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Some Observations on Accuracy of Abundance Indices Derived from Research Vessel Surveys

by

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Introduction

In order to help evaluate the cost-benefit ratio of surveys it is necessary to have some idea of the magnitude of change in stock size that is considered significant, as well as the magnitude of change we are able to detect and with what probability. Clearly one of the most important questions is whether surveys can measure changes in abundance with sufficient accuracy to permit meaningful assessment of the short-term affects of fishing. However I think it is important to remember that we are also concerned with long term changes involving not just a few priority species but the entire groundfish community. In general a lower level of accuracy probably would suffice for monitoring long term changes than in the case of assessment on a year-to-year basis. My principal aim here is to provide some information on what accuracy is possible with catch-per-haul statistics from research vessel surveys.

When considering accuracy of estimates, we must distinguish between statistical precision or sampling error (variance) and the more general concept of accuracy. That is, an estimate may be very precise in terms of a small variance but have a large bias, and therefore not be very accurate. In our problem we are mainly concerned about the possible biases in the survey abundance index (catch per standard haul) as a relative measure of absolute abundance. That is, we shall consider our index unbiased if there is a constant proportionality (catchability coefficient) between our relative abundance index and the true absolute abundance of the stock. Note however that in terms of estimating actual numbers in the population, our relative abundance index is always biased so long as the catchability coefficient is <1.

Evidence to be presented later suggests that the assumption of constant proportionality is not unreasonable for certain species and observed stock changes in the case of joint US-USSR surveys. Consequently the following data on precision of abundance indices from these surveys probably reflects the general order of accuracy obtainable in measures of change in absolute stock size. Admittedly we will be on firmer ground when we can estimate variability of catchability coefficients, by utilizing direct (camera, acoustic) measures of abundance in conjunction with trawling.

Statistical characteristics of trawl catch data

As is well known trawl catches are highly variable even within relatively restricted areas because fish are not uniformly distributed; and random trawl hauls result in a frequency distribution of catches which is highly skewed. A major consequence of this skewness is that the variance is generally much larger than the mean resulting in very imprecise (although unbiased) estimates of the mean, and even less reliable estimates of the variance itself, except with very large sample sizes. That is, the standard error associated with the variance is particularly susceptible to departures from normality, and without a reliable estimate of the variance of course it is not possible to calculate meaningful confidence limits about the mean.

A standard approach to this general problem is to stratify the population to be sampled into high and low density units or strata, and then sample randomly within individual strata within each of which skewness is then reduced. Control of variability in this manner is one of the primary advantages to be gained from the technique of stratified random sampling. However in the case of trawl catches, considerable skewness remains even after stratification. For example the variability of variance estimates for haddock trawl catches on U.S. surveys, reflects the fact that catches within individual strata are still highly skewed (Table 1). Sampling strata used in the surveys discussed here are shown in Figures 1 and 2.

Another well known approach is to try to find a transformation which normalizes the frequency distribution of variables. We have found that on the average, stratum variances of trawl catches are approximately proportional to the square of the mean, i.e. the standard deviation is proportional to the mean. This is true for haddock (Fig. 3) and for many other species as well. This relation indicates that a log transformation is appropriate, and such a transformation tends to normalize the data and stabilize the variance (i.e. make means and variances independent). Also the log transformation converts multiplicative effects into linear additive effects. In terms of our problem of estimating proportional changes in abundance, this means that linear changes on a log scale represent estimates of multiple or factor changes on the original scale. That is, the anti-log of the difference between two log means on the linear scale. The estimates of proportional change on the original scale are believed to be essentially unbiased in the statistical sense, but it should be noted that the re-transformed mean is a biased estimate of the true mean on the linear scale (an unbiased estimate is theoretically possible).

Calculation of stratified mean and variance

The basic index of abundance dealt with here is the stratified mean catch per standard haul, calculated by weighting each stratum mean according to the proportional size (area) of the stratum relative to all strata in the set. The variance of a stratified mean is similarly derived by weighting each stratum variance in proportion to the stratum area and according to the number of hauls in the stratum.

Table 1

Stratum means (catch/haul, pounds) and variances for haddock in three sampling strata on Georges Bank. Albatross IV surveys.

	STRATUM 16				STRATUM 19				STRATUM 20			
CRUISE	No. hauls	Mean	Variance	Std. devia-tion	No. hauls	Mean	Variance	Std. devia-tion	No. hauls	Mean	Variance	Std. devia-tion
63-05	7	41	2,740	52	4	126	22,442	150	3	7	52	7
63-07	7	101	4,330	66	4	291	66,992	259	4	115	33,379	183
64-01	10	41	857	29	7	147	37,875	194	5	37	1,322	36
64-210	8	300	338,823	582	5	364	209,248	457	5	356	70,072	264
64-13	7	148	31,926	179	6	168	26,652	163	5	335	155,074	394
65-2	6	73	6,309	80	6	392	243,932	494	5	21	338	18
65-510	8	405	682,555	826	6	800	2,019,784	1421	5	618	188,942	435
65-14	7	78	3,266	57	5	171	14,377	120	5	332	160,830	401
66-601	7	73	17,357	132	6	49	6,058	78	5	43	1,243	35
66-614	7	62	1,423	38	6	54	15,495	124	5	126	11,584	108
67-721	8	14	564	24	9	52	4,096	64	6	37	4,140	65
68-803	9	49	5,533	74	8	42	1,189	34	6	13	351	19
68-817	8	19	2,850	53	9	0	-	-	6	25	3,574	60
69-902	14	71	26,570	163	8	45	1,831	43	6	3	41	6
69-908	10	7	185	14	9	6	124	11	6	23	2,610	51
69-911	12	4	117	11	9	7	413	20	6	16	1,137	34
70-703	10	130	120,926	348	8	11	409	20	5	5	76	9

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Computational formulae are:

$$\bar{y}_{st} = \frac{1}{N} \sum_h N_h \bar{y}_h$$

$$V(\bar{y}_{st}) = \frac{1}{N^2} \sum_h \frac{N_h^2 S_h^2}{n_h},$$

where $\bar{y}_{st}$ and $V(\bar{y}_{st})$ are the stratified mean catch per haul and its variance respectively, of some set of strata, and

N_h = area of the h^{th} stratum

$N = \sum_h N_h$ = total area of all strata in the set

$\bar{y}_h$ = mean catch per haul in the h^{th} stratum

n_h = number of standard hauls in h^{th} stratum

S_h^2 = variance of catches in the h^{th} stratum

Examples of precision on linear scale

It is of interest to look at some examples of sampling errors of stratified means on a non-transformed scale before proceeding on to the log scale. Recall that in the examples of haddock data for individual strata, the standard deviation was on the average about equal to the mean (Fig. 3, Table 1). That is, coefficients of variation (ratio of standard deviation to the mean) were on the order of 100 percent with 5-7 hauls per sample. In the case of stratified means for haddock on Georges Bank (representing about 60 hauls in strata 13-25 combined) the average CV is only about 25 percent (Table 2). Similar values were obtained for cod.

In spite of the observed variability in estimates of individual stratum variances, we note that the CV's of the stratified means are reasonably consistent from year to year suggesting that the estimates of $V(\bar{y}_{st})$ may be approximately correct. Essentially we have computed a weighted mean of variances from 13 strata, and since most of these strata appear to have about the same variance this would account for the consistency among estimates of $V(\bar{y}_{st})$.

Stratified means for yellowtail on Georges Bank show CV's similar to those for cod and haddock (Table 3). Also shown in Table 3 are stratified means for the three principal strata for yellowtail, representing about half of the total area of the strata set, 13-25. The CV's are only slightly greater on average for this subset of strata than for the entire set, although there were less than half as many hauls in the subset. Very little information on yellowtail was gained by sampling outside these three principal strata.

