Comparison of commercial fishery and research catch data

David S. Fox and Richard M. Starr

Abstract: Participants in the U.S. west coast groundfish trawl fishery are required to maintain logbook records that provide a detailed set of species, catch, and effort data with broad temporal and spatial coverage. We used a geographic information system to compare catch data collected from the Oregon commercial trawl fishery with data from U.S. National Marine Fisheries Service research cruises conducted at the same time in the same area. We compared catch locations, catch rates, and biomass estimates for five species, for 1980–1989. Patterns of distribution and relative abundance derived from logbook data closely resembled those from National Marine Fisheries Service triennial trawl research data. Summer season density estimates from logbook data displayed narrower 95% confidence intervals than estimates derived from an entire year, suggesting that sampling in summer months maximizes the statistical reliability of research results. Graphical and statistical analyses indicated that information derived from logbooks can augment research data and improve estimates of the distribution and relative abundance of commercial fish species.

Résumé : Les participants à la pêche du poisson de fond au chalut sur la côte ouest des États-Unis doivent tenir des journaux de bord qui fournissent une série détaillée de données sur les espèces, les captures et l'effort, avec une vaste couverture spatiale et temporelle. Nous avons utilisé un système d'information géographique pour comparer les données sur les captures recueillies par le secteur de la pêche commerciale au chalut en Oregon aux données obtenues par les campagnes de recherche menées en même temps et dans la même région par le U.S. National Marine Fisheries Service. Nous avons comparé la localisation des captures, les taux de capture et les estimations de la biomasse pour cinq espèces, sur la période 1980–1989. Les patrons de distribution et d'abondance relative tirés des données des journaux de bord ressemblaient étroitement aux données des campagnes triennales de recherche au chalut menées par le National Marine Fisheries Service. Les estimations de la densité pendant la période estivale établies à partir des données des journaux de bord présentaient des intervalles de confiance plus étroits à 95% que les estimations tirées de l'année entière, ce qui permet de penser que l'échantillonnage pratiqué pendant les mois d'été maximise la fiabilité statistique des résultats de la recherche. Les analyses graphiques et statistiques indiquent que l'information tirée des journaux de bord peut enrichir les données scientifiques et améliorer les estimations de la distribution et de l'abondance relative des espèces de poissons commercialement exploitées.
[Traduit par la Rédaction]

Introduction

The west coast of the United States is home to a well-developed commercial trawl fishery. Over 377 vessels operated in the Oregon, Washington, and California groundfish trawl fishery in 1991; the reported total catch was more than 278 000 t (Pacific Fishery Management Council 1991). The west coast states, National Marine Fisheries Service (NMFS), and Pacific Fishery Management Council (PFMC) jointly manage catch and effort in the groundfish fishery using a variety of methods such as limited entry, gear restrictions, catch quotas, and trip limits. In a review of PFMC stock assessment methodologies, a U.S. National Academy of Sciences panel suggested that the PFMC consider the use of fishery logbooks to augment research data (Pacific Fishery Management Council 1995).

Oregon trawlers have been required to maintain fishery records since the 1960s, and the PFMC has required fishers to keep records since 1984. These fishery logbooks provide a detailed set of catch and effort data with broad temporal and spatial coverage. In addition to logbook records, an elaborate coastwide monitoring system provides records of the actual weights of fish sold to processors (Pacific Fishery Management Council 1991). Although large amounts of site-specific information are compiled as part of these coastwide data collection programs, much of the data are not used for assessing fish populations, primarily because of the large volume of data and concerns about potential data biases.

Fishery logbooks were used by Gabriel and Tyler (1980), Gabriel (1982), and Tyler et al. (1984) to describe the distribution of commercial fishing effort off Oregon and Washington. Until recently, however, coastwide catch information has been collected, but typically not analyzed, partially because of the complexity of managing and plotting large numbers of geographic data points. With the availability of efficient geographic information systems (GIS), tools now are available to display and analyze large spatial data bases.

We adapted and used a GIS to compare data from the Oregon commercial trawl fishery with data from NMFS research cruises conducted at the same time in the same area (Fig. 1). Our objectives were to map fishery and research catch locations for five species and compare catch distribution patterns, catch rates, and biomass estimates. We suggest that if logbook

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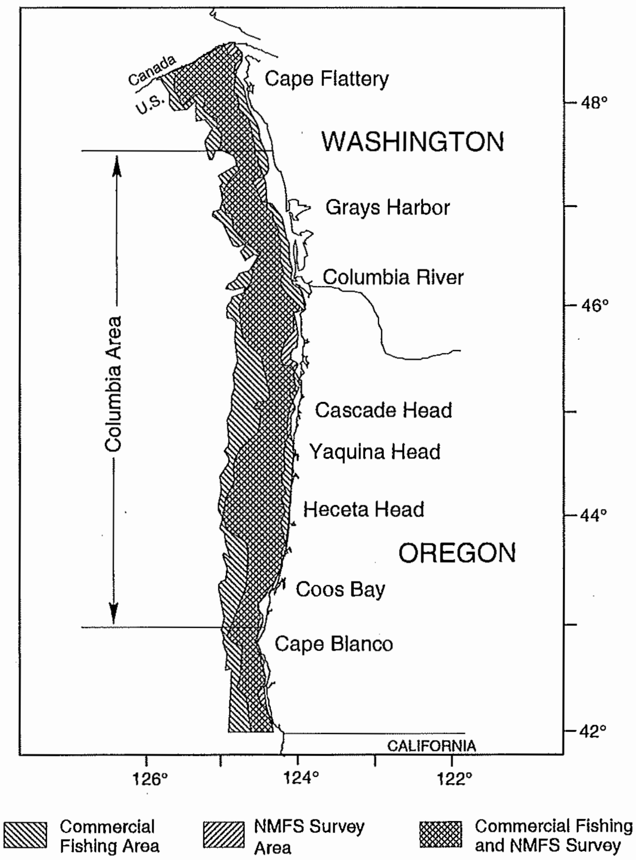
Fig. 1. Commercial fishing and NMFS survey areas in the Columbia Fishery Management Area along the Oregon and Washington coast.



and research data are closely correlated, then logbook data can complement research data and can be used to improve estimates of the distribution and abundance of selected species.

Methods

Data sets

Commercial fishing data used in these analyses were compiled from groundfish bottom trawl fishery logbooks collected by the Oregon Department of Fish and Wildlife (ODFW) from 1980 to 1989. This 10-year logbook data base contains over 130 000 individual records, each representing a single trawl tow. Information for each record includes vessel number, gear type, port of landing, date, latitude and longitude, effort in trawl hours, and catch in pounds for each species or market category reported. Three major gear and net configurations are used in the west coast groundfish fishery: midwater trawls, bottom trawls equipped with roller gear, and bottom trawls without roller gear (sole nets). Our analysis included only the two bottom trawl gear configurations. We computed catch per unit effort (CPUE), expressed in kilograms per hour, for each species in each tow. We had insufficient information to adjust effort for differences in fishing power among the vessels, years, or gear configurations. For a similar reason, we did not adjust catch for discard of unwanted fish at sea.

The procedures used for collecting and processing logbook data included catch recording by fishers, logbook collection, logbook screening, computer data entry, and error checking. The numerous fishing vessels and trips provided a large quantity of data, so we were selective of information included in the analyses. Only those logbooks that were complete and legible and had location information for each tow were analyzed. We used only those logbooks that had closely corresponding fish landing records, enabling the use of weights recorded at the dock. Computer error checking procedures included automated and manual review checks to detect tows that had unreasonable locations with respect to depth or distance from a previous tow. The application of these quality assurance steps resulted in the use of about 50% of the tows executed by the fishery.

