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Canadian Atlantic Fisheries  
Scientific Advisory Committee

CAFSAC Research Document 85/32

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Comité scientifique consultatif des  
pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 85/32

**An Analytical Assessment of  
the 4X Cod Fishery**

by

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### Abstract

For the second year in a row, the 30,000 t TAC for 4X cod was not caught; 1984 landings were 25,262 t. Fish aged 3-5 comprised the largest proportion of the catch numbers, while full recruitment to the fishery occurred at age 5. Research vessel surveys suggest that 5+ numbers have been relatively stable since the late '70s; however, RV biomass appears to be declining. A new standardized commercial catch rate series was developed for the major 4X gear/tonnage class categories; the series was consistent with the individual catch rate trends and showed a monotonic decline since 1978. For the first time, all cod in 4X were assumed to comprise a unit stock, thus enabling an analytical assessment to be performed. Cohort analysis indicates that fishing mortality has consistently exceeded both  $F_{0.1}=0.17$  and  $F_{max}=0.29$ . The Survivor program and RV calibration of the cohort analysis both suggested that terminal fishing mortality was around 0.45. Cohort calibration with the standardized catch rate series resulted in a higher  $F_t$ . Catch projections were somewhat equivocal due to the short time series of data; however,  $F_{0.1}$  catches over the next 2 years appear to be substantially lower than the long-term yield of 29,000 t.

### Résumé

Deux ans de suite, le total admissible des prises (TPA) de morue dans la zone 4X de l'OPANO n'a pas atteint 30 000 t. En 1984, les quantités débarquées ont atteint 25 262 t. Les poissons âgés de 3 à 5 ans représentaient la majeure partie du nombre des prises, tandis que le plein recrutement dans les pêcheries n'avait lieu que pour le poisson de 5 ans. Les relevés effectués par les navires de recherche suggèrent que le nombre de poissons de plus de 5 ans est relativement stable depuis la fin des années 1970; toutefois, la biomasse enregistrée par les navires de recherche semble décliner. On a établi une nouvelle série normalisée des taux de prises commerciales, pour les principales catégories d'engins de pêche/jauge dans la zone 4X; la série concordait avec les tendances des taux de prise individuels et montrait un déclin monotone depuis 1978. Pour la première fois, on a admis que toutes les morues de la zone 4X représentaient un stock unitaire, ce qui nous a permis d'effectuer une évaluation analytique. L'analyse des cohortes indique que la mortalité par pêche a continuellement dépassé à la fois  $F_{0.1} = 0,17$  et  $F_{max} = 0,29$ . Le programme relatif au taux de survie et l'étalonnage sur le navire de recherche de l'analyse des cohortes ont tous deux suggéré que la mortalité par pêche de dernière année se situait autour de 0,45. L'étalonnage des cohortes avec la série normalisée du taux de prise a donné un  $F_t$  un peu plus élevé. Les projections relatives aux prises étaient légèrement équivoques, en raison de la brièveté de la collecte des données; toutefois, les prises  $F_{0.1}$  pendant les deux années suivantes semblent substantiellement plus basses que la production projetée à long terme de 29 000 tonnes.

## Introduction

Several factors complicate the assessment of cod in NAFO Division 4X. First of all, stock identification has not yet been completed, although there appear to be 1 or more offshore components and a complex of inshore stocks (Templeman, 1962; Gagné et al., MS 1983; Campana and Simon, MS 1984). Cod from the offshore and Georges Bank may also migrate inshore, especially during the summer (Wise, 1963; W.T. Stobo, unpub.). These mixed stocks cannot yet be differentiated among the landings. The stock question is now being addressed through major tagging studies: 6,500 mature cod were tagged on Browns and Georges Banks in the spring of both 1984 and 1985. In the interim, assessment by unit stock is currently impossible.

A second complication is the preponderance of small (tonnage class 1 = TC-1) vessels in the fishery. These vessels are not required to carry log books and thus provide no effort data. Further, their landing slips are often completed as to unit area landed, not fished.

Finally, much of the inshore area is rough-bottomed and consequently unavailable to research survey gear.

All of these factors suggest that a breakdown of the 4X cod fishery into unit areas (Figure 1) or offshore/inshore regions would be somewhat arbitrary. While analytical assessments of offshore cod may have been justified in the past (Halliday, MS 1974), our current view of the stock structure, combined with the apparent demise of the large vessel-offshore fishery and the tremendous travelling power of the small vessels of today (a significant number of TC-1s fish Georges Bank in the summer) indicate that such an approach is no longer possible. Accordingly, 4X cod has been treated as a unit stock for the purposes of this assessment. The mixed nature of both the fish and the fishery suggest that this assumption should not bias the results of the assessment to a large degree.

## Nominal Landings

Historically, the cod fishery in 4X has been prosecuted by a Canadian inshore fleet. Between 1947 and 1961, total landings for the Division averaged close to 15,000 t, with less than 3,000 t estimated as having come from the offshore grounds. The introduction of large foreign trawlers in 1962 resulted in a rapid increase in catches, which peaked at 35,500 t in 1968 (Table 1). Imposition of quotas on 4X haddock in 1970 substantially reduced cod catches (to approximately 22,000 t), emphasizing the by-catch nature of many cod landings. Since 1976, the fishery has been essentially 100% Canadian and has increased its landings to almost 32,000 t; 1983 and 1984 have seen a marked decline in landings (Figure 2).

The recent decline in cod catches is largely attributable to reduced landings by longliners (LL). In contrast small (TC2-3) otter trawlers (OT) substantially exceeded their allocation, the only gear category to have done so (Table 2). As the allocation limit was approached, misreporting to 5Y resulted. This misreporting is documented in the Appendix, and all

landings reported here have been adjusted accordingly. A breakdown of landings by gear, tonnage class, and unit area is presented in Table 3. Landings were split evenly between draggers and fixed gear. Catches by TC-1 vessels accounted for 35% of the total, considerably lower than in past years. Again, much of this decline is attributed to reduced catches by longliners, who in turn have blamed dogfish and aberrant temperature conditions for their reduced effort. While there is little evidence of temperature anomalies, dogfish abundance appears to be at a record high (C. Annand, unpub.).

### Age Composition of the Catch

Quarterly age-length keys were calculated for each of the major Canadian gear types (pooled among tonnage classes) from commercial samples. Sixty-five samples were collected from the commercial catch in 1984 (Table 4). Coverage was not so complete in the late 1970s, leaving some quarters unsampled for a given gear sector. In these instances, samples from adjacent quarters (before and after) were pooled to give an arithmetic mean for the age composition of the missing quarter. Missing weights at age were calculated similarly, but were weighted by numbers at age in each sample. Missing gillnet (GN) samples were approximated by the corresponding longline sample. Foreign (mainly USA) numbers at age were calculated using Canadian OT age-length keys (yearly). Landings by miscellaneous gears were incorporated through a pro-rated increase in total numbers at age. Length-weight relationships were derived from research survey data from the appropriate season (Jan.-June relationships based on March surveys). In years where a survey was not conducted, a seasonal mean across years was calculated.

Table 5 presents catch at age for each of the major gear sectors. The overall catch at age is presented in Table 6. Catch curves from these data suggest that age 5 fish are fully recruited to the fishery. Fish aged 3-5 comprise the largest proportion of the catch numbers while ages 3-6 make up most of the catch biomass (Table 7). No temporal trends are apparent in the weight at age matrix (Table 8).

### Stock Abundance Indices

#### Research Vessel Surveys

Random stratified surveys of the Scotian Shelf have been conducted since 1970; Strata 70-95 comprise the offshore and Bay of Fundy region of 4X (Figure 3). Surveys between 1970 and 1981 were carried out by the A.T. Cameron, while the Lady Hammond was used in 1982 and the Alfred Needler in subsequent years. Since no consistent differences were noted in the catchability of these vessels (for cod), no inter-vessel conversion factors have been applied. All RV data have been presented in terms of A.T. Cameron trawlable units.

Age-structured survey population estimates are presented in Table 9a. Table 9b presents the same data adjusted to the beginning of the year (through within-cohort, log-transformed means of adjacent years). While 5+

numbers appear to have increased through the early 1970s, subsequent years suggest relative stability in the numbers of fully-recruited fish (Figure 4). The same cannot be said for 5+ biomass; 1983 and 1984 values are the lowest of the time series (Figure 4; Table 10). In terms of recruitment, the 1980 year-class appears to be strong and will now be fully recruited to the fishery. The 1982 year-class may also prove to be strong, but it is too soon to be sure.

### Commercial Catch Rates

Last year's assessment (Campana and Simon, MS 1984) clearly demonstrated the futility of examining catch rate trends on a unit area basis. However, divisional catch rates show more promise. Six gear/TC categories (4-LL; 2-OT) were selected for quarterly catch rate analyses on the basis of the amount of effort data available. Discussions with fishermen indicate that longliners are more diligent in completing their logbooks. However, longliner catch rates are susceptible to the vagaries of feeding behaviour. For this reason, otter trawler catch rates were also calculated using an index that is liable to be more accurate, albeit less precise -- days fishing. Both sets of catch rate data are presented in Table 11. Trends are similar in both cases, but smoother in the latter (Figure 5). All show a substantial decline in catch rates over the past 7 years. The decline in the OT catch rate was unexpected considering the almost universal acceptance of the highly-efficient Gourock Rockhopper in the past 2-3 years. A standardized catch rate also decreased monotonically (Figure 6). Catch rates were standardized by normalizing the post-1976 catch rates over years within a given gear/quarter, and then averaging across gear components within years. An effort-weighted trend is not presented, but was very similar to the standardized curve.

## Estimation of Stock Size

### Survivor

As an index of terminal F for SPA calibration, the program Survivor has performed well in "a posteriori" analyses (O'Boyle et al., MS 1984; Gagné et al., MS 1984). Survivor was run on 4X cod using a calibration block of 1977-83 (ages 2-7) and full recruitment to the survey gear at age 6. The results are presented in Table 12. Terminal F on 5+ fish was calculated as 0.40. The low CVs suggest an excellent fit of the model to the data. However, this observation is tempered by the small range in the RV data. Since Survivor constrains through the origin, the coefficients of variation (CV) are (at least in part), due to the "two-point" nature of the relationship. This in itself is not necessarily a liability, since it suggests that fishing mortality and population size have remained relatively constant since 1977. As will be seen later, this suggestion is supported by the results of the cohort analysis.

### Cohort Analysis

Cohort analyses were run on the catch-at-age matrix in Table 6. Natural mortality was set at 0.2 and the age of full recruitment at 5.

Fishing mortality on the oldest age group was a weighted mean (weighted on population numbers) of  $F$ 's on the fully recruited age groups. Partial recruitment in the final year was set at the mean of the years 1977-83; the partial recruitment of age 5+ fish in 1984 was set at 1.0. Cohort runs were conducted for terminal  $F$ s of 0.2-0.8 at 0.05 intervals.

### Calibration of the SPA

Calibration of the cohort runs was difficult in view of the short time series of population estimates. The problem was exacerbated by the relative stability in the survey estimates since 1977; this resulted in a narrow range of values through which the regression was calculated. Caveats aside, the best relationship (in terms of correlation coefficient and minimization of the residuals of the last 3 years) was  $F_t = 0.40$  (Table 13; Figure 7). Beginning of the year RV estimates (age 5+) were used since no significant relationship developed when mid-year RV and mid-year SPA data were used.

Commercial catch rates were also used in calibration. The mid-year SPA fishable biomass was calculated as

$$(\text{POP} \times e^{-(F+M) \times .5}) \times \text{mean weight} \times \text{partial recruitment}$$

for each cohort run. Partial recruitment was set to 1.0 for all fully-recruited ages. Fishable biomass was tuned against the standardized pooled catch rate (using both indices of effort), the standardized LL catch rate and the standardized OT catch rate. All of these relationships were similar. Residuals of the last 3 years were minimized when  $F_t = .45$ , but the overall relationship was not significant.  $R^2$  values continued to increase above  $F_t = .80$ . Thus, catch rates could not be used as objective indicators of  $F_t$ . Visual examination of the tuning plots suggested that  $F_t$  was greater than or equal to .55, with 1980 as an outlier.

Calibration of the cohort runs against both RV and commercial catch rates produced estimates of  $F_t = .40-.55$ . This range is consistent with the estimate derived from Survivor ( $F_t = .40$ ). Accordingly, 0.45 was selected as the best indicator of  $F_t$ . The corresponding cohort run is presented in Table 14.