Examples of precision on log scale

On the log scale the variances are nearly stabilized and the CV's of stratified means are on the order of 10-15 percent for the same species and strata (Table 4). However note that now we are interested in the absolute rather than relative size of the standard deviation. For haddock ±2 S.D.'s (± .40) corresponds to ± 50 percent on the linear scale. Thus there is no great improvement in

Stratified mean catch per haul (pounds, linear) of cod and haddock on Georges Bank, (strata 13-25), and estimates of precision. Albatross IV fall surveys.

Year	Mean	Variance	S.D.	S.D./Mean	Mean± 2 S.D.
			COD		
1963	24.18	43.35	6.58	.27	11.0-37.3
1964	15.74	20.89	4.57	.29	6.6-24.9
1965	15.90	26.04	5.10	.32	5.7-26.1
1966	11.10	5.87	2.42	.22	6.3-15.9
1967	18.43	17.85	4.22	.23	10.0-26.9
1968	11.66	8.54	2.92	.25	5.8-17.5
1969	10.91	4.79	2.19	.20	6.5-15.3
			HADDOCK		
1963	112.83	590.75	24.30	.22	64.2-161.4
1964	165.68	1032.11	32.13	.19	101.4-229.9
1965	123.66	411.58	20.29	.16	83.1-164.2
1966	47.22	99.39	9.97	.21	27.3-67.2
1967	44.05	103.86	10.19	.23	23.7-64.4
1968	20.53	52.18	7.22	.35	6.1-35.0
1969	12.70	16.62	4.08	.32	4.5-20.9

Table 2

Stratified mean catch per haul (pounds, linear) of yellowtail on Georges Bank, and estimates of precision. Albatross IV fall surveys.

Year	Mean	Variance	S.D.	S.D./Mean	Mean ± 2 S.D.	No. hauls
	STRATA 13-25 (15,300 sq. miles)					
1963	18.00	11.56	3.40	.19	11.2-24.8	57
1964	18.58	53.27	7.30	.39	4.0-33.2	63
1965	12.36	15.73	3.97	.32	4.4-20.3	66
1966	5.38	3.07	1.75	.32	2.1-8.6	67
1967	9.71	6.91	2.63	.27	4.4-15.0	65
1968	14.73	11.33	3.37	.23	8.0-21.5	62
1969	12.02	9.73	3.12	.26	5.8-18.3	66
1970	6.37	3.49	1.87	.29	2.6-10.1	70
	STRATA 13, 16, 19 (7,800 sq. miles)					
1963	23.10	33.19	5.76	.25	11.6-34.6	16
1964	32.10	194.97	13.96	.43	4.2-60.0	18
1965	18.48	56.99	7.55	.41	3.4-33.6	19
1966	8.71	11.35	3.37	.39	2.0-15.4	19
1967	16.58	25.96	5.10	.31	6.4-26.8	25
1968	24.50	40.78	6.38	.26	11.7-37.3	25
1969	21.44	36.96	6.08	.28	9.3-33.6	30
1970	10.69	12.44	3.53	.33	3.6-17.8	24

Table 3

Stratified mean catch per haul (lb., $\log_e$ scale) and measures of precision for selected species. Albatross IV fall surveys, Strata 13-25

Fall Cruise	Mean	Variance	S.D.	S.D./ mean	2 S.D.	Mean ± 2 S.D.	Factor diff.
			YELLOWTAIL				
63-7	1.97	.026805	.1637	.08	.33	1.64-2.30	1.9
64-13	1.41	.037142	.1927	.14	.38	1.03-1.79	2.1
65-14	1.32	.029119	.1706	.13	.34	.98-1.66	2.0
66-14	0.96	.025860	.1608	.17	.32	.64-1.28	1.9
67-21	1.32	.027724	.1665	.13	.33	.99-1.65	1.9
68-17	1.40	.038260	.1956	.14	.39	1.01-1.79	2.2
69-11	1.35	.025200	.1587	.12	.32	1.03-1.67	1.9
70-6	0.96	.0204	.1428	.15	.28	.68-1.24	1.8
			HADDOCK				
63-7	3.34	.052176	.2284	.07	.46	2.88-3.80	2.5
64-13	3.86	.080315	.2834	.07	.57	3.29-4.43	3.1
65-14	4.02	.042355	.2058	.05	.41	3.61-4.43	2.3
66-14	2.43	.044512	.2110	.09	.42	2.01-2.85	2.3
67-21	2.45	.052075	.2282	.09	.46	1.99-2.91	2.5
68-17	1.15	.029587	.1720	.15	.34	0.81-1.49	2.0
69-11	1.10	.021536	.1467	.13	.29	0.81-1.39	1.8
70-6	1.35	.0345	.1857	.14	.37	0.98-1.72	2.1
			COD				
63-7	1.75	.084829	.2912	.17	.58	1.17-2.33	3.2
64-13	1.29	.056270	.2372	.18	.47	0.82-1.76	2.6
65-14	1.32	.041737	.2043	.15	.41	0.91-1.73	2.2
66-14	1.20	.040673	.2017	.17	.40	0.80-1.60	2.2
67-21	1.74	.047301	.2175	.12	.44	1.30-2.18	2.4
68-17	1.04	.031888	.1786	.17	.36	0.68-1.40	2.1
69-11	1.32	.025381	.1593	.12	.32	1.00-1.64	1.9
70-6	1.35	.0332	.1822	.13	.36	0.99-1.71	2.1

Table 4

the size of difference (proportional change on linear scale) we are able to detect as compared with the non-transformed scale, but we have more consistent estimates of those differences over the range of abundance levels, and the estimated confidence intervals more closely approximate true 95 percent fiducial limits. Results of stratified estimates for cod and haddock off western Nova Scotia are comparable to those on Georges Bank (Table 5).

The most significant feature of these data is that they indicate the present survey cannot detect with high probability proportional changes in abundance which are less than a factor of about 2. That is, the $\log_e$ difference between the lower and upper limits of the 95 percent C.I. is about 0.7 corresponding to a factor difference of 2 on the linear scale; and to be very sure that two means are significantly different there must be no overlap in the 95 percent confidence intervals.

Sample size vs. precision

Some first approximations have been made of the relation between precision of stratified means and sample size (total number of haul The calculations are based on the general formula for estimating required sample size in stratified random sampling:

$$n = \frac{\sum_h \frac{W_h^2 S_h^2}{w_h}}{V + \frac{1}{N} \sum_h W_h S_h^2}$$

and in terms of this problem,

W_h and S_h are as defined earlier,

$w_h = \frac{n_h}{n}$, the observed relative sampling effort in the h^{th} stratum (the ratio of the number of hauls in the h^{th} stratum to the total number of hauls, n, in all strata of the specified set)

V = desired variance of the stratified mean

N = total number of possible hauls in the area represented by strata in the set.

Since the number of hauls in our survey is very small relative to the total number possible (strata 13-25 cover roughly 15,000 square miles and each standard haul covers approximately .01 square mile), the second term in the denominator is extremely small compared with the first. Thus,

$$n \doteq \frac{1}{V} \Sigma \frac{W_h^2 S_h^2}{w_h}$$

Using the above formula and average values of S_h^2 for haddock and w_h based on eight Albatross IV fall surveys, estimates were made of the sample sizes required to achieve various levels of precision. For example, if we wanted to be able to detect proportional changes in abundance of ±20 percent with high probability, this would require an interval of ±2 S.D.'s = ±.18 on the natural log scale, and thus S.D. = .09 and V = .0081. Substituting this value of V in the above formula, n = 338 hauls. Results of calculations for levels of precision between 10-100 percent of the stratified mean for haddock are given in Table 6. The same computations for yellowtail in strata 13, 16, and 19 (representing about half of Georges Bank) are also shown in Table 6.

Stratified mean catch per haul ($\log_e$ pounds) and variance esti
for cod and haddock off western Nova Scotia. Albatross IV fal
surveys in strata 31-35, 41, 42.

