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1985 Stock Status of Division 4RST Redfish

by

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ABSTRACT

Redfish landings for NAFO Divisions 4RST have declined from a high of 130,000 t in 1973 to 15,000 t in 1980, increased to about 36,000 t in 1984 and declined to near 28,000 t in 1985. The commercial catch rates were standardized to Maritimes and Quebec tonnage class 4 otter trawlers fishing in Division 4R in January 1959. The standardized catch rate was 1.28 t/h in 1983, 1.20 t/h in 1984 and 0.95 t/h in 1985. An analysis of catch rates by tonnage class of vessels, provincial home port, season, year and area using a quadrat system was conducted. The analysis indicates redfish were less abundant in the mouth of the Esquiman Channel during 1985. Warmer bottom temperatures (5 - 10°C) in this area in 1985 appear to have influenced redfish distributions.

Research surveys, sequential population analysis and non-linear production modelling indicates a population biomass of about 500,000 t in 1985. Fishing mortality rates in 1985 were calculated at F = 0.07. Projections off the non-linear production model indicates approximately 50,000 t of redfish can be harvested from the Gulf of St. Lawrence in 1986 and in 1987.

RÉSUMÉ

Les débarquements de sébaste dans les divisions 4R, 4S, et 4T sont passés d'un sommet de 130 000 t en 1973 à 15 000 t en 1980, pour remonter à environ 36 000 t en 1984 et retomber à près de 28 000 t en 1985. Les taux de prises commerciales ont été normalisées pour correspondre aux chalutiers de catégorie 4 des Maritimes et du Québec qui pêchaient dans la division 4R en janvier 1959. Les taux de prises normalisées étaient de 1.28 t/h en 1983, de 1.20 t/h en 1984 et de 0.95 t/h en 1985. Au moyen d'un système de quadrats, on a effectué une analyse des taux de prises par classe de tonnage de bateau, par port d'attache provincial, par saison, par année et par secteur. L'analyse montre qu'en 1985, le sébaste a été moins nombreux dans l'embouchure du chenal d'Esquiman. Il semble que les températures de fond plus chaudes (de 5 - 10°C) relevées dans ce secteur en 1985 ont influencé la répartition du sébaste.

Les relevés, les analyses séquentielles de population, et les modèles de production non linéaire a indiqué la présence d'une biomasse d'envion 500 000 t en 1985. Le taux de mortalité due à la pêche s'établissait à F = 0.07 en 1985. Les prévisions faites d'après le modèle de production non linéaire indiquent que l'on peut capturer environ 50 000 t de sébaste dans le golfe Saint-Laurent en 1986 et en 1987.

INTRODUCTION

The Division 4RST redfish fishery commenced in 1952 in the Gulf of St. Lawrence (Sandeman 1973). Landings from 1952-1982 have been summarized by Maguire et al. (1983). Landings by division since 1979 are presented (Table 1). It is estimated that the landings were 35,780 t in 1984 and 27,827 t in 1985. This represents a decline in total landings of 7,953 t in 1985 compared to 1984. The changes in total landings since 1952 are shown in Figure 1. The fishery has been concentrated in the mouth of the Esquiman Channel at depths from 200-400 meters.

Nominal Catches

Provisional catch statistics for 1985 from Gulf, Quebec, Scotia-Fundy and Newfoundland regions were summarized by NAFO divisions, region and year (Table 1). Division 4S had the largest share of the redfish catch (12,175 t), followed by Div. 4R (11,611 t) and then Div. 4T (4,041 t). The decline in landings is most pronounced in Div. 4T between 1984 and 1985. The fishery is mainly Canadian; only 12 t were taken by France in Div. 4R. Catches were highest for Maritimes (CAN-M) vessels in Div. 4R while catches were highest for Quebec (CAN-Q) vessels in Div. 4S. Quebec vessels exhibited a 33% drop in landings in Divisions 4RST in 1985 compared to 1984. This was influenced by two factors (DFO 1986). Fishing effort dropped due to a labour conflict in August on the Magdalen Islands and to a lesser extent because of a decline in catch-per-unit-effort (CPUE) by Quebec vessels.

Nominal catches by division, region and month are summarized in Table 2. The largest catches were taken during October, September and July for Divisions 4RST. The catches were highest in the fall due to increased fishing effort by all components of the redfish fleet.

