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Reliability of Trawl Survey Estimates of Juvenile Halibut Abundance

by

Cyreis C. Schmitt

International Pacific Halibut Commission
P. O. Box 95009, Seattle, Washington, USA 98145-2009

SPECIAL SESSION ON BIOLOGICAL SURVEYS

Abstract

Since the early 1960's, the International Pacific Halibut Commission has annually conducted trawl surveys to assess the abundance of juvenile halibut in selected regions of the Northeast Pacific Ocean and Bering Sea. Indices of year-class abundance based on systematic and stratified sampling were estimated for each region and age group in the catches. In general, correlations between any two of these indices were poor. The ability of survey data to predict recruitment to the adult population also was poor, as shown by comparisons of juvenile indices to three measures of adult abundance. Estimates of mortality during the period between juvenile and adult abundance assessments could not fully explain the differences.

Introduction

The International Pacific Halibut Commission (IPHC) began a bottom trawl survey program in the early 1960's. Initially, the surveys were exploratory and provided general information on the size, age, and distribution of Pacific halibut (Hippoglossus stenolepis) below commercial size. Subsequently, the emphasis shifted toward assessment of year-class abundance, and these abundance estimates were regarded as an index of potential recruitment to the commercial setline fishery five to seven years later.

IPHC's survey program has not been previously reviewed, primarily because of inadequate data for comparison from other sources. Until recently, very few year classes had been assessed by the survey and subsequently exploited by the commercial fishery, thereby precluding evaluation of the survey's main objective of providing an index of pre-recruit abundance. Even now, only data for approximately ten year classes are available for comparison.

In this review, two indices of relative year-class abundance of juveniles are estimated. One index is based on systematic sampling theory in accordance with the survey design. For another, data are analyzed as if they were collected in a stratified manner. To test the predictive capability of these indices, they are compared with two independent measures of year-class abundance of adults: catch per unit of effort (CPUE) from the commercial fishery and estimated absolute abundance (numbers) from a cohort analysis of catch-at-age data. Finally, indices of year-class abundance of juveniles are compared to their estimated abundance at birth.

Survey Methods

When IPHC began its trawl survey program in the early 1960's, the objective was to provide data on halibut below commercial size, 65 cm.

Those smaller than 65 cm were termed "juveniles", regardless of age or maturity. For comparative purposes, this definition is used throughout this study even though the minimum size limit was raised to 81.3 cm in 1973.

Juvenile halibut inhabit most areas of the continental shelf of the Northeast Pacific Ocean and Bering Sea, to depths in excess of 100 m. In addition to covering this broad geographic area, the annual trawl surveys were designed to monitor juvenile halibut over much of their size and depth ranges (Figure 1). To systematically survey large juveniles, five grids of "offshore" stations were fished with a standard 400-mesh eastern otter trawl with a 90 mm mesh codend. In the Northeast Pacific Ocean, a total of 110 "offshore" stations are located in four regions. The Bering Sea sampling grid consists of thirty-four offshore stations. To monitor smaller juveniles, six groups of "inshore" stations were established in selected areas close to shore. Twenty-seven inshore stations in the Northeast Pacific and five in the Bering Sea are sampled twice during each annual survey. These stations are not arranged in a grid pattern and are surveyed with a smaller version of the trawl net used at offshore stations. This net is approximately two-thirds the size of the large net and has a 32 mm mesh codend.

The surveys began in the eastern Bering Sea about the first of June each year, progressed into the Pacific Ocean, and proceeded in an easterly direction across the Gulf of Alaska. The survey of each region was scheduled for the same time each year but the actual fishing dates varied slightly from year to year. During the 1960's, some regions were not sampled every year.

Commercial otter trawl vessels were chartered for the surveys. The speed of trawling was regulated to approximately three knots. A standard haul was sixty minutes at offshore stations and 15 minutes at inshore stations. Beginning in 1979, towing time at offshore stations was shortened to thirty minutes.

All halibut were measured and otoliths were taken from a sample for age determination.

Indices of Juvenile Abundance

Two indices of juvenile abundance based on systematic and stratified systematic sampling methods are developed for each offshore region and year class. For inshore regions, only one index based on systematic sampling is estimated. Major points in the development of these indices include (1) the use of catch per unit of effort (CPUE) as a measure of relative abundance, (2) the use of median CPUE as a good estimate of relative abundance based on the frequency distributions of sample values, and (3) the assumptions and estimation methods for systematic and stratified sampling.

Catch Per Unit of Effort

Assumptions and potential errors inherent in the use of CPUE as a measure of relative abundance have been extensively studied. Errors affecting CPUE from bottom trawl surveys arise from changes in the coefficient of catchability for fish in trawls, fish distribution, and fish behavior. These errors can seriously bias the estimates of relative abundance (e.g., Byrne, et al. 1981; Carrothers 1981; and Foster, et al. 1981).

IPHC standardized many of its trawling procedures to minimize sampling error, but it is not known how successful these procedures were toward achieving a reproducible, standard haul. IPHC also standardized sampling locations and survey timing in hopes of minimizing errors from changes in fish distribution, but these errors may still be substantial in survey data. Errors arising from changes in the behavior of juvenile halibut have not been studied.

For juvenile survey data, catch refers to number of halibut less than 65 cm. The number of halibut at each age in the catch is estimated from the length frequency of the catch and an age-length key. Keys are compiled for each region and year and usually contain more than 200 observations. Effort is expressed in terms of towing time on the bottom. Most hauls are of standard duration: 60 minutes with the large net and 15 minutes with the small net. For hauls not of standard duration, estimates of CPUE for total catches and by age are adjusted to the standard.

Median CPUE

Most sampling theory is based on the mean of sample values, and in many studies of trawl survey data, the mean of CPUE values is considered an abundance index (e.g., Clark and Brown 1977; Forest and Minet 1981; Halliday and Koeller 1981). I have taken a different approach, one which relies on the median rather than the mean of sample values. A disadvantage in using the median is that standard statistical tests cannot be used to compare indices of abundance, and therefore, less powerful rank tests are used in this study.

The CPUE frequency distribution of fish in most trawl surveys is positively skewed (Leaman 1981; Smith 1981; Taylor 1953). The frequency distributions of CPUE for juvenile halibut are also positively skewed. In a study of confidence limits about means and medians of a series of net catches, Moyle and Lound (1960) report that "in skewed series the median is generally more descriptive of average conditions than the mean." For any positively-skewed distribution, data are distributed equally on both sides of the median, not the mean (McCaughran 1981). Also, the median is much less sensitive to extreme observations than the mean. Furthermore, the reliability of survey indices of juvenile abundance is tested by comparisons to other indices and Moyle and Lound state that the median "appears to be most useful for evaluating and comparing catches of nets where: (1) the number of net sets (sample size) is small; and (2) fish of a particular species are taken in most of the sets." Juvenile trawl survey data meet these conditions. In addition, I assume that finite sampling theory, for which the mean may be an appropriate measure of abundance, is not valid because only a very small fraction of the population is sampled by the surveys. For example, each index region in the juvenile surveys covers more than 1800 square miles, but less than 1 square mile of it is actually trawled each year.

For most regions, the CPUE frequency distribution for total catches (all juveniles less than 65 cm) resembles a lognormal distribution. The hypothesis that ln[(C+1)/E] is normally distributed is not rejected in modified Kolmogorov-Smirnov tests of fit (Schmitt 1985). In these tests, data for all years were combined and hauls with no catch were included.

Because the CPUE frequency distributions are positively skewed, relative annual abundance of juveniles is estimated by median CPUE of total catches. To include hauls with no catch, let $CPUE_m = (C_m+1)/E$, where C_m is the catch in a standard haul at station $\underline{m}$ and E is the standard haul duration. Given that $CPUE_m$ is lognormally distributed, then by the method of maximum likelihood (Aitchison and Brown 1969), median CPUE for the $\underline{i}^{th}$ group of $\underline{n}$ stations, such as a region-year, is

$$\widehat{MED}(CPUE_i) = e^{\frac{1}{n}\sum_{m=1}^{n} \ln CPUE_m} .$$

Its variance is estimated by

$$Var(\widehat{MED}(CPUE_i)) = \frac{\sum_{m=1}^{n}\left[\ln CPUE_m - \ln(\widehat{MED}(CPUE_i))\right]^2}{n(n-1)} .$$

The CPUE frequency distribution for every age group in the catch cannot be lognormal given that CPUE of the total catch is lognormally distributed because the sum of lognormal distributions is not lognormal

(Aitchison and Brown, op. cit.). Also, when $CPUE_{mk}$ is modified in the usual way to include data from hauls with no catch of the given age group $\underline{k}$ (i.e., $CPUE_{mk} = (C_{mk}+1)/E$), the $CPUE_{mk}$ frequency distributions are not lognormal. For offshore regions, estimated catches of many age groups frequently are small numbers and their increase by one halibut significantly affects the CPUE frequency distributions. The hypothesis that $\ln[(C_{mk}+1)/E]$ is normally distributed was accepted in only 4 of 25 Kolmogorov-Smirnov tests for ages two through six, the dominant age groups in the catches (Schmitt, op. cit.). Therefore, the maximum likelihood estimate of the median is not used as an index of year-class abundance.