The scientific fishery data used in this study originated from a series of NMFS Pacific west coast bottom trawl surveys of groundfish resources conducted in 1980, 1983, 1986, and 1989. The surveys, often referred to as triennial trawl surveys, contained excellent spatial and temporal overlap with the commercial fishery data set. NMFS sampled depths ranging from 55 to 366 m. The surveys were conducted from early July to early October of each survey year. NMFS completed tows at 1572 stations during the four surveys in the Oregon–Washington area; the commercial logbook data set contained 13 244 tows for the months and geographic areas that overlapped with the NMFS surveys.

Triennial trawl survey methods are described by Gunderson and Sample (1980), Weinberg et al. (1984, 1994), Coleman (1986, 1988), Dark and Wilkins (1994), and Weinberg (1994). NMFS used a Nor'eastern high-opening bottom trawl equipped with roller gear, which was similar in size and construction to most commercial roller trawl gear used during the 1980s, except for the cod-end mesh size. NMFS used a 32-mm cod-end mesh liner, whereas the commercial fleet generally used a cod-end mesh of between 76 and 114 mm. NMFS trawled at a speed similar to that of commercial bottom trawlers, but tows were about 0.5 h long, whereas commercial bottom tows averaged 2.8 h.

Our analysis included five species: Dover sole (*Microstomus pacificus*), English sole (*Pleuronectes vetulus*), sablefish (*Anoplopoma fimbria*), yellowtail rockfish (*Sebastes flavidus*), and shortspine thornyhead (*Sebastolobus alascanus*). Dover sole, English sole, and sablefish were reported in logbooks as individual species throughout the 1980s. Yellowtail rockfish has been reported by trawlers separately since 1985 and thornyhead has been reported since 1984 as a combination of shortspine and longspine thornyhead (*Sebastolobus altivelis*). ODFW catch sampling conducted in 1989, however, indicated that the commercial catch of thornyhead consisted of at least 92% shortspine in the areas and times that coincided with the NMFS surveys (Oregon Department of Fish and Wildlife, unpublished data).

We examined the relative contribution of fishes in the NMFS catch that were below the size that would be commercially retained but we did not have size-frequency information for each tow and thus could not adjust NMFS catches to account for submarket-sized fishes. The size thresholds for commercial retention of the five study species were determined from ODFW market sample data (Oregon Department of Fish and Wildlife, unpublished data).

We used three approaches to compare commercial and research catch data. First, we compared spatial patterns of catch distribution by overlapping coastwide isopleths of CPUE. Second, we compared NMFS and logbook CPUE stratified by depth and latitude using statistical and graphical techniques. Finally, we compared species biomass estimates derived with similar methods for each data type.

Spatial patterns of CPUE

We visually compared spatial patterns of CPUE by examining contour maps developed from logbook and research catches. Logbook data used for the contour maps included only those trawls that fell within the same time frame and depth range as each of the NMFS cruises. We used all tows deemed adequate for analysis by NMFS. For both data types, analyses included tows that caught the species of interest as well as tows with no catch of the species.

We computed and plotted isopleths representing the 50th, 75th, and 90th percentile levels of CPUE for each species, year, and data type, using commercial GIS and contouring software packages. The 50th percentiles of CPUE for yellowtail rockfish and shortspine thornyhead were either zero or nearly zero because there were many tows with no catch of the species. Therefore, only the 75th and 90th percentile isopleths were mapped for those species.

For each species, we compared logbook and research catch locations by overlaying the CPUE maps and evaluating the geographic co-occurrence of the polygons defined by the isopleths. We also computed the total surface area of polygons and the total area of overlap between the two data types. The amount of spatial overlap was calculated by determining the percentage of the surface area covered by logbook CPUE isopleths that co-occurred with corresponding levels of CPUE from the NMFS data.

Graphical and statistical comparison of CPUE

As a second method of comparing CPUE, we examined NMFS and commercial fishery data graphically and statistically. Both data sets were stratified by year, increments of 94 m of depth (50 fthm), and 30 min of latitude. There were 52 possible strata (4 depth increments by 13 latitude increments) in the area sampled by each of the NMFS surveys. We transformed the individual tow CPUE values using a $\ln(x + 1)$ transformation (Zar 1974), and calculated frequency of occurrence and mean CPUE for both research and logbook data sets. We compared frequency distributions using the Kolmogorov–Smirnov two-sample test (Sokal and Rohlf 1981).

We used a parametric simple linear correlation analysis (Snedecor and Cochran 1967) on the transformed data to compare logbook and NMFS mean CPUE. Mean CPUE represents the sum of individual tow CPUE divided by the number of tows. The computations included both tows that caught the target species and those with no catch. We computed separate mean CPUE values for roller net, sole net, and combined bottom nets to analyze the effects of different net types on the correlation analysis.

In the logbook data set, we calculated mean CPUE for all strata that contained 10 or more tows; sample size ranged from 10 to 1180 tows per stratum. We used a threshold of 10 tows to minimize spurious CPUE values resulting from data collected from a single vessel or fishing trip. The computation of mean CPUE in the research data set included all tows within each stratum that were deemed adequate for analysis by NMFS (National Marine Fisheries Service 1989). Research sample size ranged from 1 to 120 tows per stratum.

Biomass comparisons

Our third approach to data comparison involved estimating biomass from the logbook data and comparing the estimates with similar values generated from NMFS data. We estimated biomass from the logbook data using an area swept methodology similar to that employed by NMFS (Gunderson and Sample 1980). We obtained footrope specifications and estimates of net opening width for several gear types used in Oregon (Wathne 1977; Amos 1985; Danish Institute of Fisheries Technology 1987). On the basis of information from 13 types of trawl nets, opening width averaged 41.6% (range 29.0–49.0%) of the footrope length. Footrope length of bottom trawl gear averaged 22.8 m, with a range of 17.2–39.1 m (Oregon Department of Fish and Wildlife, unpublished data from a 1985 and 1986 survey of the Oregon trawl fleet). Applying the average ratio of net opening width to average footrope length, we estimated an average net opening width for the trawl fleet of 9.5 m. For comparison, NMFS used a trawl net with a 32.2-m footrope and an opening width of 42% (13.5 m) (Gunderson and Sample 1980). Commercial vessel speed averaged 4.5 km/h with a range of 3.3–5.6 km/h (Oregon Department of Fish and Wildlife, unpublished data from a 1985 and 1986 survey of the Oregon trawl fleet). Prescribed trawling speed for triennial trawl surveys was 5.6 km/h.

We calculated the average area swept per trawl hour for commercial gear to be 4.2 ha/h. A similar computation for NMFS gear yielded a value of 7.5 ha/h. Employing the same data stratification scheme of depth and latitude described above, we estimated surface area with the

Table 1. Percentiles of CPUE (kg/h) calculated from commercial logbook and NMFS triennial trawl cruise data.

		Logbook CPUE percentiles			NMFS CPUE percentiles		
	Year	50th	75th	90th	50th	75th	90th
Dover sole	1980	88.0	129.3	159.7	7.5	27.9	60.7
	1983	49.6	97.7	153.6	14.5	55.5	104.7
	1986	38.4	87.8	157.4	18.6	43.5	89.9
	1989	54.4	102.0	143.7	17.0	37.1	75.5
Sablefish	1980	4.8	33.5	105.9	4.0	18.5	160.6
	1983	9.3	36.5	61.1	8.1	35.3	119.5
	1986	7.8	30.3	70.0	11.8	41.8	90.7
	1989	8.8	19.5	39.0	3.4	27.1	121.7
English sole	1980	3.1	13.5	27.5	0.5	2.7	19.1
	1983	3.3	9.8	24.5	2.2	11.9	27.6
	1986	1.0	16.0	34.7	2.7	16.1	35.6
	1989	3.4	16.3	37.6	2.7	23.3	49.1
Yellowtail rockfish	1986		0.7	32.7		9.3	55.3
	1989		14.5	93.3		0.9	21.8
Shortspine thornyhead	1986		3.8	10.8		3.2	13.0
	1989		6.2	21.6		3.6	12.3

GIS software, and then estimated biomass for each stratum using logbook data as follows:

$$\text{biomass within each stratum (kg)} = (\text{stratum area (ha)} / 4.2\ \text{ha/h}) \times \text{mean stratum CPUE (kg/h)}$$

We produced two types of biomass estimates from fishery logbook data. The first method provided a biomass estimate that was comparable with NMFS triennial trawl survey biomass estimates for the Columbia Fishery Management Area. We computed a biomass for each stratum using only July–September data and summed only the strata within the Columbia Fishery Management Area (43°00′ to 47°30′) and three depth increments from 94 to 360 m. To make the NMFS and logbook data directly comparable, we divided biomass by total strata surface area to produce a catch weight per hectare. We computed 95% confidence intervals (CI) for each estimate using methods described in Cochran (1977). NMFS computed 95% CI using the same methods (Gunderson and Sample 1980).