The redfish fishery is primarily by otter trawls in the Gulf of St. Lawrence. Of the total landings, 24,973 t were taken by bottom trawlers and 1070 t by shrimp trawlers using bottom trawls (Table 3). In 1985, 93.6% of the redfish landed were caught using bottom trawls. Tonnage class (TC) 4 vessels using bottom trawls took 69% of the total catch in 1985 (Table 4). Tonnage class 5 vessels took 25% of the total landings in 1985.

A breakdown of catches according to division, gear and tonnage class is given in Table 3. The percent of total landings taken by midwater TC-5 trawlers increased from 1.4% in 1984 (Rubec et al. 1985a) to 6.1% in 1985 (Table 5).

Commercial Sampling

Port samplers and observers from Gulf, Quebec and Scotia-Fundy regions measured the length of 24,019 redfish during 1985 (Table 6). Observers measured 10,288 redfish (42.8%). Slightly more females than males were measured. Juveniles were measured as a by-catch with shrimp trawlers from Quebec and Newfoundland.

The catch at age analysis used in 1985 (Rubec et al. 1985a) may have been biased by the disproportionate numbers of redfish measured by observers in comparison to samples for overall landings. Consequently the catch at age analysis for 1984 was recalculated excluding a large proportion of the observer data. The new 1984 catch at age analysis used 42,677 measurements. Observer data was only used for the fall and winter months when no port sampling was conducted. Table 7 summarizes the numbers of male and female redfish from 1984 measured by month, division and gear type. Bottom trawlers (OTB) and midwater trawlers (OTM) using 90 mm or greater mesh are separated from shrimp trawlers (ST) using less than 60 mm mesh. Length frequency samples were adequate for most months where large landings ocurred. November and December landings in Division 4T were not sampled.

Table 8 summarizes the numbers of male and female redfish from 1985 measured by month, division and gear type. The nominal catches in metric tons (t) are indicated as well. A total of 21,058 measurements were used for the catch at age analysis. It would have been desirable to have more shrimp trawl and midwater trawl samples. The sampling was adequate for bottom trawling for most months and divisions.

Catch Rates

For the past 4-5 years, the Gulf of St. Lawrence redfish fishery has been directed at the deep-water redfish (*Sebates mentella*) early 1970's year classes (CAFSAC 1984). During 1985, Gulf-based processors expressed concern about declining catch rates per day at sea. At advisory committee meetings they stated that due to the declining abundance of redfish their companies were in financial jeopardy. They were concerned that non-Gulf based vessels were catching too many redfish by fishing in the fall and winter. The non-Gulf processors expressed satisfaction with their catch rates.

Another concern of Gulf processors is that more time is being spent searching for schools of redfish and hence fewer redfish are being taken per trip. They admit to concentrating their effort on schools of redfish. Biological advice has been based on catch per hour calculations in the multiplicative model. Catch rates (t/h) might stay high despite the fact that the number of schools could be declining. If more time is spent searching for schools, catch per day fished would decline more rapidly than catch per hour.

Factors which influence trip duration are the size of the vessel, time of year, and the time redfish will keep on ice in the ship's hold. Gulf and non-Gulf TC-4 vessels have a smaller storage capacity than non-Gulf TC-5 vessels. Non-Gulf TC-5 vessels are built to withstand winter conditions.

To address these concerns, catch-effort data were taken from NAFO statistical bulletins from 1981-1984, provisional statistics branch data for 1984 and 1985 and from logbook records from 1983-1985. The data were tabulated in terms of catch per hour and catch per day on a monthly and on an annual basis.

Catch per day on ground is based on days on the fishing grounds and does not include the time spent going to and from the fishing areas. Catch per day at sea includes travel to and from the fishing grounds, but these data are not always reported in NAFO bulletins. Consequently, comparisons were made between catch per hour and catch per day on ground.

Table 9 summarizes yearly catch rates of TC-4 and 5 bottom trawlers. Both Gulf and non-Gulf based TC-4 vessels had high catch rates in 1981-1982 which decline progressively to 1985 (Figure 2). Catch rates for TC-5 vessels decline to 1983, then increase in 1984 and drop in 1985.

It is possible to compare mean catch per hour with mean catch per day on ground by normalizing each year's data with the means of all years from 1981-1985. Figure 3 compares the relative catch rates per hour and per day. There is little difference between catch per hour and catch per day for TC-4 Gulf and TC-4 and 5 non-Gulf vessels. Consequently, it doesn't seem that more time is spent searching for schools of redfish on the fishing grounds.

