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Sampling Requirements for Estimating the Bycatch of Pacific Halibut (*Hippoglossus stenolepis*) in the On-bottom Trawl Fishery in Hecate Strait

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SAMPLING REQUIREMENTS FOR ESTIMATING THE BYCATCH OF PACIFIC HALIBUT (*Hippoglossus stenolepis*) IN THE ON-BOTTOM TRAWL FISHERY IN HECATE STRAIT

by

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ABSTRACT

Fargo, J., R. D. Stanley and C. M. Hand. 1991. Sampling requirements for estimating the bycatch of Pacific halibut (*Hippoglossus stenolepis*) in the on-bottom trawl fishery in Hecate Strait. Can. Manuscr. Rep. Fish. Aquat. Sci. 2135: 13 p.

We investigated the precision of the bycatch estimate for halibut in the mixed species trawl fishery in Hecate Strait, derived from stratified mean CPUE. Using data collected from a 1981-82 observer program, we estimated mean CPUE for halibut and its variance for three areas of differing halibut habitat and density. From these estimates, we derived the relationship between precision of the estimate of the stratified mean CPUE and sample size (number of tows observed). Assuming that the sampling of tows is random, we found that precision of the stratified mean CPUE decreased from ±50% to ±22% when the number of observations increased from 30 to 200 tows. Precision decreased to ±10% with a sample size of 850 tows. We estimate that a random sample of 20 commercial trips from this fishery, about 320 tows, of which ±80% (250) could be observed, will yield an estimate of the stratified mean CPUE for halibut, for Hecate Strait, with a precision of ±20% 19 times out of 20. We caution that because tows within a trip are not independent, and because we can expect considerable among trip variation, bycatch estimates based on a limited number of trips (<= 5) could be seriously biased.

RÉSUMÉ

Fargo, J., R. D. Stanley and C. M. Hand. 1991. Sampling requirements for estimating the bycatch of Pacific halibut (*Hippoglossus stenolepis*) in the on-bottom trawl fishery in Hecate Strait. Can. Manuscr. Rep. Fish. Aquat. Sci. 2135: 13 p.

Nous avons vérifié la précision de l'estimation de la pêche accessoire de flétans du Pacifique dans la pêche mixte au chalut de fond dans le détroit d'Hecate; l'estimation correspondait à la moyenne stratifiée de la PUE. Au moyen des données recueillies lors d'un programme d'observation qui s'est tenu en 1981-1982, nous avons estimé la PUE moyenne du flétan ainsi que sa variance dans trois régions correspondant à des densités de flétans et des habitats différents. En nous fondant sur ces estimations, nous avons calculé la relation entre la précision de l'estimation de la moyenne stratifiée de la PUE et l'importance des échantillons (par exemple, nombre de traits de chalut soumis à l'observation). Dans l'hypothèse que l'échantillonnage des traits se fait au hasard, nous avons constaté que la précision passait de plus ou moins 50 % à plus ou moins 22 % lorsque le nombre d'observations passait de 30 à 200 traits de chalut. La précision passait à plus ou moins 10 % lorsque l'échantillonnage portait sur 850 traits de chalut. Nous avons estimé qu'un échantillon constitué au hasard de vingt expéditions commerciales dans ce lieu de pêche, soit environ 320 traits de chalut dont 80 % faisant l'objet d'observations (250), devrait conduire à une estimation de la moyenne stratifiée de la PUE du flétan, dans le détroit d'Hecate, avec une précision de plus ou moins 20 % 19 fois sur 20. Il y a cependant une mise en garde: parce que les traits de chalut, au cours d'une même expédition, ne sont pas indépendants, et parce qu'on doit s'attendre à une considérable variation entre les expéditions, les estimations de prise accessoire fondées sur un numbre limité d'expéditions (5 ou moins) pourraient comporter des erreurs systématiques importantes.

INTRODUCTION

This report examines the error of estimates of the stratified mean CPUE for halibut from an observer program designed to study halibut bycatch in the Hecate Strait trawl fishery. We derived the relationship between error in the stratified mean CPUE and sample size using 1981-82 observer data for this area.

