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A comparison of the influence of stratification by depth zone and by individual strata on research vessel abundance estimates

by

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ABSTRACT

Stratification by depth zone and by individual strata were compared as to their effect on cod abundance estimates from research surveys in NAFO Subdiv. 3Ps. Stratification by depth zone was proposed as a means of providing population estimates for surveys where coverage was incomplete and when catches were highly variable. Combining strata within depth zones effectively increased the number of sets in the new strata and generally reduced the variances associated with the abundance estimates. Estimates of mean numbers per tow from both methods followed similar patterns.

RESUME

On a comparé la stratification par zone bathymétrique et par strate individuelle quant aux effets sur les estimations d'abondance de la morue des relevés par navires de recherche dans la subdiv. 3Ps de l'OPANO. La stratification par zone bathymétrique a été suggérée comme moyen d'obtenir des estimations de population dans les relevés où la couverture avait été incomplète et les prises très variables. Une combinaison des strates et des zones bathymétriques augmente effectivement le nombre de traits de chalut dans le nouvelles strates et réduit en général la variance associée aux estimations d'abondance. Les estimations des nombres de poisson par trait par les deux méthodes ont généralement les mêmes caractéristiques.

INTRODUCTION

In recent cod stock assessments catch information from stratified-random research vessel surveys, in terms of mean number per standard tow plus biomass estimates, have been used to provide indices of changes in stock status. With adequate sampling, the data obtained from stratification by individual strata should provide reasonably good estimates of population numbers and biomass within acceptable confidence limits. The results from most surveys and strata have supported this but there have been surveys where coverage in terms of tows per strata has been minimal (2) or whole strata omitted, and those where the variation between catches has been large enough to produce wide confidence limits. One attempt to reduce this variation has been to combine the data by depth zone. This effectively increases the number of sets per 'strata' and provides estimates for surveys when some strata have been omitted. This paper presents a comparison of data obtained for cod from research vessel surveys in Subdivision 3Ps when the data are stratified by individual strata and with strata combined by depth zone.

DATA

The stratification scheme for Subdivision 3Ps is shown in Fig. 1. Surveys have been conducted since 1972 with the results in terms of cod biomass per stratum being shown in Table 1. Tables 2 and 3 show the mean numbers per standard tow at age using the two stratification options (by individual strata

and by depth zone) along with the associated means and confidence limits. Similarly Fig. 2 compares the mean numbers per tow for all ages for the same two stratification options. The trends in mean number per tow for both options followed a similar pattern with those for depth stratification having a higher value than by individual strata with the exception of that shown for 1979. The confidence limits about the means as shown in Tables 2 and 3 were fairly consistent for years other than 1979 and 1981 (Table 2).

To provide an equivalent comparison between the two stratification options, an index termed the 'Relative Spread' (Upper confidence limit-lower limit/mean) was used. Table 4 and Fig. 3 show the data used and the results obtained. For both stratification options this index fluctuated about the value of 1.0 except for the high values observed for the stratification by the individual strata option in 1979 and 1981. When comparing the data shown in Fig. 2 it can be seen that the high 'Relative Spread' value for 1979 coincided with the reversal of trend value for mean number per tow shown in 1979.

Fig. 2b would suggest that there are considerable differences in the variances associated with the results obtained from the two stratification options for the years 1979 and 1981. A breakdown of the 1981 data is shown in Table 5. It can be seen that the number of sets per stratum were minimal for most strata. The variances were always higher for the depth zones when these were obtained cumulatively by individual strata as opposed to stratification by depth zone.

Tables 6 to 9 provide a detailed look at frequencies of weight caught by indicated weight category for each set and depth range for the survey conducted during 1983. This survey had the best coverage in terms of total number of sets per survey and total sets per stratum. It is apparent that the majority of catches were small (0-10kg) for all depth strata as well as for most individual strata. As such any data bias or distortion that might occur as a result of combining strata by depth zone should be minimal.