### **Yield-Per-Recruit**

Yield-per-recruit was calculated using the mean partial recruitment of 1977-83 at  $F_t = .45$ . Weights-at-age were based on 1984 values in one run and mean values in another. The results were similar.  $F_{0.1}$  is 0.17 for 4X cod (Table 15).

Long-term yield of 4X cod was estimated from the geometric mean of age 1 recruitment between 1977-83 ( $25,855 \times 10^3$ ). Expected annual yield (long-term) at  $F_{0.1}$  is 29,000 t.

## Catch Projections

Catch was projected to 1986 using 1984 weights-at-age, the mean of the 1977-83 partial recruitments (at  $F_t = .45$ ), and a GM value for age 1 recruitment (Table 16). For 1985 the catch was assumed to be at  $F_{0.1}$  yielding 13,000 t for 1985 and 16,100 t for 1986 (Table 17).

## Conclusions

Previous assessments of 4X cod have primarily been based on qualitative indices of stock well-being. As such, derivation of fishing mortalities was difficult. Catch curves indicated that past levels probably exceeded  $F_{0.1}$ , but were not necessarily indicative of current levels. The analytical assessment presented here allows more precise estimates to be made, and strongly suggests that fully-recruited  $F$  in 1984 exceeded both  $F_{0.1}$  and  $F_{max}$ . Mean fish weight in the catch supports this statement (Figure 8).

The relatively short time series of data limits the predictive power of this assessment. Catch projections and yield per recruit models are particularly sensitive to estimates of partial recruitment -- the latter are generally calculated as mean values across the time series. While this time series is only 8 years, it is encouraging to note that at least half of the  $F$  matrix has converged (due to the high  $F$  values therein). A comparison of mean partial recruitments between the first and last half of the matrix yields little difference and suggests that current estimates are accurate, even if imprecise.

Both the qualitative and quantitative indices of stock abundance appear to be consistent among themselves. Research vessel and cohort analysis population estimates indicate that the numbers of fully-recruited fish have remained relatively constant over the past 8 years. RV biomass, commercial catch rates, and fishable biomass have all declined in the last half of this period, although it is possible that 1984 saw an end to the decline. The reason for a decline in biomass while numbers remained constant is unknown. It is possible that this trend will be reversed with the full recruitment of the strong 1980 year-class to the fishery.

This fishery has a long history of exploitation above  $F_{max}$  (Halliday MS 1971, MS 1974; Sinclair MS 1980; de Lafontaine MS 1981; Gagné et al. MS 1983; Campana and Simon MS 1984; this document). Through this period, the stock has not crashed, although yields have probably been suboptimal. However, we note that several stocks exist in this complex, and that differential fishing pressure on one of them could conceivably affect it adversely. This possibility can be better assessed once the time series of the analytical assessment has been extended by several years.

## Acknowledgements

S.J. Smith provided useful comments on an earlier version of the manuscript. We also thank Valerie Myra for having typed the document.

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Table 1. 4X cod nominal catches (t) by country, 1948-1984.

Year	Canada	Spain	USSR	USA	FRG	France	Japan	UK	Others	Total	% Canada (M&Q)
1948	17761	-	-	1999	-	-	-	-	-	19760	89.9
1949	14282	-	-	1799	-	-	-	-	-	16081	88.9
1950	19088	-	-	1581	-	-	-	-	-	20669	92.4
1951	16543	-	-	1639	-	-	-	-	-	18182	91.0
1952	16570	-	-	1651	-	-	-	-	-	18221	90.9
1953	12903	-	-	1461	-	-	-	-	-	14364	89.8
1954	14614	-	-	2523	-	19	-	-	-	17156	85.2
1955	13291	-	-	1378	-	-	-	-	-	14669	90.6
1956	14655	-	-	1663	-	-	-	-	-	16318	89.8
1957	13544	-	-	1083	-	-	-	-	-	14627	92.6
1958	11074	-	-	1147	-	-	-	-	-	12221	90.6
1959	12866	-	-	862	-	-	-	-	-	13728	93.7
1960	12123	-	-	1605	-	-	-	-	-	13728	88.3
1961	12423	2	9	1261	-	-	-	-	-	13695	90.7
1962	14549	3	80	1197	-	-	-	-	-	15829	91.9
1963	15790	1	684	1301	9	-	-	-	-	17785	88.8
1964	21067	-	2922	1413	338	-	-	7	8	25755	81.8
1965	24221	144	1553	871	125	-	-	-	-	26914	90.0
1966	24164	803	4961	966	-	-	-	-	5	30899	78.2
1967	27814	2536	667	1445	-	-	-	-	-	32462	85.7
1968	30770	2829	1061	859	-	24	-	-	-	35543	86.6
1969	24056	8217	1	448	-	3	-	-	1	32726	73.5
1970	17994	3647	10	499	-	-	152	-	-	22302	80.7
1971	20181	2615	337	239	-	-	6	-	-	23378	86.3
1972	20479	1547	30	323	2	-	-	-	-	22381	91.5
1973	20002	1519	562	136	-	-	5	-	-	22224	90.0
1974	19005	1640	119	385	15	5	-	2	-	21171	89.8
1975	19493	900	207	483	3	-	-	-	5	21091	92.4
1976	16138	175	-	341	-	-	-	-	3	16657	96.9
1977	21990	-	4	760	-	185	-	-	-	22939	95.9
1978	23728	-	6	279	2	-	3	-	1	24019	98.8
1979	28677	-	-	48	-	-	1	-	-	28726	99.8
1980	31090	2	94	75	-	-	10	-	-	31271	99.4
1981	31090	-	-	127	-	-	5	-	-	31222	99.6
1982	32708	-	-	-	-	-	-	-	-	32708	100.0
1983 <sup>1</sup>	28975	-	11	286	-	-	1	-	-	29273	99.0
1984 <sup>1</sup>	25068	-	5	189	-	-	-	-	-	25262	99.2

<sup>1</sup> Preliminary

Table 2. Canadian quota allocation and reported Maritime landings by gear category for cod in 4X and 5Y. Landings are derived from Atlantic quota reports (FG = fixed gear; MG = mobile gear).

Year	Gear	4X		5Y	
		Allocation	Reported Landings	Allocation	Reported Landings
1981	All gear	Unlimited	30742	192	599
1982	All gear	30000	31520	200	871
	FG < 65'	20250	20505	/	/
	MG < 65'	6000	7942	200	871
	FG 65-100'	200	168	/	/
	MG 65-100'	400	150	/	/
	> 100'	3150	2494	/	/
1983	All gear	30000	25610	1500	2578
	FG < 65'	20250	14892	700	176
	MG < 65'	8000*	9167	700	2394
	FG 65-100'	200	54	/	/
	MG 65-100'	400	192	/	/
	> 100'	3150	1305	100	8
1984 <sup>1</sup>	All gear	30000	24088	1500	1404
	FG < 65'	20250	12206	700	164
	MG < 65'	6000	10201	700	1240
	FG 65-100'	200	5	/	/
	MG 65-100'	400	88	/	/
	> 100'	3150	1588	100	0

\* adjusted in mid-year

<sup>1</sup> Preliminary

Table 3. Nominal catch (t) of 4X cod in the Maritimes. Underlined catches represent the most dominant TC for a gear/unit area.

Year	Unit <sup>B</sup> Area	OTB					LL / LHP <sup>A</sup>				GN		Misc.	Total
		1	2	3	4	5	1	2	3	4	1	2		
1983	M	4	22	<u>42</u>	1	<u>321</u>	<u>1339</u>	257	187	/	1131	4	146	3454
	N	/	168	159	92	<u>379</u>	<u>3</u>	<u>609</u>	180	2	/	6	121	1719
	O	81	<u>462</u>	320	65	<u>307</u>	<u>5962</u>	<u>365</u>	140	3	725	141	126	8697
	P	/	<u>1023</u>	647	15	84	<u>7</u>	<u>714</u>	337	3	/	/	2	2832
	Q	234	<u>828</u>	<u>1341</u>	26	/	<u>721</u>	<u>329</u>	23	/	1	7	176	3686
	R	266	1334	<u>2399</u>	15	/	<u>612</u>	32	/	/	38	13	2	4711
	S	52	289	<u>494</u>	11	/	<u>771</u>	39	6	/	156	42	6	1866
	U	1	608	<u>821</u>	75	/	<u>1</u>	<u>448</u>	7	2	/	14	18	1995
Total		638	4734	6223	300	1091	9416	2793	880	10	2051	227	597	28960
1984	M	/	17	26	2	<u>315</u>	<u>762</u>	395	124	/	536	12	77	2266
	N	/	190	269	34	<u>1064</u>	<u>31</u>	<u>570</u>	199	2	/	9	9	2377
	O	68	<u>528</u>	355	47	68	<u>4282</u>	<u>391</u>	59	/	392	140	67	6397
	P	4	244	<u>399</u>	/	66	<u>178</u>	<u>560</u>	386	/	/	/	/	1837
	Q	95	692	<u>1148</u>	14	/	<u>540</u>	<u>56</u>	41	/	4	/	175	2765
	R	235	1202	<u>1774</u>	/	/	<u>562</u>	8	/	/	2	/	2	3785
	S	119	<u>423</u>	<u>391</u>	/	/	<u>421</u>	14	1	/	179	43	27	1618
	U	/	901	<u>1898</u>	12	/	<u>/</u>	<u>929</u>	167	1	/	18	94	4020
Total		521	4197	6260	109	1513	6778	2923	977	3	1112	222	451	25066

\* Catches misreported as being from 5Y have been allocated proportionally among OTB TC 2 and 3 vessels in 4X (see Appendix).

<sup>A</sup> LHP = handline

<sup>B</sup> See Figure 1 for location of unit area; U = unspecified.

Table 4. Data used to generate quarterly age/length keys for 4X cod.

## A) Landings

Year	OTB				Longline & Handline				Gillnet			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1977	645	2570	2274	1283	1624	4067	4265	1877	57	483	550	1041
1978	1102	2262	2950	1155	2466	3328	4891	1643	188	549	626	1296
1979	1094	2246	2100	2242	1848	4108	6710	1898	384	497	446	2317
1980	1757	4453	2780	1922	2175	5529	5388	2720	368	678	625	1073
1981	1559	2171	2892	1987	4429	5655	6115	2766	532	436	799	1219
1982	763	3529	4124	2648	4241	5468	6018	2162	587	844	1039	798
1983	1647	4640	5048	1653	2819	4898	4001	1378	213	510	1186	370
1984	1501	2519	6714	1867	2744	3139	3164	1633	108	182	783	262

## B) Samples

Year	OTB				Longline & Handline				Gillnet			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
1977	2	-	4	1	13	1	3	1	-	-	-	-
1978	5	-	3	-	8	1	-	-	-	-	1	-
1979	2	-	2	4	2	3	6	-	-	-	-	-
1980	5	3	2	5	12	7	3	8	1	-	2	-
1981	8	5	3	1	11	17	4	5	-	1	2	2
1982	3	10	3	2	6	7	6	3	-	-	1	3
1983	3	6	14	8	4	11	12	8	-	-	3	1
1984	5	4	13	3	8	19	9	1	-	-	3	-

## C) A/B Values

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
1977	.008 / 3.05	.008 / 3.045	.007 / 3.072	.007 / 3.1
1978	.008 / 3.05	.008 / 3.045	.009 / 3.023	.007 / 3.1
1979	.006 / 3.099	.007 / 3.063	.009 / 3.027	.004 / 3.208
1980	.009 / 3.025	.008 / 3.058	.007 / 3.091	.007 / 3.091
1981	.008 / 3.05	.008 / 3.045	.008 / 3.056	.009 / 3.034
1982	.008 / 3.027	.01 / 2.992	.012 / 2.957	.006 / 3.107
1983	.008 / 3.05	.008 / 3.045	.010 / 3.003	.006 / 3.136
1984	.008 / 3.05	.008 / 3.042	.009 / 3.034	.006 / 3.115

Table 5. Catch at age ('000) by major gear category.

