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Abundance indices of 4VsW cod

by

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Abstract

The total catch of cod for 4VsW was 52,130 t in 1984, almost entirely taken by Canada. Otter trawlers fishing in Subdivision 4Vs caught approximately 70% of the total catch. The commercial catch rate index increased by about 15% between 1983 and 1984. Though the catch rate index has continued to increase since 1975, the rate of increase has slowed down since 1980. Research survey abundance indices, ages 5-12, also increased between 1983 and 1984 but by a larger margin of approximately 40%. The magnitude of this increase was largely attributable to one large catch of cod in Stratum 43.

Résumé

La prise totale de morue dans la zone 4VsW s'est établie à 52 130 t en 1984, cette prise étant presque entièrement attribuable au Canada. Les chalutiers qui pêchaient dans la subdivision 4Vs ont capturé environ 70 % de la prise totale. Le taux de capture commerciale a augmenté d'approximativement 15 % entre 1983 et 1984. Bien que ce taux de capture n'ait cessé de croître depuis 1975, sa croissance ralentit depuis 1980. Les études de dénombrement révèlent aussi une augmentation, plus notable celle-ci, des indices d'abondance de la morue âgée de 5 à 12 ans. La hausse est en effet d'environ 40 % par rapport à 1984. L'ampleur de cette augmentation est due en grande partie à une grosse prise de morue dans le Stratum 43.

Introduction

Nominal Catch

Catches of cod in Subdivision 4Vs and Division 4W have been under TAC regulation since 1973. Prior to the extension of jurisdiction by Canada in 1977, the majority of the catch was taken by Spain (Table 1). Canadian catches have increased substantially since that time, especially those taken by otter trawls in Subdivision 4Vs (Table 2). Sampling of the commercial catch for length and age composition was inadequate prior to 1977 and many assumptions were made in deriving the catch at age (Halliday 1976; Doubleday 1976; Gray 1978). This deficiency of basic data should be kept in mind when interpreting the results of sequential population analysis.

Fishery Distribution

Otter trawlers have been the major gear sector in the 4VsW cod fishery in recent years (Table 2). Set by set catch and effort data from a portion of the Canadian offshore otter trawler fleet engaged in this fishery from 1981-1984 was available from the Scotia-Fundy International Observer Program. Catch and effort from cod directed sets were aggregated by 10-min squares and CPUE was calculated. The data were plotted to compare the distribution and seasonality of the fishery among years (Fig. 1). In spring, areas of high CPUE were found in the eastern and western portion of Subdivision 4Vs, south of Sable Island in Division 4W, and in Middle Bank northwest of Sable Island (Fig. 1a). The fall fishery (Fig. 1b) showed a different distribution, mainly in Subdivision 4Vs on the shallower portion of Banquereau Bank. Within seasons, there was no indication of a shift in location of the fishery over the 4-yr period.

Abundance Indices

Commercial Catch Rates

Catch and effort statistics by month and division were derived from Table 5 of NAFO (ICNAF) Statistical Bulletins for 1965-82. Preliminary data for Scotia-Fundy based trawlers in 1983-84 were obtained from the Department of Fisheries and Oceans, Canada. Initially, all observations were included in an analysis using a multiplicative model (Gavaris 1980). The plots of residuals versus catch and versus effort revealed disproportionately more negative and positive residuals, respectively, for low values. This was taken as an indication of systematic bias caused by truncation of small numbers. In subsequent analysis, all observations where either the catch or effort was less than 10 units were excluded.

Analyses of catch rate data, separately by country-gear-tonnage class combinations, reaffirmed the general trends observed by Gagné et al. (1984). Spanish pair trawl and Canada-Maritimes longline data indicated a decline from the late 1960's to 1975 while Canada-Maritimes otter trawl catch rates showed no trend. The 1978 and 1979 data points for the otter trawl data appeared abnormally high. In keeping with the analysis by Gagné et al. (1984), Canada-Maritimes otter trawl data prior to 1974 and for 1978-79 were excluded from further analysis.

The remaining data were analyzed using a multiplicative model incorporating country-gear-tonnage class combinations, divisions, months and years as categories. The residual plots showed seven unusually large residuals (Table 3). When these points were eliminated, the model fit improved but the resulting catch rate series did not change appreciably.

A plot of residuals versus log (catch x effort) indicated that data points with higher catch and effort had smaller residuals, suggesting that weighted regression should be applied. An iterative procedure was employed whereby blocks of data, assumed to be homogeneous with respect to variance, were identified and their residuals were used to estimate the weighting factors for the regression analysis (Judge et al. 1980). As is to be expected, the application of weighted regression improved the precision of parameter estimates but did not affect the estimates significantly.

Parameter estimates for several months and country-gear-tonnage class combinations were close enough in value to permit grouping within category types. This reduced the number of parameters required while not worsening the fit of the model. The analysis of variance for the final model shows that all category types were significant and that 63% of the variation in the data was explained by the model (Table 4). The parameter estimates for the categories, other than years, are also given in Table 4. Catch rates in Subdivision 4Vs are somewhat higher than those in Division 4W, an observation which has been made previously. Also, catch rates are generally higher in fall and winter, a phenomenon probably associated with pre-spawning and spawning behavior. For trawlers of the same origin, catch rate increases with tonnage class whereas for longliners it does not.