For the second estimate of biomass from logbooks, we computed an average annual CPUE per stratum by first calculating four seasonal CPUE values and then averaging the seasonal values within each stratum. We then summed the strata within the Columbia Fishery Management Area between 94 and 360 m and divided the resultant biomass estimates by the total surface area of the strata. These biomass estimates allowed us to explore the effects of sampling during one season relative to year-round sampling.

Results

Spatial comparison

For all species, the 50th, 75th, and 90th percentile levels of CPUE were of similar magnitude (Table 1) and spatially co-occurred (Fig. 2). In each of the data sets, the highest catch rates for Dover sole occurred off Cape Flattery, Gray's Harbor, the Columbia River, Cascade Head, Heceta Head, and Cape Blanco (Fig. 2). Centers of the 90th percentile of research and logbook CPUE were in similar locations from year to year. Isopleth maps of 1980 data showed areas of high research

Fig. 2. Isopleths of the 50th, 75th, and 90th percentiles of CPUE for commercial fishery and NMFS triennial trawl cruises for Dover sole, sablefish, English sole, yellowtail rockfish, and shortspine thornyhead.

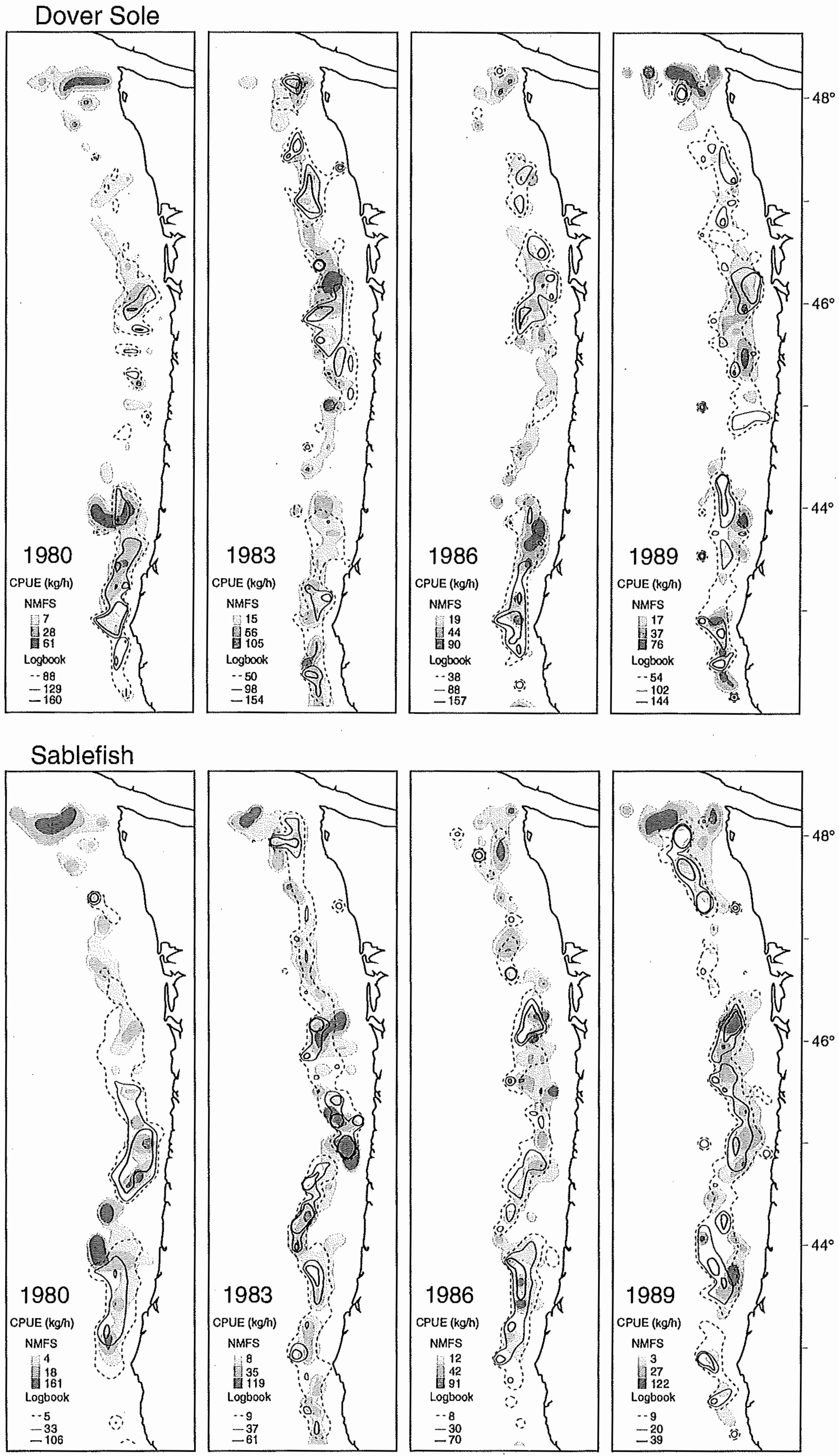
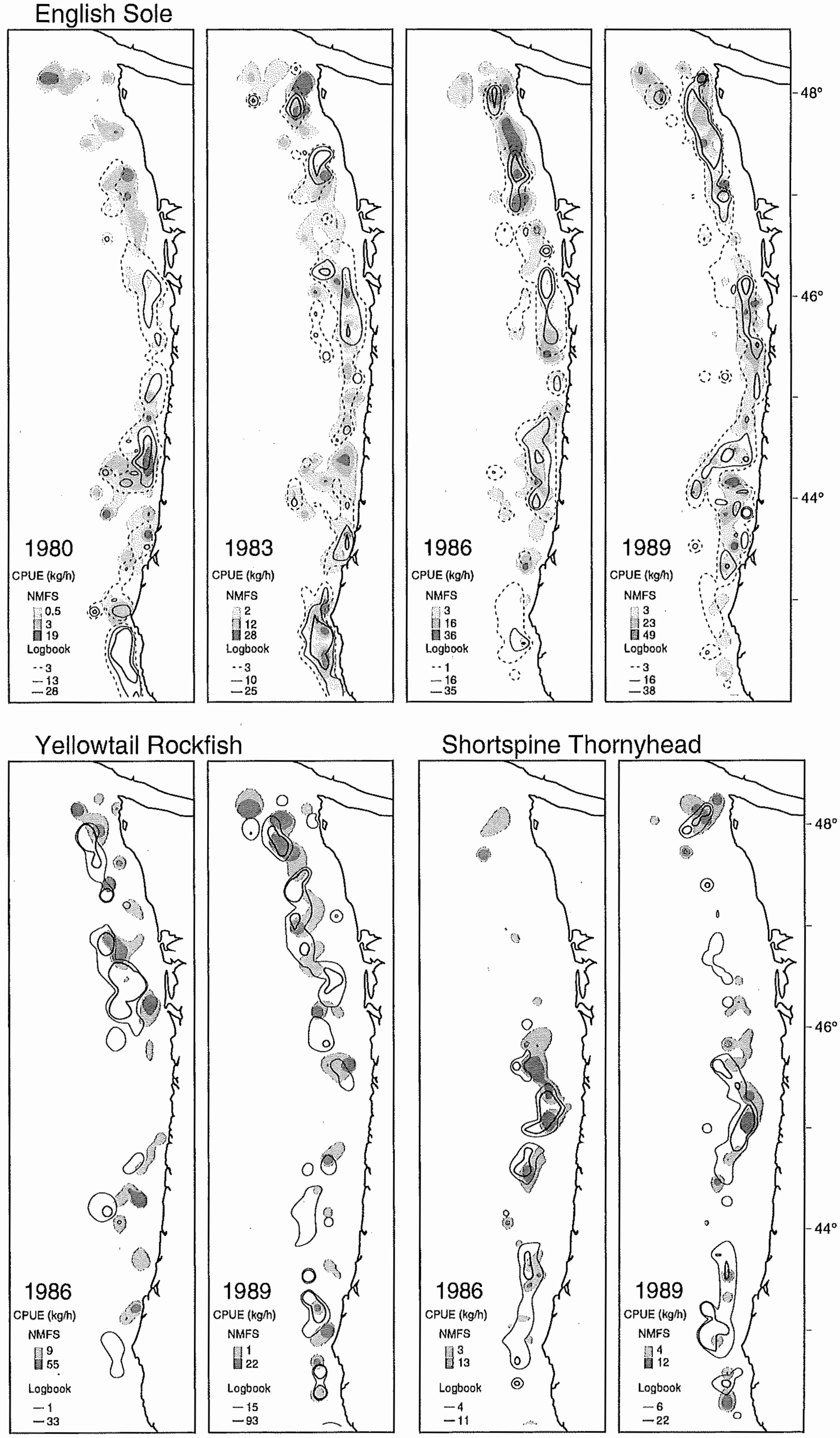