		LL NUMBERS AT AGE (000)						4/ 5/85	
		1977	1978	1979	1980	1981	1982	1983	1984
1		0	5	0	0	0	0	0	0
2		233	76	246	710	199	401	79	18
3		1390	793	860	2708	2102	1339	983	326
4		882	1117	1857	1042	2633	2788	718	1446
5		1116	896	1314	1288	1089	1781	873	803
6		498	1177	458	606	785	415	623	538
7		177	349	306	227	381	262	295	253
8		123	109	120	96	226	163	190	93
9		57	30	41	38	123	93	90	42
10		60	16	41	33	51	70	48	41
11		30	4	14	4	20	18	38	24
12		21	4	10	8	16	18	6	22
13		8	1	0	0	18	16	18	5
1+		4595	4577	5267	6760	7643	7364	3961	3611
2+		4595	4572	5267	6760	7643	7364	3961	3611
3+		4362	4496	5021	6050	7444	6963	3882	3593
4+		2972	3703	4161	3342	5342	5624	2899	3267
5+		2090	2586	2304	2300	2709	2836	2181	1821
6+		974	1690	990	1012	1620	1055	1308	1018
7+		476	513	532	406	835	640	685	480
8+		299	164	226	179	454	378	390	227
9+		176	55	106	83	228	215	200	134
10+		119	25	65	45	105	122	110	92
11+		59	9	24	12	54	52	62	51
12+		29	5	10	8	34	34	24	27
13+		8	1	0	0	18	16	18	5

		OT NUMBERS AT AGE (000)						4/ 5/85	
		1977	1978	1979	1980	1981	1982	1983	1984
1		2	1	0	0	0	0	3	36
2		941	240	126	118	650	549	680	744
3		1097	1115	303	1651	1724	1147	2895	1943
4		513	859	906	606	1317	1432	1379	1599
5		258	717	614	793	345	1051	885	804
6		143	243	261	436	140	249	429	266
7		54	103	90	118	53	74	122	132
8		106	25	33	107	26	34	24	46
9		29	12	17	30	12	21	19	10
10		8	1	17	17	3	8	11	8
11		0	2	1	7	5	4	3	1
12		14	1	2	7	1	3	2	0
13		0	0	1	4	1	1	0	1
1+		3166	3319	2370	3894	4278	4573	6452	5589
2+		3164	3318	2370	3894	4278	4573	6449	5553
3+		2222	3078	2245	3776	3628	4024	5769	4809
4+		1125	1963	1941	2125	1905	2877	2874	2866
5+		612	1104	1036	1519	587	1445	1495	1267
6+		354	387	421	727	242	394	609	463
7+		211	144	160	291	102	146	180	197
8+		157	41	71	172	49	72	58	65
9+		51	16	38	65	22	38	34	19
10+		22	4	21	35	10	16	15	10
11+		14	3	4	18	7	9	5	2
12+		14	1	3	11	2	5	2	1
13+		0	0	1	4	1	1	0	1



Table 6. Catch at age.

Age	CATCH NUMBERS AT AGE							24/ 4/85	
	1977	1978	1979	1980	1981	1982	1983	1984	
1	2	11	0	0	0	0	3	37	
2	1439	393	496	943	885	1000	793	786	
3	3046	2321	1644	4902	4102	2610	4084	2369	
4	1724	2391	3617	1907	4500	4578	2223	3259	
5	1651	1906	2500	2410	1688	3304	2229	1785	
6	777	1711	892	1227	1043	825	1149	893	
7	279	547	515	408	525	399	556	426	
8	279	168	189	245	288	270	243	155	
9	105	51	71	81	164	136	128	55	
10	83	20	72	57	65	99	67	51	
11	36	6	18	12	29	41	48	30	
12	43	5	15	18	17	25	9	23	
13	10	1	1	4	19	18	18	6	
1+	9475	9531	10030	12214	13326	13306	11552	9876	
2+	9473	9520	10030	12214	13326	13306	11548	9839	
3+	8033	9128	9534	11271	12441	12306	10755	9052	
4+	4987	6807	7889	6368	8339	9696	6671	6684	
5+	3263	4416	4272	4461	3839	5119	4448	3424	
6+	1612	2511	1772	2051	2151	1814	2219	1639	
7+	835	800	880	824	1108	989	1070	746	
8+	556	252	365	416	583	590	513	320	
9+	277	84	176	172	294	319	270	165	
10+	172	33	105	91	130	183	143	110	
11+	89	13	33	34	65	84	75	59	
12+	53	6	16	22	37	43	28	30	
13+	10	1	1	4	19	18	18	6	

Age	PERCENT CATCH NUMBERS AT AGE							4/ 5/85	
	1977	1978	1979	1980	1981	1982	1983	1984	
1	0.03	0.11	0.00	0.00	0.00	0.00	0.03	0.37	
2	15.13	4.12	4.94	7.72	6.64	7.51	6.86	7.95	
3	32.01	24.34	16.37	40.12	30.74	19.61	35.33	23.94	
4	18.11	25.08	36.02	15.61	33.73	34.40	19.23	32.94	
5	17.35	19.99	24.90	19.72	12.65	24.83	19.28	18.04	
6	8.17	17.95	8.88	10.04	7.82	6.20	9.94	9.02	
7	2.93	5.74	5.13	3.34	3.94	3.00	4.81	4.31	
8	2.94	1.76	1.88	2.00	2.16	2.03	2.10	1.57	
9	1.10	0.53	0.71	0.66	1.23	1.02	1.11	0.55	
10	0.87	0.21	0.71	0.46	0.49	0.74	0.58	0.51	
11	0.38	0.07	0.18	0.09	0.21	0.31	0.41	0.30	
12	0.46	0.06	0.15	0.15	0.13	0.19	0.08	0.24	
13	0.10	0.01	0.01	0.03	0.14	0.14	0.16	0.06	

Table 7. Catch biomass at age.

		CATCH BIOMASS AT AGE							30/ 4/85
		1977	1978	1979	1980	1981	1982	1983	1984
1		1	5	0	0	0	0	1	14
2		1528	347	497	666	664	813	668	771
3		3885	3981	2320	6889	5039	3458	5361	3587
4		3193	4773	7685	4125	8807	8410	4106	6614
5		3827	4772	8036	7130	4698	9388	5827	4953
6		3278	6077	3778	5824	3713	3422	4868	3441
7		1569	2353	2758	2741	2939	2176	3091	2294
8		2118	1089	1384	1669	2085	1912	1982	1186
9		950	355	605	763	1362	1145	1336	513
10		768	245	818	560	728	901	786	590
11		386	57	186	136	344	414	565	393
12		625	53	172	258	213	347	144	245
13		150	11	19	47	298	253	298	89
14		436	0	76	10	92	0	100	31
15		33	20	0	18	29	50	0	51
16		182	18	110	36	120	0	33	249
1+		22929	24155	28445	30873	31132	32688	29165	25022
2+		22928	24150	28445	30873	31132	32688	29164	25007
3+		21400	23803	27948	30206	30468	31876	28496	24236
4+		17515	19822	25628	23317	25429	28418	23135	20649
5+		14322	15049	17943	19192	16621	20008	19029	14035
6+		10495	10277	9907	12062	11923	10620	13201	9082
7+		7217	4200	6129	6238	8210	7198	8333	5641
8+		5648	1848	3371	3497	5271	5022	5243	3347
9+		3530	758	1987	1829	3186	3109	3261	2161
10+		2580	404	1382	1066	1824	1964	1925	1648
11+		1812	159	564	506	1096	1064	1139	1058
12+		1426	102	377	370	752	650	574	665
13+		801	49	205	112	539	303	430	421
14+		650	38	186	65	241	50	133	332
15+		215	38	110	55	148	50	33	301
16+		182	18	110	36	120	0	33	249

		PERCENT CATCH BIOMASS AT AGE							30/ 4/85
		1977	1978	1979	1980	1981	1982	1983	1984
1		0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.06
2		6.66	1.44	1.75	2.16	2.13	2.49	2.29	3.08
3		16.94	16.48	8.16	22.31	16.19	10.58	18.38	14.34
4		13.93	19.76	27.02	13.36	28.29	25.73	14.08	26.43
5		16.69	19.75	28.25	23.10	15.09	28.72	19.98	19.80
6		14.30	25.16	13.28	18.86	11.93	10.47	16.69	13.75
7		6.84	9.74	9.70	8.88	9.44	6.66	10.60	9.17
8		9.24	4.51	4.86	5.40	6.70	5.85	6.80	4.74
9		4.15	1.47	2.13	2.47	4.38	3.50	4.58	2.05
10		3.35	1.02	2.88	1.81	2.34	2.76	2.69	2.36
11		1.68	0.23	0.66	0.44	1.10	1.27	1.94	1.57
12		2.73	0.22	0.61	0.84	0.68	1.06	0.49	0.98
13		0.66	0.04	0.07	0.15	0.96	0.77	1.02	0.36
14		1.90	0.00	0.27	0.03	0.30	0.00	0.34	0.12
15		0.14	0.08	0.00	0.06	0.09	0.15	0.00	0.21
16		0.79	0.07	0.39	0.12	0.38	0.00	0.11	1.00



Table 8. Mean weight at age in the commercial catch (kg).

I	MEAN WEIGHT AT AGE							
	1977	1978	1979	1980	1981	1982	1983	1984
1	0.48	0.51	0.00	0.00	0.00	0.00	0.36	0.39
2	1.06	0.88	1.00	0.71	0.75	0.81	0.84	0.98
3	1.28	1.72	1.41	1.41	1.23	1.32	1.31	1.51
4	1.85	2.00	2.12	2.16	1.96	1.84	1.85	2.03
5	2.32	2.50	3.21	2.96	2.78	2.84	2.61	2.77
6	4.22	3.55	4.24	4.75	3.56	4.15	4.24	3.85
7	5.62	4.30	5.35	6.72	5.59	5.45	5.55	5.38
8	7.58	6.47	7.32	6.82	7.23	7.08	8.17	7.64
9	9.06	6.97	8.51	9.41	8.31	8.40	10.45	9.39
10	9.28	12.14	11.43	9.67	11.18	9.09	11.66	11.65
11	10.69	8.81	10.52	11.74	12.04	10.11	11.88	13.24
12	14.42	9.80	11.81	14.39	12.32	14.00	15.50	10.45
13	15.76	10.19	16.95	11.20	15.44	13.72	16.19	14.20
14	16.33	0.00	13.80	9.32	15.09	0.00	16.26	15.17
15	15.33	16.95	0.00	17.54	14.16	16.54	0.00	16.86
16	15.61	16.69	16.52	17.42	16.83	0.00	16.29	17.28

Table 9. Numbers at age in RV surveys of 4X. Surveys between 1970-81 were made by the A.T. Cameron, 1982 by the Lady Hammond, and 1983-84 by the Alfred Needler. All values converted to A.T.C. units. No inter-vessel conversion factors were used.

a) Summer

STRATA 70-95

3/ 4/85

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0	0	0	27	190	0	0	27	0	2134	72	85	159	0	
1	1104	392	295	134	482	1257	166	372	232	3391	240	2595	852	164	943
2	1758	8239	1832	2576	1140	3072	1331	2764	1252	4392	1026	2820	2099	1253	6339
3	2769	4579	3597	1365	5645	1810	2833	4956	2070	2195	3303	2660	2074	4829	4148
4	4932	736	3189	2430	1308	3530	2330	3060	3013	2322	1326	3002	2174	2763	2777
5	2168	1684	834	771	2192	2375	2158	904	1761	2019	1225	1573	1788	1720	2276
6	2911	764	570	307	1176	1343	907	1434	630	1116	1667	1018	1023	1076	841
7	1230	1074	147	184	184	863	465	418	482	528	536	560	280	437	590
8	602	53	642	59	0	282	252	248	107	350	248	456	289	0	73
9	202	0	264	211	54	176	65	53	84	59	148	126	250	89	77
10	110	20	125	53	26	32	66	31	0	72	0	108	77	44	30
11	16	0	29	34	41	194	15	45	0	97	81	31	36	0	0
12	0	0	29	7	0	172	0	14	0	0	0	8	31	0	0
0+	17802	17541	11553	8158	12438	15106	10588	14299	9658	16541	11934	15029	11057	12535	18095
1+	17802	17541	11553	8131	12248	15106	10588	14299	9631	16541	9800	14957	10972	12376	18095
2+	16698	17149	11258	7997	11766	13849	10422	13927	9399	13150	9560	12362	10120	12212	17152
3+	14940	8910	9426	5421	10626	10777	9091	11163	8147	8758	8534	9542	8021	10958	10813
4+	12171	4331	5829	4056	4981	8967	6258	6207	6077	6563	5231	6882	5946	6129	6664
5+	7239	3595	2640	1626	3673	5437	3928	3147	3064	4241	3905	3880	3772	3366	3887
6+	5071	1911	1806	855	1481	3062	1770	2243	1303	2222	2680	2307	1985	1647	1611
7+	2160	1147	1236	548	305	1719	863	809	673	1106	1013	1289	962	570	769
8+	930	73	1089	364	121	856	398	391	191	578	477	729	682	133	180
9+	328	20	447	305	121	574	146	143	84	228	229	273	393	133	107
10+	126	20	183	94	67	398	81	90	0	169	81	147	144	44	30
11+	16	0	58	41	41	366	15	59	0	97	81	39	67	0	0
12+	0	0	29	7	0	172	0	14	0	0	0	8	31	0	0

b) Beginning of year numbers calculated from the mean of log-transformed, within-cohort values between adjacent years.