Table 10 gives the directed landings and effort ($\geq$ 50% redfish in the catch) for Divs. 4RST from 1981-1985. The landings of Gulf TC-4 vessels increase to 21,327 t in 1984 and decline to 13,072 t in 1985. Non-Gulf TC-4 and 5 vessels have increased their directed landings. The increase in landings and effort reflect increased quotas since 1981.

Logbook records were obtained from the statistics branches of DFO for the four Atlantic regions. The localities where fishing occurred were determined by converting Loran C records and Decca 6 or Decca 9 records to latitude and longitude values. The data were then assigned to 30° x 30° quadrats. This system has been used previously by the Quebec provincial government. Redfish fishing effort from 1975-1982 was summarized by Lussiaà-Berdou and Maguire (1983).

The Quebec provincial data (1975-1982) and more recent Quebec federal DFO data (1983-1985) gives a time series which can be used to compare changes in the distribution of the redfish fishery. Quebec data were plotted to show the distribution of fishing effort from 1975-1985. The 30° x 30° quadrats with more than 75% fishing effort have been mapped (Figure 4). The distribution of 75% of the effort of TC-4 Gulf and TC-4 and 5 non-Gulf vessels has also been depicted for 1984 and 1985 (Figure 5).

The area in which 75% of the effort was expended in 1984 and especially 1985 was considerably larger than in the previous 5 years for Quebec vessels (Table 11). This was also quite obvious in maps showing the distribution of 100% of the effort (not presented). Quebec boats went further afield fishing at the western end of Anticosti Island in 1984 and 1985. This area was not heavily fished previously. From the comparison of catch per hour and catch per day on ground, it is apparent that searching time for redfish schools has not increased on the fishing ground between the east end of Anticosti Island and the Port au Port Peninsula. However, the conclusion that searching time has not increased may not exactly hold, since it may take longer to get to fishing grounds west of Anticosti Island and northwards in the Esquiman Channel.

Non-Gulf TC-4 vessels concentrated 75% of their fishing effort in 3 quadrats in 1984 (S5, S6 and R8). Quadrat S5 is east of Beauge Bank; R8 is off the mouth of St. George's Bay, Nfld (Figure 5). Non-Gulf TC-5 vessels concentrated 75% of their fishing effort in 5 quadrats during 1984 (Figure 5). During 1985, 75% of the fishing effort took place in 4 quadrats. It is apparent that non-Gulf based TC-4 and 5 vessels adopted a fishing strategy of fishing in selected areas of Div. 4R during 1984 and 1985.

Examination of monthly effort and catch rates by month (not presented), indicates that a large part of the non-Gulf fishery was in the fall from August to October. In 1985 no effort was exerted by TC-5 vessels in the Gulf during June and July. Catch rates were generally higher in the fall and winter months.

Redfish catch rates during 1985 declined over previous years (Table 9). Gulf-based TC-4 vessels experienced a 15% drop in CPUE (t/h) in 1985 compared to 1984. There has been a 42% drop in Gulf TC-4 CPUE's since 1981. Non-Gulf TC-4 vessels experienced a 24% catch rate drop in 1985 compared to 1984 and a 47% decline in CPUE since 1981. Non-Gulf TC-5 vessels had a 11% drop in CPUE in 1985 compared to 1984. There has been a 37% drop in TC-5 CPUE since 1981.

Catch rates of TC-4 Gulf vessels were generally higher than TC-4 non-Gulf vessels (Table 9). This may be because Gulf based vessels are all stern trawlers, while some of the non-Gulf vessels are less efficient side trawlers. Non-Gulf TC-4 vessels experienced an increase in CPUE in 1984. This probably resulted from these vessels expending more effort in the fall in selected areas, in comparison to Gulf-based TC-4 boats which fished more in the summer months over a wider area.

Non-Gulf TC-5 vessels being larger had higher catch rates than TC-4 vessels (Table 9). Higher catch rates in 1984 and 1985 in comparison to 1983 could be due to the strategy of TC-5 vessels fishing in the fall and winter in selected areas, in order to optimize catch rates in areas where redfish tend to aggregate during the winter (Atkinson 1984).