The relationships of mean numbers per tow from both stratification schemes to cohort population numbers (Bishop and Gavaris, 1983) are shown in Table 10 and Fig. 3. While the relationship using depth zone strata was only marginally better than that by individual strata, it is obviously not significant for both. As seen from Fig. 3, exclusion of the 1981 value would be very detrimental to an already poor regression relationship.

DISCUSSION

The stratification design in which biomass and numbers are calculated for individual strata should provide reliable estimates if the number of tows is sufficiently large to counteract the effect of wide variation in catch sizes. As stated previously this has not always been possible mainly because of time constraints. Strata have received minimum or no coverage and in some instances (ie. 1979 and 81) the highly variable catches within strata have produced very wide confidence limits about the means. Combining strata by depth zone

increases the number of sets for the 'strata' and generally reduces the variances associated with the estimates. With the data presented statistical confidence was improved after stratifying by depth zone although the mean values obtained for both methods followed similar patterns.

References

Bishop, C.A. and S. Gavaris. 1983 MS. Assessment of the cod stock in Subdivision 3Ps. CAFSAC Res. Doc. 83/32.

Table 1. Cod biomass (MT) from stratified random cruises in Subdivision 3Ps.

Depth Range (Fm.)	Strata	Area	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
0-30	314	974	0	-	1328	-	2357	249	0	-	432	369	2028	13103
	320	1320	-	729	-	-	1335	-	-	-	2946	23087	1920	5618
TOTAL			0	729	1328	-	3692	249	0	-	3378	23456	3948	18721
31-50	308	112	-	181	279	205	193	311	38	125	240	305	490	766
	312	272	210	-	243	335	456	1047	343	151	-	165	766	524
	315	827	1480	0	592	0	1747	1550	-	1836	235	0	528	2451
	321	1189	1917	0	-	-	1742	-	2037	-	1880	1419	2845	2419
	325	944	-	-	-	-	2	-	180	820	28	1109	85	294
	326	166	-	-	-	-	-	-	0	2	3	0	54	326
TOTAL			3607	181	1114	540	4140	2908	2598	2934	2386	2998	4768	6780
51-100	307	395	2918	6133	3919	884	1127	2097	3222	4105	1763	13723	3028	892
	311	317	3885	590	2432	763	627	411	154	1106	3792	761	1943	3256
	317	193	101	286	589	154	551	491	-	368	536	268	1582	3685
	319	984	4604	662	478	481	3102	2493	-	10637	1652	15068	3548	3799
	322	1567	-	-	-	-	5183	-	491	14	2599	26	3705	4932
	323	696	736	-	-	-	368	63	1652	-	775	491	1215	858
	324	494	-	-	-	-	8	-	-	29	0	-	430	618
TOTAL			12244	7671	7418	2292	10966	5555	5519	16259	11117	30337	15451	18040
101-151	306	419	-	-	376	719	214	161	416	710	457	2652	1211	1250
	309	296	662	975	479	311	178	192	103	1558	863	2983	338	926
	310	170	1008	191	377	2183	-	0	154	119	0	817	608	134
	313	165	371	29	144	242	142	41	50	1036	127	446	283	74
	316	189	271	937	63	58	77	17	-	65	61	25	-	207
	318	123	173	11	4	0	0	6	-	36	790	-	136	11
TOTAL			2485	2143	1443	3513	611	417	723	3524	2298	6923	3076	2602
151-200	705	195	-	-	66	0	0	60	1	91	674	1310	22	27
	706	476	-	-	23	-	-	76	-	356	827	304	30	32
	707	93	-	-	5	0	0	228	-	326	190	-	-	7
	715	132	-	-	-	1	1	31	142	352	499	168	154	338
	716	539	-	-	-	-	-	92	781	303	248	1608	168	147
TOTAL					94	1	1	487	924	1428	2438	3390	374	551
201-300	708	117	-	-	-	0	-	11	-	177	4633	-	-	0
	711	961	-	-	-	-	-	-	-	-	1113	0	0	7
	712	973	-	-	-	-	-	-	-	9077	282	259	353	0
	713	950	-	-	-	0	-	-	-	-	0	850	0	36
	714	1195	-	-	-	-	-	-	-	-	0	161	0	163
TOTAL			-	-	-	0	-	11	-	9254	6028	1270	353	206