Fig. 2 (*concluded*).



CPUE off Cape Flattery without corresponding high logbook catch rates. Conversely, logbook data showed high catch rates off southern Oregon in 1980 without corresponding high research catch rates. In each case, the discrepancy was caused by lack of either commercial or research sampling effort (Fig. 3).

The highest catch rates for sablefish occurred off Cape Flattery, the Columbia River, and Cascade Head, and from Heceta Head to Cape Blanco (Fig. 2). Centers of the 90th percentile of research and logbook CPUE were in similar locations with two exceptions. NMFS cruises in 1980 and 1983 showed high catch rates off Cape Flattery that were not apparent from logbook data. In both cases, there was a lack of commercial fishing effort in those areas (Fig. 3).

The highest catch rates for English sole occurred off northern Washington, Gray's Harbor, the Columbia River, Yaquina Head, Heceta Head, and southern Oregon (Fig. 2). Centers of the 90th percentile of research and logbook CPUE were in similar locations, except that CPUE maps for 1980 and 1986 showed generally lower research catch rates off the Columbia River. Logbook catch rates for 1980 and 1986 in southern Oregon also were high without corresponding high research catch rates, but those differences can be attributed to a lack of research sampling effort (Fig. 3).

The highest catch rates for yellowtail rockfish occurred off northern Washington, Gray's Harbor, Cascade Head, Heceta Head, and Cape Blanco. Centers of the 90th percentile of research and logbook CPUE were in similar locations, but logbook data indicated larger areas of high catch rates than did the research data. Similarly, locations of high CPUE for shortspine thornyhead overlapped with triennial trawl data, but logbook data suggested a broader distribution of high CPUE compared with the research data.

In terms of percent overlap between data types, more than 66% of high logbook catch locations (defined by isopleths of 50th percentile of CPUE) occurred in the same area as high research catches for Dover sole, English sole, and sablefish (Table 2). Overlap ranged from 60 to 81% for the 50th percentile polygons, from 23 to 63% for the 75th percentile polygons, and from 13 to 47% for the 90th percentile polygons (Table 2). Overlap of surface area for shortspine thornyhead CPUE isopleths averaged 58 and 57%, respectively, for the 75th and 90th percentiles of CPUE. Overlap of surface area for yellowtail rockfish CPUE isopleths averaged 40 and 19%, respectively, for the 75th and 90th percentiles of CPUE.

English sole and shortspine thornyhead below market size contributed relatively large amounts to NMFS catch (Table 3), but we found no obvious areas where this caused NMFS and logbook data to differ in spatial distribution. For the 1 year in which we had research length-frequency information by tow, concentrations of submarket-sized English sole were caught in areas that also contained high commercial English sole catches.

Graphical and statistical comparison of CPUE

Both research and logbook data bases contained a large proportion of tows with no catch of a species. Even after the data were transformed, the frequency distributions were skewed (Fig. 4). The ranges of CPUE and shapes of the frequency histograms were similar between research and logbook data. The most obvious difference between the two data sets was the occurrence of a larger percentage of smaller catches in the research data set. A Kolmogorov–Smirnov two-sample test showed no significant differences between frequency distributions for any of the species except yellowtail rockfish (Table 4).

Linear correlation analysis comparing logbook and research CPUE yielded significant results in all but one case (Table 5). Dover sole CPUEs were correlated for sole nets ($P < 0.05$) but not for roller nets. Correlation coefficients were similar between gear types for most species. For sablefish, however, the correlation coefficient was almost two times higher for sole nets than for roller nets.

Biomass comparisons

Logbook biomass estimates for all species were similar in magnitude to those derived from research data, with the exception of logbook biomass estimates for Dover sole, which were three to six times greater than those derived from research catches (Fig. 5). Biomass estimates for English sole, sablefish, and yellowtail rockfish exhibited overlapping 95% CI for all years compared.

For Dover sole, logbook biomass estimates exhibited a general decreasing trend from 1980 through 1985. The trend appeared to be level or slightly increasing from 1986 through 1989; a linear regression fitted to all years yielded a line with a negative slope ($P < 0.05$; Table 6). The biomass trend derived from research catches was flat for Dover sole for the entire period. Because much of the commercial fishery for Dover sole occurs beyond the range of the triennial trawl cruises, we compared logbook biomass estimates with NMFS slope survey biomass estimates (Table 7). The 95% CI of the 1984, 1988, and 1989 slope surveys overlapped with the corresponding estimates from the logbook data.

For sablefish, logbook biomass estimates generally decreased, except for slight increases in 1986 and 1987. A linear regression fitted to all years yielded a line with a negative slope (Table 6); the regression was highly significant ($P < 0.001$) when the data were analyzed without the 1987 data. Biomass trends derived from research catches fluctuated out of phase with logbook estimates, and a linear regression fitted to all years yielded a line with a slightly positive slope.

Biomass estimates generated from logbooks for English sole were consistent from 1980 to 1985, then sharply increased from 1985 to 1989. A line fit to all years had a significantly positive slope ($P < 0.05$). Biomass trends derived from research catches were similar.

Biomass estimates generated from logbooks for yellowtail rockfish increased each year from 1985 to 1989. A linear regression fit to all years yielded a line with a positive slope. The two research data points resulted in a level trend in biomass. Logbook biomass estimates for shortspine thornyhead rockfish exhibited a level trend from 1984 to 1988. The biomass estimate for 1989 was twice that of previous estimates. The two research data points resulted in a decreasing trend in biomass.

For each species, biomass estimates derived from commercial fishery logbook data for the summer season were similar to estimates derived for an entire year (Fig. 6). An average of 34% of the fishing effort occurred in the summer. For both Dover sole and sablefish, biomass estimates derived from year-round data were lower than those derived from one season's data, with overlap of the 95% CI in some years. For English sole, the summer period provided higher biomass

Fig. 3. Locations of commercial tows used in the logbook data base, and NMFS triennial trawl survey tow locations for the years 1980, 1983, 1986, and 1989.