In 1990, the mixed species, on-bottom trawl fishery in Hecate Strait involved 510 vessel trips which landed 10,824 t of groundfish. These landings were dominated by five species: rock sole (*Lepidopsetta bilineata*), English sole (*Parophrys vetulus*), Dover sole (*Microstomus pacificus*), Pacific cod (*Gadus macrocephalus*), and arrowtooth flounder (*Atheresthes stomias*). As part of a multispecies research project (Tyler 1989, Fargo and Tyler 1991), we have identified three distinct fish assemblages associated with three habitats, each containing different densities of halibut that are available to bottom trawlers in the Strait. More than 50 species of marine fishes, are components of one or more of these assemblages. The different assemblages are affected to varying degrees by the commercial fishery.

One of the more valuable component species caught by the trawlers is Pacific halibut. Retention of halibut by the trawlers has been prohibited since 1944. This regulation was recommended by the International Pacific Halibut Commission, and is based on the argument that most halibut caught by trawlers are of sub-optimal size (Myhre 1969). The commercial fishery for halibut, at present, is restricted to hook and line gear.

The bycatch of halibut in the trawl fishery in Hecate Strait has been estimated in previous studies by Hoag (1971), Ketchen (1981) and Stanley (1984). Interest in the estimate of bycatch has recently been rekindled in light of changes in efficiency of commercial trawlers over the last decade as well as growing controversy over the halibut bycatch in the Alaska trawl fishery.

METHODS

We grouped Hecate Strait into the three sub-areas defined by assemblage analyses. Hecate Strait was chosen for our case study because the proposed budget for the bycatch study limited it to a portion of the coast and because prior information on halibut bycatch was available for this area. We are also interested in estimates of the amount of groundfish discards in the commercial trawl fishery in Hecate Strait. This information is required to produce assemblage stock assessments for the region.

The most recent data on halibut bycatch in the Hecate Strait trawl fishery were collected by observers in 1981-82 (Stanley 1985). We used this data set for our analysis. The data were non-normal in distribution; therefore, we log transformed them by ln(x+1) to normalize their distribution. The Shapiro-Wilk (Shapiro and Wilk 1965) test for correlation between the normal scores and transformed values was used as a criterion for determining normality.

We calculated mean CPUE and variance for the three sub-areas, estimated the stratified mean CPUE and then calculated the sample size associated with different amounts of error in this statistic. If mean CPUE, $\overline{c}_i$, for each stratum i, is weighted by the number of tows, n_i, in each stratum and the total number of tows observed in all three strata is n, an estimate of the stratified mean CPUE, $\overline{y}_{st}$, is given by

$$\overline{Y}_{st} = \frac{\sum_{i=1}^{3} n_i \times \overline{c}_i}{n}$$

(Cochran 1977 eq. 5.1).

The backtransform value of $\overline{y}_{st}$ is

$$\overline{u}_{st} = \exp(\overline{y}_{st}+1)$$

The variance, $s^2(\overline{y}_{st})$, of $\overline{y}_{st}$ is given by

$$s^2(\overline{y}_{st}) = \sum_{i=1}^{3} \frac{w_i \times s_i^2}{n_i} - \sum_{i=1}^{3} \frac{w_i \times s_i^2}{N}$$

(Cochran 1977 eq. 5.13), where w_i is the proportion of tows in stratum i, s_i^2 is the variance among tows in stratum i and N is the total number of tows for the fishery. The second term on the right in this equation represents a reduction due to the finite population correction factor.

The 95% confidence interval ,B, for $\overline{y}_{st}$, is

$$B = 2\sqrt{s^2(\overline{y}_{st})}$$

(Scheaffer et al. 1979 eq. 5.6).

The approximate sample size, n_s, required to estimate $\overline{y}_{st}$ with 95% confidence is

$$n_s = \frac{\sum_{i=1}^{3} N_i^2 \times s_i^2 / w_i}{N^2 D + \sum_{i=1}^{3} N_i s_i^2}$$

(Scheaffer et al. 1979 eq. 5.8), where N_i is the total number of tows allocated to stratum i, in our case allocated proportional to effort for the 1990 fishery, and $D=B^2/4$.

We calculated B for $\overline{u}_{st}$ for precision varying from ±5% to ±50%. Then we used log(B) along with estimates of s_i^2 for the transformed 1981-82 halibut data in stratum i to estimate n_s. We used $B/\overline{u}_{st}$ to determine the relationship between n_s and relative precision.