The fishing pattern of Quebec redfish trawlers (Figure 4) shows a concentration of fishing effort, especially in 1981, in the area of Divs. 4R and 4S between Anticosti Island and Cape St. George, Nfld. This concentration may have led to catch rates higher than would have occurred had the early 1970's year classes been more widely distributed. For this reason the catch rates were not taken at face value (Maguire et al 1983). Subsequent assessments have been consistent with the results of the 1983 assessment in indicating that fishing mortalities estimated were too low due to an upward bias in the commercial standardized catch rate (Rubec et al 1984; 1985a).

The average commercial catch rate of Quebec-based vessels in the areas where 75% of the effort occurred goes from 1.17 kg/h to 0.83 kg/h in 1985 (Table 12). This represents a 30% drop in CPUE on the fishing grounds. The dispersal of commercial Quebec and Gulf TC-4 effort noted in 1984 and 1985 is consistent with the hypothesis that a dispersion of the early 1970's year classes during the summer months has occurred in recent years.

Other indices of abundance are presented in Table 12. Total biomass estimates from Lady Hammond summer research vessel surveys indicate an increase in population biomass in 1985 over 1984. But this is due to juvenile redfish which have not yet entered the commercial fishery. In 1985, juveniles (younger than age 10) comprised 35% of the population biomass. Excluding juveniles and only considering redfish age 10 and older, the adult recruited biomass declined 29% in 1985 compared to 1984.

Using catch per tow (weight) data from the 1984 and 1985 research surveys, mean catch per tow (Table 12) was calculated for the quadrats which received 75% of the commercial effort for the two years (Figure 4). All age groups were included in the calculations. The mean weight per tow was 388 kg in 1984 and 220 kg in 1985. This represents a 43% drop in CPUE in the area of interest to the commercial fishery.

The multiplicative model was used to obtain the standardized commercial catch rate. The standardized CPUE for all vessels went from 1.20 kg/h in 1984 to 0.95 kg/h in 1985 (Table 12). This represents a 21% drop in the standardized CPUE. The drop in CPUE for Divs. 4RST was not as great as in the more localized area which received 75% of the commercial fishing effort.

Shift to High Lift Trawls

Most vessels directing at redfish in the Gulf have switched to the use of Engel high lift trawls. Catch rates were adjusted to compensate for the estimated 28% increase in catchability using the Engel trawl (Rubec et al. 1985a). Some CAN-N TC-4 vessels still do not have high lift trawls. Logbooks from Newfoundland were examined to determine the proportion of vessels with high lift trawls by month during 1985 (Table 13). These data were utilized in the catch rate standardization (Gavaris 1980).

Commercial Catch Rate Standardization

Commercial catch rates have been used as an abundance index due to changes in research vessels, gear and the brevity of the research vessel time series. Commercial catch rate data (Rubec et al. 1985a) was modified to include revised NAFO Statistical Bulletin data from 1977 to 1981. For 1980 and 1981, adjustments to the various NAFO divisions and tonnage class data were made to account for the conversion to high lift trawls as described by Rubec et al. (1985a). Four time series matrices were modified (from 1977 to 1981) and updated with provisional catch-effort statistics for 1984 and 1985.

Multiple regressions were conducted on four matrices of catch-effort data. The regressions were conducted using the following weighting factors:

effort and the fourth root of catch X effort. These weighting factors have been found to be the most useful with the data over the past three years. The data set used (up to 1977) with the combinations by gear and months were identical to that used by Maguire et al. (1983).

The multiplicative model (STANDARD.WS) adapted by D. Gascon for IBM compatible microcomputers was run for the unadjusted catch rate matrix up to 1985. The unadjusted catch rate index for the multiple regression weighted by effort is presented for comparison with the subsequent regressions using adjusted catch rate data (Table 14). The runs with unadjusted and adjusted data indicated that the conditions reported previously were still appropriate for gear and months(Maguire et al. 1983; Rubec et al. 1984; 1985). Weighting by effort gave the highest correlations and the smoothest relationships for residual plots. Effort consistently gave a higher R^2 value compared to the fourth root of catch X effort. All regressions showed a pattern similar to that depicted for the adjusted TC-4 CAN-M+Q data (Figure 6).