Median CPUE used to estimate relative year-class abundance is the middle value in the CPUE sample for each age, region, and year class. For this nonparametric estimate of median CPUE, no assumption is made regarding the distribution of CPUE values and no modification is necessary to include hauls with no catch. Moyle and Lound (op. cit.) report that this statistic may be used for a series of net catches when the number of sets is small and fish of a particular species are taken in most hauls. These conditions are met for those age groups used as indices of year-class abundance of juvenile halibut. For each age $\underline{k}$ and region-year stratum $\underline{i}$, median $CPUE_{ik}$ is estimated by

$$\mathrm{MED}(\widehat{CPUE}_{ik}) = \widehat{CPUE}_{mk,x+1} - \left(\frac{\sum_{q=1}^{x} f_q - \frac{n}{2}}{f_x} \right) (\widehat{CPUE}_{mk,x+1} - \widehat{CPUE}_{mkx})$$

where $\underline{x}$ designates the $CPUE_{mk}$ value such that half the $CPUE_{mk}$ estimates are smaller than $CPUE_{mkx}$ and half are larger, and f_q is the frequency of CPUE values in interval $\underline{q}$.

<u>Systematic Sampling</u>

Offshore regions are sampled in a grid pattern resembling an aligned systematic design. In systematic sampling, the location of the first sample is randomly selected and all other samples are spaced at regular intervals from it. In contrast, sample positions in IPHC's trawl surveys are identical every year (stations) and are often fished in the same sequence. The effect of these departures from true systematic sampling on juvenile abundance estimates is not known, but is assumed to be minor.

For offshore regions, indices of abundance based on systematic sampling are the maximum likelihood estimates of median CPUE for total catches and nonparametric estimates of median CPUE for each age in the catch. Maximum likelihood estimates of median CPUE for total catches are computed rather than nonparametric medians because variances of the maximum likelihood estimates can be estimated.

Sampling at inshore regions is similar to that at offshore regions in that station locations are fixed, although not in a grid pattern. Each inshore region contains five or six closely-spaced stations, and each station is fished twice. Median CPUE's were estimated for these ten to twelve hauls in the same way as for offshore regions.

<u>Stratified Systematic Sampling</u>

Juvenile halibut are contagiously distributed and, therefore, estimates of year-class abundance may be improved by stratifying CPUE data. Systematic surveys may adequately assess the spatial distribution of an aggregated population, but they do not give precise estimates of parameters, such as median density, over the entire area (Leaman 1981). The lack of replicate samples in systematic sampling leads to the imprecision of parameter estimates. Stratified random sampling generally provides more precise estimates if the variance is greater among strata than within strata. Variances in median length and ln(CPUE) of juvenile halibut are larger among depth strata than within them (Schmitt, op. cit.). Although IPHC's survey data are not collected in a stratified random manner, a compromise, in which the systematically-collected data are post-stratified for analysis, may improve upon systematic estimates of year-class abundance. Leaman (op. cit.) reported that estimates of relative abundance may be improved by systematically surveying an area that has already been stratified by some criterion. Therefore, to increase the precision and, potentially, the accuracy of indices of juvenile abundance, CPUE data from offshore regions are post-stratified by depth of haul. Because age is closely related to length of juveniles, CPUE estimates by age are also post-stratified by depth. Depth strata were 0-35, 36-50, and greater than 50 fathoms. Data from inshore regions are not post-stratified by depth because only a few stations were fished in each region and they were all located in relatively shallow water.

Median CPUE is a measure of density and an unbiased estimate of overall density in a region is the area-weighted sum of densities in each stratum (Quinn, et al. 1983). Thus, stratified indices of juvenile abundance in region-year $\underline{i}$ are the area-weighted sums of median CPUE for total catches in the depth strata:

$$\widehat{\mathrm{MED}}(\mathrm{CPUE}_i) = \sum_{h=1}^{3} W_h \cdot \widehat{\mathrm{MED}}(\mathrm{CPUE}_{ih})$$

where: W_h = the proportion of the bottom area in the region that lies within depth stratum $\underline{h}$.

Variances of these post-stratified estimates of relative juvenile abundance are estimated from the variances for each stratum:

$$\mathrm{Var}(\widehat{\mathrm{MED}}(\mathrm{CPUE}_i)) = \sum_{h=1}^{3} W_h^2 \cdot \mathrm{Var}(\mathrm{MED}(\mathrm{CPUE}_{ih})) \quad .$$

Stratified median CPUE for each age $\underline{k}$ also is an area-weighted sum of median CPUE estimates for age $\underline{k}$ in each stratum:

$$\widehat{\mathrm{MED}}(\mathrm{CPUE}_{ik}) = \sum_{h=1}^{3} W_h \cdot \widehat{\mathrm{MED}}(\mathrm{CPUE}_{ikh}) \quad .$$

Comparisons Among Juvenile Indices

Numerous indices of juvenile abundance are estimated from IPHC's trawl survey data. Indices of annual abundance are estimated for each region and indices of year-class abundance are available for each region and age in the catch. In addition, abundance indices for offshore regions are estimated by two different methods.

Indices of juvenile abundance in each survey region are analyzed separately because the relationship between juveniles in one region and those in another is uncertain. Available information indicates that juveniles from different index regions probably do not intermingle, at least during the summer survey period. Several thousand juveniles have been tagged and released in the index regions during the trawl surveys and more than one hundred have been recaptured during subsequent trawl surveys. Of these recoveries, all were recaptured in the release region; none were recaptured in another index region, either inshore or offshore.

Although median CPUE is estimated for every age group in survey catches, indices of year-class abundance include only two- to six-year-olds for offshore regions and one- to three-year-olds for inshore regions because these age groups constitute the bulk of the catches in every region.

Offshore Regions

Systematic and stratified indices of juvenile abundance closely agree for every region and nearly every age in the catch. Therefore, only stratified estimates are considered hereafter to simplify discussion of so many indices. All pertinent comparisons were made with systematic estimates and the results were nearly identical to those for stratified estimates.

With few exceptions, no two indices of juvenile abundance show the same trend over time. Trends in relative annual abundance differ among regions, and trends in relative year-class abundance differ among capture ages and regions.

Although trends in annual abundance at most offshore regions show some similarities over the years, the index of abundance in one region usually is not significantly rank-correlated with indices in other regions. For all regions except Cape St. Elias, stratified median CPUE for total catches is highest during the 1960's, declines to its lowest level during the mid-1970's, and then rises to approximately its long-term average by the 1980's. Median CPUE at Cape St. Elias is fairly stable until the late 1970's, but more than doubles thereafter (Table 1). Despite these similarities, Spearman rank correlation coefficients are significant for only two of ten possible regional pairings (Schmitt, op. cit.).

Stratified indices of year-clas abundance not only differ among regions but also among different ages of capture in the same region (Figures 2-6). Two striking features of these figures suggest that CPUE of juvenile halibut in the trawl surveys is greatly affected by changes in availability of juveniles. First, a few years of extremely high CPUE's stand out in every region, but the years of such extremes differ by region. Perhaps these outstanding values represent only localized concentrations and are not indicative of relative year-class abundance. However, in every region relative abundance of every age group is low for a series of years during the mid-1970's. This consistency among regions may indicate that CPUE is a reliable measure of year-class abundance during this period or perhaps juveniles were concentrated outside the survey regions during the mid-1970's. The second feature evident in these figures is that all age groups within a region show nearly identical trends in relative abundance by year and not by year class. For example, relative abundance of three-, four- and five-year-olds at Unimak is greatest in 1968, but relative abundance of four- and five-year-olds in 1969 is very low (Figure 3). In general, an outstanding year class in one survey is not outstanding in successive surveys of the same region.

Inshore Regions

Trends in annual abundance since the 1960's are similar in several inshore regions. For example, abundance at Trinity, Alitak, and Kayak is relatively low during 1971, 1976, and 1979-1981. Peak abundances in these regions occur prior to 1970, although in different years (Table 2). However, indices of relative year-class abundance at inshore regions are apparently affected by changes in availability of juveniles. The synchronicity in CPUE for most age groups in the catch that was observed at offshore regions is also apparent at inshore regions (Figures 7-12).

Inshore and Offshore Regions

Estimates of relative year-class abundance at inshore regions correlate poorly with year-class abundance at nearby offshore regions. Systematic indices of abundance at each age, one, two, and three, in inshore regions were compared to systematic indices for each age, two through six, at nearby offshore regions. The Spearman rank correlation between these indices is significant for only 12 of 75 comparisons (Schmitt, op. cit.).