RESULTS

The correlation coefficient between the normal scores of the log transformed data and the log transformed data (Figure 1) indicated that there was not sufficient reason to reject the null hypothesis that the transformed data differed significantly from a normal distribution ($0.05 > p > 0.01$). The distribution of the transformed data is presented in Figure 2. The high frequency of zero observations (9%) may be a cause for concern when applying statistical methods, as we have here, which assume the distribution is normal. Alternative analytical methods will be applied to the data set being collected to estimate bycatch in 1990-91 to eliminate this problem. However, we feel that the results of this study are adequate to determine the approximate sample size required to estimate halibut bycatch.

The sample size, mean and variance for the transformed data and the fishing effort (tows) are listed by stratum in Table 1. Approximate 95% confidence intervals for $\overline{y}_{st}$ known to various levels of precision and the corresponding intervals for $\overline{u}_{st}$ are listed in Table 2. The precision curve for $\overline{y}_{st}$ is presented in Figure 3.

We project that the precision for $\overline{y}_{st}$ will vary from approximately $\pm 50\%$ for 30 tows observed to $\pm 5\%$ for 2400 tows observed. In 1990, the trawlers made an average 16 tows per trip in Hecate Strait or a total of 5876 tows.

Our analysis indicates that around 850 tows would be required to achieve a precision of $\pm 10\%$ in $\overline{y}_{st}$. This translates to coverage of between 70 and 94 trips, or a coverage equivalent to 19%-26% of the fishery. Assuming a cost of $4000/trip, observer coverage alone would cost $280,000 - $376,000. Coverage of 20-25 trips (4%-5% of the fishery) ($80,000-$100,000), will provide estimates of the bycatch of halibut with a precision of about $\pm 20\%$.

DISCUSSION

We have summarized the relationship between expected precision and sample size to provide some guidance for the design of this bycatch study. In estimating this relationship, we have made some simplifying assumptions. First, trawlers travel to areas other than Hecate Strait during one trip. If the proportion of these 'mixed-area' trips is greater in 1991-92 than in 1990, more tows will be conducted outside of the Strait, thus reducing the effective sample size for the same number of trips.

We made the statistical assumption that each tow is an independent observation although there are significant among trip contributors to the variance. A low number of tows (< 100) implies very few trips such that specific skipper, vessel and net effects will bias the results. This is likely to occur under budgetary constraint or if sampling effort is partitioned to include areas other than Hecate Strait in order to broaden coverage. Vessel and skipper effects will also lead to bias if the cooperation of the commercial fishing fleet is low. Then, catch rate estimates will reflect only those vessel skippers that would take observers, regardless of the amount of sampling effort. However, we have received a promise of cooperation from the trawl industry and cooperation during the initial phase of the program has been excellent. To date, no trawl captains have refused to take observers when asked and 8 out of the 20-25 trips scheduled have been completed.

Differences in abundance and distribution of halibut between 1989 and 1991 could also cause the estimate and precision bounds to differ from our projections. The extent

that biotic and abiotic factors influence the distribution and density of halibut in Hecate Strait is not known. However, halibut abundance and distribution within the Strait appear to be relatively consistent over short (3-4 year) time periods (Fargo et al. 1990). Curiously, all of the estimates of halibut bycatch from past studies are similar ($\pm$ 20%).

Small sample sizes and nonnormally distributed data will require alternative statistical treatment, such as bootstraping, of the data collected to enable estimation of the bycatch. We can also use additional predictive variables to derive the final estimate of bycatch. These variables could include season, fishing effort and gear type and could effectively reduce the error around the bycatch estimate from the levels presented here. Allocation of effort for the study will also affect the precision of the final estimate of bycatch. In addition to the analysis described here, we allocated sampling effort in proportion to expected bycatch by stratum. This had the effect of improving overall precision at the 20-25 trip level by about 5%. There may be little opportunity to optimize the placement of observers because the program is voluntary. However, the first eight observer trips appear to have resulted in area coverage proportional to the fishery during that time period.

Finally, consideration of sampling levels and partitioning of sampling effort to get broader albeit less precise coverage should be tempered by the need to do additional monitoring of bycatch in subsequent years. If managers implement major regulatory changes to reduce bycatch, they will create a defacto need for continued monitoring to assess the impact of the changes. The need to detect change over time may put a much higher premium on precision of the baseline estimate. Precise estimates for specific areas like Hecate Strait, may prove to be more useful over time than less precise estimates of larger regions such as the B.C. coast.

