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Analysis of ZN Hook and Line Logbook Date: Strait of Georgia Managment Region

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Abstract

Logbook data collected from the directed hook and line fishery for inshore rockfishes in the Strait of Georgia management region were evaluated for their ability to provide stock assessment information. Relative to alternative data sources, the structure of logbook data provides improved measures of fishing effort and finer spatial resolution of fishing locations. The management tactics applied to the fishery since 1986 are described and their influence on logbook data is considered. In the absence of fishery-independent indices, the utility of CPUE to index the stock is thought to be poor given the restricted mobility of rockfish relative to the capabilities of the fishing fleet (hyperstability of CPUE). Thus, it was concluded that CPUE may serve as a late warning of stock decline rather than a timely indicator.

Time series of catch per unit effort have declined throughout the Strait of Georgia region for quillback and copper rockfishes. In recent years, copper rockfish comprised a greater proportion of the landings in the Gulf Islands (statistical areas 17, 18, and 19) than formerly observed. Although the evidence is not conclusive given the available indicators, these analyses are consistent with a decline in the abundance of rockfishes, particularly in the southern Strait of Georgia. Suggestions are provided for future modeling of logbook data.

Résumé

Les données des registres de la pêche à la ligne dirigée des sébastes côtiers dans la région de gestion du détroit de Géorgie sont évaluées dans le contexte de l'évaluation des stocks. Par rapport à d'autres sources de données, la structure des données des registres permet une meilleure mesure de l'effort de pêche et une résolution plus fine des lieux de pêche. Les approches de gestion appliquées à la pêche depuis 1986 sont décrites et l'on évalue leur influence sur les données des registres. En l'absence d'indices indépendants de la pêche, il est indiqué que la valeur du PUE comme indice du stock est limitée étant donné la faible mobilité des sébastes par rapport à celle de la flottille de pêche (hyperstabilité du PUE). Il est donc conclu que le PUE constitue un indice tardif du déclin des stocks et non un indice en temps réel.

Les séries chronologiques des prises par unité d'effort des sébastes à dos épineux et cuivré ont diminué dans tout le détroit de Géorgie. Ces dernières années, le sébaste cuivré représentait une plus grande proportion des débarquements des îles Gulf (zones statistiques 17, 18 et 19). Bien que les indices ne permettent pas de tirer des conclusions, ces analyses font état d'une diminution de l'abondance des sébastes, notamment dans la partie sud du détroit de Géorgie. Des suggestions sont aussi faites relativement à la modélisation des données des registres.

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1. Introduction

In 1986, Fisheries and Oceans Canada (DFO) initiated a logbook program for the hook and line rockfish (*Sebastes*) fishery conducted in British Columbia. Participation in this fishery is limited to fishers holding a category Zn licence and is restricted to hook and line gear. In the Strait of Georgia management region, rockfish landings are dominated by quillback (*Sebastes maliger*), copper (*S. caurinus*) and yelloweye (*S. ruberrimus*) rockfishes; the former two species are a highly valued product in the burgeoning live fish market. The logbook program was developed to address shortcomings in the commercial fish slip catch database, which grouped rockfish catch into the "red snapper" and "other rockfish" species categories (Hand and Richards 1988, Hand *et al.* 1990). The red snapper category was considered to be yelloweye rockfish, while the other rockfish category encompassed all other rockfish species. In addition to the limited species resolution, the fish slip database recorded catch locations as DFO statistical areas and effort as days fished. In this paper, logbook data recorded by Zn licenced fishers in the Strait of Georgia region are analyzed to determine their ability to provide assessment information on inshore rockfishes. In addition, the management tactics applied to the fishery since 1986 are described and their influence on logbook data is considered.

There are no time series of fishery independent data for the hook and line rockfish fishery; the only available indices of stock status are derived from commercial fish slip or logbook data. Although a time series of fishery independent data does not exist, surveys have been conducted at various locations in the Strait of Georgia (Richards and Cass 1987, Richards and Hand 1987, Richards *et al.* 1988, Yamanaka and Richards 1993). The logbook data provide a finer spatial and temporal resolution of catch and effort data than is possible with the commercial fish slip data. In concert with the newly established dockside monitoring program (DMP), logbook data enable improved accounting of catch by species relative to fish slip data.

Impacts of the hook and line fishery on inshore rockfishes have proven difficult to assess due to the multi-species nature of the fishery and the variety of gear configurations employed. Mortality of inshore rockfishes arises not only from the Zn fishery but also from the recreational fishery, First Nations allocations, and incidental catch in halibut, salmon troll, and dogfish fisheries. The biology of *Sebastes* compounds the assessment problem as described by Francis (1986), Leaman (1991), and Kronlund (1997). Specifically, rockfishes are a long-lived species complex with low natural mortality. Inshore species tend to be relatively sedentary and exhibit affinity to specific habitat (Matthews 1990, O'Connell and Carlile 1993, Richards 1986).

There have been four developments in the hook and line rockfish fishery in the Strait of Georgia that may have significant impacts on the logbook data:

1. The application of total allowable catch (TAC) restrictions beginning in 1991;

2. The implementation of limited entry in 1992 which reduced the number of licences from 592 to 74 and coincided with a significant reduction in TAC;

3. The application of fishing periods with species-based catch limits beginning in 1995;

4. The establishment of mandatory dockside monitoring of landings beginning in 1995 for all landings under a Zn licence category.

The logbook data were analyzed to determine the impacts of the first two developments. The effects of fishing periods and the dockside monitoring program cannot be evaluated until a database is available to link the two data sources.

Management regions represent geographic divisions of coastal British Columbia (B.C.), each of which contain statistical areas. The terms statistical area and area are used interchangeably in this document, as are the terms management region and region. Data considered in this analysis correspond to the Strait of Georgia management region, which includes statistical areas 12 to 20, 28, and 29. The species category "other rockfish" (OR) is used in the commercial fish slip database and stock assessment documents to mean rockfish species other than yelloweye rockfish. In the Strait of Georgia region, the species category "red snapper" (RS) largely consists of yelloweye rockfish while "other rockfish" are predominately quillback rockfish (Yamanaka and Kronlund 1997). However, reference to "other rockfish" in management plans developed by the Groundfish Hook and Line Management Unit includes only quillback, copper, china (*S. nebulosus*), and tiger (*S. nigrocinctus*) rockfishes. The hook and line fishery in the Strait of Georgia region is sometimes referred to as the "Inside" Zn fishery. The term "management tactic" is used deliberately to separate the plan stating how catch is removed from the stock (the strategy) from the tools used to implement the plan (Hilborn and Walters 1992).

2. Description of the logbook data

Fishers are required to complete logbooks as a condition of licence. Although the quality of logbooks was variable in the early years of the program, the diligence of fishers in recording logbook data has increased in recent years. The logbook program has been operated on a user pay basis since 1994 to cover the costs of printing, keypunching, and the development of data entry software. Haigh and Richards (1997) described a relational database for the logbook data and documented changes to the logbook data that have occurred since the inception of the program in 1986.

2.1 Data structure

The essential data in the logbooks consist of catch by species, and effort for a fishing event. For each fishing event, the logbook forms allow recording of the number of pieces caught by species, the time fished, and the fishing location (latitude and longitude). Gear type and characteristics can be recorded, as can the date and depth at which fishing occurred. The fishing event is well defined for longline gear: a fishing event is a longline set where the times of deployment and recovery delimit the time fished. The logbook forms allow the start and end locations of a set to be recorded, along with the total number of hooks, or the number of skates and hooks per skate. Thus, time fished, or the product of time fished and the number of hooks fished, are available as measures of effort for longline gear.

The definition of a fishing event for hand line gear is less clear. In practice, fishers select a locality to fish each day, but may move many kilometers in the course of the day depending on catch success, weather, or other factors. A number of distinct sites (individual reefs) separated by hundreds of meters or kilometers may be fished each day. In this situation, some fishers may record only one location in their logbooks, while others may record each distinct site fished. Some fishers estimate the time fished as the difference between the start and end time of the fishing day, while others try to adjust for time moving among specific sites or other periods when active fishing does not occur. Thus, search time may be included in the time fished, in contrast to longline gear, where time fished does not include search time. Hand line effort can be time fished, or time fished times the number of hooks. For this analysis, a hand line fishing event is interpreted as the fishing conducted at a particular location (latitude and longitude) recorded in the logbooks. Thus, more than one fishing event can be recorded by the same hand line fisher on a given day.

A fishing trip may include multiple fishing events for a vessel identified by a Canadian Fishing Vessel (CFV) number. The structure of the catch and effort data is longitudinal, meaning that each vessel is observed more than once over time. Annual time-series accrue for fishing vessels, although the series for a given vessel can be discontinuous due to intermittent participation in the rockfish fishery among years. Data also accumulate over time within a year each time a vessel makes a fishing trip. For example, Table 1 lists the number of vessels that submitted logbooks, the total number of fishing trips, and the total number of fishing events for both longline and hand line gears. The mean hours fished per vessel each year is also listed in Table 1. Information by trip is only available since 1994.

The effect of limited entry in 1992 can be seen in the reduction of participating vessels by a factor of two thirds, and reductions in the total number of longline sets and hand line events. However, for the hand line gear type, there is an increasing trend in the number of fishing events since 1992, coincident with a decline in the number of longline sets. These trends can be attributed, in part, to an emphasis on the live rockfish fishery in the Strait of Georgia region. Over the same period, there is an increasing trend in the mean time (hrs) fished per vessel for hand line gear.

2.2 Problems in the logbook data structure

It is not currently possible to reconstruct information by trip for historical logbook data prior to 1994 for reasons described by Haigh and Richards (1997). Also, changes in the logbook format over time have caused inconsistent practice for recording catch by weight, pieces, or both. Major changes to the recording of catch include using a piece count from 1986 to 1988, round weights from 1989 to 1993, and a piece count by set in conjunction with a total round weight estimate by trip from 1993 to 1996. For example, many historical records indicate the number of pieces per set, but estimates of total weight apply to a single page of the logbook which may or may not constitute a fishing trip. Thus, Haigh and Richards (1997) described an algorithm to apportion the aggregate weight of species to fishing events. These problems have been addressed in recent years with the addition of a trip identification field and a piece count by set. Further work on the database is required to resolve coding discrepancies in the "captain" field so that the effects of individual fishers on catch success can be examined.

The quality and completeness of logbooks are variable among fishers and across time (Haigh and Richards 1997). There is no real-time validation of the logbooks, they are simply entered into the database "as is". Perhaps the most critical weakness is that there is no requirement to confirm logbook compliance at the time of dockside monitoring. The logbook records can be uniquely linked to the corresponding dockside monitoring records using the hail number assigned to a fisher when calling for a dockside monitor. At present, there is no requirement to confirm that the hail number is recorded in the logbook, nor is there an existing database to perform the linkage between logbook and dockside monitoring data.

2.3 Advantages of the logbook data

The logbook data offer several advantages over both the historical fish slip database and the current dockside monitoring program (DMP). The fields available in each of the data sources are listed in Table 2 for convenience. The three sources of data are evaluated by factors relevant to stock assessment in the following list:

1. **Catch by species**: Commercial fish slips did not resolve catch to species. Only the species categories "red snapper" and "other rockfish" were recorded. The logbooks and DMP allow improved accounting of catch by species in terms of pieces and weight (kg), respectively.

2. **Resolution of fishing location**: The spatial resolution of fish slips was to DFO statistical area. The DMP identifies rockfish catch only to DFO management regions, a level of resolution less than that of the fish slips. Logbooks allow fishers to record longline sets by latitude and longitude, and hand line fishing localities by latitude and longitude. In theory, if logbook data and DMP data are linked, the spatial resolution of the DMP data could be increased. However, no database exists at this time to perform the linkage.

3. **Determination of effort**: Effort could be resolved only to the number of fishing days in a trip using the commercial fish slip data. The DMP does not allow estimation of effort (other than trip length in days). Logbooks offer potentially improved estimates of soak time for longline gear, and finer resolution of time fished within a day for hand line gear. The logbooks also provide the number of hooks deployed for both gear types. It is not clear, however, that fishing time, or time fished in conjunction with the number of hooks, is the best measure of effort since search time may not be reflected in logbooks.

3. Characteristics of the fishery

This section provides a brief description of the current status of the fishery and establishes the credibility of logbook data relative to dockside monitoring and commercial fish slip data.