	Total Area per Depth Range							
0-30	2294	-	3378	23456	3948	18721
31-50	3510	2934	2386	2998	4768	6780
51-100	4646	16259	11117	30337	15451	18040
101-150	1362	3524	2298	6923	3076	2602
151-200	1435	1428	2438	3390	374	551
201-300	4196	9254	6028	1270	353	206
TOTAL		33399	27645	68374	27970	46900

Table 2. Mean number of cod per tow from research vessel surveys in Subdivision 3Ps (stratification by individual strata) from the depth range 57-366 m.

Age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	.05	.04	1.26	.66	0.27	0.01	0.00	1.47	0.26	0.05	0.82	0.39
2	1.18	1.74	3.59	1.33	3.81	.34	0.53	0.61	7.23	0.88	1.98	0.75
3	2.09	1.96	3.42	3.75	2.13	4.38	0.79	0.89	2.14	4.63	.87	1.52
4	4.29	2.66	2.30	3.41	3.63	3.84	2.97	8.24	1.05	8.17	6.50	0.80
5	2.87	3.03	2.93	2.10	2.18	3.52	1.30	19.77	2.79	8.04	3.33	4.34
6	1.92	.86	2.88	1.94	1.08	1.04	.94	3.12	2.39	7.41	1.59	2.12
7	2.56	1.81	.82	1.74	.69	.27	.68	1.04	.53	6.01	2.08	0.66
8	1.51	.70	.70	.65	.67	.22	.47	.55	.55	1.09	2.12	1.17
9	.63	.95	.54	.43	.17	.34	.28	.22	.18	1.17	.57	2.14
10	.37	.22	.28	.26	.09	.12	.26	.19	.17	.30	.12	.90
11	.16	.06	.09	.09	.08	.02	.09	.04	.11	.08	.09	.38
12	.09	.06	.07	.04	.10	.05	.03	.02	.16	.10	.04	.13
13	.05	.01	.05	.05	.00	.05	.04	.02	.07	.14	.02	.05
14	.10	.03	.05	.00	.00	.02	.00	.03	.00	.07	.01	.04
14+	.47	.17	.08	.05	.10	.05	.13		.08	.07	.09	.11
Total	18.35	14.31	19.05	16.50	15.00	14.28	8.51	36.21	17.72	38.21	20.23	15.51
Confidence Limits												
Upper	28.62	25.67	25.02	23.38	23.26	19.81	12.44	319.07	23.82	256.23	27.45	21.94
Lower	8.08	2.96	13.08	9.61	6.73	8.75	4.59	-246.66	11.61	-179.80	13.01	9.09
Sets	42	53	78	56	64	94	41	74	63	46	70	111

Table 3. Mean number of cod per tow from research vessel surveys in Subdivision 3Ps (stratification by depth zone - 57 to 366m).