Fall ruise	Mean	Variance	S.D.	S.D./ mean	2 S.D.	95% CI	Factor diff.
HADDOCK							
5-14	3.61	.1918	.4379	.12	.88	2.73-4.49	5.8
6-614	3.22	.1321	.3634	.11	.73	2.50-3.94	4.3
7-721	3.87	.1073	.3276	.08	.66	3.21-4.53	3.7
8-817	2.93	.0598	.2445	.08	.49	2.45-3.41	2.7
9-911	2.68	.0593	.2435	.09	.49	2.20-3.16	2.7
0-706	2.82	.0352	.1876	.07	.38	2.44-3.20	2.1
COD							
5-14	3.25	.1492	.3863	.12	.77	2.47-4.03	4.7
6-614	2.71	.1608	.4010	.15	.80	1.91-3.51	5.0
7-721	2.16	.1051	.3242	.15	.65	1.52-2.80	3.7
8-817	1.86	.0949	.3080	.16	.62	1.24-2.48	3.5
9-911	1.74	.0887	.2978	.17	.60	1.14-2.34	3.3
0-706	1.77	.0500	.2236	.13	.45	1.32-2.22	2.5

Table 5

Table 6

First approximations to sample sized (total number hauls) required for specified precision of stratified mean abundance indices ($\log_e$ catch/haul in pounds) from Albatross IV surveys on Georges Bank.[1/]

LEVEL OF PRECISION: Percentage change linear scale	LEVEL OF PRECISION: 2 standard deviations, linear scale	Total number hauls required, approximately proportional allocation: Haddock (strata 13-25)	Total number hauls required, approximately proportional allocation: Yellowtail (strata 13, 16, 19)
± 10%	±.10	>500	>500
± 20%	±.18	338	253
± 30%	±.26	164	120
± 50%	±.40	70	51
±100%	±.69	23	17

1/ An empirical measure of the improvement in precision with increase in sample size was obtained on the 1971 spring groundfish survey by pooling results of two cruises on Georges Bank, one in March and one in May. The pooled data shown below represent an increase in numbers of hauls of about 50 percent over the standard sampling rate, and resulted in reductions in standard deviations of about the magnitude predicted by the analysis based on the 1963-70 series of cruises shown above.

--Spring 1971 groundfish survey.

	Cruise 1		Cruise 2		Cruises 1 & 2	
	2 SD's	No. Hauls	2 SD's	No. Hauls	2 SD's	No. Hauls
Haddock (Strata 13-25)	.38	71	.53	37	.32	108
Yellowtail (Strata 13, 16, 19)	.52	30	.51	17	.37	47

These data suggest that the cost of detecting with high probability changes of stock size as small as ±10 percent would be extremely high. It is even doubtful that we could justify the cost of measuring changes within ±20 percent; to get to this level it would appear that for haddock we would need to make nearly 5 times as many hauls as in the current survey which employs about 65 hauls in strata 13-25 and achieves a precision of roughly ±50 percent (Table 6). In sampling for yellowtail it would appear that we would need almost as many hauls for strata 13, 16, and 19 alone, in order to obtain comparable levels of precision.

These results should be considered as first approximations since we have not fully investigated all of the characteristics of these data. For example it is possible that some improvement could be achieved with a modified log transformation which would further improve normalization of the data. Also it is possible that we could make significant gain in precision by additional stratification according to time of day, for those species exhibiting strong diurnal variations in availability. Additional stratification would cost something however, either in terms of fewer degrees of freedom for estimating stratum means and variances, or additional time at sea, or both. Thus there is no guarantee that additional stratification would achieve a net gain in information per unit cost. Further it is possible that the region could be more effectively stratified, for example by utilizing additional information on bottom sediments relative to groundfish distribution. However this too could only result in slight gains so long as we are interested in many species distributed over a wide area.

I think the most promising approach lies in controlling or at least monitoring the haul-to-haul performance of the trawl; for example we do not have a precise measure of groundspeed, nor do we know what variations occur in wingspread and headrope height. Even direction of tow relative to bottom currents may be important for some species.

Even after all such improvements are incorporated however, it seems clear to me that there cannot be any drastic change in the observed relation between precision and sample size. The hard fact is that in sampling organisms with highly contagious distributions, achieving high precision will require intensive sampling.

So far we have been considering the precision of a single mean. It is of course possible to combine seasonal means into a single annual index which would have a smaller variance. For example if the means of two surveys were averaged, the standard deviation of the resulting mean would be reduced by approximately a factor of 0.7 (assuming homogeneous variances for the original means). Thus if the separate standard deviations were on the order of .2 (corresponding to a ±50 percent level of precision), the standard deviation of the combined mean would be about .14, corresponding to a ±30 percent precision level. Essentially the same precision would have been achieved by simply doubling the sampling effort on one cruise, and in that sense there would be no gain in accuracy through combination of two cruises. However by combining results of more than one season within a given year, there is less likelihood of bias due to variation in seasonal availability factors.

Finally it should be noted that in most cases it usually takes at least several years for major changes in stock size to occur. Given annual surveys, we then have a number of points in a time series with which to test for a significant slope or trend, and precision of such a test would be greater than that indicated for a single survey.

Comparisons between research and commercial abundance indices

Returning now to the more general concept of accuracy, we need to consider further the problem of bias in conjunction with precision. In particular we are concerned about the possibility that the ratio of our relative abundance indices to the absolute (unknown) abundance may not be constant at difference levels of absolute abundance. We may gain some insight into this question by comparing abundance indices derived from both research and commercial catch data. However we must use care in making such comparisons because both types of data are subject to error. The commercial data are potentially more subject to serious bias, and research data are usually characterized by larger sampling errors.

Potential major sources of bias in the commercial data are 1) changes in the effective unit of effort usually related to economic or technological factors, and 2) possible variation in efficiency of what is thought to be a standard unit of effort, resulting from variations in availability of fish independent of absolute abundance (e.g. environmentally controlled variations in aggregation). With proper sample design the research vessel index is free of the first bias, but still may be subject to bias from changes in availability. For example the catchability coefficient for a given species and research trawl may change due to a change in vertical distribution of the species, in response to some environmental factor or even as a function of absolute abundance itself. The possibility of a significant bias of this type intuitively would seem to be much greater for a species for which the trawl has a very low efficiency. We shall return to this point later in comparing joint US-USSR survey results.

From the standpoint of precision it is important to recognize that the commercial abundance index nearly always will be more precise than a research index simply because it is based on a very large number of hauls. However we seldom obtain variance estimates for commercial indices since at best it is a very complicated task involving many sources of error. It is a relatively simple matter to obtain statistically valid estimates of sampling error from surveys but unfortunately the errors are large.

With the above characteristics in mind we may now turn to some comparisons of research and commercial indices. Fourth quarter U.S. landings/day figures for cod, haddock, and yellowtail on Georges Bank, and U.S. fall survey abundance indices for strata 13-25, are tabulated for the period 1963-1969 in Table 7. The percentage deviations of each index from the '63-'69 mean are plotted in Figure 4, and it is clear that the two indices are correlated for haddock and yellowtail.

For yellowtail the commercial and research indices show quite similar trends in relative abundance; and the magnitude of changes indicated by the research indices was not much greater than that indicated by the commercial indices (Fig. 4). Correlation coefficients were .95 (linear scale, survey) and .81 (log scale, survey), and both are significant at the 95 percent probability level.

The correspondence is perhaps almost too good in this case. That is, if the research index is accurate to within only ±50 percent changes in abundance, then one might not expect such close correspondence from year to year when the actual yellowtail abundance

Table 7

Fourth quarter U.S. commercial abundance indices and Albatross IV fall survey indices for cod, haddock and yellowtail on Georges Bank. Commercial index: Landings/day (lb. x 10^{-3}) 5Z east. Survey index: stratified mean catch/haul (lb., linear and $\log_e$) strata 13-25.