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Table 1. Number of tows, mean CPUE, variance and proportion of effort by stratum for the 1981-82 data.

	n_i	$\overline{c}_i$	$\exp(\overline{c}_i + 1)$ (lb/h)	s_i^2	w_i
stratum 1	215	2.406	13.7	2.618	0.35
stratum 2	177	4.003	54.7	3.075	0.28
stratum 3	136	3.52	33.9	1.908	0.37
stratified mean	528	3.229	25.3	0.563	

Table 2. Precision and 95% confidence intervals for $\overline{u}_{st}$ and corresponding values for $\overline{y}_{st}$ for the 1981-82 data.

Precision in $\overline{u}_{st}$	95% confidence interval	Precision in $\overline{y}_{st}$	95% confidence interval
5	23.99 - 26.51	1.5	3.178 - 3.278
10	22.73 - 27.78	3.1	3.123 - 3.324
15	21.46 - 29.04	4.7	3.066 - 3.369
20	20.20 - 30.30	6.3	3.006 - 3.411
25	18.94 - 31.56	7.9	2.941 - 3.452
30	17.68 - 32.83	9.6	2.872 - 3.491
35	16.41 - 34.09	11.3	2.798 - 3.529
40	15.15 - 35.35	13.1	2.718 - 3.565
45	13.89 - 36.61	15.0	2.631 - 3.600
50	12.63 - 37.88	17.0	2.536 - 3.634