Age	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	.06	.12	1.00	.84	.31	.02	.00	2.69	.24	.06	1.15	.43
2	1.64	3.34	5.11	1.53	4.85	.36	.77	1.26	8.94	1.23	2.41	.78
3	3.20	2.48	4.30	4.35	2.90	3.92	.70	1.19	2.92	6.29	1.13	1.58
4	5.16	3.57	3.25	4.29	4.35	3.59	3.28	5.35	1.15	7.02	8.03	.94
5	2.89	3.40	4.07	2.49	1.93	4.23	1.85	14.01	3.11	7.41	4.11	5.16
6	1.88	.93	3.98	2.25	.76	1.24	1.20	3.64	2.73	8.93	1.92	2.50
7	2.62	1.91	1.15	1.95	.48	.32	.84	1.65	.62	8.62	2.43	.73
8	1.50	.75	.91	.67	.49	.27	.63	.89	.64	1.79	2.45	1.30
9	.69	1.02	.71	.49	.15	.38	.32	.36	.21	1.95	.67	2.34
10	.44	.27	.35	.30	.08	.15	.34	.30	.19	.52	.15	.99
11	.20	.10	.10	.11	.09	.03	.15	.08	.14	.14	.09	.43
12	.11	.07	.07	.03	.05	.06	.06	.05	.17	.19	.04	.15
13	.07	.01	.05	.07	.00	.09	.05	.05	.07	.15	.02	.05
14	.14	.03	.10	.00	.00	.02	.00	.06	.00	.12	.02	.05
14+	.55	.26	.14	.06	.10	.08	.16		.07	.16	.08	.11
Total	21.16	18.28	25.31	19.43	16.51	14.77	10.36	31.56	21.19	44.57	24.72	17.57
Confidence Limits												
Upper	33.40	28.95	33.49	30.82	22.29	19.77	14.76	51.51	30.15	78.5	33.22	25.86
Lower	8.92	7.61	17.13	8.05	10.74	9.77	5.96	11.60	12.24	10.64	16.22	9.28
Sets	42	53	78	56	64	94	41	74	63	46	70	111

Table 4. Comparison of stratification by individual strata and depth zone for mean number per tow with associated confidence limits and 'relative spread' for cod in Subdivision 3Ps.

	Strata Option	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Mean	1	18.35	14.31	19.05	16.50	15.00	14.28	8.51	36.21	17.72	38.21	20.23	15.51
	2	21.16	18.28	25.31	19.43	16.51	14.77	10.36	31.56	21.19	44.57	24.72	17.57
Upper limit	1	28.62	25.67	25.02	23.38	23.26	19.81	12.44	319.07	23.82	256.23	27.45	21.94
	2	33.40	28.95	33.49	30.82	22.29	19.77	14.76	51.51	30.15	78.50	33.22	25.86
Lower limit	1	8.08	2.96	13.08	9.61	6.73	8.75	4.59	-246.66	11.61	-179.80	13.01	9.09
	2	8.92	7.61	17.13	8.05	10.74	9.77	5.96	11.60	12.24	10.64	16.22	9.28
Relative spread	1	1.06	1.59	0.63	.83	1.10	.77	0.92	15.62	0.69	11.41	0.71	0.83
	2	1.16	1.17	0.65	1.17	0.70	0.68	0.85	1.26	0.85	1.52	0.69	0.94

1=All strata (31-200 ftm)

2=Strata by depth zone (31-50; 51-100; 101-150; 151-200)

$$\text{Relative spread} = \frac{\text{Upper limit} - \text{Lower limit}}{\text{mean}}$$

Table 5. Details of cod catches from a stratified random survey in Subdivision 3Ps in 1981.

		Number of sets	Numbers caught Variance	Range	Number of Sets	Numbers Caught Variance	Range
31-50	308	2	4.50	4-7			
	312	2	24.50	1-8			
	315	2	-	0	12	8.45	0-8
	321	2	4.50	3-6			
	325	2	2.0	2-4			
	326	2	-	0			
Total		12	35.50				
51-100	307	3	39132.08	12-401			
	311	2	512.00	13-45			
	317	2	2047.99	11-75			
	319	2	57799.66	6-346	13	18527.16	1-401
	322	2	2.0	3-5			
	323	2	0.50	1-2			
	324	-	-	-			
Total		13	99494.23				
101-150	306	3	1850.33	43-128			
	309	2	840.49	61-102			
	310	2	392.00	37-65			
	313	2	40.50	17-26	11	1785.85	0-128
	316	2	4.50	0-3			
	318	-	-	-			
		11	3127.82				
151-200	705	2	12.50	65-70			
	706	2	98.00	0-14			
	707	-	-	-	10	746.45	0-70
	715	2	60.50	3-14			
	716	4	594.91	2-51			
Total		10	765.91				