Since a conversion factor was only determined for TC-4 (M+Q) vessels, this regression was considered to be the most representative of the actual trend in population abundance. A comparison with the other runs (Table 14) indicates that adjusting the model for TC-5 (M+Q) vessels or TC-4 and 5 CAN (M+Q) plus TC-4 and 5 CAN-N vessels does not change the results significantly, because these other gear categories comprise a small proportion of the total landings. The adjusted regression for CAN-(M+Q) TC-4 vessels (Figure 6) was similar to the regression reported last year (Rubec et al. 1985). The 1982 point on the regression with the revised NAFO data is higher than the value determined previously.

The results of the regression for TC-4 CAN (M+Q) vessels weighted by effort are presented in Tables 15-17. The resulting Analysis of Variance (ANOVA) is shown in Table 15. The ANOVA shows that all category types were significant and that 58% of the variation in the data was explained by the model. The standard errors about the categories in the model are shown in Table 16. The parameter estimates on a log scale and box plots indicated further combinations of categories were possible, but residual plots indicated they were not necessary. The standardized catch rates (t/h), total catch and effort are presented (Table 17). The standardized catch rates have increased since 1977 (0.60 t/h) to 1.32 t/h in 1981, 1.27 t/h in 1982, 1.29 t/h in 1983 and decreased to 1.20 t/h in 1984 and 0.95 t/h in 1985.

Catch at Age

Due to problems with 1984 age determinations, the otoliths were re-examined, new age length keys prepared and the catch at age calculations were repeated. Length frequencies by month from the commercial fishery for 1984 were combined for each sex separately using computer software described by Gavaris and Gavaris (1983). The analyses were conducted on a Corona microcomputer using the computer program CATCH.WS adapted by D. Gascon, Quebec Region, with some modifications by J. Wright. A new front-end program (CATCH PREP.WS) running on microcomputer written by J. Wright, was used to read Gulf Region codes and formats.

CATCH.WS was used to weight monthly length frequencies. Length frequencies were combined within each NAFO Division and within main gear types (OTB, ST and OTM), by displaying the data as plots and combining months with similar distributions (Figure 7). The 1985 catch at age analysis was calculated in a similar fashion. The sequence of frequency combinations are shown in Figure 8. The combinations were made for each sex to obtain annual length frequencies. The 1984 male frequency (Figure 9) and female frequency (Figure 10) distributions are depicted. Males were most prevalent at 30 cm, females at 32 cm. In 1985 males were most abundant in the commercial catch at 30-31 cm (Figure 11), while females were most prevalent at lengths of 32-33 cm (Figure 12). The commercial catch at age for sexes combined for 1984 (Figure 13) and 1985 (Figure 14) are depicted.

Age length keys were constructed separately for males and females for 1984 (Tables 18 and 19) and for 1985 (Tables 20 and 21). Unsexed fish less than 16 cm were added to both male and female age-length keys. The age length keys were merged with the corresponding yearly frequencies to produce catch at age tables for each sex and the sexes combined. Table 22 presents the 1984 calculations for catch at age sexes combined. Table 23 presents the 1985 catch at age calculations. The catch at age matrix from 1972 to 1983 was updated with 1984 and 1985 data (Table 24).

Weights at Age

The 1972 to 1983 weights at age were taken from Rubec et al. (1984). Weights at age for 1984 and 1985 (Table 25) were calculated as part of the CATCH.WS program from average length at age and the following weight-length relationships (McKone et al. 1980).

$$\text{Male wt} = 0.01659\ FL^{2.9548}$$

$$\text{Female wt} = 0.01372\ FL^{3.0210}$$

Where FL signifies fork length in centimeters and weights are in grams.

Partial Recruitment

Various methods for calculating partial recruitment (PR) vectors exist (O'Boyle 1981). Historical averaging was conducted using a computer program (LEVER) running on the BIO Cyber. By inputting last year's PR vector, the terminal fishing mortality ($F_t = 0.05$) and the present catch at age matrix (Table 24), a VPA run was conducted to derive a mortality matrix. Each column in the mortality matrix for ages 5-29 was divided by the mean F value for a range of fully recruited ages after these values had been weighted by the population numbers for ages 14-29. This derived a PR matrix for the years 1972 to 1985. By averaging across the PR matrix, a new PR vector was derived. The PR vector was then iterated in further VPA calculations, until no change occurred in the mortality matrix and resulting PR vector. A new PR vector fully recruited at age 15 was derived. This was normalized for ages

