77**	**80**	**42**	**27**	**11**	**9**	**24**	**33**	**65**	**98**
Catch	**717**	**609**	**807**	**164**	**136**	**82**	**2**	**10**	**7**	**4**	**3**	**2**	**1**	**1**	**4**	**1**	**1**	**4**
Expl.	**0.2843**	**0.3459**	**0.6346**	**0.1709**	**0.1311**	**0.1072**	**0.1896**	**0.1082**	**0.0867**	**0.0458**	**0.0594**	**0.0639**	**0.0726**	**0.1246**	**0.1790**	**0.0195**	**0.0126**	**0.0364**

Table 6.3.7. Estimated shortraker rockfish biomass (t).

Depth (m)	3C			3D			5AB			5CD			5EN			5ES		
	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998	1996	1997	1998
100	5	8	11	38	0	0	19	0	1	42	6	7	-	-	-	-	-	-
200	12	8	11	7	0	0	5	5	1	19	21	2	11	-	-	13	19	0
300	8	2	1	1	1	2	15	7	3	58	72	32	12	12	5	9	3	2
400	5	8	6	4	1	0	7	4	0	180	134	69	8	17	26	106	18	4
500	15	8	8	10	90	5	7	20	0	41	20	34	4	12	19	46	45	2
600	10	7	4	0	4	8	2	8	1	116	-	-	0	1	2	87	29	19
700	3	4	1	0	0	1	0	4	0	27	16	4	-	1	1	32	27	11
800	3	0	1	0	0	1	1	0	51	167	-	31	-	2	1	32	6	1
900	0	0	0	3	0	0	0	0	3	24	-	-	-	2	-	2	0	2
1000	0	0	0	0	0	0	-	-	0	0	-	-	-	0	-	8	0	0
1100	0	4	0	0	0	0	-	0	-	41	-	-	-	-	-	0	-	-
1200	0	7	0	-	2	0	-	-	-	-	-	-	-	-	-	0	754	-
1300	0	0	0	0	0	0	-	-	0	-	-	-	-	-	-	18	45	-
1400	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-
1500	0	0	5	-	0	0	-	-	-	0	-	-	-	-	-	-	-	-
1600	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1700	0	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**61**	**54**	**48**	**62**	**98**	**17**	**56**	**49**	**60**	**717**	**269**	**180**	**34**	**46**	**54**	**353**	**945**	**40**
Catch	**41.963**	**24.918**	**21.274**	**6.8262**	**3.6723**	**2.6454**	**4.3205**	**6.3685**	**0.895**	**55.371**	**13.429**	**10.351**	**5.6079**	**3.5172**	**6.5061**	**29.933**	**7.3569**	**3.3103**
Expl.	**0.6844**	**0.4578**	**0.4467**	**0.1108**	**0.0375**	**0.1555**	**0.0775**	**0.1302**	**0.0149**	**0.0772**	**0.0499**	**0.0575**	**0.1636**	**0.0757**	**0.1212**	**0.0848**	**0.0078**	**0.0829**

Table 7.1. Parameter estimates for Pacific ocean perch; yellowmouth, redstripe, and rougheye rockfish; and shortspine and longspine thornyheads. Biological parameters $(r, f, B_0, g, d, w_r, l, k)$ determine the reference points $(h^\#, F^\#, h^*, F^*, C^*, B^*, A^*, W^*, h_{50\%}, C_{50\%})$ defined in section 5.3.

Parameter	POP		Yellowmouth		Redstripe		Rougheye		Shortspine		Longspine	
g	-1	0	-1	0	-1	0	-1	0	-1	0	-1	0
r	9	9	9	9	9	9	18	18	20	20	15	15
f	5	5	5	5	5	5	5	5	5	5	5	5
B_0	100	100	100	100	100	100	100	100	100	100	100	100
d	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.09	0.09	0.08	0.08
w_r	0.590	0.590	0.665	0.665	0.209	0.209	1.493	1.493	0.328	0.328	0.075	0.075
l	0.105	0.105	0.146	0.146	0.029	0.029	0.015	0.015	0.450	0.450	0.007	0.007
k	0.912	0.912	0.907	0.907	0.899	0.899	0.998	0.998	0.998	0.998	0.962	0.962
$h^\#$	0.129	0.129	0.123	0.123	0.148	0.148	0.089	0.089	0.108	0.108	0.191	0.191
$F^\#$	0.138	0.138	0.131	0.131	0.160	0.160	0.093	0.093	0.114	0.114	0.212	0.212
h^*	0.045	0.060	0.043	0.057	0.051	0.068	0.030	0.040	0.039	0.052	0.069	0.091
F^*	0.046	0.062	0.044	0.059	0.053	0.071	0.030	0.040	0.040	0.053	0.071	0.095
C^*	1.548	2.589	1.499	2.498	1.728	2.919	0.954	1.620	1.484	2.404	2.378	4.004
B^*	34.411	43.359	34.752	43.685	33.585	42.705	32.212	40.815	37.665	46.571	34.606	44.048
A^*	18.784	17.369	18.991	17.585	18.113	16.700	34.030	31.600	26.946	26.301	20.983	20.111
W^*	0.867	0.844	1.100	1.066	0.245	0.242	1.671	1.644	3.406	3.124	0.095	0.093
$h_{50\%}$	0.039	0.039	0.038	0.038	0.043	0.043	0.024	0.024	0.038	0.038	0.059	0.059
$C_{50\%}$	1.534	2.329	1.488	2.257	1.705	2.588	0.938	1.423	1.483	2.250	2.350	3.567

Table 8.1. Reliability of bottom trawl surveys to assess slope/shelf rockfish species along the BC coast.

Species	Reliability of trawl surveys
Pacific ocean perch*	Good: Fish on bottom or dive to bottom
Yellowmouth rockfish*	Good minus: Not quite as good as POP
Yellowtail rockfish	Poor: Not reliably on bottom, high variability
Redstripe rockfish	Poor: Not reliably on bottom
Shortspine/longspine thornyheads*	Excellent: Always on bottom, not aggregated
Rougheye/Shortraker rockfish*	Good minus: Aggregation a problem
Silvergray rockfish	Poor plus: Patchy and variable
Canary rockfish	Poor plus to Good minus: On bad ground

* Species or complex conducive to assessment by bottom trawl surveys.

Table 8.1.1. Classification of towable bottom based on bottom type, ability of net to stay on the bottom, and duration of the tow for survey purposes.

Code	Colour	Description
1	Blue	Net stays on bottom for at least 30 minutes.
2	Green	Rolling bottom, net occasionally leaves bottom and changes configuration during 30-minute tow, small possibility of hang-up.
3	Yellow	Rolling bottom, net leaves bottom and changes configuration frequently and dramatically during 30 min tow, high risk of hang-up.
4	Red	Cannot set the net, cannot tow for at least 15 minutes.

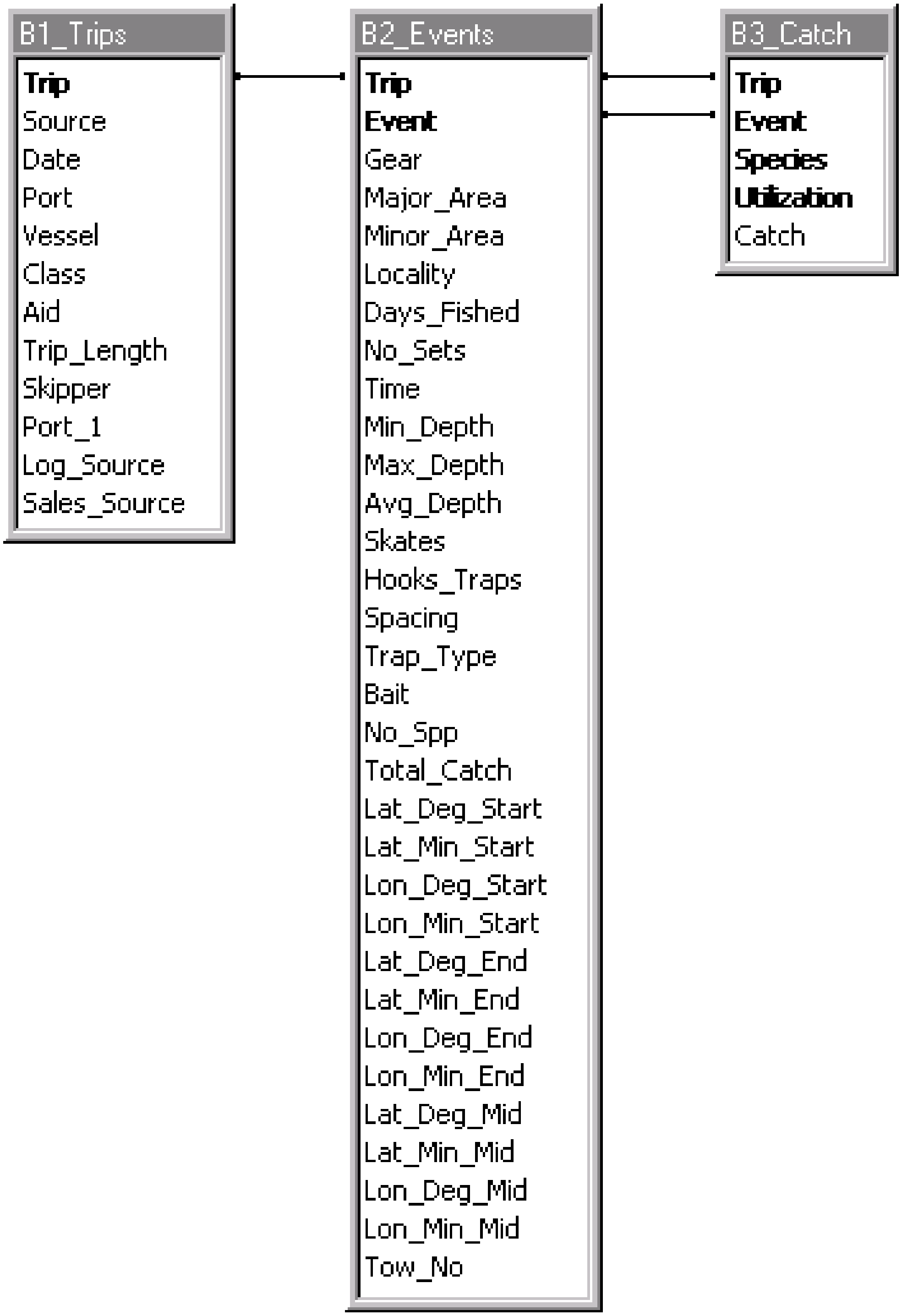


Figure 3.1.1. Links among the primary data tables of GFCatch.

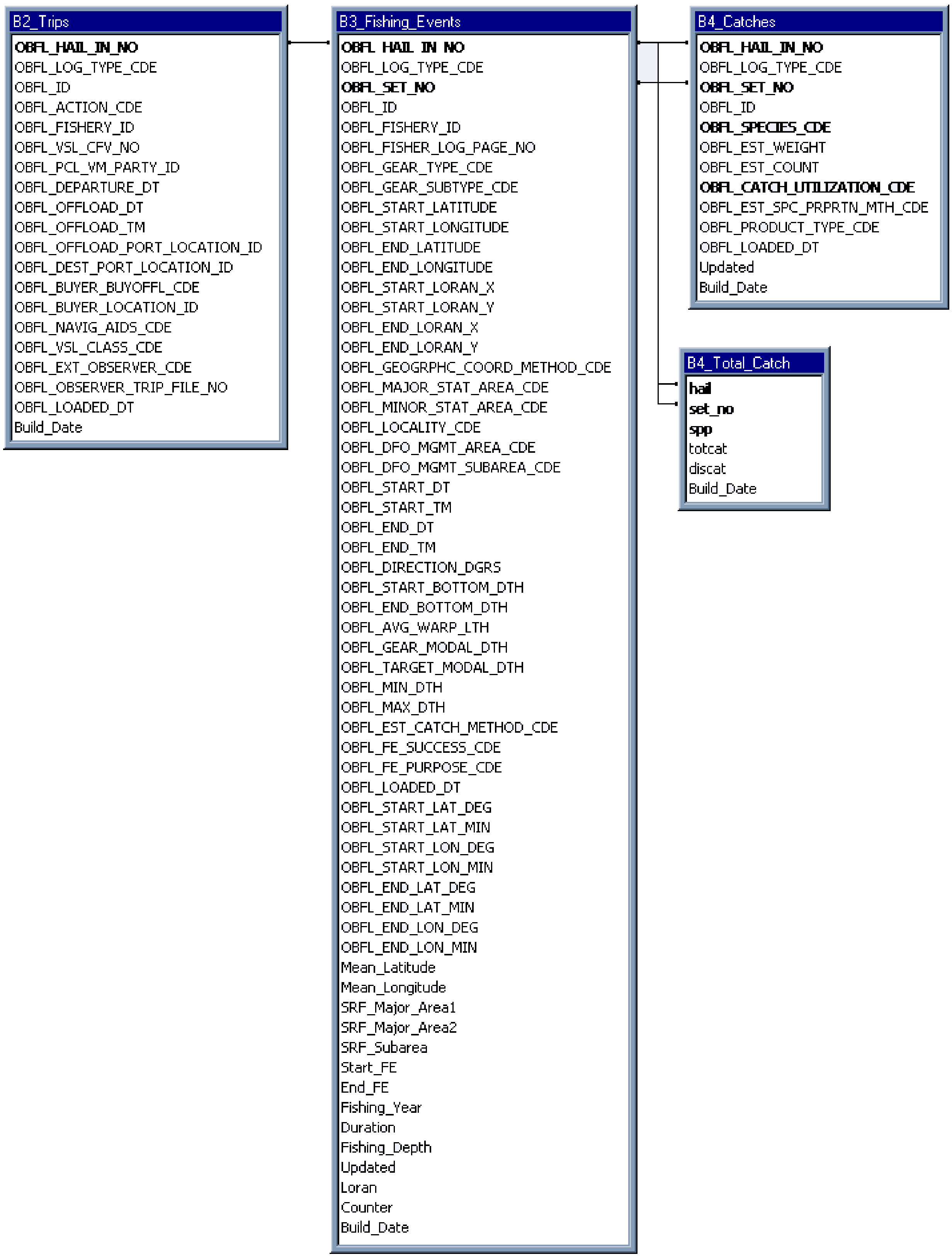


Figure 3.2.1. Links among the primary data tables of PacHarvest.

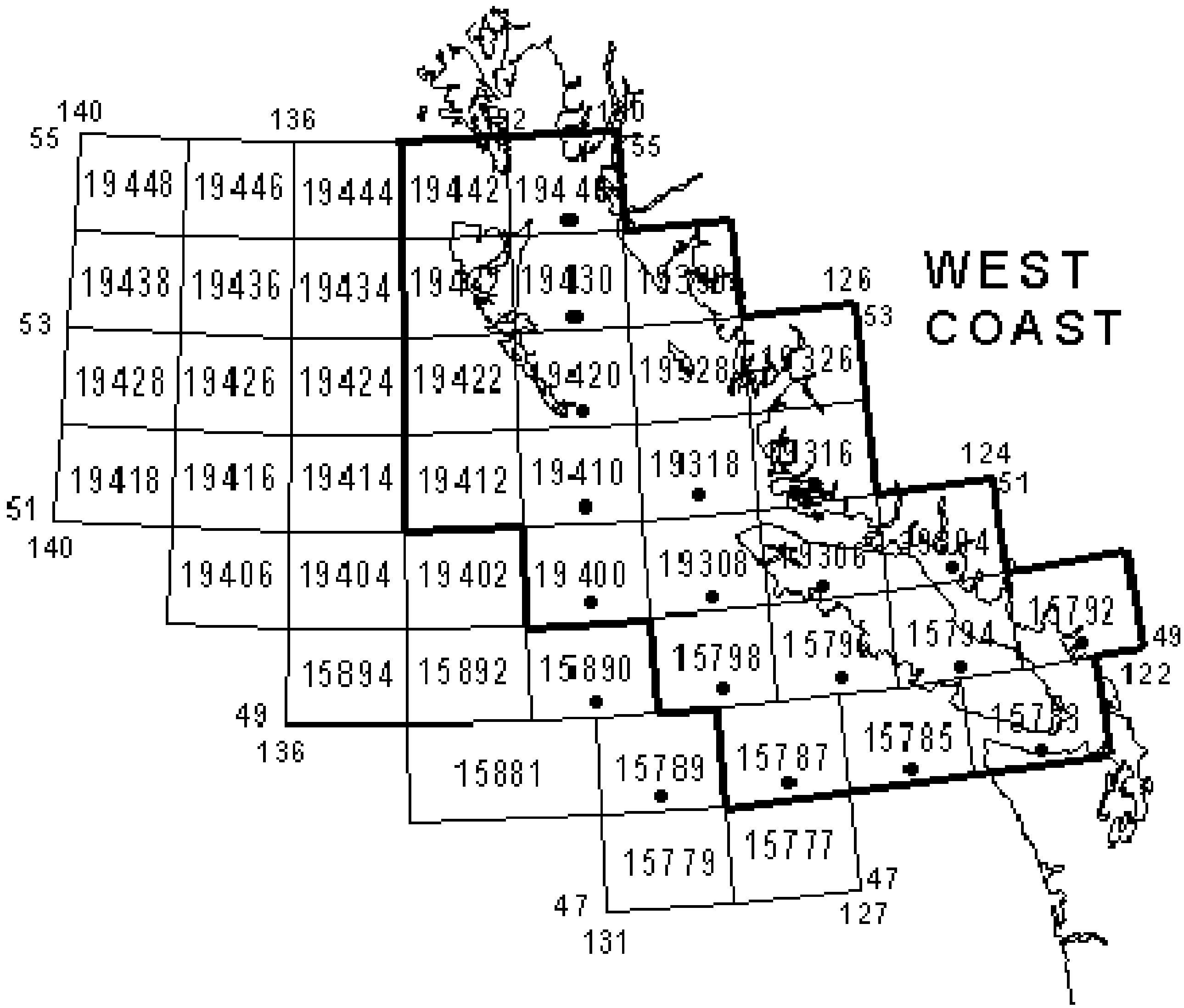


Figure 3.6.1. Canadian Hydrographic Service Natural Resource Map coverage for the coast of British Columbia. Maps used to build the bathymetric rectangle are outlined.

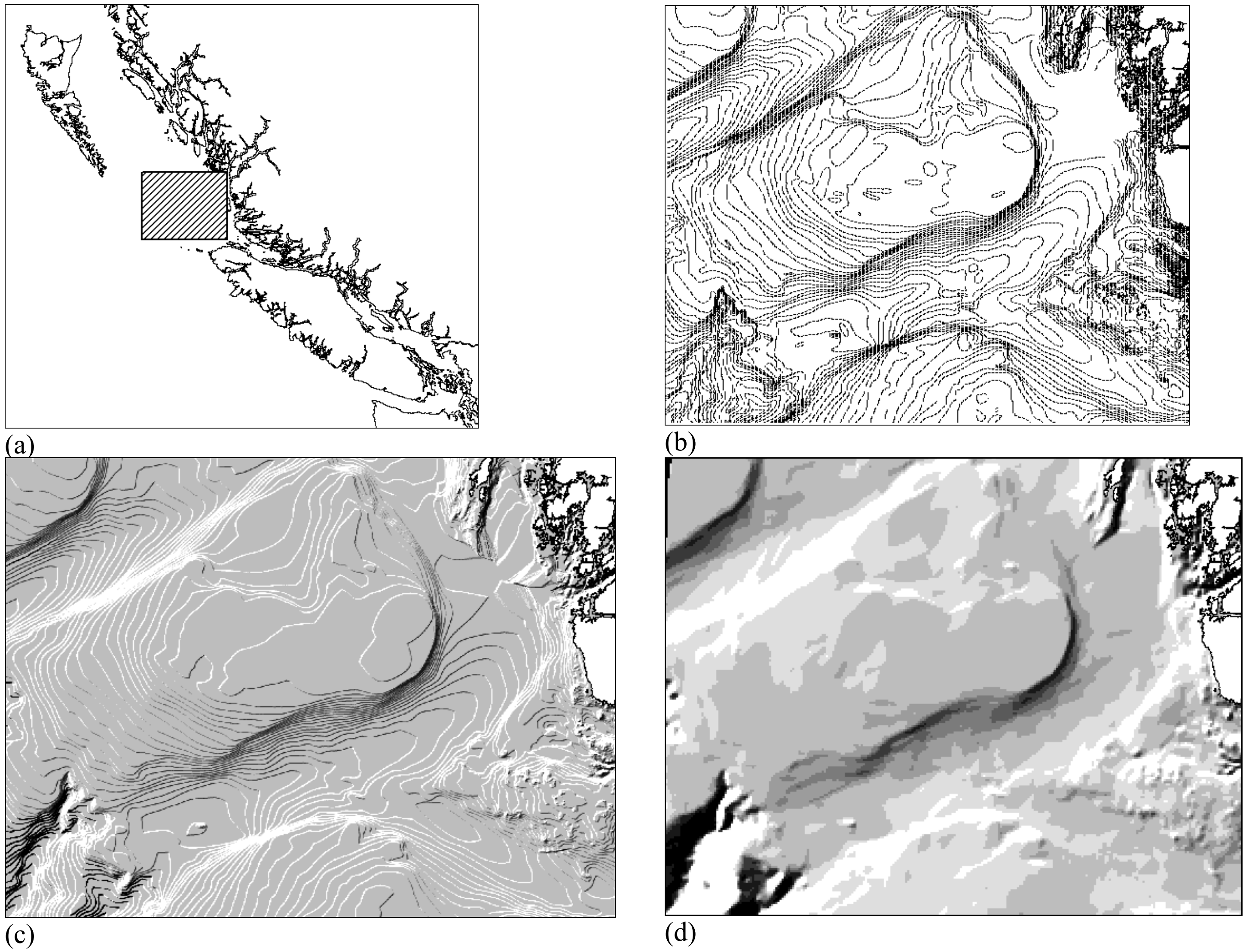


Figure. 3.6.2. Comparison of two bathymetric interpolators in Arcview GIS 3.1. (a) Area of the coast used for comparison is indicated by the hatched box. (b) Contour point data extracted from digital Natural Resource Map. (c) Hillshade view of bathymetric surface interpolated using Arcview's Inverse Distance Weighted (IDW) algorithm. (d) Hillshade view of bathymetric surface interpolated using a Triangulated Irregular Network.

