

NOAA Technical Memorandum NMFS



JULY 1986

SAMPLING STRATEGIES FOR THE WASHINGTON-OREGON-CALIFORNIA SABLEFISH FISHERY

Joseph E. Hightower



NOAA-TM-NMFS-SWFC-63

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Region

NOAA Technical Memorandum NMFS

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

NOAA Technical Memorandum NMFS

This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information; and have not received complete formal review, editorial control, or detailed editing.



JULY 1986

SAMPLING STRATEGIES FOR THE WASHINGTON-OREGON-CALIFORNIA SABLEFISH FISHERY

**Joseph E. Hightower
Southwest Fisheries Center
National Marine Fisheries Service, NOAA
Tiburon, California 94920**

NOAA-TM-NMFS-SWFC-63

**U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries**

INTRODUCTION

Sablefish (Anoplopoma fimbria) range from Baja California north to the Bering Sea and southwest to the coast of Japan (Deweese 1980). A commercial fishery has existed for over a century, although the resource has been fished heavily only since the 1960's (Low et al. 1976). Since 1976, estimated landings for the Washington-Oregon-California (WOC) fishery have ranged from 7,208 to 18,840 metric tons (t) and, in 1984, were about equal in magnitude in the three states (Parks and Shaw 1985). According to preliminary PacFIN reports, primary gear types used in 1984 were bottom trawls (56% of landings), traps (27%), and longlines (7%).

With 1983 landings worth an estimated \$8,000,000, the sablefish has become one of the most valuable species in the WOC groundfish fishery (Parks and Shaw 1985). Despite its commercial importance, however, only a limited amount of information is available on the status of the resource (Francis 1984). The relative lack of data can be attributed not only to the absence of a coastwide sampling plan, but also to practical problems that would limit the effectiveness of any port sampling program. For effective management, additional information is needed concerning the size of the resource and the biological characteristics of discarded and landed sablefish (Fougner and Abramson 1983). Objectives of this report are (1) to obtain rough estimates of required sample sizes; (2) to discuss practical problems in estimating sablefish catches; and (3) to examine alternative sampling programs to determine costs of acquiring the data and reliability of the data for management.

Sample Size Requirements

For many commercially important marine fishes, cohort analysis (Murphy 1965) of catch-at-age data provides estimates of stock size and fishing mortality that are the basis for management decisions. A significant advantage of this type of stock reconstruction is that information on fishing effort, catchability, and gear selectivity is not required (Deriso et al. 1985). This is particularly advantageous in the Pacific Coast groundfish fishery because the reliability of effort data obtained through logbook programs is low.

To obtain the necessary information for cohort analysis, a probability-based port sampling program has been used since 1977 to determine the age and species composition of trawl-caught rockfish landed in California. Similar sampling programs have been implemented in Oregon and Washington. The California sampling plan is a two-stage stratified random design with port, month, and market category used to define strata, and boat trips within strata as first-stage sampling units (Sen 1984). Stratification by market category is necessary because the catch is sorted at sea. Cluster samples of 25 or 50 pounds (depending on the species) are taken from the landings in a particular market category. Sen (1984) recently reviewed the California sampling plan and determined that a slightly modified version would be both statistically valid and operationally feasible. Sen also used historical data to determine the minimum level of sampling effort that would provide acceptably precise estimates of catch by species, age, and sex.

A limited amount of historical data is available for the sablefish fishery, and these data can be used to obtain similar (but much rougher) estimates of minimal sampling effort. Historical data used in this analysis

were obtained for the Eureka and Coos Bay trawl fisheries (Quirolo and Richmond¹). In both cases, length and sex data were available for 25 to 50 fish per trip for five trips during a 12- (Eureka) or 13-month (Coos Bay) period. Total lengths from Eureka samples were converted to fork lengths using the conversion factor reported by Phillips (1954). Individual weights were available for some Coos Bay samples; weights were estimated from a length-weight relationship (Maeda and Hankin 1983) for the remaining samples. Rough estimates of numbers-at-age were obtained by using sex-specific von Bertalanffy growth curves (McFarlane and Beamish 1983a) to convert length to age. Nearly all trawl-caught sablefish landed in these ports are classified as "smalls" (usually 3 to 5 pounds round weight), so only samples from the "small" market category were analyzed. To expand sample data to obtain annual estimates, the total weight landed in Eureka was assumed to be equal to the weight of "small" sablefish. In Coos Bay, sample data could be used to estimate the proportion of total landings classified as "smalls", and the total weight landed was multiplied by this estimate (92%).

A port sampling program based on the rockfish design was simulated by drawing fish randomly without replacement until two 50-pound clusters (± 1 fish) were taken from each sample. Variance estimators developed for the rockfish plan (Sen 1984) were used to determine minimum sample sizes required to obtain coefficients of variation (CV) of 10 and 20% for mean number per cluster by age and sex (Table 1). Estimates of within-trip variances were less than 0.005 in all cases; however, these estimates may be low because both cluster samples were taken from a single larger sample and, therefore, were not independent. Within-trip variance components are negligible in many cases (Tomlinson 1971, Sen 1984, Chester and Waters 1985), so this error may be of minor practical importance.

An average of about 30 sablefish trips per year should be sampled to obtain estimates with CV's of 20% or less (Table 1). This average was obtained by excluding results for less abundant age groups (those for which mean number per cluster was less than one). More sampling would be required in order to obtain precise estimates for all ages. It should be emphasized that these results were obtained for samples from one market category and one gear type, and that much better estimates of required sample sizes will be obtained when data have been collected from other strata. Once sample data have been collected, it will also be possible to evaluate the appropriateness of 25- and 50-pound clusters for sablefish. For example, a larger cluster size might be required for "medium" and "large" market categories in order to obtain an adequate number of fish per cluster.

Sen (1984) obtained similar required sample sizes for the rockfish fishery and suggested that a minimum of four samples, each of two clusters, should be taken from each major species group landed in each port-month stratum. In both the sablefish and rockfish fisheries, unrealistically high sample sizes would be required to achieve CV's of 10% (Table 1; Sen 1984), so a 20% CV may be a more realistic goal. Two of four criteria used to define an adequate sampling intensity in the Pacific halibut (Hippoglossus stenolepis) fishery also are based on a target CV of 20% for catch-at-age estimates (Quinn et al. 1983).

One way to reduce required sampling effort is to base sample size determinations on estimates combined over strata. For example, Sen (1984) showed that quarterly estimates of mean number per cluster would be unreliable unless additional samplers were hired, even though acceptably precise annual estimates could be obtained by the existing staff. After sufficient sample data have been collected, a similar analysis should be done for sablefish by

combining estimates over ports. For the two ports analyzed in this report, I estimated that a total of about 24 trips per year should be sampled in the two ports to obtain combined estimates with CV's of about 20% (Table 2). If allocated evenly between the two ports, this result suggests that a sample of one trip per month from each port might be sufficient. (If only one sample is taken per month, samples would have to be combined into quarterly "strata" in order to estimate variances.)

Results from the rockfish sampling program provide another guideline for estimating required sampling effort. For combined 1981 landings from Monterey, San Francisco, Fort Bragg, Morro Bay, and Eureka, Sen (1984) estimated CV's for number of widow rockfish (Sebastes entomelas), chilipepper (S. goodei), and bocaccio (S. paucispinis) per cluster by sex and age. CV's were about 20% for commonly occurring ages; therefore, the level of sampling used in 1981 might be considered minimally adequate. The weight landed in the 232 sampled trips was about 10% of total landings so this might also be a useful guideline for the sablefish sampling program.