5-29 by dividing by the mean of the PR values for ages 15-29. The PR vector obtained after smoothing with the Tukey method is the following:

AGE	5	6	7	8	9	10	11	12	13	14	15-29
PR	.100	.100	.130	.220	.315	.355	.380	.445	.540	.705	1.0

Tuning VPA

Calibration functions in LEVER for regressing various parameters to determine terminal fishing mortalities from VPA were used. Regressions of 5+ biomass versus CPUE were conducted with the PR vector fully recruited at age 15. Various terminal fishing mortalities ranging from $F_t = 0.01$ to $F_t = 0.10$ were tried in the VPA's at various natural mortalities (M = 0.10, 0.07, 0.05, 0.04, 0.03, 0.02) respectively. The optimal F_t at each M value was calculated (Table 26). The 1984 and 1985 research vessel population biomass estimates were used as a reference. The best F_t value optimized from VPA occurs near $F_t = 0.07$ and M = 0.02. The lowest positive intercept, the highest correlation coefficient (R) and minimizing the square of the residuals on the last 3 years were used as tuning criteria.

Sequential Population Analysis

Cohort population estimates (Rivard 1982) at $F_t = 0.07$ and M = 0.02 are presented in Table 27. The cohort run indicates a population biomass of 520,000 t in 1985 (Table 28). Fishing mortalities are summarized in Table 29.

Calculation of Total Mortality (Z)

Various methods were attempted in order to calculate the total mortality (Z) for Divs. 4RST redfish. The best results were obtained by taking the natural logarithm of landings (in the catch at age matrix) divided by the standardized effort (h) from the multiplicative model for the 1956-1960 year classes. Several linear regressions were conducted on the data (Figure 15). The regression of ln C/E versus years (1972-1985) indicates a total mortality Z=0.107.

Research Vessel Surveys 1984 and 1985

Research vessel survey data collected on the Lady Hammond in 1984 and 1985 were analyzed to determine redfish abundance by depth strata. These data have been examined in relation with bottom water temperature data to determine whether redfish have changed their spatial distribution in response to changing environmental conditions.

The 1984 survey was reduced from 26 days to 13 days duration due to engine problems with the Lady Hammond. Consequently, only 108 sets (104 successful) were made in 11 days from July 6-19, 1984. The survey from August 6-30, 1985 sampled 190 sets. But, due to gear damage and other factors there were only 179 valid tows.

The methods of measuring and recording data on field input sheets followed the Scotia-Fundy system of codes and formats in 1984 (Koeller 1981). In 1985, a Shipboard Data System (SDS) for the acquisition of digitized computer compatible data was implemented (Rubec et al. 1985b).

At most stations during 1984 and 1985 an expendible bathythermograph (XBT) was used to obtain a temperature profile which was recorded by an HP-85 microcomputer on board ship. There were 104 XBT profiles collected in 1984 and 175 profiles in 1985.

Due to problems with implementing the RVAN population biomass program, the 1984 and 1985 surveys were analyzed using the program CATCH.WS. The 1984 and 1985 R/V data were reformatted to read length frequencies, sample weights, total weights and commercial age-length key information etc., into CATCH.WS. The area expansion calculations of weights per tow to biomass per stratum were accomplished using LOTUS 1-2-3 on the microcomputer. Table 30 presents the population biomass estimates for 1984 and 1985. There was estimated to be 473,209 t of redfish in the Gulf in 1984 and 486,222 t in 1985.

Since the 1984 and 1985 R/V age determinations were not available, the age-length keys from commercial sampling were used in CATCH.WS in conjunction with R/V length frequencies to obtain estimates of the R/V catch at age. Tables 31 and 32 summarize the mean weight and mean length per fish as well as the estimated numbers at age for 1984 and 1985 respectively. Tables 33 and 34 summarize the percent per thousand numbers at length, numbers at age and the biomass at age calculated for 1984 and for 1985.

The length frequencies for sexes combined are compared between commercial sampling surveys (Figure 16) and R/V surveys (Figure 17) for 1984 and for 1985 (Figures 18 and 19). In 1985, there appeared to be relatively more redfish caught in the commercial fishery in the 22 to 28 cm length range. This was not seen in previous years (1982-1984). More fish in this size range may have been caught due to the expansion of the range being fished. Examination of length frequencies on a smaller geographic scale might give more information to clarify whether this is due to depletion of the dominant early 1970's year classes or to a greater abundance of juveniles being caught by commercial vessels.