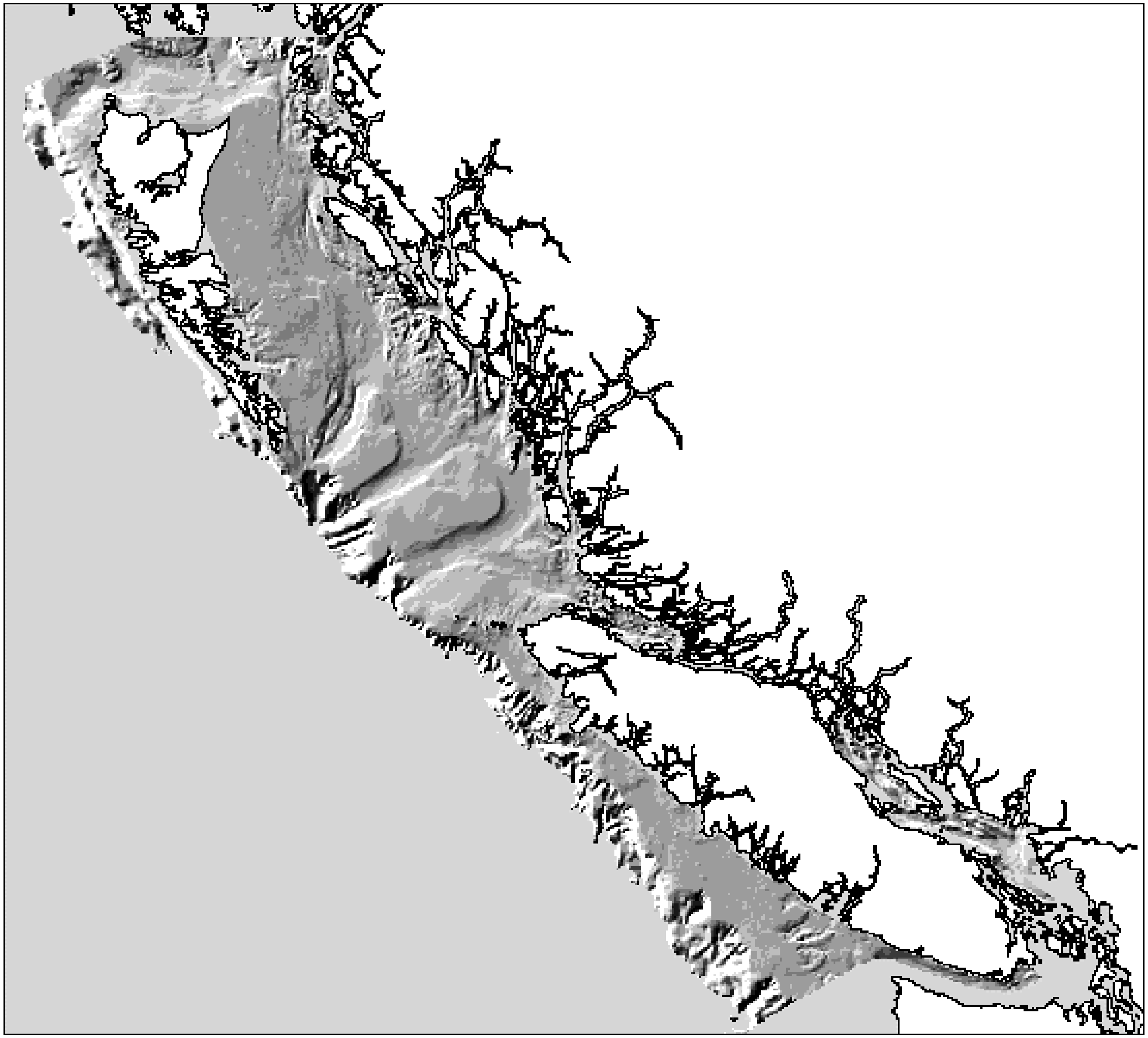


Figure 3.6.3. Hillshade view of BC coast bathymetry down to 1700 m.

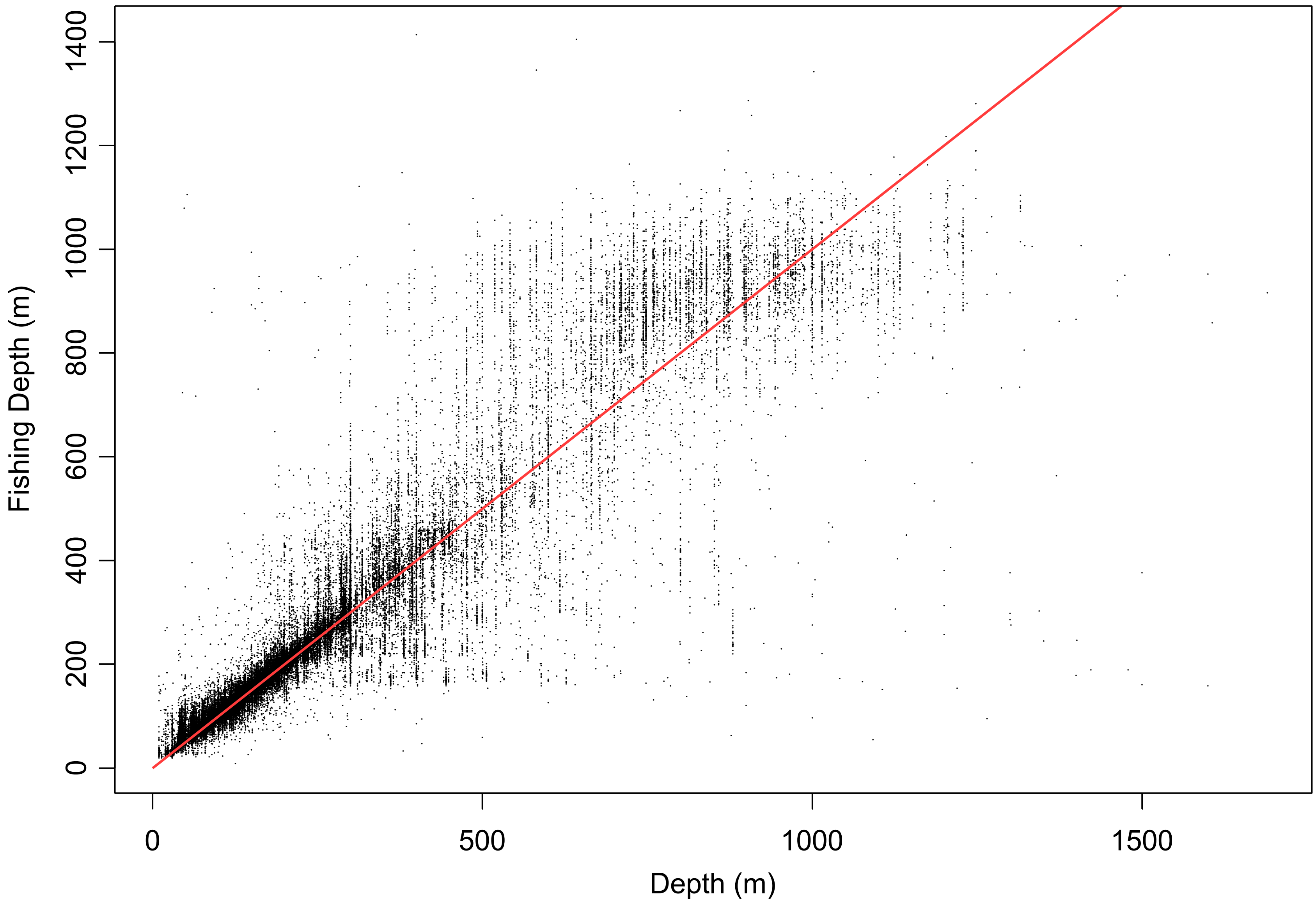


Figure 3.6.4. Fishing depth plotted against depth obtained from coastal bathymetry.

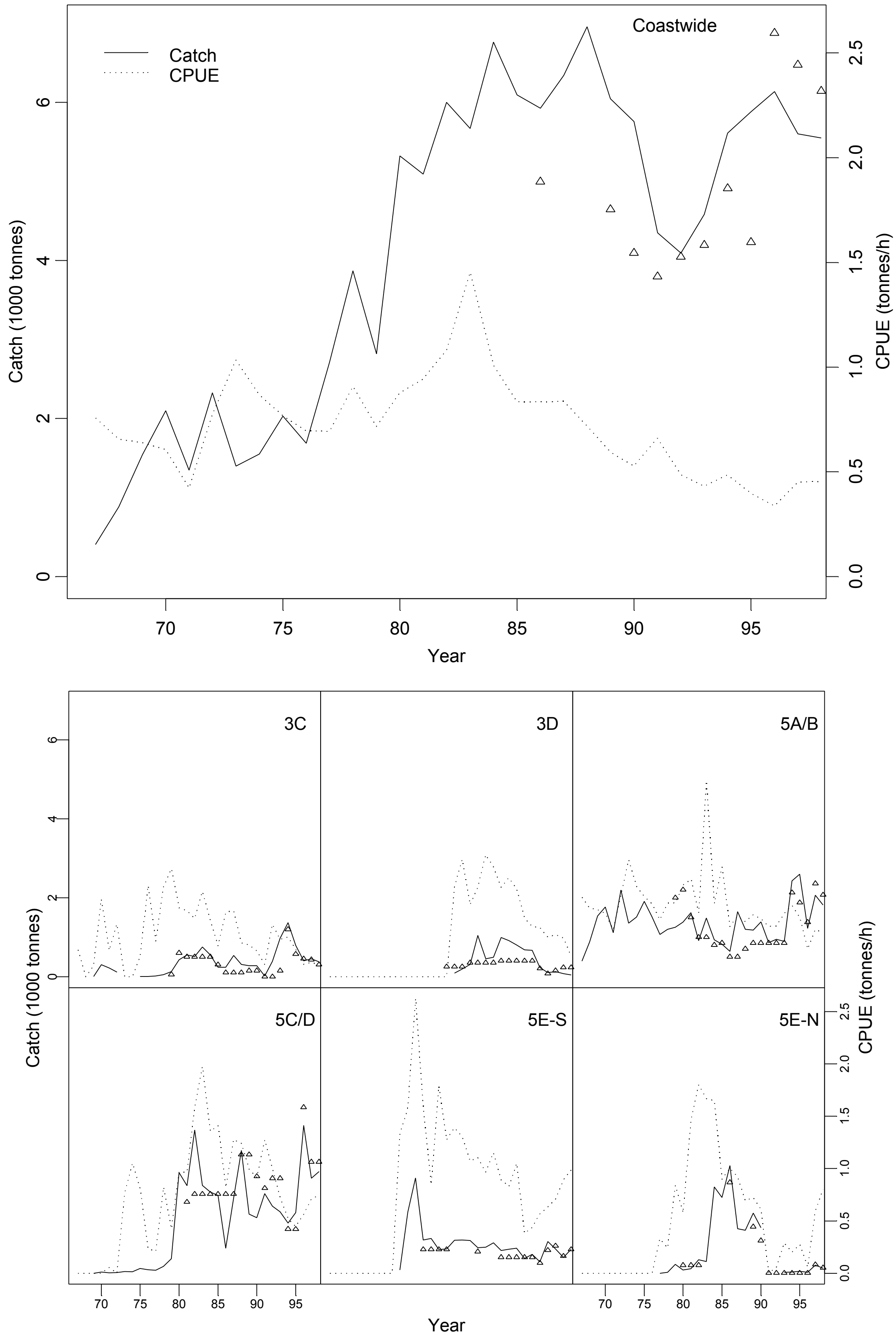


Figure 4.1.1. Pacific ocean perch catch (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

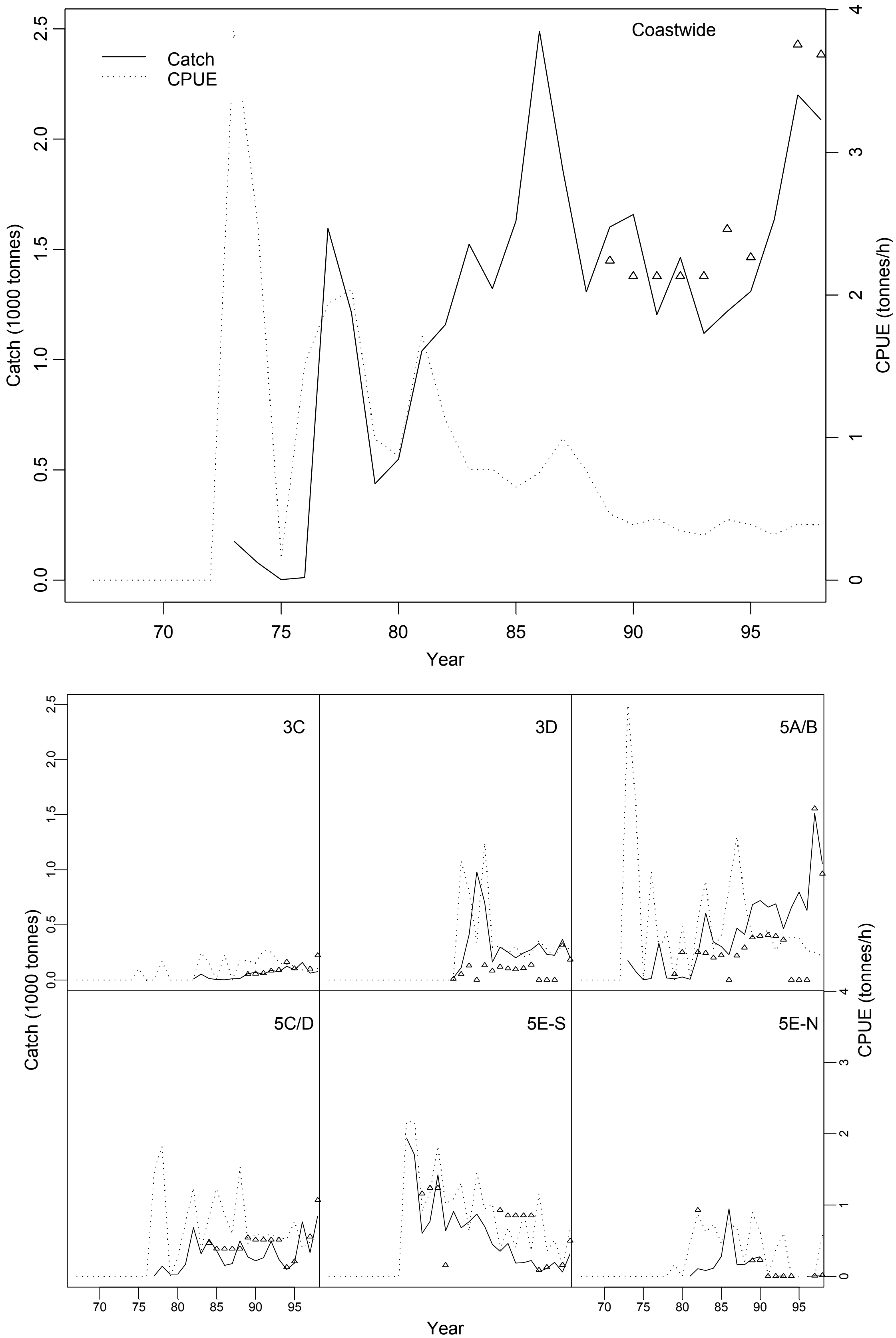


Figure 4.1.2. Yellowmouth rockfish catch (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

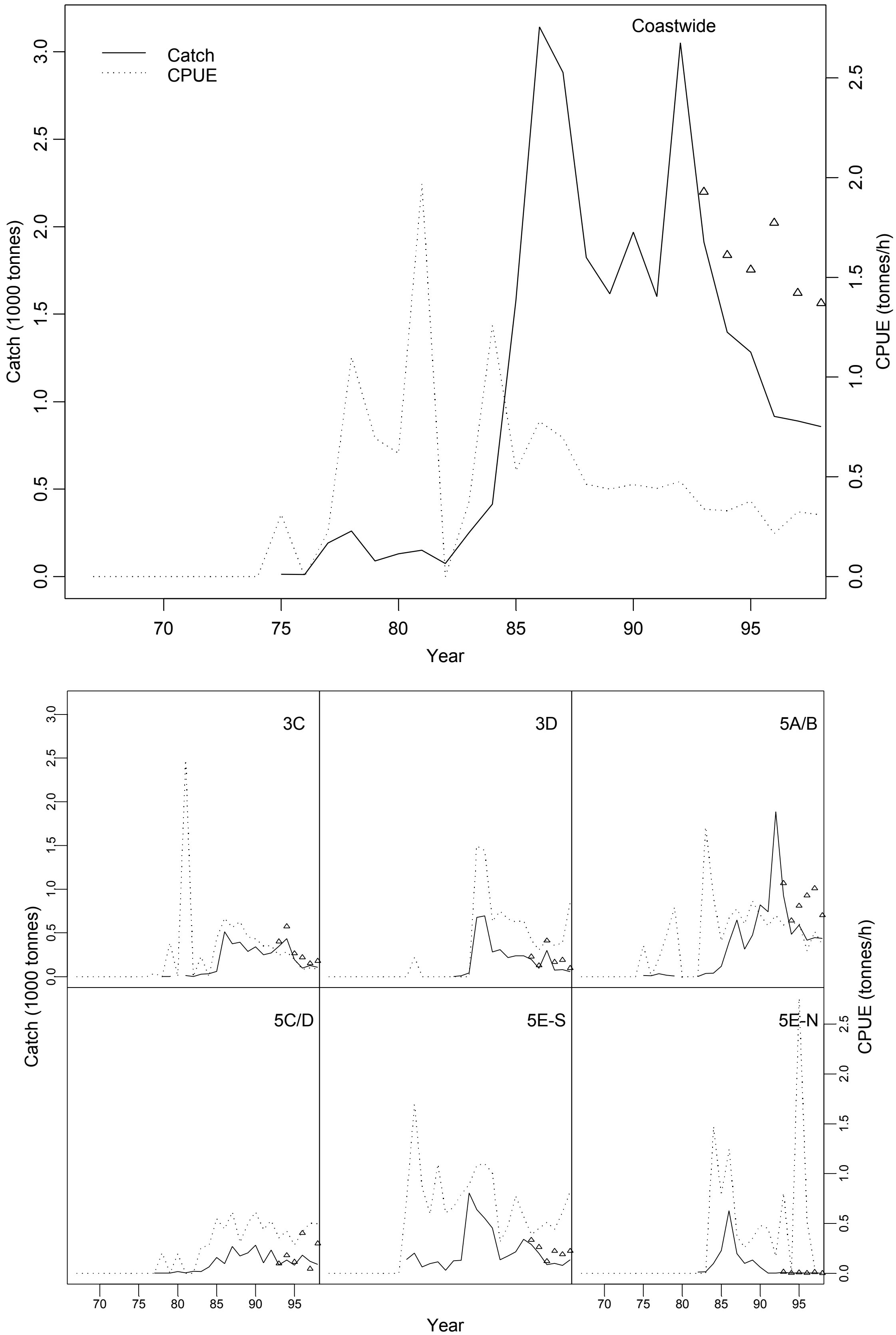


Figure 4.1.3. Redstripe rockfish catch (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

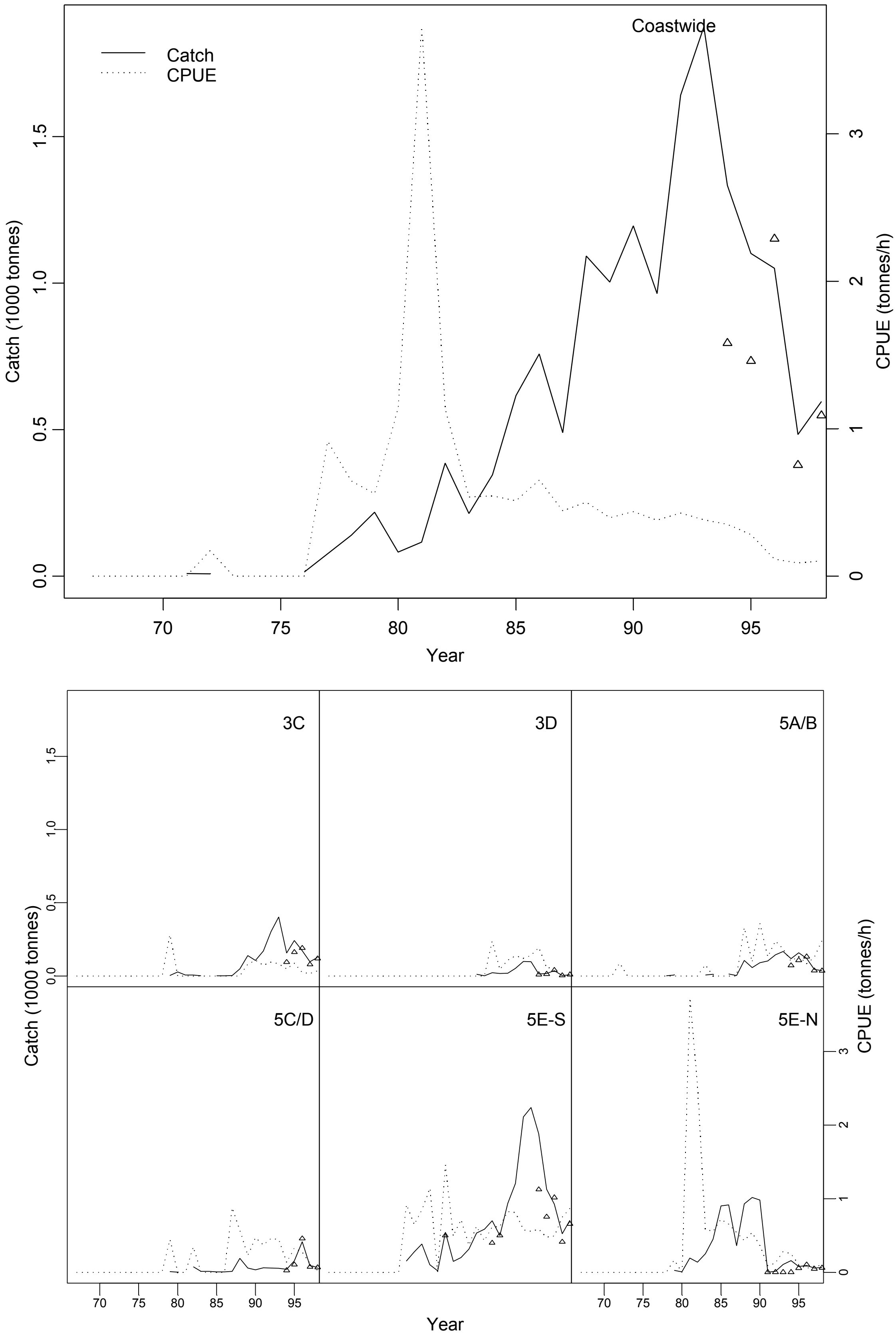
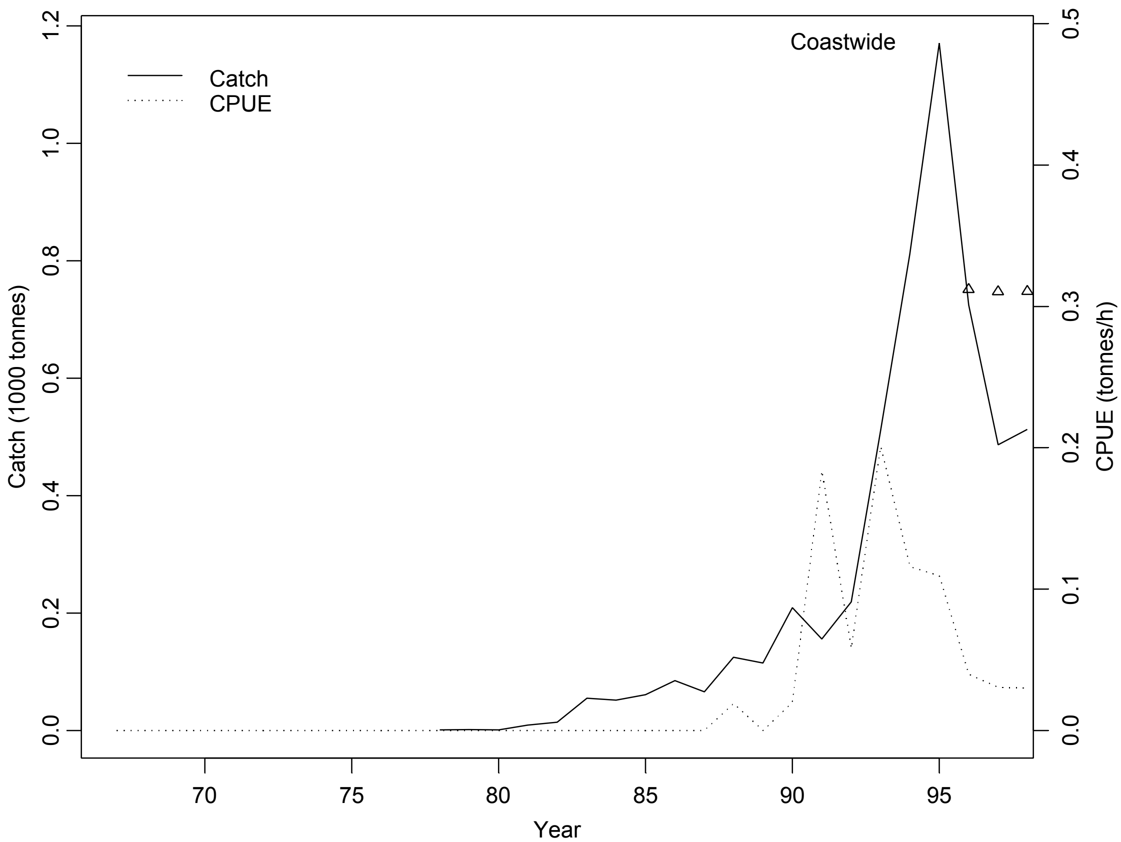


Figure 4.1.4. Rougheye rockfish catch (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.