More than twenty species of *Sebastes* are landed in the directed hook and line fishery for rockfishes. A list of species and common names, with species abbreviations and numeric codes, is shown in Table 3. The species landed in the Strait of Georgia region are indicated under the column titled "SG". The landings are dominated by quillback, yelloweye, and copper rockfishes. The species compositions by weight (tonnes) determined from dockside monitoring and from logbooks are shown for 1996 in Figure 1. Total catch weight for each species is measured directly by dockside monitors. For logbook data, total catch weight for each species may be a sum of (1) estimated weights recorded by a fisher, and (2) a product of the number of pieces and a species specific mean weight. For this analysis, mean weights by species were computed by dividing the total weight for each species by the total number of pieces for each species recorded in logbooks for all available records in the period 1994 to 1996. That is, a coast wide ratio estimator of mean weight for each species was computed.

Inspection of the 1996 catch summarized in Figure 1 shows that the logbook data underestimated total landings of quillback rockfish (105 tonnes) relative to dockside monitoring (121 tonnes). Similarly, the estimated landings of copper rockfish was lower for logbooks at 20 tonnes, as compared to 27 tonnes computed from dockside monitoring data. There was good agreement in total landings for yelloweye rockfish from the two data sources (29 tonnes by logbooks and 32 tonnes by dockside monitoring). A greater number of species were recorded by dockside monitoring, however, these species contributed only a minor amount to the total landings.

Historical fish slip data collected since 1956 offer the only alternative to logbook data for comparing time series of catch and effort. These data are available electronically by gear type beginning in 1982. Unfortunately, fish slip data can be resolved only to the species categories "red snapper" (RS) and "other rockfish" (OR). Since the RS category is assumed to consist largely of yelloweye rockfish in the Strait of Georgia, direct

comparison is made between RS data from fish slips and yelloweye data from logbooks. The OR category is assumed to include all species except yelloweye rockfish. The historical catch and effort series for longline and hand line gears are shown in Figure 2 for RS and in Figure 3 for OR. The upper panels in each figure show catch (tonnes) and effort (days fished) derived from commercial fish slips from 1982 to 1995, the period over which fish slip data are available electronically. The lower panels in each figure show catch (tonnes) and effort as time fished (hrs) summarized from logbook data.

Prior to 1991, the logbook data indicated greater landings of yelloweye rockfish by longline gear than is recorded by fish slip data (Figure 2). From 1991 onwards, the agreement between the two longline catch series is good. For example, both data sources capture a peak in landings of about 80 tonnes in 1994. For hand line gear, there is poor agreement between the two series prior to 1992. The catch of yelloweye rockfish derived from logbooks grossly underestimated red snapper catch determined from fish slip data. Reasons for the discrepancy may include errors in the species composition of the red snapper category, bias in either data source, or undetected errors in data entry (*e.g.* incorrect gear coding).

Effort for RS was recorded as days fished on fish slips, while yelloweye effort was recorded as hours fished on logbooks. Although the two effort measures are not directly comparable, similar trends in the effort series for both gear types are evident (Figure 2). However, the fish slip data captured a sharp upturn in longline RS effort in 1995 that is not reflected in the yelloweye effort derived from logbook data.

Trends in catch and effort for OR do not compare well for longline gear, possibly due to the relatively minor component of longline effort in the Strait of Georgia fishery (Figure 3). Reasonable agreement in total catch of other rockfish by hand line gear between fish slips and logbooks is apparent after 1988. However, trends in effort diverge after 1992 for hand line gear.

The distribution of the total landings of rockfishes among fishers can be shown by plotting the proportion of the total landings as a function of the proportion of fishing vessels submitting logbooks. This relationship is shown for 1986, 1991, 1992, and 1996 in Figure 4. A straight line of slope one would correspond to equal shares of the rockfish landings in the fishery. In years prior to limited entry, for example, about 80 to 85 percent of the catch was accounted for by 40 percent of the vessels. After limited entry in 1992, about 70 percent of the total landings of rockfishes was caught by 40 percent of the vessel.

The distributions of fishing events by species (quillback, copper, and yelloweye) and gear type are shown in Figure 5. The plotted points correspond to rockfish fishing events in 1996. The fraction of log records with completed latitude and longitude fields is indicated on each panel. Hand line activity is largely clustered in the Gulf Islands (statistical areas 17, 18, 19), Campbell River (statistical area 13), and near the north eastern tip of Vancouver Island in Queen Charlotte Strait (statistical area 12, subareas numbered less than 9, and greater than 16). Subsequent analyses of catch and effort

trends in this paper are based on these geographic localities. Very limited longline activity occurs in the Gulf Islands, with most effort being concentrated in Queen Charlotte Strait. Compliance with geo-referencing has been improving since 1992, but is still relatively low at about 30 percent of the fishing events for hand line gear.

4. Management tactics

A wide range of management tactics have been applied to the hook and line fishery since 1986 (Appendix 1). The management tactics listed in Table 4 and Appendix 1 are described in more detail by the management plans for the hook and line fishery prepared by the Groundfish Management Unit (*e.g.* 1997 Management Plan: Groundfish by Hook and Line) and summarized by Kronlund (1997). A substantial increase in the number of tactics applied to the fishery each year since 1992 clouds the among year comparison of catch and effort data derived from logbooks (Table 4). For this reason, it is worthwhile to understand the details of the various tactics. Gear has been restricted to hook and line configurations (*e.g.* longline, troll, hand line) since the inception of the Zn fishery. Size-limits and sex-specific harvest restrictions have not been used to manage inshore rockfishes.

No management restrictions were applied to the commercial fishery prior to 1986. Licence limitation was implemented in 1992, reducing the number of licences from 592 to 74 in the Strait of Georgia region. A variety of closures were implemented from 1987 to 1991 (Appendix 1). Annual quotas were set for the first time in 1991 for the red snapper (50 t) and other rockfish (300 t) species categories, although yield recommendations have been provided since 1987 (Stocker *et al.* 1988). Development of a live fish product was encouraged by managers following limited entry, but was not formalized until 1994:

> "*All rockfish species (Sebastes sp.), with the exception of yelloweye rockfish, shall be landed alive. The number of live rockfish (exclusive of yelloweye rockfish), in pieces, shall not be less than eighty percent (80%) of the total number of rockfish pieces (exclusive of yelloweye rockfish) landed at any time. Yelloweye rockfish may be landed dead or alive*". (1994 Management Plan: Groundfish by Hook and Line).

Prior to 1995, annual quotas were assigned for yelloweye rockfish and the OR species category (Table 5). Recall that "other rockfish" was defined as quillback, copper, china and tiger rockfishes in the management plans. Beginning in 1995, the number of species categories was increased to include yelloweye (YE) and 6 additional species aggregates (A1 to A6). On a coast wide basis, aggregates were managed by quota for each of the five management regions. The number of aggregates was again increased in 1996 to a total of 7 groups (Table 5). For the Strait of Georgia management region, the "other rockfish" category is the same as A1 (quillback, copper) and A2 (china, tiger) combined, so the effects of aggregate management *per se* are likely not significant for the

Strait of Georgia region (quotas were applied to that combination of species prior to the inception of "aggregate management"). However, see Kronlund (1997) for a discussion of the drawbacks of using aggregate management for the inshore rockfish fishery.

Catch limitation by fishing period was introduced in 1995. For each licence holder, the date of the first rockfish landing of the year determines the start of the first fishing period. Subsequent fishing periods begin on the same date each following month and run continuously until the end of the fishing year (see, for example, the 1995 Management Plan: Groundfish by Hook and Line). For example, if a fisher makes his first rockfish landing on June 17, then all subsequent fishing periods commence on the 17th of each month until the fishing year ends. Thus, the scheduling of fishing periods is not the same for all licence holders. This measure was proposed by industry and management as a tactic for extending the fishing season and by managers as a tactic for reducing effort. There are no restrictions on the number of landings per fishing period. For licence holders in the Strait of Georgia, the catch restrictions have changed each year from 1995 to 1997 (Table 6).

Fishery performance as measured by the difference between the quota and actual catch is summarized in Table 7 for yelloweye rockfish and in Table 8 for other rockfish. Since the advent of dockside monitoring in 1995, the quota and catch have been in close agreement. Prior to 1995, the groundfish management plans specify other rockfish to be quillback, copper, china, and tiger rockfishes, while recommended yields and catch for other rockfish include all *Sebastes* except yelloweye rockfish. Therefore, catch totals for other rockfish prior to 1995 include species other than quillback, copper, china and tiger rockfishes.

5. Catch per unit effort

The dominant species in the Zn landings for the Strait of Georgia region are quillback, copper, and yelloweye rockfishes, and to a lesser extent black (*S. melanops*), yellowtail (*S. flavidus*), china and tiger rockfishes. The biology of *Sebastes* and the capabilities of the fleet suggest catch per unit effort is not a timely or sensitive indicator of stock abundance. Quillback, copper and yelloweye rockfishes exhibit strong affinity for specific habitat (Matthews 1990, O'Connell and Carlile 1993, Richards 1986) and the ability to return to specific reefs following experimental displacement (Matthews 1990). Although localized seasonal depth migration has been documented, these species are considered to be relatively sedentary as adults with no known long distance migration.

Continual improvement in electronic global positioning systems and sonar equipment over the last decade has enabled fishers to accurately and repeatedly target discrete locations based on prior fishing success. The mechanism for spatial depletion of rockfishes likely consists of a progressive decline of localized stocks with apparently low adult mobility. Because rockfishes exhibit strong habitat affinity, commercial catch per unit effort (CPUE) can be maintained, or increased due to improved technology, despite

the overall decrease of stock abundance (Archibald *et al.* 1983, Leaman 1991). While commercial CPUE may respond to large changes in stock biomass, it may not be particularly sensitive to stock abundance at low stock levels (Leaman 1991).

A second reason CPUE may be a deceptive indicator of stock status relates to the discrepancy between the scale of assessment and management, and that of the depletion. Past assessments of inshore rockfishes aggregated data at the level of the statistical area, and management tactics have been applied at the level of the management region. Hyperstability of CPUE (Hilborn and Walters 1992) can occur within statistical areas, which are sufficiently large to allow the fleet to move to more productive localities in response to declining catch rates. Persistent decline in CPUE may then serve only as a late warning of over-harvest. Thus, catch per unit effort cannot be considered an operationally useful measurement for ensuring sustainable harvest of inshore rockfishes. Nevertheless, commercial CPUE is the only time series that can potentially serve as a stock index; there are no fishery independent time series of stock abundance.

The mean of ratio estimator was used to compute annual CPUE. It is defined as the average of individual catch rates for each fishing event:

$$R = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{E_i} \quad ,$$

where C_i is the catch and E_i is effort over the $i=1,...,n$ fishing events. The robustness of this estimator to outliers can be increased by trimming observations from each tail of the distribution of catch rates, C_i/E_i. For example, median CPUE can be estimated by trimming 50 percent of the observations from each tail of the ranked observations. For both longline and hand line CPUE, catch can be expressed in terms of weight (kg) or pieces, while effort can be specified in terms of hours or hooks times hours.

Past practice for assessments of the groundfish trawl fishery has been to define directed fishing through some form of qualification level, *e.g.* observations may be restricted to include fishing events that achieve a specified proportion of the target species, or contain a specified weight of the target species. A qualification level is not the best criterion for the multi-species Zn fishery, where anywhere from tens to hundreds of kilograms of several species of rockfishes may be caught in various proportions over a fishing day. A few tens of kilograms of live rockfishes can constitute a good days fishing for smaller operators in the Strait of Georgia region. As an alternative to qualification level, the following algorithm was applied to the logbook data to determine fishing activity directed on rockfishes:

1. Determine the species with the highest catch weight for each fishing event (set, fishing day);

2. Where no target species was specified by the fisher, assign the species with the highest catch weight to be the target species;

3. Exclude fishing events where the target species was not a *Sebastes*.

The small proportion of troll gear records (approximately 2 percent) in the logbook data were lumped with hand line gear records. Following the application of the directed fishing algorithm, analyses of hand line gear excluded logbook records where:

1. The number of hooks was greater than 20. In these cases the gear code is likely coded incorrectly or a data entry error exists;

2. The reported time fished exceeded 24 hours. These records likely represent pooling of two or more days fishing;

3. The CPUE (kg/hr) exceeded 30 for a single species.

For example, a total of 953 hand line fishing events for quillback rockfish were excluded out of a total of 42129 events over the 11 years of data. Additionally, two events with catches greater than 1000 kg were excluded for hand line quillback data.