	COD			HADDOCK			YELLOWTAIL		
		Survey			Survey			Survey	
YEAR	Comm.	lb.	$\log_e$ lb.	Comm.	lb.	$\log_e$ lb.	Comm.	lb.	$\log_e$ lb.
1963	2.1	25.1	1.8	8.2	118.6	3.3	8.7	21.6	2.0
1964	1.4	15.6	1.3	10.8	193.6	3.9	8.0	22.3	1.4
1965	0.8	7.5	1.3	14.9	131.0	4.0	7.3	14.7	1.3
1966	1.8	8.8	1.2	9.4	51.4	2.4	4.5	6.5	1.0
1967	2.5	20.0	1.7	5.7	43.1	2.4	6.1	11.7	1.3
1968	2.8	10.8	1.0	6.1	19.2	1.2	7.7	17.7	1.4
1969	5.1	7.5	1.3	4.8	5.6	1.1	6.1	14.4	1.4

(based on fairly reliable commercial indices) appeared to vary by no more than about 30 percent from the mean. In other words there may be some indication here that variance estimates may be inflated. More detailed study will be required to clarify this notion.

For Georges Bank haddock correlation coefficients are also significant at the 95 percent level - .74 and .84 for linear and log scales respectively. Corresponding trends in abundance are indicated but the research indices show a much greater magnitude of change in stock size than is indicated by the U.S. commercial index. In this case however the commercial indices are believed to have been negatively biased particularly in the mid-1960's as has been described by Hennemuth (1968). Another feature is that the efficiency of vessels remaining in the fishery after 1967 probably was above average, which might be the explanation for the apparent discrepancy in trend between the two sets of indices in the late 1960's. It should be emphasized that changes in efficiency of commercial fleets are quite likely when stock levels change drastically.

There is less consistency between commercial and research indices for Georges Bank cod than for yellowtail and haddock. Up to 1967 there was a rough similarity in trends, but thereafter the correspondence is poor (Fig. 4). Correlation coefficients do not differ significantly from zero. In the later years it is possible that the scarcity of haddock may have resulted in a partial shift of effort toward cod, in which case the commercial index would have a positive bias. This too will require more detailed study.

Another set of comparisons is provided by U. S. commercial and research indices for haddock off western Nova Scotia (Table 8). The best comparison is afforded by the first quarter commercial indices vs. the spring research indices and these show quite a consistent picture both with respect to trend and magnitude of change (Fig. 5). Trends are basically similar between fall surveys and annual commercial indices, but an unusually large discrepancy occurred in 1967. Sampling error was not particularly high in that year (see Table 5) and so far I have no explanation for the apparent discrepancy.

Still another set of comparisons is available for red hake in southern New England. During the period 1965-1968 there was a rapid steady decline in abundance shown by both the catch per haul statistics of the USSR fleet and the U.S survey (Table 9, Fig. 6). The commercial data suggest that by 1968 abundance had dropped to about one-quarter the 1965 level, and the survey data imply a decline to about one-third the 1965 level. Abundance appeared to increase again in 1969 as indicated by both commercial and research indices. In contrast to southern New England comparisons for Georges Bank show poor correspondence between the commercial and research data for red hake (Table 9, Fig. 7). This may be partly due to the fact that after 1965 the principal fishing effort by the Soviet fleet on red hake occurred in southern New England, and Georges Bank effort was not directed specifically toward red hake.

To summarize briefly the comparisons among commercial and research indices, it appears that survey indices more often than not provide about the same trends and relative changes in stock size as do commercial indices. This I think is basically encouraging. The problem now is how to improve precision.

Haddock abundance indices for 4X based on U.S. commercial data and *Albatross IV* surveys. Commercial index: U.S. landings per day, metric tons rd. fresh, Browns Bank. Survey: stratified mean catch per haul ($\log_e$ pounds), strata 31-35, 41, 42

	Commercial		Survey	
Year	Annual	1st Qtr.	Fall	Spring
1963		6.9		
1964	7.5	6.9	-	-
1965	6.5	5.3	3.61	-
1966	4.7	6.8	3.22	3.72
1967	5.4	3.4	3.87	-
1968	4.5	3.3	2.93	3.13
1969	3.4	3.2	2.68	2.53
1970			2.82	2.99

Table 8

Abundance indices for red hake in New England waters based on catch per haul statistics from USSR fleet[1/], and joint US-USSR groundfish surveys[2/]

	RED HAKE					
	So. New England (strata 1-12)			Georges Bank (strata 13-25)		
	Fleet	Survey		Fleet	Survey	
Year	USSR	USSR	USA	USSR	USSR	USA
1965	2.44		1.85	1.32		0.78
1966	1.69		1.48	2.39		0.72
1967	0.96	2.07	1.05	0.96	0.84	0.46
1968	0.56	1.88	0.79	0.62	1.79	0.64
1969	1.75[3/]	2.20	1.18	-	1.03	0.85
1970	-	2.36	1.35	-		0.44

1/ Catch per haul hour for red hake from ICNAF research document 70/39 by Richter, for "stocks I and II" which correspond approximately to strata sets 13-25 and 1-12 respectively.

2/ Stratified mean catch per haul (pounds, natural log scale).

3/ Estimate provided on graph by Dr. Noskov at Working Group in Copenhagen, January 1971.

Table 9

Comparisons between U.S. and USSR survey indices

The larger USSR trawls appear to have up to 5 times the fishing power of the U.S. survey trawl for some species, as indicated by trawl comparison experiments and joint surveys since 1967 (ICNAF Res. Doc's. 68/86, 70-80). The question arises whether there is any significant relation between fishing power and accuracy of the abundance indices. We have been particularly concerned about the possibility that in the case of species for which our U.S. gear has relatively low fishing power (e.g. red and silver hake), relatively minor changes in behavior and especially vertical distribution might change availability enough to obscure real changes in abundance. So far there is no clear evidence of any such disadvantage with the smaller trawl from the standpoint of accuracy.

With respect to sampling errors we find that variances of stratified means are fairly comparable for the two sizes of gear, and they appear to be rather independent of fishing power differentials. For example the fishing power differential is large for red hake but quite small for cod, haddock, and yellowtail, and yet variances are quite similar for all these species and both types of trawl in New England waters (Tables 10, 11). Generally similar results were obtained in the 1970 surveys off Nova Scotia (Table 12).

With respect to comparability of trends we find very close correspondence between the indices for red hake in southern New England, in both direction and magnitude (Fig. 6). The correspondence is not as good for silver hake in the southern New England area but the direction of change is the same from year to year (Fig. 7). More variability between the two indices was encountered for both red and silver hake on Georges Bank, where they were less abundant, but again the correspondence was better for red hake (Figs. 6, 7). These data are difficult to interpret because the USSR trawl used in 1969 was not the same as that used in 1967 and 1968; the 1969 gear probably had greater fishing power.

Literature cited

Hennemuth, R. C. 1968.
Status of the Georges Bank haddock stock and effect of recent high levels of effort. ICNAF Res. Doc. 68/92.

Stratified mean catch per haul (log_e pounds) of selected species in southern New England (strata 1-12). U.S. and USSR joint surveys.