The distribution of sets sampled in 1984 and 1985 are shown in Figures 20 and 21. Associated with most sets an XBT temperature profile was taken. The distribution of bottom temperatures are depicted for 1984 (Figure 22) and for 1985 (Figure 23). For the 1984 survey (Figure 22), there was a shrinkage of the area with bottom temperatures of 5°C or higher in comparison to temperature plots for R/V surveys from 1979-1983 (not presented). In 1985, it can be inferred from Figure 23 that there was an expansion of the area with bottom temperatures $\geq 5°C$. This is consistent with the interpretation that bottom water temperatures were warmer in the area normally fished in 1985 compared to 1984. Data from the winter Gadus Atlantica surveys for 1984 and 1985, which also indicated warmer bottom water temperatures in 1985 (A Fréchet, pers. comm. 1986).

The distributions determined by R/V surveys indicated that redfish were more abundant further north and west in 1985 (Figures 20 and 21). Three dimensional plots of catch per tow versus depth and bottom temperature were examined (Figure 24). These plots suggest that redfish were found in deeper water (greater than 150 fathoms) in 1985. Duncan's range tests for mean catch per tow by depth range for 1984 and 1985 also indicate that redfish were more prevalent below 150 fathoms in 1985. Most sets on the R/V surveys were made at bottom water temperatures of 4.0 - 5.5°C. Mean catches per standardized tow were highest at 5.5 - 7.0°C for both 1984 and 1985.

Redfish are generally taken by the commercial fishery at depths between 125 and 150 fathoms (229-274 m). Changes in the distribution of the preferred temperature zones appear to have caused redfish to change their geographic and depth distributions. By moving into deeper water and possibly off the bottom (Atkinson, pers. comm. 1985) redfish would be less vulnerable to commercial bottom trawling. The situation is complex with respect to the effect of temperature on the distribution of redfish. Further statistical analysis of the data is being conducted. Cooperation with oceanographers is required to further study the problem.

Figures 16 and 18 indicate strong recruitment of juvenile redfish (15-18 cm) which probably represent year classes from the early 1980's. The abundance of these smaller fish in the length frequencies (particularly 1985) indicates good future recruitment to the fishery. However, in the next 3-4 years, recruitment will be poor and the biomass of commercial sized redfish (greater than 25 cm) will decline.

Production Modelling

Both equilibrium and non-equilibrium production models were run. Both used the standardized effort from the multiplicative model and catch as input. The Pella-Tomlinson version of the equilibrium model was run using unlagged effort data, and effort data lagged 6, 8, 10 and 12 years. The regression of CPUE in effort using a lag of 8 years had the highest R^2 but serial correlation existed in the data. Since the yield vs effort plots did not fit the actual data; the equilibrium model is not considered appropriate.

The analysis using the non-equilibrium model has been conducted by Rivard and Gavaris (1986). The analysis indicates a fishing mortality rate F at 2/3 effort MEY of 0.098 ($\cong$ 0.10). The model predicts a Maximum Equilibrium Yield (MEY) of 56,500 t and a yield at 2/3 MEY of 50,222 t. The non-equilibrium model implies a population biomass level of 508,000 t (for January 1, 1986) and a fishing mortality rate F of 0.074 for 1985. This population biomass level is very close to the biomass level (487,000 t) estimated from the 1985 research vessel survey and the 520,000 t biomass (Table 27) estimated from cohort analysis (F_t = 0.07 and M = 0.02).

DISCUSSION

The results of SPA showed no convergence in any part of the matrix and were thus not appropriate for assessing the terminal fishing mortality (F_t). Consequently the results of the non-equilibrium production model were used for this purpose.

The fishing mortality (F=0.098) was calculated at 2/3 effort (MEY) using the non-equilibrium production model (Rivard and Gavaris 1986). This value is considered to be approximately equal to exploitation at $F_{0.1}$ obtained from yield per recruit models such as Thompson and Bell.

A natural mortality (M) of 0.10 has been assumed in SPA, although there is no scientific study to establish its validity. The optimizations on SPA (Table 26) compared with R/V survey estimates and the non-equilibrium production analysis (Rivard and Gavaris 1986) both suggest that M is lower than 0.10. Further study is needed so that the selection of a new and more appropriate level of M will be objective and defensible. It is noted that the use of the non-equilibrium model avoids the question of an appropriate level of M.