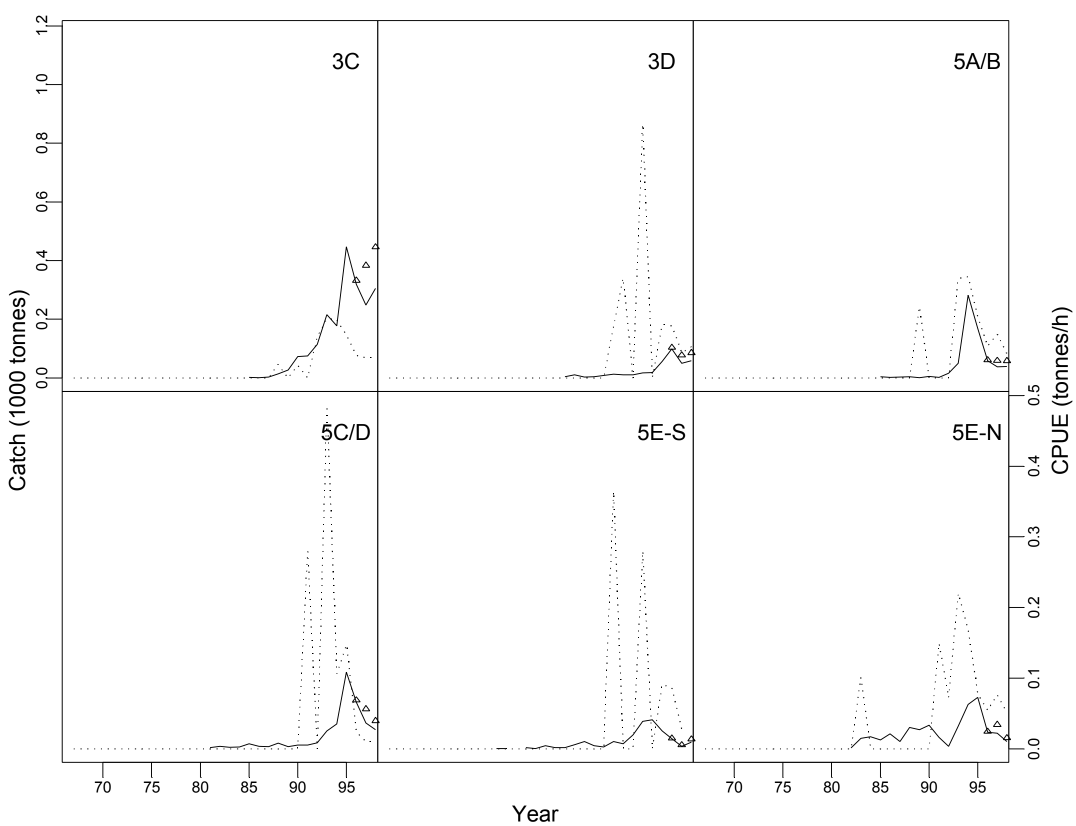


Figure 4.1.5. Shortspine thornyhead (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

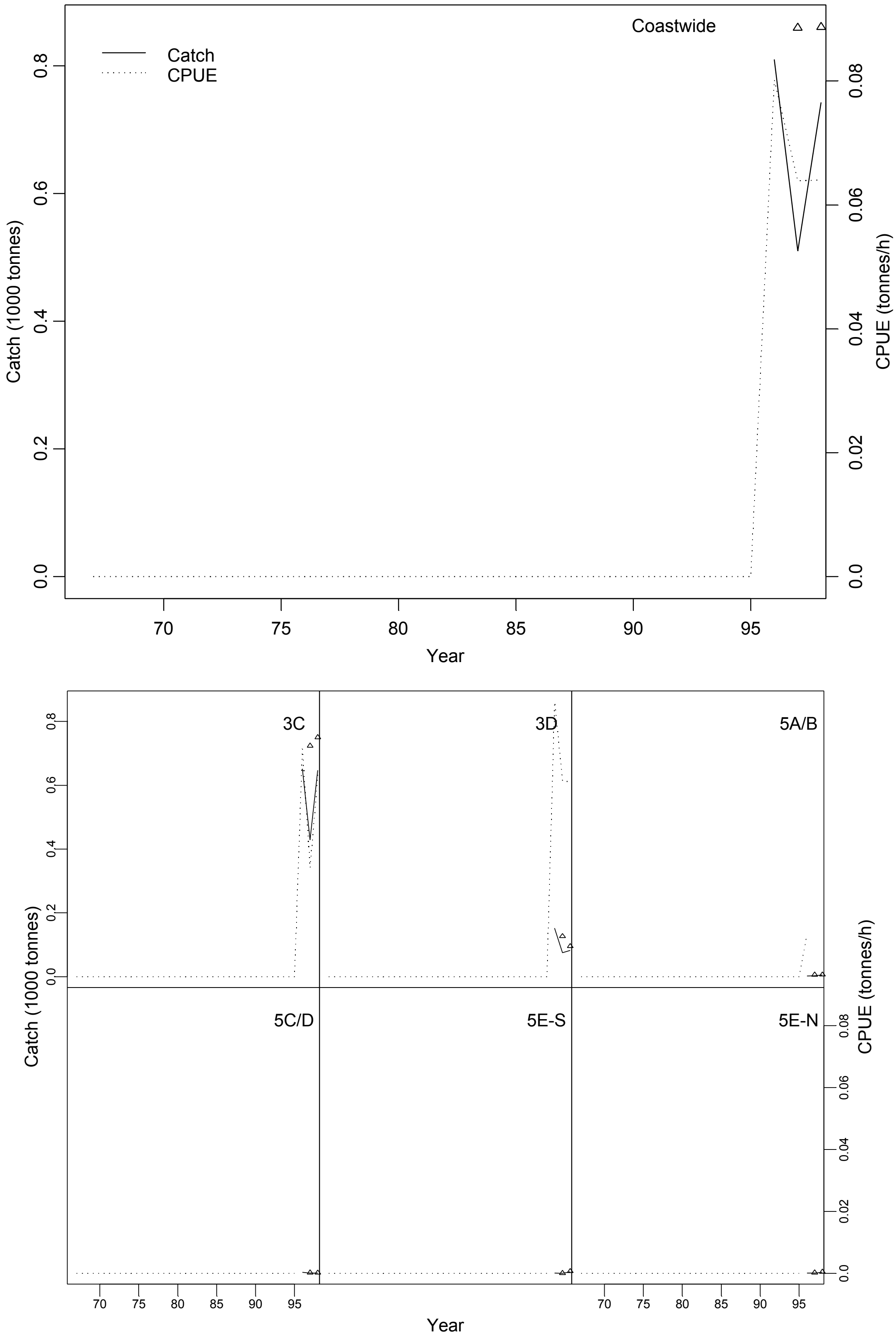


Figure 4.1.6. Longspine thornyhead (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

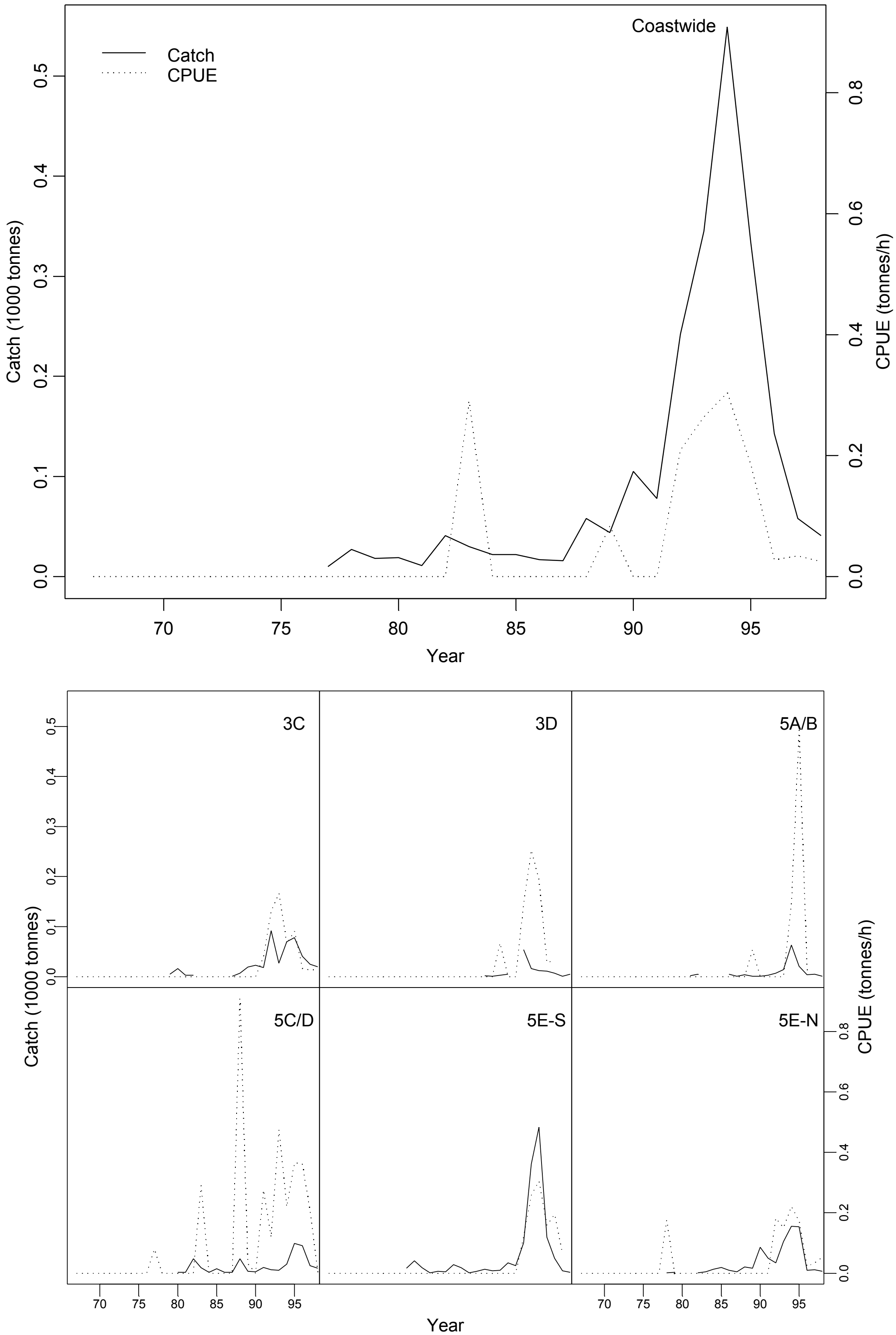


Figure 4.1.7. Shortraker rockfish (trawl = solid line, hook and line = dashed line) and 20% qualified CPUE (dotted line). Annual quotas plotted as triangles.

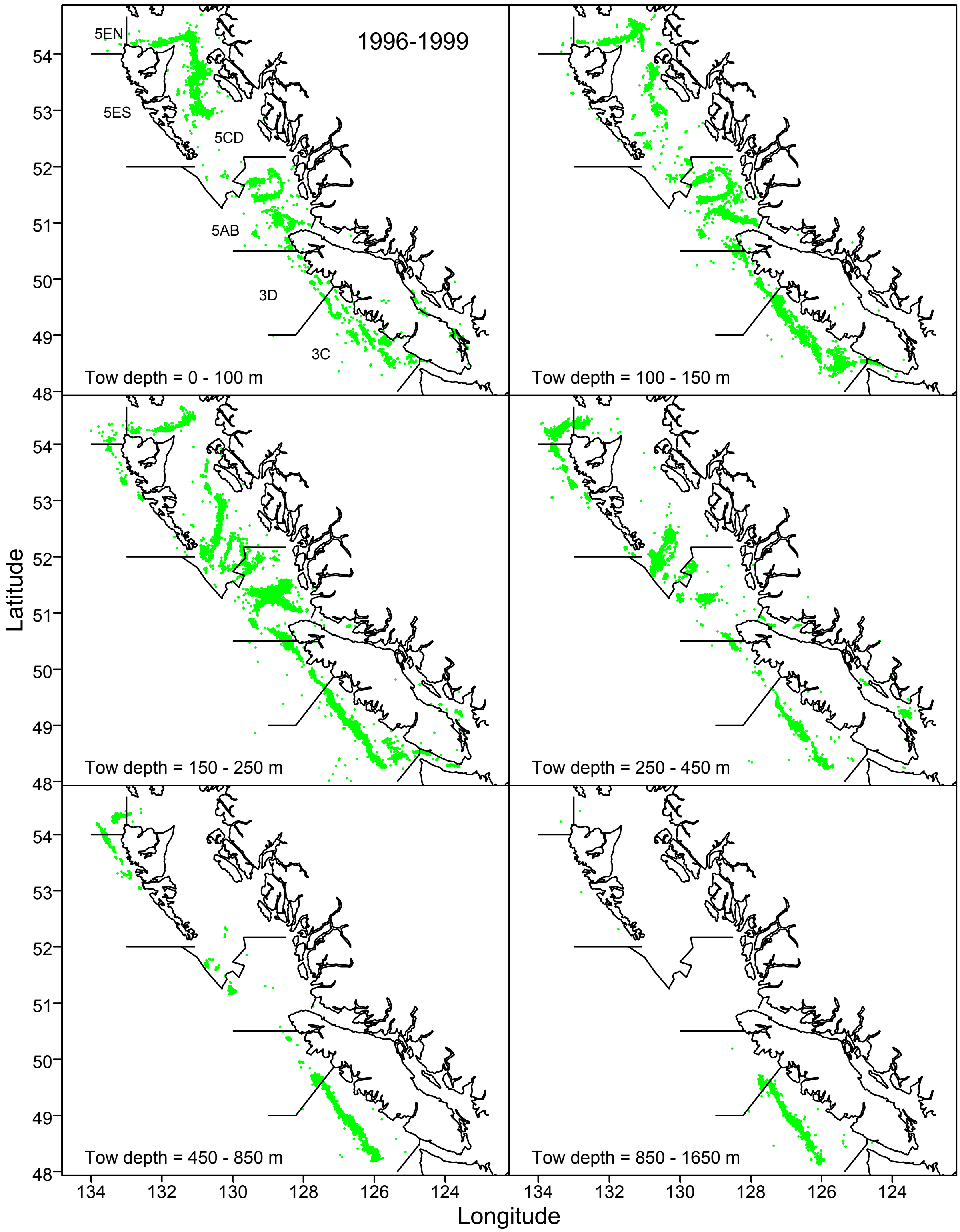


Figure 4.2.1. Trawl tow locations, stratified by fishing depth along the BC coast, Jan 1996 to Mar 1999. Slope rockfish assessment areas indicated in first panel.

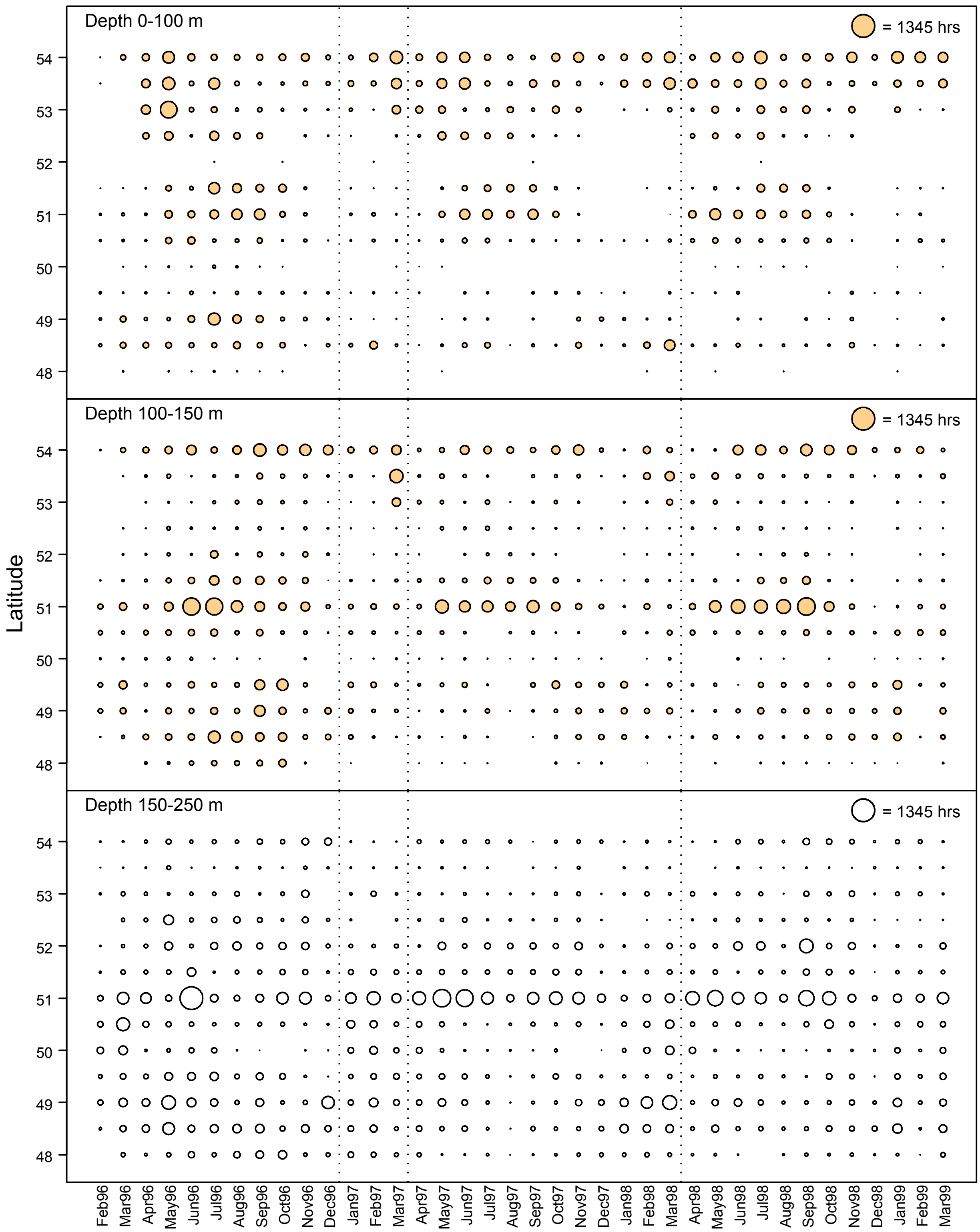


Figure 4.2.2. Trawl effort by month and latitude for the fishing depths 0–250 m, Feb 1996 to Mar 1999.