YEAR	Strat.mean		Variance		S. D.		S.D./mean		No. hauls	
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
RED HAKE										
1967 1/	1.05	2.07	.0229	.0554	.1513	.2354	.14	.11	65	40
1968	0.79	1.88	.0238	.0421	.1543	.2052	.20	.11	62	46
1969 2/	1.18	2.20	.0236	.0760	.1536	.2757	.13	.12	66	42
1970	1.35	2.36	.0199	.0314	.1411	.1772	.10	.08	64	56
SILVER HAKE										
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	1.63	2.64	.0202	.0579	.1421	.2406	.09	.09		
1968	1.80	3.62	.0155	.0404	.1245	.2010	.07	.06		
1969	1.20	3.38	.0142	.0676	.1192	.2600	.10	.08		
1970	1.35	3.71	.0125	.0273	.1118	.1652	.08	.04		
YELLOWTAIL										
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	2.25	1.70	.0270	.0514	.1643	.2267	.07	.13		
1968	2.03	1.78	.0380	.0592	.1949	.2433	.10	.14		
1969	2.00	1.75	.0361	.0708	.1900	.2661	.10	.15		
1970	2.12	1.50	.0420	.0657	.2049	.2563	.10	.17		

1/ No hauls in stratum 10; sampling in strata 9, 11, 12 restricted to area west of 70° W.

2/ 24.6 m trawl used by USSR vessel in 1969; 27.1 m trawl used by USSR vessels in all other surveys.

Table 10

Stratified mean catch per haul ($\log_e$ pounds) of selected species in Georges Bank (strata 13-25. U.S. and USSR joint surveys.

YEAR	Mean		Variance		S. D.		S.D./mean		No. hauls	
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
C O D										
1967	1.74	-	.0473	-	.2175	-	.12	-	67	-
1968 1/	1.04	1.19	.0319	.0400	.1786	.2000	.17	.17	69	49
1969 2/	1.32	1.59	.0254	.0178	.1594	.1334	.12	.08	73	37
1970 3/	1.35	0.87	.0332	.0367	.1822	.1916	.13	.22	70	31
H A D D O C K										
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	2.45	1.07	.0521	-	.2282	-	.09	-		
1968	1.15	1.07	.0296	.0248	.1720	.1667	.15	.16		
1969	1.10	1.65	.0215	.0649	.1466	.2548	.13	.15		
1970	1.35	0.57	.0345	.0285	.1857	.1688	.14	.30		
Y E L L O W T A I L										
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
1967	1.32	-	.0277	-	.1664	-	.13	-		
1968	1.40	1.01	.0382	.0340	.1954	.1844	.14	.18		
1969	1.35	1.91	.0252	.0615	.1587	.2480	.12	.13		
1970	0.96	1.80	.0204	.0878	.1428	.2963	.15	.16		

1/ No hauls in stratum 25; only one haul each in strata 15, 17 and 22.

2/ 24.6 m trawl used by USSR vessel in 1969; 27.1 m trawl used by USSR vessels in all other surveys.

3/ No hauls in strata 23-25 by USSR vessel in 1970.

Table 11

Table 12

Stratified means (catch per haul, $\log_e$ pounds) and measures of precision for selected species in 1970 surveys in Division 4X (sampling strata 31, 32, 41-49)

KVANT - 34 hauls   ALBATROSS IV - 45 hauls

Species	Stratified mean		Variance		S.D.		Mean $\pm$ 2 S.D.		Factor difference	
	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR	U.S.	USSR
Cod	1.20	0.55	.0690	.0416	.2627	.2040	.68-1.72	.15-.95	2.9	2.2
Haddock	2.05	1.81	.0231	.0574	.1520	.2396	1.75-2.35	1.33-2.29	1.8	2.6
Am. Dab	0.83	0.21	.0214	.0041	.1463	.0640	.53-1.13	.09-.33	1.8	1.3
Yellowtail	0.35	0.11	.0227	.0041	.1507	.0640	.05-.65	0 -.23	1.8	1.3
Silver hake	0.85	1.02	.0216	.0941	.1470	.3068	.55-1.15	.40-1.64	1.8	3.4

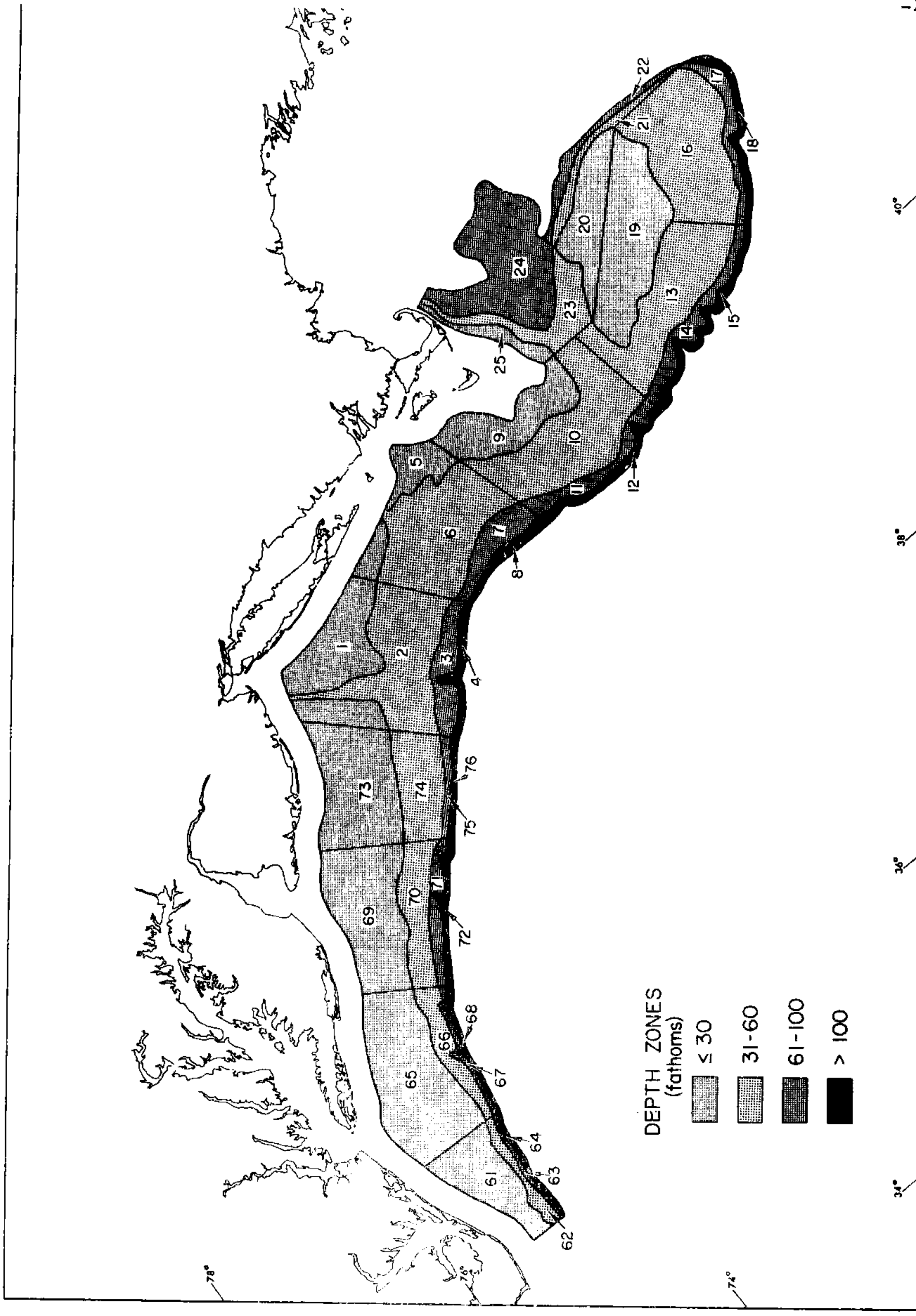

Figure 1. Sampling strata used in 1970 joint US-USSR groundfish surveys from Cape Hatteras to Georges Bank.