The estimates of predicted ln catch rate and the retransformed catch rate series, uses Canada-Maritimes, tonnage class 5 in Subdivision 4Vs and in January as a standard (Table 5). The series shows a marked decline from the late 1960's to 1975 then a rapid recovery to 1980 followed by a more gradual rise to 1984. The current level is about two-thirds of the historical maximum (Fig. 2). This pattern differs somewhat from that presented by Gagné et al. (1984). In the catch rate series presented by Gagné et al. (1983, 1984) and Maguire et al. (1982), the decline is not as pronounced as in the present analysis which more closely resembles the trends shown by Halliday (1976), Doubleday (1976) and Gray (1978).

Research Surveys

Stratified-random bottom-trawl surveys have been conducted on the Scotian Shelf since 1970. As in the past, data were analyzed using formulas described in Halliday and Koeller (1981). There are two basic differences between the survey results presented in this document and those in Gagné et al. (1983). First, it was found that the distance towed, which is used to standardize tows, was wrongly calculated for one set in the 1973 survey. The set in question was very influential in arriving at an estimate of population size. Consequently, the revised estimate for population numbers in 1973 was considerably lower, but the 1973 estimate remained unusually high. Second, in accordance with the recommendation made by the

SSS Subcommittee, no conversion factor has been applied between LADY HAMMOND and ALFRED NEEDLER catches.

The survey results by age (Table 6) suggest that cod are not fully recruited to the survey until age 4. Although there is considerable variance associated with these estimates, the general trend displayed is a decline to 1975 followed by an increase. For ages 4 through 7, the estimates of population numbers increased considerably from 1983 to 1984. For ages 5 to 12, population estimates of numbers in Stratum 43 increased by a factor of 6 while other strata generally showed only a moderate increase, if any (Table 7, Fig. 3). Stratum 43 is one of the largest and is discontinuous. These features suggest that density in this stratum may be relatively heterogenous. There were four tows conducted in Stratum 43 during the 1984 survey. The age composition shows considerable variation between tows and the tow with the largest catch had more than 20 times the number of cod than the next largest tow (Table 8).

Population size estimates increased abruptly in 1982, the first year in which the A.T. CAMERON did not conduct the survey. The increase is most apparent for ages 4 and younger. Furthermore, the statistical distribution of catch per tow is thought to be skewed. Thus strong year-classes may be overestimated with the conventional analysis. Though it has been noted that the 1978-80 year-classes are relatively strong, it appears that their abundance may be over-estimated by the surveys.

The estimates of mean number per tow (ages 5-12) by stratum were examined to investigate patterns in density between 1981 and 1984 (Fig. 4). The patterns are fairly consistent over this time period, indicating that density is highest in the mixed-depth strata north of Banquereau and lowest west-north-west of Sable Island.

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Table 1. 4VsW cod nominal catches by country and NAFO Divisions.

YEAR	CANADA	FRANCE	PORTUGAL	SPAIN	USSR	OTHERS	TOTAL	SUBDIV. 4Vs	DIV. 4W	TAC
1958	17938	4577	1095	14857	-	124	38591	23790	14801	-
1959	20069	16378	8384	19999	-	1196	66026	47063	18963	-
1960	18389	1018	1720	29391	-	126	50645	27689	22956	-
1961	19697	3252	2321	40884	113	42	66309	34237	32072	-
1962	17579	2645	341	42146	2383	60	65154	26350	38804	-
1963	13144	72	617	44528	9505	307	68173	27566	40607	-
1964	14330	1010	-	39690	7133	1094	63257	25496	37761	-
1965	23104	536	88	39280	7856	124	70988	36713	34275	-
1966	17690	1494	-	43157	5473	356	68170	27163	41007	-
1967	18464	77	102	33934	1068	512	54157	26607	27550	-
1968	24888	225	-	50418	4865	29	80425	48781	31644	-
1969	14188	217	-	32305	2783	664	50157	22309	27848	-
1970	11818	420	296	41926	2521	446	57427	28632	28795	-
1971	17064	4	18	30864	4506	107	52563	24128	28435	-
1972	19987	495	856	28542	4646	7119	61645	36533	25112	-
1973	15929	922	849	30883	2918	2569	54070	23401	30669	60500
1974	10700	34	1464	27384	3096	1060	43739	19610	24130	60000
1975	9939	1867	546	15611	3042	1512	32517	11694	20823	60000
1976	9567	697	-	11090	1018	2035	24407	11553	12854	30000
1977	9890	68	-	-	97	335	10390	2873	7517	7000
1978	24642	437	-	57	218	51	25405	10357	15048	7000
1979	39219	18	-	2	683	108	40030	15393	24637	30000
1980	48821	17	5	5	338	66	49252	31378	17874	45000
1981	53053	-	-	-	630	35	53718	32107	21611	50000
1982	55675	-	-	-	45	34	55754	40110	15644	55600
1983[1]	50898	-	1230	-	190	62	52380	33170	19210	64000
1984	51765[2]	-	287[3]	-	50[3]	28[3]	52130	42339	9791	55000

[1] Preliminary NAFO

[2] Preliminary Scotia-Fundy and Newfoundland

[3] FLASH

Table 2. Canadian catch of 4VsW cod by gear and (sub) Division (from NAFO).