An estimate of the number of otoliths to be aged can be obtained by following the approach used for Pacific halibut (Southward 1976, Quinn et al. 1983). This sampling scheme is simpler to simulate than the two-stage design used for rockfish, because samples are pooled over trips within each stratum. The design used for Pacific halibut is also interesting because it incorporates double sampling. Using this approach, length might be determined for a large sample of fish but only a subsample of the fish would be aged.

Estimates of the number of Pacific halibut landed by age are obtained by first estimating the total number landed and then estimating the age distribution of the catch. Because samples are pooled over trips, the only data required to estimate the variance for catch at age are estimates of total

weight landed, mean weight per fish, and proportions in each length and age class. Estimates of these parameters were available for sablefish, so a rough estimate of required sample sizes could be made.

Sablefish landings in 1984 were 14,067 t, or about 1,000 t per port group for the 14 port groups landing at least 2.5% of total landings in 1983 or 1984 (Table 3). Sample size estimates were made for an "average" port with annual landings of 1,000 t. Landings were allocated among market categories as 53% small, 17% medium, and 30% large (Swartzman et al. 1985), and estimates were formed separately by market category.

Following Quinn et al. (1983), let the total number landed in market category j be estimated as

$$\hat{C}_j = W_j / \bar{w}_j \quad (1)$$

where W_j is the total weight landed and \bar{w}_j is the mean weight of the L_j sampled fish. Based on a subsample of all otoliths collected in the stratum, the proportion of fish landed in market category j that are age k would be

$$\hat{p}_{jk} = \sum_l \hat{p}_{jl} \hat{p}_{jkl} \quad (2)$$

where \hat{p}_{jl} is the estimated proportion of fish in market category j and length category l and \hat{p}_{jkl} is the proportion of fish in market category j and length category l that are age k . An estimate of the number of age- k fish landed in market category j would be

$$\hat{C}_{jk} = \hat{C}_j \hat{p}_{jk} \quad (3)$$

To estimate required sample sizes, an estimate of $V(C_{jk})$ is needed. Following Quinn et al. (1983) but ignoring the finite population correction factor (L_j/C_j) , let

$$V(\hat{C}_{jk}) \doteq \hat{p}_{jk}^2 V(\hat{C}_j) + \hat{C}_j^2 V(\hat{p}_{jk}) \quad (4)$$

where

$$V(\hat{C}_j) \doteq \left[W_j^2 / \bar{w}_j^4 \right] \left[V(w_j) / L_j \right] \quad (5)$$

and where $V(w_j)$ is the variance for weight of fish in market category j . The variance for \hat{p}_{jk} would be estimated as

$$V(\hat{p}_{jk}) \doteq \sum_l \left[\frac{p_{jl}^2 p_{jkl} (1 - p_{jkl})}{f L_{jl} - 1} + \frac{p_{jl} (p_{jkl} - p_{jk})^2}{L_j} \right] \quad (6)$$

where L_{jl} is the number of measured fish that are in length category l and f is the fraction of the L_{jl} fish that are aged. For simplicity, it was assumed that a total of L fish would be measured and that L_j would be obtained by multiplying L by the historical proportion of landings in market category j .

Sample data collected at Coos Bay were used to estimate \bar{w}_j and $V(w_j)$. Because sufficient data on length and age distributions by market category were unavailable, estimates of p_{jl} , p_{jk} , and p_{jkl} were obtained as follows. The underlying age distribution was obtained by assuming that the natural mortality rate was 0.1 (McFarlane and Beamish 1983a), the fishing mortality rate was 0.25, and recruitment was knife-edged at age 3. A random sample of 10,000 fish was drawn from the age distribution defined by these parameters, and fish were assumed to be male or female with 0.5 probability. Length was determined from sex-specific growth curves, and weight was obtained from a length-weight relationship (Klein 1986). A normally distributed error term with mean 0 and CV of 10% was used to introduce a random component in the age-length and length-weight relationships. Each fish was then assigned to the small (<2.2 kg), medium (2.2-3.2 kg), or large (>3.2 kg) market category so

that estimates could be obtained for each stratum.

Required sample sizes were obtained by determining the minimum number to be measured and aged to obtain a CV of 20% for \hat{C}_g , the least abundant age class that comprised at least 5% of the total number landed (Table 4). Based on results for sample sizes of 250 to 2,000, it appears that about 400 fish should be aged, so the fraction aged would depend on the number measured. Benefits of double sampling appear to be negligible in this case; a similar result was reported for Pacific halibut (Quinn et al. 1983). Double sampling would be of greater value if aging effort was allocated optimally among length strata (Lenarz²). Under optimal allocation, proportionally fewer small fish would be sampled because length is a better predictor of age for small fish.

According to this analysis, the total number of fish to be aged would be about 5,600, or 400 in each of 14 "average" ports. In practice, a more complex sample design will be needed because the age composition of landings varies with time, location, and gear type. The effects of these additional sources of variability are not known; nevertheless, these results should provide some indication of the number of otoliths that should be aged.

Practical problems in sampling sablefish catches are described in the following section. These problems will reduce the accuracy and precision of estimates obtained by port sampling so a sea sampling program will also be considered. In either case, the above estimates of required sampling effort (sample about one to three trips per port-month category, or sample trips landing at least 10% of total landings) should serve as a rough guideline until a sampling program has begun and better estimates of variances can be made.

Practical Problems in Sampling the Catch

Discarding

Management recommendations based on landings data may be inappropriate if a significant fraction of the catch is discarded. Discarding may occur if (1) fish are smaller than the minimum marketable size; (2) demand for fish in a particular market category is low; (3) a trip limit regulates the amount of fish that can be landed; or (4) a minimum size limit has been established. Some discarding of submarketable sablefish (those less than 18 inches) undoubtedly occurs, particularly in the trawl fishery. However, recent at-sea samples of Eureka trawl catches suggest that few fish smaller than 18 inches are caught at usual trawling depths (greater than 100 fm) (Fujiwara and Hankin 1984). Recent data from the National Marine Fisheries Service (NMFS) survey suggest that most trap-caught sablefish will be larger than 18 inches (Parks and Shaw 1985). Finally, results from recent Japan-U.S. joint longline surveys in the Eastern Bering Sea, Aleutian region, and Gulf of Alaska suggest that few fish smaller than 18 inches would be caught using longline gear (Sasaki 1983b).

A more significant source of bias may be the discarding that occurs when market demand is low. For example, Hardwick (1983) noted that trawlers have been catching and discarding sablefish for over 20 years for lack of markets. Herrman and Harry (1963) sampled Oregon trawl catches from 1950 to 1961 and estimated that 80% (by weight) of the sablefish was discarded. Heimann and Miller (1960) reported that Morro Bay trawlers discarded 86% of sablefish catches (by weight). Heimann (1963) reported that Monterey trawlers discarded 32, 16, and 0% (by weight) of sablefish caught in water 30-60, 60-130, and 130-200 fm deep, respectively.