Indices of Adult Abundance

Three measures of adult abundance are available to compare with each index of juvenile year-class abundance. Two of these measures indicate year-class abundance of adults. First, setline CPUE from the commercial fishery is available by age and year class. Second, absolute abundance of adults by age and year class is available from cohort analysis of commercial catch data. The third measure is annual biomass of the spawning stock, and it indicates relative year-class abundance of their progeny at birth because fecundity is proportional to weight. These indices of adult abundance are estimated by IPHC as part of its annual stock assessment work. The assumptions, errors, and estimation methods are thoroughly discussed in published reports (i.e., Deriso and Quinn 1983; Hoag and McNaughton 1978; Myhre, et al. 1977; and Quinn, et al. 1983, 1984), and the data are given by Schmitt (1985).

Setline CPUE

Setline CPUE is the estimated number of halibut caught per standard skate of setline fishing gear. Perhaps the most representative index of year-class abundance available from CPUE data is the total contribution to the setline fishery by a year class over its fishable lifetime. For example, a year class that yielded consistently high values of setline CPUE throughout its lifetime is considered to be more abundant than one that produced low CPUE values or a mixture of high and low values. Most halibut in the setline catch are between 8 and 20 years old. Accordingly, I approximate this "lifetime contribution" of a year class by the cumulative CPUE of 8- to 20-year-olds. Estimates of lifetime contribution are available for few year classes assessed by the juvenile survey, and consequently, setline CPUE of an indicator age group, 9-year-olds, is used as an index of adult year-class abundance for comparisons with juvenile abundance indices. Results of Spearman tests, which compare the ranks of CPUE at each adult age in a year class to its lifetime CPUE ranking, show that CPUE of 9-year-olds had the highest rank correlation (Schmitt, op. cit.).

Cohort Analysis

Estimates of the absolute number of halibut are available from a cohort analysis of data from commercial catches. The numbers for each age group, 8- to 20-year-olds, were estimated as described by Deriso and Quinn (1983). To simplify comparisons between commercial fishery and trawl survey indices, only the number of 9-year-olds is used to indicate adult year-class abundance.

Parent Biomass

Biomass of 12- to 20-year-olds is considered an index of spawning stock size and potential year-class abundance of their progeny. Fecundity is proportional to weight, so the potential number of eggs produced each year is proportional to the biomass of the female spawning stock. The age of 50% maturity for females is twelve years (Schmitt and Skud 1978). Data on sex ratio are not available annually, and it is assumed that the biomass of all 12- to 20-year-olds is indicative of the relative number of eggs spawned.

Comparisons Among Adult Indices

Cohort estimates of numerical abundance parallel those of setline CPUE for the 1953-1973 year classes but the trend in biomass of the parent stock matches those for setline CPUE and cohort abundance only for the 1956-1968 year classes (Figure 13). Relative year-class abundance, measured by the number and CPUE of nine-year-olds, generally declined until the mid-1960's year classes and increased thereafter. In contrast, trends in parent biomass increased steadily from 1935 to peak abundance in 1956 and then declined rapidly to its former low level by the mid-1970's.

Comparisons Between Juvenile and Adult Indices

The reliability of data from IPHC's trawl surveys as a predictor of recruitment to the fishable population is tested by comparing survey indices of relative year-class abundance of juveniles to indices of adult year-class abundance. Correlations between juvenile and adult indices of year-class abundance are poor. The rank correlation between each stratified index of juvenile year-class abundance and setline CPUE of 9-year-olds is significant in only 3 of 25 tests. Similarly, the rank correlation between each stratified index and the number of 9-year-olds is sigificant in only 1 of 25 tests. Indices of juvenile year-class abundance at offshore regions usually are poorly correlated with parent biomass. Only 6 of 25 Spearman rank tests showed significant, positive correlations. For inshore regions, the relationship between systematic CPUE by age and parent biomass is significant for one-year-olds in the Bering Sea, Unimak, and Shelikof regions, but is not significant at older ages in any region. It is noteworthy that the relationship is not significant for other inshore regions, where median CPUE's for juveniles are much higher.

Discussion

Indices of juvenile abundance from survey data are poor predictors of recruitment to the fishable population, measured by number and setline CPUE of nine-year-olds. Indices of year-class abundance of juveniles also do not correlate with estimates of year-class abundance at the egg stage.

The general lack of agreement between juvenile and adult indices may arise from: 1) poor assessments during the juvenile stage; 2) poor assessments during the adult stage; 3) changes in relative year-class abundance between juvenile and adult assessments; or 4) some combination of these factors. Each index in this study is based on certain assumptions and has errors of unknown magnitude associated with it. Variance estimates are not always available, and the comparative reliability of these indices is not known. Point estimates of year-class abundance are imprecise, so greater reliance is placed on comparisons of long-term trends. The results must be viewed with these qualifications in mind.

Setline CPUE and number of adults estimated by cohort analysis probably are the most reliable measures of year-class abundance examined in this study. The commercial fishery data used for these indices are collected as part of an intensive and well-designed sampling program. Also, many vessels participate in the fishery and fishing grounds are located throughout the entire summer range of adult halibut. Consequently, fishery data probably are representative of the adult population. If it is assumed that these indices are good measures of adult year-class abundance, then the reliability of assessments during the juvenile stage depends on substantial changes in year-class abundance during the interim.

Mortality is the only force that can alter year-class abundance. Very little is known about natural mortality of sublegal halibut and it is commonly assumed to be constant in time and area for stock assessment analyses. Most fishing mortality of juveniles results from incidental capture by fisheries targeting on other species. Incidental mortality upon year classes can only be roughly approximated because estimates of the age composition of the incidental catch and resultant mortality are not available. To approximate year-class mortality from all sources, I assume that all mortality occurs at five years of age. Thus, an annual incidental mortality of 20 million pounds in 1966 represents a 20 million pounds reduction in the 1961 year class. Under this assumption, incidental mortality was relatively constant for year classes spawned during the 1960's and declined for year classes of the 1970's.

Although incidental mortality of juveniles certainly altered the abundance of year classes during the interval between survey and fishery assessments, it cannot account entirely for the differences in these assessments. To coincide with the observed trends in incidental mortality and adult abundance (Figure 14), year-class abundance of juveniles should be relatively constant through the late 1960's and increase slightly thereafter. However, none of the survey indices of juvenile year-class abundance show this trend. In general, stratified estimates of year-class abundance decline during the 1960's, remain at low levels until the late 1970's, and increase thereafter.

Poor correspondence among trends in incidental mortality and juvenile and adult indices of year-class abundance does not necessarily mean that juvenile indices are poor. Adverse environmental conditions may have affected the survival of juveniles after survey assessments, and estimated trends in incidental mortality are only rough approximations to the actual reductions in year-class abundance.

Many factors contribute to the apparently poor relationship between juvenile and adult indices of year-class abundance. The lengthy duration between assessments of juvenile and adult abundances provides great opportunity for substantial alteration of relative year-class abundance. In addition, the migratory behavior of juveniles complicates the interpretation of index comparisons because the relationship between halibut in one area to those in another is uncertain. Changes in distribution unrelated to migration to natal areas also affect estimates of survey CPUE. Low sampling effort is another factor contributing to the poor survey results. Juvenile halibut inhabit large areas of the Bering Sea and Northeast Pacific Ocean and a maximum of 144 offshore and 27 inshore stations are trawled each year. The lack of variance estimates also makes it more difficult to evaluate the reliability of survey indices. The surveys of each region are conducted during a brief period each summer and it is not known how dependent the results are on the sampling period. Perhaps the trawl survey samples transient populations that bear little relation to year-class abundance.

Summary

Since the early 1960's, IPHC has conducted trawl surveys to assess the abundance of juvenile halibut in selected regions in the Northeast Pacific Ocean and Bering Sea. The abundance estimates from survey data have been regarded as an index of potential recruitment to the commercial fishery five to seven years later. The objective of this study is to evaluate the predictive potential of the juvenile survey data.

Indices of juvenile year-class abundance were estimated by two methods. One index was based on systematic sampling theory in accordance with the survey design. For another index, data were post-stratified by bottom depth.

Most correlations among indices of juvenile abundance were poor. The relative abundance of a particular year class usually was not the same in all regions, nor was it the same over several ages in subsequent surveys of the same region.

The predictive ability of survey data was tested by comparing indices of year-class abundance of juveniles to indices of year-class abundance of adults. Indices of adult abundance included the number of halibut and fishery CPUE for a representative age group. Agreement between indices of juvenile and adult abundance was rare.

In conclusion, the ability of IPHC trawl survey data to either predict recruitment to the fishery or measure year-class abundance of juveniles was poor. The survey indices probably are unreliable because they apparently are greatly affected by changes in availability and/or sampling error. Survey indices generally did not agree with other measures of year-class abundance, either at the egg stage or adult stage, and estimates of mortality during the interim could not fully explain the differences.

List of References

Aitchison, J., and J.A.C. Brown. 1969. The Lognormal Distribution with Special Reference to its Uses in Economics. Cambridge University Press, New York, 176 p.