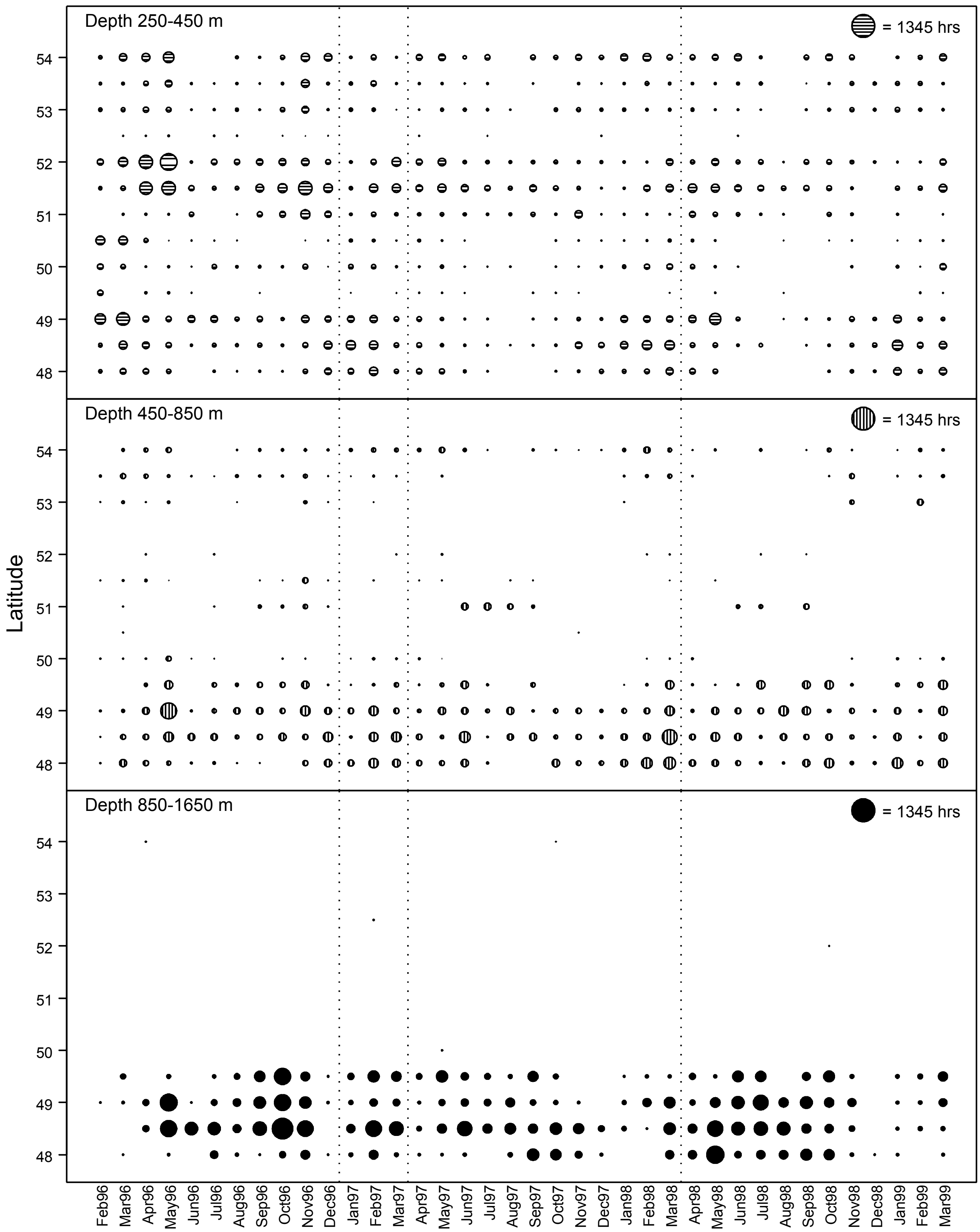


Figure 4.2.2. Trawl effort by month and latitude for the fishing depths 250–1650 m, Feb 1996 to Mar 1999.

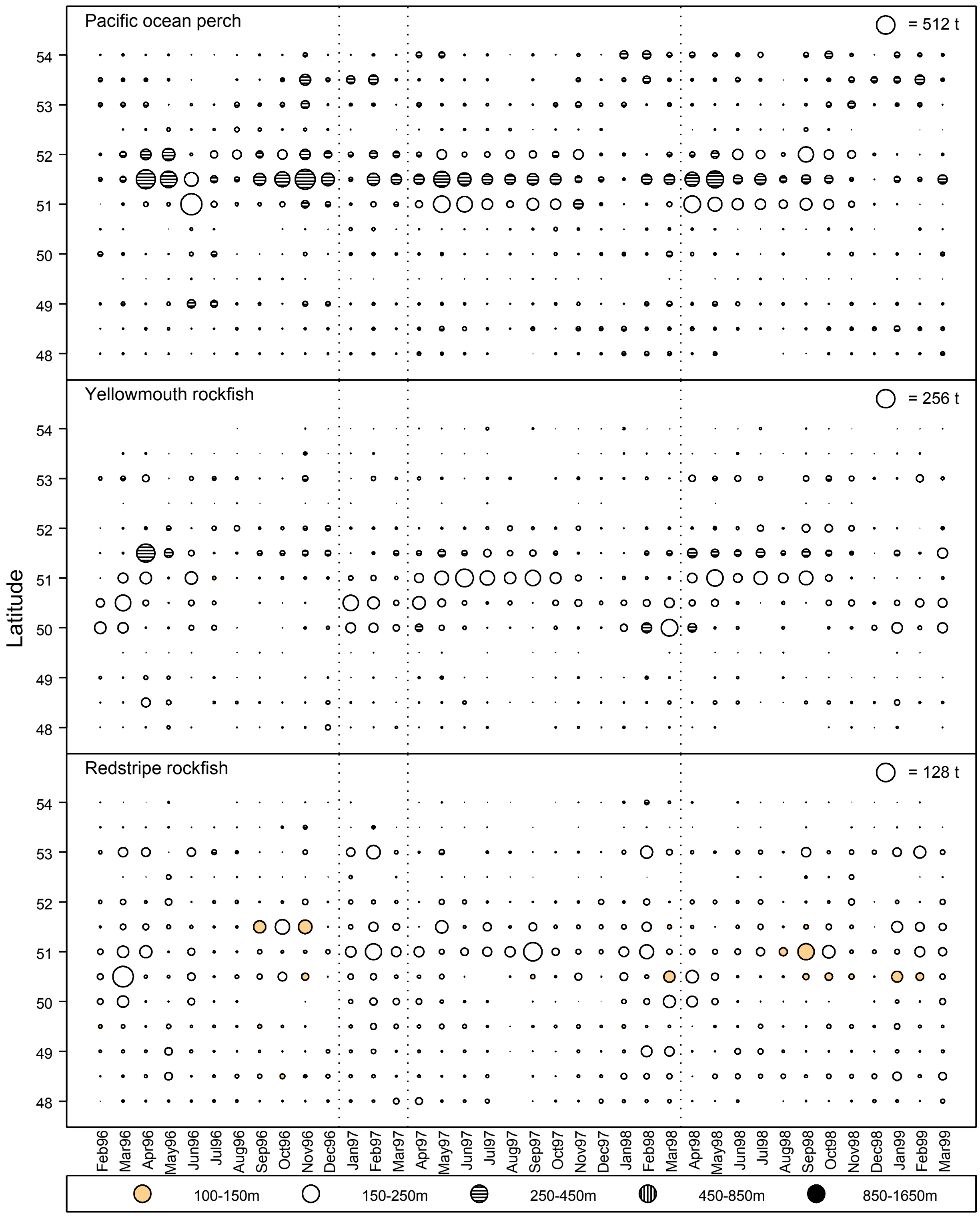


Figure 4.2.3. Trawl catch by species, month, latitude, and mean fishing depth weighted by catch for Pacific ocean perch, yellowmouth rockfish, and redstripe rockfish.

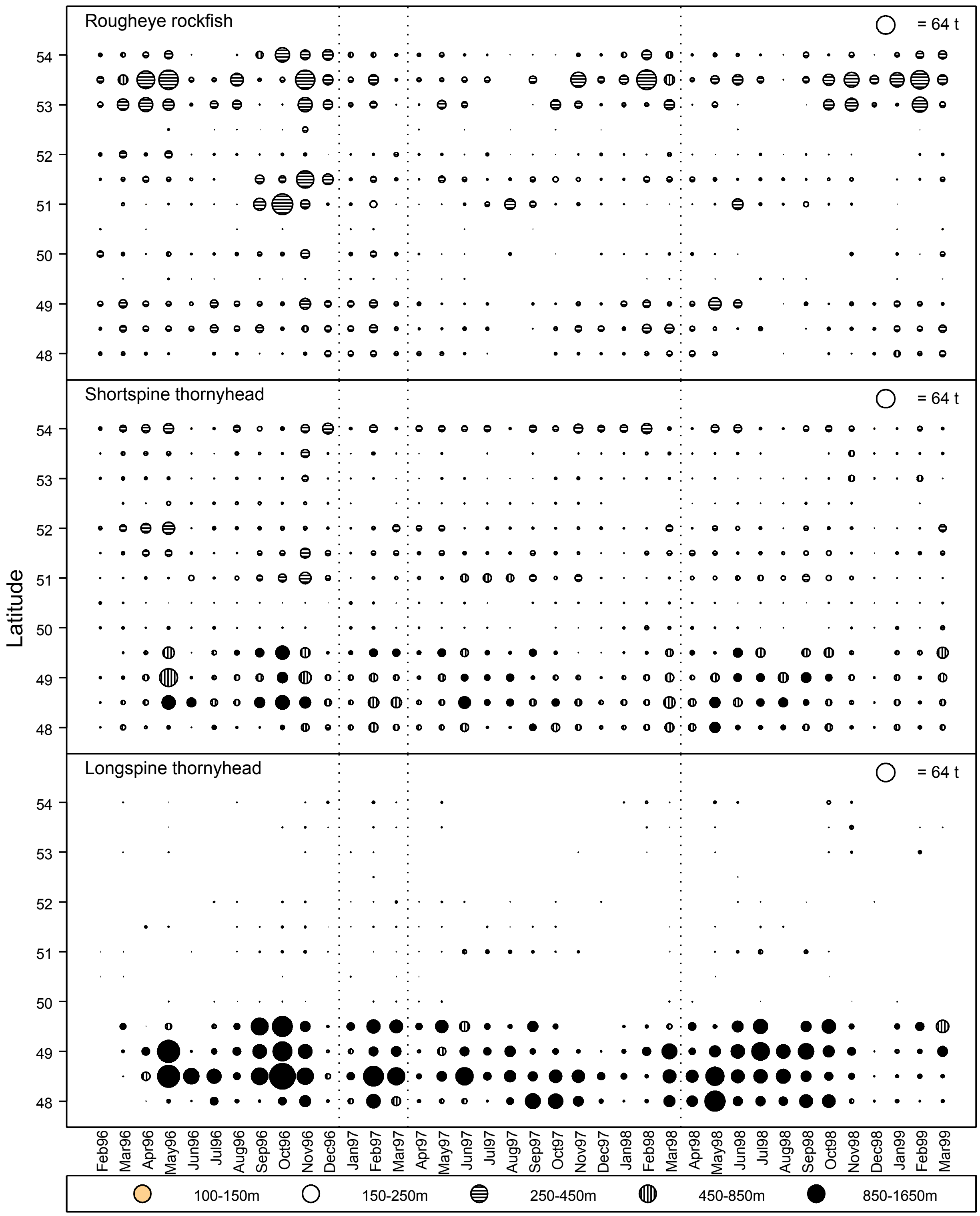


Figure 4.2.3. Trawl catch by species, month, latitude, and mean fishing depth weighted by catch for rougheye rockfish, shortspine thornyhead, and longspine thornyhead.

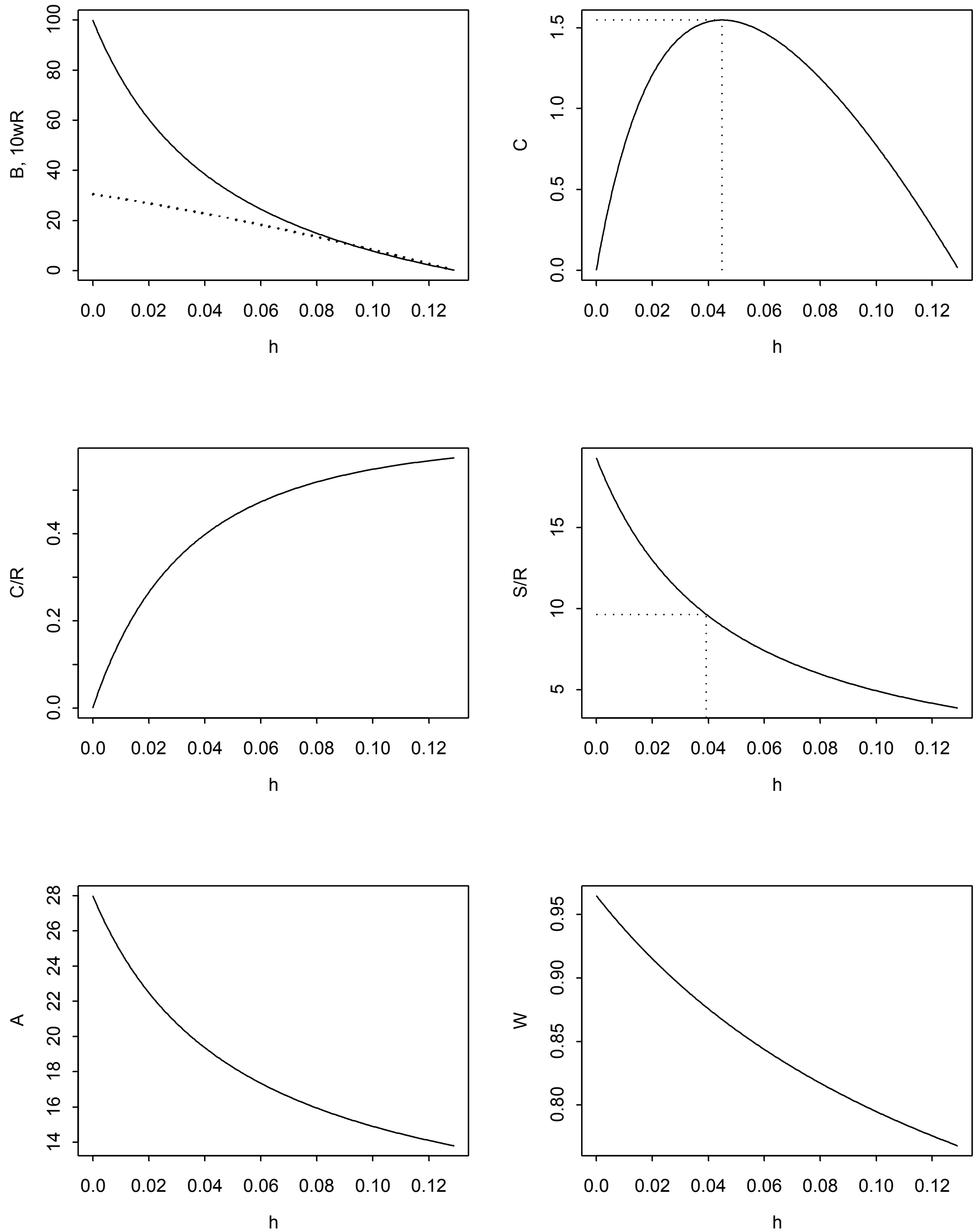


Figure 5.3.1. Equilibrium levels of biomass *B*, catch *C*, yield per recruit *C/R*, spawner biomass per recruit *S/R*, age *A*, and weight *W* in relation to a sustained harvest rate *h*, based on a Beverton-Holt model with $g = -1$ and biological parameters for Pacific ocean perch (Table 7.1, column 1). A dotted curve in the upper left panel represents ten times the recruitment biomass ($10\, w_r R$). Dotted lines in the upper right panel indicate the MSY point (C^*, h^*). Similarly, dotted lines in the *S/R* plot indicate the point $h_{50\%}$, where $S/R = 0.5\ S_0 / R_0$.

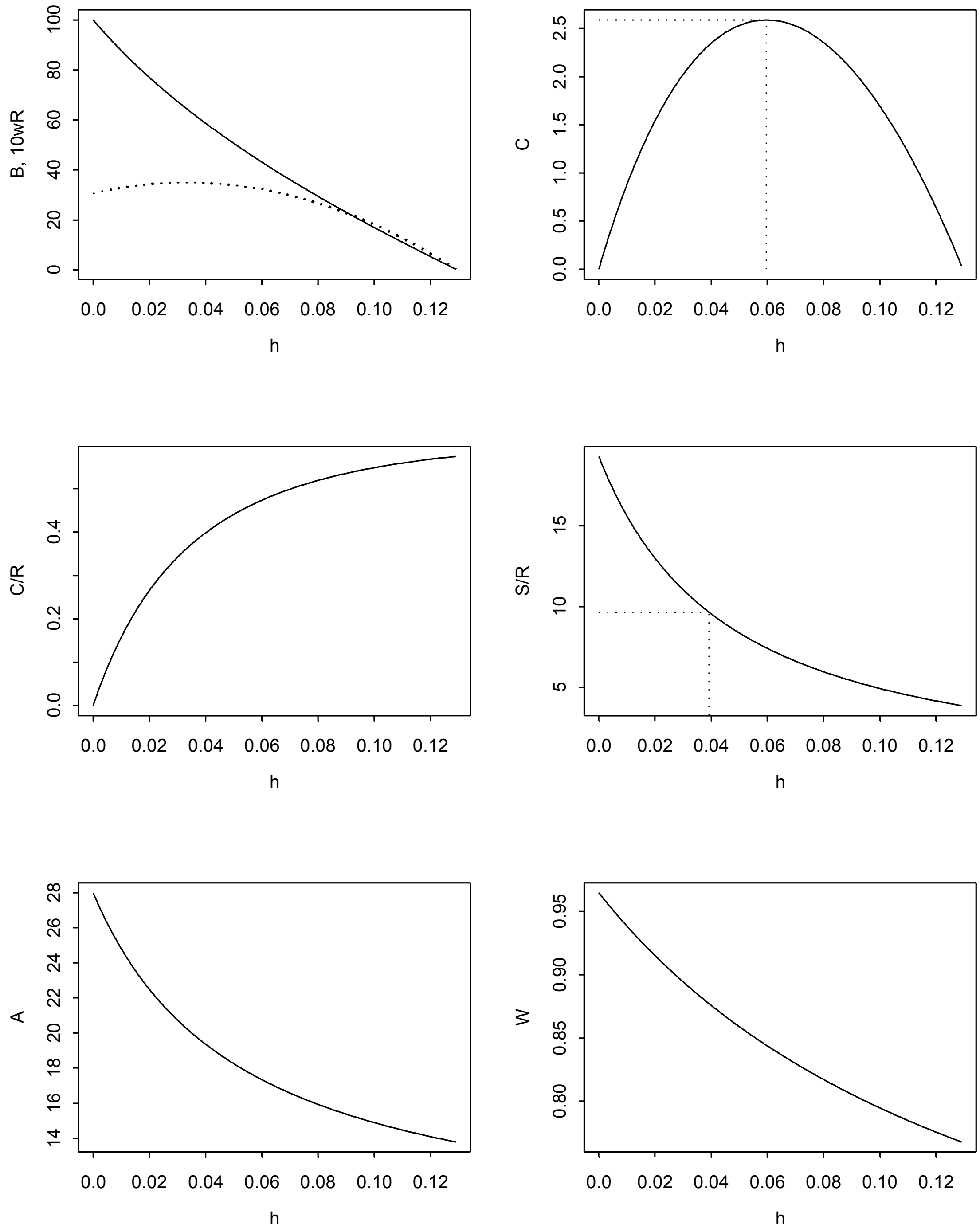


Figure 5.3.2. As in Fig. 5.3.1, equilibrium quantities in relation to a sustained harvest rate *h*, based on a Ricker model with $g = 0$ and biological parameters for Pacific ocean perch (Table 7.1, column 2).

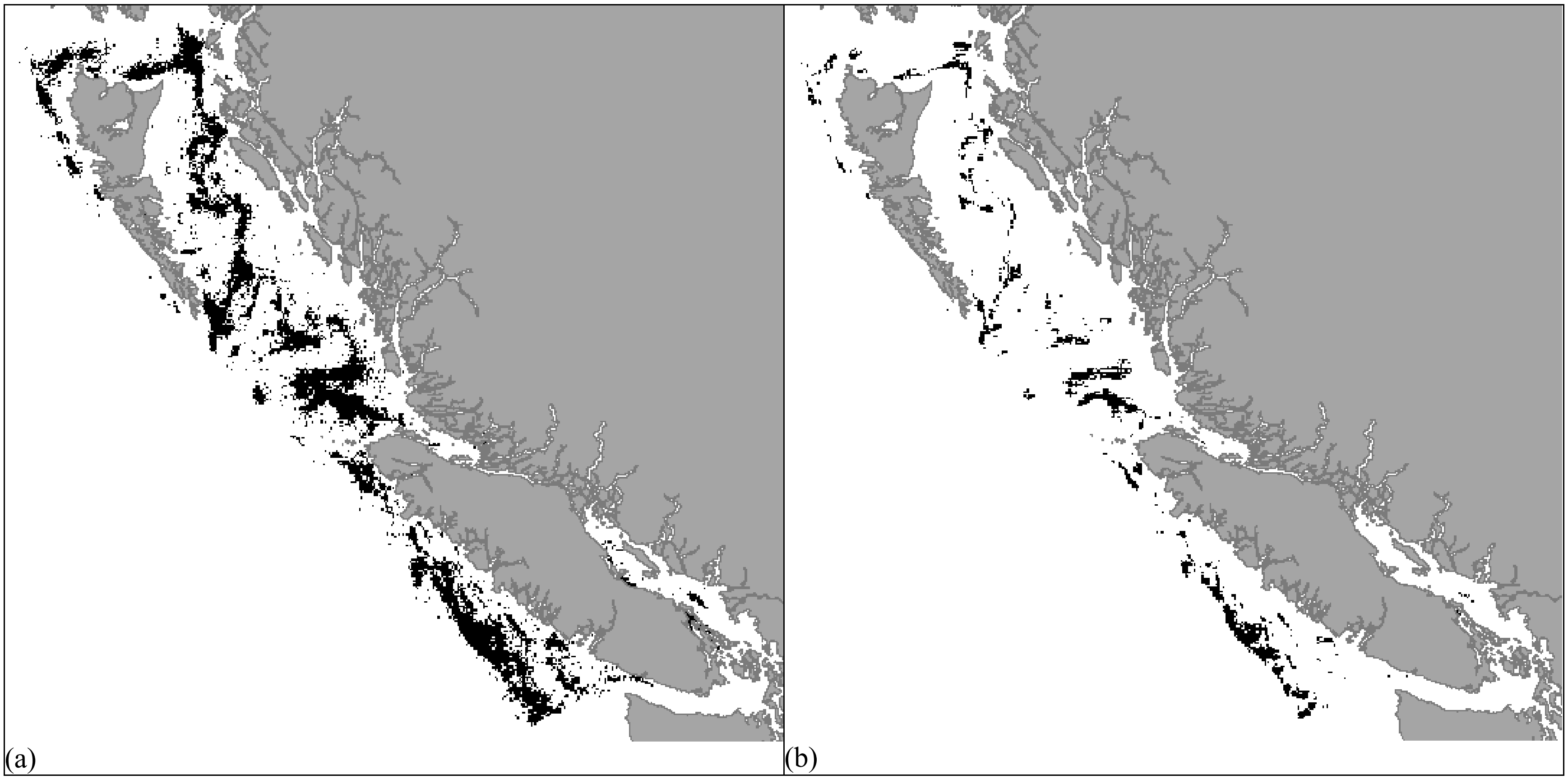


Figure 6.1.1. Blocks at least partially swept (a) and blocks fully swept (b) by the trawl fleet .