5.1 Exploratory analyses of catch and effort data

Catch as a function of time fished (hrs) and number of hooks is shown in Figure 6 for quillback rockfish caught by hand line gear. Each panel of the figure shows a scatterplot of catch versus time fished, where each point represents a fishing event. The solid line in each panel is a smoothed trend line fit by loess (Cleveland 1993). The lower panels show data prior to limited entry in 1992, while the upper panels show data accumulated after limited entry. Working from left to right, the panels display data with a progressively greater number of hooks fished from 0 to 20 hooks. The data are stratified by number of hooks so that roughly equal numbers of observations occur in each panel The range of hook numbers included in each panel is indicated by the darker shading in the strip labeled "Hooks".

A positive, approximately linear relationship appears to hold between catch and time fished which tends to flatten at higher numbers of hooks. There appears to be no benefit to fishing higher numbers of hooks. There is little difference between pre and post-limited entry periods. One notable feature is the higher frequency of catches above 200 kg in the period following limited entry (upper panels). Based on these observations, effort is represented by time fished in all subsequent analyses of hand line gear.

5.2 Temporal and spatial trends in catch per unit effort

Catch, effort, and catch per unit effort series for hand line gear are presented by locality in Figure 7 through Figure 9. The upper three panels of each figure show the time series of catch (tonnes) and effort (hours) for Queen Charlotte Strait, Campbell River, and the Gulf Islands. Corresponding trends in CPUE estimates are shown in the

lower three panels for each locality. Three mean of ratio CPUE series are presented: (1) the mean CPUE (solid line), (2) the 10 percent trimmed mean (dashed line), and (3) the median CPUE (dot-dash line).

Catch and effort trends for A1 (quillback and copper rockfishes) are comparable within each locality (Figure 7). The time series show an increase in catch and effort in the years immediately preceding 1992, followed by a significant drop in both variables in 1992 when limited entry and a reduced quota for A1 species were implemented (Table 8). These trends likely reflect an anticipatory response by fishers: qualification for limited entry was based in part on landings, so fishers attempted to improve their likelihood of qualification by increasing their catch. However, CPUE did not generally increase in response to increased fishing effort during the 1989 to 1991 period. Over the 1986 to 1996 period, there is a general decline in CPUE for all three localities. The trends in CPUE for Campbell River and the Gulf Islands show two periods of decline separated limited entry in 1992. The "step-up" in CPUE in 1992 likely reflects the reduced number of vessels active in the fishery (Table 1). These CPUE trends suggest that the logbook data series is effectively broken into two portions by limited entry. The CPUE trend for Queen Charlotte Strait does not show the step in 1992, but does exhibit a general decline over time. The catch, effort and CPUE trends for quillback rockfish shown in Figure 8 are qualitatively the same as those for A1. This is not surprising, given that quillback rockfish constitute most of the landings in the fishery.

The trends for yelloweye rockfish are not as stable as those for quillback rockfish due to the relatively low targeting of yelloweye by hand line gear in the Strait of Georgia (Figure 9). Data for the Queen Charlotte Strait locality reflect the general reduction in catch and effort following limited entry in 1992, after a period of increased catch and effort from 1989 to 1991. Catch per unit effort has declined since 1992 in both Queen Charlotte Strait and the Campbell River area. Over the time series, the magnitude of CPUE decreases from Queen Charlotte Strait southward to the Gulf Islands.

5.3 Seasonal trends in catch per unit effort

Figure 10 shows both the distribution of fishing events among years, and the relationship between CPUE (ln kg/hr) and Julian day within a year. Each panel represents one year of CPUE data for quillback rockfish in the Strait of Georgia region. A smoothed trend line is superimposed on each scatterplot. Data were logged to stabilize the variance. There appears to be little evidence of seasonal trends with Julian day, although there is a tendency to lower CPUE values in recent years.

5.4 Trends in species composition by locality

Logbooks were used to compute the weight of the rockfish catch by species for Queen Charlotte Strait, Campbell River, and the Gulf Islands. The annual proportions by weight of quillback, copper, and yelloweye rockfish by gear are shown in Figure 11. For

example, the proportion of quillback rockfish in 1996 was computed as the total weight of quillback rockfish divided by the total weight of all species of rockfishes landed. The trends by locality are summarized below:

1. **Queen Charlotte Strait**: The proportion of yelloweye rockfish landed by longline gear declined in 1996 coincident with an increase in the proportion of quillback rockfish. Yelloweye rockfish dominated the longline catch by weight. For hand line gear, the proportions of quillback, copper, and yelloweye rockfishes have been stable over time, with quillback rockfish contributing about 80 percent of the landed catch by weight.

2. **Campbell River**: The proportion of yelloweye rockfish landed by longline gear has varied inversely to the proportion of quillback rockfish following a period of stability which ended in 1994. Proportions by weight of quillback, copper, and yelloweye have remained relatively stable over time in the hand line fishery. Quillback rockfish account for about 75 percent of the landed catch in this locality.

3. **Gulf Islands**: Longline species proportions have been erratic due to the relatively low effort expended in this locality. The proportion of quillback rockfish caught by hand line gear has decreased from about 80 percent in 1993 to about 55 percent in 1996. There was a coincident increase in copper rockfish from less than 20 percent in 1993 to about 40 percent in 1996, while proportions of yelloweye rockfish have remained relatively stable.

The change in species proportions in Queen Charlotte Strait likely reflect a general change in gear types from longline to hand line to target the more lucrative live rockfish market. This change is reflected in Table 1 by declining numbers of longline sets and hours fished over time, coincident with an increase in hand line effort. If the inverse trends in the proportions of quillback and copper rockfishes persist in the Gulf Islands, there may be cause for concern. The trends may be due to one or more of the following:

1. Decreased availability of quillback rockfish caused by fishing mortality

2. Decreased availability of quillback rockfish relative to copper rockfish due to natural population fluctuations;

3. Increased incentive to land copper rockfish because of improved prices.

6. Impacts of management tactics on logbook data

Four developments that may have significant impacts on logbook data were identified in Section 1. Significant reduction in the TAC for other rockfish coincides with the implementation of limited entry in 1992 when the other rockfish TAC was

reduced from 300 tonnes to 130 tonnes (Table 8, Figure 3). Correspondingly, a reduction in the landings of other rockfish was observed from 366 tonnes in 1991 to 148 tonnes in 1992. Although the red snapper TAC was 50 tonnes in 1991, there was no reduction in landings from historical levels until 1992 (Table 7, Figure 2).

Direct effects of fishing period catch limitation could be assessed through analysis of the dockside monitoring data. For example, the numbers of vessels achieving catch limits of A1 or yelloweye rockfish within periods could be computed. Because fishing period is not captured by logbooks, it is not possible to assess the potential impacts on logbook data until database systems are developed to link the logbooks with dockside monitoring through hail number. Two analyses are recommended when the database is available: (1) determine the frequency with which attainment of A1 period limit occurs before that of A2 or YE (and vice versa); (2) examine the species composition of the landings before and after the attainment of any fishing period limit. The former analysis may indicate whether fishing period limits constitute a real limitation. If the species composition differs markedly after a limit is attained, then either the fishers can target species very effectively or there is evidence of discarding.

The implementation of the dockside monitoring program (DMP) in 1995 corresponded with observed declines in catch rate from 1994 to 1996. Weight by species recorded in logbooks were estimated by each fisher, at least up to the implementation of the DMP. Beginning in 1995, however, measured weights obtained from the DMP port monitors may be entered in the logbooks rather than the fishers estimated weights. Thus, if estimated weights are positively biased, the apparent decline in catch rate by weight could be due in part to the DMP as more accurate weights by species are recorded in log books. Catch rate measured in pieces over the same period should not be subject to the same bias, since pieces are not recorded by dockside monitors. Plots of CPUE (pieces/hr) over time (not shown) show trends similar to those shown in Figure 7 through Figure 9.

7. Discussion

The logbook program was initiated for the Zn hook and line fishery due to the limitations of the commercial fish slip data. Logbook data provide information on catch, effort, location, depth range fished and species composition to a higher resolution than that available from fish slip data. As pointed out by Stanley (1992), however, logbook data are not without shortcomings:

1. Costs of data processing, validation, and storage are borne by the managing agency, and by industry in the case of Zn logbooks;

2. Control of data quality may be variable due to non-compliance or mis-reporting, deliberate or accidental.

For the hook and line fishery, the logbook data represent the only source of catch and effort data that can be collected at a scale appropriate to the biology and assessment requirements of inshore rockfishes. Accurate geo-referencing of fishing events by latitude and longitude is the key advantage of the logbook program over other fishery-dependent data sources. This is not to say that a stock index derived from logbook data, *i.e.* catch rate, constitutes an operationally useful indicator of rockfish status. However, information on fleet movement and catch composition at a fine spatial scale may serve to warn of localized depletion, albeit after the fact.

The logbook data may not have sufficient resolution to reliably detect changes in species composition at depth. Typically, the depth range specified is quite broad, on average about 38 meters, so that the species composition is integrated over a depth interval. One major piece of information not captured by logbooks or dockside monitoring relates to biological characteristic of landed fish (weight, length, sex, maturity, age). Significant changes in these variables may warn of negative fishing effects on stocks or wasteful harvest practice. For example, the live rockfish market pays premium prices for fish ranging from 0.7 to 1.0 kg. Fish outside this range may be discarded to maximize income.

Alternatives to the choice of mean weights by species coast wide from 1993 to 1996 could be used in analyses. For example, mean weight may vary among areas, and mean size could have declined over time. The latter option is difficult to evaluate since only pieces were recorded in logbooks from 1986 to 1988 and round weights from 1989 to 1992. The overall trends are unlikely to change as a result of refinements to the pieces to weight conversion.

7.1 Trends in CPUE and species composition

Hilborn and Walters (1992) stated that it is "*simply irresistible to try to use catch per unit effort data ... as an index of abundance*". Arguments against the use of CPUE as a measure of stock status for inshore rockfishes were presented in Section 5. Even if these arguments prove groundless, the prospects for a stock index based on catch rate are not good in the face of changing management tactics. The information content of fishery derived data with respect to stock assessment is potentially diminished by perturbations to times series caused by the accumulation of tactics. The decade of logbook data collected thus far straddles the implementation of limited entry, cutting the effective length of the time series in half. It is not clear what impacts fishing periods and associated catch limits will have on the long term behavior of catch per unit effort.

This paper does not consider CPUE to be an operationally useful indicator, since at best it likely reveals past excesses in harvest. Despite this drawback, the fact remains that catch and effort data represent the only long term series available for inshore rockfishes. The question becomes whether the declines in CPUE documented in this paper reflect a decrease in abundance for quillback rockfish, in particular. If the CPUE index does reflect the impacts of removals, attributable to the Zn fishery (and other

sources), was the harvest at a non-sustainable level as opposed to fishing down to a lower equilibrium point? In isolation, the logbook data cannot answer that question. However, logbook data can contribute to diagnosing over harvest by (1) allowing fleet movement to be tracked at a fine scale through geo-referencing, (2) tracking changes in species composition in the catch that may be attributable to serial depletion of species, and less usefully (3) determining the point at which the commercial fishery becomes unprofitable.

The inverse trends in the proportions of quillback and copper rockfishes noted for the Gulf Islands locality may be benign. However, Murie (1991) conducted experimental removals of rockfishes on rocky reefs in the Gulf Islands. The distributions of quillback and copper rockfishes overlap, with quillback rockfish tending to deeper waters. Densities of copper rockfish were found to increase following removal of quillback rockfish. This suggests one possible mechanism for the increase in the proportion of copper rockfish in the Gulf Islands locality. As quillback rockfish are removed by fishing, copper rockfish may expand their distribution into habitat normally dominated by quillback rockfish. Examination of minimum and maximum depth fished (analysis not shown) suggested no movement of fishing effort into shallower water to target copper rockfish.

7.2 Directions for modeling logbook data

One problem with analyzing logbook data is that a large number of "observations" are generated at the level of fishing events. In any modeling of these data, an unrealistically large number of degrees of freedom arise if fishing events are regarded as independent events, which they are not. One viewpoint of the logbook data is that it is a census, as opposed to a sample survey, where in theory all of the population elements are measured. There is measurement error in catch and effort, but there is no variability due to sampling since all vessels should turn in log information each year. An alternate perspective is that the logbooks sample fishing activity occurring over time and missing data are common due to variable levels of compliance.

