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Variability of *ALBATROSS IV* catch per tow

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The Northeast Fisheries Center began a series of standardized trawl surveys in Subareas 4, 5, and 6 in 1973 using the *ALBATROSS IV*. These surveys were designed to provide, inter alia, estimates of changes in abundance from year to year. From 1963-66, the surveys were conducted from Division 4X to Division 6A three times a year - autumn (October-November), winter (February-March) and summer (June-July). From 1967 to date, they have been conducted twice a year, autumn and spring (March-April), and extended to include Divisions 6B and C. The latter period included joint surveys in the autumn with USSR research vessels.

The stratified random design was used; the strata selected on the basis of depth and area. The early series included about 180-190 tows per cruise, the later about 270-290 tows. The strata are portrayed in Figure 1. A more complete description is given in Grosslein (1969).

The data from these surveys have been used extensively in assessment work. However, because a groundfish trawl is used, question has been raised as to their precision in measuring relative changes in the standing crop of pelagic species.

This paper presents a preliminary analysis of the variability of the surveys.

Precision of stratum estimates

The *ALBATROSS IV* survey was conducted using a stratified random design. Each sample was a 30-minute tow with the 36 Yankee trawl which covered .01 square miles of bottom on each tow. Table 1 gives the trawlable area for each strata, and the number of samples (tows) taken in each strata for all the cruises of the *ALBATROSS IV* 1963-1970. The mean number of tows per strata was 4.7 with a range of 15. The sampling fraction of bottom area was of the order of 10^{-5}.

For the h^{th} stratum, the estimated mean catch of a species,

$$x_h = \frac{1}{n_h} \sum_{i}^{n_h} x_{hi}, \text{ where } n_n = \text{the number of tows, } x_{hi} = \text{the number of fish caught per tow.}$$

The estimated variance of x_{hj},

$$s_h^2 = \sum_{i}^{n_h} \frac{(x_{hi} - x_h)^2}{n_h - 1}$$

The mean, x_h is plotted against the variance s_h^2, for all strata and cruises from 1963 to 1970, inclusive, for several species (Figures 2 to 8). These include examples of the traditional groundfish, semi-pelagic and pelagic species, and all species combined.

The linear relation is obvious. The line drawn on the graphs has a slope, $B = {}^1/_2$, and an intercept at (1,1), or

$$\log x_{h.} = B \log s_h^2$$

This line implies that

$$x_h = (s_h^2)^{1/2}, \text{ or a relative variation equal to } 100\%$$

The haddock (Figure 2), red hake (Figure 3), yellowtail (Figure 4) and silver hake (Figure 5) all follow consistently the above relation throughout the extent of observation which cover four orders of magnitude. The points for mackerel and herring (Figures 6 and 7) lie on a line that is parallel to the reference line but somewhat below it.

This indicates that the coefficient of variance of mackerel and herring is about 1.5 times that of the other species. The scatter of points about the line is similar to the other species, however, and the scatter in all cases is also fairly uniform along the entire line.

The plot for all finfish (Figure 8) indicates a slope much less than that of the individual species. The coefficient of variance of total fish catch is, thus, less than that of the individual species, on the order of $s_h^{-1/2}$.

The plotted points are differentiated by two periods: 1963-66 and 1967-70. The latter include additional strata south of Hudson Canyon to Cape Hatteras (Divisions 6B and C). Examination does not indicate any difference in the relation between the two data sets.

Precision of stratified estimates

The stratified mean numbers per tow,

$$x_{st} = \frac{1}{N} \sum_{h}^{L} N_h x_h$$

The variance of the stratified mean,

$$s^2_{st} = \frac{1}{N^2} \sum_{h}^{L} \frac{N_h}{n_h} \frac{(N_h - n_h)}{(n_n - 1} s^2_h.$$

The precision of the stratified estimates is expected to be much better than that for a stratum. The reduction depends on the total number of samples in the strata and the variation among stratum means, thus it is not useful to generalize. Instead, a series of calculations of x_{st}, s^2_{st} and s_{st}/x_{st} have been made for the species used before (Table 2) based on the autumn survey series.

The relative standard error, s_{st}/x_{st}, averaged about .28 for all species except mackerel, which was about twice this level. Additional calculations for mackerel have been made from the spring cruises (Table 3). The relative standard error estimated from these data averaged .40 for the 36 Yankee trawl and .61 for the larger 41 trawl used in 1973-75.

Discussion

The stratum estimates of variability illustrate a high degree of consistency and uniformity for all species. Mackerel and herring do appear to have a moderately higher relative variability, and, of course, a coefficient of variation of 100-150% is not good. However, in almost all fishery assessment analyses, a stratified estimate is used, and the relative standard error (RSE) when 15 or more strata are combined of 25% is not excessive for fisheries data. The RSE for mackerel was higher than the other species (40 to 60%), but that for herring is not.

One basis for comparison is the variability of commercial catches, but this has not been routinely estimated for the ICNAF area.

The Subarea 5 pilot study data reported for the effort regulation studies does provide a basis for obtaining comparable estimates of variation because the time and area aggregates (30-minute area, one month time) are similar to the strata and time span of surveys. The estimated coefficients of variation (Table 4) of catch per unit effort were from 30 to 150 percent, with an average of 60 and 70 percent for FRG and Polish stern trawlers, respectively. The effort was directed at herring by the FRG fleet and at mackerel by the Polish fleet. The number of samples (vessels) per time-area averaged 41 (5 to 184) for FRG and 15 (4 to 158) for Poland.

This analysis deals only with the intrinsic precision of the estimates, not the accuracy. In measuring relative standing crop, the surveys would not be expected to have a bias, since they have a routine, standard design every year using the same gear. Commercial fleets, on the other hand, do change strategy and methods quite frequently in response to the goal of maximizing catch or catch per unit of effort. Bias, the difference between the true and observed value, can inflate the error mean square very greatly if over 10 percent, and significantly affect the assumed probability of error. In a normal frequency, if the bias is equal to the standard deviation, the probability of error is three times the presumed value. It may indeed be better to take one unbiased sample than a multitude of biased observations.

Literature cited

Grosslein, M. D. 1969. Groundfish Survey Program of BCF Woods Hole. Comm. Fish. Rev., Vol. 31, No.'s 8-9, pp. 22-35.