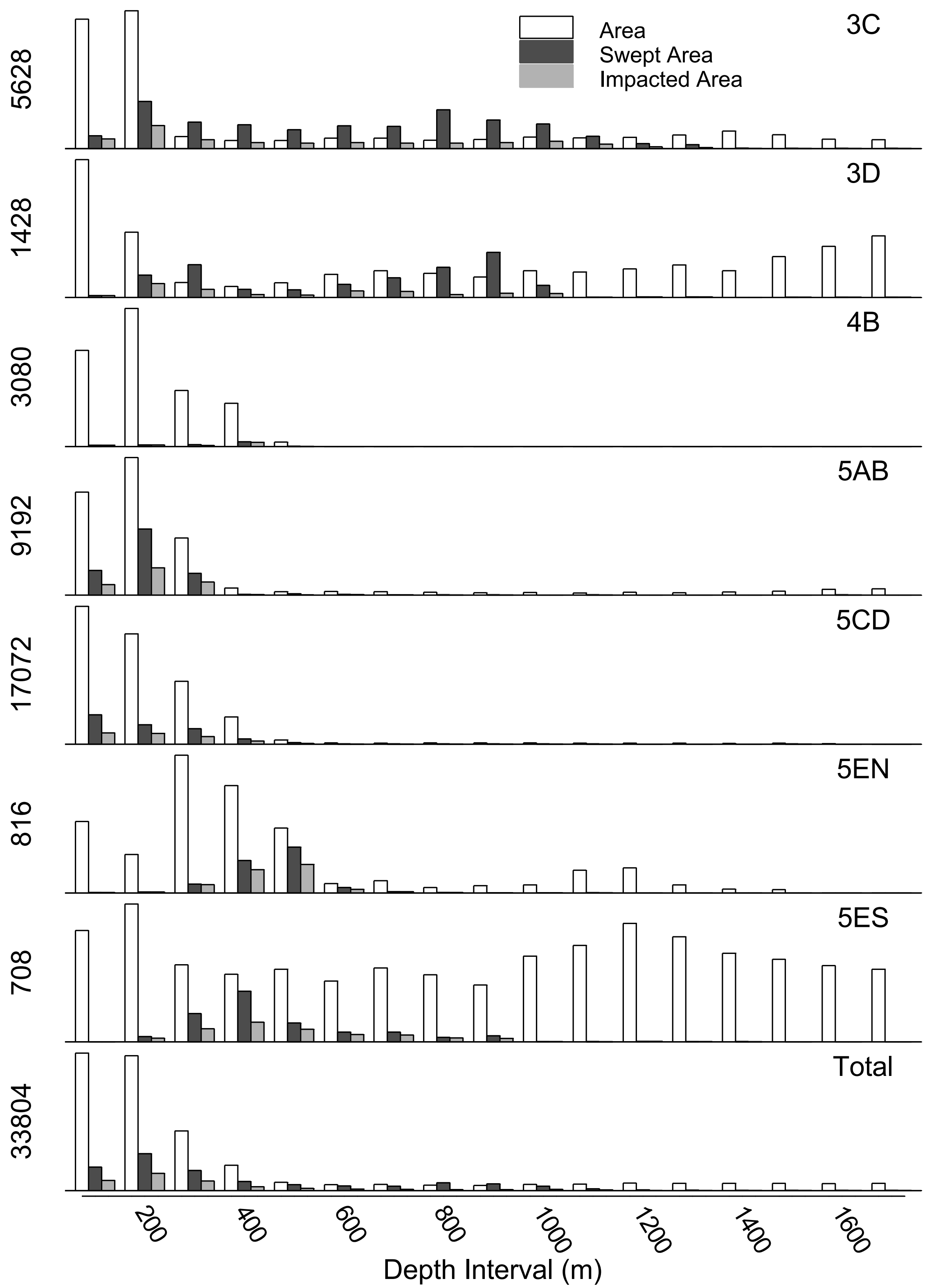


Figure 6.1.2. Areas swept and areas impacted by the trawl fleet in relation to available area, by depth and statistical area strata. Area = available bottom area, Swept Area = estimated area swept by trawl nets, Impacted area = actual bottom area impacted by nets. The number to the left of each plot indicates the scale of the largest bar in km^2.

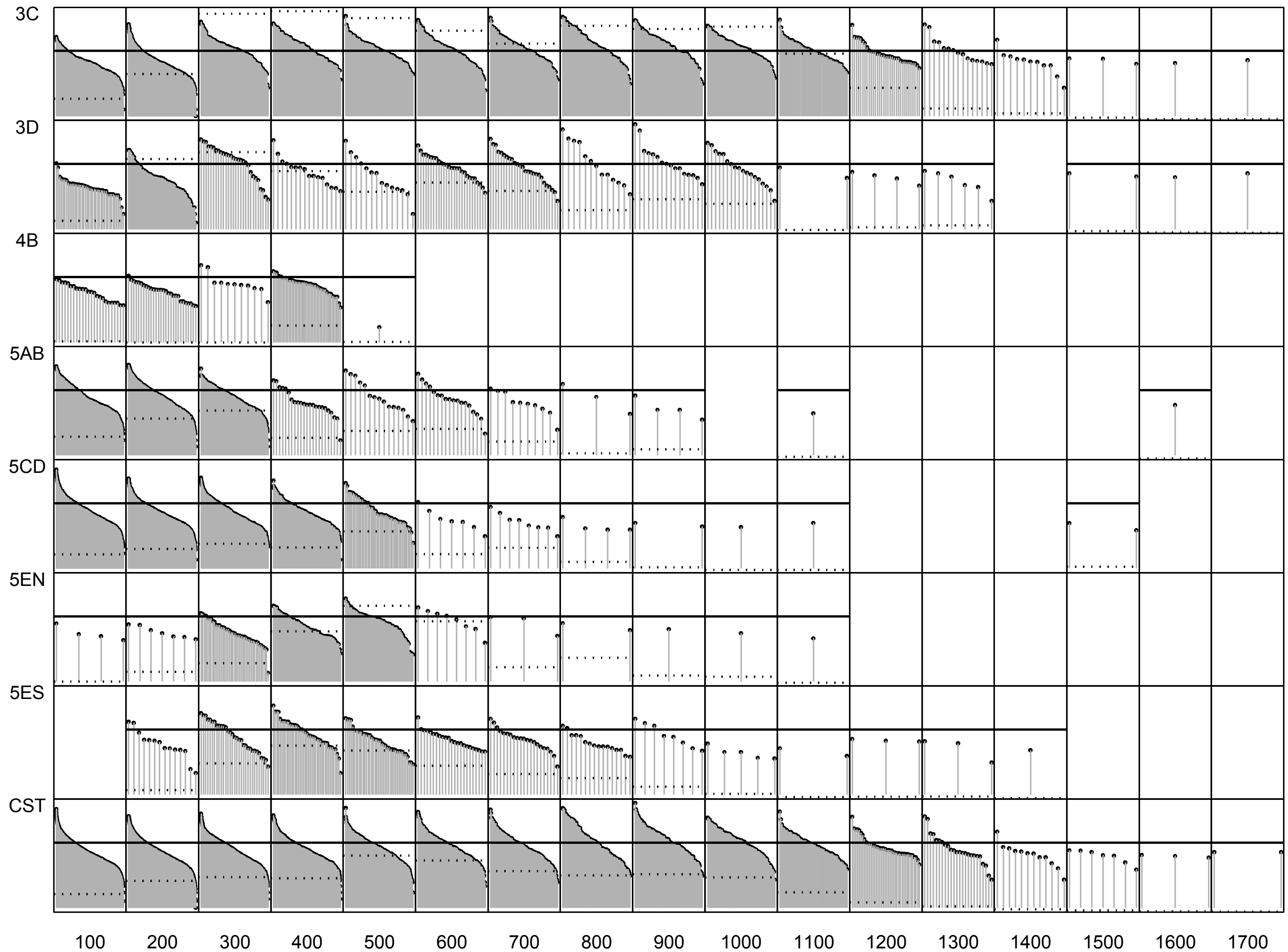


Figure 6.1.3. Distribution of swept area values in each stratum (Feb 16, 1996 – Dec 31, 1998). Each panel plots the swept area values of all blocks in a given stratum, on a log scale. The values are sorted in descending order from left to right. The solid horizontal line is drawn at $4km^2$. Thus, all points above this line represent blocks whose total area has been swept more than once. The dotted horizontal line indicates the proportion of available bottom area that has been swept in each stratum, where the height of each panel is 1.

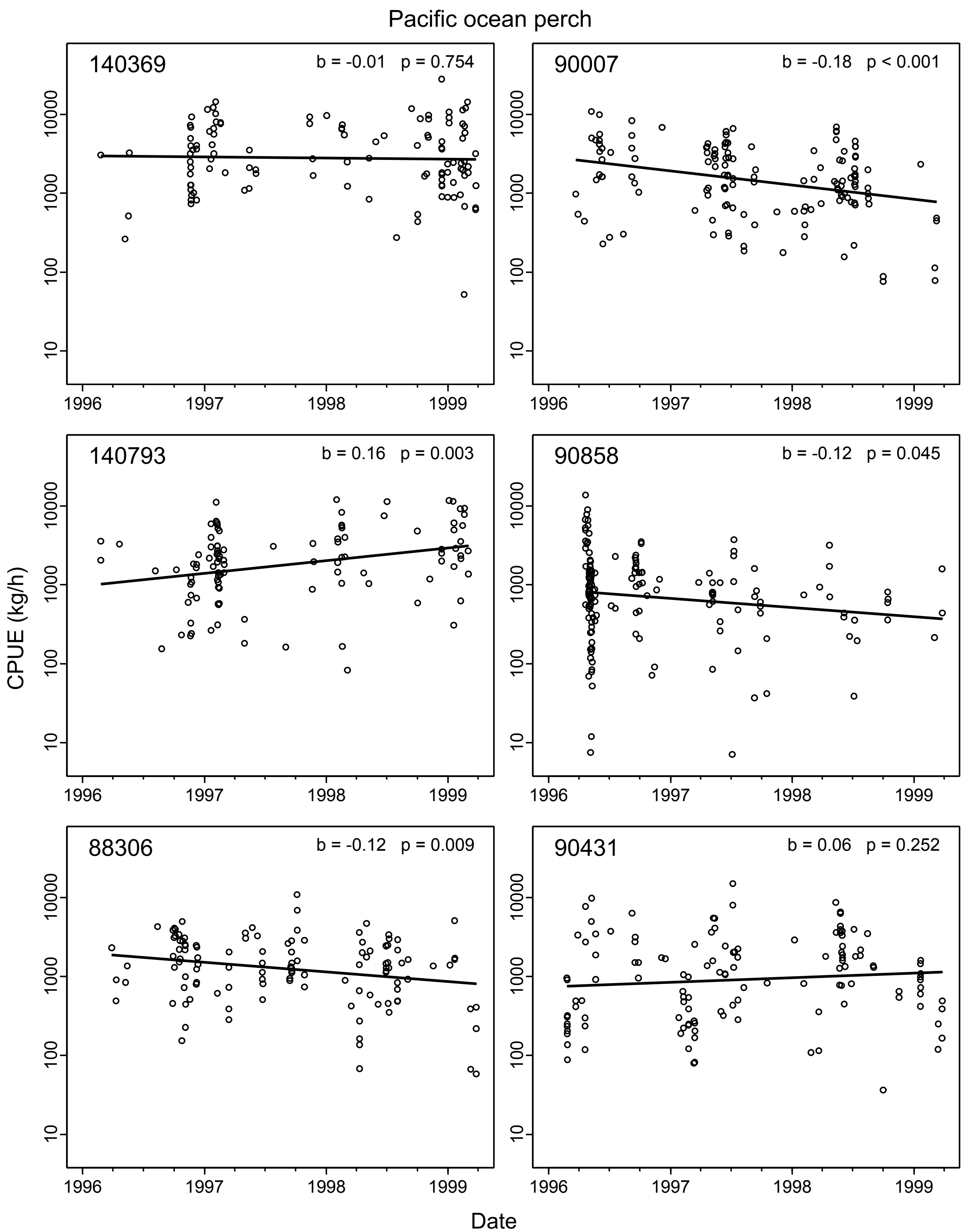


Figure 6.2.1. Pacific ocean perch CPUE over time for the six blocks in which POP catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

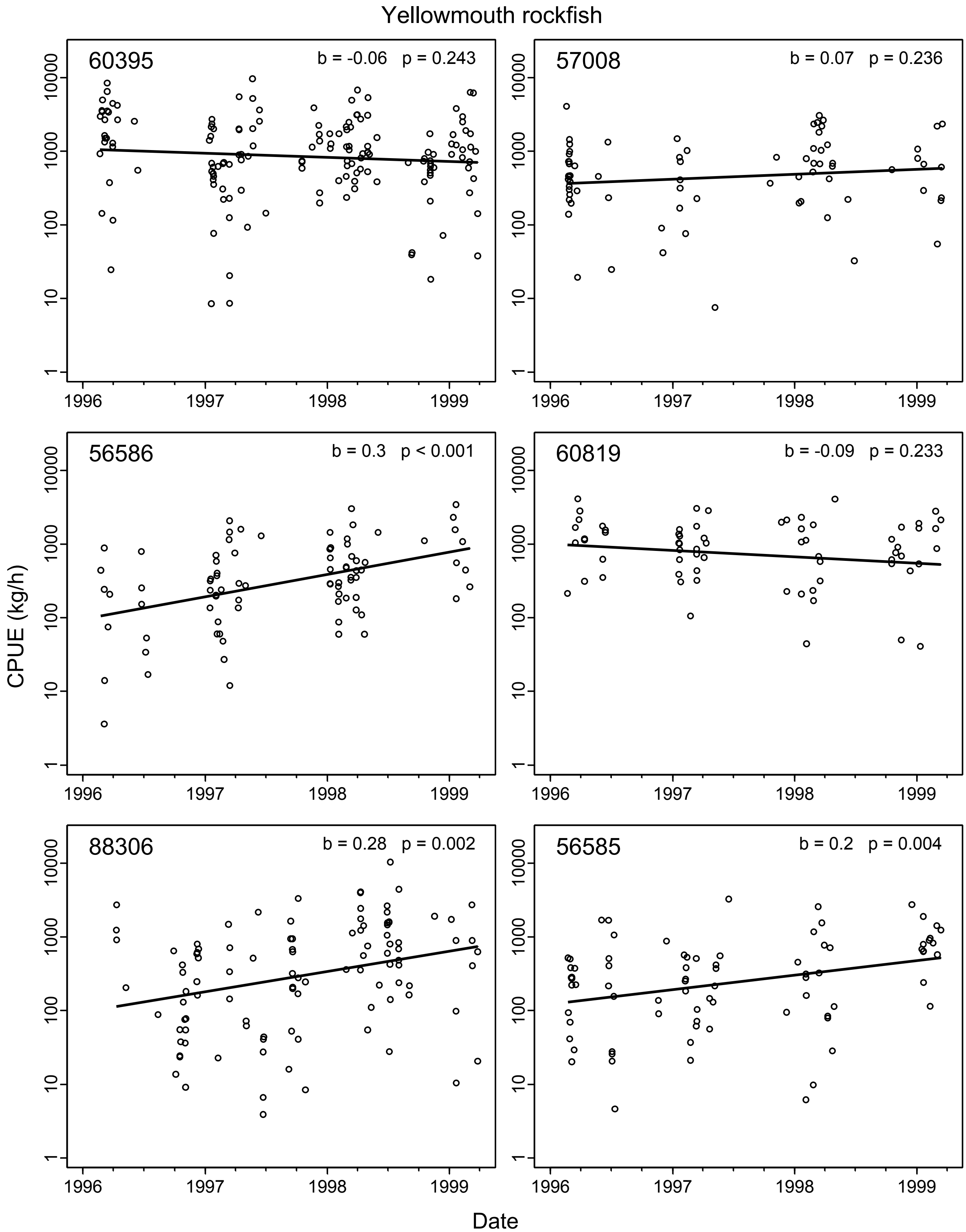


Figure 6.2.2. Yellowmouth rockfish CPUE over time for the six blocks in which yellowmouth catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

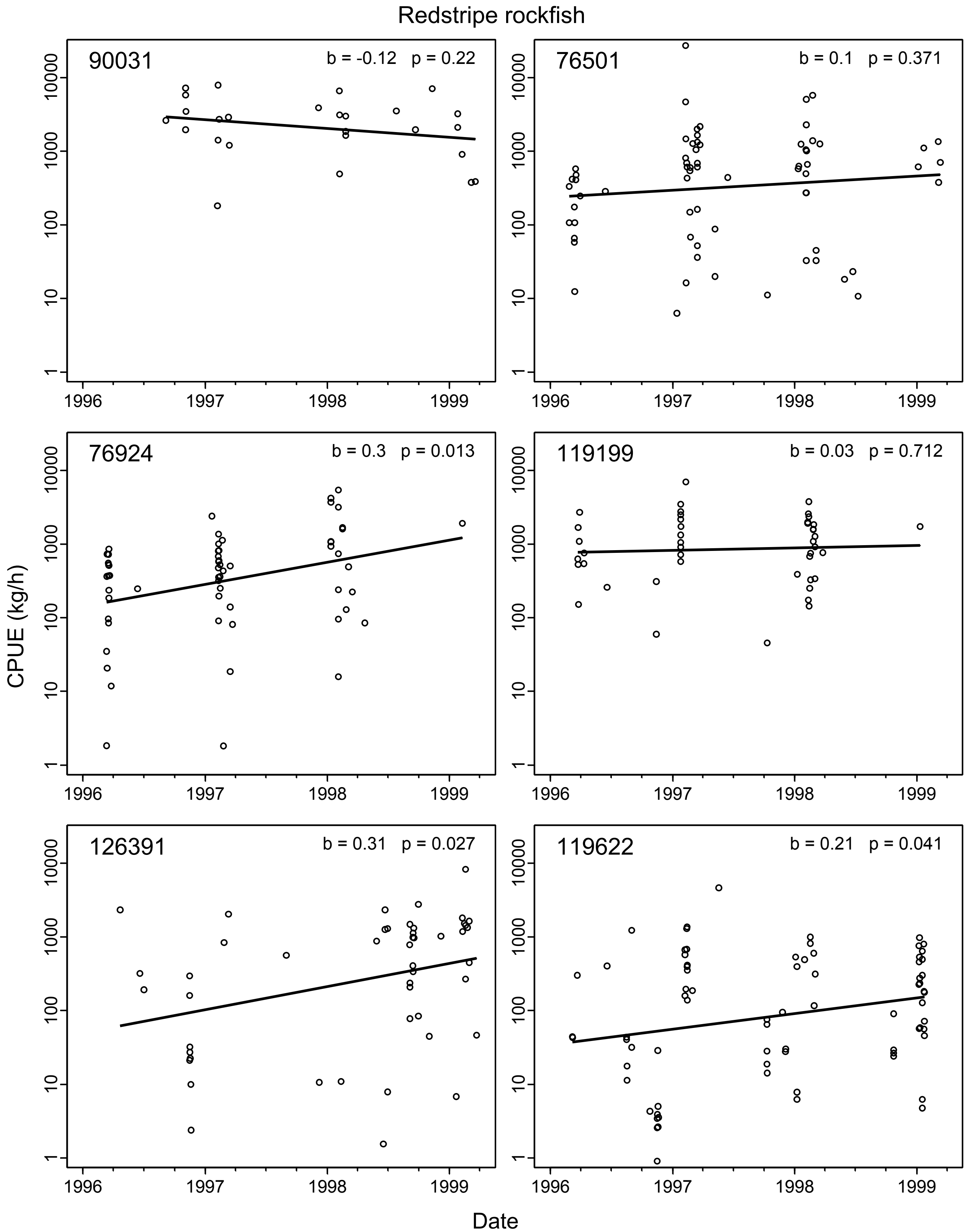


Figure 6.2.3. Redstripe rockfish CPUE over time for the six blocks in which redstripe catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

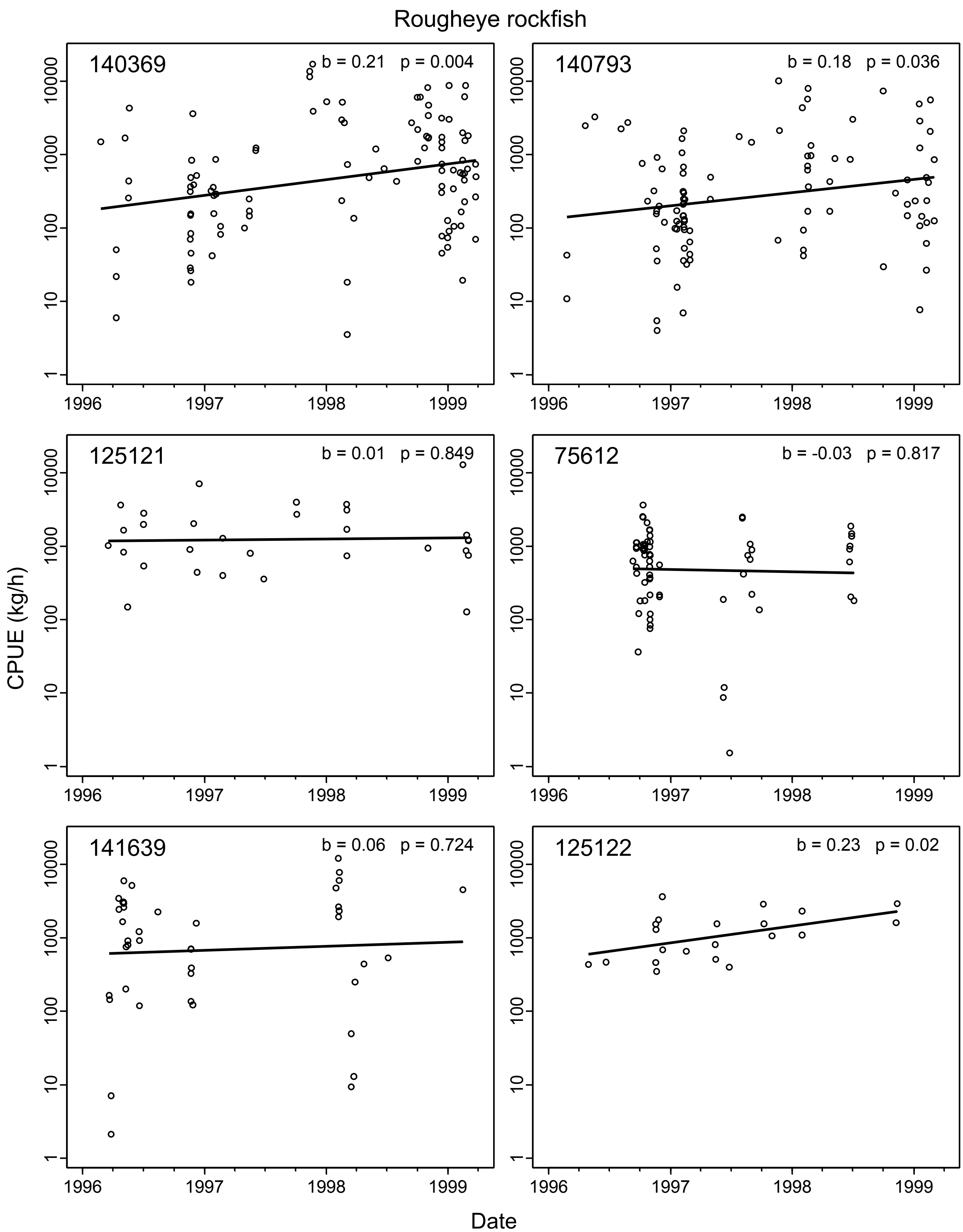


Figure 6.2.4. Rougheye rockfish CPUE over time for the six blocks in which rougheye catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