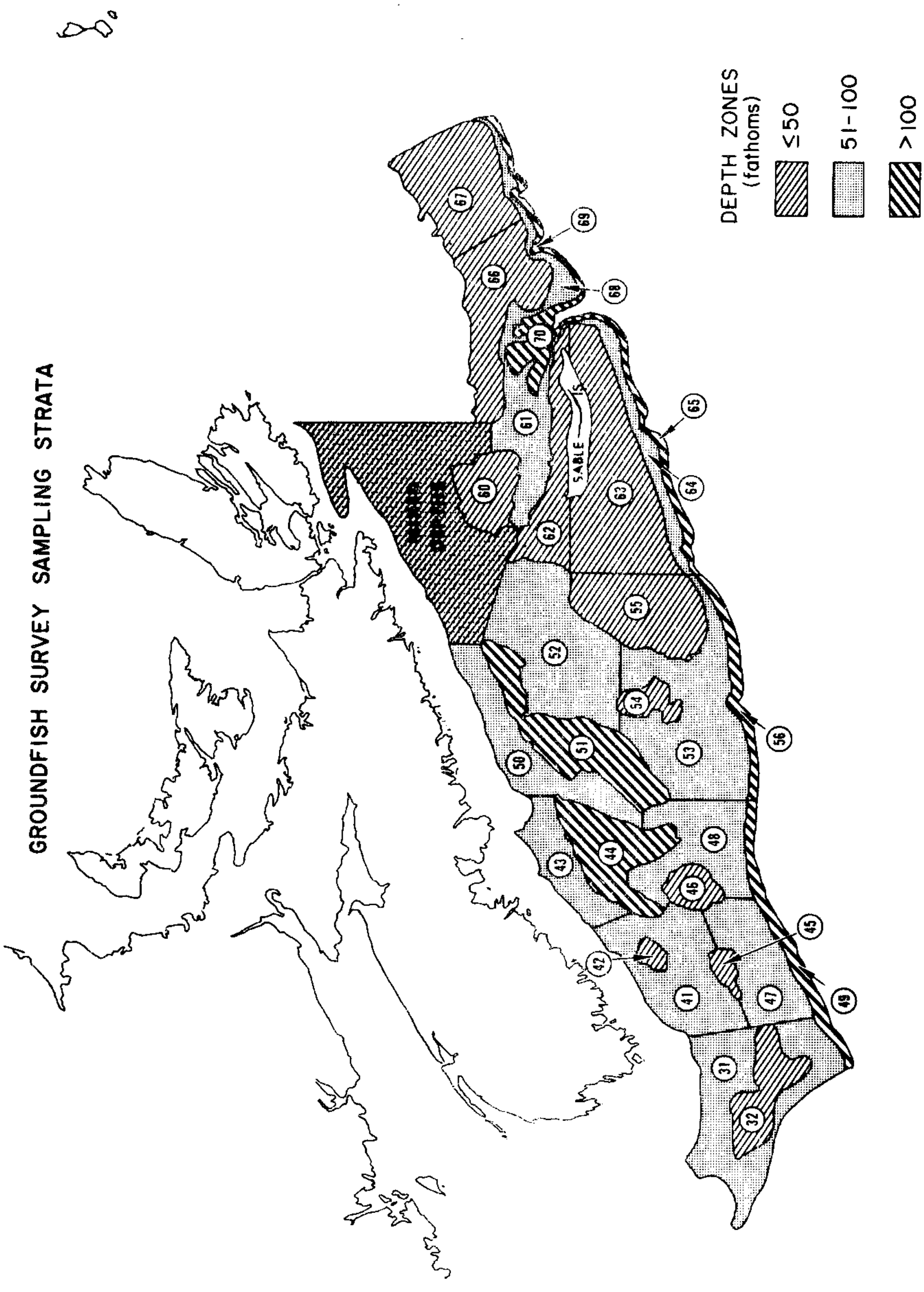

Figure 2. Sampling strata used in 1970 joint US-USSR survey on Nova Scotian shelf.

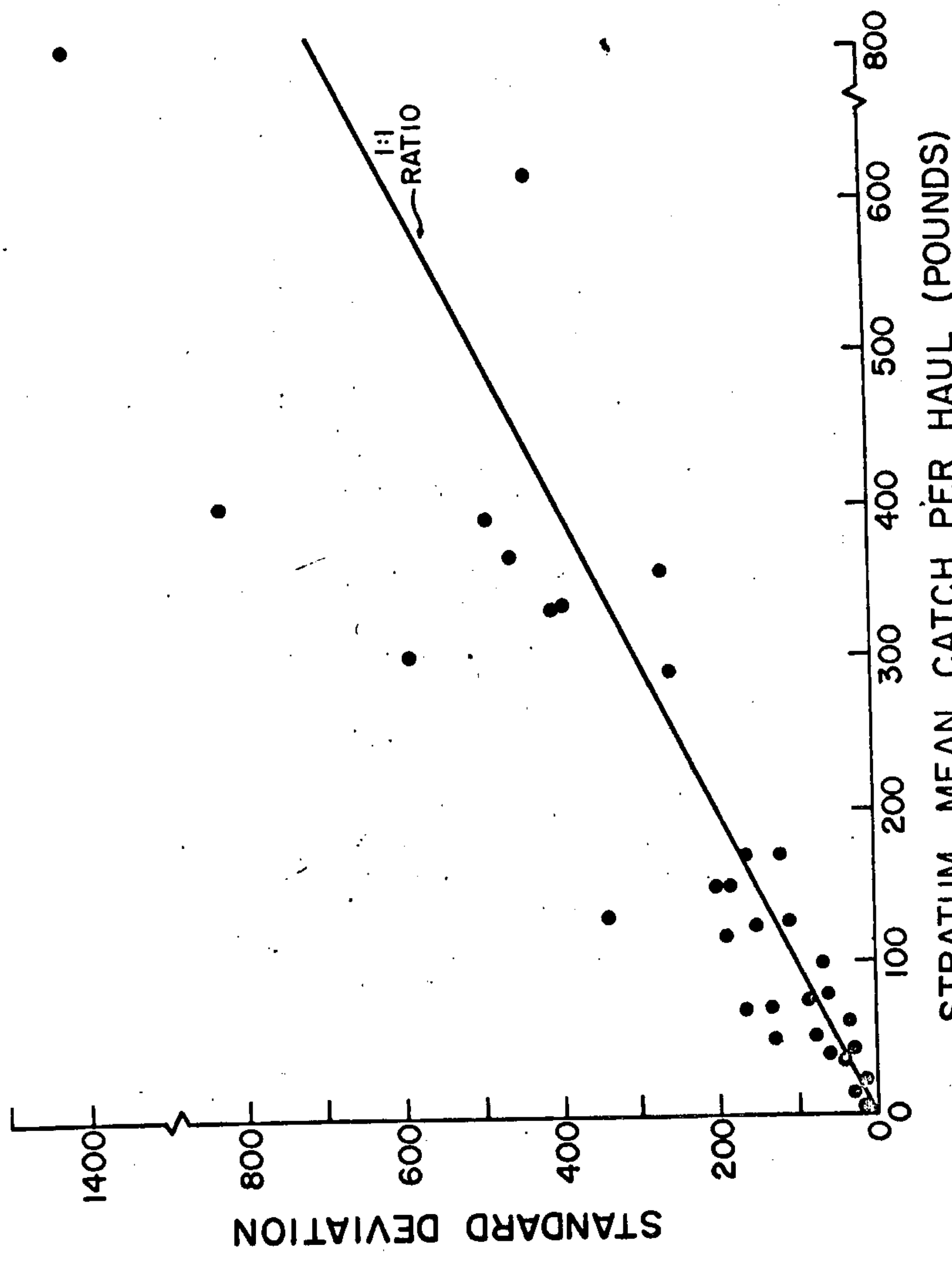

Figure 3. Scatter diagram of standard deviations and corresponding stratified means for data shown in table 1.