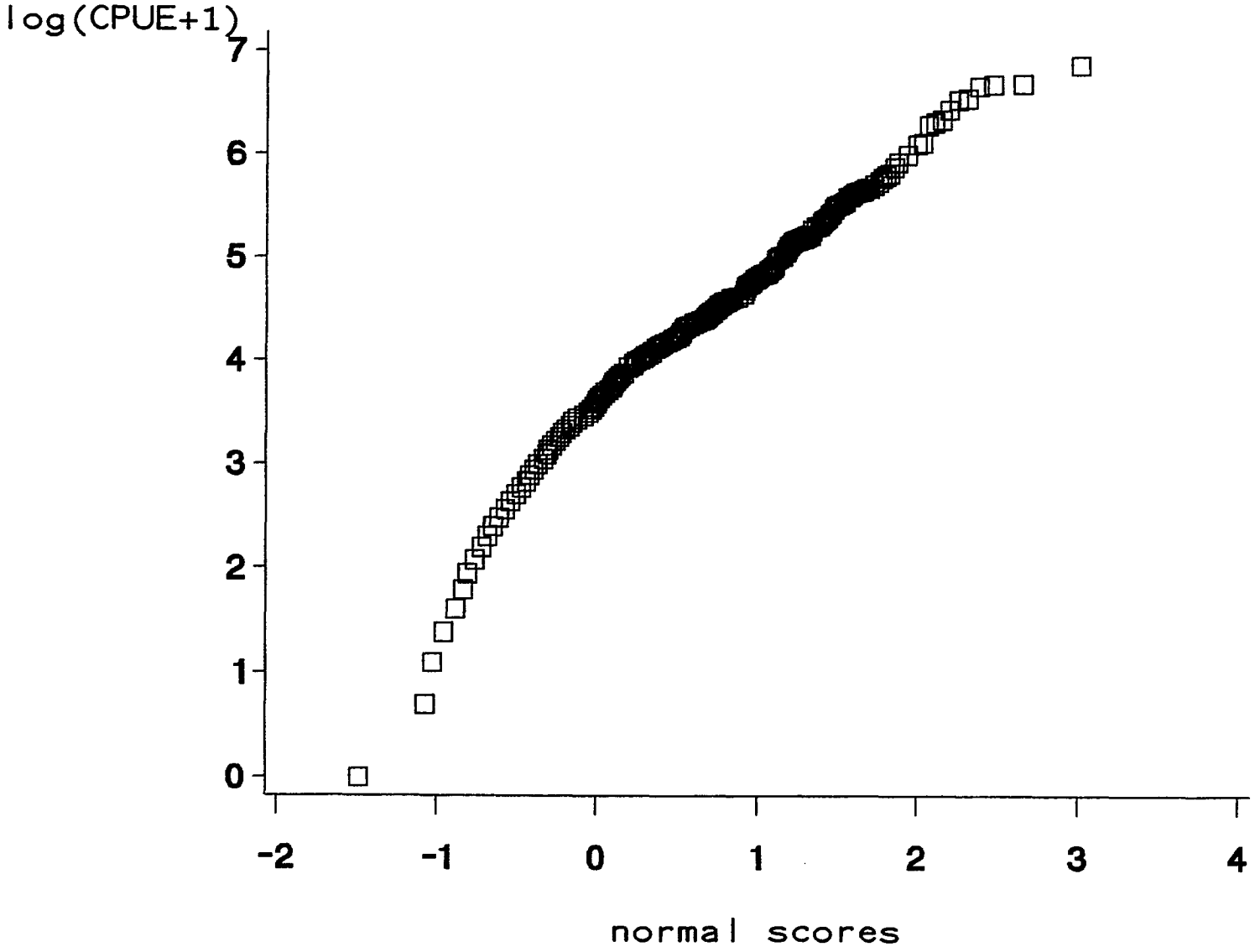


Fig. 1. Probability plot for the 1981-82 halibut CPUE data.