Byrne, C.J., T.R. Azarovitz, and M.P. Sissenwine. 1981. Factors affecting variability of research vessel trawl surveys. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 258-273.

Carrothers, P.J.G. 1981. Catch variability due to variations in groundfish otter trawl behaviour and possibilities to reduce it through instrumental fishing gear studies and improved fishing procedures. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 247-257.

Clark, S.H., and B.E. Brown. 1977. Changes in biomass of finfishes and squids from the Gulf of Maine to Cape Hatteras, 1963-1974, as determined from research vessel survey data. Fishery Bulletin. Vol. 75, No. 1, pp. 1-21.

Deriso, R.B., and T.J. Quinn II. 1983. The Pacific halibut resource and fishery in Regulatory Area 2, II. Estimates of biomass, surplus production, and reproductive value. International Pacific Halibut Commission, Scientific Report No. 67, pp. 55-89.

Forest, A., and J.P. Minet. 1981. Abundance estimates of the trawlable resources arund the islands of Saint-Pierre and Miquelon (NAFO Subdiv. 3Ps): Methods used during the French research surveys and discussion of some results. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 68-81.

Foster, J.J., C.M. Campbell, and G.C.W. Sabin. 1981. The fish catching process relevant to trawls. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 229-246.

Halliday, R.G., and P.A. Koeller. 1981. A history of Canadian groundfish trawling surveys and data usage in ICNAF Divisions 4TVWX. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 27-41.

Hoag, S.H., and R.J. McNaughton. 1978. Abundance and fishing mortality of Pacific halibut, cohort analysis, 1935-1976. Intrnational Pacific Halibut Commission, Scientific Report No. 65, 45 p.

Leaman, B.M. 1981. A brief review of survey methodology with regard to groundfish stock assessment. [IN] Doubleday, W.G., and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, pp. 113-123.

McCaughran, D.A. 1981. Estimating growth parameters for Pacific halibut from mark-recapture data. Canadian Journal of Fisheries and Aquatic Sciences 38, pp. 394-398.

Moyle, J. B., and R. Lound. 1960. Confidence limits associated with means and medians of series of net catches. Transactions of the American Fisheries Society, Vol. 89, No. 1, pp. 53-58.

Myhre, R.J., G.J. Peltonen, G. St-Pierre, B.E. Skud, and R.E. Walden. 1977. The Pacific halibut fishery: Catch, effort and CPUE, 1929-1975. International Pacific Halibut Commission, Technical Report No. 14, 94 p.

Quinn II, T.J., E.A. Best, L. Bijsterveld, and I.R. McGregor. 1983. Sampling Pacific halibut (Hippoglossus stenolepis) landings for age composition: History, evaluation, and estimation. International Pacific Halibut Commission, Scientific Report No. 68, 56 p.

Quinn II, T.J., R.B. Deriso, S.H. Hoag, and R.J. Myhre. 1984. A summary of methods of estimating annual surplus production for the Pacific halibut fishery. International North Pacific Fisheries Commission Bulletin 42, pp. 73-81.

Schmitt, C.C. 1985. Review of a trawl survey program for juvenile Pacific halibut. M.S. Thesis. University of Washington, Seattle. 182 p.

Schmitt, C.C., and B.E. Skud. 1978. Relation of fecundity to long-term changes in growth, abundance and recruitment. International Pacific Halibut Commission, Scientific Report No. 66, 31 p.

Smith, S.J. 1981. A comparison of estimators of location for skewed populations, with applications to grundfish trawl surveys. [IN] W.G. Doubleday and D. Rivard (ed.), Bottom trawl surveys. Canadian Special Publication of Fisheries and Aquatic Sciences 58, 31 p.

Taylor, C.C. 1953. Nature of variability in trawl catches. Fishery Bulletin, Vol. 54,pp. 143-166.

Table 1. Stratified indices of year-class abundance (number of halibut (65 cm per hour) and their variances by offshore region and year.

	Bering Sea		Unimak		Chirikof		Chiniak		Cape St. Elias	
Year	CPUE	Var	CPUE	Var	CPUE	Var	CPUE	Var	CPUE	Var
1961			22.8	8.81	50.3	428.68	21.0	28.83		
1962									6.2	12.93
1963	34.8	905.69								
1964					52.3	483.06	111.3	1327.08	9.5	0.07
1965					54.9	320.73	55.5	359.75	22.6	65.04
1966	22.6	78.14			39.0	120.34			17.1	15.55
1967	15.2	4.21	34.5	240.72	147.0	17747.07	27.9	1590.75	15.8	1.72
1968	10.2	2.50	78.0	0.00	61.8	355.58	27.3	29.89	19.3	5.58
1969	10.9	2.40	26.6	35.79	62.3	189.55	21.6	12.60	14.4	8.08
1970	7.5	2.10	15.1	1.16	139.7	1342.03	35.3	66.09	11.6	14.97
1971	9.4	2.19	35.5	5.90	43.6	47.47	44.7	105.09	8.8	6.73
1972	2.8	0.69	23.3	32.11	55.1	79.30	31.6	5.42	11.9	29.71
1973	4.6	0.86	26.5	38.46	45.4	95.53	28.5	276.12	11.2	7.08
1974	4.8	0.87	18.2	11.55	35.7	251.28	13.7	61.76	12.6	9.38
1975	7.3	5.70	18.1	15.57	22.5	37.72	24.7	331.34	9.4	4.53
1976	3.1	0.95	15.3	5.92	15.1	30.76	26.3	55.93	11.8	3.68
1977	9.5	4.95	15.1	6.17	22.1	33.19	21.8	29.62	14.8	22.85
1978	8.7	2.96	17.4	4.29	32.5	118.97	27.3	25.32	21.3	11.84
1979	5.6	91.23	9.8	10.30	45.8	54.59	40.8	29.32	21.5	17.99
1980	12.9	11.86	33.0	46.14	69.2	486.56	39.9	58.16	24.6	29.18
1981	14.3	7.81	44.9	439.23	31.4	92.85	48.2	204.39	32.2	31.82

Table 2. Systematic indices of juvenile abundance (number of halibut (65 cm per 15 minutes) and their variances by inshore region and year.

	Bering Sea		Unimak		Trinity		Alitak		Kayak		Shelikof	
Year	CPUE	Var	CPUE	Var	CPUE	Var	CPUE	Var	CPUE	Var	CPUE	Var
1961					102.4	1375.78	155.7	1310.82	58.4	6881.74	76.8	5852.15
1962												
1963					76.2	1336.38	86.5	1178.96	20.4	50.30	17.0	7.06
1964					133.4	1454.36	138.9	4231.92	44.6	621.62	40.3	94.70
1965							73.1	554.46	52.5	460.72	32.8	185.39
1966							73.9	158.95	117.3	2523.43	17.3	2.60
1967							288.9	7453.19				
1968	18.5	204.36	85.1	1728.50			67.6	449.91	22.9	65.48	14.2	16.29
1969	32.4	447.57	73.2	51.10			222.7	5875.23	70.5	671.86	5.8	4.02
1970	8.3	33.68	76.3	36.90			104.5	1825.54	38.2	82.67	4.4	1.54
1971	51.8	371.09	44.9	92.21	23.0	17.34	26.8	65.17	30.0	90.60	16.4	6.62
1972	32.0	477.71	12.0	5.10	32.4	136.85	55.3	671.09	87.7	786.33	5.2	1.72
1973	24.3	276.64	19.0	20.73	19.1	38.59	45.2	297.92	47.0	147.91	5.9	1.10
1974	34.8	243.72	28.6	71.90	55.5	259.46	44.5	111.90	29.2	57.64	9.4	6.09
1975	31.0	69.92	21.2	16.73	14.0	12.53	48.6	44.41	24.7	146.33	5.4	2.89
1976	14.4	42.51	8.5	3.62	11.5	6.99	19.5	36.76	22.8	11.32	6.8	4.55
1977	28.5	56.74	15.1	21.96	57.5	283.61	65.5	382.75	76.8	2946.38	6.7	57.20
1978	28.6	178.56	21.6	61.13	18.8	23.73	86.5	634.69	88.8	1808.05	26.1	28.41
1979	9.9	19.13	14.4	25.09	23.3	24.23	31.2	94.88	29.9	67.71	3.5	1.37
1980	14.6	58.58	11.9	22.46	12.4	2.89	23.6	78.70	31.8	128.07	2.1	0.26
1981	25.6	139.19	32.1	60.85	11.4	21.64	22.2	16.17	31.0	90.37	4.9	8.44