	4Vs					4W					4VsW				
YEAR	OTB	LL	SDN	MIS	TOTAL	OTB	LL	SDN	MIS	TOTAL	OTB	LL	SDN	MIS	TOTAL
1964	2056	42	2	-	2100	7324	708	88	4110	12230	9380	750	90	4110	14330
1965	7366	84	22	-	7472	10290	1339	159	3844	15632	17656	1423	181	3844	23104
1966	6374	143	14	-	6531	6614	1472	38	3035	11159	12988	1615	52	3035	17690
1967	6735	99	27	-	6861	6460	1453	71	3619	11603	13195	1552	98	3619	18464
1968	9501	48	18	-	9567	8360	1928	89	4944	15321	17861	1976	107	4944	24888
1969	3540	43	7	-	3590	4695	2647	13	3243	10598	8235	2690	20	3243	14188
1970	3054	21	1	-	3076	3602	3039	62	2039	8742	6656	3060	63	2039	11818
1971	5827	40	-	-	5867	4768	4173	26	2230	11197	10595	4213	26	2230	17064
1972	9856	115	4	-	9975	4732	3350	7	1923	10012	14588	3465	11	1923	19987
1973	6392	82	3	-	6477	4723	3173	20	1536	9452	11115	3255	23	1536	15929
1974	4644	56	-	-	4700	1335	2512	5	2148	6000	5979	2568	5	2148	10700
1975	1824	63	-	-	1887	3566	2558	11	1917	8052	5390	2621	11	1917	9939
1976	3755	42	-	-	3797	937	2289	14	2530	5770	4692	2331	14	2530	9567
1977	2751	50	4	-	2805	1873	3121	68	2023	7085	4624	3171	72	2023	9890
1978	9561	294	19	-	9874	7997	4321	839	1611	14768	17558	4615	858	1611	24642
1979	14853	438	86	-	15377	13784	5577	3245	1236	23842	28637	6015	3331	1236	39219
1980	28941	2116	321	-	31378	6298	6032	3440	1673	17443	35239	8148	3761	1673	48821
1981	27662	4274	171	-	32107	9148	7660	2433	1705	20946	36810	11934	2604	1705	53053
1982	32247	7069	794	-	40110	6352	5877	1943	1393	15565	38599	12946	2737	1393	55675
1983[1]	26817	4475	671	-	31963	11280	4451	1936	1268	18935	38097	8926	2607	1268	50898
1984[2]	37047	4118	880	22	42067	3330	3072	2141	1155	9698	40376	7191	3021	1177	51765

[1] Preliminary NAFO

[2] Preliminary Scotia-Fundy, preliminary Newfoundland

Table 3. Observations which were considered extreme and therefore excluded from the multiplicative model analysis for 4VsW cod.

Year	Country	Gear	Tonnage class	Month	Division	Catch	Effort
1971	SPAIN	PTB	4	June	4Vs	36	283
1975	CAN(M)	LLS	3	April	4W	15	18
1975	SPAIN	PTB	4	Aug.	4W	12	176
1980	CAN(M)	OTB2	5	May	4Vs	15	101
1981	CAN(M)	LLS	2	Nov.	4Vs	94	24
1983	CAN(M)	LLS	3	Oct.	4W	77	25
1984	CAN(M)	LLS	2	Oct.	4W	11	248

Table 4. Analysis of variance and parameter estimates from the analysis of catch rates for 4VsW cod, using a multiplicative model.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.793
MULTIPLE R SQUARED..... 0.629

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.254E2	2.254E2	
REGRESSION	31	4.629E2	1.493E1	70.491
TYPE 1	6	2.215E2	3.691E1	174.277
TYPE 2	1	2.859E0	2.859E0	13.497
TYPE 3	5	2.095E1	4.189E0	19.779
TYPE 4	19	1.104E2	5.812E0	27.438
RESIDUALS	1289	2.730E2	2.118E-1	
TOTAL	1321	9.613E2		

Country-gear-tonnage	Estimate	Month	Estimate
CAN(M)-OTB2-2	-0.645	July	-0.431
CAN(M)-LLS-2		June	-0.480
CAN(M)-LLS-3	-0.576	Aug.	
CAN(M)-LLS-4			
		April	
CAN(M)-OTB1-4		May	-0.339
CAN(M)-OTB2-3		Sept.	
CAN(N)-OTB1-4	0.000	Oct.	
CAN(N)-OTB2-4			
CAN(N)-OTB2-5		March	-0.171
CAN(M)-OTB2-4	0.236	Feb.	
		Nov.	-0.090
CAN(M)-OTB2-5	0.458	Dec.	
SPAIN-PTB-4	0.548	Jan.	0.000
SPAIN-PTB-5	0.927		
		Division	Estimate
		4W	-0.099
		4Vs	0.000

Table 5. Indices of ln catch rate and catch rate from the analysis of catch rates for 4VsW cod, using a multiplicative model. The effort is calculated from the ratio of catch and predicted catch rate