BEGINNING-OF-YEAR RV POPULATION

14/ 4/85

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	20	17	12	114	489	13	19	15	303	15	2353	248	118	388
2	3016	847	872	391	1217	1293	677	682	1009	1865	823	2334	1033	1020
3	2837	5444	1581	3813	1436	2950	2568	2392	1658	3809	1652	2418	3184	2280
4	1428	3821	2956	1336	4464	2054	2944	3864	2192	1706	3149	2405	2394	3662
5	2882	783	1368	2308	1763	2760	1451	2321	2466	1687	1444	2317	1934	2508
6	1287	980	506	952	1716	1468	1759	755	1402	1835	1117	1269	1387	1203
7	1768	335	324	238	1007	790	616	831	577	773	966	534	669	797
8	255	830	93	14	228	466	340	211	411	362	494	402	17	178
9	25	118	368	56	13	135	116	144	79	228	177	337	161	9
10	64	11	118	74	42	108	45	7	78	8	126	98	104	52
11	10	24	65	47	71	22	54	6	10	76	6	62	9	7
12	4	5	14	6	84	14	14	7	1	10	25	31	6	1
1+	13596	13217	8478	9349	12529	12073	10605	11237	10186	12373	12333	12455	11016	12104
2+	13576	13200	8466	9235	12041	12060	10585	11221	9883	12358	9979	12207	10897	11717
3+	10560	12353	7595	8844	10824	10767	9908	10539	8874	10493	9157	9873	9864	10696
4+	7723	6909	6013	5031	9387	7817	7340	8147	7216	6684	7505	7455	6680	8416
5+	6295	3088	3057	3694	4923	5763	4395	4283	5024	4978	4356	5050	4286	4754
6+	3413	2304	1489	1386	3161	3003	2944	1961	2557	3291	2912	2733	2352	2246
7+	2126	1324	983	434	1445	1536	1185	1207	1156	1457	1795	1465	965	1043
8+	358	989	659	197	438	745	569	375	579	683	829	931	297	247
9+	103	159	566	183	210	279	229	164	168	321	334	529	280	68
10+	78	41	198	127	197	144	114	20	89	94	157	192	119	59
11+	14	29	79	52	155	36	69	12	11	86	31	93	15	8
12+	4	5	14	6	84	14	14	7	1	10	25	31	6	1

Table 10. Weight (kg) and biomass ('000 t) at age as derived from summer RV surveys.

WEIGHT AT AGE STRATA 70-95															11/ 4/85
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.14	0.09	0.15	0.11	0.07	0.12	0.03	0.11	0.05	0.08
2	0.00	0.00	0.00	0.00	0.00	0.60	0.49	0.66	0.69	0.46	0.63	0.18	0.52	0.59	0.60
3	0.00	0.00	0.00	0.00	0.00	1.15	1.30	1.47	1.53	1.53	1.62	0.76	1.51	1.31	1.39
4	0.00	0.00	0.00	0.00	0.00	2.36	1.96	2.31	2.61	2.58	3.83	1.95	2.47	1.81	2.49
5	0.00	0.00	0.00	0.00	0.00	3.12	3.59	3.54	3.70	4.11	5.16	3.38	3.95	3.16	2.88
6	0.00	0.00	0.00	0.00	0.00	5.07	5.42	5.73	5.61	4.83	6.13	5.17	5.56	4.47	3.84
7	0.00	0.00	0.00	0.00	0.00	6.86	6.91	7.22	7.96	7.80	9.49	6.04	8.11	6.12	4.71
8	0.00	0.00	0.00	0.00	0.00	6.33	8.70	9.99	10.43	10.36	8.54	8.41	9.09	0.00	11.28
9	0.00	0.00	0.00	0.00	0.00	9.55	8.51	6.09	10.32	10.08	11.11	0.00	11.62	8.98	7.50
10	0.00	0.00	0.00	0.00	0.00	0.00	8.74	0.00	0.00	18.92	0.00	0.00	11.45	7.41	13.41
11	0.00	0.00	0.00	0.00	0.00	16.30	15.14	0.00	0.00	15.71	11.42	0.00	9.64	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	8.72	0.00	17.08	0.00	0.00	0.00	0.00	15.73	0.00	0.00

BIOMASS AT AGE STRATA 70-95															11/ 4/85
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	176	15	56	26	237	29	78	94	8	75
2	0	0	0	0	0	1843	652	1824	864	2020	646	508	1092	739	3803
3	0	0	0	0	0	2081	3683	7285	3167	3358	5351	2022	3132	6326	5766
4	0	0	0	0	0	8331	4567	7069	7864	5991	5079	5854	5370	5001	6916
5	0	0	0	0	0	7410	7747	3200	6516	8298	6321	5317	7061	5434	6555
6	0	0	0	0	0	6809	4916	8217	3534	5390	10219	5263	5688	4812	3231
7	0	0	0	0	0	5920	3213	3018	3837	4118	5087	3382	2269	2675	2777
8	0	0	0	0	0	1785	2192	2478	1116	3626	2119	3835	2623	0	822
9	0	0	0	0	0	1681	553	323	867	595	1644	0	2901	803	576
10	0	0	0	0	0	0	577	0	0	1362	0	0	879	324	404
11	0	0	0	0	0	3162	227	0	0	1524	925	0	347	0	0
12	0	0	0	0	0	1500	0	239	0	0	0	0	489	0	0
0+	0	0	0	0	0	40699	28343	33708	27790	36520	37418	26258	31943	26122	30926
1+	0	0	0	0	0	40699	28343	33708	27790	36520	37418	26258	31943	26122	30926
2+	0	0	0	0	0	40523	28328	33653	27765	36283	37389	26180	31850	26114	30850
3+	0	0	0	0	0	38679	27675	31828	26901	34263	36743	25673	30758	25375	27047
4+	0	0	0	0	0	36598	23993	24543	23734	30904	31392	23651	27626	19048	21281
5+	0	0	0	0	0	28267	19426	17474	15870	24914	26314	17797	22256	14047	14365
6+	0	0	0	0	0	20857	11679	14274	9354	16616	19993	12480	15195	8614	7809
7+	0	0	0	0	0	14048	6763	6057	5820	11225	9774	7217	9507	3802	4579
8+	0	0	0	0	0	8128	3549	3039	1983	7107	4687	3835	7238	1127	1801
9+	0	0	0	0	0	6343	1357	562	867	3481	2569	0	4615	1127	979
10+	0	0	0	0	0	4662	804	239	0	2886	925	0	1714	324	404
11+	0	0	0	0	0	4662	227	239	0	1524	925	0	836	0	0
12+	0	0	0	0	0	1500	0	239	0	0	0	0	489	0	0

Table 11. Commercial catch rates for otter trawlers (OT) and longliners (LL) in 4X (all unit areas combined). Effort values in parentheses. a) Effort units are thousands of hooks (LL) and tons/hr (OT); b) Effort is in terms of days fishing.

a)

Year	G e a r					
	LL - TC2 Jan-Mar	LL - TC2 Apr-June	LL - TC2 July-Sept	LL - TC3 Jan-Mar	OT - TC2 Apr-June	OT - TC3 July-Sept
1972	.16 ( 75)	/	/	.17 ( 178)	/	/
1973	.30 ( 50)	.34 ( 65)	.20 ( 668)	.34 ( 143)	/	/
1974	.35 ( 378)	.23 (1026)	.18 ( 914)	.33 ( 917)	.10 ( 174)	/
1975	.29 ( 457)	.26 (1310)	.16 ( 835)	.33 ( 515)	.15 ( 205)	.20 ( 173)
1976	.21 ( 381)	.20 ( 496)	.14 (1267)	.28 ( 220)	.10 ( 716)	.15 ( 313)
1977	.26 (1292)	.24 (1406)	.25 (1085)	.36 ( 846)	.17 (2576)	.35 (1159)
1978	.32 (1810)	.24 (1252)	.22 (1380)	.41 (1027)	.20 (1142)	.58 (1448)
1979	.28 (1312)	.24 (1602)	.30 (1456)	.45 ( 715)	.28 ( 923)	.31 ( 897)
1980	.25 (1067)	.19 (2594)	.21 (1045)	.35 ( 940)	.18 (4636)	.26 (1914)
1981	.31 (2231)	.23 (1550)	.17 ( 689)	.44 ( 839)	.22 (1947)	.23 ( 811)
1982	.24 (3352)	.22 (2117)	.25 (2081)	.32 (1648)	.14 (3074)	.25 (1997)
1983	.25 (1474)	.26 (1164)	.16 ( 583)	.34 ( 888)	.20 (5181)	.21 (2887)
1984	.24 (1469)	.20 ( 728)	.18 ( 166)	.29 (1011)	.12 (2574)	.24 (2780)

b)

Year	LL - TC2 Jan-Mar	LL - TC2 Apr-June	LL - TC2 July-Sept	LL - TC3 Jan-Mar	OT - TC2 Apr-June	OT - TC3 July-Sept
1972	/	/	/	/	/	/
1973	/	/	1.25 (106)	/	/	/
1974	2.71 ( 49)	1.69 (140)	1.43 (118)	3.24 ( 93)	/	/
1975	2.25 ( 59)	1.65 (203)	1.20 (108)	2.41 ( 71)	1.50 ( 20)	/
1976	1.63 ( 49)	1.29 ( 77)	1.13 (157)	2.48 ( 25)	0.86 ( 79)	1.26 ( 38)
1977	2.34 (144)	2.53 (131)	2.41 (111)	2.89 (105)	2.41 (187)	3.17 (127)
1978	3.02 (190)	2.35 (126)	1.84 (168)	3.80 (112)	1.91 (118)	4.69 (178)
1979	2.12 (170)	1.61 (236)	1.88 (230)	3.41 ( 94)	2.08 (123)	2.81 ( 98)
1980	1.73 (157)	1.37 (350)	1.32 (165)	2.92 (113)	2.27 (360)	2.83 (179)
1981	1.89 (369)	1.51 (241)	1.02 (114)	3.25 (114)	1.98 (218)	2.60 ( 73)
1982	1.85 (435)	1.41 (330)	1.61 (322)	2.55 (209)	1.64 (271)	2.50 (203)
1983	1.59 (233)	1.35 (223)	0.70 (132)	2.65 (114)	1.88 (559)	2.13 (278)
1984	1.38 (253)	1.10 (130)	0.97 ( 31)	1.99 (147)	1.08 (280)	2.22 (295)

Table 12. Results of the Survivor analysis. The calibration block was 1977-83, ages 2-7. K was set at age 6.