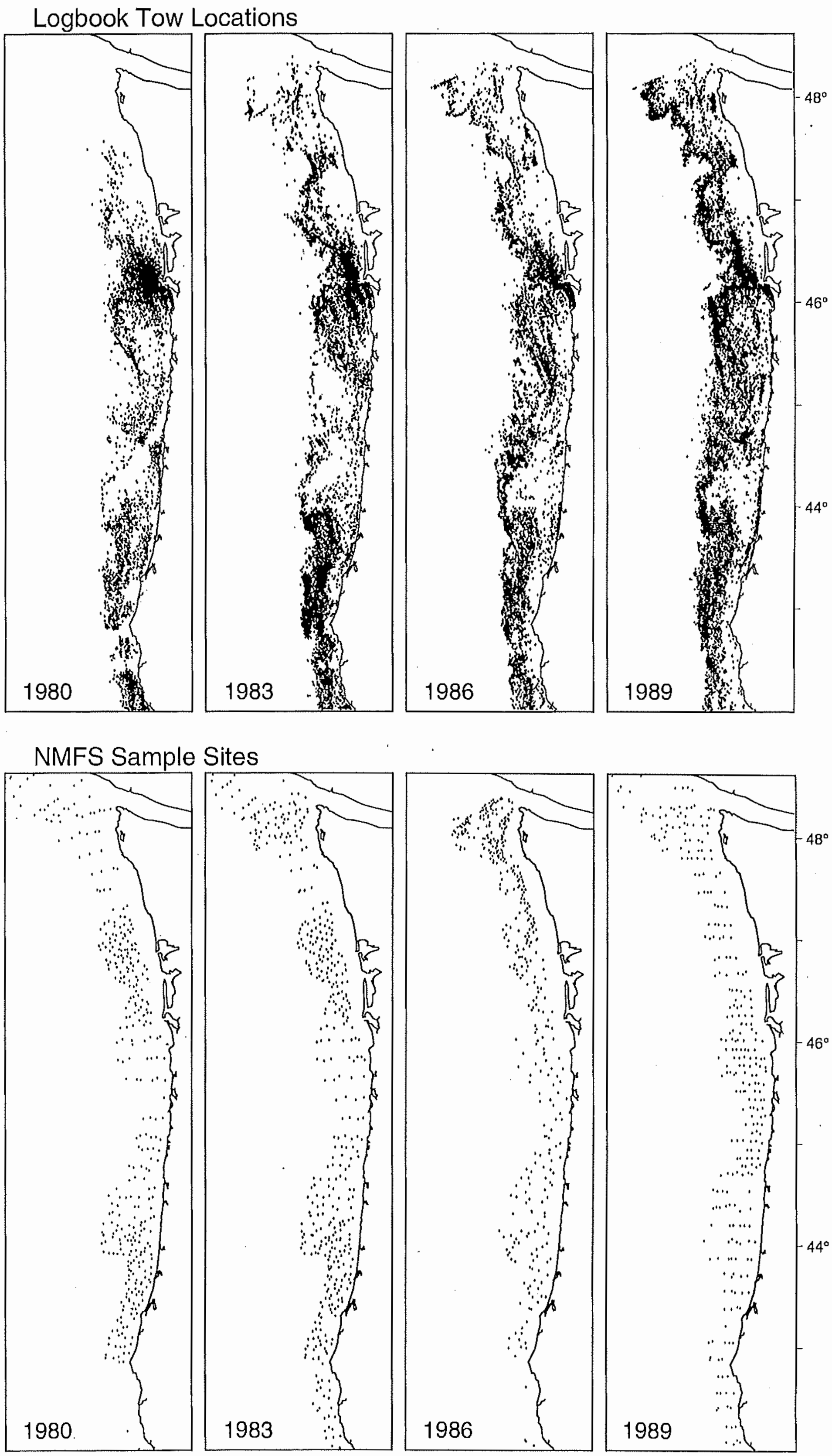


Table 2. Spatial overlap between NMFS and commercial catch areas.

	Year	Percentiles		
		50th	75th	90th
Dover sole	1980	60.3	47.1	15.4
	1983	74.4	44.1	25.0
	1986	75.9	41.4	33.3
	1989	60.8	22.6	12.5
	Mean	67.9	38.8	21.6
Sablefish	1980	65.0	44.8	23.1
	1983	80.5	62.9	46.7
	1986	76.1	41.7	44.4
	1989	72.6	51.9	25.0
	Mean	73.6	50.3	34.8
English sole	1980	66.7	54.5	40.0
	1983	65.0	47.2	33.3
	1986	66.7	48.3	30.8
	1989	66.7	50.0	22.7
	Mean	66.3	50.0	31.7
Yellowtail rockfish	1986		41.4	16.7
	1989		38.5	21.4
	Mean		40.0	19.1
Shortspine thornyhead	1986		64.7	80.0
	1989		51.7	33.3
	Mean		58.2	56.7

Note: Values are percent overlap of surface areas enclosed by the 50th, 75th, and 90th percentile CPUE isopleths of each data type. Data reflect only areas that included sampling effort for both NMFS and logbook data sets.

Table 3. Estimated minimum market size of selected species caught in the commercial fishery and percentage of NMFS survey catch (by weight) that was below market size.

	Estimated minimum market size (cm)	% NMFS catch less than minimum market size
Dover sole	30	15.5
Sablefish	41	11.9
English sole	30	48.7
Yellowtail rockfish	36	8.8
Shortspine thornyhead	27	61.0

Note: Percentages are average estimated values from the 1980, 1983, 1986, and 1989 triennial trawl surveys. Minimum market sizes were derived from ODFW port sampling data (Oregon Department of Fish and Wildlife, unpublished data).

estimates from 1980 to 1982. The 95% CI for all other years overlapped between seasons. For yellowtail rockfish and shortspine thornyhead, the 95% CI overlapped between seasons for all years.

Discussion

Comparison of logbook and research catch data

West coast fishery logbook data receive only limited use in stock assessments because scientists and managers have assumed that logbook CPUE data do not provide an accurate index of fish abundance (Ianelli et al. 1994; Methot et al. 1994; Turnock et al. 1994). This assumption is based on the concept that research catches are more apt to reflect actual fish distribution and abundance, whereas commercial fishing patterns and catches are more greatly influenced by market conditions, regulations, weather, and proximity to port. Although recent comparisons of trawl, submersible, and remotely operated vehicle surveys suggest that trawl sampling may not accurately reflect the distribution and abundance of many species (Kulbicki and Wantiez 1990; Krieger 1993; Adams et al. 1995), we chose to use the triennial trawl cruise data as a reference with which to compare commercial catches. These two data sets represent catches from similar fishing gear and methods. If fish distribution and abundance were not important determinants of commercial fish catches, we would have expected logbook

Fig. 4. Frequency histograms of $\ln(x + 1)$ transformed CPUE values derived from commercial fishery logbooks and NMFS triennial trawl cruises for (A) Dover sole, (B) sablefish, (C) English sole, (D) yellowtail rockfish, and (E) shortspine thornyhead.