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED		TOTAL	
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1965	0.7925	0.0141	2.439	0.288	70988	29111
1966	0.7183	0.0148	2.263	0.275	68170	30118
1967	0.3787	0.0126	1.614	0.180	54157	33564
1968	0.6603	0.0121	2.139	0.235	80425	37602
1969	0.6187	0.0126	2.051	0.230	50157	24455
1970	0.5145	0.0124	1.848	0.205	57427	31070
1971	0.2952	0.0094	1.487	0.144	52563	35360
1972	0.1404	0.0082	1.274	0.115	61645	48379
1973	0.0741	0.0075	1.193	0.103	54093	45349
1974	-0.2458	0.0067	0.867	0.071	43741	50471
1975	-0.4790	0.0071	0.686	0.058	32517	47389
1976	-0.2704	0.0072	0.845	0.072	24407	28873
1977	-0.1964	0.0087	0.910	0.085	10390	11422
1978	0.1195	0.0123	1.245	0.138	25405	20402
1979	0.2509	0.0114	1.421	0.151	40030	28174
1980	0.3147	0.0061	1.518	0.119	49252	32438
1981	0.2998	0.0059	1.496	0.115	53718	35906
1982	0.4189	0.0056	1.686	0.126	55754	33077
1983	0.3192	0.0058	1.525	0.116	52332	34305
1984	0.4858	0.0063	1.802	0.143	52130	28936

Table 6. Estimated numbers at age for 4VsW cod from research vessel surveys. (Numbers in thousands). (A.T. CAMERON 1970-81; L. HAMMOND 1982; A. NEEDLER 1983-84).

RESEARCH VESSEL SURVEY NUMBERS 3/ 5/85

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	1478	1539	6210	6430	5174	3372	2242	808	3033	1213	690	4589	2633	39572	1165
2	16388	7680	9674	43907	32961	8412	14066	10145	13065	10612	7064	12770	226028	37813	20894
3	5250	35664	11881	69024	19246	13000	16098	26372	31245	16044	18488	18936	189892	120818	36823
4	7714	8027	31536	56081	5623	6171	10187	17059	34205	16595	10260	30753	65976	48451	54858
5	3742	15803	5812	22484	2017	2959	6621	11353	9461	18075	17365	12057	14824	24808	37171
6	1228	5775	5989	1870	2244	675	1264	4893	3490	9053	12099	8570	8020	11398	17253
7	1532	3459	1621	2907	372	867	656	1081	889	2696	4794	4404	4325	2611	11861
8	466	1475	547	901	463	235	1308	878	185	1009	1302	1553	1850	1444	1170
9	104	638	495	431	224	433	0	244	90	411	338	533	413	395	955
10	249	70	153	514	161	23	929	0	79	83	265	650	419	222	284
11	209	137	0	166	63	0	38	161	0	45	93	163	226	64	674
12	101	58	0	0	59	68	0	62	79	5	0	74	0	29	17
1+	38461	80325	73918	204715	68607	36215	53409	73056	95821	75841	72758	95052	513606	287625	183125
2+	36983	78786	67708	198285	63433	32843	51167	72248	92788	74628	72068	90463	510973	248053	181960
3+	20595	71106	58034	154378	30472	24431	37101	62103	79723	64016	65004	77693	284945	210240	161066
4+	15345	35442	46153	85354	11226	11431	21003	35731	48478	47972	46516	58757	96053	89422	124243
5+	7631	27415	14617	29273	5603	5260	10816	18672	14273	31377	36256	28004	30077	40971	69385
6+	3889	11612	8805	6789	3586	2301	4195	7319	4812	13302	18891	15947	15253	16163	32214

Table 7. Estimated numbers by stratum for ages 5 to 12 from research vessel surveys of cod in 4VsW. (Numbers in thoudands).

Div	Depth	STRATUM	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
4Vs	<50	43	421	943	362	597	146	397	92	81	50	464	3188	1323	1229	5446	30937
		47	175	0	74	155	96	939	36	275	480	1592	10139	2386	1492	6444	512
		48	90	216	94	397	27	11	17	445	401	4233	192	354	254	92	268
	51-100	44	4219	16132	11436	4068	2969	1671	4374	7572	528	5250	4971	12332	11015	7499	16361
		49	5	17	6	39	0	10	0	5	0	57	34	0	39	58	2
		50	12	3	37	11	30	0	6	81	1	13	0	86	99	77	93
	>100	45	86	2397	332	964	77	242	143	1081	264	203	4902	2150	4431	1754	2526
		46	60	65	81	36	39	4	169	6	0	68	280	562	1029	319	486
		51	0	17	29	0	7	31	0	0	0	73	15	32	133	175	102
		52	0	13	0	0	139	157	57	89	0	383	12	0	293	568	277
4W	<50	55	21	78	599	44	195	109	508	752	728	4278	3834	2022	7436	5622	1184
		56	25	483	125	517	66	98	703	287	204	5628	1047	797	175	487	767
		58	119	377	264	17	57	89	157	991	173	2482	2797	1017	627	1305	2698
		63	0	54	46	0	71	161	67	78	57	103	64	127	27	0	171
		64	280	316	199	1674	818	341	893	160	518	2910	2011	1005	1168	439	934
	51-100	54	0	0	37	1	0	0	23	27	1	288	44	123	94	169	0
		57	1	36	0	0	24	0	0	0	9690	0	1905	41	72	54	112
		60	330	209	0	1	0	131	0	0	106	0	146	65	67	118	0
		62	10	148	74	0	51	55	387	79	0	55	0	0	59	106	0
		65	238	245	46	43	103	106	128	46	481	231	436	37	187	118	202
	>100	53	0	0	0	0	0	0	0	0	0	0	0	64	0	0	0
		61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		66	0	0	0	0	0	0	0	0	0	0	9	0	5	0	0
	mixed	59	1926	5766	749	20707	690	703	3051	6613	585	3065	225	3418	111	10013	11750

Table 8. Numbers caught at age per standard tow for sets in Stratum 43, 1984 survey.