Table 1. NUMBER OF TOWS PER STRATA FOR SURVEY CRUISES SCOTIAN SHELF TO CAPE HATTERAS

ST	AREA	DP	005	007	001	210	013	002	510	014	601	614	721	803	817	902	908	911	703	706
01	2516	1	3	5	5	4	4	4	4	4	4	4	3	6	9	7	7	7	7	9
02	2078	2	2	5	6	4	4	4	4	4	4	4	8	5	7	7	7	10	9	7
03	0566	3	5	5	5	4	4	4	4	4	4	4	3	4	3	3	3	3	8	3
04	0188	4	3	2	1	3	3	3	3	4	4	4	3	4	3	3	3	3	3	3
05	1475	1	4	4	4	5	5	5	5	3	5	5	4	4	5	5	5	7	5	5
06	2554	2	7	7	7	5	5	5	5	5	5	5	9	6	7	8	8	11	9	8
07	0514	3	6	5	5	3	4	4	4	4	4	5	5	4	4	3	3	3	4	4
08	0230	4	2	2	2	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3
09	1522	1	5	4	5	5	5	5	5	5	5	5	6	4	7	5	5	5	5	7
10	2722	2	4	4	4	5	5	5	5	5	5	5	6	6	9	8	8	8	10	9
11	0622	3	3	2	2	4	4	4	5	4	4	4	5	4	3	3	3	3	4	3
12	0176	4				2	3	3	2	4	4	4	4	3	2	3	3	3	3	2
13	2374	2	4	5	6	5	5	6	6	7	6	6	8	7	8	9	9	9	9	7
14	0656	3	6	6	6	5	5	4	4	5	4	4	4	4	4	4	4	4	4	4
15	0230	4	1	1	1	3	3	3	3	3	4	4	3	4	4	3	3	3	3	4
16	2980	2	7	7	10	8	7	6	8	7	7	7	8	9	8	14	10	12	10	8
17	0360	3	3	5	3	4	6	3	3	4	4	5	3	4	4	4	4	4	4	4
18	0172	4	2	1	1	2	2	3	2	4	4	3	3	3	3	3	3	3	3	3
19	2454	1	4	4	7	5	6	6	6	5	6	6	9	8	9	8	9	9	8	9
20	1221	1	3	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	5	6
21	0424	2	6	6	3	5	4	5	5	5	5	5	4	4	4	4	4	4	4	4
22	0454	3	6	2	6	6	4	6	6	6	6	6	4	4	4	4	4	4	4	4
23	1016	2	4	3	4	6	6	5	6	6	6	6	6	6	5	5	5	5	5	6
24	2569	3	13	11	10	6	6	6	6	6	6	6	5	6	6	6	6	6	6	8
25	0390	1	1	2	1	4	4	3	3	3	4	4	4	4	4	4	4	4	4	3
26	1014	2	5	7	7	4	4	4	4	4	4	4	5	4	4	5	5	5	5	5
27	0720	3	2	2	1	3	4	3	3	4	4	4	4	4	4	4	4	4	4	4
28	2249	4	4	6	6	6	5	6	6	6	6	6	7	7	7	7	7	7	7	7
29	3245	4	12	15	15	5	8	6	7	7	6	5	8	8	8	8	8	8	9	8
30	0619	4		1	1	3	2	2	2	3	2	2	3	3	3	3	3	3	3	3
31	1875	3	12	9	9	4	4	4	5	5	5	6	5	6	6	7	7	7	11	8
32	0655	2	5	6	7	6	5	5	5	5	5	5	4	5	5	5	5	5	5	5
33	0861	2	3	4	4	4	4	4	4	4	3	4	3	4	4	2	4	3	5	4
34	1766	3	6	5	6	5	6	5	5	5	4	5	5	5	5	5	5	5	6	5
35	1097	3				4	4	4	4	4	5	4	4	3	2	3	3	3	4	3
36	4069	4	9	9	11	6	8	8	6	5	6	6	7	8	9	8	9	8	8	9
37	2108	3	5	5	6	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5
38	2560	3	8	7	6	5	6	5	5	7	5	5	4	6	4	5	6	5	5	6
39	0730	2	2	2	1	3	3	3	3	3	4	4	2	2	3	2	3	3	3	3
40	0578	2	4	3	5	1	2	3	3	4	3	4	4	2	3	3	3	3	3	3
41	3885	3							6	4	4	4	6	6	6	6	6	6	8	15
42	0582	2							2	2	2	2	4	4	4	4	4	4	4	6
49	0198	4																		3
61	1318	1											5	3	5	3	4	3	3	5
62	0243	2											2	2	2	2	2	2	2	2
63	0086	3											2	2	2	2	2	2	2	2
64	0060	4											2	2	2	2	2	2	2	2
65	2832	1											7	8	10	8	7	9	6	9
66	0555	2											3	4	3	3	4	3	4	3
67	0086	3											3	2	2	2	1	2	1	2
68	0052	4											2	2	2	2	2	2	2	2
69	2433	1											8	7	9	7	6	6	7	8
70	1024	2											3	4	5	4	4	4	5	4
71	0281	3											3	3	2	2	2	2	3	2
72	0105	4											3	3	2	2	2	2	2	2
73	2145	1											7	6	7	5	5	5	6	7
74	1273	2											5	4	5	4	4	4	5	5
75	0139	3											3	3	2	2	2	3	3	2
76	0060	4											2	3	2	2	2	2	2	2
CR	TOT		181	183	194	175	182	177	187	193	192	194	271	262	275	266	267	276	289	294

Table 2. Stratified estimates of numbers caught per tow and variance from autumn surveys.