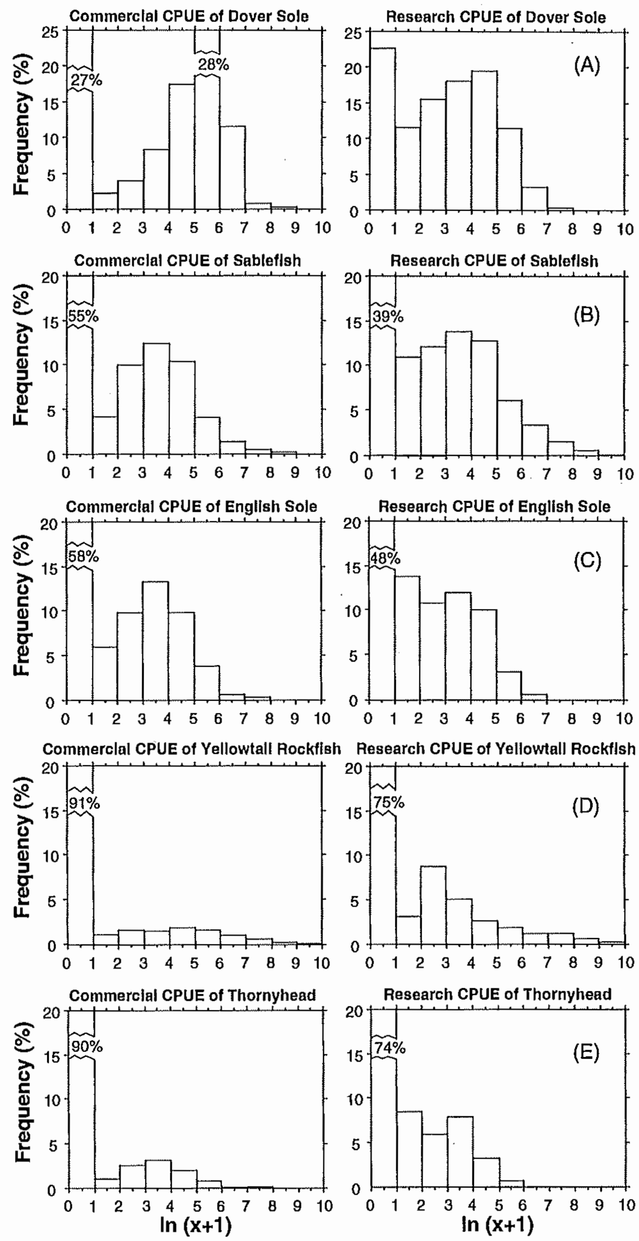


Table 4. Results of Kolmogorov–Smirnov two-sample comparison of frequency distributions of ln(x + 1) transformed CPUE calculated from commercial and research catches.

	df	No. of intervals	Maximum difference	χ^2	P
Dover sole	2	10	0.60	7.20	0.055
Sablefish	2	10	0.60	7.20	0.055
English sole	2	10	0.50	5.00	0.164
Yellowtail rockfish	2	10	0.70	9.80	0.015*
Shortspine thornyhead	2	10	0.50	5.00	0.164

Note: *, $P < 0.05$.

catch patterns to greatly deviate from research catch patterns. However, the logbook and research data sets clearly showed the same specific areas that consistently produced high catch rates, and logbook and research catch rates were significantly correlated.

There were a few time–area–species combinations in which logbook and NMFS CPUE isopleths did not coincide. Many of the areas of poor spatial correspondence can be explained by the lack of research or commercial trawl effort in the area. Some of the areas of poor spatial correspondence between the logbook and NMFS data cannot be easily explained and may reflect actual differences between research and commercial fishing techniques or gear or may be due to the grouping of many different fishing vessels and gear types in the analysis.

The similarity in frequency distribution of CPUE between logbook and research data sets suggests that, overall, the commercial fleet sampled the study area in a similar fashion as did research vessels. The high percentage of zero catches indicates that the species we studied were contagiously distributed and dispersed. Except for Dover sole, the commercial fleet did not appear to have more success targeting fishes than did research vessels. The larger proportion of high catch rates in the commercial fishery for Dover sole probably reflects the differences in gear and fishing techniques between commercial and research operations. Turnock et al. (1994) reported that the roller gear used on NMFS triennial trawl surveys proved to be less efficient for catching Dover sole than standard commercial gear.

In most widely spread fisheries, fishing effort is not evenly distributed, and there is no simple relationship between CPUE and overall fish abundance (Beverton and Holt 1957). Bannerot and Austin (1983) tested the sensitivity of CPUE frequency distribution to changing abundances for a sport fishery and suggested that for many schooling fishes, the relative frequency of zero CPUE values is a better index of abundance than is the mean CPUE. Their technique, however, requires independent estimates of CPUE and abundance. Although the relative frequency of zero CPUE values may provide additional information from research cruises, it is probably not as useful a tool for the commercial fishery, given the high level of fish-finding technology currently in the fleet. Bannerot and Austin (1983) also reported that median CPUE was a better indicator of changes in abundance than mean CPUE when using pooled data. The reverse was true for unpooled data. We used unpooled data because of the importance of maintaining a large sample size (Stanley 1992) and thus used mean CPUE in our statistical comparisons.

Differences in CPUE may also be attributable to a broader

Table 5. Results of correlation analysis (r values) between CPUE calculated from commercial and research catches.

	Bottom net types		
	All nets	Sole net	Roller net
Dover sole	0.42*	0.54*	0.21
	(147)	(82)	(36)
Sablefish	0.68*	0.70*	0.37*
	(148)	(82)	(38)
English sole	0.65*	0.65*	0.52**
	(143)	(83)	(34)
Yellowtail rockfish	0.46*	0.37**	0.51**
	(76)	(67)	(34)
Shortspine thornyhead	0.61*	0.58*	0.33*
	(77)	(68)	(35)

Note: The CPUE data used in the analysis were transformed (ln(x + 1)) mean values within strata defined by year and increments of 94 m depth and 30 min of latitude. Numbers in parentheses indicate sample size (numbers of strata with both commercial and research catches). *, $P < 0.05$; **, $P < 0.01$.

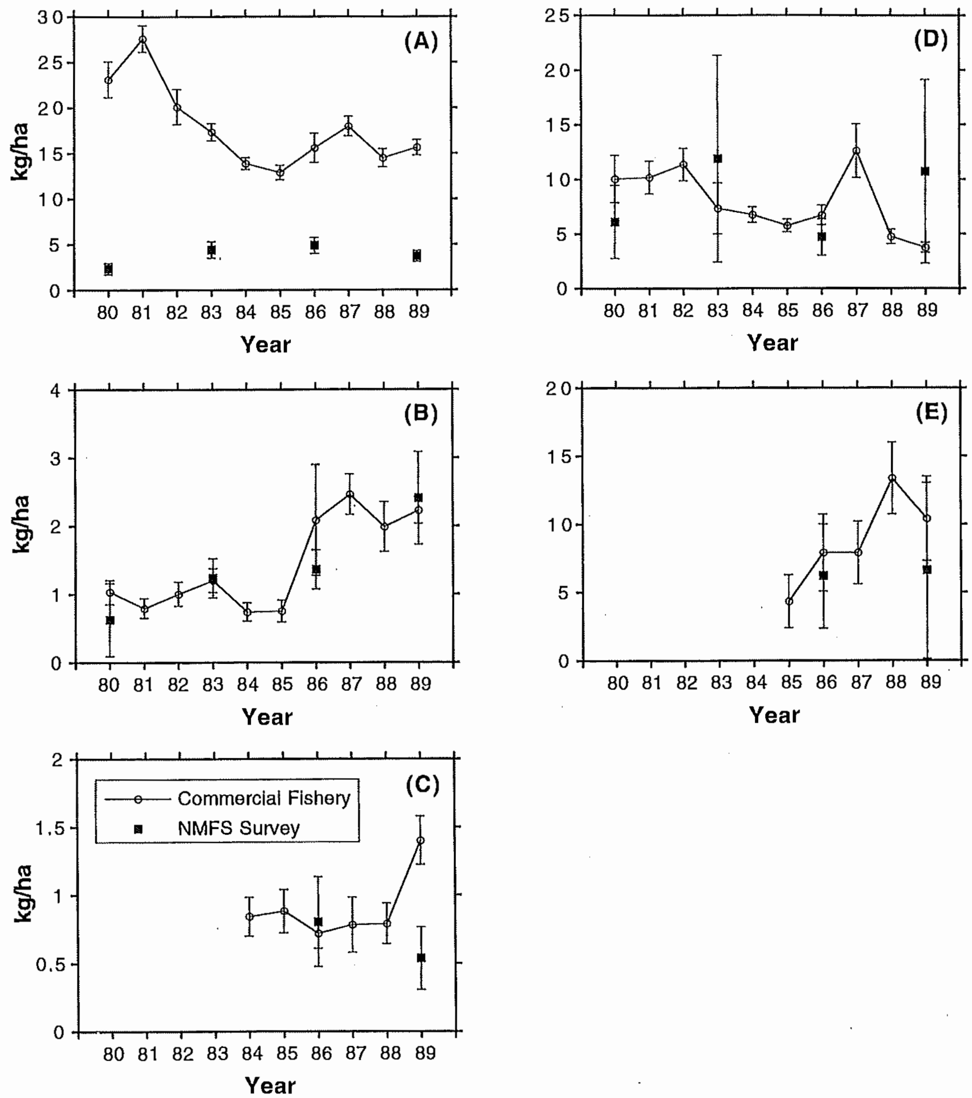
size range of fishes retained by the smaller cod-end mesh in research gear. NMFS estimated that Dover sole, sablefish, and yellowtail rockfish below commercial size contributed only a small amount to the triennial trawl survey catches by weight (Table 3) and thus had a minimal effect on overall research CPUE. However, when small fish were distributed in concentrated patches, the catch rates for the strata containing those patches may have been elevated relative to commercial catches.