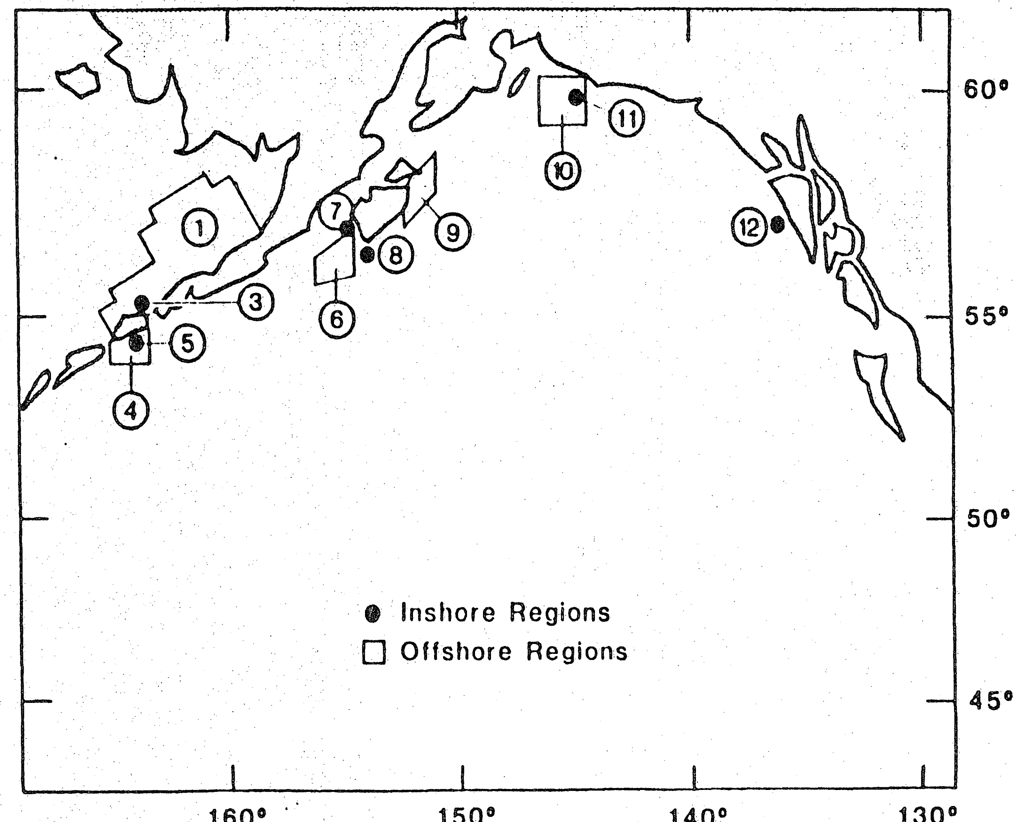

Figure 1. Index regions in IPHC trawl surveys: 1-traditional Bering Sea; 3-Bering Sea Inshore; 4-Unimak Offshore; 5-Unimak Inshore; 6-Chirikof; 7-Alitak; 8-Trinity; 9-Chiniak; 10-Cape St. Elias; 11-Kayak; 12-Shelikof.

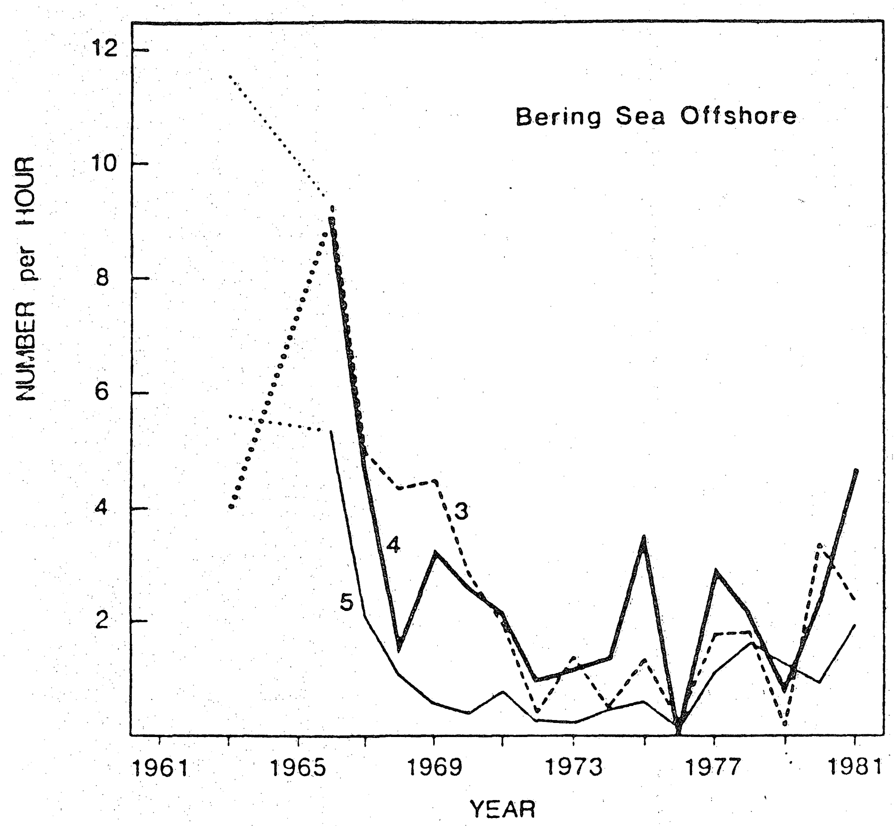

Figure 2. Stratified median CPUE at ages 3, 4, and 5 by year in the Bering Sea offshore region.

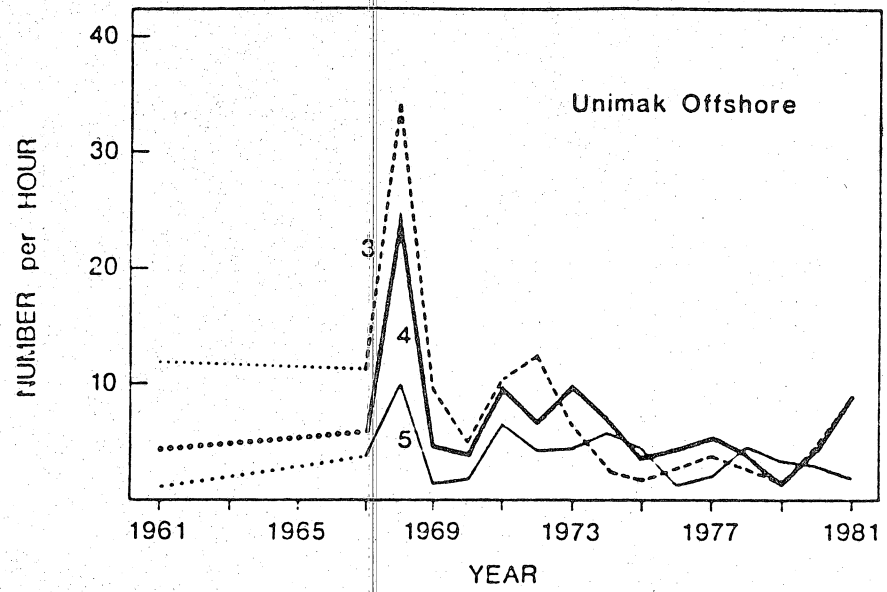

Figure 3. Stratified median CPUE at ages 3, 4, and 5 by year in the Unimak offshore region.

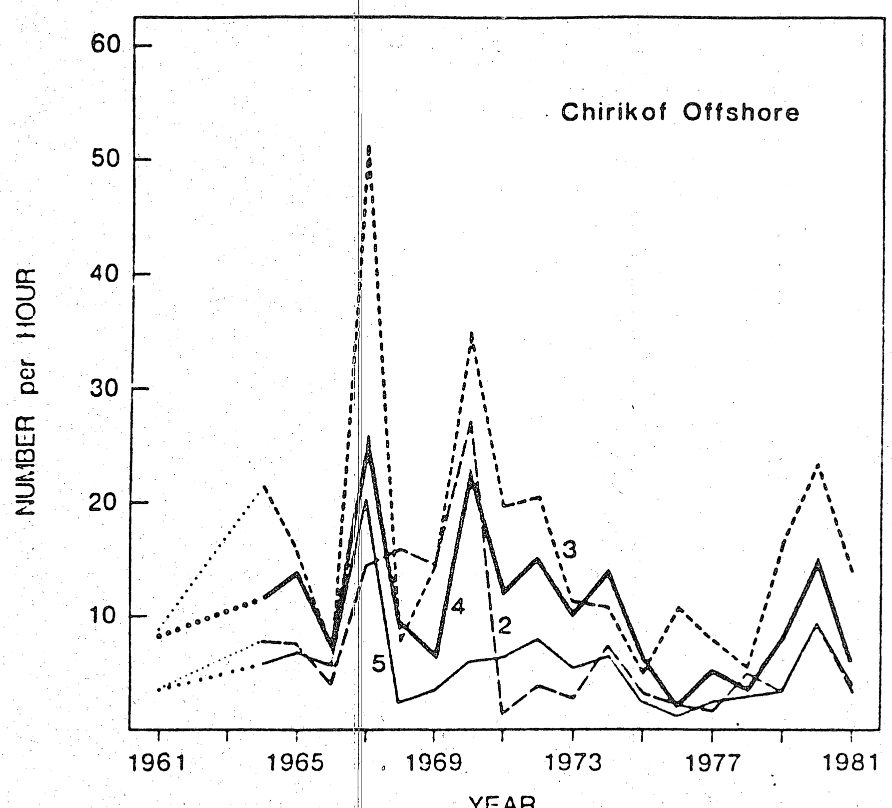

Figure 4. Stratified median CPUE at ages 2, 3, 4, and 5 by year in the Chirikof offshore region.