Demand for sablefish has increased in recent years, but some discarding still occurs when processors set restrictions (market limits) on the amount of sablefish that they are willing to buy. These market limits are most common for "small" sablefish, which comprise a large percentage of the catch. Because demand was strong throughout 1984 (Parks and Shaw 1985), discarding due to market limits probably was not a major source of bias. However, it is difficult to predict future levels of discarding in response to market limits because (1) the market for sablefish has been changing rapidly (Deweese 1980); (2) historical data on market limits are not available and are not likely to be available in the future; and (3) sablefish year-class strength fluctuates considerably (Sasaki 1983a; Tyler and McFarlane 1985) and market limits could be set if a large year class entered the fishery.

Discarding also may occur when landings reach 90% of the optimum yield (OY), because the Fishery Management Plan (FMP) states that trip limits must then be implemented (Pacific Fishery Management Council (PFMC) 1984a). These limits are intended to (1) provide an annual harvest that is about equal to the OY; (2) inhibit directed fishing but permit incidentally caught sablefish to be landed; and (3) divide the OY equitably between trawl and fixed gear components of the fishery (PFMC 1984a). A trip limit of 3,000 pounds was implemented in October 1982 when the OY of 13,400 t was exceeded (PFMC 1984b). The OY was increased to 17,400 t in November 1982; nevertheless, 1982 landings exceeded the OY. Trip limits were not required in 1983 or 1984 but were implemented in November of 1985 and the season was closed in December 1985. Future levels of discarding in response to trip limits or closures cannot be predicted, but because these restrictions would be implemented late in the year, the effect on discarding should not be substantial.

Discarding has been attributed to minimum size regulations in both the Canadian and U.S. sablefish fisheries. In the Canadian fishery, minimum size limits have been imposed since 1945 (McFarlane and Beamish 1983b). The effect of this regulation on discarding became apparent in 1972 when the size limit was waived for 3 months (McFarlane and Beamish 1983b). Trawl landings increased sharply and the size composition shifted downward because trawlers kept fish that normally would have been discarded (McFarlane and Beamish 1983b). A minimum size limit of 4 pounds has been in effect since 1977 (MacFarlane and Beamish 1983b), but data used to manage the fishery are obtained by sampling at sea (Shaw³) so the effects of discarding can be properly evaluated.

In the WOC fishery, discarding may have increased substantially in March 1983 when a minimum size limit of 22 inches was established for the area north of Point Conception (excluding Monterey Bay) (PFMC 1984a). To reduce discarding of incidentally caught sablefish, the PFMC established an allowance for sublegal fish of 333 fish, 1,000 pounds, or 10% of the weight of all sablefish on board (PFMC 1984b). Trawl fishermen argued that nearly half of captured sablefish were being discarded (Fujiwara and Hankin 1984), and in June 1983 the incidental catch allowance was increased to 5,000 pounds (PFMC 1984a). At-sea samples from Eureka trawl catches after the 5,000-pound allowance was established indicated that discarding had decreased dramatically (Fujiwara and Hankin 1984).

It should, nevertheless, be noted that a substantial fraction of sablefish caught with trawl (Fujiwara and Hankin 1984), trap (Parks and Shaw 1985), and longline gear (Phillips 1954, Sasaki 1983b, Clausen and Fujioka 1985) will be shorter than 22 inches. Thus, the amount of sablefish discarded depends in part on future management decisions. Regulations that reduce the

vulnerability of sublegal fish would not only reduce discard rates but also would reduce the need for a minimum size limit. One approach for reducing catches of small sablefish would be to increase the mesh size used in trawls and traps. For example, recent work by Klein (1986) demonstrated a strong relationship between mesh size and mean length of sablefish captured with trawls, traps, and set nets. Mesh regulations would be particularly useful for regulating fishing mortality in the trawl fishery because much of the sablefish catch is taken incidentally. An increase in trawl mesh size would not eliminate catches of small sablefish, however, because factors other than mesh size can effect gear selectivity. In some samples from trawlers targetting on flatfishes with 5-inch mesh nets, Klein (1986) observed substantial numbers of sablefish smaller than the estimated minimum retention size. Klein suggested that these fish were retained because the accumulated flatfish catch blocked net openings and reduced escapement of small sablefish.

Sampling dressed sablefish

A second practical problem in sampling sablefish landings is that sablefish are sometimes dressed (headed and gutted) at sea, making age and sex determination more difficult or impossible. For example, Klein (1985) reported that trawl, trap, and set net fishermen off the Washington coast have traditionally landed whole fish whereas longliners have delivered dressed fish. Information on the age composition of sablefish dressed at sea might be obtained by: (1) sampling at sea; (2) asking fishermen to save all heads from the last set or tow of each trip, so that otoliths can be obtained (O'Connell⁴); (3) predicting age from predicted fork length; or (4) using fin rays for aging. The first approach will be considered in some detail in a later section. The second approach has been implemented on a voluntary basis

in the longline fishery in the Gulf of Alaska. Voluntary compliance has been inadequate in some regions, however, so biologists have begun to purchase heads at a cost of \$0.50 per pound (Morrison⁵). Reliable information probably can be obtained from some fishermen but biologists acknowledge that others may provide biased samples. Because vessels would be selected at random in a probability-based sampling program, this approach probably would not be practical for the WOC sablefish fishery. The third approach would provide some information on age composition that could supplement information obtained from fish processed on shore. The fork length of dressed fish can be estimated by measuring the distance from the insertion of dorsal fin to the center of the tail (Maeda and Hankin 1983) using the conversion factor reported by Phillips (1954). Age can then be predicted from fork length using an age-length key. Some errors would be introduced by using an age-length key because (1) sablefish length-at-age differs significantly by sex (McFarlane and Beamish 1983a) and sex can only be determined by examining the gonads; and (2) length-at-age is essentially constant beyond age 15 (McFarlane and Beamish 1983a) so predictions would be unreliable for old fish. Finally, sablefish cannot be aged reliably using fin rays. Beamish and Chilton (1982) found that growth zones were difficult to find and that the number of zones did not seem reasonable, given the size of the fish. In addition, fin rays often had evidence of resorption and were difficult to process.

Even for fish that are processed on shore, logistical problems can make age and sex determination difficult. The primary difficulty is that, for fish that will be eastern-dressed, the body cavity cannot be cut to examine the gonads, so sex can only be determined at the processing line when the viscera are removed. When fish are to be shipped before processing, otoliths probably could be collected but the sex of sampled fish would be unknown. Sex-related

differences in length-at-age become pronounced at about age 10 (McFarlane and Beamish 1983a), and the catchability of these older fish probably would differ by sex.

A similar problem occurs in sampling landings of Pacific halibut, which always are eviscerated at sea (Quinn et al. 1983). Work has begun on development of a method to predict the sex of sampled fish from otolith weight, otolith length, and age (Quinn et al. 1983), so this approach might be used for sablefish as well. It may be difficult to develop a simple, reliable classification algorithm for sablefish because otolith characteristics appear to vary by year class (Lai 1985). A sex-specific stock reconstruction analysis may not be needed, however, unless a substantial fraction of the catch is older than age 10.

The above observations illustrate that sablefish are caught, landed, and processed in a variety of ways. Adequate information for management can be obtained only if the sampling program can adapt in response to changes in the fishery. In the following section, several sampling programs are discussed, including the type of information obtained, the reliability of that information, the costs of sampling, and stock assessment techniques that could be used with each type of information.