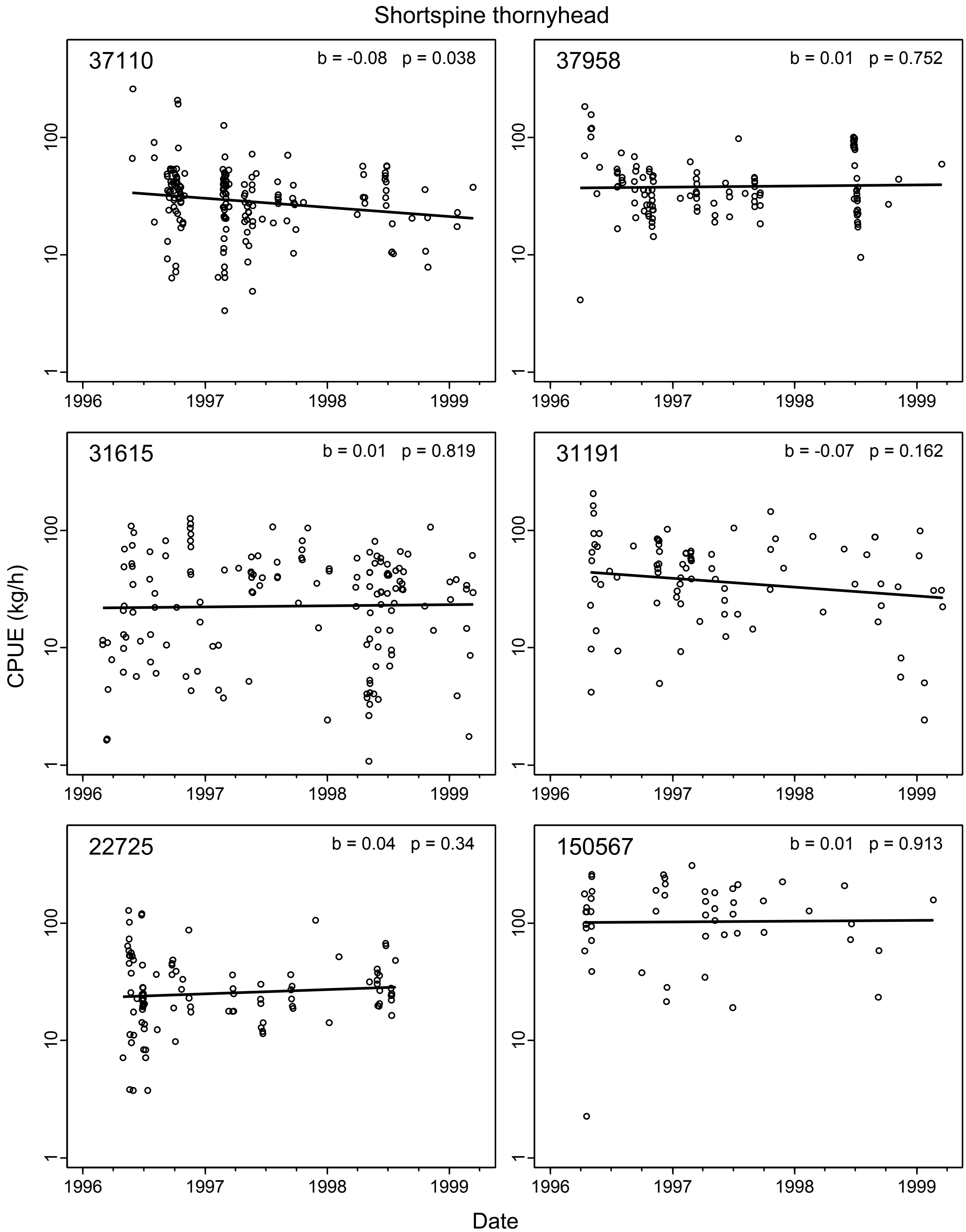


Figure 6.2.5. Shortspine thornyhead CPUE over time for the six blocks in which shortspine catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

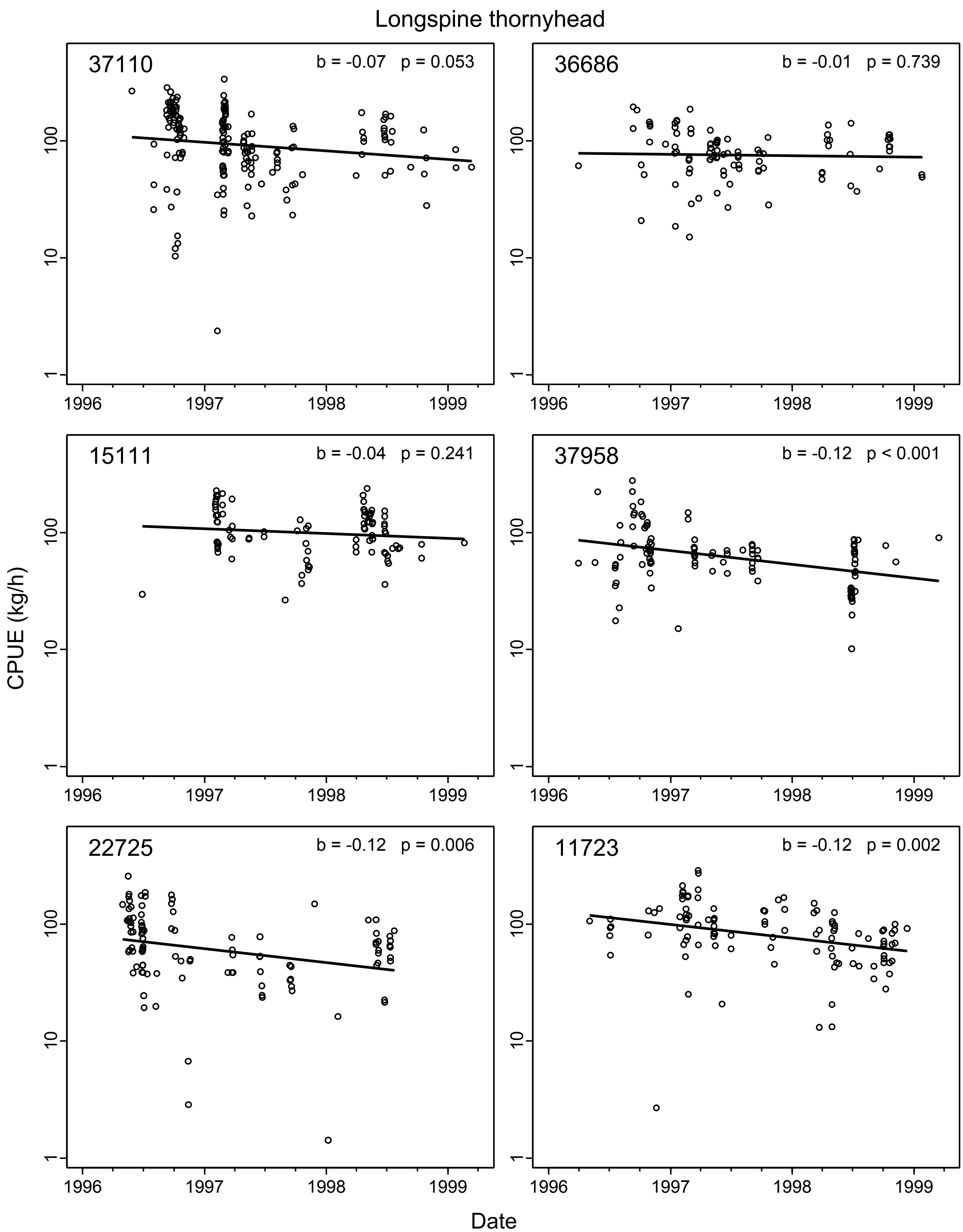


Figure 6.2.6. Longspine thornyhead CPUE over time for the six blocks in which longspine catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

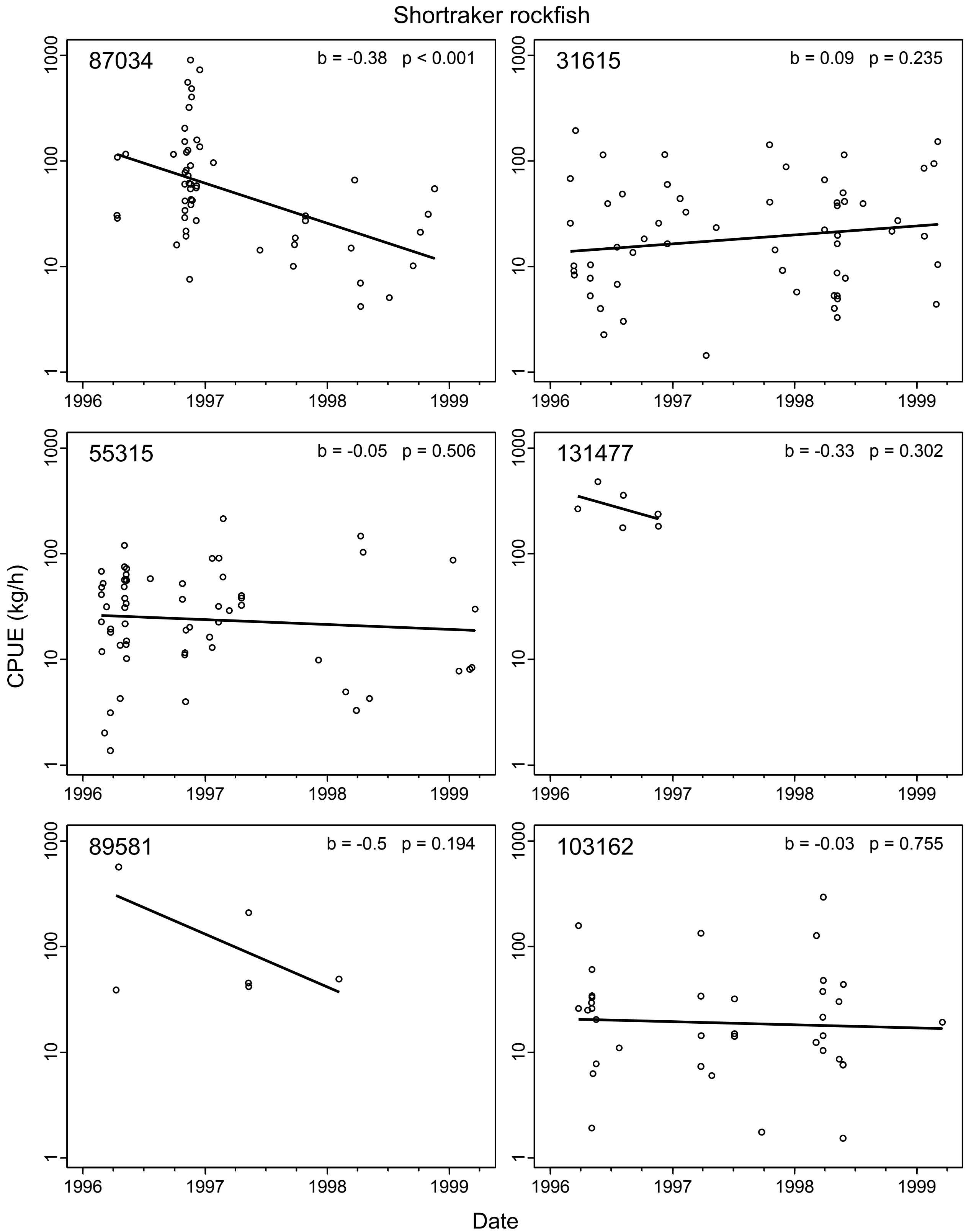


Figure 6.2.7. Shortraker rockfish CPUE over time for the six blocks in which shortraker catch was greatest. Slope (b) and significance (p) of regression line is indicated in upper right, block number in upper left.

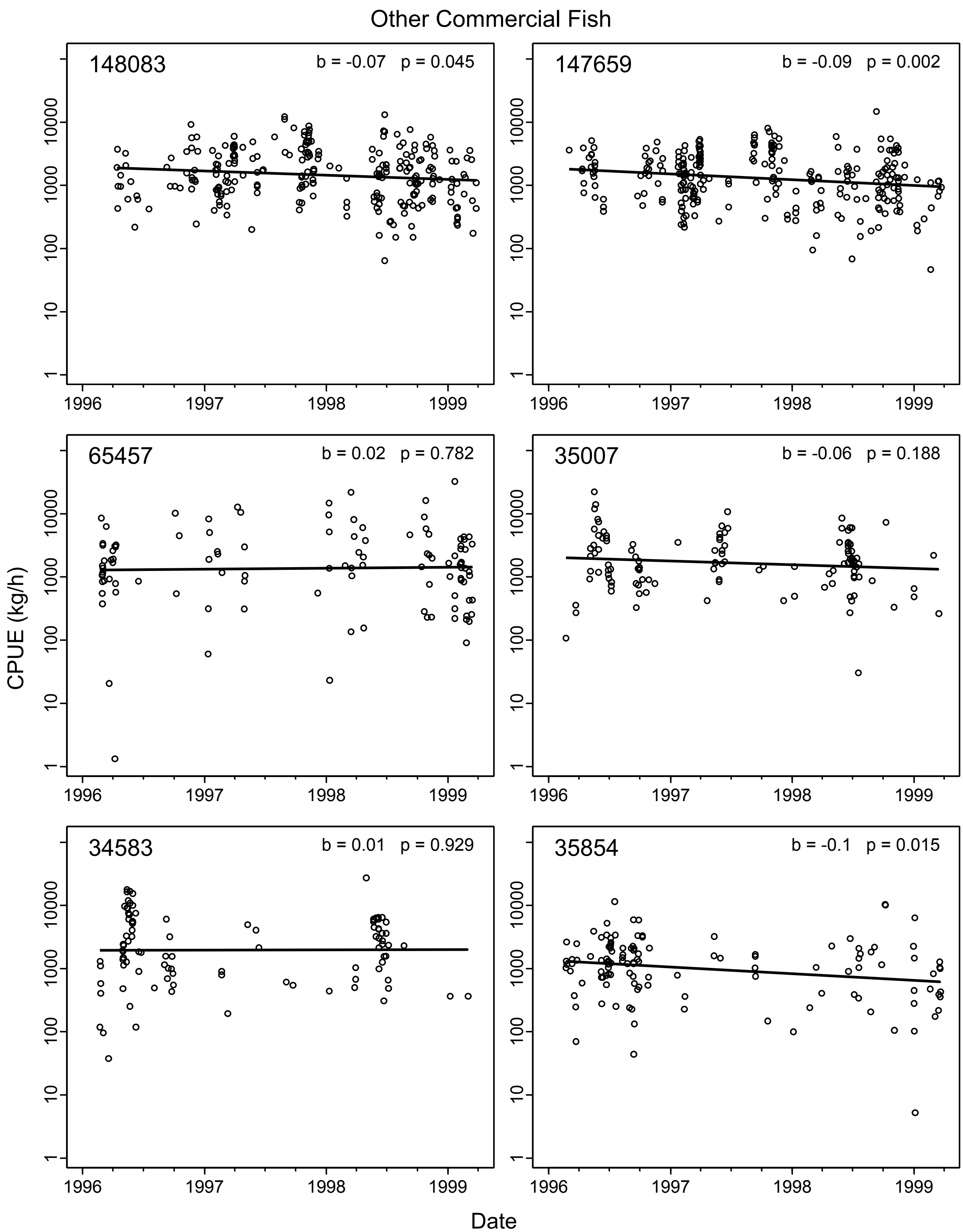


Figure 6.2.8. Other commercial fish CPUE over time for the six blocks in which commercial fish catch was greatest. Slope (b) and significance (p) of regression line in upper right, block number in upper left.

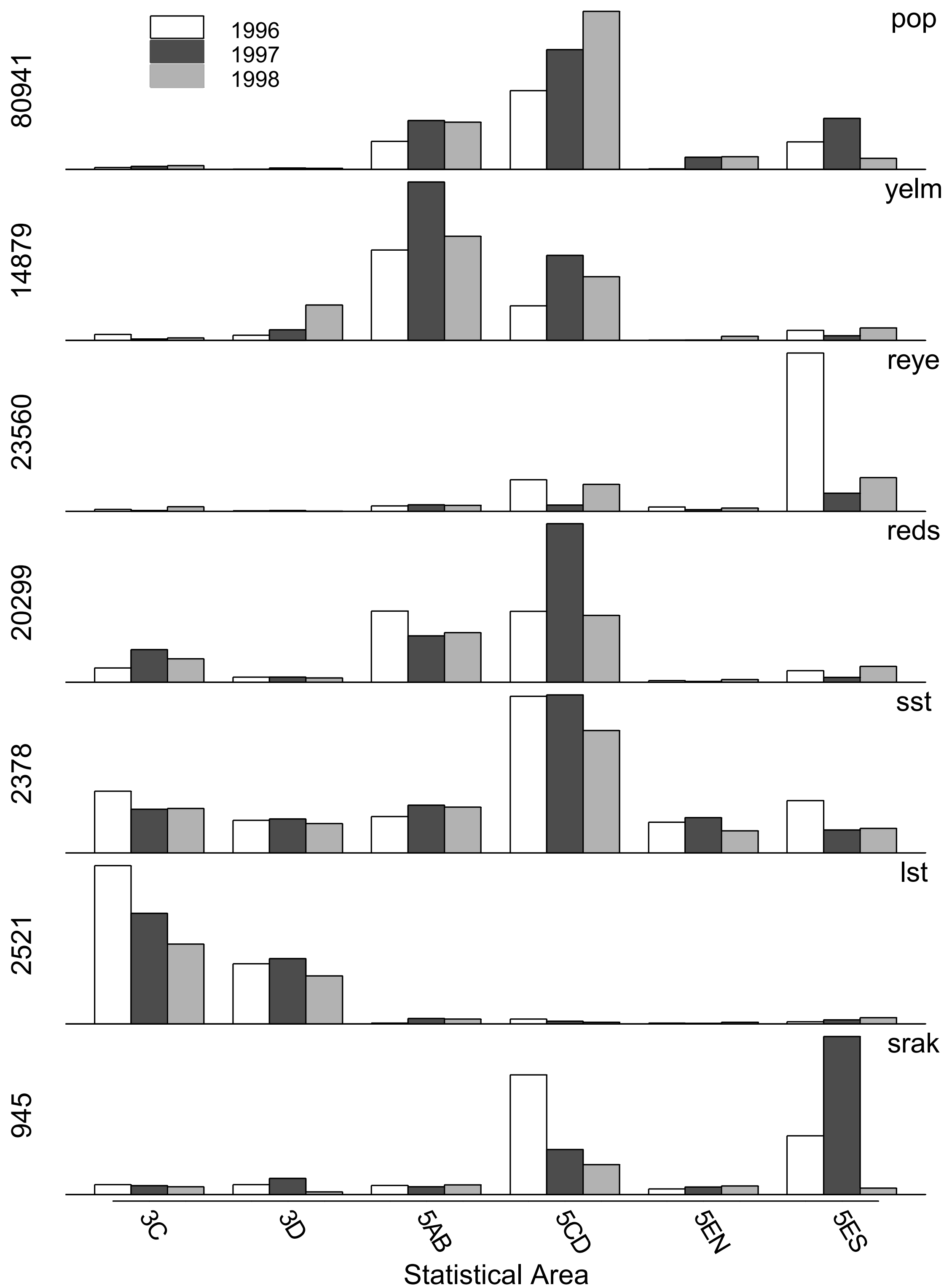


Figure 6.3.1. Biomass estimates for each slope rockfish species by statistical area. pop = Pacific ocean perch, yelm = yellowmouth rockfish, reye = rougheye rockfish, reds = redstripe rockfish, sst = shortspine thornyhead, lst = longspine thornyhead, srak = shortraker rockfish. The number to the left of each plot indicates the scale of the largest bar in tonnes.

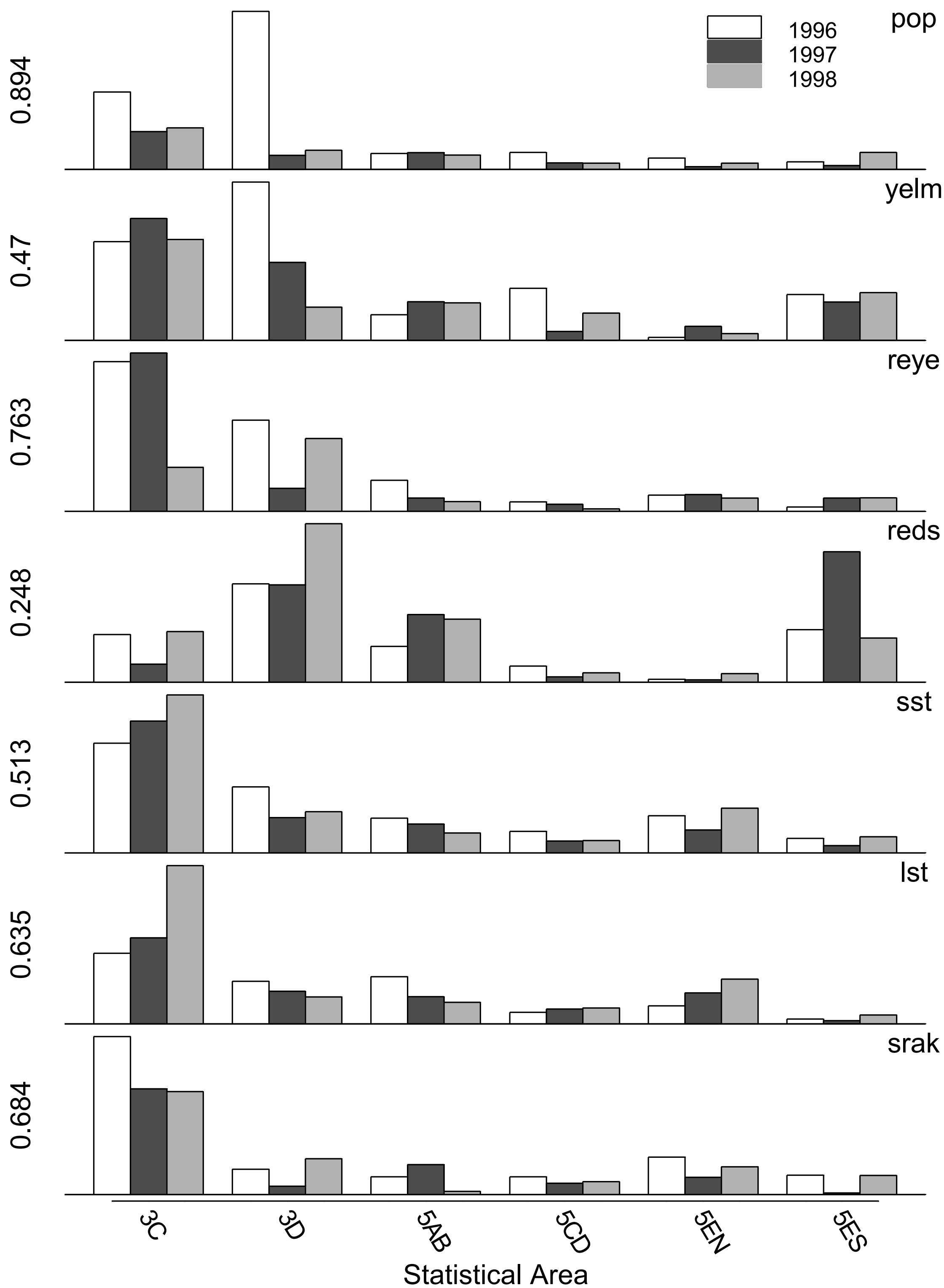


Figure 6.3.2. Slope rockfish exploitation rates by statistical area, based on biomass estimates and commercial trawl catch. pop = Pacific ocean perch, yelm = yellowmouth rockfish, reye = rougheye rockfish, reds = redstripe rockfish, sst = shortspine thornyhead, lst = longspine thornyhead, srak = shortraker rockfish. The number to the left of each plot indicates the scale of the largest bar.