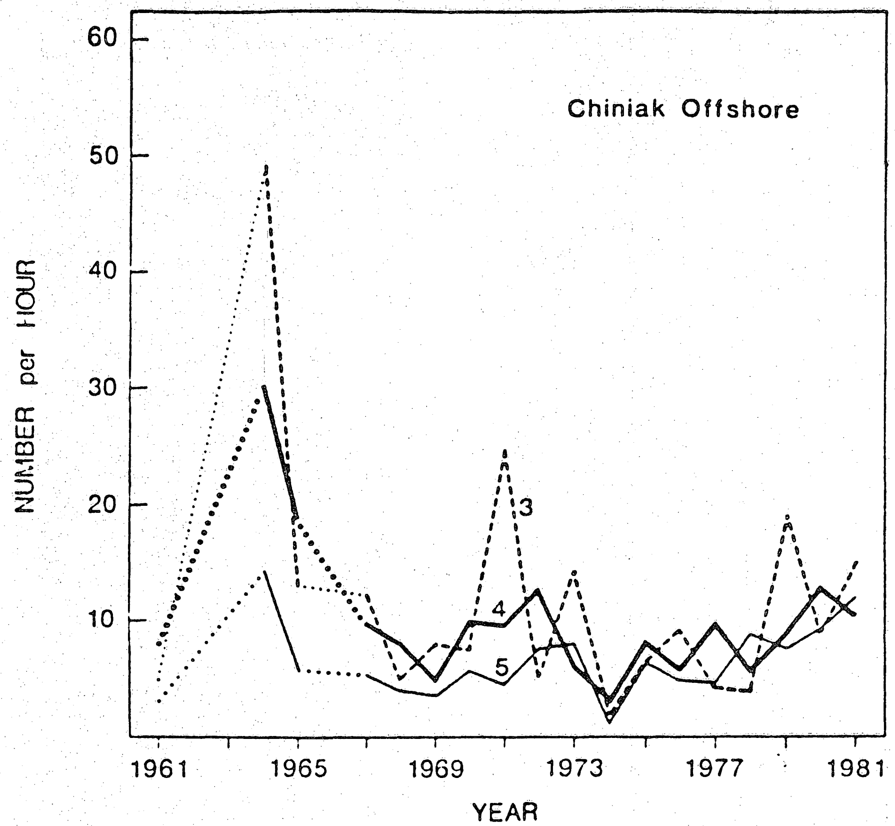

Figure 5. Stratified median CPUE at ages 3, 4, and 5 by year in the Chiniak offshore region.

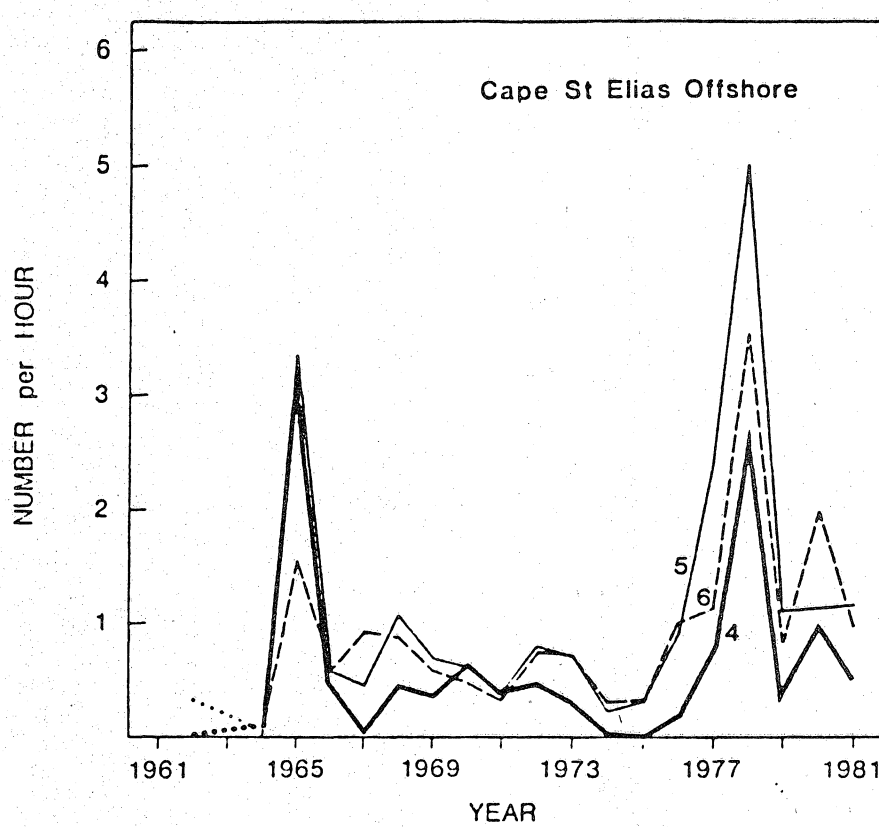

Figure 6. Stratified median CPUE at ages 4, 5, and 6 by year in the Cape St. Elias offshore region.

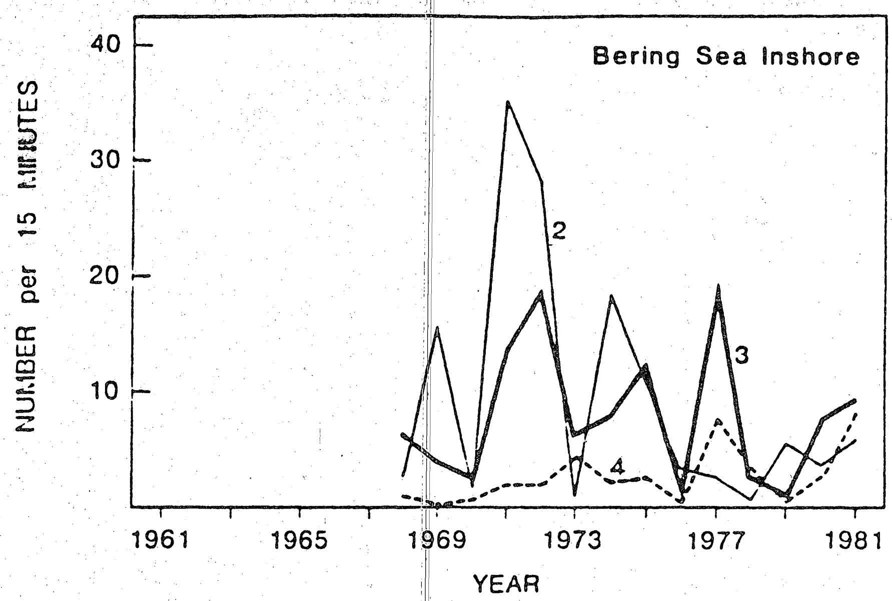

Figure 7. Systematic median CPUE at ages 2, 3, and 4 by year in the Bering Sea inshore region.

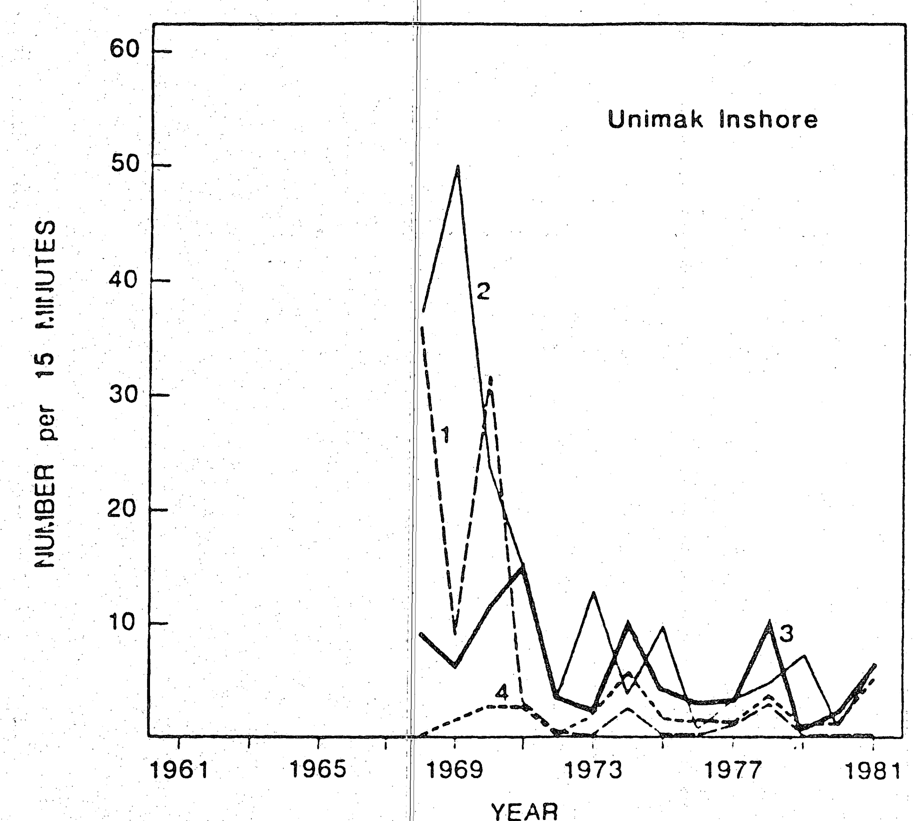

Figure 8. Systematic median CPUE at ages 1, 2, 3, and 4 by year in the Unimak inshore region.