INTEGRATED CATCH 85/05/10

	1977	1978	1979	1980	1981	1982	1983	1984
2	17621	12020	22735	18414	10238	10593	3315	414
3	12409	12702	8890	16068	12718	6759	6135	1246
4	5958	7711	7680	5663	8704	6469	3353	1714
5	4178	3229	4094	3583	3012	3780	2265	939
6	1361	1896	1399	1692	1400	1347	1125	470
7	353	519	570	567	607	507	483	224
8	147	86	99	129	152	142	128	82

ITERATION 1 RMS=0.3230000697  
 a/a CHANGE IN SURVIVORS=34.53122307

AGE	SURVIVORS	K
2	60417	10.60
3	9703	4.95
4	7879	3.40
5	4258	2.89
6	1070	2.06
7	870	2.06
8	78	2.06

FINAL ITERATION (13)

INTEGRATED SURVIVORS 85/05/10

	1977	1978	1979	1980	1981	1982	1983	1984
2	0	288	2614	2632	8575	12990	13097	66771
3	1383	0	236	2140	2155	7020	10635	10723
4	1431	1132	0	193	1752	1765	5748	8707
5	536	1172	927	0	158	1435	1445	4706
6	826	439	959	759	0	129	1175	1183
7	192	676	359	786	621	0	106	962
8	364	157	554	294	643	509	0	87

POPULATION NUMBERS 85/05/10

	1977	1978	1979	1980	1981	1982	1983	1984
2	17621	12308	25349	21046	18813	23383	16412	67184
3	13792	12702	9125	18208	14874	13780	16771	11969
4	7389	8843	7680	5856	10656	8233	9101	10421
5	4714	4401	5021	3583	3170	5215	3709	5645
6	2187	2334	2358	2451	1400	1476	2300	1652
7	544	1195	930	1353	1228	507	589	1186
8	510	246	653	423	795	651	128	168

ESTIMATED SURVIVORS 85/05/10

	1977	1978	1979	1980	1981	1982	1983	1984
2	3180	340	7925	0	9756	7190	7383	60408
3	4035	0	658	115	223	2127	13164	17453
4	1803	1025	84	0	641	555	4467	6984
5	0	927	868	0	764	844	2008	5110
6	964	0	544	1054	421	460	807	1141
7	376	350	362	397	404	51	369	895
8	329	119	562	345	712	409	0	62

WEIGHTED SURVIVORS 85/05/10

	1977	1978	1979	1980	1981	1982	1983	1984
2	0	0	23	0	546	1693	5683	60408
3	11	0	1	2	8	677	1800	4018
4	27	11	0	0	18	44	1141	4385
5	0	38	18	0	2	60	234	1893
6	63	0	74	44	0	5	211	784
7	33	144	71	167	106	0	12	556
8	329	109	294	195	277	271	0	58

RMS=0.1229572659

ESTIMATED SURVIVORS FOR AGE 8 (WEIGHTED)

YEAR	SURVIVORS	VARIANCE	STANDARD ERROR	C.V. (σ/μ)
1977	329	28084	168	50.97
1978	142	4762	69	48.60
1979	501	29272	171	34.17
1980	266	15858	126	47.34
1981	582	36923	192	33.04
1982	460	25168	159	34.49
1983	0	0	1	33149.14
1984	78	2280	48	60.95

ESTIMATED SURVIVORS FOR 1984 (WEIGHTED)

AGE	SURVIVORS	VARIANCE	STANDARD ERROR	C.V. (σ/μ)
2	60408	486709740	22061	36.52
3	9701	10470339	3236	33.35
4	7877	6024804	2455	31.16
5	4257	1733526	1317	30.93
6	1070	222054	471	44.05
7	870	98688	314	36.12
8	78	2280	48	60.95

FINAL ESTIMATION FOR K

AGE	K	LN(K)	VAR(LN(K))	STANDARD ERROR	D.F.
2	10.60	2.2561	0.2091	0.1728	1
3	4.95	1.5471	0.1046	0.1223	1
4	3.40	1.2043	0.0366	0.0723	1
5	2.89	1.0131	0.0986	0.1187	1
6	2.06	0.6179	0.2072	0.1217	13
7	2.06	0.6179	0.2072	0.1217	13
8	2.06	0.6179	0.2072	0.1217	13

Table 12. Continued

		RESIDUALS							85/05/10
I		1977	1978	1979	1980	1981	1982	1983	1984
2		0.5082	0.0751	0.6076	-0.6605	0.4628	-0.0493	-0.2117	-0.0001
3		0.5759	-0.2149	0.1745	-0.1076	-0.1219	-0.2943	0.3544	0.5398
4		0.3410	0.1459	0.0265	-0.2627	-0.0442	-0.1089	0.0305	-0.0997
5		-0.5890	0.1465	0.1514	-0.0110	0.3617	-0.0082	0.2936	0.1542
6		0.2995	-0.5883	-0.0267	0.3352	0.4029	0.3549	-0.0378	0.0465
7		0.4572	-0.1868	0.1559	-0.2044	-0.0638	0.1273	0.4242	0.0230
8		-0.0003	-0.1090	0.0977	0.1886	0.1659	-0.0918	-4.1272	-0.1159

MEAN OF RESIDUALS=-0.005590550532  
 STANDARD DEVIATION OF RESIDUALS=0.6270223392

		OUTLIERS OF RESIDUALS							85/05/10
I		1977	1978	1979	1980	1981	1982	1983	1984
2		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8		0.00	0.00	0.00	0.00	0.00	0.00	-4.13	0.00

NEWTON  
 NAME OF CATCH MATRIX ?...  
 DCAGE  
 NATURAL MORTALITY ?...  
 0:  
 .2  
 STARTING YEAR AND AGE ?...  
 0:

1977	2		
2	74650	0.0117	
3	14454	0.1987	
4	13199	0.3161	
5	7159	0.3198	
6	2283	0.5579	
7	1529	0.3645	
8	264	1.0159	
1977	707	0.5654	
1978	357	0.7216	
1979	819	0.2923	
1980	572	0.6003	
1981	1027	0.3682	
1982	858	0.4234	
1983	247	11.5042	
1984	264	1.0159	

$$F_t = .40$$

Table 13. Summary of tuning results; age 5+ fish from the cohort analysis were regressed upon 5+ fish from the beginning of the year RV estimate. \* Denotes best fit.

$F_t$	Slope	Y Intercept	$R^2$	Sum of Residuals of Last 3 Years
.20	1.43	7834	.026	9528
.25	1.30	7303	.058	5765
.30	1.22	6951	.141	3261
.35	1.15	6699	.328	1477
.40	1.11	6511	.390*	967*
.45	1.07	6365	.244	1391
.50	1.04	6248	.147	2196
.55	1.02	6153	.099	2853
.60	1.00	6075	.073	3398
.65	.98	6008	.057	3857
.70	.97	5952	.047	4249
.75	.96	5903	.040	4587
.80	.95	5860	.035	4881





Table 15. Yield-per-recruit analysis for 4X cod. Weights at age and partial recruitment were based on the mean from 1977-83.

YIELD PER RECRUIT ANALYSIS - VERSION YLDW,YLD,0

85/05/07 11.37

INPUT DATA

<u>AGE</u>	<u>WEIGHT</u>	<u>FR</u>	<u>M</u>
1	0.435	0.000	0.20
2	0.880	0.090	0.20
3	1.398	0.436	0.20
4	1.976	0.700	0.20
5	2.751	1.000	0.20
6	4.069	1.000	0.20
7	5.496	1.000	0.20
8	7.288	1.000	0.20
9	8.812	1.000	0.20
10	10.788	1.000	0.20
11	11.128	1.000	0.20
12	12.836	1.000	0.20
13	14.207	1.000	0.20
14	14.328	1.000	0.20
15	16.230	1.000	0.20
16	16.663	1.000	0.20

85/05/07 11.37

CURRENT STATE SETTINGS

FIRST AGE: 1      LAST AGE: 16  
 MAXIMUM VALUE FOR FISHING MORTALITY: 2  
 FINITE DIFFERENCE STEP SIZE (EPS): 1E-6  
 ERROR TOLERANCE FOR CALCULATED F0.1, FMAX (TOL): 0.005  
 NUMBER OF SEGMENTS FOR MULTISECTION: 10

85/05/07 11.37

RESULTS

F0.1	FMAX	YIELD(F0.1)	YIELD(FMAX)
0.17	0.29	1.12	1.20

Table 16. Input to catch projection.

Age	Population No. ('000)	Weights at age (kg)**	Partial Recruitment***
1	25855*	0.39	0.00
2	21835	0.98	0.09
3	14617	1.51	0.44
4	13233	2.03	0.70
5	5395	2.77	1.00
6	2699	3.85	1.00
7	1287	5.38	1.00
8	469	7.64	1.00
9	165	9.39	1.00
10	153	11.65	1.00
11	90	13.24	1.00
12	71	10.45	1.00
13	19	14.20	1.00

\* GM of age 1 recruitment between 1977-83.

\*\* 1984 values.

\*\*\* Mean of 1977-83 values for ages 1-4.

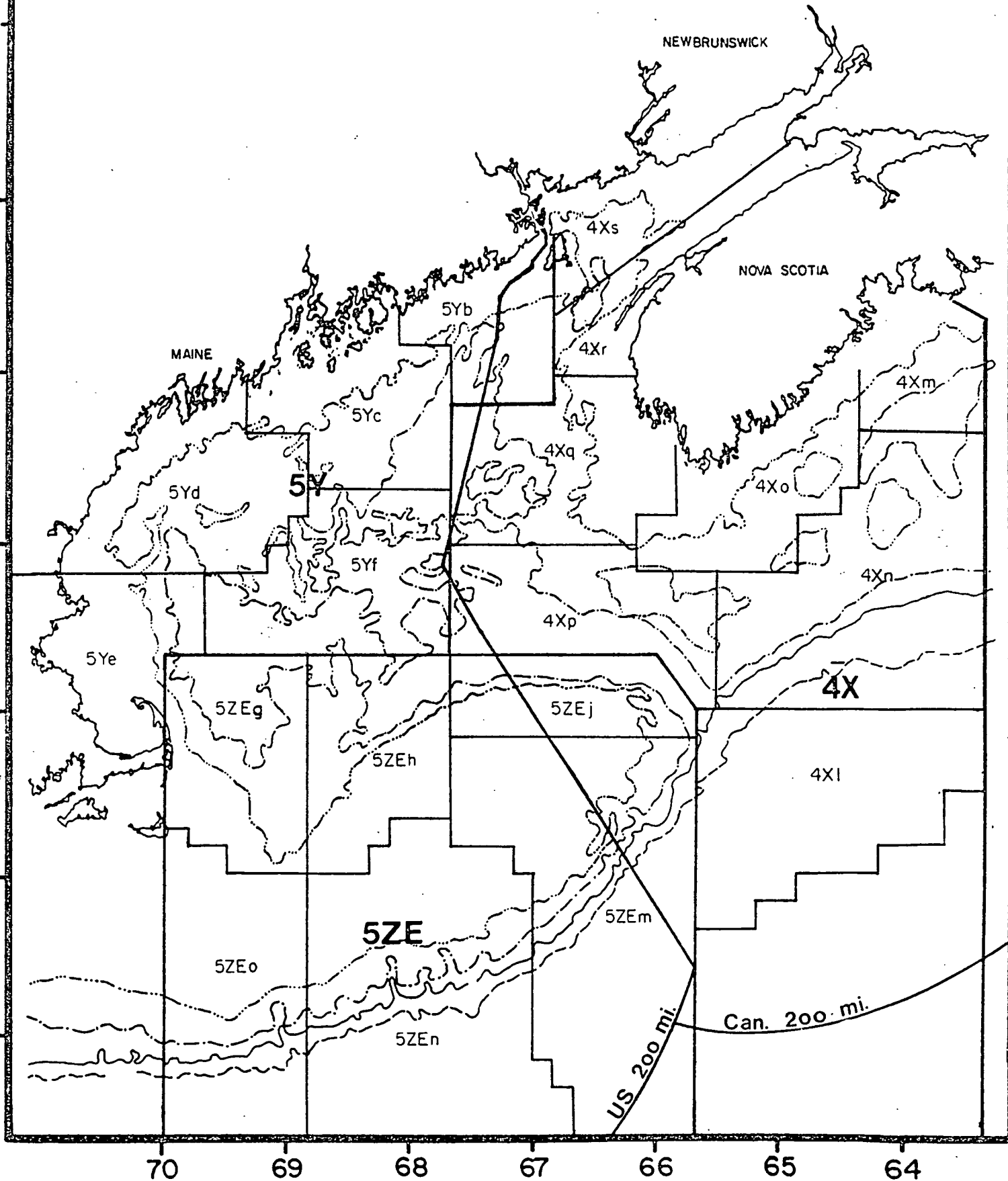
Table 17. Catch projection for 4X cod assuming that the  $F_{0.1}$  catch is caught in 1985.