Table 6. Frequencies of cod catches by strata from the depth zone 57-91 m (31-50fm) from the A. Needler trip # 9 in Subdivision 3Ps in 1983

	57-91m						
	308	312	315	321	325	326	TOTAL
weight caught (kg.)							
0-10			5	4	6		15
11-20		1		2	2	1	6
21-30		1		1		1	3
31-40	1	1		1		1	4
41-50				1			1
51-60			1				1
61-70	1						1
71-80							
81-90							
91-100			1				1
greater than 100	1		1	1			3
TOTAL	3	3	8	10	8	3	35

Table 7. Frequencies of cod catches by strata from the depth zone 92-183m (51-100 fm) from the A. Needler Trip # 9 in Subdivision 3Ps in 1983.

	92-183m							
	307	311	317	319	322	323	324	TOTAL
Weight caught (kg)								
0-10				5	3	4	2	14
11-20	1	1				1	1	4
21-30	2		1	1	1			5
31-40		1						1
41-50	1				3		1	5
51-60					1	1		2
61-70								
71-80					1			1
81-90					2			2
91-100								
greater than 100		1	2	1				4
TOTAL	4	3	3	7	11	6	4	38

Table 8. Frequencies of cod catches by strata from the depth zone 184-274 m (101-150 fm) from the A. Needler Trip # 9 in Subdivision 3Ps in 1983.

	184-274m						
	306	309	310	313	316	318	TOTAL
Weight caught (kg)							
0-10		1	2	2	2	3	10
11-20		1		1	1		3
21-30	2		1				3
31-40	1				1		2
41-50							
51-60							
61-70							
71-80	1						1
81-90							
91-100							
greater than 100		1					1
TOTAL	4	3	3	3	4	3	20

Table 9. Frequencies of cod catches by stratum from the depth zone 275-366m (151-200 fm) from the A. Needler, Trip # 9 in Subdivision 3Ps in 1983.

	275-366m					
	705	706	707	715	716	Total
Weight caught (kg)						
0-10	3	5	3	1	4	16
11-20				1		1
21-30						
31-40						
41-50						
51-60						
61-70						
71-80						
81-90				1		1
91-100						
greater than 100						
TOTAL	3	5	3	3	4	18

Table 10. Relationship of mean numbers per tow from two stratification methods to cohort numbers for subdivision 3Ps cod.

Year	Mean number per tow -Age 3+		Cohort #'s
	(By strata)	(By depth zone)	Age 3+ ($X10^{-6}$)
1972	17.12	19.46	140.6
1973	12.53	14.82	125.4
1974	14.20	19.20	117.6
1975	14.51	17.06	125.2
1976	10.92	11.35	136.6
1977	13.93	14.39	162.1
1978	7.98	9.59	149.7
1979	34.13	27.61	127.8
1980	10.23	12.01	122.8
1981	37.25	43.28	169.7
1982	17.43	21.16	135.0
1983	14.37	16.36	
r^2	.12	.16	
Int.	127.15	123.9	
Slope	.60	.71	
Pred. cohort age 3+	135.75	135.56	