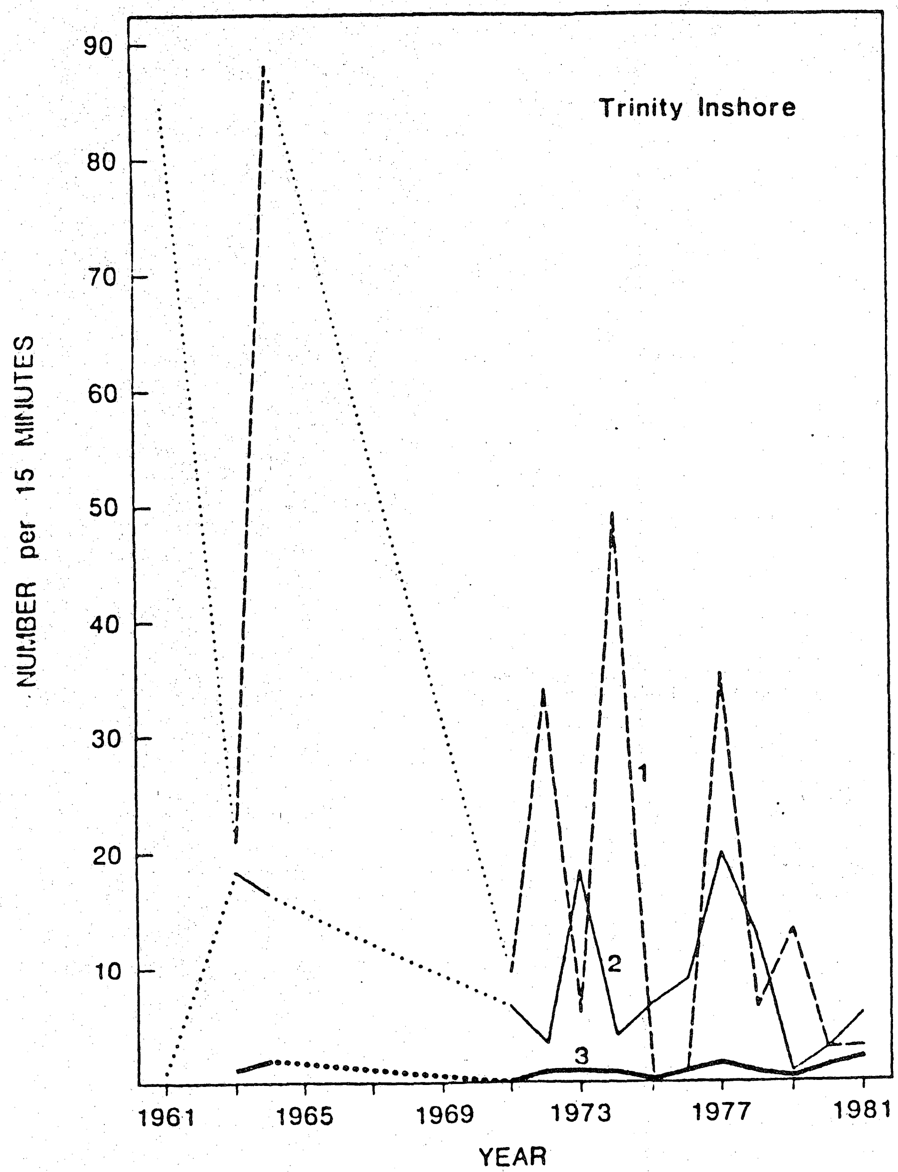

Figure 9. Systematic median CPUE at ages 1, 2, and 3 by year in the Trinity inshore region.

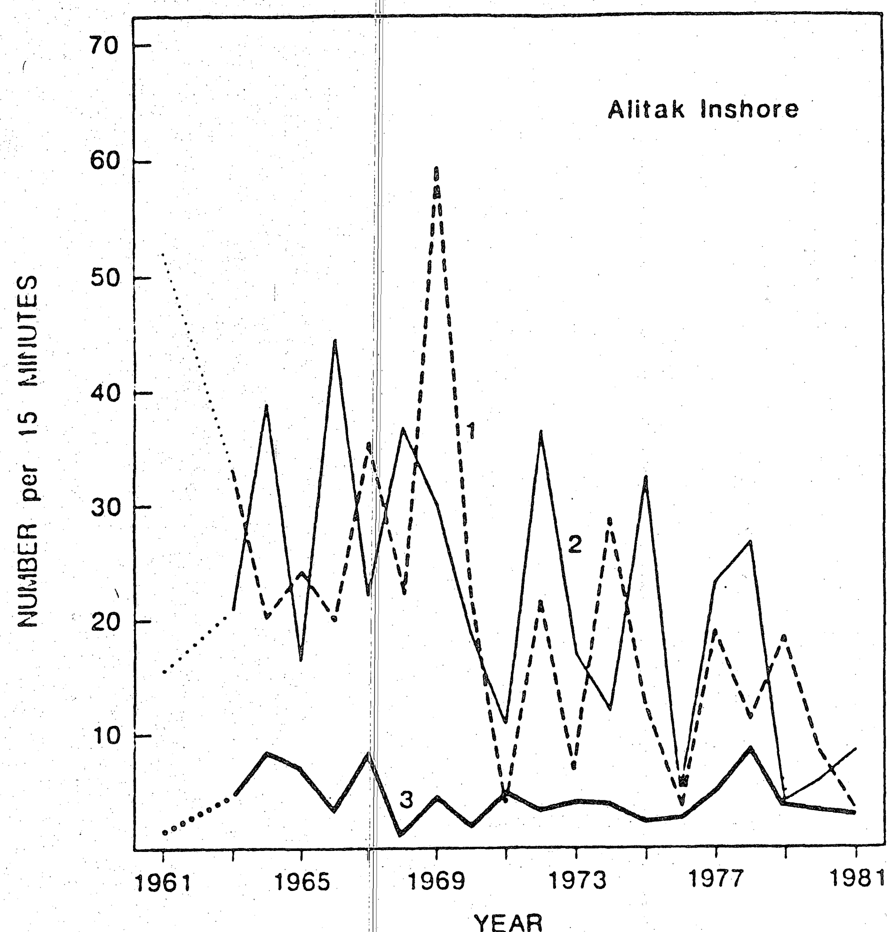

Figure 10. Systematic median CPUE at ages 1, 2, and 3 by year in the Alitak inshore region.

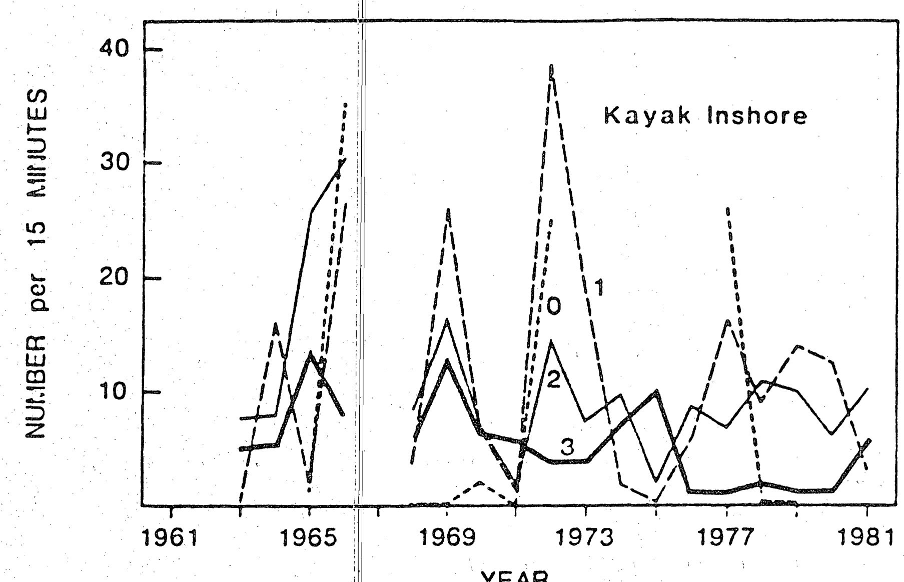

Figure 11. Systematic median CPUE at ages 0, 1, 2, and 3 by year in the Kayak inshore region.