Age	Set 12	59	60	73
1	.05	0.00	0.00	1.30
2	7.34	2.60	9.58	16.93
3	1.59	8.38	91.46	12.54
4	.72	15.55	476.05	13.85
5	.02	9.83	463.26	11.41
6		5.07	209.27	4.07
7		4.53	177.08	4.25
8		1.76	11.60	.65
9		.29	14.31	.34
10		.60		
11		.49		
12				
1+	9.72	49.10	1452.61	65.33

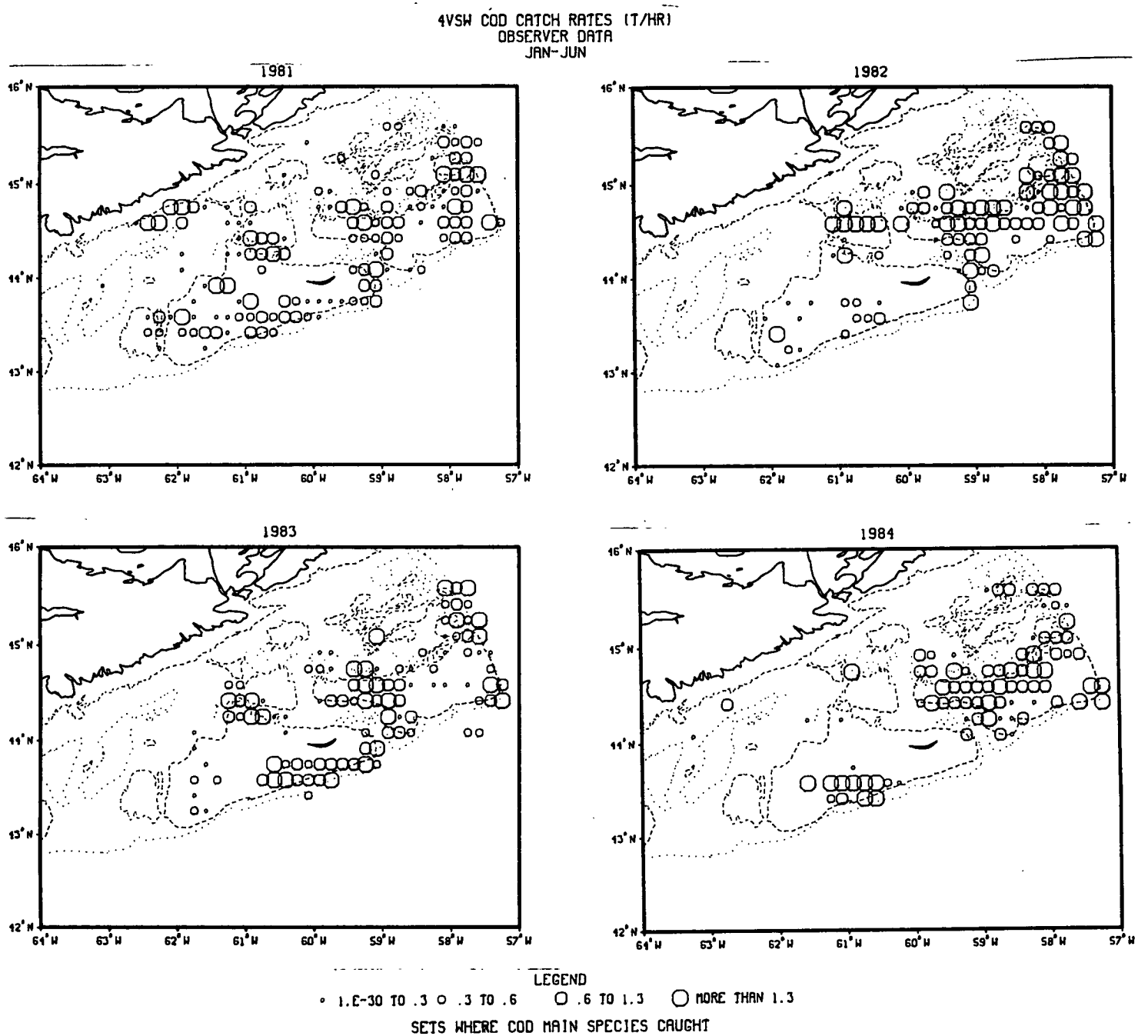

Fig. 1a. Fishery distribution by 10' squares. Symbol size indicates catch rate.