From a modeling perspective, the logbook data *for a given fishing year* are akin to a longitudinal mixed effects problem:

1. The trajectory of catch and effort over years from a single vessel could be considered a fixed effect in the model;

2. Observations are made sequentially in time (among and within fishing years) on the same sampling units (fishing vessels);

3. The catch and effort data arise from a three stage process in which a number of observations (fishing events) are made on each fishing trip for a particular fishing vessel. Fishing events on a trip may be correlated due to the spatial proximity of sets or reefs and because the same vessel and captain conducted the fishing.

Observations are correlated since the same sampling units (fishing vessels) are being measured over time. There are logically three strata of variation (annual trajectories could be modeled as a fixed effect):

1. among vessels within a fishing season;

2. within vessels among fishing trips;

3. within fishing trips among fishing events.

These components of variance are the "random effects" and allow a means of reducing the apparent degrees of freedom. For example, the fishing events for a fishing trip are considered to be a sample from a population of possible fishing events (a random effect) rather than specified in the sense of treatment levels in an experimental design (a fixed effect).

Because of variable participation in the fishery, the data are highly unbalanced in the sense that the number of vessels each fishing season is variable, as are the number of trips per vessel and fishing events per trip (Table 1). This feature of the data raises technical difficulties that will require relatively sophisticated estimation procedures to resolve. The benefits of the modeling approach outlined above are:

1. Improved accounting of the correlated structure of the data resulting, in a (more correct) reduction in apparent degrees of freedom;

2. Improved estimation of variance components attributable to specific factors which, in turn, allows the computation of confidence intervals and statistical evaluation of trends over time;

3. The ability to determine sampling required to achieve specified levels of precision in estimates of catch rate, total catch, or total effort, should the logbook program be cut back, and for catch and effort research.

7.3 Recommendations

1. **Enforce the verification of hail numbers in logbooks at the time of dockside monitoring.** This will ensure that a linkage between logbooks and the DMP data can be performed.

2. **Develop a database to provide the linkage between logbook data and dockside monitoring data.**

3. **Work with industry to increase compliance with the provision of latitude and longitude data.** Precise spatial information is a key component of increasing assessment capabilities for inshore rockfishes. Following improvements in

compliance, the precision of latitude and longitude should be increased to the highest possible resolution (*i.e.* degrees, minutes, seconds).

4. **Management tactics should not be changed annually to minimize perturbations to fishery-dependent time series.** Planning should take place on a multi-year basis, with contingencies for negative stock impacts.

5. **Proceed with modeling to reflect the structure of the logbook data, and incorporate the models into analyses of logbook data for all management regions.**

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Appendix 1 Management Tactics for the Inside Rockfish Fishery

Year	Management Tactics
<1986	No restrictions on commercial fishing
1986	**Logbooks:** • logbook program implemented **Fixed season closure:** • 15 Feb to 15 Apr
1987	**Fixed season closure:** • 01 Jan to 15 Apr **TAC:** • 75 t quota in area 12 under permit
1988	**Fixed season closure:** • 01 Jan to 30 Apr **Area closure**: • subareas 13-2 to 13-9, 13-11, 13-27
1989	**Fixed season closure:** • 01 Jan to 30 Apr **Area closure**: • subareas 13-2 to 13-9, 13-11, 13-27
1990	**Fixed season closure**: • 01 Jan to 30 Apr and 01 Nov to 31 Dec **Area closure**: • subareas 13-2 to 13-9, 13-11, 13-27
1991	**Fixed season closure**: • 01 Jan to 14 May **Area closure** • subareas 13-2 to 13-9, 13-11, 13-27 **TAC**: • YE quota 50 t. • OR quota 300 t.

1992	**Limited entry:** • 74 vessels licenced **Fixed season closure**: • 01 Jan to 30 Jun **Catch-limited opening**: • 01 Jul to 06 Sep • 29 Sep to 13 Dec (OR), 31 Dec (YE) **Area closure**: • subareas 13-2 to 13-9, 13-11, 13-27 **TAC**: • YE quota 59 t • OR quota 130 t
1993	**Limited entry**: • 74 vessels licenced **Catch-limited opening**: • YE opened 01 Jan until 20 t landed • 15 Jun to YE and OR quota attained **Area closure**: • subareas 13-2, 13-9, 13-11, 13-27 **TAC**: • YE quota 70 t • OR quota 140 t
1994	**Limited entry**: • 74 vessels licenced **Logbooks**: • logbooks revised • user-pay program implemented **Fixed season closure**: • 01 Jan to 14 Jun, but see catch-limited openings **Catch-limited opening**: • YE 01 Jan until 20 t landed, 15 Jun for balance of YE TAC • OR 15 Jun until 140 t, 01 Dec for balance of OR TAC **Area closure**: • subareas 13-2 to 13-9, 13-11,13.27, 14-11, 14-14, 16-3, 16-4, 17-7, 17-14, 17-20, 17-21, 18-8, 19-1, 19-6, 19-7 to 19-12, 20-6, 20-7, 28, 29-7 to 29-17 **TAC**: • YE quota 70 t • OR quota 150 t **Live fish policy**: • minimum 80% live landings (pieces) of all rockfish species except YE

1995	**Limited entry:** • 74 vessels licenced **Dockside monitoring of landings:** • user pay validation for all landings of Zn licence holders **Fixed season closure**: • 01 Jan to 14 Jun **Area closure**: • subareas 13-2 to 13-9, 13-11 and 13-27 **Aggregate management**: • catch managed using species aggregates **TAC**: • YE quota 62 t (32 t directed fishing, YE catch thereafter combined with A2 to A6 bycatch to a maximum of 20% of A1 per landing) • A1, A2 combined quota 150 t **Fishing period catch limits**: • 3,500 lb. A1 per fishing period • 6000 lb. YE per fishing period • A2 to A6 bycatch limited to 20% of A1 and YE by round weight per landing • overage of A1 up to a maximum of 20% per fishing period is deducted from the vessel's next fishing period • no restrictions on the number of rockfish landings per fishing period
1996	**Limited entry:** • 70 vessels licenced **Dockside monitoring of landings:** • user pay validation for all landings of Zn licence holders **Fixed season closure**: • 01 Jan to 14 Jun **Area closure**: • subareas 13-2 to 13-9, 13-11, 13-27, 14-11,14-14,16-3,16-4,17-7,17-14, 17-20, 17-21, 18-18, 19-1, 19-6, 19-7 to19-12, 20-6, 20-7, 28, 29-7 to 29-17 **Aggregate management**: • species composition of aggregates revised **TAC**: • YE quota 26 t directed fishing (bycatch limited to 20% of A1 per landing thereafter) • A1, A2 quota 150 t **Fishing period catch limits**: • 1,800 lb. A1 per fishing period • 600 lb. A2 to A7 combined per fishing period • 2,500 lb. YE per fishing period • overage on each of A1, A2-A7 combined, YE up to a maximum of 10% per fishing period is deducted from the vessel's next fishing period • no restriction on the number of landings per period

1997	**Limited entry:** • 70 vessels licenced **Dockside monitoring of landings:** • user pay validation for all landings of Zn licence holders **Fixed season closure**: • 01 Jan to 14 Jun **Area closure**: • Sub-areas 13-2 to 13-9, 13-11, 13-27, 14-11,14-14,16-3,16-4,17-7,17-14, 17-20, 17-21, 18-18, 19-1, 19-6, 19-7 to19-12, 20-6, 20-7, 28, 29-7 to 29-17 **TAC:** • YE 24 t directed fishing (bycatch limited to 20% of A1 per landing thereafter • A1,A2 quota 143 t **Fishing period catch limits**: • 1,500 lb. A1 per fishing period • 600 lb. A2-A7 combined per fishing period • 2,500 lb. YE per fishing period • overage on each of A1, A2-A7 combined, and YE up to a maximum of 10% per fishing period is deducted from the vessel's next fishing period • no restriction on the number of landings per period

Table 1 Summary of logbook data for longline and hand line gear types.

		Longline				Hand line			
Year	Active vessels	Trips	Sets	Mean sets per vessel	Mean effort per vessel (hrs)	Trips	Events	Mean events per vessel	Mean effort per vessel (hrs)
1986	210	na	1377	24.16	189.96	na	5338	32.55	196.12
1987	169	na	770	14.53	129.70	na	3821	30.81	181.58
1988	160	na	843	18.33	184.20	na	3691	31.55	184.91
1989	273	na	2223	24.43	262.41	na	6360	33.13	210.98
1990	299	na	1779	18.73	193.59	na	6381	29.96	184.54
1991	226	na	1033	19.13	213.17	na	6070	33.91	222.78
1992	71	na	617	28.05	133.23	na	2299	45.08	281.76
1993	69	na	409	27.27	161.40	na	2982	51.41	335.31
1994	63	60	264	26.40	183.20	730	3357	59.95	370.57
1995	78	56	265	13.25	73.90	744	3606	54.64	340.82
1996	64	50	268	14.11	84.79	590	3125	57.87	391.52

Table 2 Logbook, fish slip, and dockside monitoring data fields.

Zn Logbooks	Commercial Fish slips	Dockside Monitoring
CFV number	data_type	hail in number
captain	acceptance_status	offload log number
target species	keypunch_date	tab number
bait type	slip_number	CFV number
gear type	detail_line_number	vessel name
number hooks / string	gear	licence id number
number strings / lines	period	reference number
date	year	landing number
latitude	month	captain
longitude	day	landing port
minimum depth fished	days_fishing	buyer
maximum depth fished	stat area	offloader
statistical area	district	offload date
statistical subarea	processing_region	monitoring hours
time fished	location	fishing method YE
YE pieces	disposal	amount landed YE
QB pieces	company	fishing method Agg. 1 QB
CP pieces	plant	amount landed Agg. 1 QB
species 1	landing_status	fishing method Agg. 1 CP
pieces 1	species	amount landed Agg. 1 CP
species 2	sp_future	...
pieces 2	landed_form	(for all species landed)
...	std_form	...
species 12	pieces	YE amt quota mgmt area A
pieces 12	weight	YE amt quota mgmt area B
YE round weight	price	...
QB round weight	value	(all quota species,
CP round weight	cfv_type	all management regions)
round weight 1	cfv_person	record flag
round weight 2	licence	incident
...	licence_future	overage YE
round weight 12	packer_cfv	relinquished YE
	calc_pieces_weight_flag	...
date unloaded	calc_price_flag	(for all quota species)
hail report number	filler	...
buyer / processor		relinquishment
comment		comment
error		

Table 3 List of rockfish (*Sebastes*) species caught by Zn hook and line. The filled circles under "SG" indicate that the species is landed under a Zn licence in the Strait of Georgia.

Species	Common name	Abbreviation	Code	SG
Scorpaenidae	Scorpionfishes	SCORP	388	●
S. aleutianus	Rougheye rockfish	ROUGH	394	●
S. alutus	Pacific Ocean Perch	POP	396	●
S. auriculatus	Brown rockfish	BOLIN	398	
S. aurora	Aurora rockfish	AUROR	400	●
S. babcocki	Redbanded rockfish	REDBA	401	●
S. borealis	Shortraker rockfish	SHORT	403	●
S. brevispinus	Silvergray rockfish	SILVE	405	●
S. caurinus	Copper rockfish	COPPE	407	●
S. ciliatus	Dusky rockfish	DUSKY	409	●
S. crameri	Darkblotched rockfish	DARKB	410	●
S. diploproa	Splitnose rockfish	SPLIT	412	●
S. elongatus	Greenstriped rockfish	GREEN	414	●
S. emphaeus	Puget Sound rockfish	PUGET	415	
S. entomelas	Widow rockfish	WIDOW	417	●
S. flavidus	Yellowtail rockfish	YTAIL	418	●
S. goodei	Chilipepper rockfish	CHILI	420	
S. helvomaculatus	Rosethorn rockfish	ROSET	421	●
S. jordani	Shortbelly rockfish	SBELL	423	
S. maliger	Quillback rockfish	QUILL	424	●
S. melanops	Black rockfish	BLACK	426	●
S. miniatus	Vermillion rockfish	VERMI	428	●
S. mystinus	Blue rockfish	BLUE	429	●
S. nebulosus	China rockfish	CHINA	431	●
S. nigrocinctus	Tiger rockfish	TIGER	433	●
S. paucispinus	Bocaccio	LONGJ	435	
S. pinniger	Canary rockfish	CANAR	437	●
S. proriger	Redstripe rockfish	REDST	439	●
S. reedi	Yellowmouth rockfish	YMOUT	440	●
S. ruberrimus	Yelloweye rockfish	YEYE	442	●
S. saxicola	Stripetail rockfish	STRIP	444	
S. variegatus	Harlequin rockfish	HARLE	446	
S. zacentrus	Sharpchin rockfish	SHARP	450	

Table 4 Summary of management tactics applied to the Strait of Georgia fishery. The filled circles indicate the year(s) that each tactic was in effect.