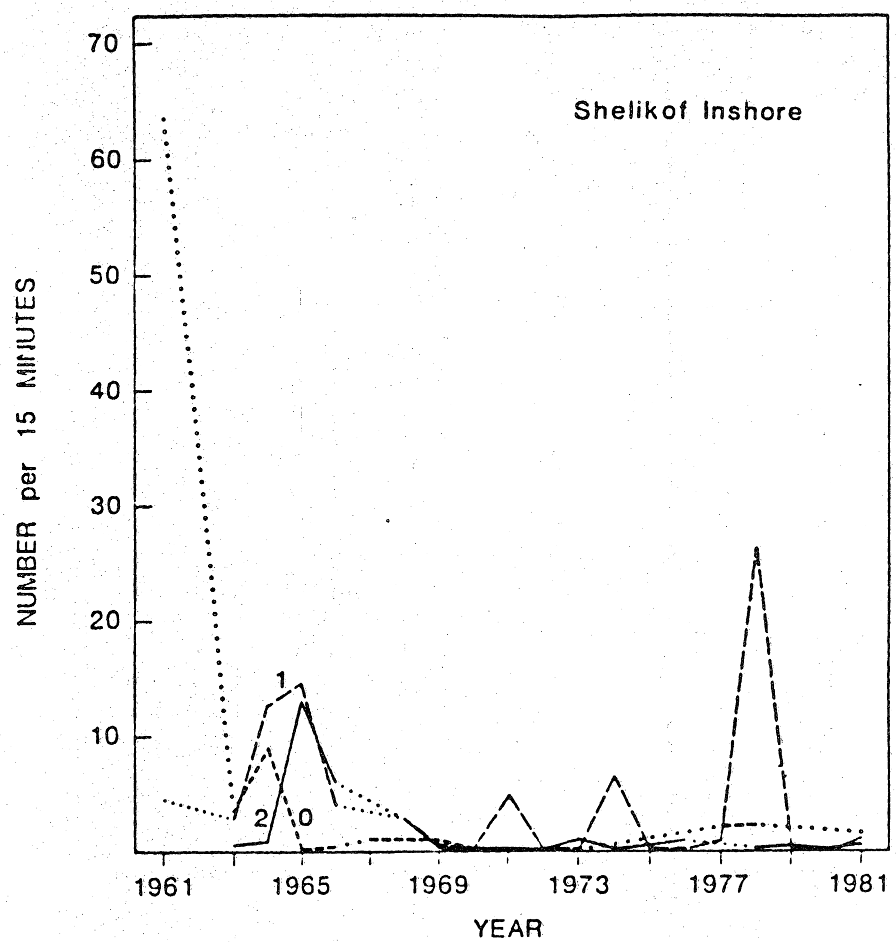

Figure 12. Systematic median CPUE at ages 0, 1, and 2 by year in the Shelikof inshore region.

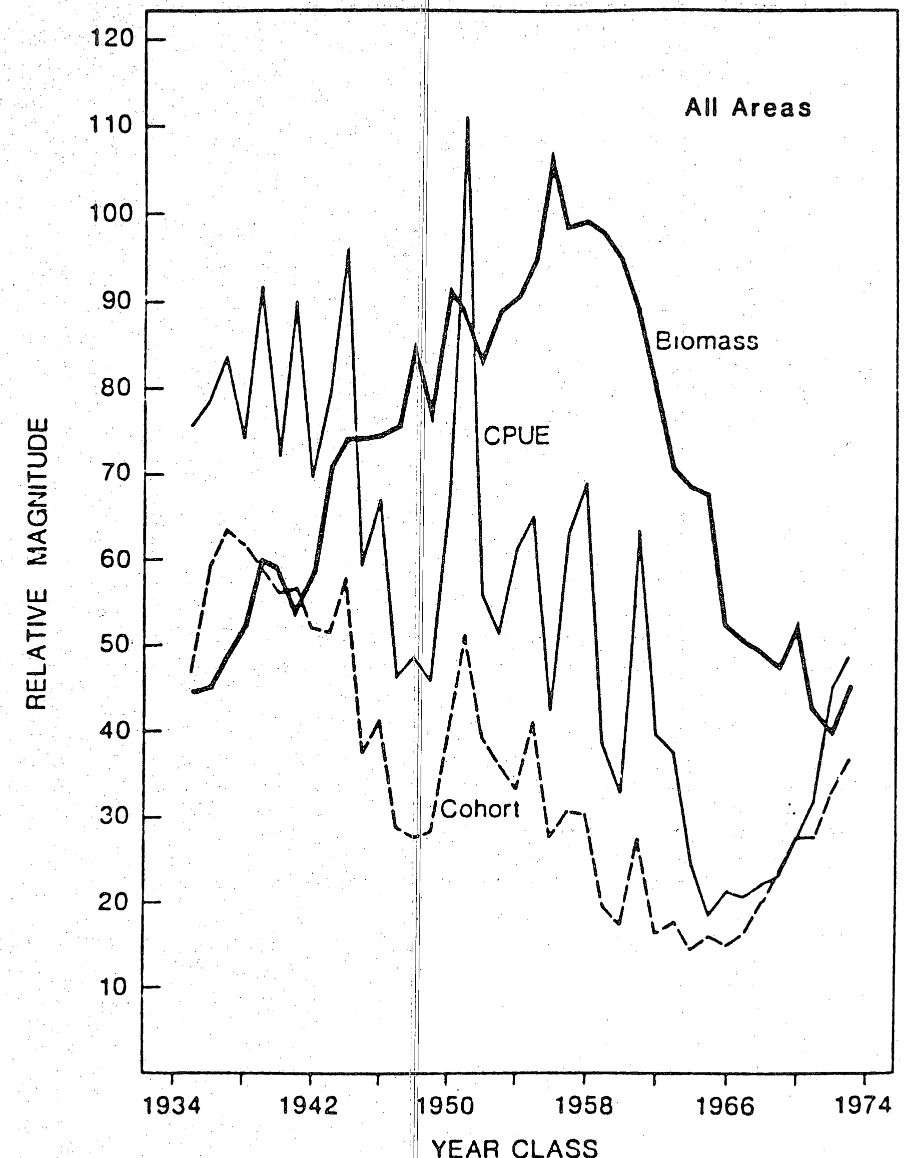

Figure 13. Setline CPUE and cohort abundance of 9-year-olds by year class and parent biomass by year class.

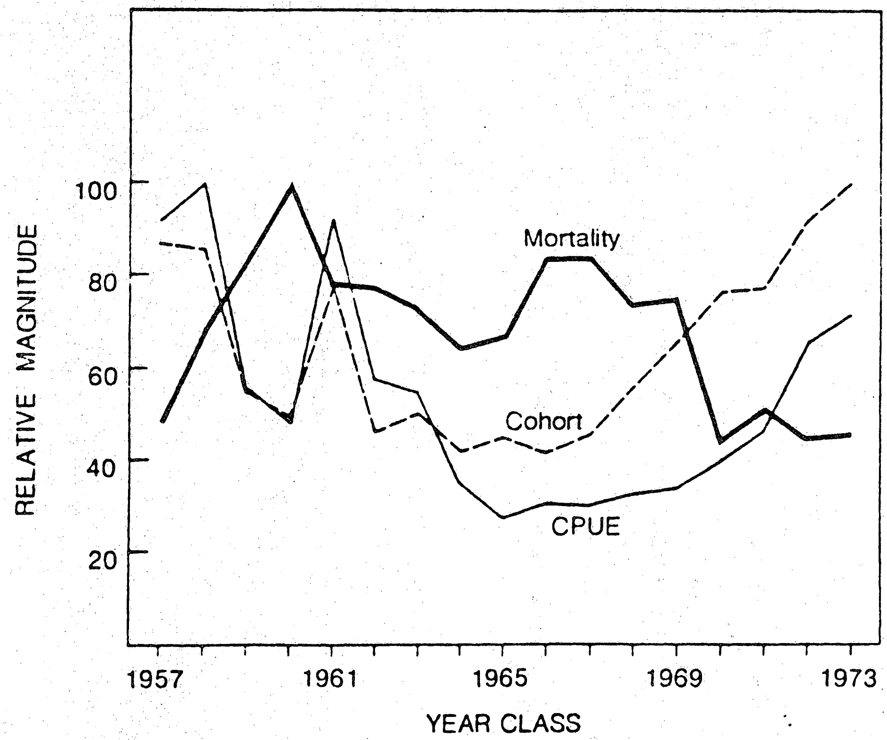

Figure 14. Trends in setline CPUE, cohort abundance, and incidental mortality by year class. Estimates of setline CPUE and cohort abundance are for 9-year-olds and trends in incidental mortality are advanced five years from the year of catch to approximate mortality upon year classes.