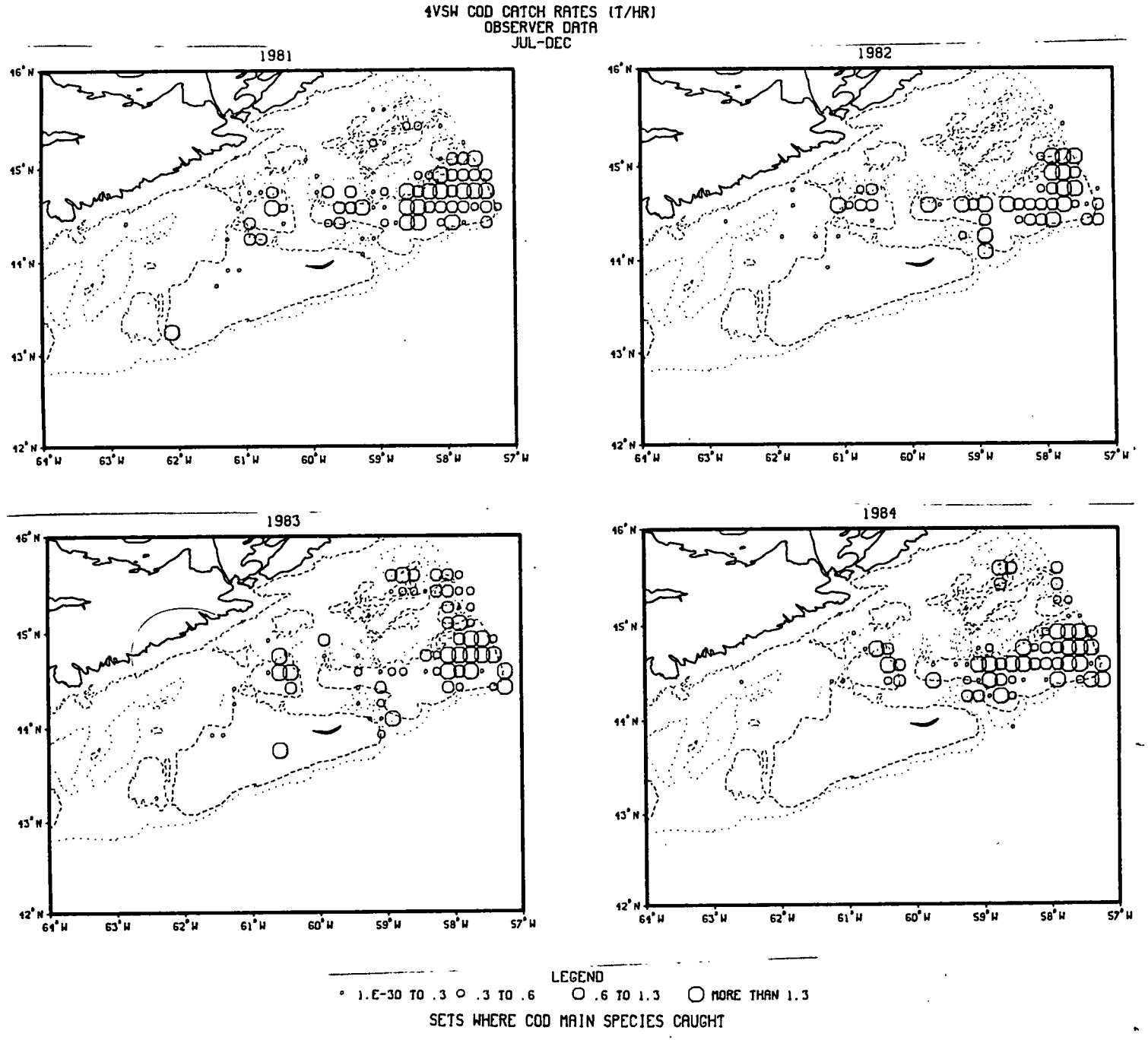

Fig. 1b. Fishery distribution by 10' squares. Symbol size indicates catch rate.