Year	Fixed Season	Catch-limited Season	Annual TAC	Limited Entry	Fishing Periods	Fishing Options	Aggregate Mgmt.
<1986							
1986	●						
1987	●						
1988	●						
1989	●						
1990	●						
1991	●	●	●				
1992	●	●	●	●			
1993	●	●	●	●			
1994	●	●	●	●			
1995	●	●	●	●	●	●	●
1996	●	●	●	●	●	●	●
1997	●	●	●	●	●	●	●

Table 5 Rockfish aggregates in the Zn Hook and Line Fishery.

Year	Aggregate	Species
<1995	YE	yelloweye
	OR	quillback, copper, china, tiger
1995	YE	yelloweye
	A1	quillback, copper
	A2	china, tiger
	A3	canary, silvergray, yellowtail, widow
	A4	rougheye, shortraker, shortspine and longspine thornyheads
	A5	Pacific ocean perch, yellowmouth, redstripe
	A6	all other species (*Sebastes* sp.) except YE and A1-A5
> 1995	YE	yelloweye
	A1	quillback, copper
	A2	china, tiger
	A3	canary, silvergray
	A4	rougheye, shortraker, shortspine and longspine thornyhead
	A5	Pacific ocean perch, yellowmouth, redstripe
	A6	yellowtail, black, widow
	A7	all other species (*Sebastes* sp.) except YE and A1-A6

Table 6 Fishing period limits for the Inside (Strait of Georgia) category Zn Licence.

Limit	1995	1996	1997
A1	3500 lb.	1800 lb.	1500 lb.
A2-A6	< 20% of A1,YE/landing	na	na
A2-A7	na	600 lb.	600 lb.
A3-A7	< landed weight A1/period		
YE < Cap	6000 lb.	2500 lb.	2500 lb.
YE > Cap	Added to A2-A6 after 32t	<20% of A1/landing after 26t	<20% A1/landing after 24t
Overage	maximum 20% A1 deducted from next period	maximum of 10% of A1-A7,YE deducted from next fishing period	maximum of 10% of A1-A7,YE deducted from next period

Table 7 Yelloweye recommended yield, TAC, catch and the difference between catch and TAC for the Strait of Georgia management region. In 1996 and 1997, quotas were specified for each statistical area only, no overall regional quota was recommended.

Year	Rec. Yield (t)	TAC (t)	Catch (t)	Difference (t)
1986	na	na	94	na
1987	na	na	101	na
1988	na	na	131	na
1989	50-100	na	126	na
1990	25-75	na	135	na
1991	50	50	115	65
1992	59-86	59	30	-29
1993	81-121	70	42	-28
1994	31-48	70	86	16
1995	25-38	62	40	-22
1996	-	38	32	-6
1997	-	24	-	-

Table 8 Other rockfish recommended yield, TAC, catch and the difference between catch and TAC for the Strait of Georgia management region. In 1996 and 1997, quotas were specified for each statistical area only, no overall regional quota was recommended.

Year	Rec. Yield (t)	Quota (t)	Catch (t)	Difference (t)
1986	na	na	432	na
1987	150-300	na	322	na
1988	275-375	na	366	na
1989	275-500	na	335	na
1990	225-475	na	335	na
1991	400	300	366	66
1992	185-277	130	148	18
1993	236-358	140	157	17
1994	181-270	150	188	38
1995	176-269	150	153	3
1996	-	150	155	-
1997	-	143	-	-

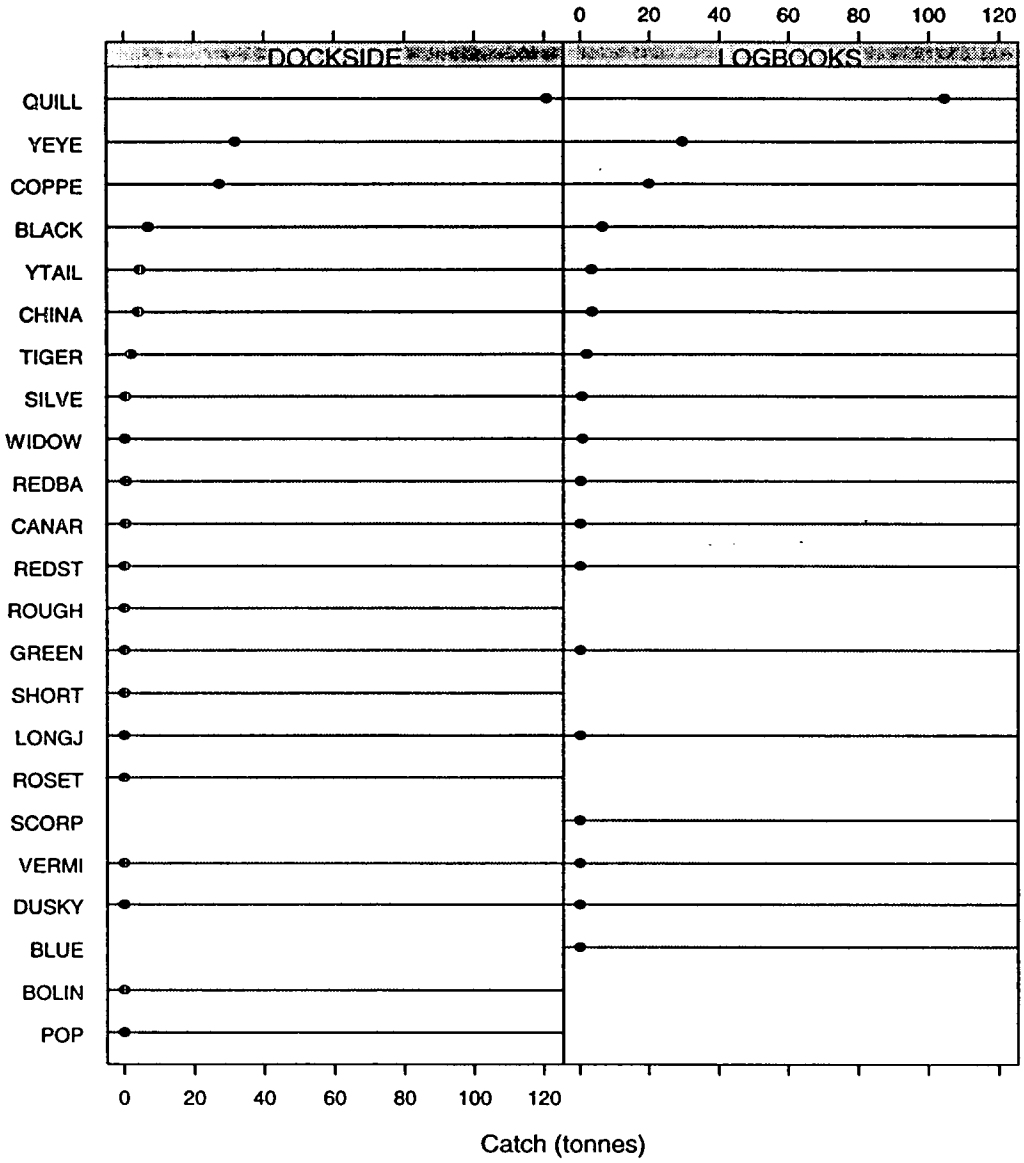

Figure 1 Estimated total catch (tonnes) by species in 1996 derived from dockside monitoring data (left panel) and logbook data (right panel).

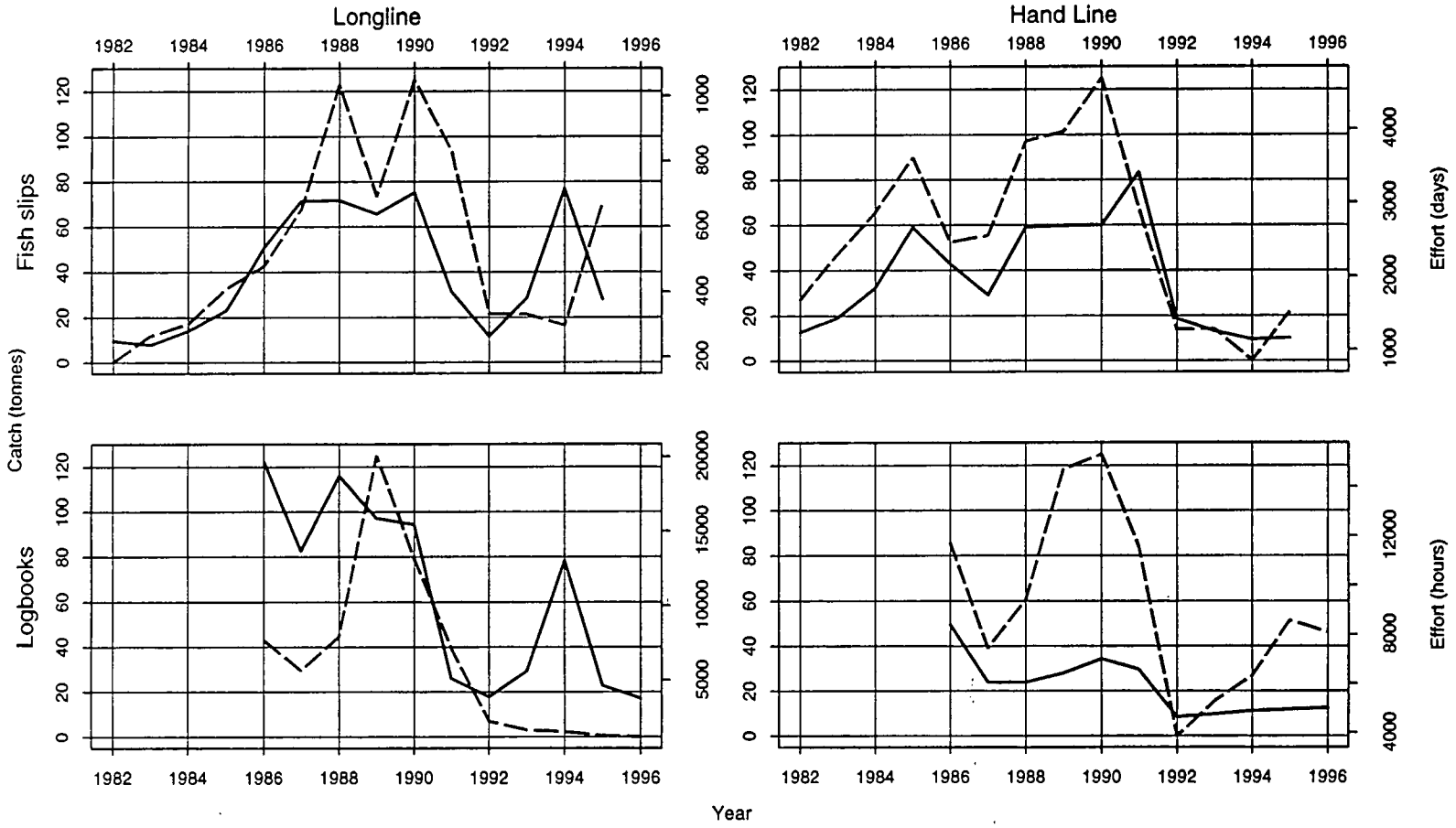

Figure 2 Annual catch statistics for "red snapper" in the Strait of Georgia by gear type from fish slips and logbooks. Catch (tonnes, solid line) and effort (days fished, dotted line) of RS derived from fish slip data are shown in the upper two panels. Catch (tonnes, solid line) and effort (hours fished, dotted line) of yelloweye rockfish derived from logbooks are shown in the lower two panels.