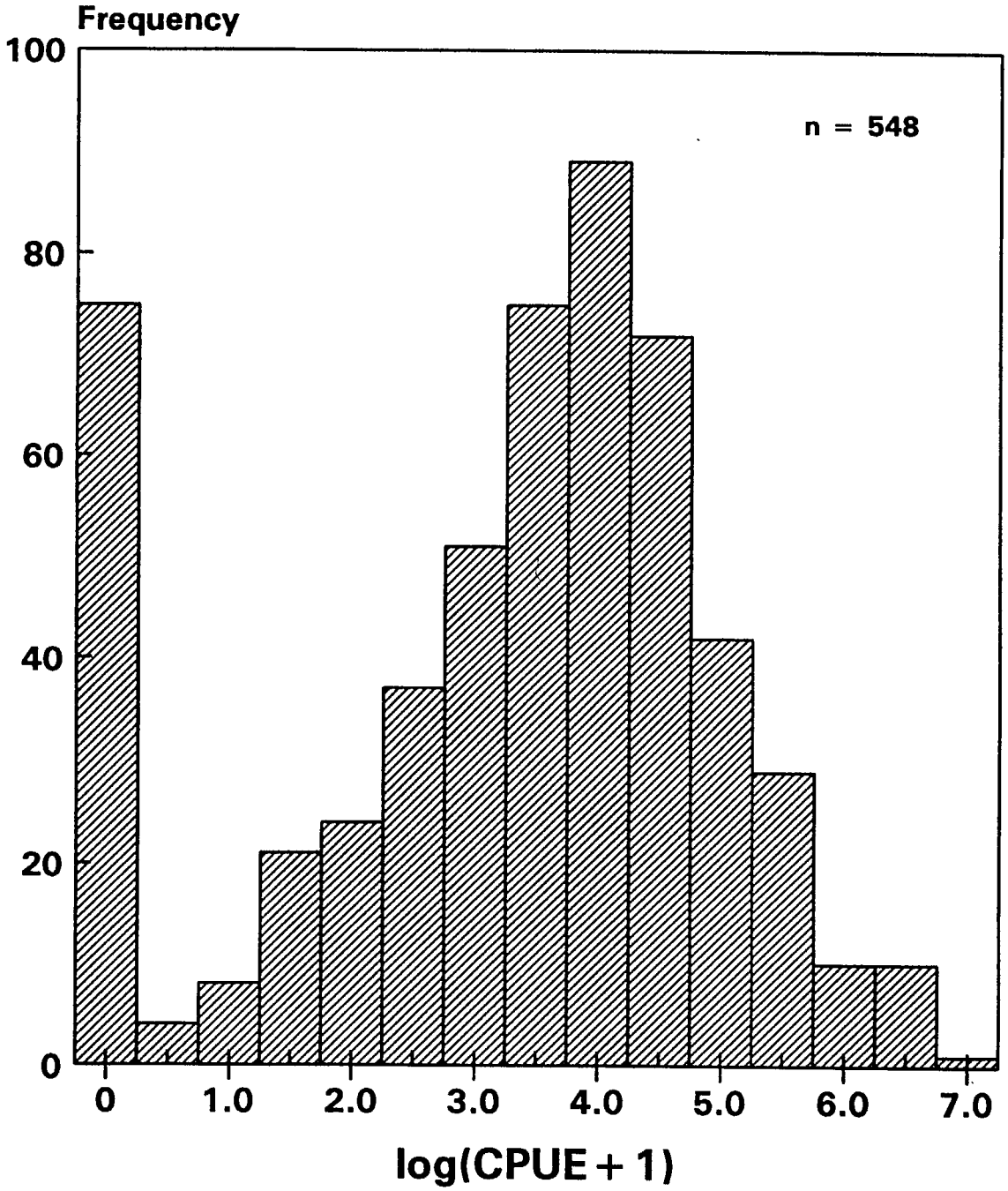
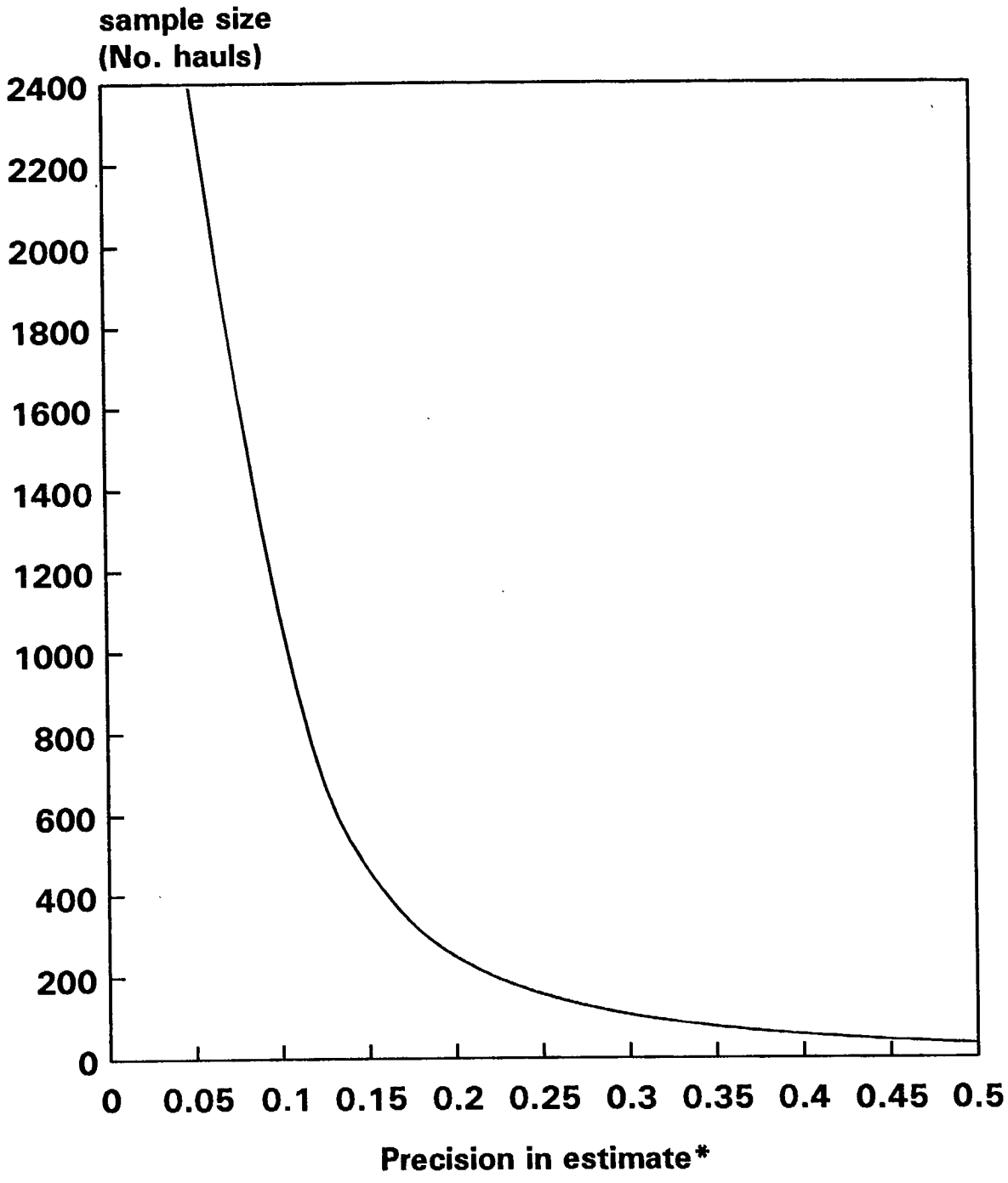


Fig. 2. Frequency distribution for the 1981-82 halibut CPUE data after log transformation.



* +/- % stratified mean (95% confidence)

Fig. 3. Precision curve for halibut bycatch estimated from the 1981-82 data, with sampling effort proportional to effort in the commercial trawl fishery in Hecate Strait in 1990.

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