The relationship between research and logbook biomass estimates varied from good to poor, depending on species. English sole provided the closest agreement between research and commercial catches, probably because research and commercial fishing techniques were similar and the shallow benthic habitats occupied by English sole were well sampled by both research and commercial trawls.

Dover sole biomass estimates exhibited the greatest difference between research and logbook data. Both data sets displayed relatively low variability, but annual biomass estimates were significantly different ($P < 0.05$). Logbook biomass estimates for Dover sole were 4.7 times greater on average than estimates from triennial trawl surveys. This discrepancy can be explained primarily by differences in fishing gear. Turnock et al. (1994) reported that NMFS slope surveys using chain disk gear caught Dover sole at about four times the rate of the triennial trawl survey gear. Adjusting triennial trawl catches upwards by a factor of four would result in a better correspondence between logbook and triennial trawl survey data. We considered comparing logbook and NMFS slope surveys but decided that a more detailed consideration of the fishing gear used in deeper water would be required to enable a quantitative comparison between logbook and NMFS slope survey data.

Both research and logbook estimates of biomass for schooling yellowtail rockfish were highly variable. Weinberg et al. (1994) described unsuccessful efforts to reduce sample variability for yellowtail rockfish in NMFS surveys by increasing sampling effort. In the much larger logbook data set, the combination of a few extremely high catch rates with incidental catches from many tows also resulted in high variances of yellowtail rockfish biomass estimates. Additional variability was introduced into the logbook data by the fact that the net

Fig. 5. Biomass estimates and 95% CI derived from trawls conducted from July to September in the commercial fishery and NMFS triennial trawl cruises for (A) Dover sole, (B) English sole, (C) shortspine thornyhead, (D) sablefish, and (E) yellowtail rockfish.



height of different gear types was not considered in the area-swept analysis. An alternative expansion method of partitioning out the small areas occupied by schools (on the basis of high logbook CPUE) from the larger low density areas may provide a less variable CPUE estimate. Although there may be ways to manipulate the data to reduce variability of biomass estimates, Krieger (1993) and Adams et al. (1995) cautioned that trawl surveys poorly estimate the abundance of midwater rockfishes. Richards and Schnute (1986) also suggested that CPUE may be a poor index of abundance for rockfishes.

Logbook and research estimates of biomass for shortspine thornyhead were low, perhaps because of the fact that most individuals reside in the deeper portions of the study area. Since we chose only areas that had both adequate logbook and adequate NMFS tows, the deeper portions of the study area are probably underrepresented.

Use of logbook data to augment research cruises

Our results indicate that data collected from research cruises and the commercial fishery are similar. It follows, then, that commercial fishery logbook data may be used to evaluate or augment research data, especially if the PFMC chooses to manage fisheries in small area units. Logbooks may become the only cost-effective way to increase the amount of information available in specific areas. Since the commercial fishery samples every month of every year and at many thousand sites, logbook data may provide information to help identify sampling error, increase sample size, or fill spatial and temporal gaps in research data. Although logbook data can be used effectively for area management, Stanley (1992) cautions against selecting management areas that are too small to provide sufficient data for adequate estimates of CPUE.

The larger number of biomass estimates generated by logbook data provided a different view of biomass trends for several of the species. The additional information provided by logbooks should be useful in tuning population models and helping managers to identify the degree of risk and uncertainty in stock assessments, thus aiding in the development of

Table 6. Trends in biomass derived from linear regression analysis applied to annual biomass estimates from logbook and research catch data.

	Slope	Intercept	r	P	MS	F
Dover sole						
NMFS	0.157	–307.1	0.54	0.46	1.1	1.8
Logbook	–1.066	2133.4	0.70	0.02*	93.8	7.9
Sablefish						
NMFS	0.221	–430.9	0.25	0.75	2.2	0.1
Logbook	–0.552	1102.5	0.56	0.09	25.1	3.7
Logbook[a]	–0.775	1545.5	0.91	0.0006***	45.4	35.7
English sole						
NMFS	0.182	–360.5	0.95	0.04*	1.5	20.4
Logbook	0.176	–348.4	0.78	0.007*	2.6	12.7
Yellowtail rockfish						
NMFS	0.133	–258.6	na	na	na	na
Logbook	1.762	–3491.7	0.83	0.08	31.0	6.7
Shortspine thornyhead						
NMFS	–0.076	151.2	na	na	na	na
Logbook	0.074	–145.7	0.55	0.26	0.1	1.8

Note: na, not applicable (line had only two points).*, $P < 0.05$; ***, $P < 0.001$.

[a]Sablefish biomass trends derived from logbook data that excluded an anomalously high biomass estimate in 1987.

Table 7. Biomass estimates and 95% confidence intervals (CI) derived from the 1984, 1988, and 1989 NMFS slope surveys and commercial data from the same depths and latitudes as the corresponding slope surveys.

	Slope surveys		Logbook data	
Year	Biomass (kg/ha)	95% CI (kg/ha)	Biomass (kg/ha)	95% CI (kg/ha)
1984	20.0	5.6	19.2	4.8
1988	41.2	28.7	25.5	9.4
1989	45.8	11.5	24.6	7.6

Note: Summaries of the slope surveys were obtained from Raymore and Weinberg (1990) and Parks et al. (1993).

risk-based fishery models, such as proposed by Hilborn et al. (1993).

NMFS triennial trawl cruises occur primarily in summer months, whereas the commercial fishery occurs the entire year. We analyzed the logbook data by season to determine if a seasonal estimate of biomass provided a different picture of biomass trends relative to sampling conducted over all seasons. Analysis of the summer logbook data provided as good an indication of interannual trends in biomass as did the analysis of the entire year. Interestingly, although the summer season contained only one third of the total annual sampling effort, biomass estimates displayed consistently narrower 95% CI than estimates derived from an entire year of logbook data. This implies that in addition to the obvious logistical advantages to surveying in the summer, NMFS is maximizing the statistical reliability of the triennial trawl cruise data by sampling in the summer. These results were somewhat different from those presented by Smith (1980) and Large (1992), who demonstrated significant seasonal effects on CPUE in trawl fisheries.

Factors affecting the use of commercial fishery data

Cooperation from a large number of commercial fishers is obviously critical for logbooks to be useful. Proper collection, preparation, and analysis of logbook data are also essential to maximizing the usefulness of the information. Logbook data need to be thoroughly error checked with verification of depth and locational information. Species and pounds hailed on the logbooks need to match the delivery tickets or be close enough to enable correction and adjustment.