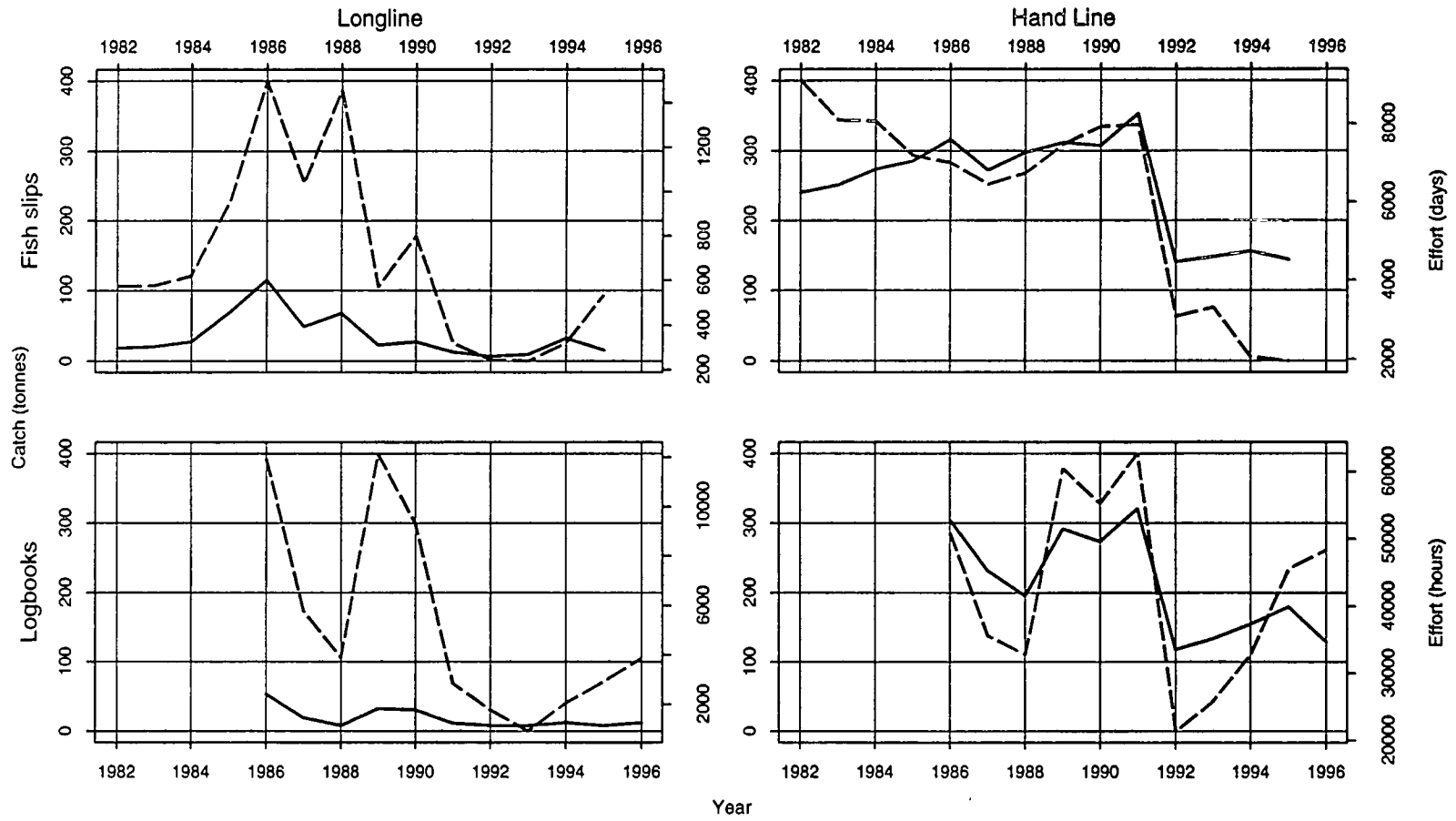

Figure 3 Annual catch statistics for "other rockfish" (OR) in the Strait of Georgia by gear type from fish slips and logbooks. Catch (tonnes, solid line) and effort (days fished, dotted line) of OR derived from fish slip data are shown in the upper two panels. Catch (tonnes, solid line) and effort (hours fished, dotted line) of OR rockfish derived from logbooks are shown in the lower two panels.

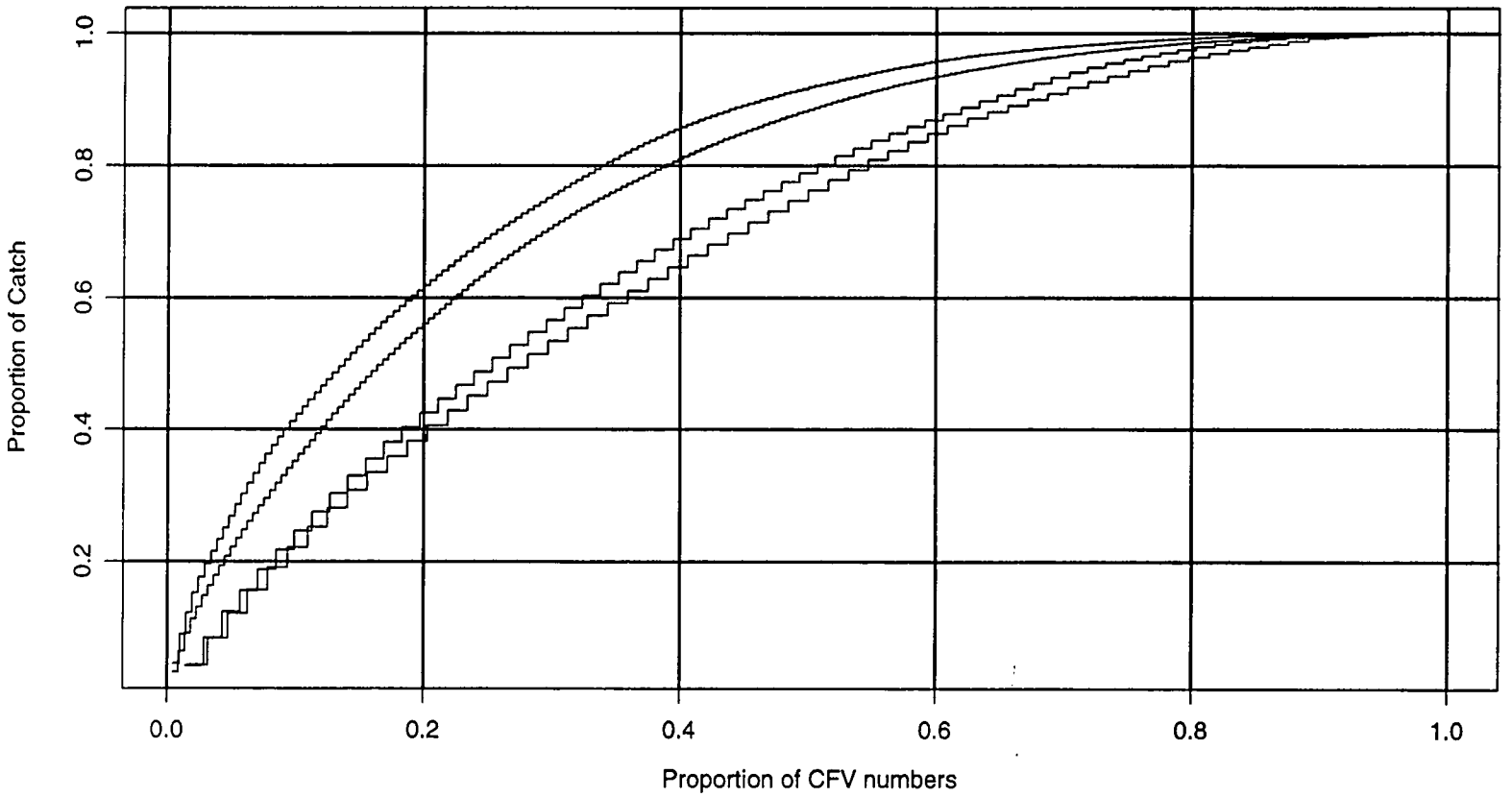

Figure 4 Proportion of total rockfish catch by weight as a function of the proportion of active vessels for 1986, 1991, 1992, and 1996 listed in order from top to bottom.

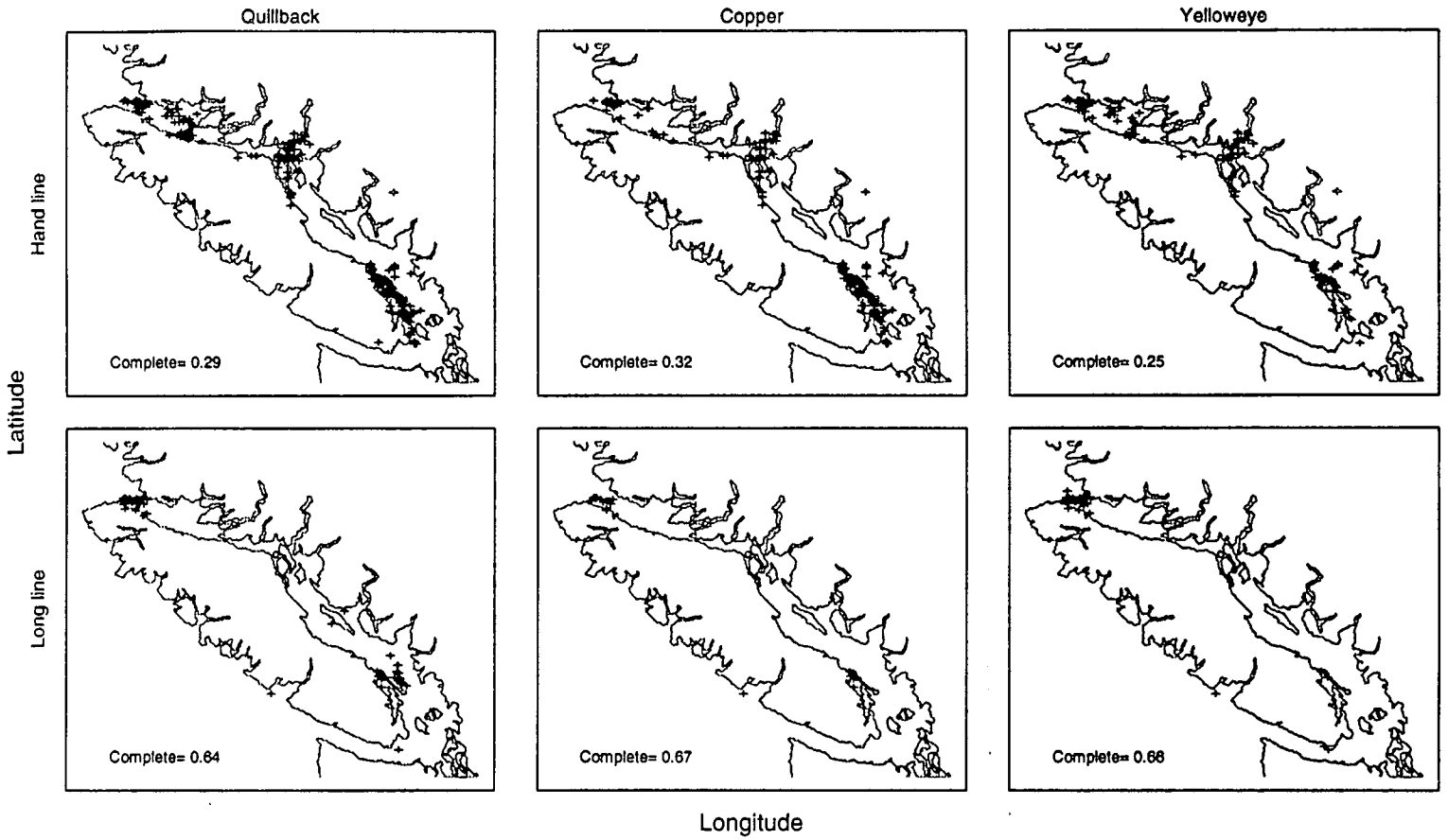

Figure 5 Spatial distribution of fishing activity for three species by gear type in 1996. The fraction of fishing events with completed latitude and longitude information is indicated in the lower left corner of each panel.