SPP	Strata set	Cruise	X_{st}	S^2_{st}	S_{st}	$\frac{S_{st}}{X_{st}}$
Silver hake	1-12	007	42.8	94.9	9.7	.23
		013	45.2	33.0	5.7	.13
		014	96.1	183.0	13.5	.14
		614	190.3	5482.7	74.0	.39
		721	28.9	19.5	4.4	.15
		817	131.4	1979.7	44.5	.34
		911	37.8	67.1	8.2	.22
		706	56.6	166.5	12.9	.23
	13-25	007	34.2	59.8	7.7	.23
		013	9.4	4.9	2.2	.24
		014	7.0	1.6	1.3	.18
		614	10.7	6.3	2.5	.23
		721	5.6	1.6	1.3	.23
		817	18.2	20.4	4.5	.25
		911	14.0	9.5	3.1	.22
		706	10.1	5.4	2.3	.23
	26-30	007	224.0	2033.2	45.1	.20
		013	25.6	18.1	4.2	.17
		014	45.9	355.8	18.9	.41
		614	15.7	7.7	2.8	.18
		721	10.6	9.2	3.0	.20
		817	7.0	8.4	2.9	.41
		911	14.8	14.9	3.9	.26
		706	16.3	33.6	5.8	.36
	Average					.24
Red hake	1-12	007	38.3	234.8	15.3	.40
		013	22.2	55.4	7.4	.34
		014	30.9	60.3	7.8	.25
		614	28.9	119.0	10.9	.38
		721	12.1	16.4	4.0	.33
		817	20.7	29.2	5.4	.26
		911	20.0	28.1	5.3	.27
		706	24.4	17.7	4.2	.17
	13-25	007	24.0	46.7	6.8	.28
		013	8.7	8.8	3.0	.34
		014	7.7	6.9	2.6	.34
		614	4.8	1.8	1.3	.28
		721	2.6	0.8	0.9	.34
		817	4.4	1.0	1.0	.23
		911	11.4	9.1	3.0	.26
		706	6.6	3.7	1.9	.29
	Average					.30

Table 2. (cont'd)

SPP	Strata set	Cruise	X_{st}	S^2_{st}	S_{st}	$\frac{S_{st}}{X_{st}}$
Haddock	13-25	007	109.0	380.5	19.5	.18
		013	159.5	908.9	30.1	.19
		014	82.3	166.1	12.9	.16
		614	24.2	22.8	4.8	.20
		721	13.6	16.6	4.1	.30
		817	4.8	3.7	1.9	.40
		911	2.4	0.5	0.7	.29
		706	6.3	11.0	3.3	.53
	Average					.28
Yellowtail flounder	13-25	007	24.1	21.2	4.6	.19
		013	18.2	44.5	6.7	.37
		014	12.5	12.2	3.5	.28
		614	11.7	13.7	3.7	.32
		721	13.8	11.6	3.4	.25
		817	20.1	18.9	4.3	.22
		911	17.4	13.1	3.6	.21
		706	10.1	4.3	2.1	.21
	5-12	007	43.4	111.5	3.4	.08
		013	51.2	104.3	10.2	.20
		014	32.6	53.1	7.3	.22
		614	42.3	81.4	9.0	.21
		721	48.6	59.6	7.7	.16
		817	33.9	106.4	10.3	.30
		911	46.2	232.3	15.2	.33
		706	33.5	118.8	10.9	.33
	Average					.24
Mackerel	1-40	007	.1	.01	.1	1.0
	61-76	013	.01	.0001	.01	1.0
		014	.21	.005	.1	.34
		614	.31	.007	.1	.27
		721	6.6	30.4	5.5	.84
		817	.6	.06	.2	.41
		911	16.3	240.8	15.5	.95
		706	.2	.004	.06	.32
		716	.31	.03	.17	.56
		728	.37	.02	.14	.38
		738	.30	.01	.1	.33
		748	.70	.20	.45	.64
		758	.04	.003	.02	.43
	Average					.57

Table 2 (cont'd)

SPP	Strata	Cruise	X_{st}	S_{st}	S_{st}	$\frac{S_{st}}{X_{st}}$
Herring	1-25	007	2.8	1.6	1.26	.45
		013	0.5	.03	.2	.35
		014	3.4	0.8	.9	.26
		614	7.6	2.7	1.6	.22
		721	2.5	.4	.6	.25
		817	.8	.02	.1	.18
		911	.4	.01	.1	.25
		706	.2	.004	.1	.32
	1-25	007	2.8	1.6	1.3	.45
	63-76	013	.5	.03	.2	.35
		014	3.4	.8	.9	.26
		614	7.6	2.7	1.6	.22
		721	1.8	0.2	.4	.25
		817	.6	.01	.1	.17
		911	.3	.01	.1	.33
		706	.2	.002	.04	.22
Average						.28

Table 3. Stratified estimates of numbers caught per tow and variance for mackerel on Spring Surveys, Strata 1-14, 61-76.

Cruise	X_{ST} No./tow	X^2_{ST} Variance	S_{ST} Std. dev.	$\frac{S_{ST}}{X_{ST}}$
803	99.02	1358.5	36.8	.37
902	0.68	0.2	0.3	.50
703	13.04	17.1	4.1	.32
711	17.70	54.4	7.4	.42
722	11.69	22.4	4.7	.41
*733	28.83	711.0	26.7	.92
*744	3.09	1.3	1.2	.37
*753	1.90	1.1	1.0	.54

*Adjusted from No. 41 trawl catches to equivalent No. 36 trawl catches using a 3.25:1 ratio.

Table 4. Coefficients of variation of Polish and FRG commercial fleets.

Coef. Var.	Frequency Polish	FRG
.2	1	
.3	5	
.4	3	3
.5	8	6
.6	6	3
.7	11	4
.8	8	3
.9	7	1
1.0	5	1
1.2	1	
1.3	1	
1.4	1	
1.5	2	
Total	59	21
Average	.7	.6