POPULATION NUMBERS				FISHING MORTALITY			CATCH NUMBERS				
	1984	1985	1986		1984	1985	1986		1984	1985	1986
1	25855	25855	25855	1	0.002	0.000	0.000	1	37	1	1
2	21835	21135	21168	2	0.041	0.018	0.018	2	786	342	343
3	14617	17167	16995	3	0.196	0.087	0.087	3	2369	1302	1289
4	13233	9835	12881	4	0.315	0.140	0.140	4	3259	1168	1530
5	5395	7905	7000	5	0.450	0.200	0.200	5	1785	1303	1154
6	2699	2816	5299	6	0.450	0.200	0.200	6	893	464	873
7	1287	1409	1888	7	0.450	0.200	0.200	7	426	232	311
8	469	672	944	8	0.450	0.200	0.200	8	155	111	156
9	165	245	451	9	0.450	0.200	0.200	9	55	40	74
10	153	86	164	10	0.450	0.200	0.200	10	51	14	27
11	90	80	58	11	0.450	0.200	0.200	11	30	13	10
12	71	47	54	12	0.450	0.200	0.200	12	23	8	9
13	19	37	31	13	0.450	0.200	0.200	13	6	6	5
1+	95889	87289	92787	1+	0.147	0.068	0.074	1+	9876	5004	5781
2+	60033	61434	66932					2+	9839	5003	5780
3+	38198	40299	45765					3+	9052	4661	5437
4+	23581	23132	28770					4+	6684	3360	4149

POPULATION BIOMASS (AVERAGE)				CATCH BIOMASS			
	1984	1985	1986		1984	1985	1986
1	9132.21	9138.94	9138.94	1	14	0	0
2	19031.16	18621.38	18650.01	2	771	335	336
3	18277.78	22599.17	22372.49	3	3587	1971	1951
4	20984.26	16917.19	22157.43	4	6614	2370	3104
5	11006.83	18077.50	16006.55	5	4953	3616	3201
6	7647.14	8946.19	16831.72	6	3441	1789	3366
7	5096.91	6251.10	8377.41	7	2294	1250	1675
8	2636.21	4230.47	5943.62	8	1186	846	1189
9	1139.53	1895.84	3485.15	9	513	379	697
10	1310.29	827.92	1577.90	10	590	166	316
11	873.21	870.84	630.34	11	393	174	126
12	543.75	403.43	460.89	12	245	81	92
13	198.02	432.44	367.54	13	89	86	74
1+	97877.31	109212.40	126000.00	1+	24690	13064	16128
2+	88745.10	100073.46	116861.07	2+	24676	13064	16127
3+	69713.94	81452.09	98211.06	3+	23905	12728	15792
4+	51436.16	58852.92	75838.57	4+	20317	10757	13840

Figure 1. Unit Areas and MAFO Div./Subdiv.



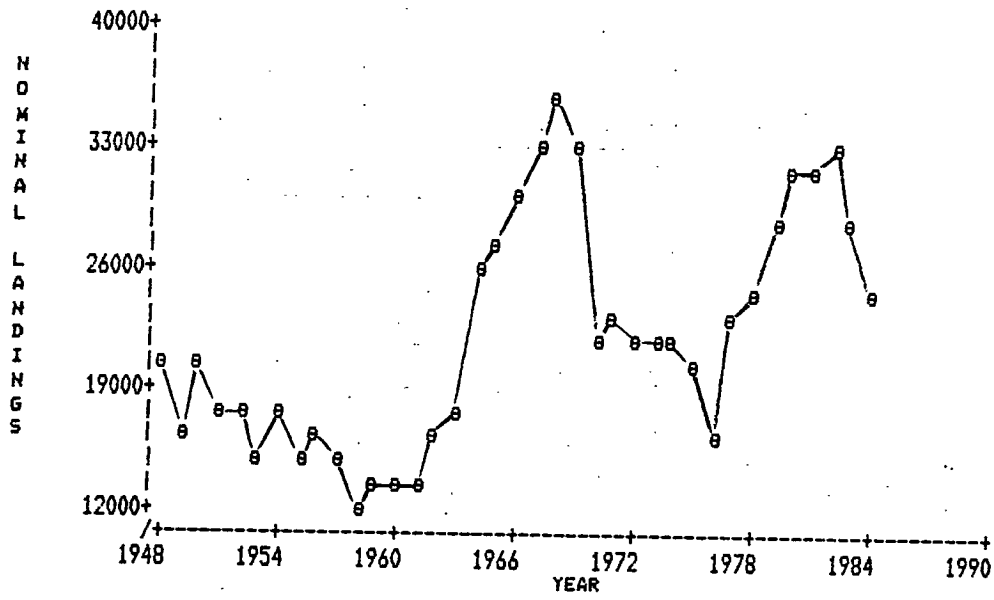


Figure 2. Nominal landings (t) of 4X cod between 1948 and 1984.

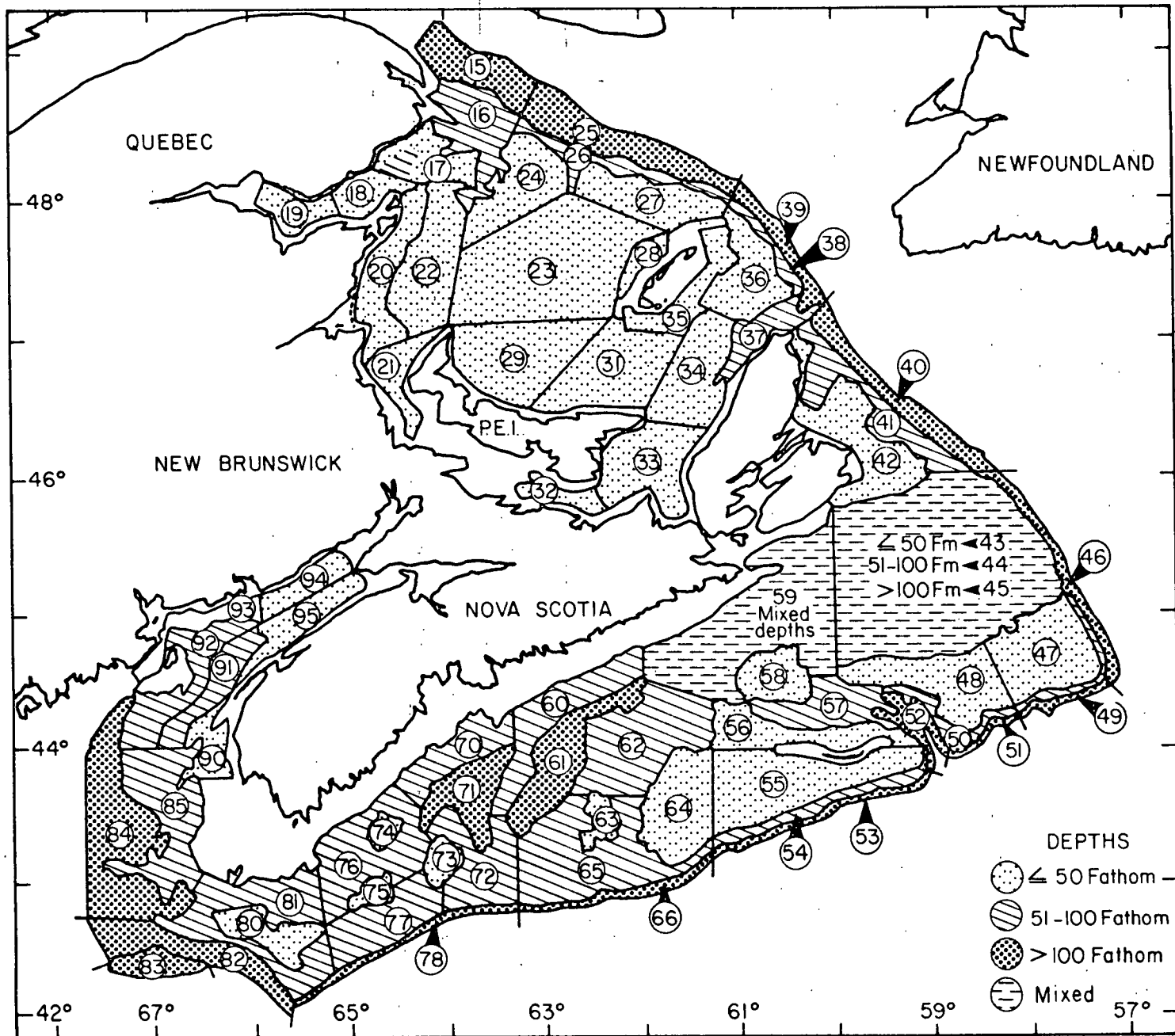


Figure 3. Stratification scheme used for the research groundfish surveys.

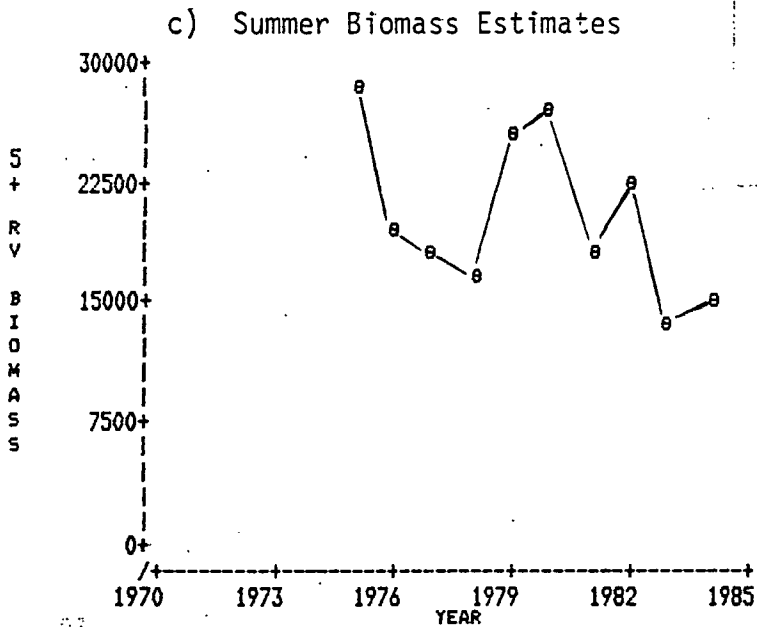
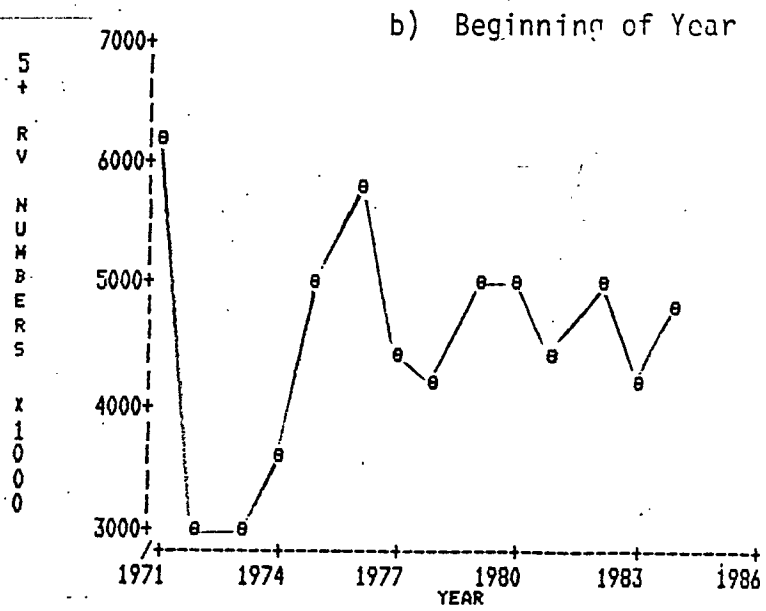
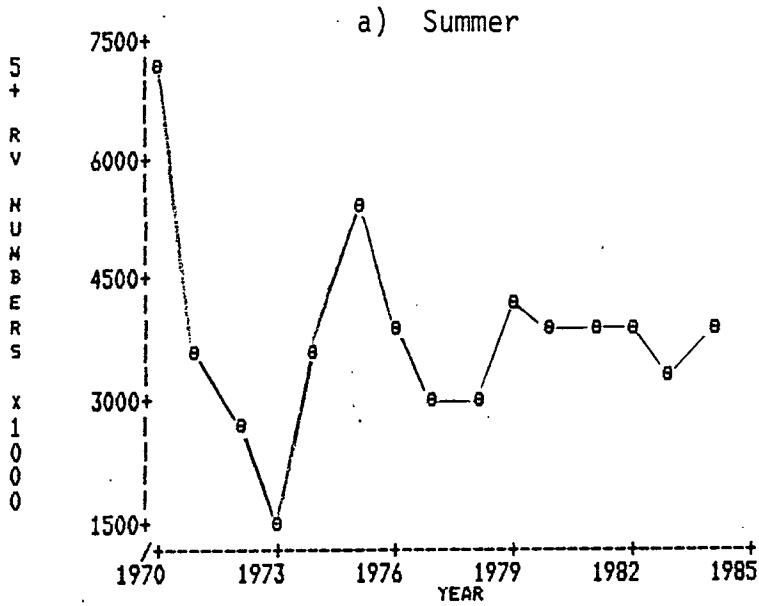


Figure 4. Trends in abundance (x1000) as determined from RV surveys.