Alternative Sampling Programs

Sea sampling

The primary motivation for sampling at sea is that an unknown fraction of the total catch is discarded. If the fraction discarded is substantial, then observers should be used to estimate numbers caught and discarded so that accurate estimates of fishing mortality can be made.

Observer programs have been used to monitor foreign fisheries in waters off the United States (Nelson et al. 1981) and Canada (Kulka and Waldron 1983). A primary reason why the U.S. program is feasible is that the foreign fishing fleet is required to fund the program (Nelson et al. 1981). Observer programs have been used less frequently in domestic fisheries because of the expense, but the information obtained can be superior to that obtained by port sampling.

Sampling strategy

The following recommendations are based in part on an unpublished document, prepared in 1977 by Tomlinson⁶, that outlined alternative strategies for sampling California rockfish catches. Additional information was obtained from articles written by Burns et al. (1983) and Saila (1983), as well as from discussions with field biologists.

The recommended approach for sampling sablefish catches at sea is a three-stage stratified sampling plan, with trips as a first stage, hauls (or tows, depending on gear type) as a second stage, and clusters as a third stage. Trips to be observed should be selected randomly within each port-month-gear stratum. On each sampled trip, randomly selected hauls would be sampled as follows. One or more cluster (basket) samples would be taken from the portion of the catch that will be landed and one cluster sample (possibly larger in size) would be taken from the portion that will be discarded. The total weight of each cluster would be determined and otoliths would be collected from all fish in each cluster. There should be about 20 fish per cluster if baskets hold about 50 pounds.

The following notation refers to trips within a particular stratum. Estimates of total numbers caught or discarded (and their variances) can be obtained by summing over strata. All references to numbers of fish refer to numbers by age class. Let

N = total number of trips

H_i = total number of hauls on the i th sampled trip

n = number of randomly sampled trips

h_i = number of randomly sampled hauls on trip i

m_{ij} = number of cluster samples taken from haul j of trip i

W = total weight of fish landed for all trips

W_i = total weight of fish landed on trip i

\hat{W}_{ij} = total weight of fish discarded from haul j of trip i (estimated jointly by captain and observer (Burns et al. 1983))

w_{ijk} = weight of the k th cluster sample from haul j of trip i

\hat{w}_{ij} = weight of the sample taken from the discarded catch from haul j of trip i

y_{ijk} = number of fish in the k th cluster from haul j of trip i

\hat{y}_{ij} = number of fish in the sample taken from the discarded catch from haul j of trip i

The weight of a cluster sample is assumed to be essentially constant and the value is estimated as

$$\bar{w} = \sum_i^n \sum_j^{h_i} \sum_k^{m_{ij}} w_{ijk} / \sum_i^n \sum_j^{h_i} m_{ij} . \quad (7)$$

To estimate the total number of fish (of a particular age) landed in a stratum, let

$$\bar{y}_{ij} = \frac{m_{ij}}{\sum_k} y_{ijk} / m_{ij} \quad (8)$$

= mean number per cluster from haul j of trip i

$$\bar{y}_i = \frac{h_i}{\sum_j} \bar{y}_{ij} / h_i \quad (9)$$

= mean number per cluster on trip i (Note: weight landed is not determined separately by haul so the estimate is not weighted by haul size)

$$\bar{y} \doteq \frac{\sum_i^n W_i \bar{y}_i}{\sum_i^n W_i} \quad (10)$$

= mean number per cluster; weighted by trip size

$$\hat{Y} \doteq (W/\bar{w}) \bar{y} \quad (11)$$

= estimate of total number landed.

A conservative estimate of the variance can be obtained by using a jackknife approach (Efron and Gong 1983, Sen 1984). Let

$$v(\hat{Y}) \doteq (W/\bar{w})^2 (n-1) / n \sum_i^n (\bar{y}_i' - \bar{y})^2 \quad (12)$$

where

$$\bar{y}_i' = \frac{W_1 \bar{y}_1 + W_2 \bar{y}_2 + \dots + W_{(i-1)} \bar{y}_{(i-1)}}{W_1 + W_2 + \dots + W_{(i-1)}} + \frac{W_{(i+1)} \bar{y}_{(i+1)} + \dots + W_n \bar{y}_n}{W_{(i+1)} + \dots + W_n} \quad (13)$$

For simplicity, within-trip variances are assumed to be negligible when compared to the variance between trips. Variability between hauls can be estimated because several hauls can be sampled per trip, but it probably would be difficult to obtain more than one sample per haul since the discarded catch must also be sampled. The estimate of mean number per cluster in (10) is termed a ratio estimate because both the numerator and denominator vary from sample to sample (Cochran 1963). This estimate is biased, but should be more efficient than the corresponding unbiased estimate because trips larger in size receive higher weight at the estimation stage (Sen 1984).

To estimate the total number of fish (of a particular age) discarded in a stratum, let

$$Y'_{ij} = (W'_{ij}/w'_{ij}) y'_{ij} \quad (14)$$

= estimated number discarded from the j th haul of trip i

$$\bar{Y}'_i = \sum_j^{h_i} Y'_{ij}/h_i \quad (15)$$

= mean number discarded per haul of trip i

$$\hat{Y}' = (N/n) \sum_i^n H_i \bar{Y}'_i \quad (16)$$

= estimate of total number discarded.

Ignoring errors introduced by estimating the number discarded in sampled hauls (Y'_{ij}), an estimate of the variance would be

$$\begin{aligned}
v(\hat{Y}') &= \frac{nN(N-n)}{\left(\sum_i^n H_i\right)^2} \sum_i^n \frac{(H_i \bar{Y}'_i - (\sum_i^n H_i \bar{Y}'_i / n))^2}{n-1} \\
&+ \frac{nN}{\left(\sum_i^n H_i\right)^2} \frac{\sum_i^n H_i (H_i - h_i) s_{2i}^2}{h_i}
\end{aligned} \tag{17}$$

(Cochran 1963, p. 304), where

$$s_{2i}^2 = \sum_j^{h_i} (Y'_{ij} - \bar{Y}'_i)^2 / (h_i - 1) \tag{18}$$

and the mean number of hauls per trip is estimated as $\sum_i^n H_i / n$. As noted by Sen (1984), N would not be known but can be estimated as

$$\hat{N} = W / \left(\sum_i^n W_i / n \right) \tag{19}$$

A better estimate of number discarded per haul could be obtained by measuring total discards in numbers of baskets (Saila 1983). The above sampling plan is proposed under the assumption that, in some cases, a substantial quantity will be discarded and counting baskets of discards will not be practical.

Required sampling effort

Based on the earlier analysis of trawl catches (Tables 1 and 2), it appears that acceptably precise estimates could be obtained by sampling one to three trips per month in each port. Within each port-month combination, sampled trips might be allocated among gears according to the proportion of

landings each gear contributes. By limiting sampling to the 14 major port groups defined earlier and by assuming that a 50-pound cluster would contain about 20 fish, an annual sample of 7,000 to 20,000 otoliths could be collected ($14 \text{ ports} \times 1\text{-}3 \text{ trips/month} \times 1 \text{ sampled haul/trip} \times 2 \text{ cluster samples/haul} \times 12 \text{ months} \times 20 \text{ fish}$). It would be easy for observers to sample more than one haul per trip, so a much larger number of otoliths could easily be collected. In most instances, however, within-trip variability is much lower than variability between trips, so little additional information would be obtained by intensively sampling the catch of any one trip. In practice, observers probably would obtain sample data from most hauls, but only a subsample of all collected otoliths would be aged. Subsampling would be particularly useful for smaller fish because reliable age-length keys could be developed.