Evaluating, then adjusting, estimated catch can create several problems. We created a ratio of estimated catch of a species by tow for each trip, then replaced estimated catch with the product of the ratio times the official landing record. In some instances, a species was caught in small quantities but not recorded in the logbook. In those cases, the total official weight of that species was distributed among all tows. At other times, a species was caught and recorded in large quantities on one tow and caught in small quantities, but not recorded, on other tows. In those cases, all of the official catch of that species was allocated to one tow. In the first instance, the adjustment process would overestimate distribution and underestimate the number of zero catches. In the second instance, the adjustment process would result in a restricted distribution and overestimate the number of zero catches. Kimura (1981) and Stanley (1992) avoided these problems by analyzing only those catch records that contained more than 25% of a species. Although their approach resolves the problem of falsely distributing small catches, Kimura (1981) stated that the use of qualifying criteria can greatly affect estimates of relative abundance. We minimized potential distributional problems by plotting the isopleths representing catches greater than the 50th percentile of CPUE and minimized the effect on mean CPUE by using only logbooks with closely corresponding landing records.

Market demand, quotas, and by-catch regulations all influence fishing operations and thus the landed catch of vessels. Occasionally market demand is large enough to start a new fishery or completely stop catch of a species for a period. The effects of usual market demands, however, are difficult to distinguish from other factors affecting fishing strategies. We made no attempt to account for market influences on fishing patterns; we were primarily interested in distributional patterns of reported catch.

Sampson (1991) modeled factors that lead commercial fishers to choose a fishing location and concluded that distance from port can be a major factor influencing the selection of a fishing ground. In his model, distance from port affected CPUE, and he cautioned against calculating CPUE using a simple ratio of total catch to total effort. We agree that CPUE should not be calculated as a simple ratio and agree with Stanley (1992) that it is important to carefully select the size of the spatiotemporal unit used to represent a central tendency of CPUE. Using individual tows rather than pooled data provided a large enough sample size to enable us to estimate CPUE in small time and area units.

The discard of fishes in the commercial fishery provides a potentially major discrepancy between logbook and research estimates of fish abundance. The problem is especially difficult to address if discard occurs at different rates in different locations. If discard rates are known and are consistent in time and space, however, biomass estimates derived from logbooks

Fig. 6. Biomass estimates and 95% CI derived from trawls conducted from July to September in the commercial fishery compared with biomass estimates derived for an entire year from the commercial fishery for (A) Dover sole, (B) English sole, (C) shortspine thornyhead, (D) sablefish, and (E) yellowtail rockfish.

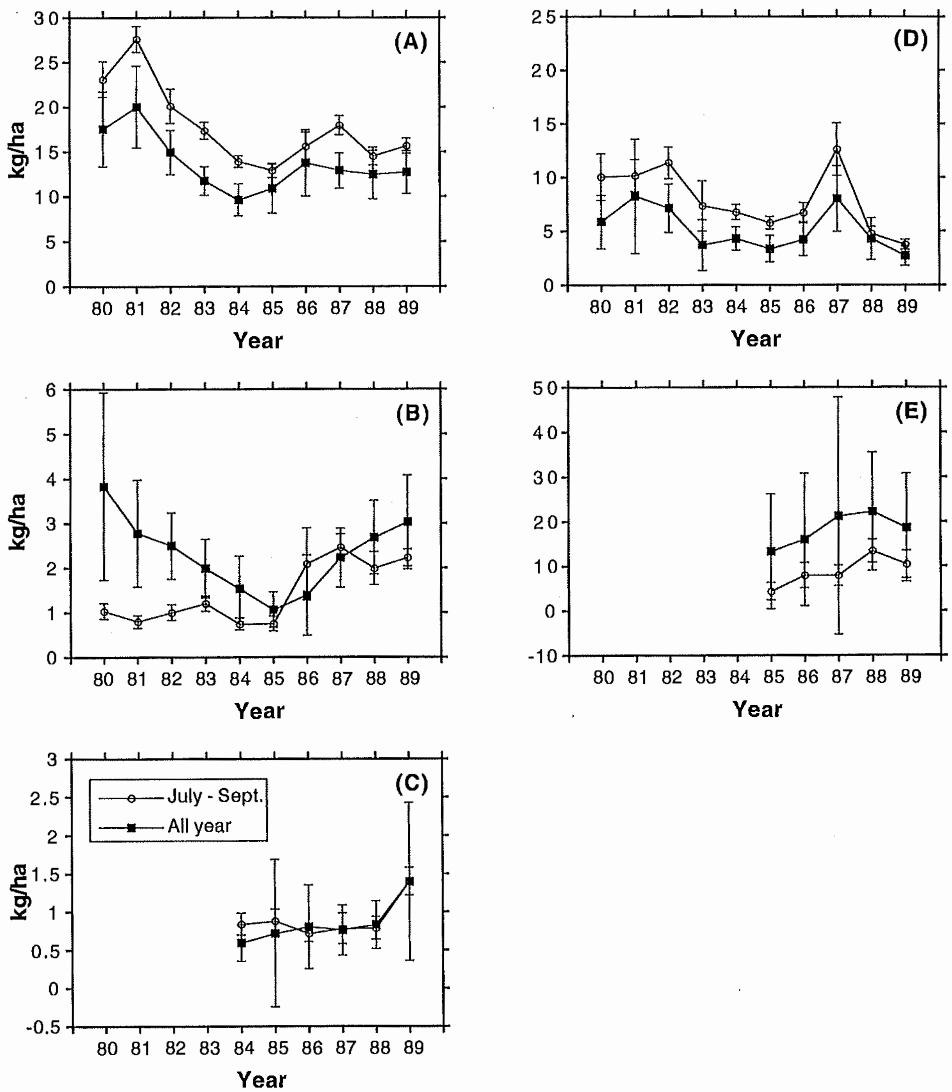


Table 8. Estimated discard rates used for the most recent stock assessments of the species analyzed in this study (data from Pikitch et al. 1988; Sampson 1993; Tagart 1993; Ianelli et al. 1994; Methot et al. 1994; Turnock et al. 1994).

	Years	Discard %
Dover sole	1982–1994	5
Sablefish	1982–1987	31
	1988–1992	25
English sole[a]	1977–1984	18
	1985–1992	12
Yellowtail rockfish	1985–1992	16
Shortspine thornyhead	1980–1987	13–17
	1988–1989	8

[a]Discard of female fish only.

could be scaled for comparison with research estimates. For the species we selected, discard was assumed to be consistent or to vary by a small amount during the 1980s (Table 8). This assumption may be invalid, however, for species with stringent catch quotas or by-catch regulations (Pikitch et al. 1988; Pikitch 1991). This problem can be minimized with the adoption of fishery observer programs.

A critical assumption in the use of any trawl surveys is the fishing efficiency of the gear and resulting catchability of fishes. For estimating biomass, NMFS assumed a catchability of 1.0 for their surveys, indicating that all fish in the path of a trawl would be caught and there is no herding effect (Methot et al. 1994). We made the same assumption for commercial trawls. For short periods, constant catchability may be a valid assumption. Over longer periods, such as a decade or more, the assumption of constant catchability is probably invalid. Kimura (1981), for example, reported that echo sounders and improved roller gear doubled the estimated efficiency of commercial vessels. Catchability should be studied periodically to ensure that CPUE estimates are comparable from year to year. A multiplicative model, such as the ones used by Gavaris (1980), Kimura (1981), or Large (1992), may then be needed to account for variability associated with differences in gear.

It is apparent that commercial fishery logbook data provide a comprehensive source of information because of the broad temporal and spatial fishing patterns of the fleet. For the period 1980–1989, estimates of fish distribution and relative abundance derived from logbook data closely resembled those from NMFS triennial trawl research data. Commercial fishery and research survey estimates of biomass were similar for species that are well sampled by trawl nets. These results suggest that information derived from logbooks can augment research data and improve estimates of the distribution and relative abundance of commercial fish species.

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