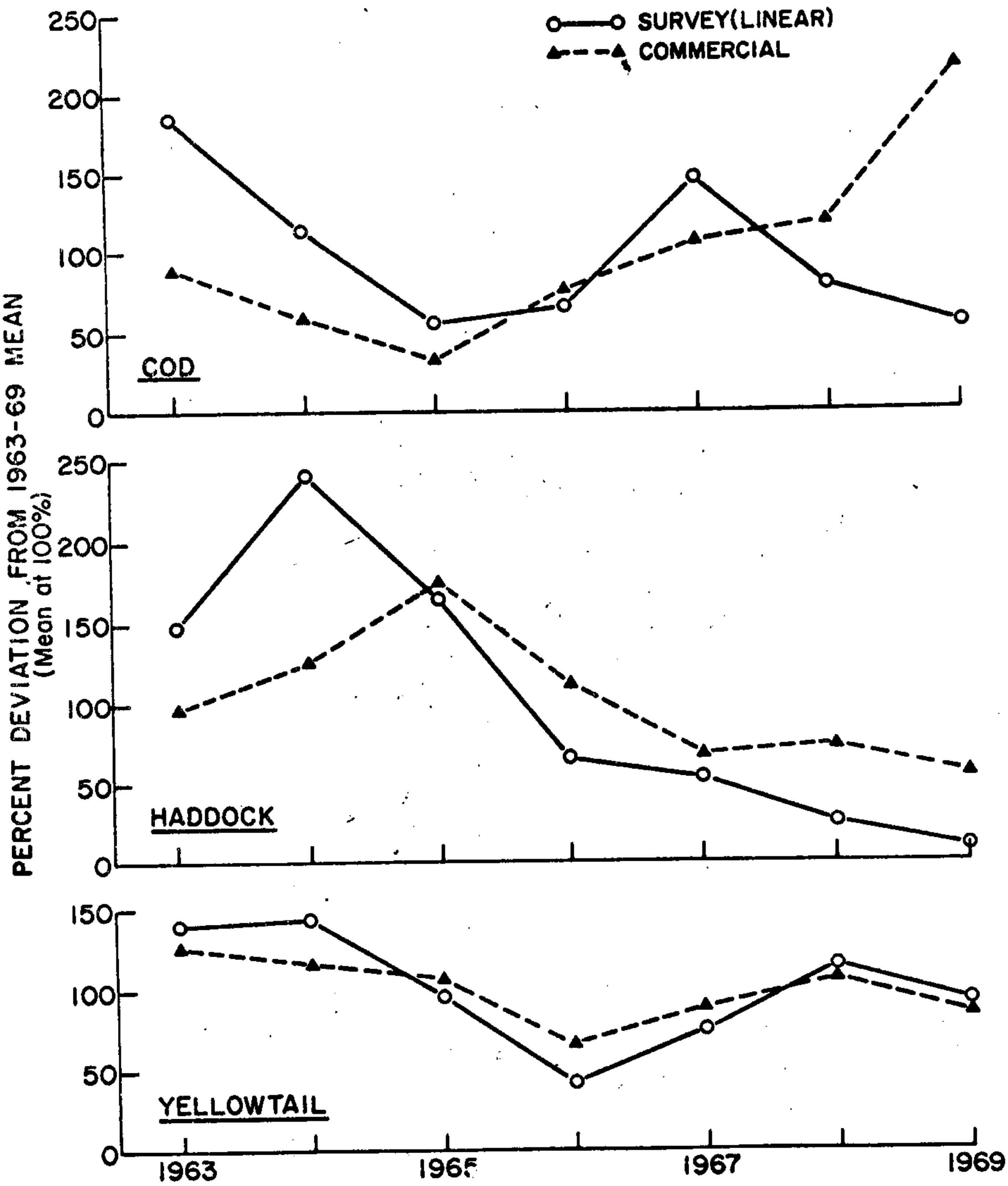

Figure 4. U.S. Commercial vs. survey abundance indices on Georges Bank.

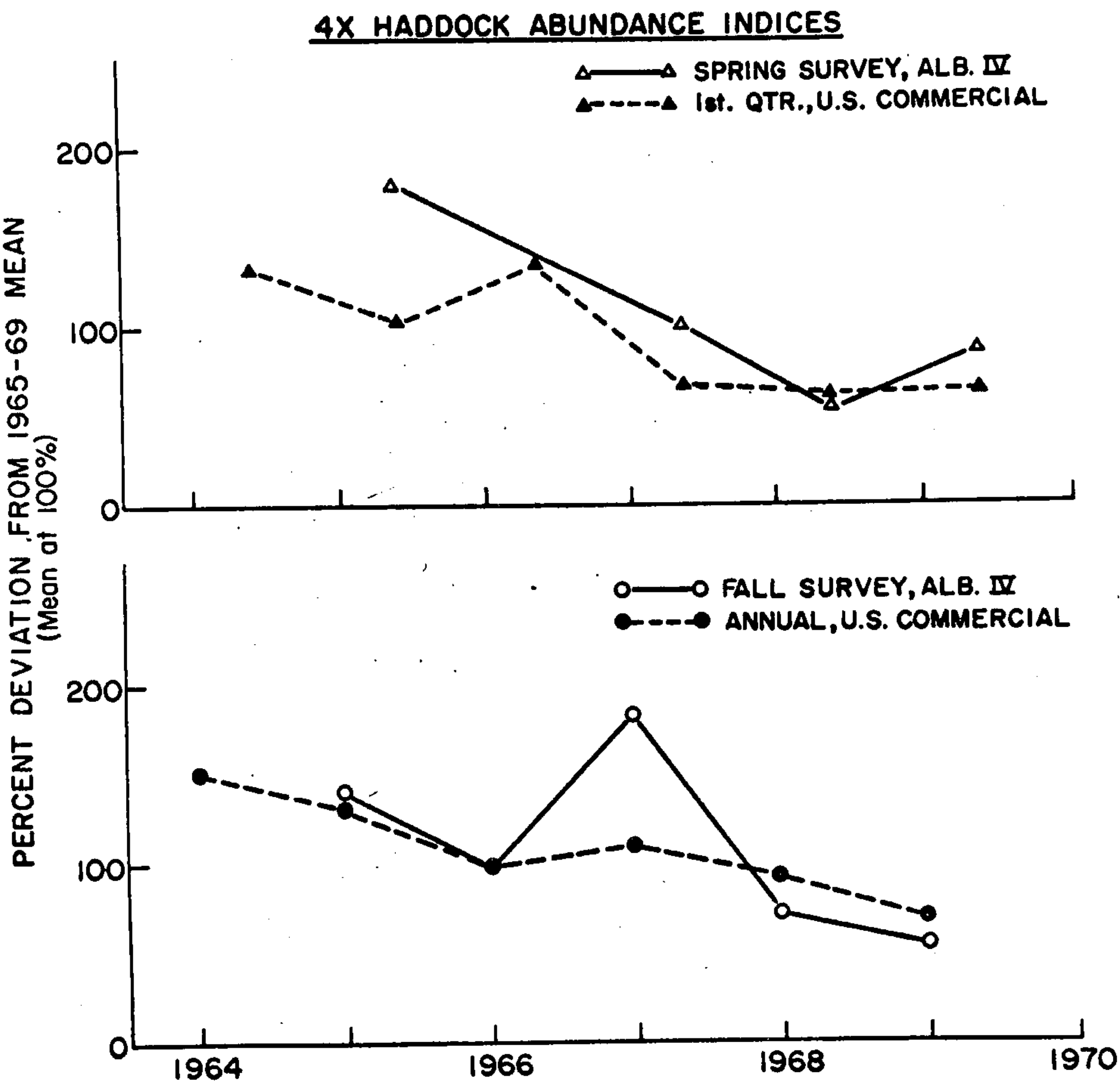

Figure 5. U.S. Commercial vs. survey abundance indices for haddock in Division 4X.