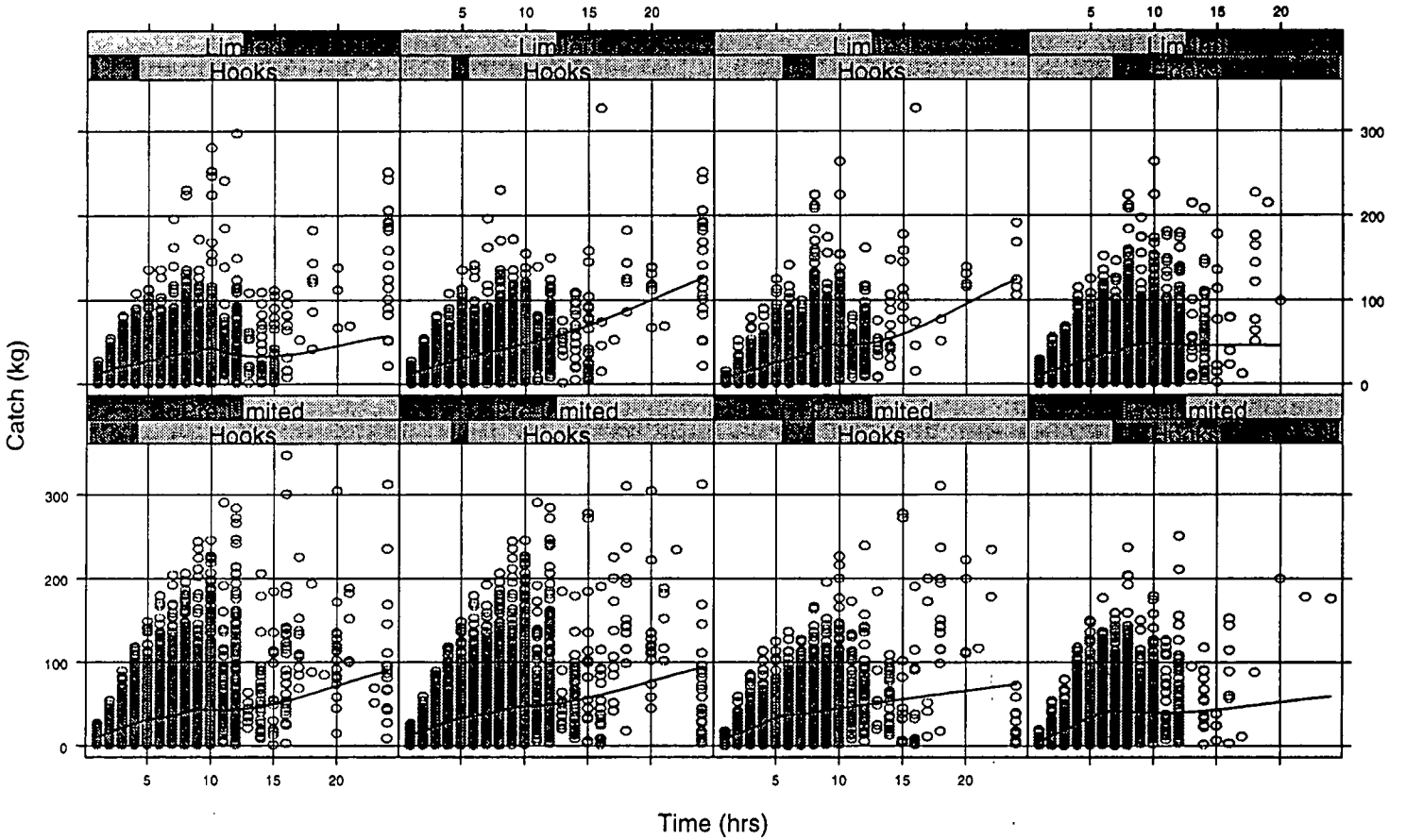

Figure 6 Catch (kg) as a function of time fished (hrs) and number of hooks for pre-limited entry (lower panels) and limited entry periods (upper panels). Each point represents the catch of quillback rockfish for a hand line fishing event. The solid line in each panel represents the smoothed trend fit by loess. The number of hooks fished is indicated by the dark shading in the strip labeled "Hooks".

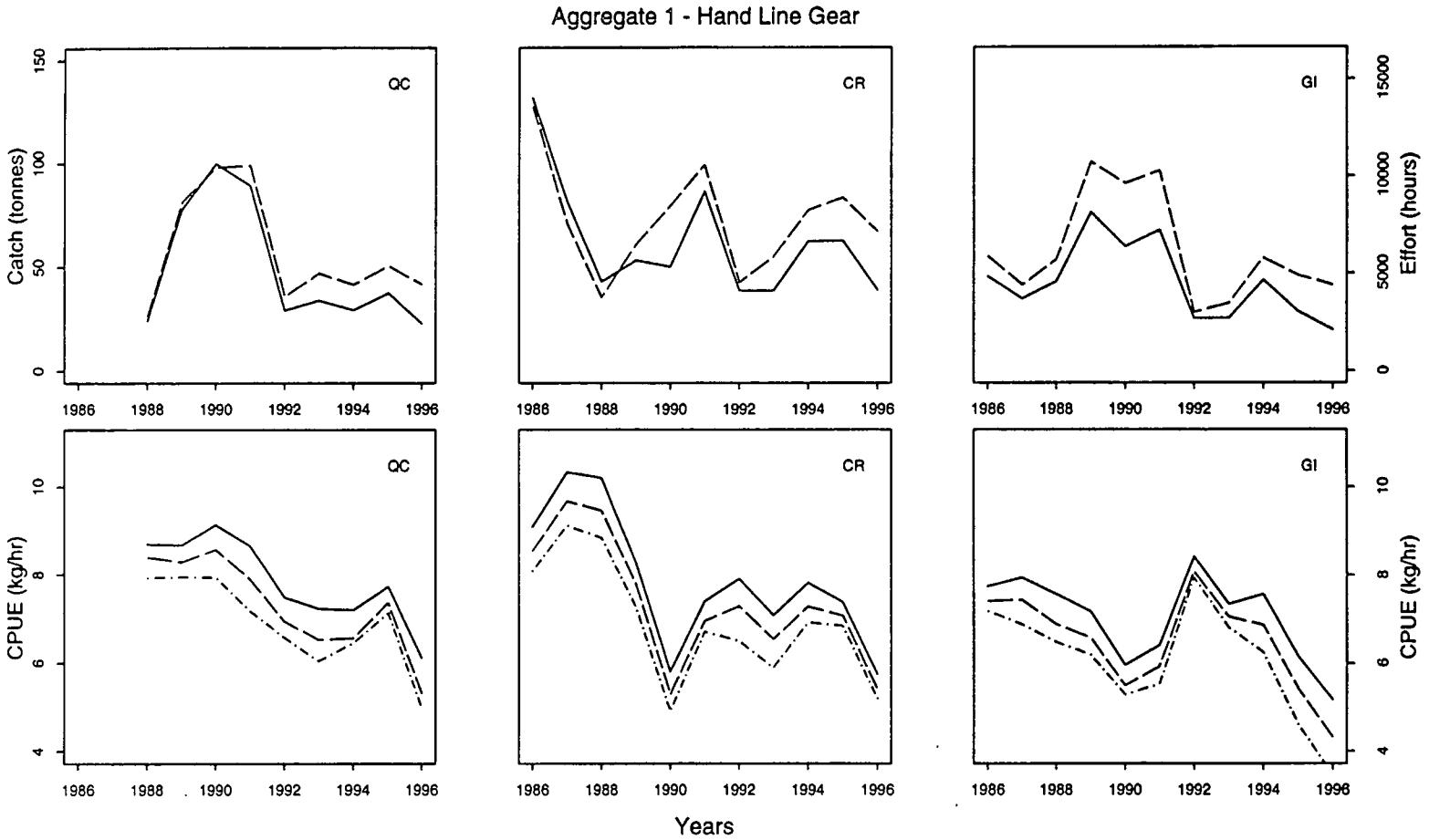

Figure 7 Catch, effort, and catch per unit effort for quillback and copper rockfish (aggregate 1) caught by hand line gear in three localities. The upper three panels represent annual time series of catch (tonnes, solid line) and effort (hours fished, dashed line) in the Queen Charlotte Strait (QC), Campbell River (CR) and Gulf Islands (GI) localities. The lower three panels show mean catch per unit effort (kg/hr) (solid line), a 10% trimmed mean CPUE (dashed line) and median CPUE (dot-dash line) for each locality by year.

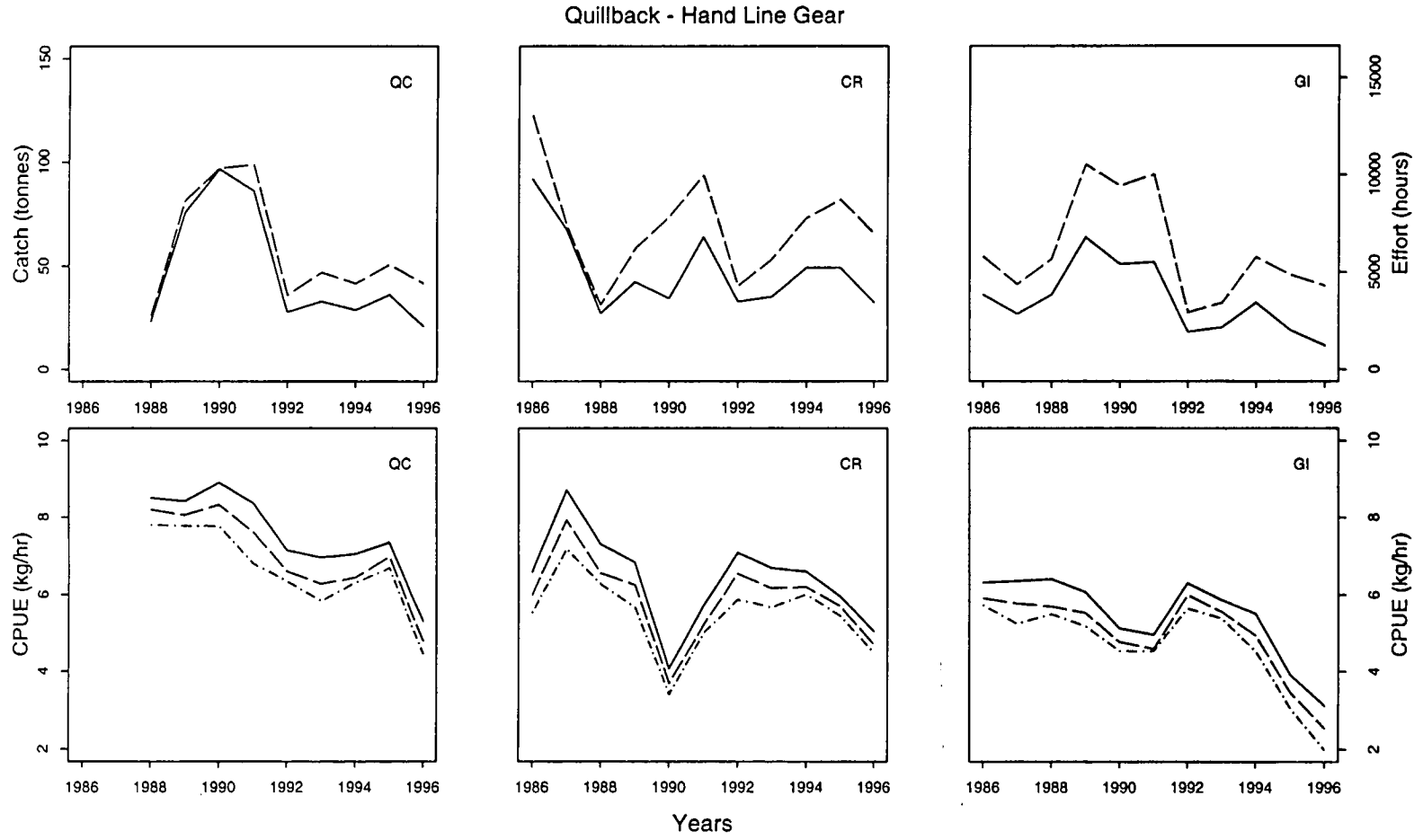

Figure 8 Catch, effort, and catch per unit effort for quillback rockfish caught by hand line gear in three localities. The upper three panels represent annual time series of catch (tonnes, solid line) and effort (hours fished, dashed line) in the Queen Charlotte Strait (QC), Campbell River (CR) and Gulf Islands (GI) localities. The lower three panels show mean catch per unit effort (kg/hr) (solid line), a 10% trimmed mean CPUE (dashed line) and median CPUE (dot-dash line) for each locality by year.