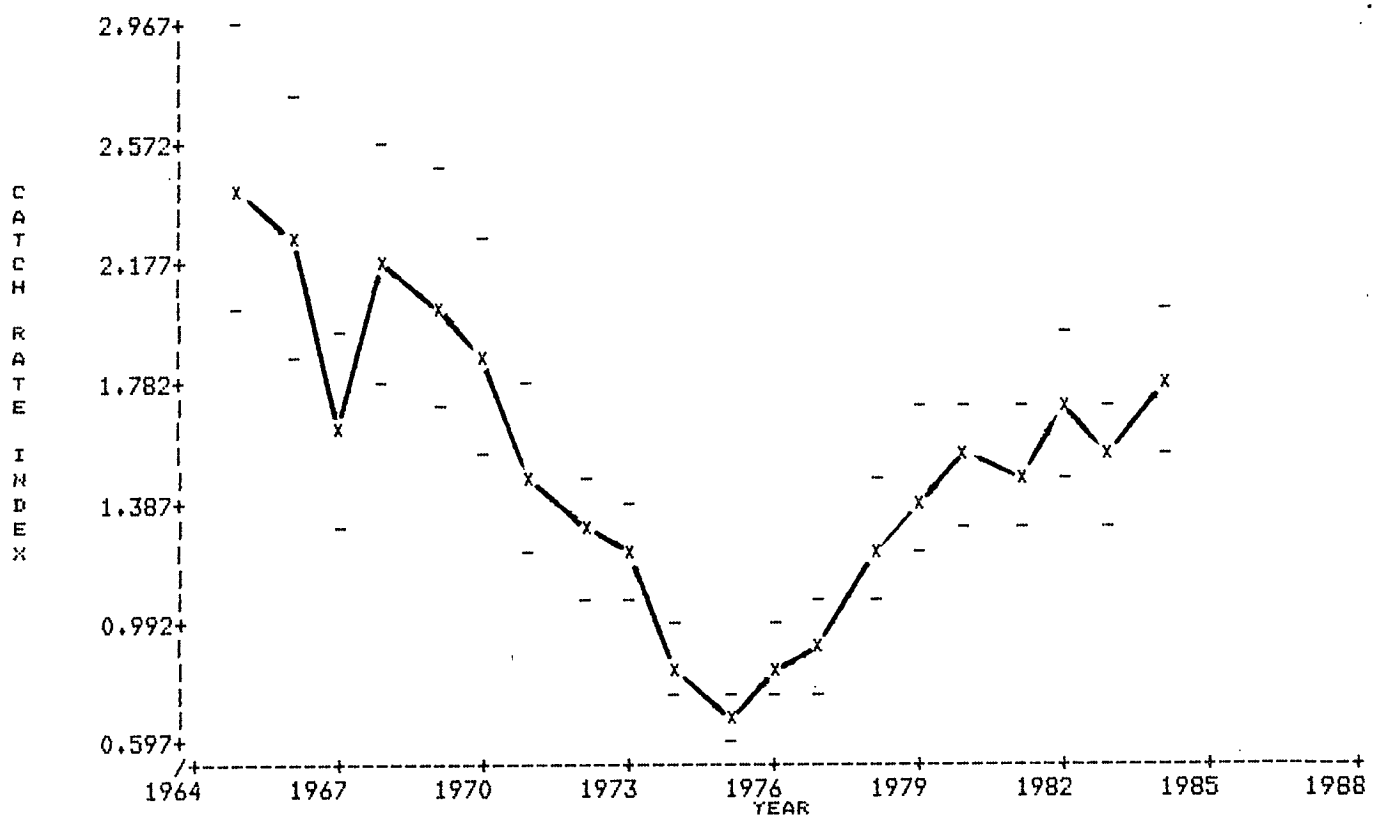

Fig. 2. Predicted catch rate index showing approximate 90% confidence limits from an analysis of catch rates for cod in 4VsW, using a multiplicative model.