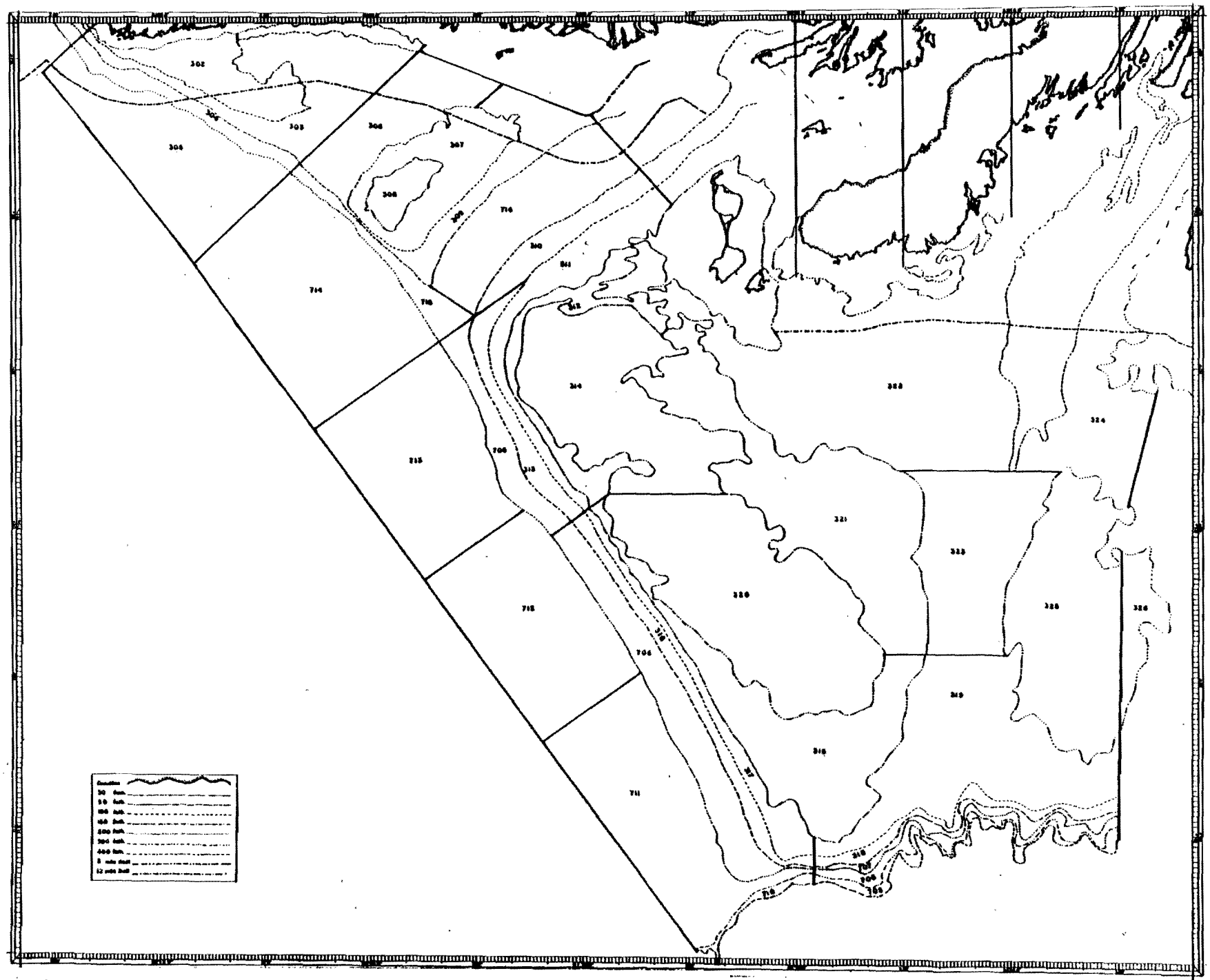

Fig. 1. Stratification design for NAFO Subdivision 3Ps.