Because sampling would be conducted in at least 14 ports, a staff of at least 14 observers and 1 project coordinator would be needed. One or two technicians also would be needed to age the collected otoliths and to maintain the database. More observers would be needed if trip length frequently exceeded 1 week. Assuming that a staff of 14 observers, 1 project coordinator, and 1 technician would be sufficient, salary costs could exceed \$300,000. Additional costs would include travel and liability insurance, as well as the administrative cost associated with establishing an observer program.

Possible analyses

The primary analysis probably would be a stock reconstruction analysis using age-specific estimates of total catch (landed plus discarded catch). Additional analyses based only on landed catch could be done to determine if a port sampling program would be sufficient. The biomass-based models derived

by Schnute (1985) also should be considered because information on fishing effort will be available and because fewer fish would need to be aged to provide the needed supplemental information on growth and natural mortality.

Port sampling

There would be several advantages in adapting the rockfish port sampling plan for use with sablefish. One advantage is that the same information on age composition of landings is needed. Another advantage is that both sablefish and rockfish may be sorted at sea into market categories, so a similar sampling scheme is needed for both. (Sablefish landings actually would be easier to sample than rockfish landings because sablefish are not mixed with other species.) Yet another advantage is that a network of port samplers is already in place so a sampling program for sablefish could be implemented relatively quickly. Finally, port biologists are very familiar with the sampling program and its objectives and fish buyers have become accustomed to accomodating port samplers. Buyers interviewed in California and Oregon ports indicated that a similar sampling program for sablefish should not create any additional logistical problems.

Sampling strategy

The recommended sampling strategy is one of the approaches presented by Sen (1984) in his analysis of the California rockfish sampling program. A two-stage stratified sampling plan would be used, with trips as a first stage and clusters as a second stage. As in the sampling program for rockfish, arrival times cannot be predicted so boatloads would be selected arbitrarily within each port-month-gear stratum. A random ordering of returning boats can be assumed, so this approach should be approximately valid (Tomlinson 1971,

Sen 1984).

Sablefish often are landed separately by market categories based on size, so sampled landings should be post-stratified by market category (Sen 1984). Two cluster samples should be taken from the landings of each market category sampled on a selected trip. Both Tomlinson (1971) and Sen (1984) have argued that samples obtained by selecting a fixed number of individual fish are likely to be biased, so clusters would be defined in terms of weight. Cluster samples of whole fish should be 50 pounds (± 5 lb), whereas a 25-pound cluster (± 2 lb) of dressed fish should be sufficient. The length of all sampled fish should be measured and age and sex should be determined whenever possible.

The procedure for obtaining cluster samples will vary, depending on whether samples are collected from bins or from a processing line. The important point is that the two cluster samples should be taken from separate bins or at separate times during the period when fish are being processed, so that a better overall measure of the age and size composition of the landed catch is obtained. The existing staff of port samplers is familiar with the importance of obtaining unbiased random samples, so any logistical problems encountered when sampling can (hopefully) be overcome.

The following notation refers to landings within a particular stratum. In this case, references to numbers landed apply not only to numbers by age class, but also to numbers by length class. The most significant change in notation from that used in the sea sampling program is that estimates are formed separately for each market category. It is not necessary for all landed categories to be sampled on any particular trip, but only that samples from each market category are collected at some point during the month. Let

- n_j = number of landings sampled from market category j
 m_{ij} = number of cluster samples taken from trip i , market category j
 W_j = total weight landed in market category j
 W_{ij} = total weight landed in market category j , trip i
 w_{ijk} = weight of the k th cluster sample from market category j , trip i
 y_{ijk} = number of fish in the k th cluster sample from market category j ,
 trip i

The following estimators, derived by Sen (1984), are based on the assumption that the weight of a cluster sample can vary among market categories and trips. That assumption is made here because sablefish may be landed whole, dressed, or frozen into blocks so a flexible sample design is required. When blocks of frozen fish are landed, each block would be a cluster sample. Otherwise, cluster samples should be as close as possible to the target weight of 50 lb for whole fish or 25 lb for dressed fish. Let

$$\bar{w}_{ij} = \sum_k^{m_{ij}} w_{ijk} / m_{ij} \quad (20)$$

$$\bar{y}_{ij} = \sum_k^{m_{ij}} y_{ijk} / m_{ij} \quad (21)$$

$$\hat{R}_{ij} = \bar{y}_{ij} / \bar{w}_{ij} \quad (22)$$

= estimated number per pound landed in market
 category j , trip i

$$\hat{R}_j = \frac{\sum_i^{n_j} w_{ij} \hat{R}_{ij}}{\sum_i^{n_j} w_{ij}} \quad (23)$$

= mean number per pound in the j th market category, weighted by trip size

$$\hat{Y} = \sum_j \hat{R}_j W_j \quad (24)$$

= total number landed.

The total weight landed in market category j (W_j) should be obtained from actual recorded landing weights, rather than an adjusted total representing round weight. If only adjusted totals are available, then cluster weights (w_{ijk}) and trip sizes (W_{ij}) must also be adjusted using the same correction factor.

Ignoring the within-trip variance component and assuming a zero correlation between strata, a jackknife estimate of the variance in total number landed would be

$$v(Y) \doteq \sum_j W_j^2 \left[\frac{n_j - 1}{n_j} \sum_i^{n_j} (\hat{R}_{i'j} - \hat{R}_{j'})^2 \right] \quad (25)$$

where

$$\hat{R}_{i'j} = \frac{\hat{R}_{1j} W_{1j} + \hat{R}_{2j} W_{2j} + \dots + \hat{R}_{(i-1)j} W_{(i-1)j}}{W_{1j} + W_{2j} + \dots + W_{(i-1)j}} + \frac{\hat{R}_{(i+1)j} W_{(i+1)j} + \dots + \hat{R}_{nj} W_{nj}}{W_{(i+1)j} + \dots + W_{nj}} \quad (26)$$

and

$$\hat{R}_j = (1/n_j) \sum_i^j R_{i,j} \quad . \quad (27)$$

Required sampling effort

The earlier observations regarding the sea sampling program generally apply here as well. A sufficient sample size for each of the 14 major port groups may be one to three trips per month-market category combination, with samples allocated among gears based on the proportion of landings each gear contributes. At this level of sampling, about 7,000 to 20,000 otoliths could be collected (14 ports \times 1-3 trips/month \times 2 cluster samples/trip \times 12 months \times 20 fish/sample). In practice, however, some fish would be landed dressed, so less otoliths would be collected than under the sea sampling program. In addition, a reliable age-length key probably can be developed for sablefish in the "small" market category; thus, only a subsample of all collected otoliths would be aged.

It is difficult to estimate the additional staff requirements for implementing this program. At ports where trawl landings predominate, sablefish samples often could be collected when other port samples were taken, so integration into the current sampling program should be easily accomplished. In other cases, additional trips to the processing plants would be required. In any case, sampling sablefish landings should not require more than 3 or 4 days per month of a sampler's time. Salary costs for the program should not exceed \$50,000 if only one technician and a project coordinator are hired. If three to five additional port samplers are hired, salary costs should not exceed \$140,000.