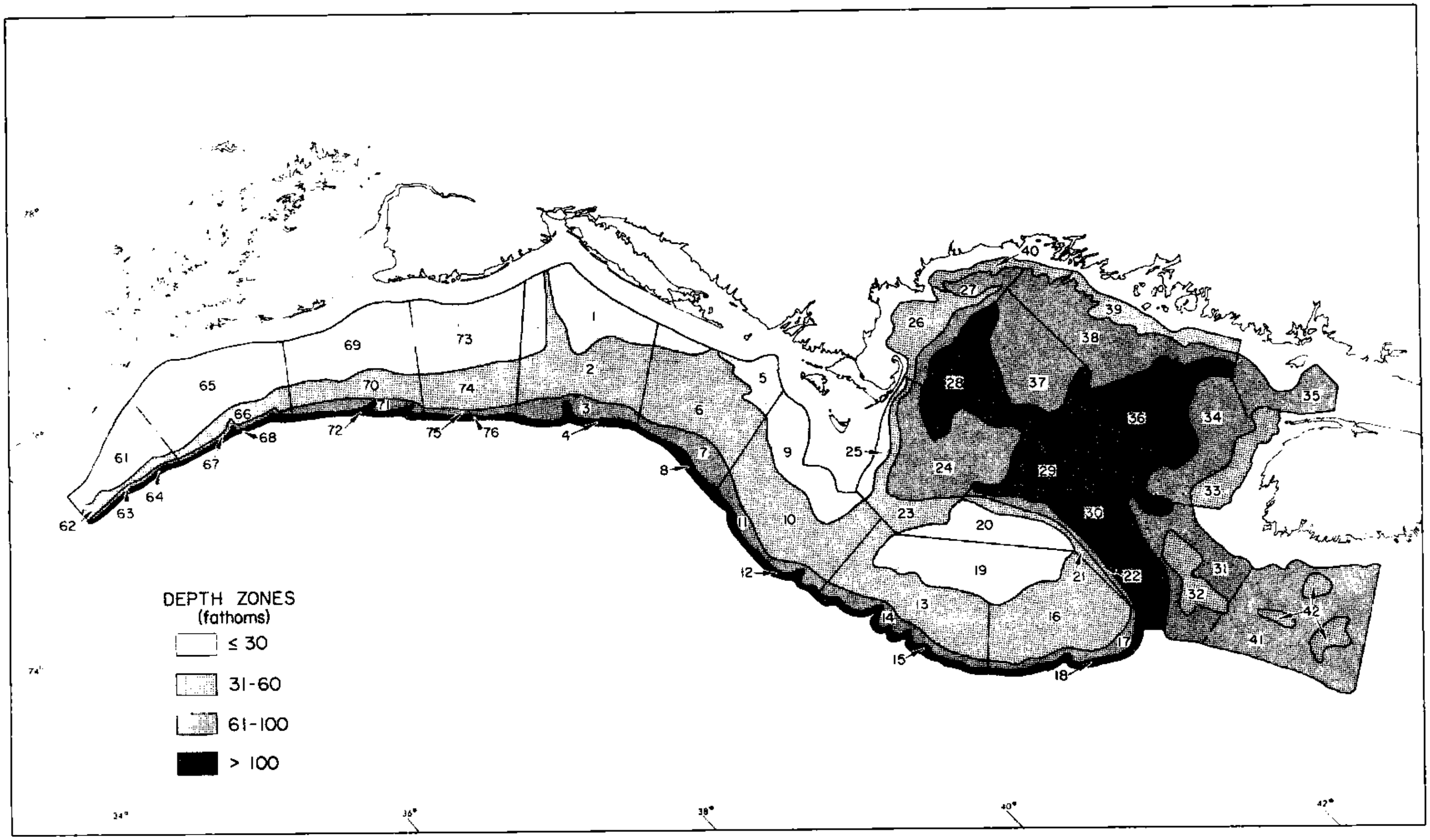

Figure 1. Strata for ALBATROSS trawl surveys.

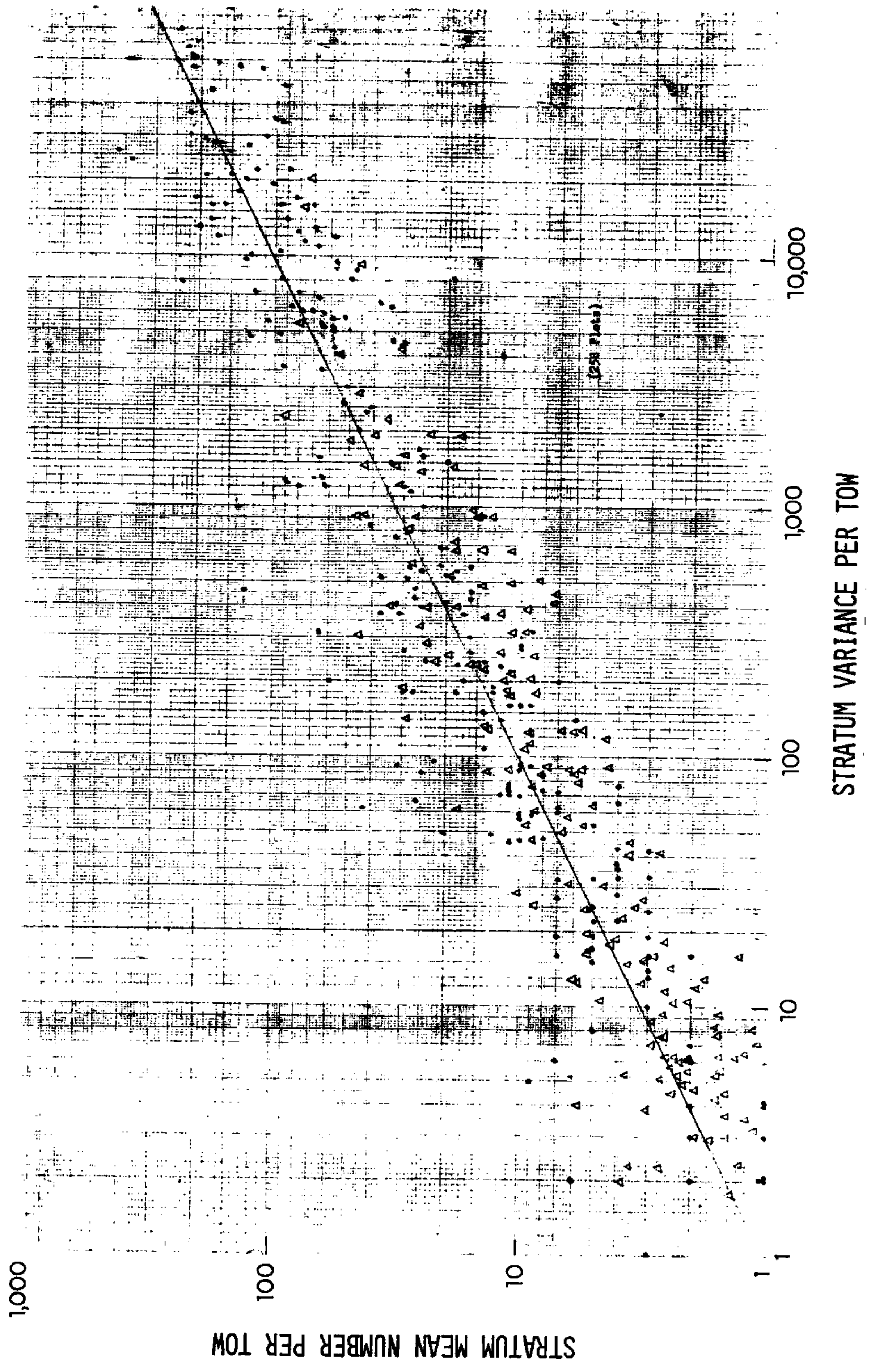

Figure 2. Stratum means, x_h, and variance, S_h^2, for haddock. Circles are for 1963-67, triangles for 1968-70.