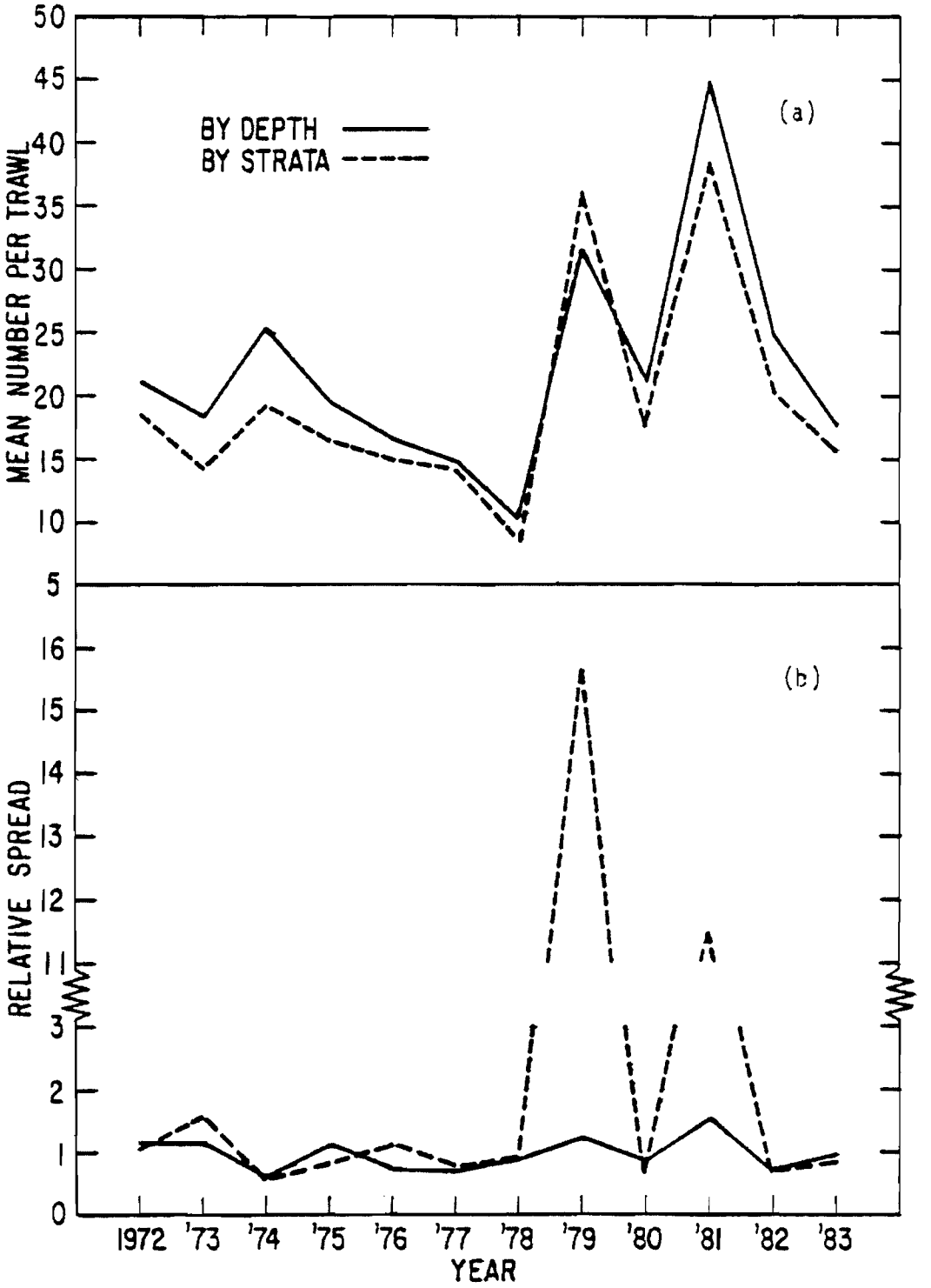

Fig. 2. Mean number per tow (a) and Relative Spread (b) estimates for cod in Subdivision 3Ps as obtained from stratification by individual strata and by depth zone.