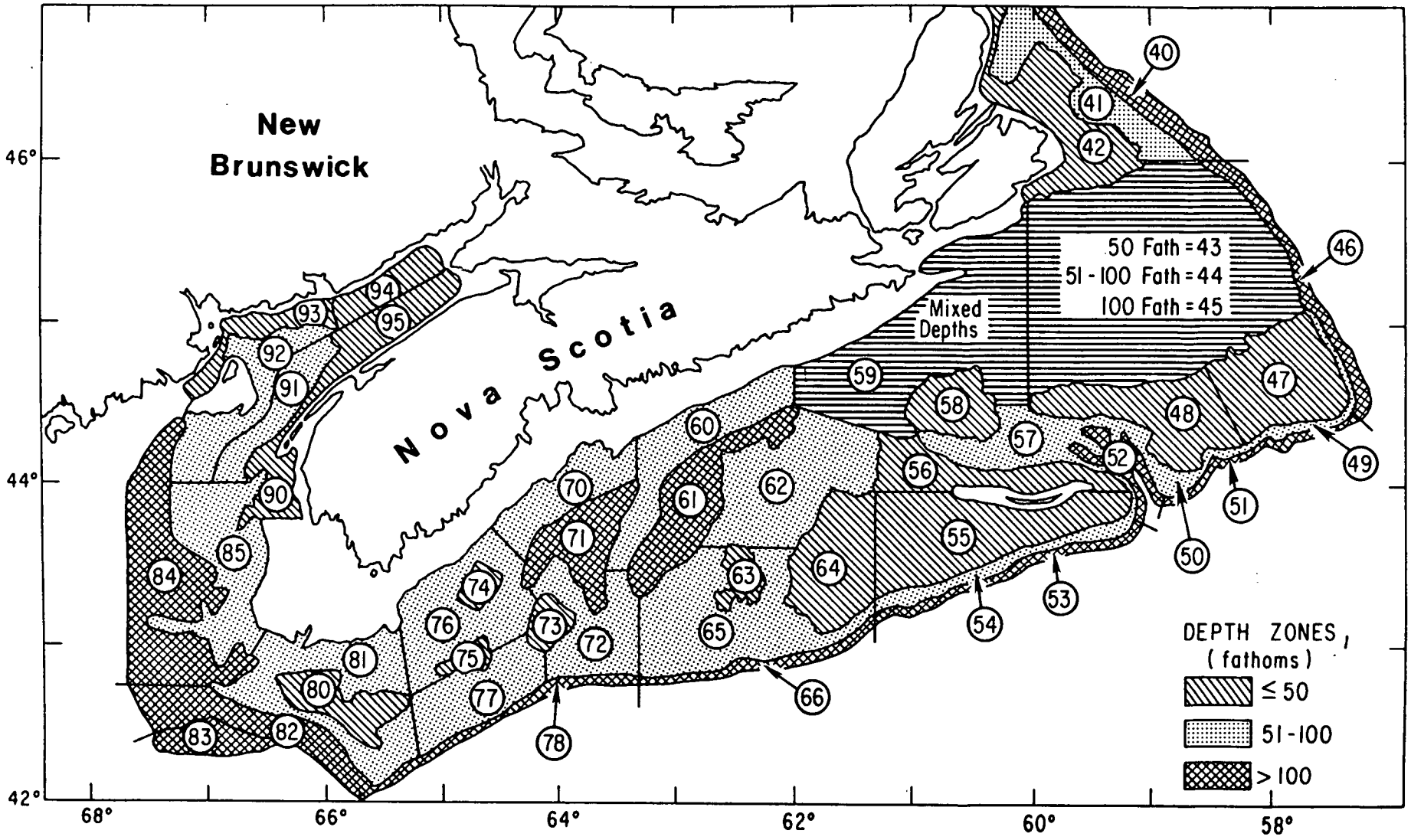

Fig. 3. Stratification scheme for the Scotian Shelf.

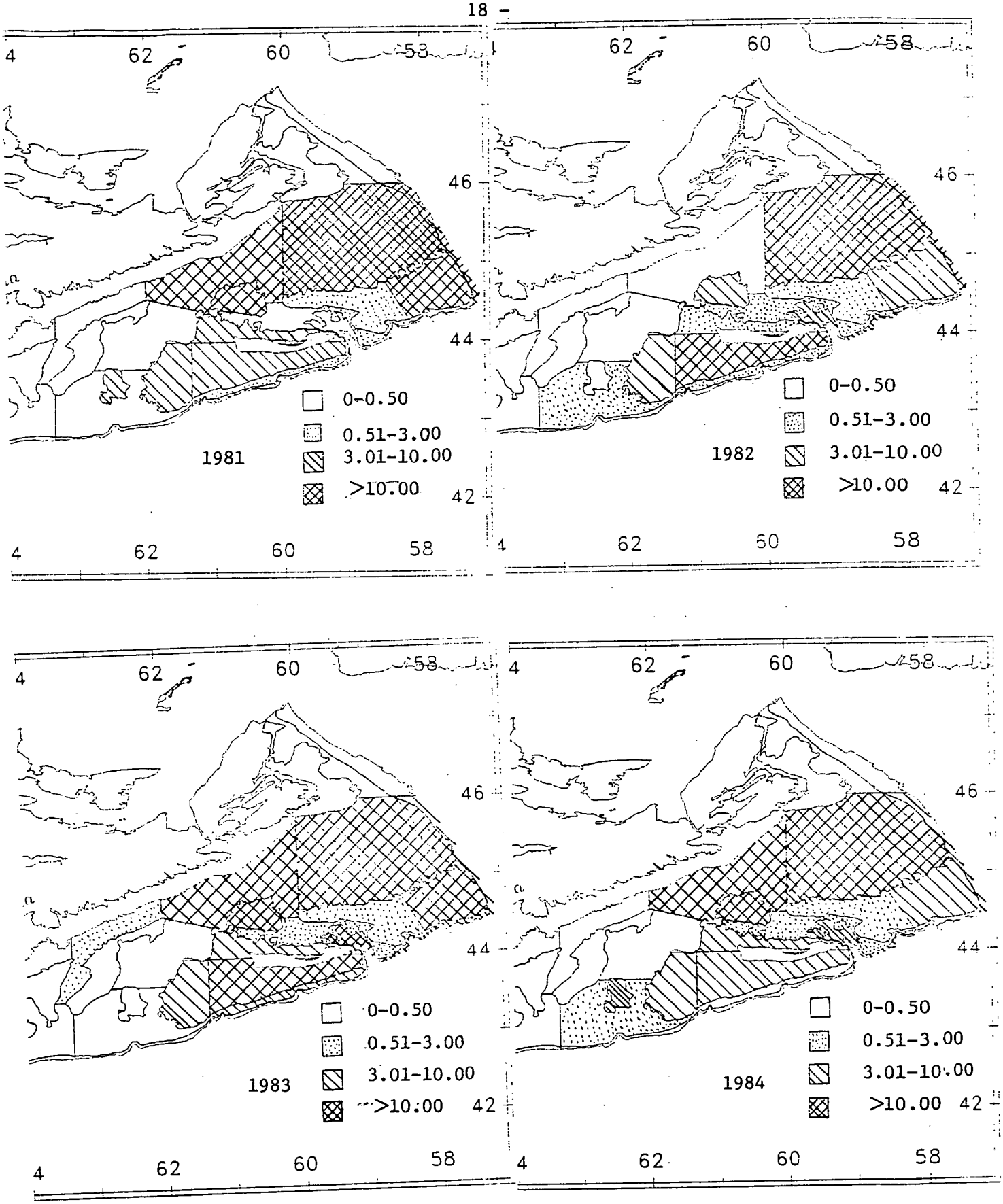

Fig. 4. Mean number of cod caught per standard tow in Strata 43-66 during July surveys, 1981-84.