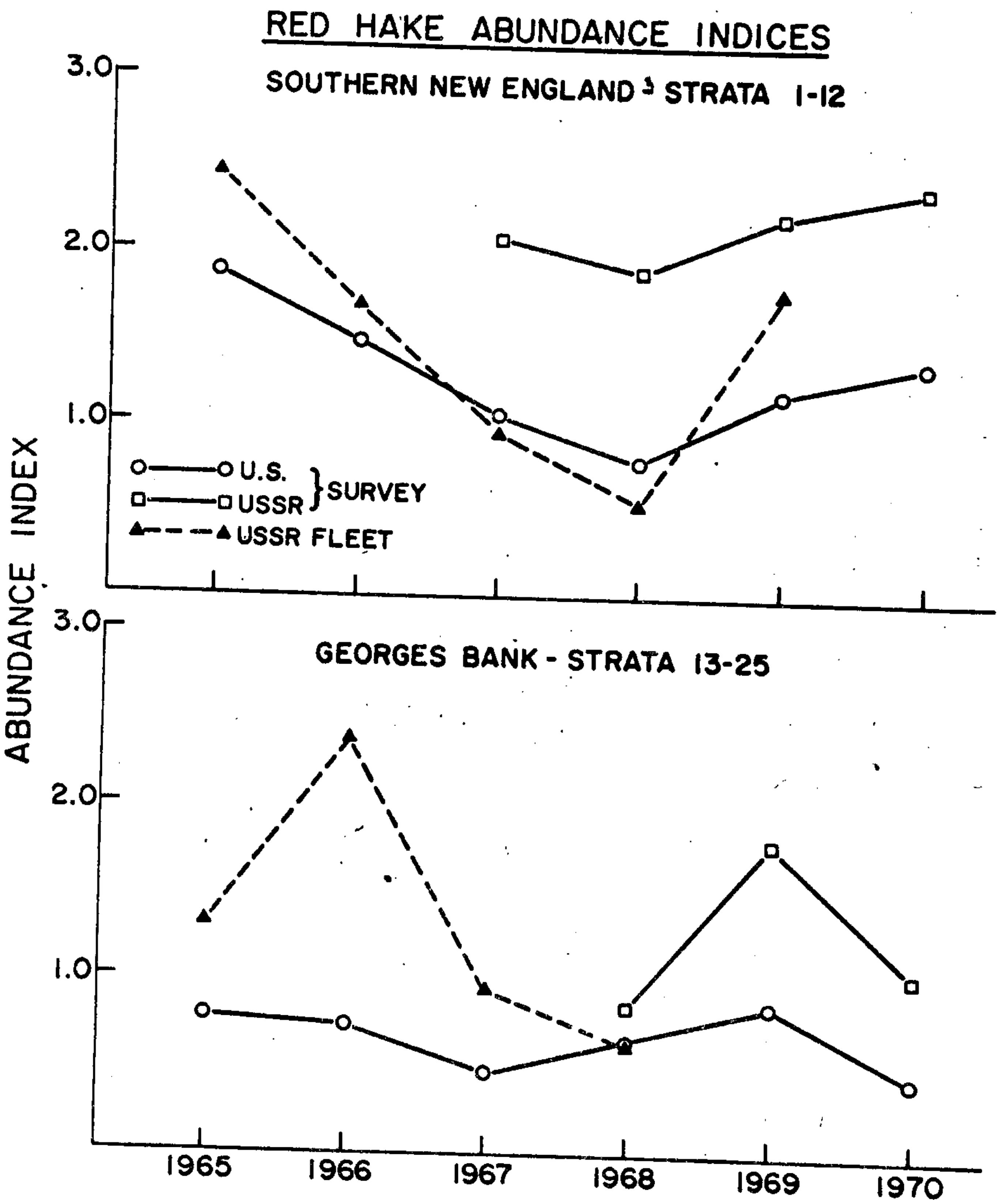

Figure 6. USSR Commercial vs. joint survey abundance indices for red hake.

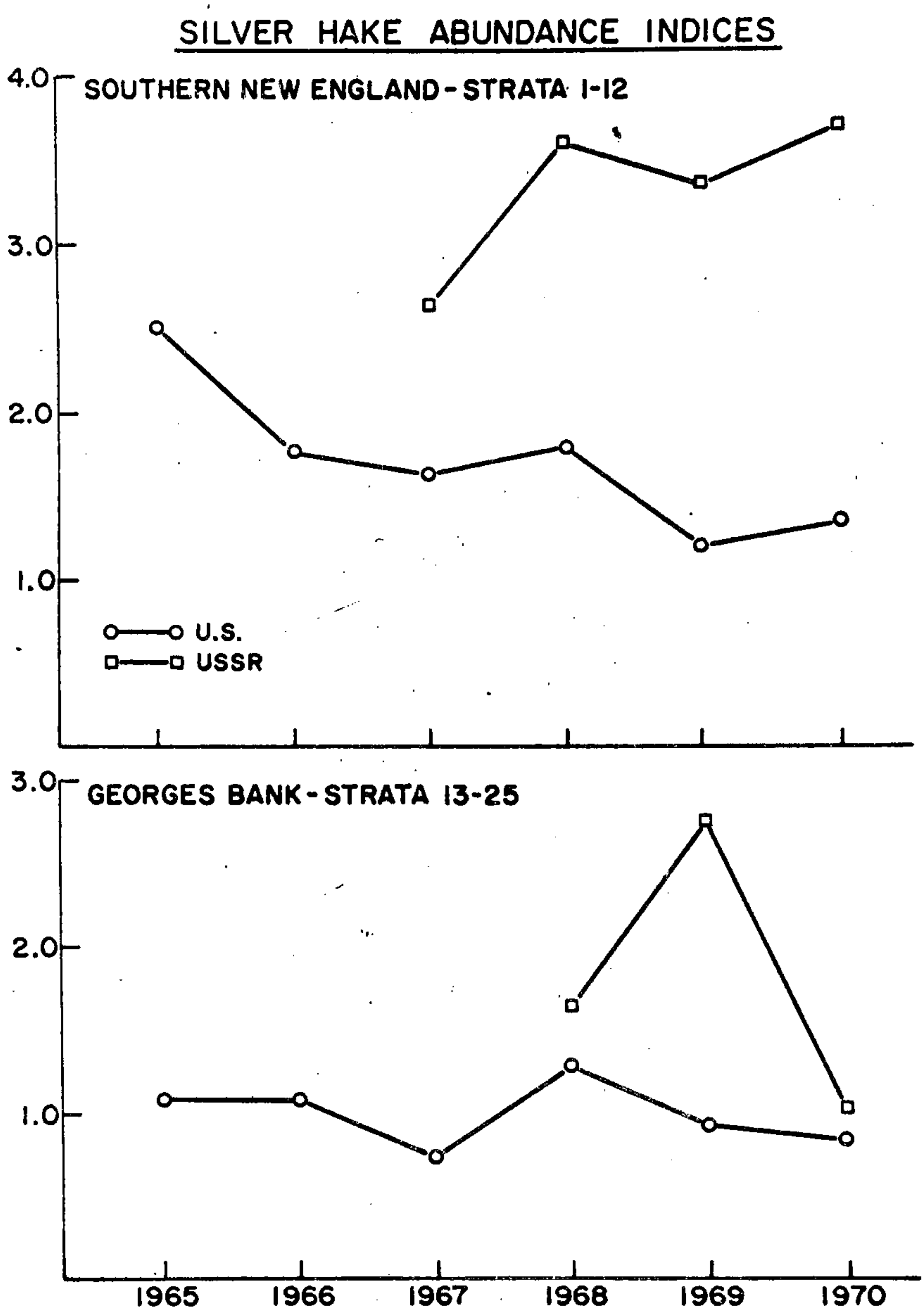

Figure 7. USSR Commercial vs. joint survey abundance indices for silver hake.