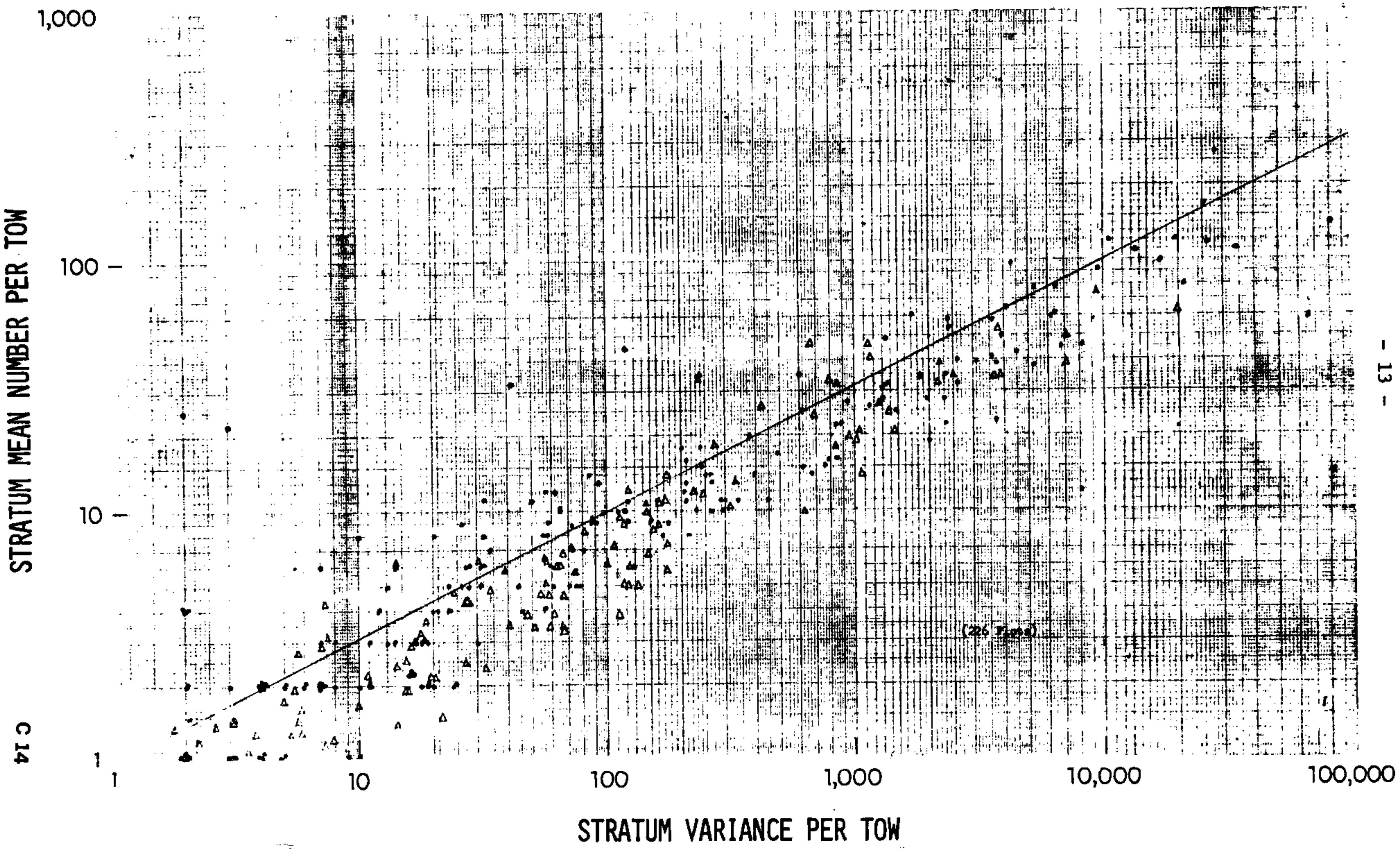

Figure 3. Stratum means, x_h, and variance, S_h^2, for red hake. Circles are for 1963-67, triangles for 1968-70.