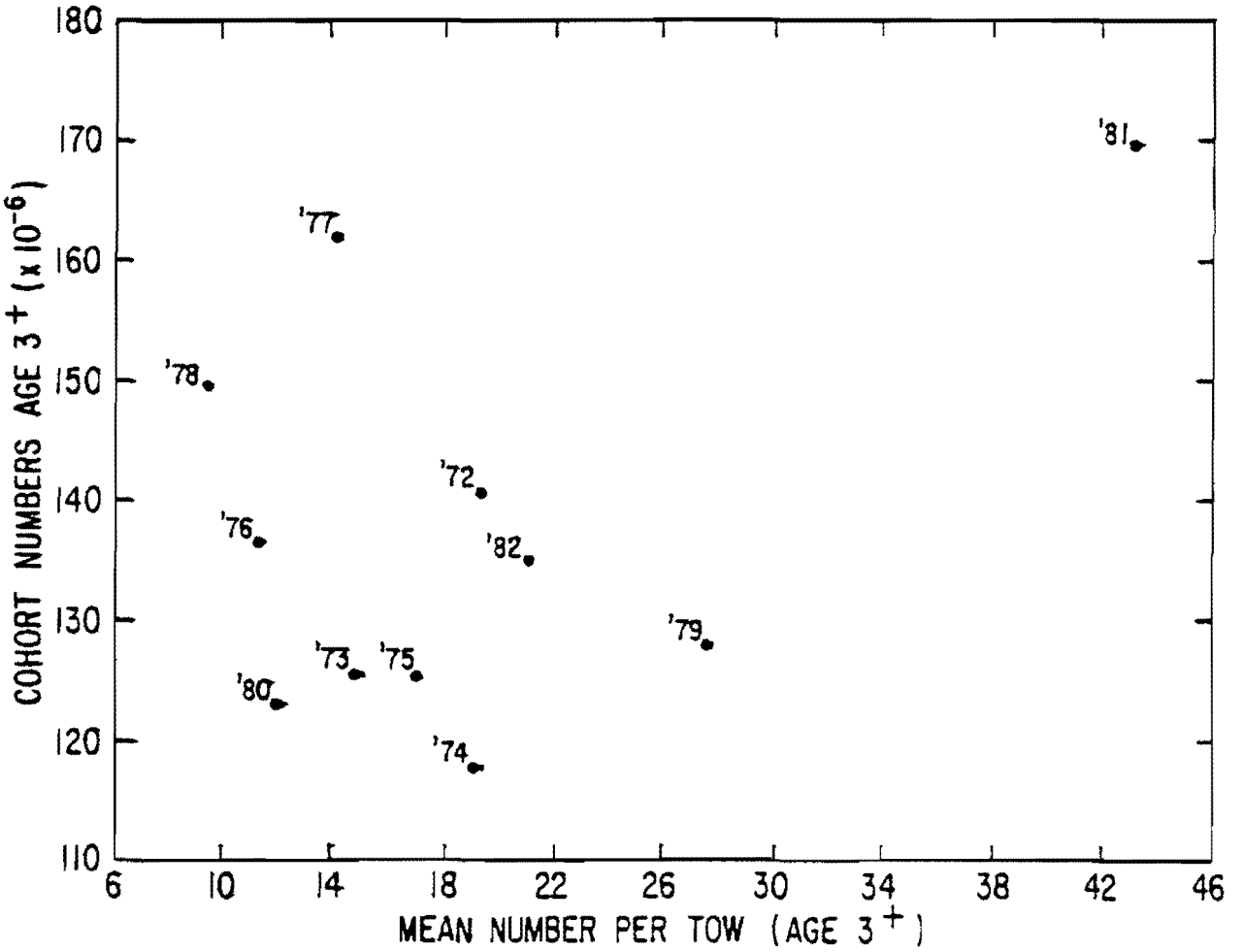

Fig. 3. Mean No. per tow (stratification by depth zone) versus cohort numbers for cod in Subdivision 3Ps.