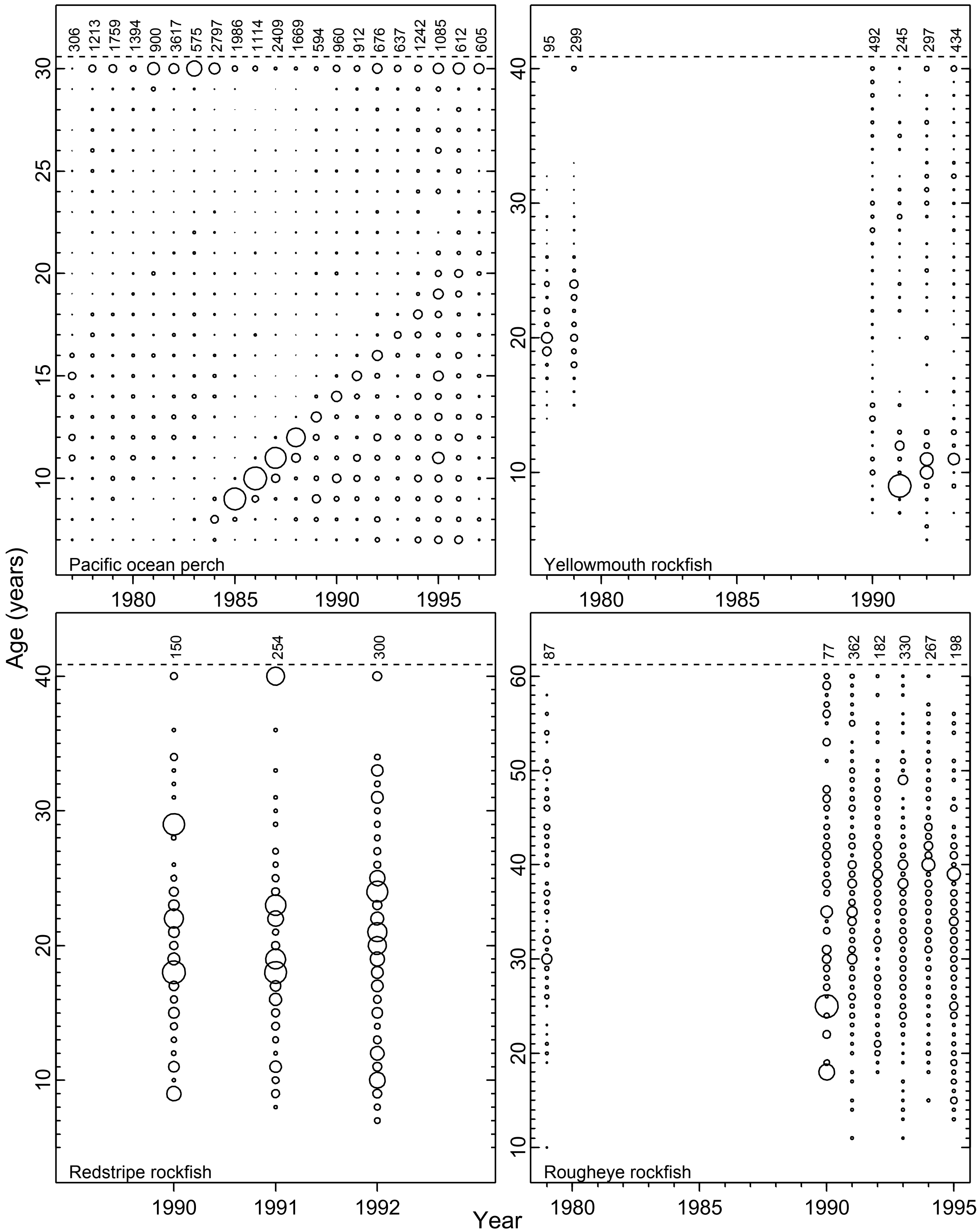


Figure 7.1. Coastwide proportion-at-age bubble plots for POP, yellowmouth, redstripe, and rougheye rockfish. Numbers along upper side of plots indicate number of specimens aged in each year. Ages outside ranges indicated are aggregated for all species but rougheye.

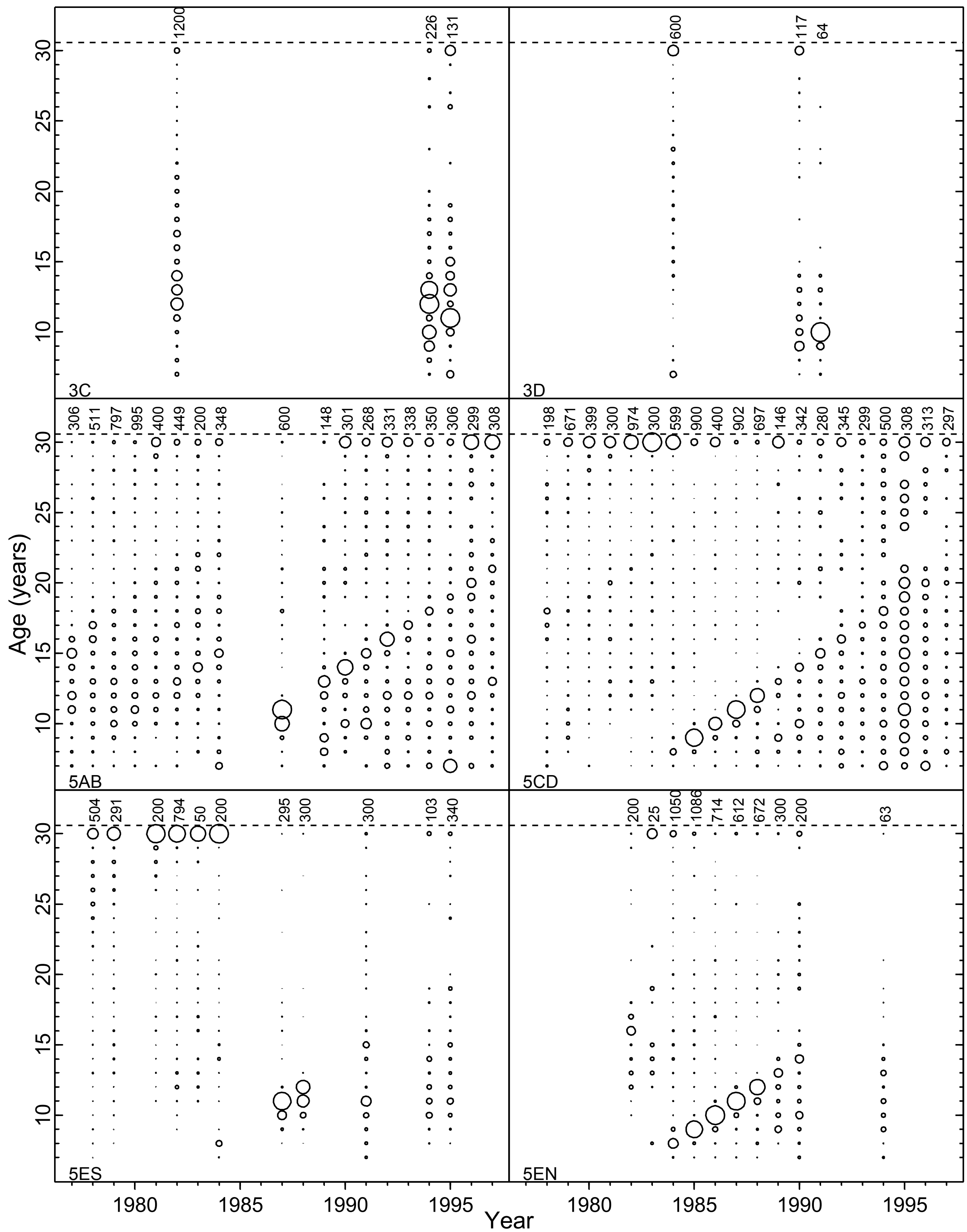


Figure 7.2. Pacific ocean perch proportion-at-age bubble plots for all assessment areas. Numbers along upper side of plots indicate the number of specimens aged in each year. Ages outside the range indicated are aggregated.

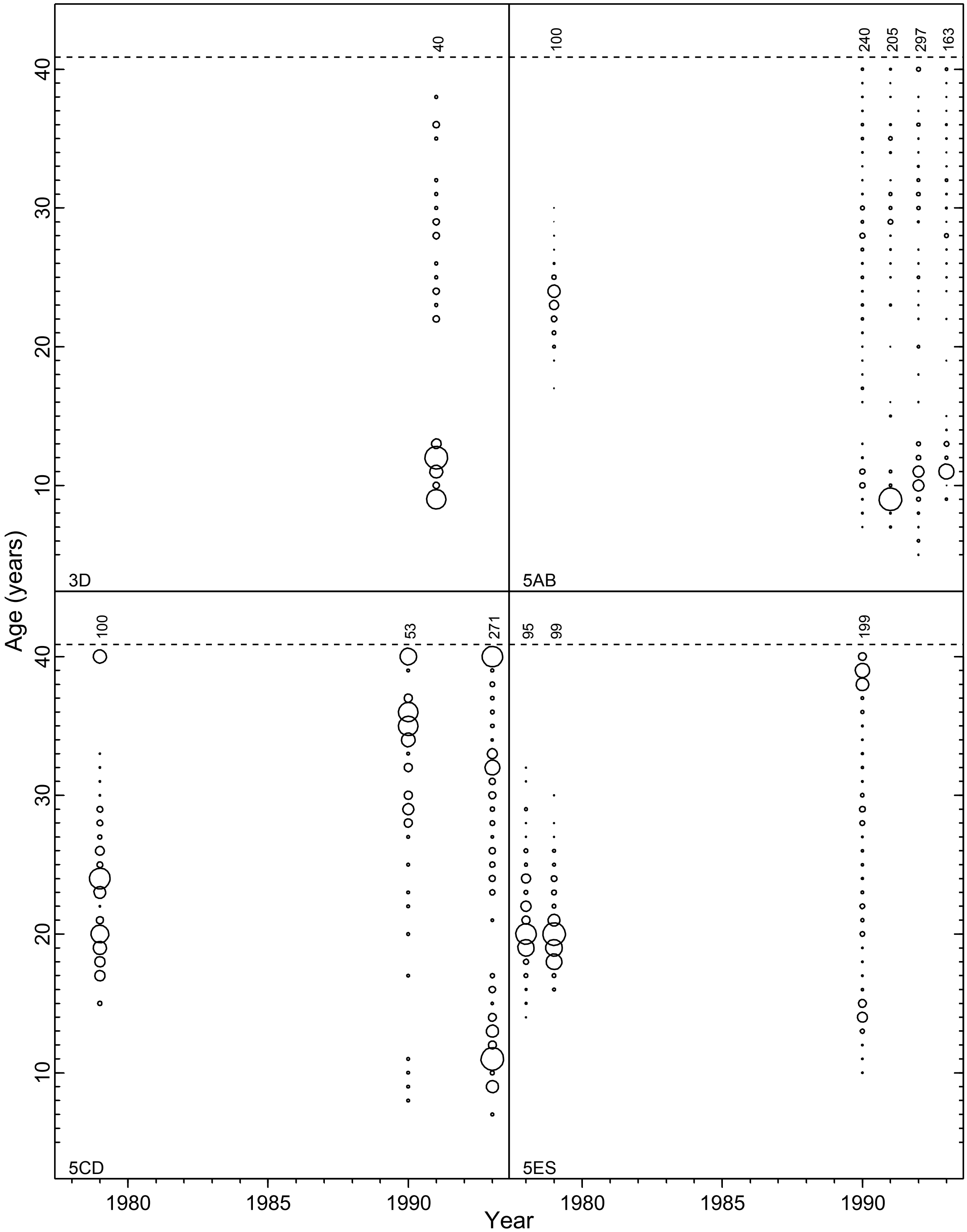


Figure 7.3. Yellowmouth rockfish proportion-at-age bubble plots for assessment areas 3D, 5AB, 5CD, and 5ES. Numbers along upper side of plots indicate the number of specimens aged in each year. Ages outside the range indicated are aggregated.

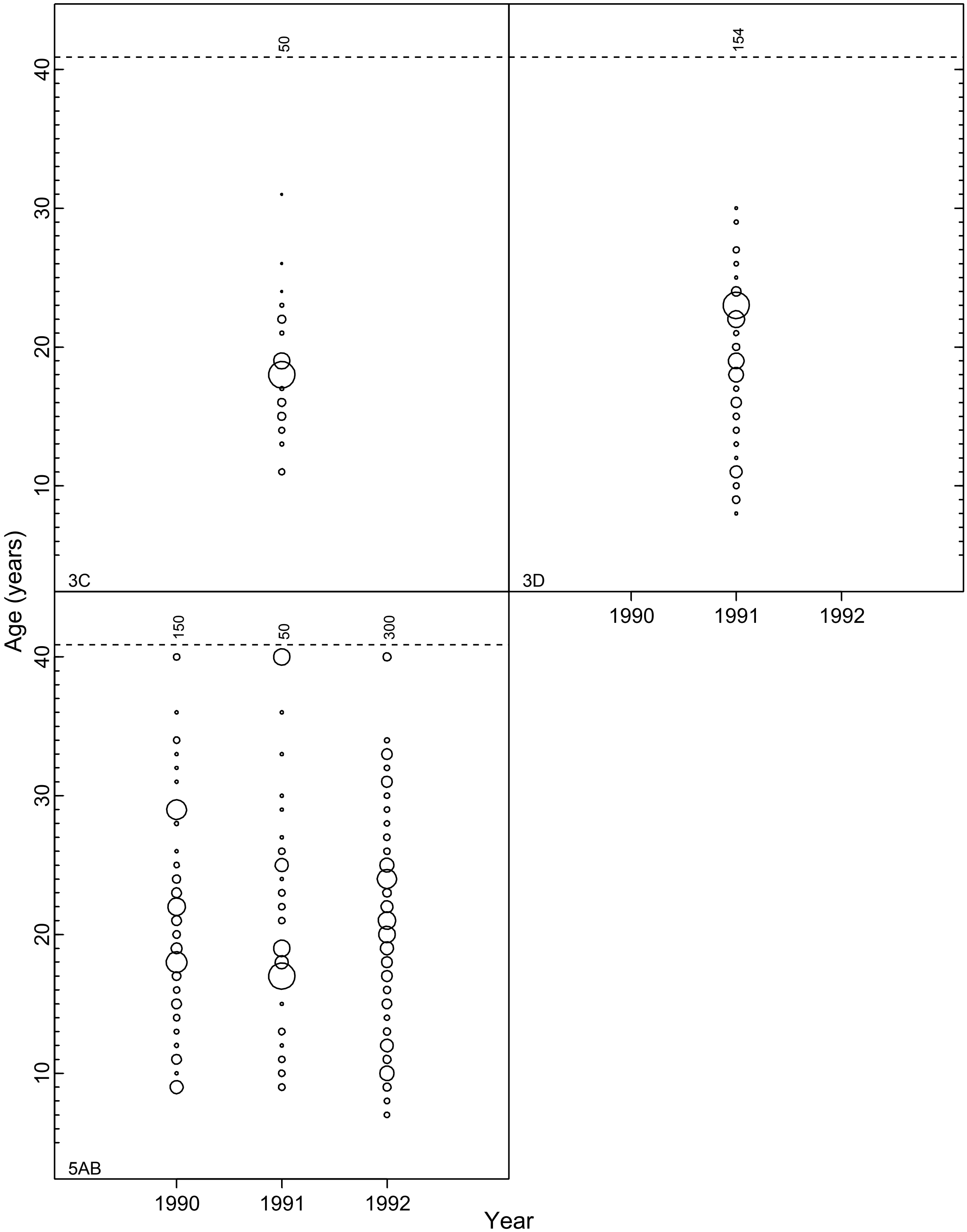


Figure 7.4. Redstripe rockfish proportion-at-age bubble plots for assessment areas 3C, 3D, and 5AB. Numbers along upper side of plots indicate the number of specimens aged in each year. Ages outside the range indicated are aggregated.

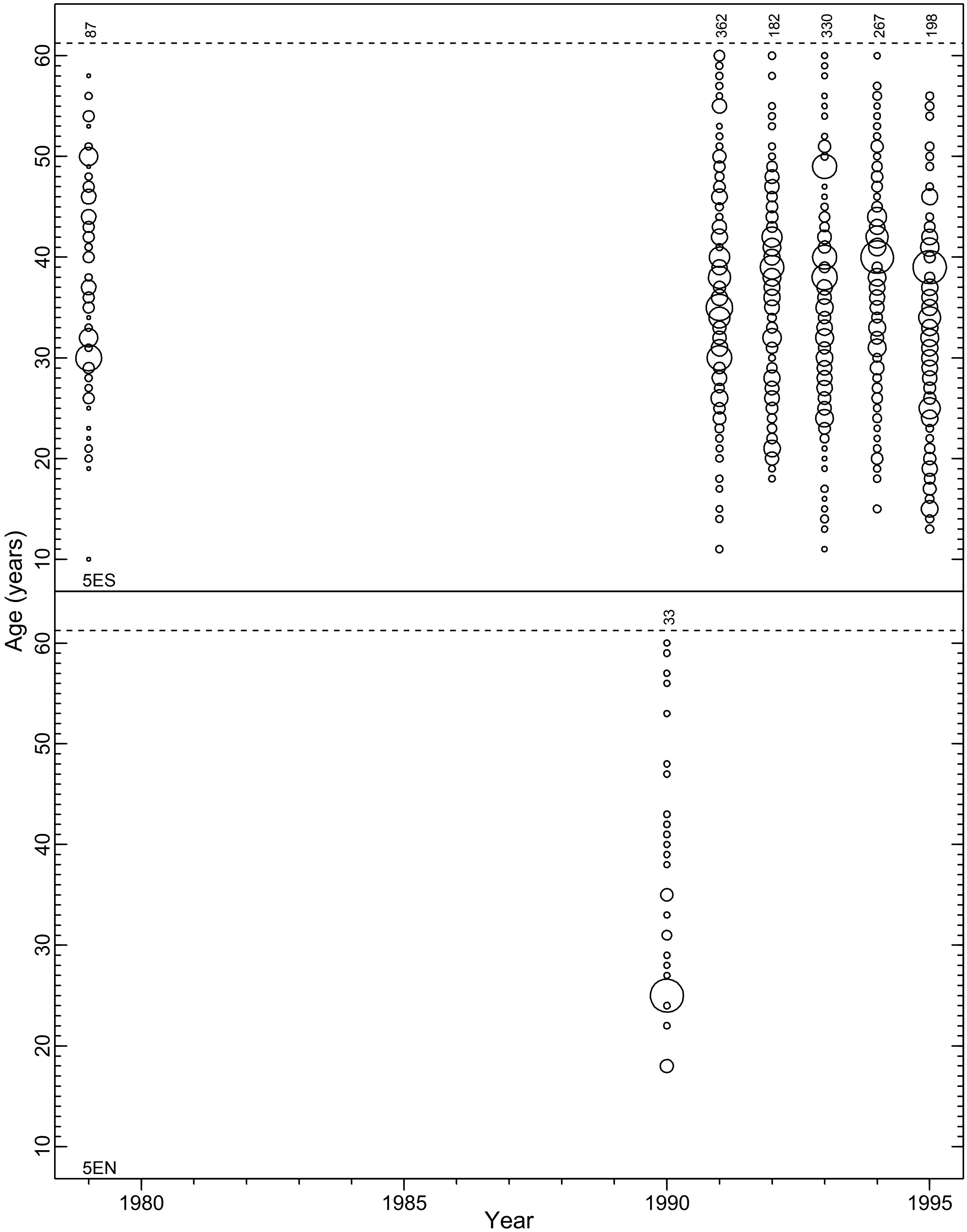


Figure 7.5. Rougheye rockfish proportion-at-age bubble plots for assessment areas 5ES and 5EN. Numbers along upper side of plots indicate the number of specimens aged in each year. Ages outside the range indicated are not aggregated.