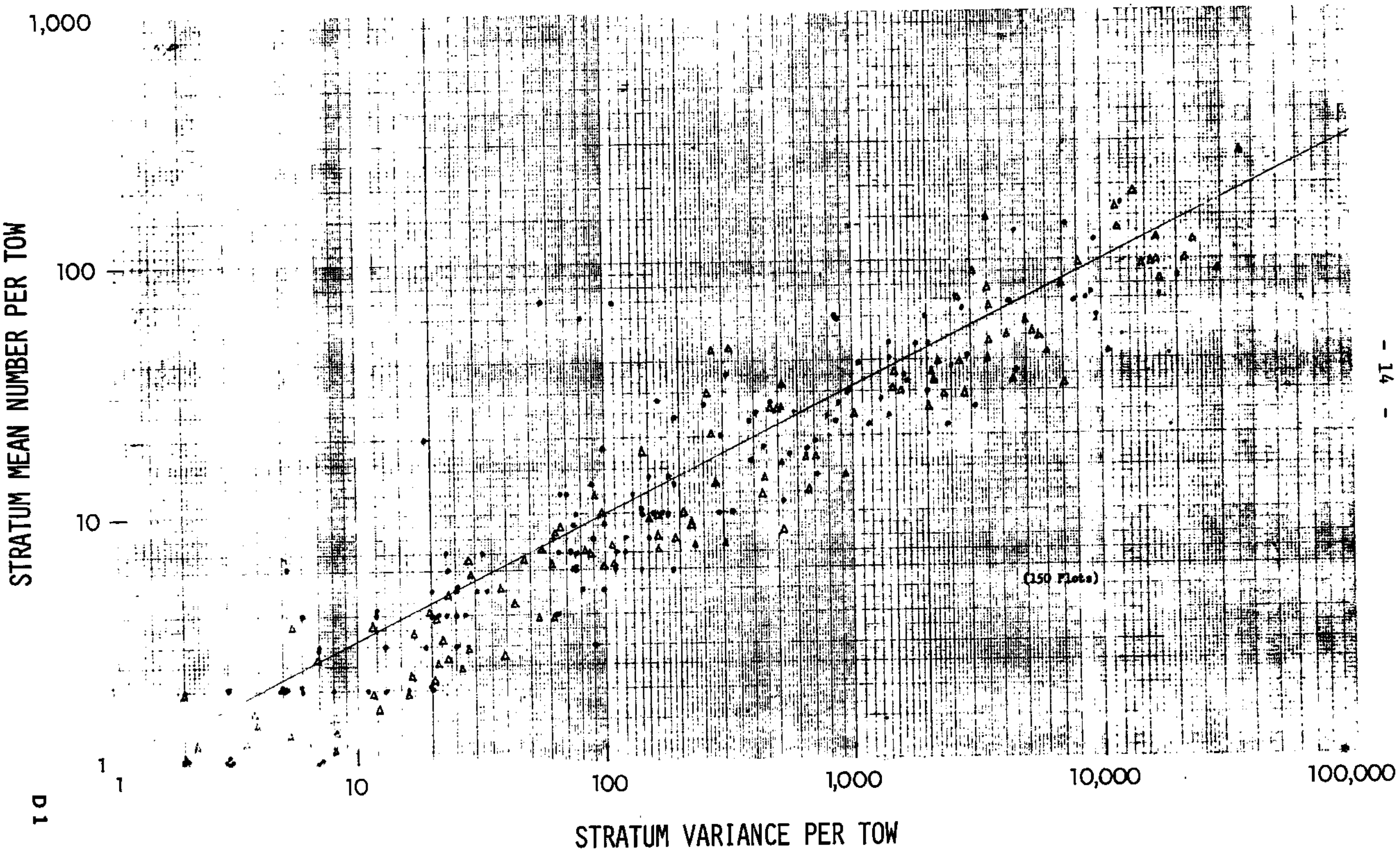

Figure 4. Stratum means, x_h, and variance, S_h^2, for yellowtail. Circles are for 1963-67, triangles for 1968-70.

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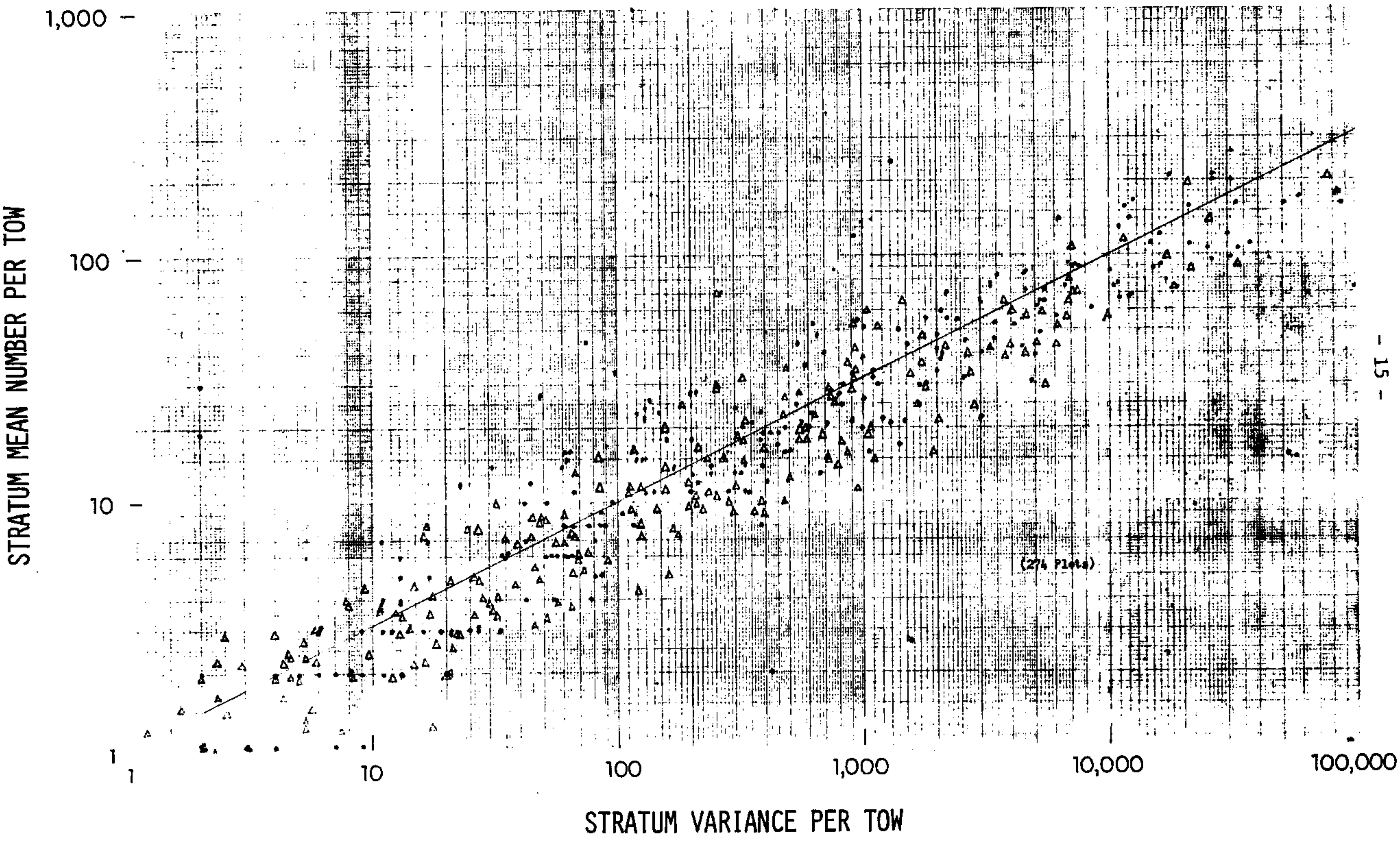

Figure 5. Stratum means, x_h, and variance, S_h^2, for silver hake. Circles are for 1963-67, triangles for 1968-70.