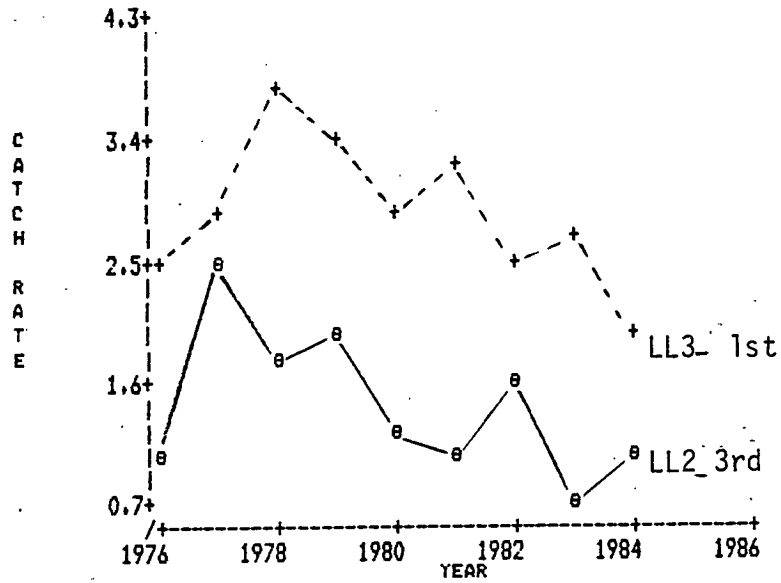
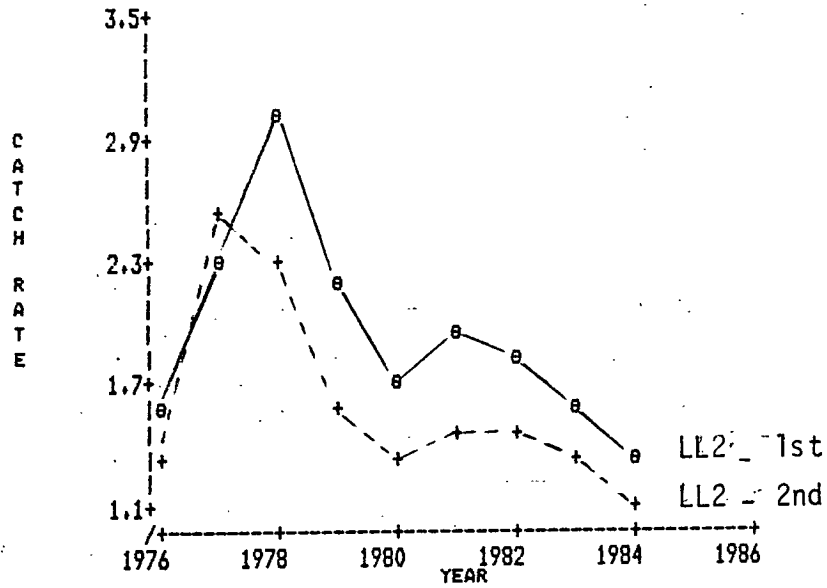


Figure 5. Quarterly catch rates of LLs and OTs in 4X. Effort is terms of days fishing.



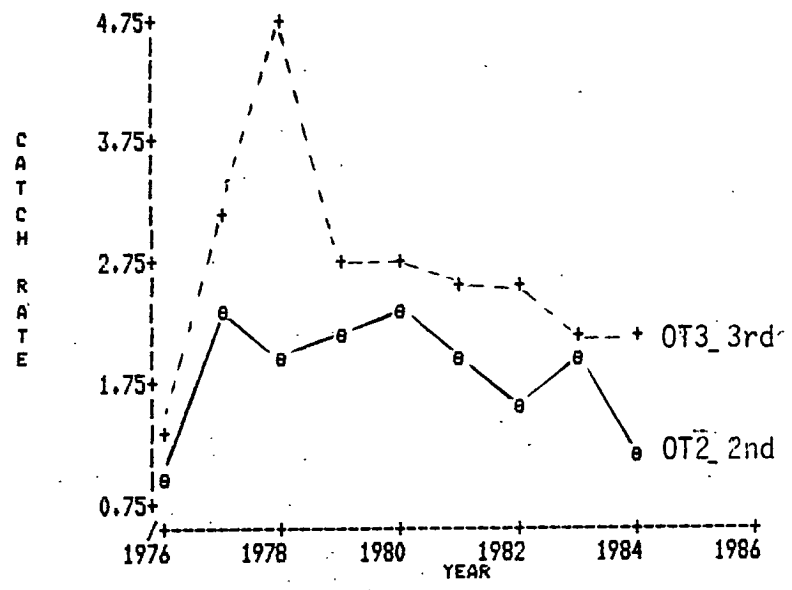
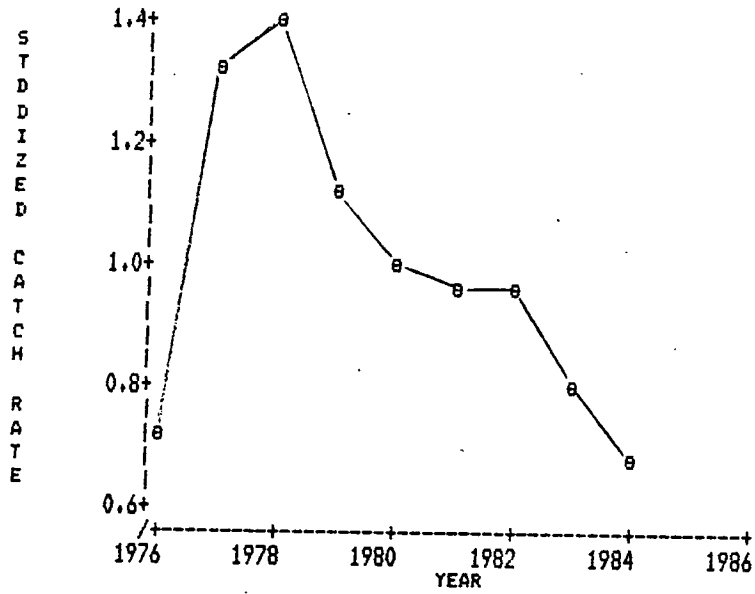
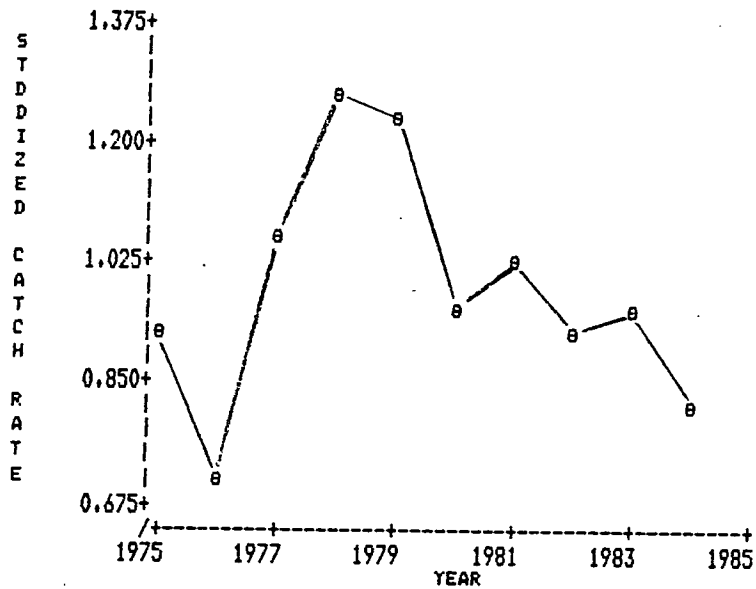


Figure 5. Continued.

Figure 6. Standardized commercial catch rate in 4X.



Effort in terms of days fishing



Effort in terms of thousands of hooks/hours.

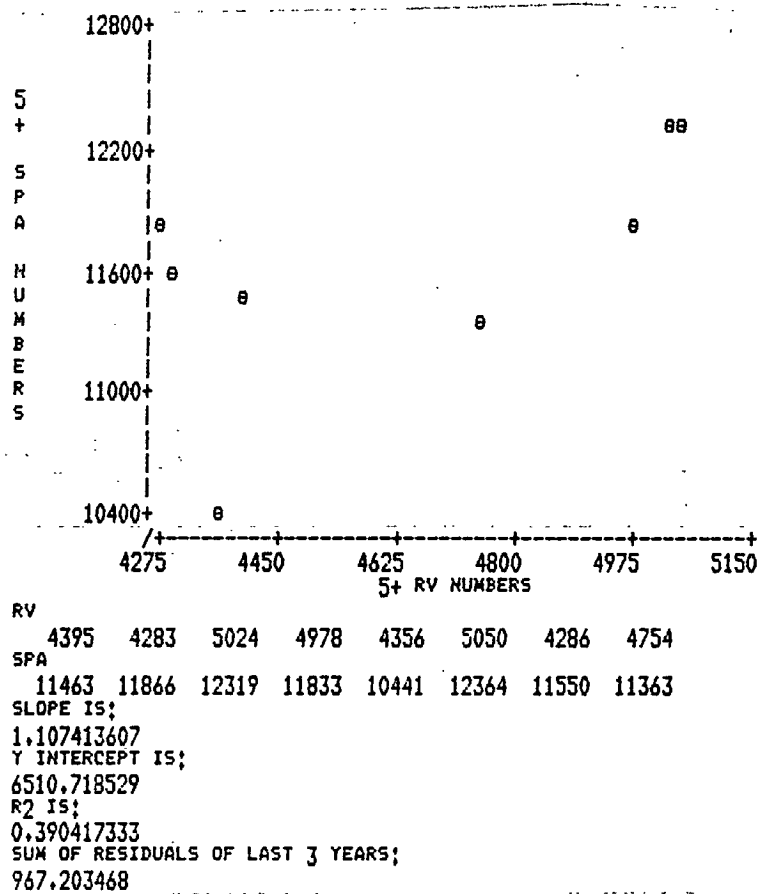


Figure 7. Regression of cohort population estimates (5+) on RV beginning of year population estimates (5+) at a terminal  $F = 0.40$ .

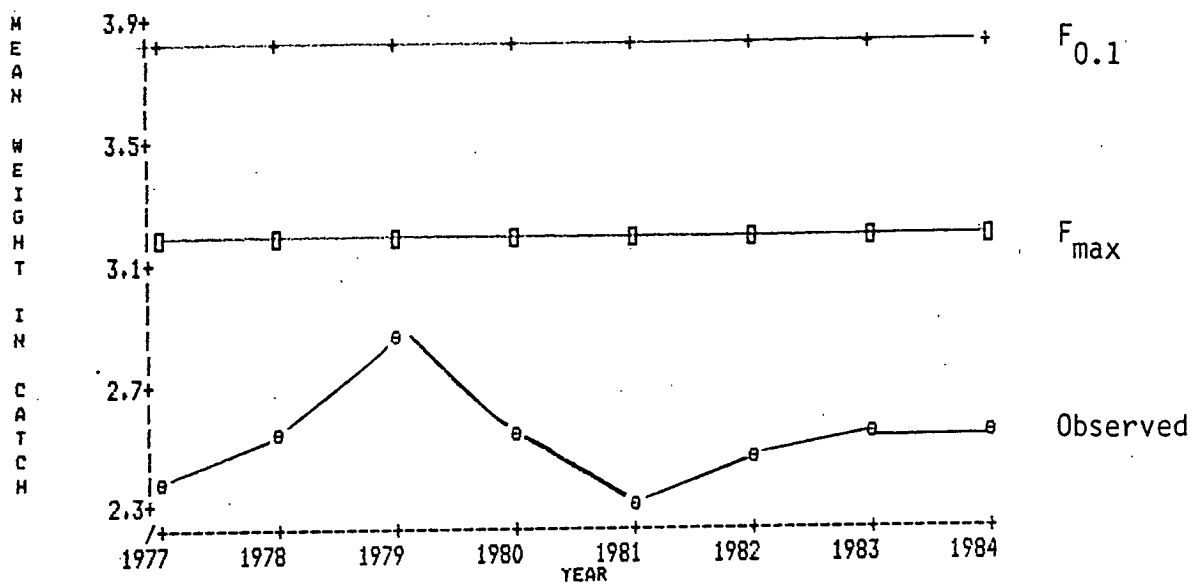


Figure 8. Observed mean fish weight versus that expected of  $F_{0.1}$  and  $F_{max}$ .