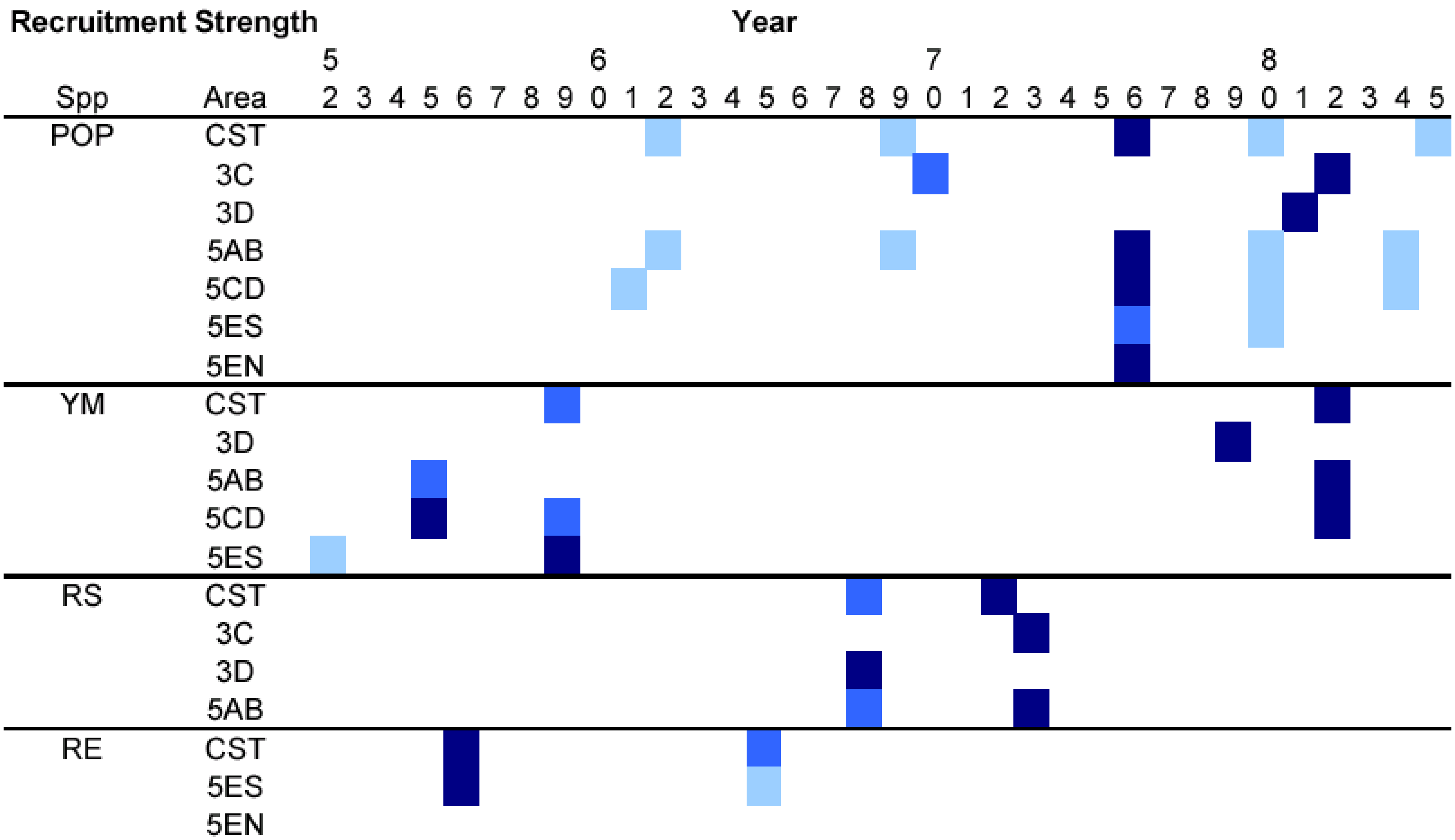


Figure 7.6. Visual representation of implied spawning years from proportion-at-age bubble plots and their relative strength (light to dark).

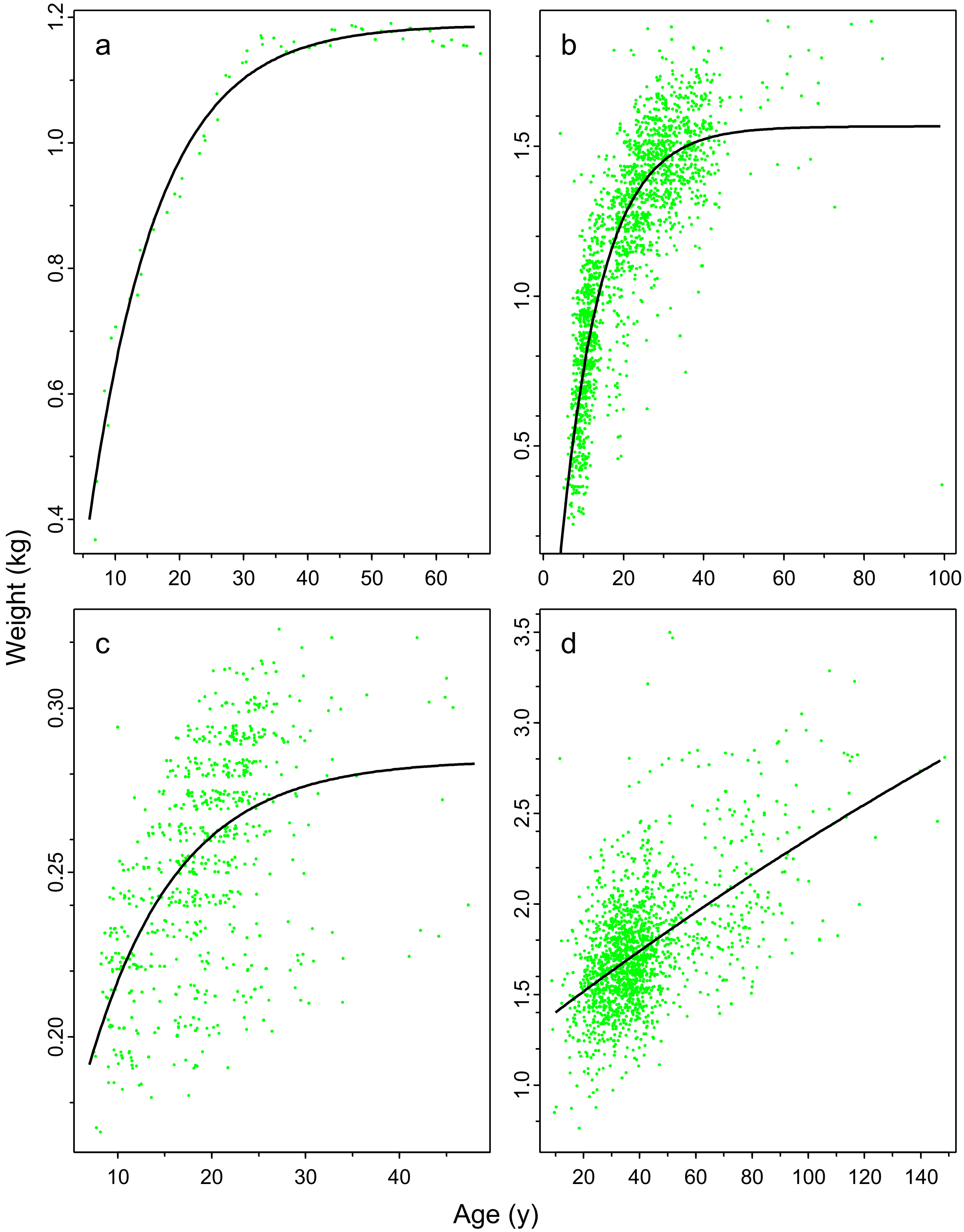


Figure 7.7. Weight vs age for (a) Pacific ocean perch, n = 61; (b) yellowmouth rockfish, n = 1862; (c) redstripe rockfish, n = 704; and (d) rougheye rockfish, n = 1696. Most weights were derived from weight-length data (yellowmouth: 100%, redstripe: 100%, rougheye: 97%). Curves through jittered data depict a von Bertalanffy relationship (see parameters in Table 7.1).

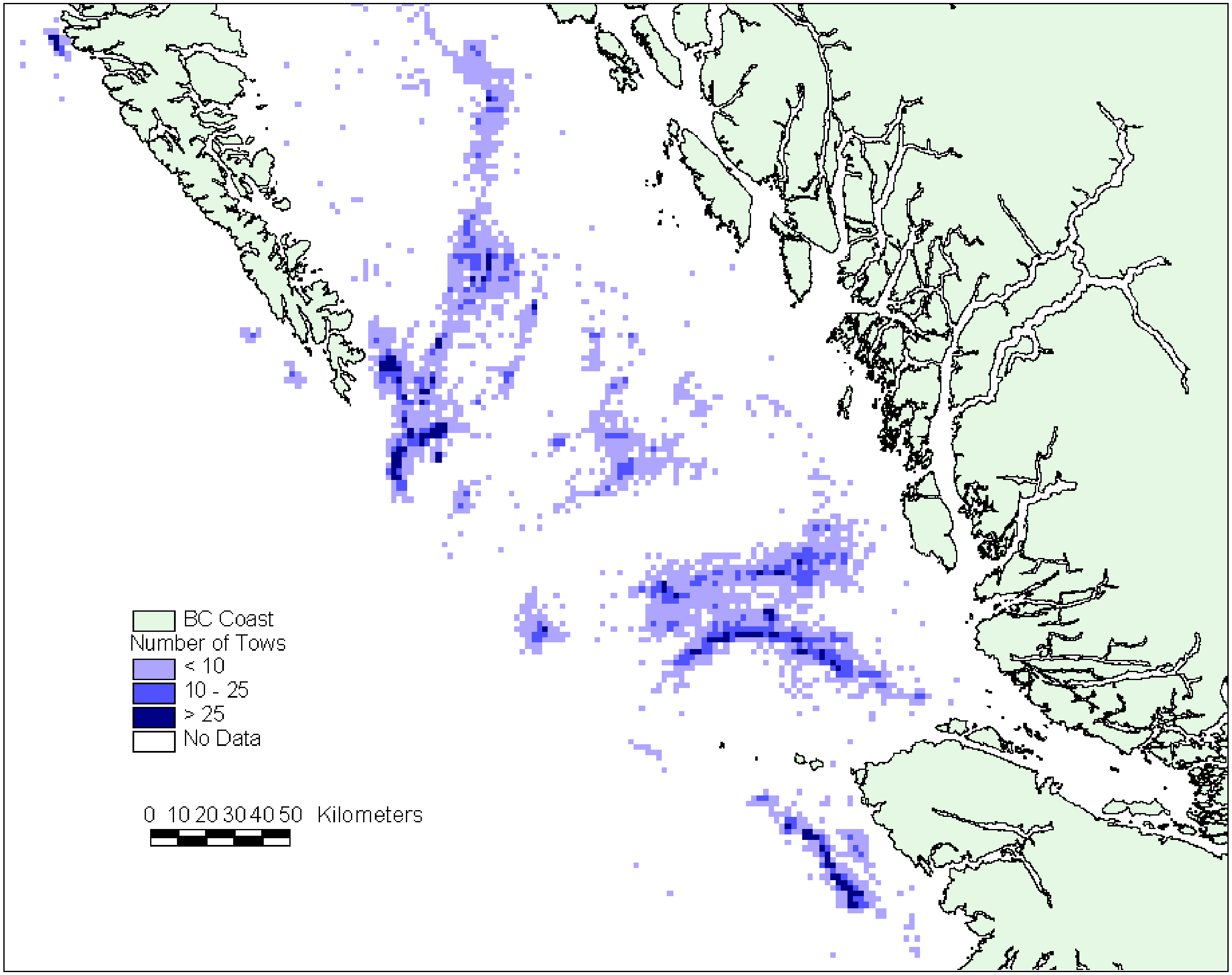


Figure 8.1. Number of tows catching bottom-dwelling slope rockfish in 4 km² blocks along the central BC coast, 1996–1999.

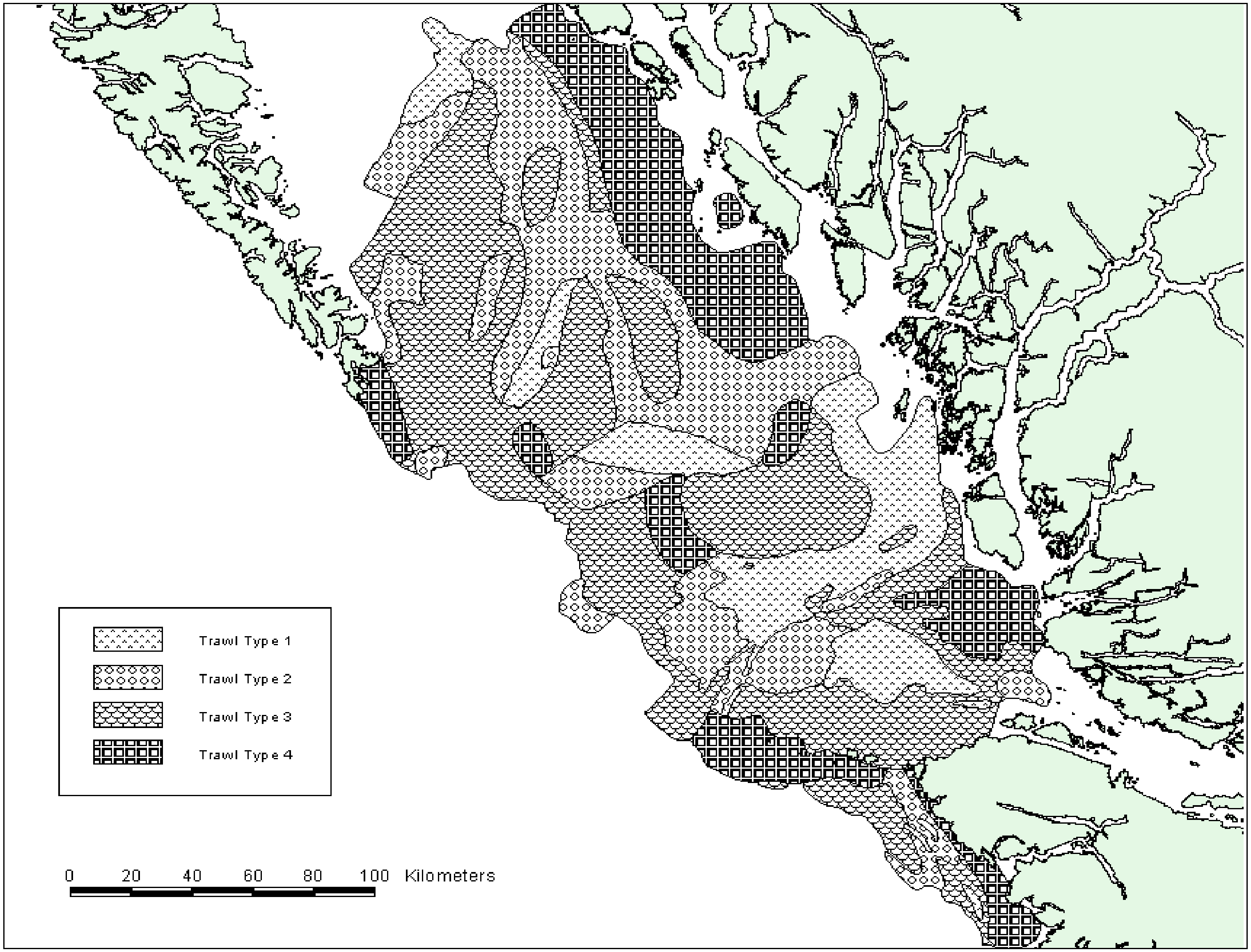


Figure 8.1.1. Classifications of bottom trawlability along the central coast of BC: Type 1 = net stays on bottom; Type 2 = rolling bottom, net occasionally leaves bottom; Type 3 = rolling bottom, net frequently leaves bottom; Type 4 = cannot set the net (see Table 8.1.1).

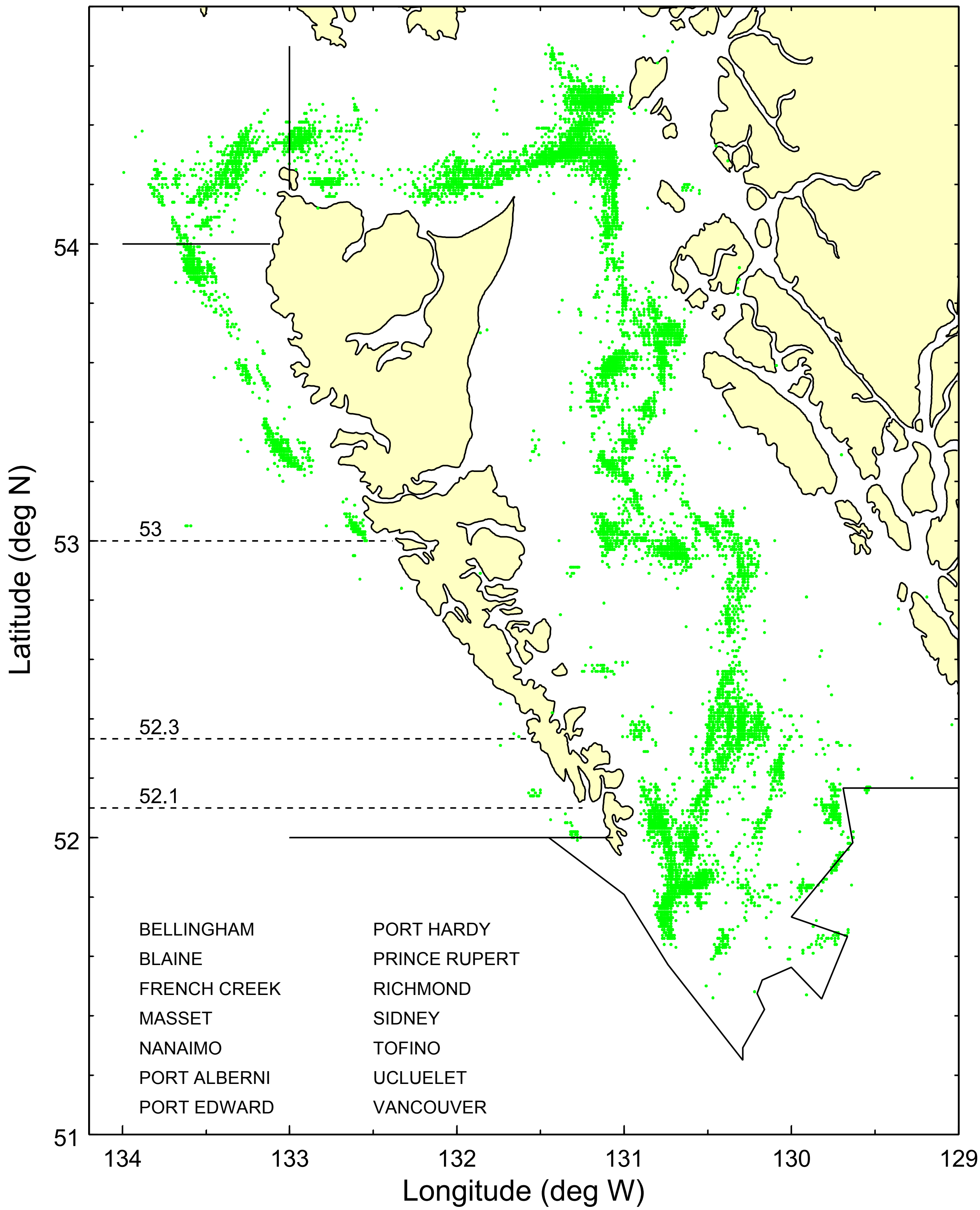


Figure 8.3.1. Three theoretical 5CD/5ES boundary shifts from 52°N to 52.1°N, 52.3°N, and 53°N. Points indicate tows which caught slope rockfish during the fishing years 1996–1998. Landing ports of these tows are indicated in lower left.

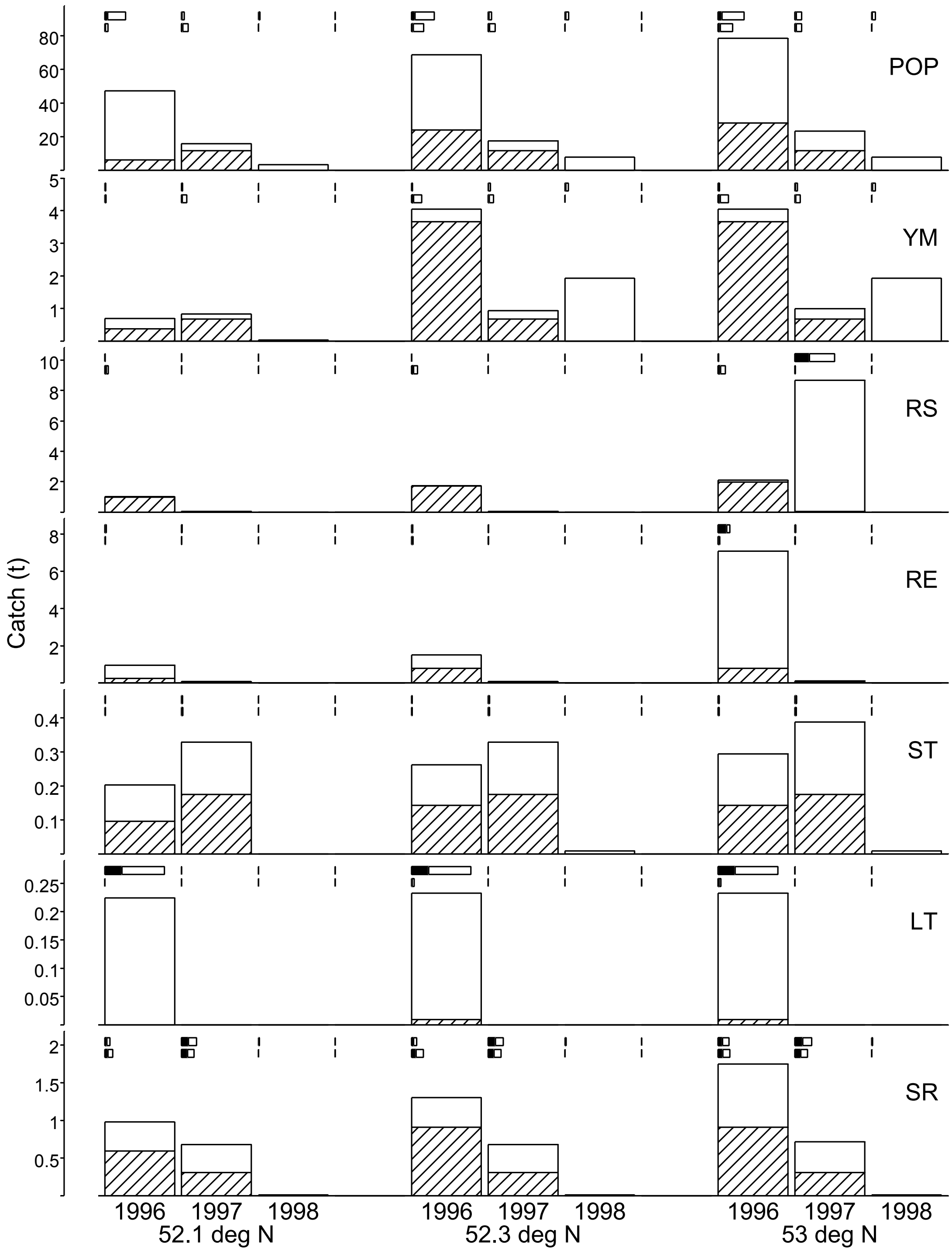


Figure 8.3.2. Catch in area affected by a theoretical 5CD/5ES boundary shift from 52°N to 52.1°N, 52.3°N, and 53°N for POP, yellowmouth (YM), redstripe (redstripe), rougheye (RE), shortspine (ST), longspine (LT), and shortraker (SR). Clear portion of barplot denotes catch by vessels landing in northern ports, striped portion denotes catch by vessels landing in southern ports. Horizontal bars above each catch bar denote northern-port catch (upper) and southern-port catch (lower) as a percentage of catch in areas 5CD (black) and 5E (white). Note: Horizontal bars are scaled to 25% (= width of catch bars).