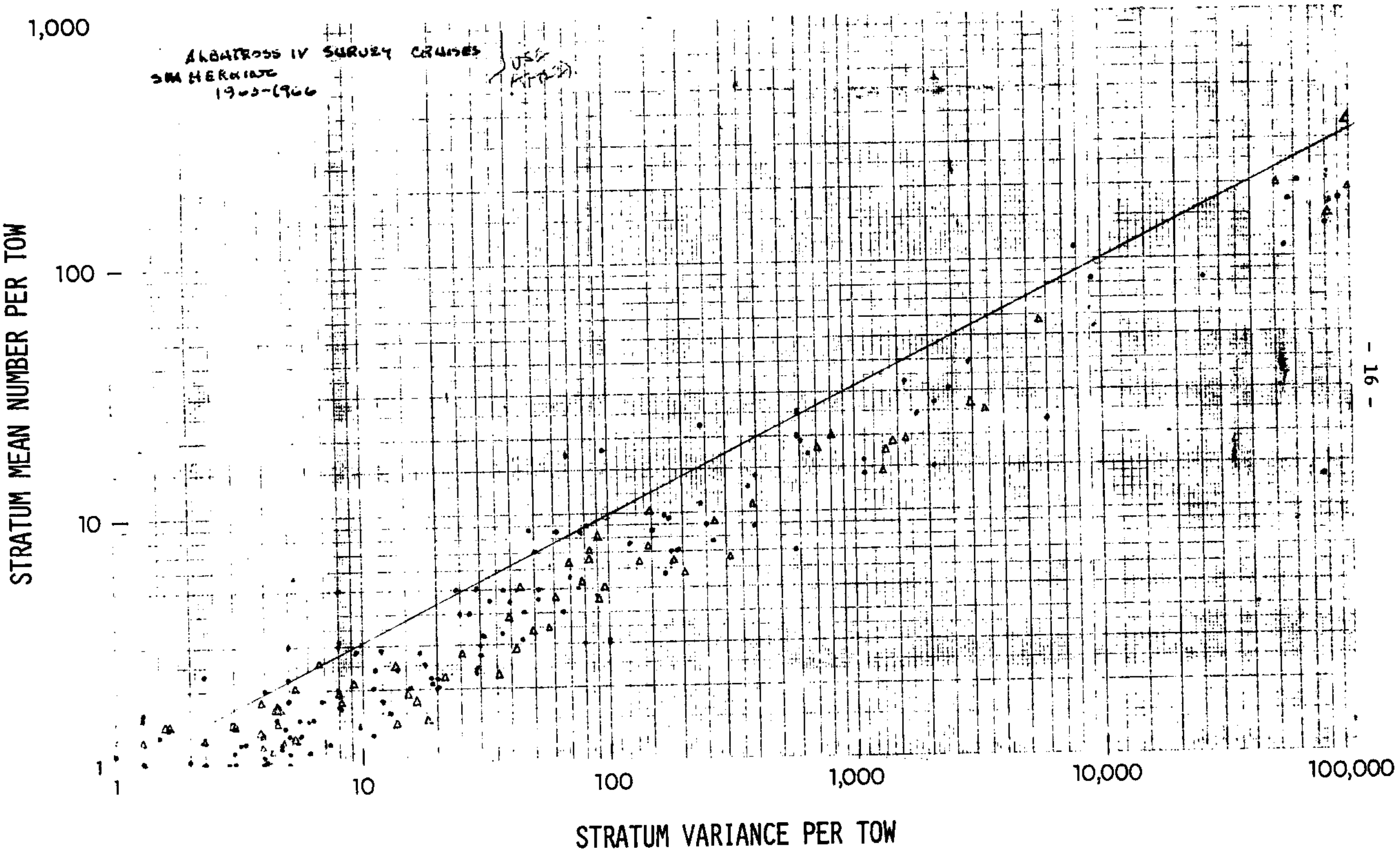

Figure 6. Stratum means, x_h, and variance, S_h^2, for herring. Circles are for 1963-67, triangles for 1968-70.