Possible analyses

Because fork or total length can be determined or predicted accurately for all sampled fish, the primary analysis probably would be a length-based stock reconstruction analysis (Jones 1979, Pauly 1984). These length-based models have been particularly useful in managing tropical fisheries because aging a sample of the catch may be difficult or impossible (Jones 1981). The models provide estimates of historical levels of abundance and fishing mortality rates by length rather than age class. One advantage of the length-structured model is that it can be used even if a substantial fraction of the catch is processed at sea. Another reason for using this approach is that sablefish are difficult to age, and the precision associated with the break-and-burn aging technique is low (Lai 1985). An additional reason is that the age distribution of fish processed at sea may differ significantly from that of fish processed on shore. This would clearly be the case in Washington, where longline-caught fish are processed at sea and fish caught with trawls, traps, and set nets are processed on shore (Klein 1985).

The more traditional age-structured stock reconstruction analysis also can be done, by using an age-length key to estimate ages of dressed fish. Information on age composition would be obtained from landings of whole fish and from collections made on NMFS surveys. The age-structured model will provide estimates of year-class strength that cannot be obtained from the length-structured model. This information can be used to explore the relationship between year class strength and environmental factors so that we can better predict future levels of abundance. Analyses of this type would be particularly useful for sablefish because year class strength is known to vary widely over time. The age-structured model also will be a useful check on the length-structured model because the latter model was derived for stocks at

equilibrium. For this reason, the length-structured model probably should be used to analyze estimates of average catch-at-length, so that fluctuations in year class strength would have less effect.

The biomass-based models derived by Schnute (1985) would be less useful in this case because estimates of fishing effort would not be available. Rough estimates of fishing effort could be obtained from estimates of total landings and NMFS survey catch per unit of effort. The reliability of this approach would be limited because survey data for any particular site are collected only semiannually.

DISCUSSION

One obvious alternative is to continue monitoring total landings and to manage the fishery using the same approaches used to date. The recommended harvest originally given in the FMP was based on trawl survey data and preliminary information on sablefish distribution (PFMC 1982). Updated harvest recommendations have been based on an analysis of landings per unit of sablefish habitat (McDevitt and Stauffer⁷) and comparative studies incorporating results from the NMFS survey cruises and studies of the Canadian sablefish fishery (Francis 1984). Comparative studies of the Canadian fishery are particularly valuable because Canadian scientists first developed the technique for aging sablefish (Beamish and Chilton 1982). Once the age of sampled fish could be determined, it was possible to obtain estimates of longevity and natural mortality as well as age-specific estimates of length, maturity, and fecundity (McFarlane and Beamish 1983a, Mason et al. 1983). In addition, Canadian sablefish catches have been sampled since 1977 and a stock reconstruction analysis has been completed (Tyler and McFarlane 1985).

One advantage of implementing either a sea or port sampling program is that estimates of the length and age composition of sablefish catches would be obtained for the entire WOC fishery. A sampling program can be justified for this reason alone, because most historical data were obtained by aging with scales or whole otoliths and it has been shown that those techniques often produce underestimates of age (Beamish and Chilton 1982).

If a sampling program is implemented, one of the alternatives would be to establish a full-scale observer program. This approach would provide reliable information about catch-at-age, as well as information on fishing effort, locations fished, and on the response of the fleet to changes in fishery regulations. An additional benefit would be that information on numbers of fish caught and discarded would be obtained for several other species in the multispecies trawl fishery. It is worth noting that the practical problems outlined above also are encountered in the Canadian sablefish fishery, and essentially all information used to manage that fishery is obtained by sampling at sea.

Drawbacks of an observer program include: (1) resistance from fishermen who would resent further interference by state and federal management agencies; (2) lack of room and facilities for an observer on many vessels; and (3) concerns with the safety of observers. The first drawback could further increase the cost of the program. For example, in an ongoing observer program for the Oregon trawl fleet, a financial incentive (\$100/trip) was required to obtain the cooperation of most fishermen (Pikitch⁸). Obtaining the cooperation of a sufficiently large percentage of sablefish fishermen in three states fishing with at least three gear types would be a substantial undertaking. If a long-term observer program was implemented, one approach that would reduce many of the logistical difficulties would be to require

fishermen to accomodate observers if requested.

Another alternative approach would be to sample landings intensively and to conduct limited sea sampling to estimate numbers discarded. A disadvantage of limited sea sampling is that fishermen might use different tactics on observed trips. The primary advantage is that fewer trips would need to be monitored because most discarding occurs on trawlers, so observers might be able to monitor vessels from more than one port. This would result in lower salary costs, although increased travel costs would partially offset the savings. In addition, most of the logistical and organizational difficulties associated with sea sampling would remain. It is difficult to estimate sampling effort required to obtain reliable estimates of discards. The amount discarded will vary from year to year, so the amount of sea sampling required will vary as well.

The final alternative would be to port sample only. Three factors suggest that a port sampling program may be sufficient for effective management. Firstly, simulation results have demonstrated that a sustained discard rate of 40% of young (age-2) fish had a negligible impact on a stock reconstruction analysis of landings data (Rivard 1983). One reason why this result was obtained appears to have been because fish at age 2 were only partially recruited to the simulated fishery. Another reason may have been because the independent information used to refine the starting fishing mortality estimates was an index of abundance for older fish, so errors in estimating abundance of age-2 fish did not affect the "tuning" process. A similar approach could be used for sablefish to incorporate the auxillary information obtained from the NMFS survey cruises. For example, changes in the relative abundance of fish in the large market category (round weight greater than 7 pounds) might be used to refine the starting fishing mortality

estimates. Secondly, a recent study of Eureka trawl vessels demonstrated that a negligible amount of sablefish (0.6% by weight) is being discarded under the current set of regulations and market conditions (Fujiwara and Hankin 1984). Thirdly, for the segment of the trawl fishery between southern Washington and northern California, information on discarding will be provided for the next 3 years by the Oregon State University study.

If a port sampling program could be conducted over the same period as the discarding study, information on discarding could then be used to evaluate the quality of the port sample data, the magnitude of the discarding problem, and the value of continuing a port sampling program. During this trial period, data can also be used to obtain much more refined estimates of required sampling effort. This reanalysis should be done as soon as possible after sampling begins, because a reduction in required sampling effort would result in a lower program cost. Finally, it should be noted that sensitivity analyses can be done on stock reconstruction analyses to evaluate the effects of different levels of discarding. This approach would be equivalent to the usual approach of conducting analyses at several levels of natural mortality. Additional work with a simulated sablefish stock may also be warranted, to better evaluate the applicability of Rivard's work to sablefish.

ACKNOWLEDGEMENTS

I appreciate all the comments and suggestions that I received regarding the proposed sampling program. The following people deserve special thanks for reviewing one or more versions of this manuscript: N. Abramson, C. Cooperrider, J. Golden, F. Henry, D. Ito, W. Lenarz, A. Millikan, J. Robinson, J. Tagart, and E. Ueber.