## Appendix

Small otter trawlers (TC 2 & 3) in Southwest Nova Scotia have consistently exceeded their allocation since quotas were put on 4X cod in 1982 (Table 2). This is the only gear sector to have done so. Fishing in excess of the allocation has continued to date, despite imposition of a staged allocation timetable in 1983. Resistance to the allocation scheme has been both vocal and widespread, with the result that draggers have resorted to reporting their 4X cod catch from 5Y to get around what they view as a restrictive allocation. Support for this statement has been universal, and has come from area managers, community service officers, enforcement officers, port samplers, and all fishermen interviewed.

Further evidence is presented below.

Year	Reported Maritime Landings by OT (TC 2 & 3) (t)	
	4X Q,R,S	5Y
1979	2800	340
1980	5232	161
1981	4455	300
1982	4885	1180
1983	5042	2562
1984	4080	2886

Note that reported landings were relatively stable in 5Y up to 1981. Subsequent years suggested a 10-fold increase in fishing effort in that area as a result of the restrictive allocation in 4X. The alternate suggestion, supported by interviews with people familiar with the fishery, is that effort in 5Y has remained constant while misreporting to that area has increased. Surveillance overflights support this second hypothesis.

Year	Number of Canadian Otter Trawlers Observed -		
	in 4X	in 5Y	4X : 5Y
1981	15	0	
1982	39	4	10
1983	47	4	12
1984	19	2	10

Thus, surveillance has not noted an increased activity in 5Y relative to 4X during the period when it should have increased (1983, 1984).

While not present on small draggers in 1983, the Observer Program monitored this gear sector in 1982 and 1984. The 1982 program was small-scale, but indicated that at least some of the small draggers misreported

4X cod to 5Y (Washburn and Gillis 1984). In 1984, 88 trips were observed: 57 of these occurred in the last half of the year when the gear allocation limit was being approached. Not surprisingly, fishermen tended to be relatively accurate when completing logs for days when observers were aboard. (Nevertheless 10% of them still misreported 4X cod to 5Y.) However, the random placement of observers on vessels and the relatively large sample size can be used to statistically describe relative fishing intensity between 4X and 5Y. The observed ratio of 4X : 5Y cod landings should be a conservative indicator of fishing area. (With an observer on board, one would expect the fishermen to respect the 4X cod closure more closely than would occur otherwise.) Observers reported 57 fishing trips into 4X and only 3 into 5Y. Relative cod catches were 123 t (4X Q,R,S) and 1 t (5Y), which is a ratio of 105 : 1. Over the same time period and for the same vessels the reported landings ratio was 1.35 : 1 -- a 77-fold difference.

Misreporting is a common feature of many fisheries. In instances where its magnitude differs little among years, it introduces relatively little bias into a VPA (Rivard and Doubleday, 1979). The present situation is different in that the misreporting started recently (1982) and has reached a level approaching 10% of the total 4X cod landings. Therefore, adjustment of the landing figures was necessary. The observer-reported cod landing ratio (105 in 4X : 1 in 5Y) could have been used to adjust the landings from 1982 on. This would have left less than 300 t in 5Y after adjustment. However, the distribution of fishing effort (as monitored by observers) indicates that all valid 5Y catches are caught in close proximity to the 4X-5Y boundary (Figure A-1), and indeed appear to be within the new Canada-US boundary line. Thus, Canadian landings of 5Y cod are derived from the same stock as those from 4X; considering the short distances involved, all Canadian cod landings reported from 5Y by OT (TC-2 & 3) have been reallocated to 4X, resulting in the following catch statistics:

Year	Reported		Adjusted	
	4X	5Y	4X	5Y
1977	4777	106	4883	0
1978	4018	380	4398	0
1979	4096	340	4436	0
1980	6786	161	6947	0
1981	5731	300	6031	0
1982	6409	1180	7589	0
1983	8396	2562	10958	0
1984	7554	2905	10459	0

## 4X MESH SIZE STUDY OBSERVER DATA

1982

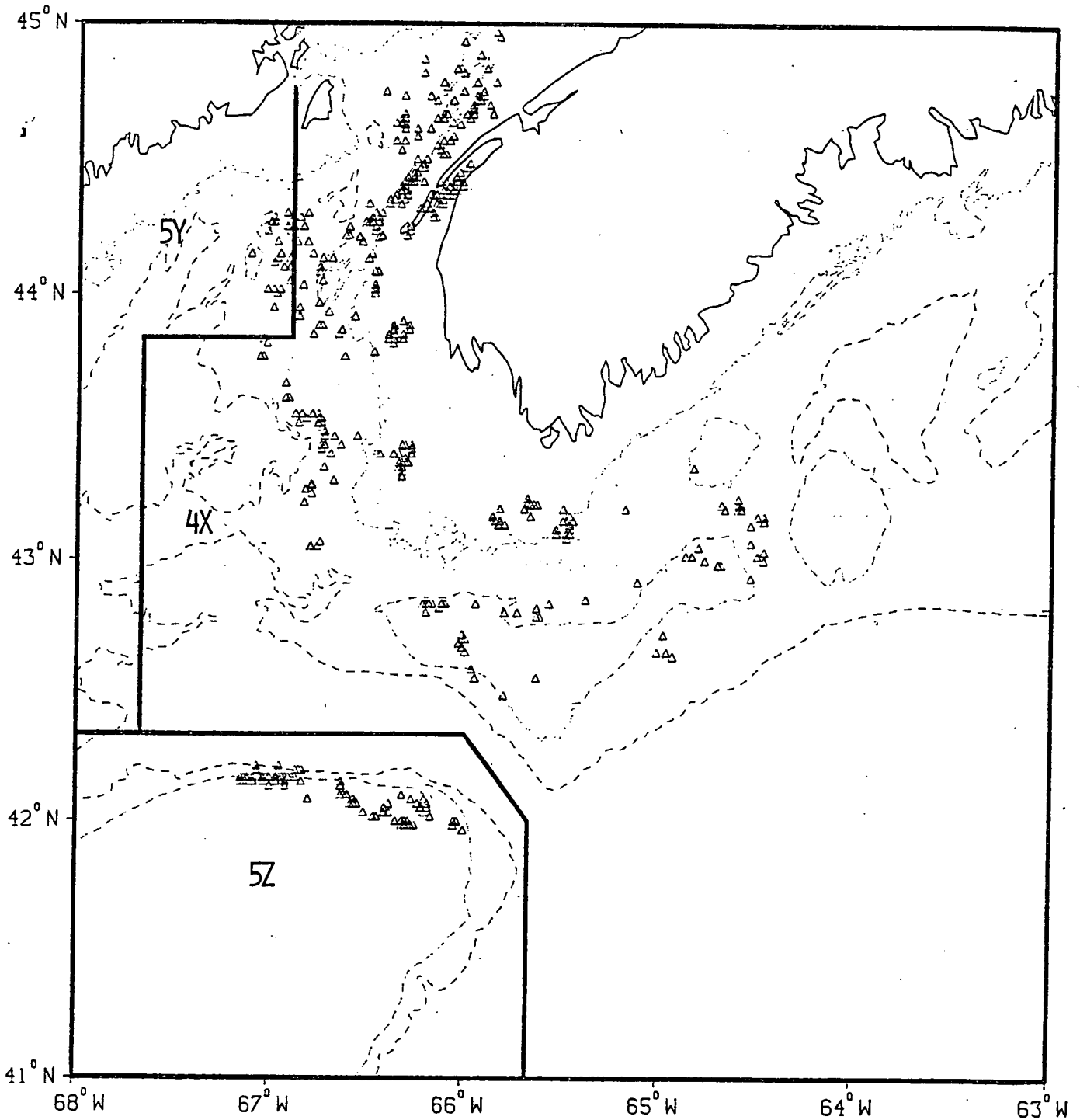


Figure A-1.. Fishing locations of small (TC 2-3) dragnets in southwest Nova Scotia in 1982 and 1984 as determined by the Observer Program.

SWNS SMALL DRAGGER  
OBSERVER PROGRAM  
DATA TO 84/11/14

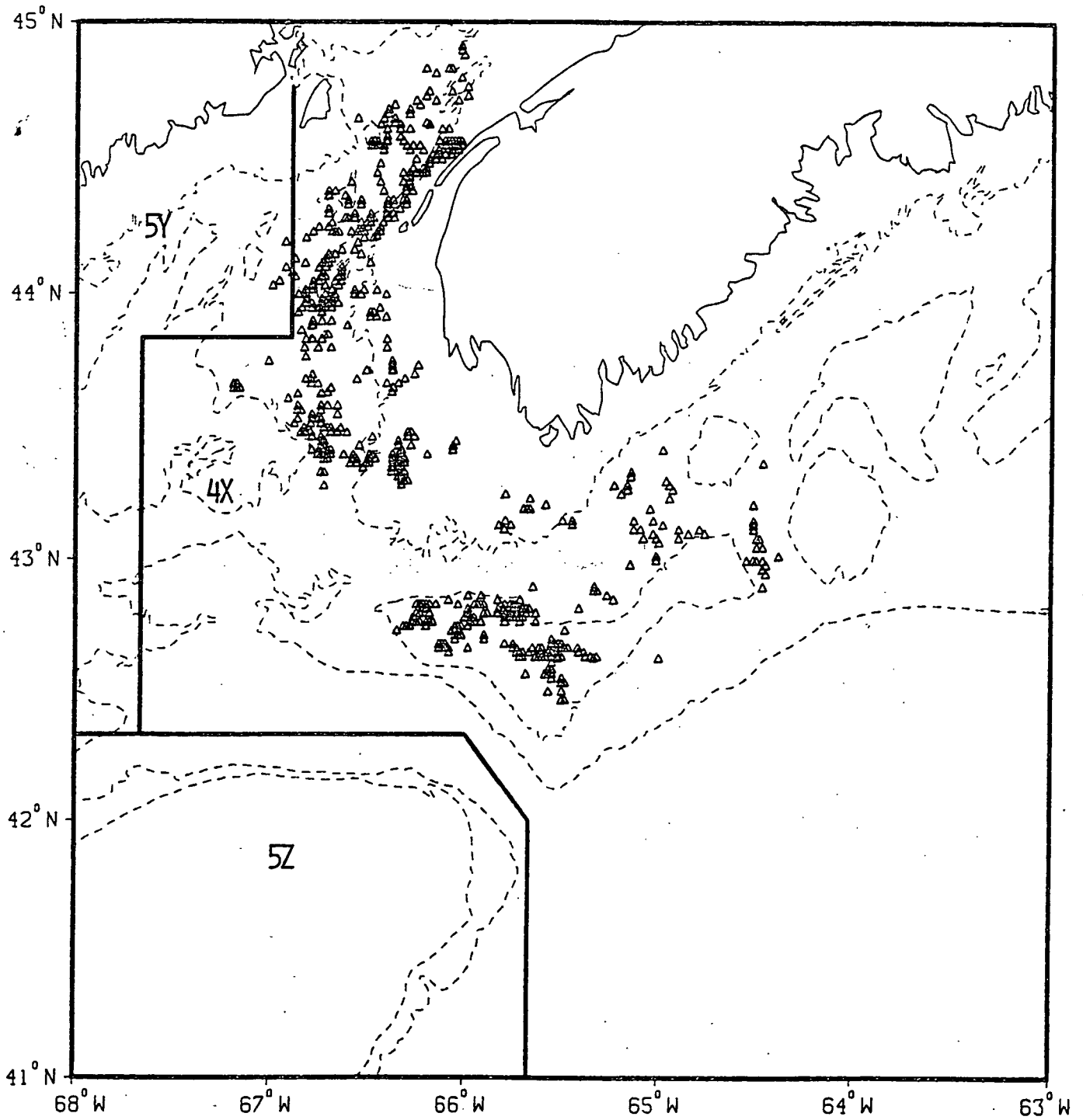


Figure A-1. Continued.