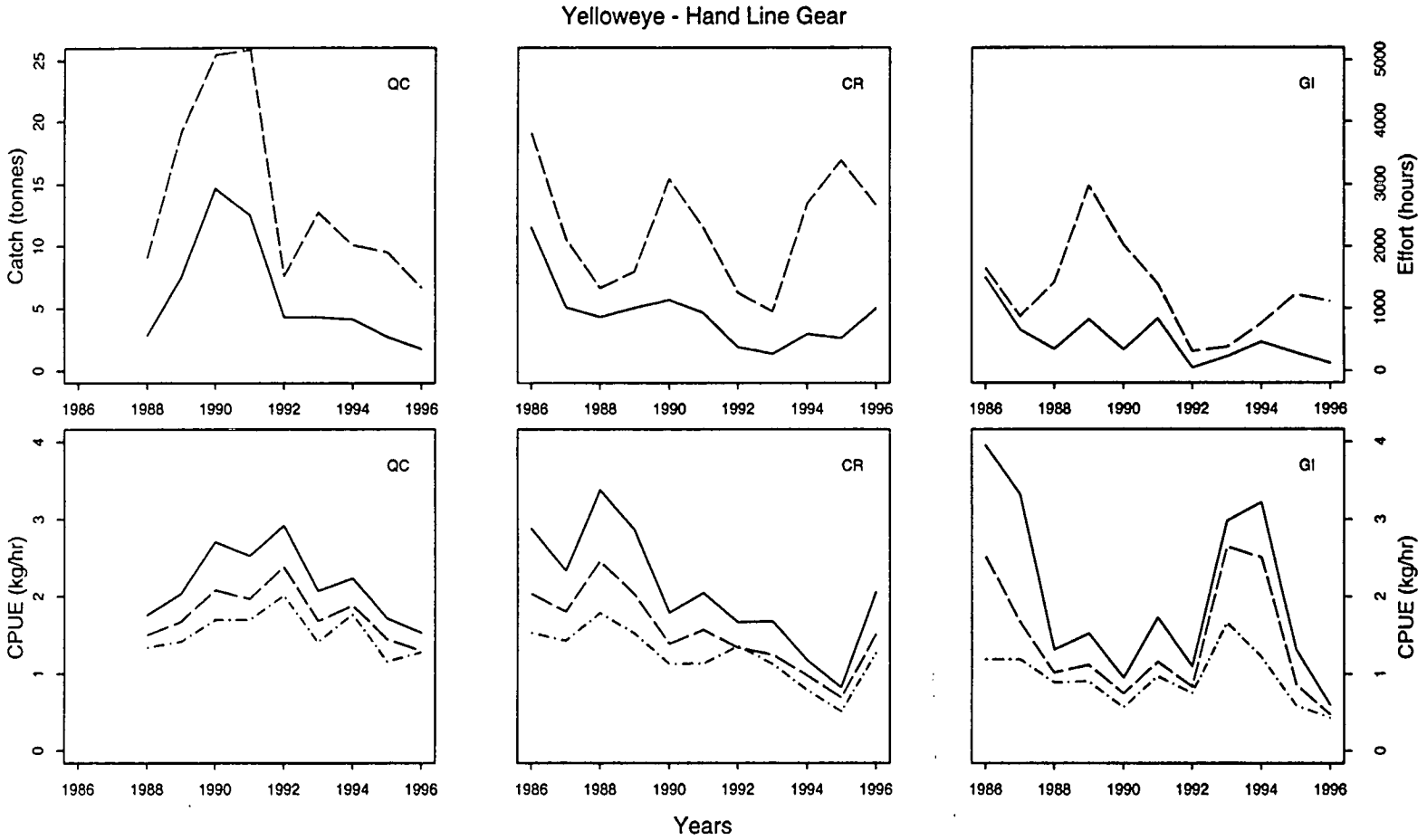

Figure 9 Catch, effort, and catch per unit effort for yelloweye rockfish caught by hand line gear in three localities. The upper three panels represent annual time series of catch (tonnes, solid line) and effort (hours fished, dashed line) in the Queen Charlotte Strait (QC), Campbell River (CR) and Gulf Islands (GI) localities. The lower three panels show mean catch per unit effort (kg/hr) (solid line), a 10% trimmed mean CPUE (dashed line) and median CPUE (dot-dash line) for each locality by year.

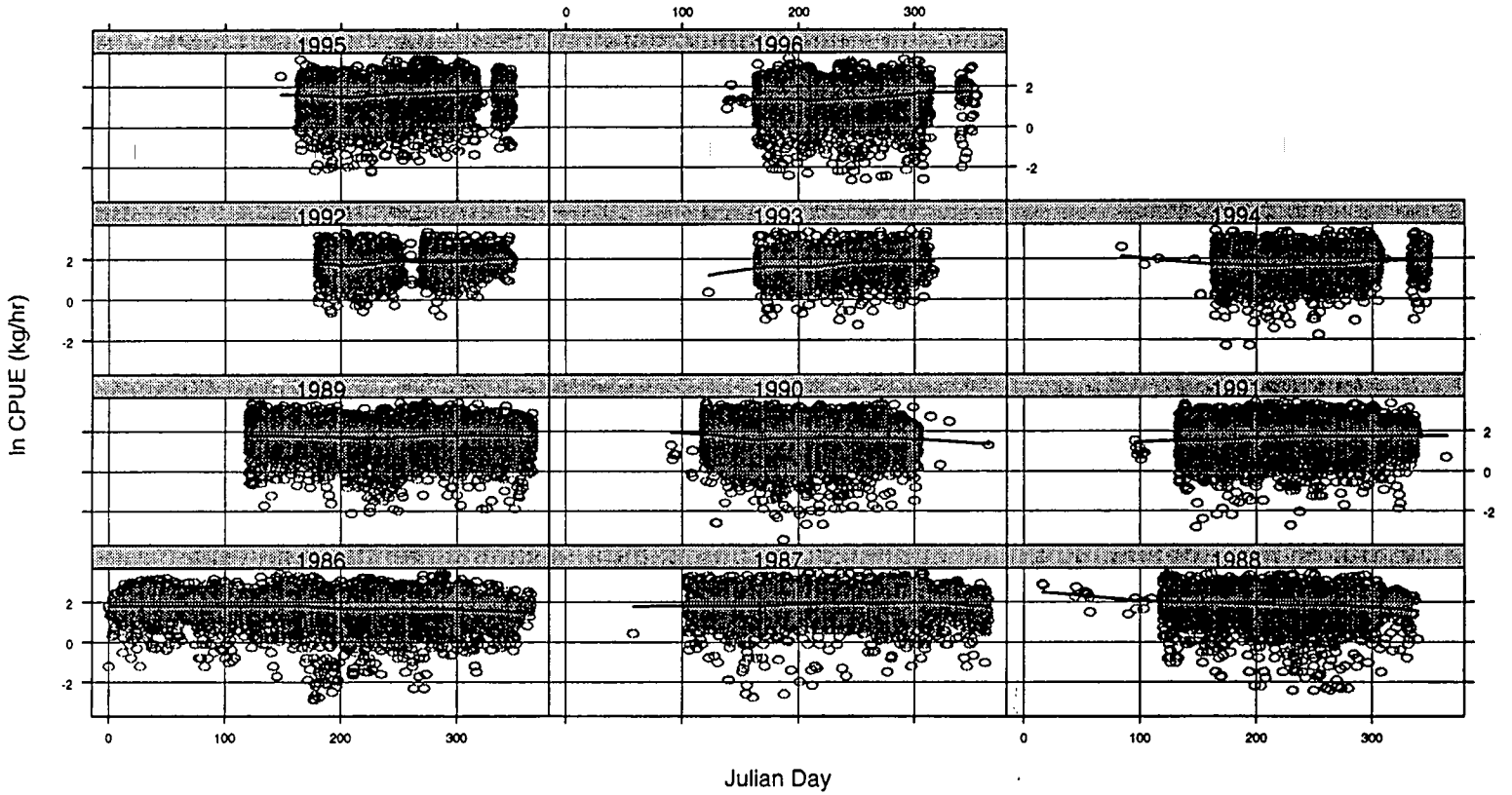

Figure 10 Catch rate as a function of Julian day and year for quillback rockfish caught by hand line gear. Each panel contains a scatterplot of (ln) CPUE (kg/hr) as a function of Julian day within the year for each fishing event. The solid line superimposed on each panel represents the smoothed trend line. The panels show the extent of fishing within each year, but no evidence of a seasonal effect. There is a tendency for lower values of CPUE overall in recent years.

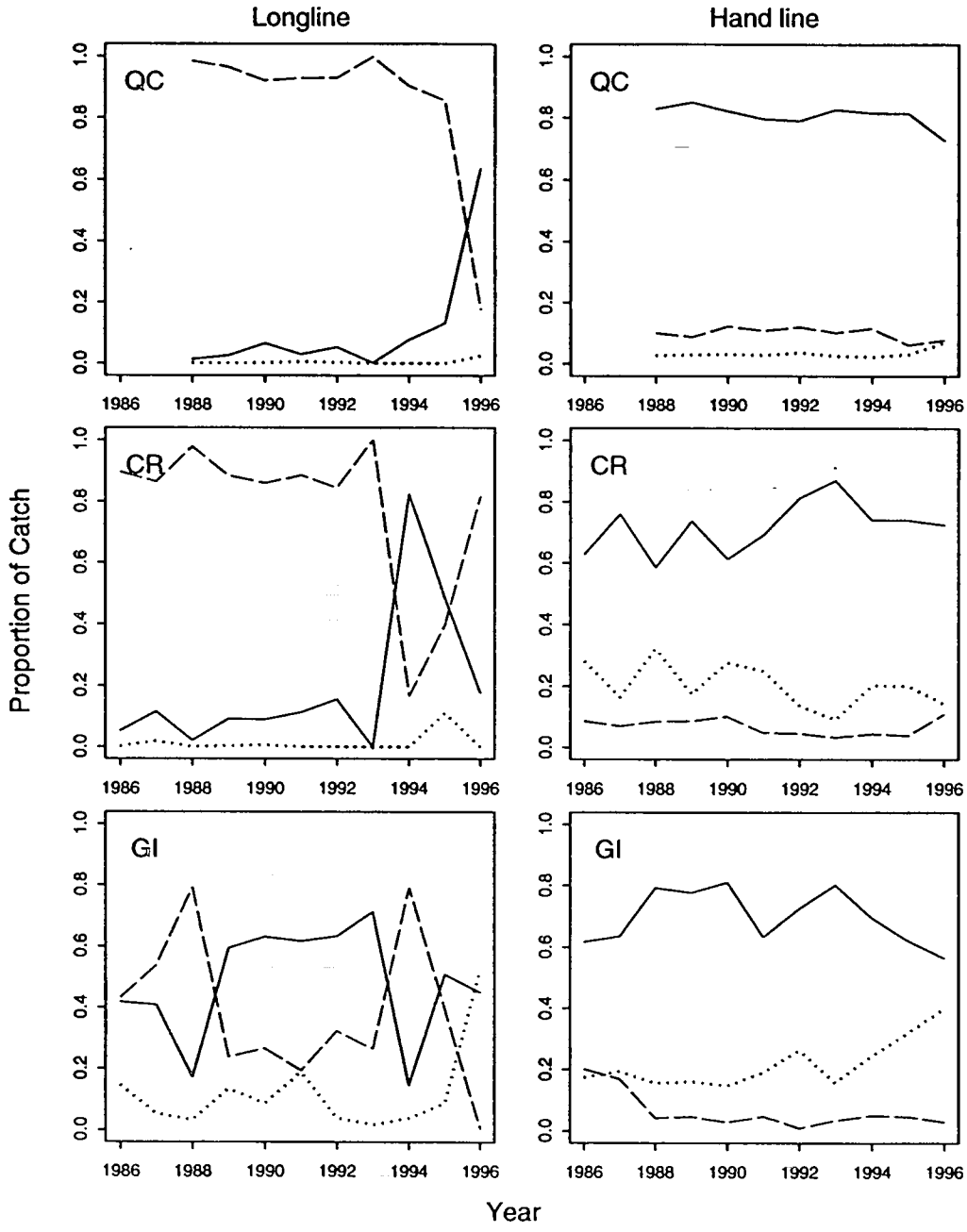

Figure 11 Catch of quillback (solid line), copper (dotted line), and yelloweye rockfish (dashed line) as a proportion of total rockfish landed annually by locality and gear. The localities are Queen Charlotte Strait (QC), Campbell River (CR) and the Gulf Islands (GI) localities.