FOOTNOTES

- ¹L. Quirollo, California Department of Fish and Game, 619 Second Street, Room 105, Eureka, CA 95501, and N. Richmond, Oregon Department of Fish and Wildlife, P.O. Box 5430, Charleston, OR 97420. Unpubl. data.
- ²W. H. Lenarz, Southwest Fisheries Center Tiburon Laboratory, National Marine Fisheries Service, NOAA, 3150 Paradise Drive, Tiburon, CA 94920, pers. commun. October 1985.
- ³B. Shaw, Pacific Biological Station, Nanaimo, British Columbia, V9R 5K6, pers. commun. May 1985.
- ⁴V. M. O'Connell, Alaska Department of Fish and Game, P.O. Box 510, Sitka, AK 99835, pers. commun. June 1985.
- ⁵R. Morrison, Alaska Department of Fish and Game, Homer, Alaska, pers. commun. June 1985.
- ⁶P. K. Tomlinson. 1977. Rockfish sampling plan. Unpubl. doc. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92037.
- ⁷McDevitt, S., and G. Stauffer. Sablefish catch per unit of habitat. Manuscr. in prep. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115-0070.
- ⁸E. Pikitch. Oregon State University, Hatfield Marine Science Center, Marine Science Drive, Newport, OR 97365, pers. commun. September 1985.

REFERENCES

Beamish, R. J., and D. E. Chilton.

1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39:277-287.

Burns, T. S., R. Schultz, and B. E. Brown.

1983. The commercial catch sampling program in the northeastern United States. In W. G. Doubleday and D. Rivard (editors), Sampling commercial catches of marine fish and invertebrates, p. 82-95. Can. Spec. Publ. Fish. Aquat. Sci. 66.

Chester, A. J., and J. R. Waters.

1985. Two-stage sampling for age distribution in the Atlantic menhaden fishery, with comments on optimal survey design. N. Am. J. Fish. Manage. 5:449-456.

Clausen, D. M., and J. T. Fujioka.

1985. Fishing performance of rectangular and conical traps off southeastern Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-76, 22 p.

Cochran, W. G.

1963. Sampling techniques. 2nd ed. John Wiley & Sons, N. Y., 413 p.

Deriso, R. B., T. J. Quinn II, and P. R. Neal.

1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42:815-824.

Deweese, C. M.

1980. The sablefish fishery. Leaflet 21155, Division of Agricultural Sciences, University of California, Berkeley, CA, 10 p.

Efron, B., and G. Gong.

1983. A leisurely look at the bootstrap, the jackknife, and cross-validation. *Am. Stat.* 37(1):36-48.

Fougner, S., and N. J. Abramson.

1983. Report of a workshop on sablefish research needs. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southwest Fish. Cent. Admin. Rep. T-83-02, Tiburon, CA 94920, 35 p.

Francis, R. C.

1984. Status of the sablefish resource of the U.S. Westcoast and recommendations for management in 1985. Appendix 3 in Status of Pacific Coast groundfish fishery and recommendations for management in 1985. Pacific Fishery Management Council, Portland, OR.

Fujiwara, S., and D. Hankin.

1984. Characteristics of blackcod captured off Eureka, California by vessels belonging to the Fishermen's Marketing Association, July 1983-August 1984. Report submitted to the Fishermen's Marketing Association.

Hardwick, J. E.

1983. Management strategies for sablefish off California, Oregon, and Washington. In Proceedings of the International Sablefish Symposium, p. 37-40. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

Heimann, R. F. G.

1963. Trawling in the Monterey Bay area, with special reference to catch composition. *Calif. Fish Game* 49:152-174.

Heimann, R. F. G., and D. J. Miller.

1960. The Morro Bay otter trawl and party boat fisheries August, 1957, to September, 1958. *Calif. Fish Game* 46:35-58.

Herrmann, R. B., and G. Y. Harry, Jr.

1963. Results of a sampling program to determine catches of Oregon trawl vessels. Pac. Mar. Fish. Comm. Bull. 6:39-51.

Jones, R.

1979. An analysis of a Nephrops stock using length composition data. Rapp. P.-v. Reun. Cons. int. Explor. Mer 175:259-269.

1981. The use of length composition data in fish stock assessments (with notes on VPA and cohort analysis). FAO (Food Agric. Organ U.N.) Fish. Circ. 734, 55 p.

Klein, S. J.

1985. Review of the set-net fishery off the Washington coast, 1982-84. Processed Rep. 85-06, 52 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA, 98115.

1986. Selectivity of trawl, trap, longline, and set-net gears to sablefish, Anoplopoma fimbria. Processed Rep. 86-06, 84 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115-0070.

Kulka, D. W., and D. Waldron.

1983. The Atlantic observer programs--a discussion of sampling from commercial catches at sea. In W. G. Doubleday and D. Rivard (editors), Sampling commercial catches of marine fish and invertebrates, p. 255-262. Can. Spec. Publ. Fish. Aquat. Sci. 66.

Lai, H.-L.

1985. Evaluation and validation of age determination for sablefish, pollock, Pacific cod and yellowfin sole; optimum sampling design using age-length key; and implications of aging variability in pollock. Ph.D. Thesis, University of Washington, Seattle, 426 p.

Low, L. L., G. K. Tanonaka, and H. H. Shippen.

1976. Sablefish of the northeastern Pacific Ocean and Bering Sea. Processed Rep. October 1976, 115 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA, 98115.

Maeda, R., and D. Hankin.

1983. Age and growth of sablefish landed in Eureka, California: a comparison of conventional surface age assignments with sectioned otolith assignments. In Proceedings of the International Sablefish Symposium, p. 81-93. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

Mason, J. C., R. J. Beamish, and G. A. McFarlane.

1983a. Sexual maturity, fecundity, spawning, and early life history of sablefish (Anoplopoma fimbria) in waters off the Pacific coast of Canada. In Proceedings of the International Sablefish Symposium, p. 137-140. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

McFarlane, G. A., and R. J. Beamish.

1983a. Biology of adult sablefish (Anoplopoma fimbria) in waters off western Canada. In Proceedings of the International Sablefish Symposium, p. 59-80. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

1983b. Overview of the fishery and management strategy for sablefish (Anoplopoma fimbria) off the west coast of Canada. In Proceedings of the International Sablefish Symposium, p. 13-35. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

Murphy, G. I.

1965. A solution of the catch equation. J. Fish. Res. Board Can. 22:191-202.

Nelson, R., Jr., R. French, and J. Wall.

1981. Sampling by U.S. observers on foreign fishing vessels in the eastern Bering Sea and Aleutian Island region, 1977-78. Mar. Fish. Rev. 43(5):1-19.

Parks, N. B., and F. R. Shaw.

1985. Abundance and size composition of sablefish (Anoplopoma fimbria) in the coastal waters of California and southern Oregon in 1984. Processed Rep. 85-16, 42 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

Pauly, D.

1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies and Reviews 8, 325 p. International Center for Living Aquatic Resources Management, Manila, Phillipines.

PFMC (Pacific Fishery Management Council).

1982. Final fishery management plan and supplemental environmental impact statement for the Washington, Oregon and California groundfish fishery. Pacific Fishery Management Council, Portland, OR.

1984a. First amendment and implementing regulations to the Pacific Coast Groundfish Fishery Management Plan incorporating the environmental assessment, the regulatory impact review/regulatory flexibility analysis, and requirements of other applicable law. Pacific Fishery Management Council, Portland, OR.

1984b. Status of Pacific Coast groundfish fishery and recommendations for management in 1985. Pacific Fishery Management Council, Portland, OR.

Phillips, J. B.

1954. The sablefish fishery in California. I. History and research. Pac. Mar. Fish. Comm. Bull. 3:5-22.

Quinn, T. J., II, E. A. Best, L. Bijsterveld, and I. R. McGregor.