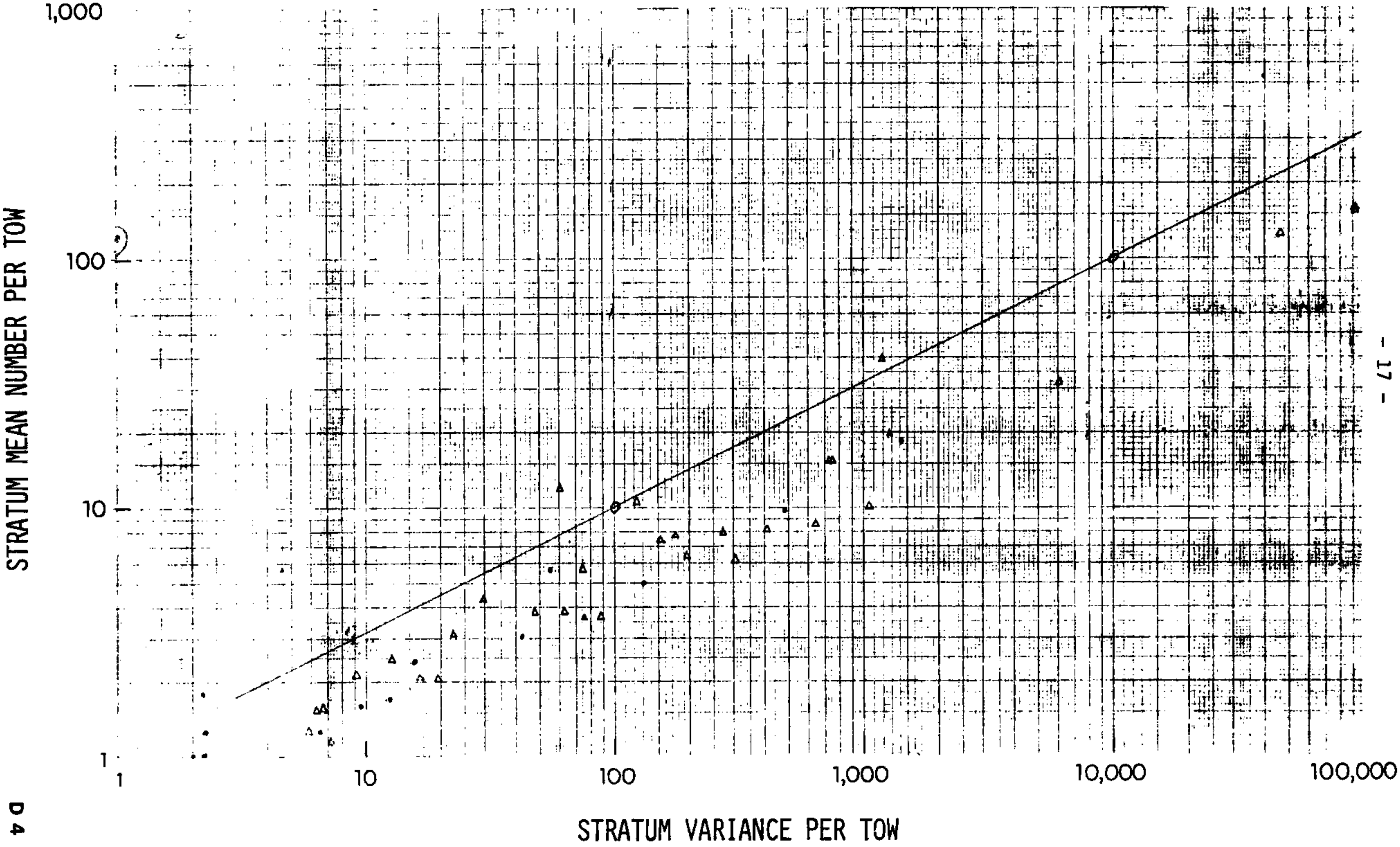

Figure 7. Stratum means, x_h, and variance, S_h^2, for mackerel. Circles are for 1963-67, triangles for 1968-70.

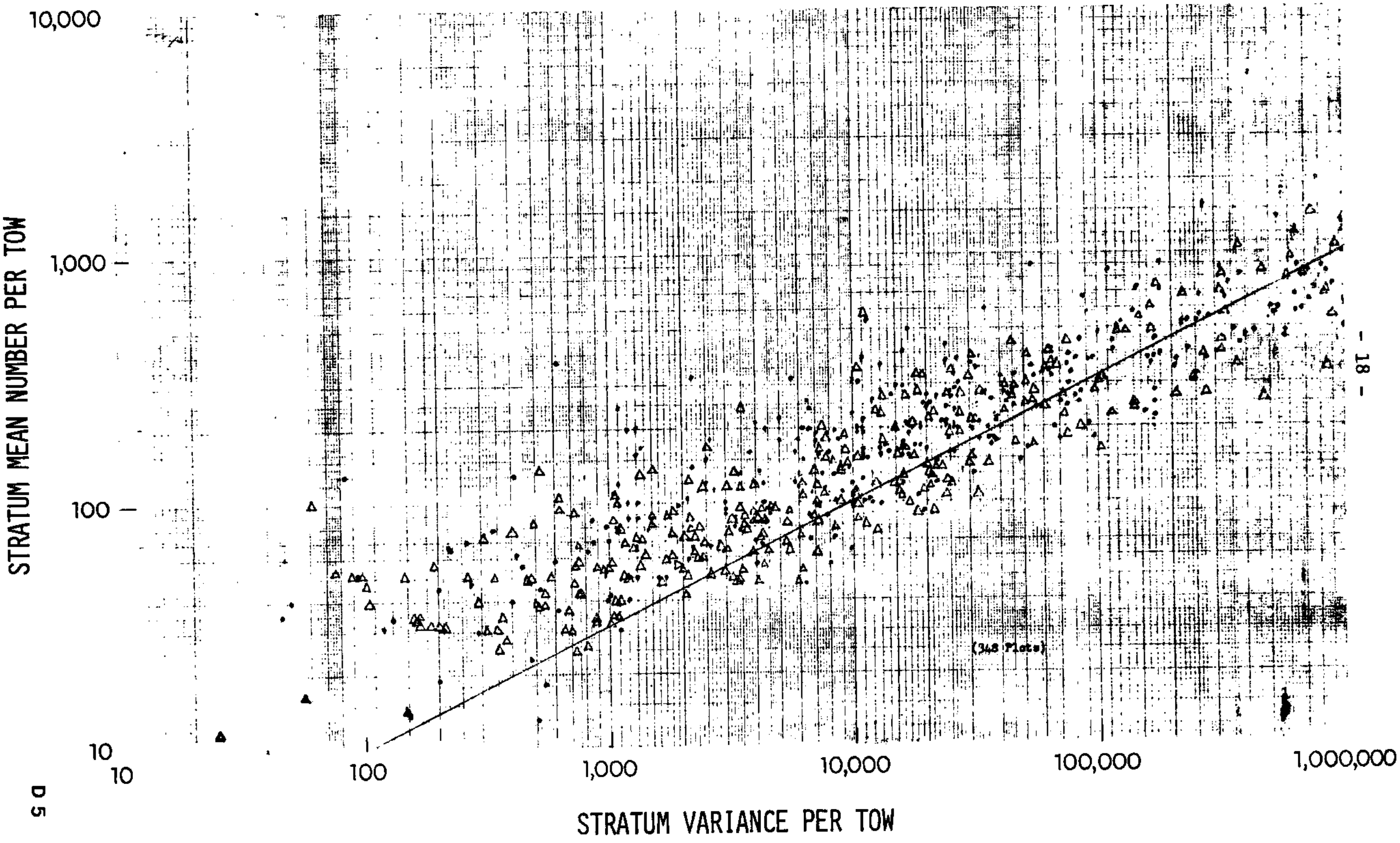

Figure 8. Stratum means, x_h, and variance, S_h^2, for all fish. Circles are for 1963-67, triangles for 1968-70.