1983. Sampling Pacific halibut (Hippoglossus stenolepis) landings for age composition: history, evaluation, and estimation. Int. Pac. Halibut Comm. Sci. Rep. 68, 56 p.

Rivard, D.

1983. Effects of systematic, analytical, and sampling errors on catch estimates: a sensitivity analysis. In W. G. Doubleday and D. Rivard (editors), Sampling commercial catches of marine fish and invertebrates, p. 114-129. Can. Spec. Publ. Fish. Aquat. Sci. 66.

Saila, S. B.

1983. Importance and assessment of discards in commercial fisheries. FAO (Food Agric. Organ. U.N.) Fish. Circ. 765, 62 p.

Sasaki, T.

1983a. Condition of sablefish stocks in recent years in the eastern Bering Sea, Aleutian region and Gulf of Alaska based on the results of field surveys. In Proceedings of the International Sablefish Symposium, p. 255-264. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

1983b. Relative abundance and size structure of sablefish in the eastern Bering Sea, Aleutian region and Gulf of Alaska based on the results of Japan-U.S. joint longline surveys from 1979 to 1982. In Proceedings of the International Sablefish Symposium, p. 239-253. Alaska Sea Grant College Program, University of Alaska, Fairbanks, Sea Grant Rep. 83-8.

Schnute, J.

1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42:414-429.

Sen, A. R.

1984. Sampling commercial rockfish landings in California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFC-45, 95 p.

Southward, G. M.

1976. Sampling landings of halibut for age composition. Int. Pac. Halibut Comm. Sci. Rep. 58, 31 p.

Swartzman, G., R. Francis, A. Hollowed, and P. Sullivan.

1985. Adaptive environmental assessment and management of the Pacific Coast Sebastes fishery. Processed Rep. 85-09, 76 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

Tomlinson, P. K.

1971. Some sampling problems in fishery work. Biometrics 27:631-641.

Tyler, A. V., and G. A. McFarlane (editors).

1985. Groundfish stock assessments for the west coast of Canada in 1984 and recommended yield options for 1985. Can. MS Rep. Fish. Aquat. Sci. 1813, 353 p.

TABLE 1.--Estimates of the variance and coefficient of variation (CV) for mean number per cluster sample by sex and age. Sample sizes are rough estimates of the number of trips required to obtain coefficients of variation (CV) of 10 or 20%. Estimates are given only for those age groups for which mean number per cluster sample exceeded 1.0.

Port	Sex	Age	Variance	CV	Sample size for	
					10% CV	20% CV
Eureka	M	3	0.849	82	181	69
		4	1.626	43	75	22
		5	1.599	63	131	44
	F	3	1.197	60	124	40
		4	2.056	68	147	51
Coos Bay	M	1	0.369	52	90	30
		2	5.563	49	84	27
		3	0.309	36	52	15
		4	0.408	18	15	4
		5	0.076	23	24	6
	F	2	5.782	51	88	29

TABLE 2.--Estimates of the variance and coefficient of variation (CV) for total number landed in both ports by sex and age. Sample sizes are rough estimates of the number of trips required to obtain coefficients of variation (CV) of 10 or 20%. Estimates are given only for those age groups for which mean number per cluster sample exceeded 1.0.

Sex	Age	Variance	CV	Sample size for	
				10% CV	20% CV
M	2	5.5E9	49	101	29
	3	8.6E8	38	65	17
	4	1.5E9	20	20	5
	5	1.1E9	37	63	17
F	2	5.7E9	50	107	30
	3	1.1E9	48	100	28
	4	1.4E9	58	135	40

TABLE 3.--Preliminary PacFIN estimates of 1983 and 1984 sablefish landings by port group.

Port group	Landings			
	1983	(%)	1984	(%)
N Puget S	1,134.5	7.8	2,184.7	15.5
S Puget S	1,310.2	9.0	993.1	7.1
Coast WA	288.0	2.0	594.6	4.2
Col R WA	643.3	4.4	641.6	4.6
Col R OR	780.2	5.4	726.9	5.2
Tillamook	73.6	0.5	39.8	0.3
Newport	1,364.2	9.4	1,827.0	13.0
Coos Bay	1,513.0	10.4	1,577.0	11.2
Brookings	925.4	6.4	667.7	4.7
Crescent	488.6	3.4	619.2	4.4
Eureka	1,152.1	7.9	911.2	6.5
Bragg	1,138.9	7.8	968.4	6.9
Bodega	130.3	0.9	114.7	0.8
SF	425.4	2.9	572.8	4.1
Monterey	630.5	4.3	552.2	3.9
Morro	77.2	0.5	136.2	1.0
S Barbara	1.8	0.0	0.9	0.0
LA	2,462.8	16.9	932.1	6.6
San Diego	1.2	0.0	0.9	0.0
Unknown CA	0.5	0.0	6.4	0.0
Total	14,541.6	100.0	14,067.2	100.0

TABLE 4.--Estimated coefficients of variation for number of age-3 and age-8 fish in a simulated catch of 1,000 t. Fish of these two ages were most and least abundant among those age groups comprising at least 5% of the total number landed.

Number measured	Proportion aged	CV's	CV's
250	0.2	23	44
	0.4	18	43
	0.6	14	34
	0.8	12	28
	1.0	11	25
500	0.2	17	43
	0.4	11	28
	0.6	9	22
	0.8	8	19
	1.0	8	16
1,000	0.2	11	28
	0.4	8	19
	0.6	6	15
	0.8	6	13
	1.0	5	11
2,000	0.2	7	19
	0.4	5	12
	0.6	5	10
	0.8	4	9
	1.0	4	8

RECENT TECHNICAL MEMORANDUMS

Copies of this and other NOAA Technical Memorandums are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167. Paper copies vary in price. Microfiche copies cost \$4.50. Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Center are listed below:

- NOAA TM-NMFS SWFC
- 53 Albacore fishing and windspeed.
P.N. SUND
(June 1985)
 - 54 Proceedings of the workshop on the fate and impact
of marine debris, 27-29, November 1985, Honolulu, Hawaii.
R.S. SHOMURA and H.O. YOSHIDA (Editors)
(August 1985)
 - 55 The Hawaiian Monk Seal and Green Turtle on Necker Island, 1983.
R.J. MORROW and E.K. BUELNA
(November 1985)
 - 56 *Proportions of species of dolphin in the eastern tropical Pacific.*
J. BARLOW and R.S. HOLT
(January 1986)
 - 57 A budget simulation model for west coast albacore trollers.
S.F. HERRICK and K.L. CARLSON
(February 1986)
 - 58 The Hawaiian Monk Seal on Lisianski Island: 1983.
T.C. JOHANOS and A.K.H. KAM
(February 1986)
 - 59 Hawaiian Monk Seal observations and captive maintenance project
at Kure Atoll, 1981.
W.G. GILMARTIN, R.J. MORROW, and A.M. HOUTMAN
(March 1986)
 - 60 Determining fish movements from an "archival" tag:
precision of geographical positions made from a time series of
swimming temperature and depth.
P. SMITH and D. GOODMAN
(May 1986)
 - 61 The limitations of fish tracking systems: acoustic and
satellite techniques.
I.G. PRIEDE
(May 1986)
 - 62 Procedures for sampling dolphins: A handbook
for shipboard observers.
A.C. MYRICK, JR.
(July 1986)