Entering the weights at age for 1985 (Table 25) and PR vector fully recruited at age 15 and a natural mortality of M = 0.02 into the Thompson and Bell yield per recruit model (Rivard 1982) derives an estimate of $F_{0.1}$= 0.098 (Table 35). This agreement with the non-equilibrium data suggests M is approximately 0.02 or 0.03. It is important to emphasize however, that exploitation at 2/3 effort MEY for this stock is not equivalent to $F_{0.1}$ management, and the interpretation of $F_{0.1}$ and yield per recruit for Divs. 4RST redfish are not clear.

Projections

Projections of population numbers and catch biomasses derived from the 1985 population numbers obtained by cohort analysis (Table 26) were attempted. The projections assumed a G.M. recruitment of 287 million[1] used

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[1]This value is high compared to the age 5 population numbers calculated from cohort for 1985 (Table 27). It is the same as used in previous assessments. If the GM recruitment from 1972 to 1982 (118 million fish) was used the difference in projected catch is less than 1%.

in previous assessments (Rubec et al 1984; 1985a). The projection using the flat-top PR vector fully recruited at age 15, M = 0.02 and $F_{0.1}$ = 0.098 resulted in a 5+ catch biomass of 38,847 t in 1986 and 39,455 t in 1987.

Management advice is based upon projections from the non-linear equilibrium production model (Rivard and Gavaris 1986). At 2/3 the effort giving MEY, the non-equilibrium yield was calculated to be 50,242 t. At 2/3 the effort giving MEY, the non-equilibrium yield was estimated to be 50,014 t for 1986. This catch would correspond to a fishing mortality rate of 0.10 for 1986. The 2/3 effort MEY level for 1987 is estimated to be 50,054 t. A comparison of the population parameters estimated by the present paper and by use of the non-linear production model is given in Table 35.

The differences in projections (Table 35) between the non-linear equilibrium and SPA models are not well understood. A likely explanation may be that the non-linear model places more emphasis on all years, while the drop in catch rates in 1985 is reflected in SPA. The drop in catch rates may be due to changes in environmental conditions. Warmer bottom temperatures may have caused redfish to move off the bottom, making them less vulnerable to bottom trawls. The 29% decline in 10+ redfish R/V biomass in 1985 compared to 1984 (Table 12) is most explicable by a change in redfish distribution rather than due to mortality.

CONCLUSIONS

The 1985 assessment of Divs. 4RST redfish using SPA showed close agreement with results obtained by the non-linear production model (Rivard and Gavaris 1986). The non-linear production model was used as the basis of management advice and projections, due to reservations about the use of SPA because of concern over the lack of convergence of the analysis, wide confidence intervals obtained by sensitivity analysis and the appropriate choice of a natural mortality value.

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Table 1: Nominal catches (metric tonnes) of redfish by division, country, region and year in the Gulf of St. Lawrence.

	4R					4S					4T					4RST	
YEAR	CAN-N	CAN-M	CAN-Q	FRAN	TOTAL	CAN-N	CAN-M	CAN-Q	FRAN	TOTAL	CAN-N	CAN-M	CAN-Q	FRAN	TOTAL	QUOTA	TOTAL
1979	717	1722	1197	127	3763	32	2408	5189	0	7629	74	1773	1795	0	3642	16000	15034
1980	709	2476	1567	57	4809	184	2444	5497	0	8125	0	668	1230	0	1898	16000	14832
1981	1207	3802	2660	16	7685	411	3618	6144	0	10173	270	1100	1321	0	2691	20000	20549
1982	1880	4028	3492	10	9410	358	6792	6647	0	13797	117	498	2607	0	3222	28000 31000[a]	26429
1983	2015	5049	3361	38	10463	36	6963	4496	0	11495	41	656	1850	0	2547	31000 33000[a]	24505
1984[b]	2176	7849	2408	47	12480	81	6136	7421	0	13638	1	5612	4049	0	9662	50600	35780
1985[b]	2613	7629	1357	12	11611	743	6331	5101	0	12175	2	1216	2823	0	4041	50600	27827

[a]Quota changed during year after consultation with fishing industry.
[b]Provisional data

Table 2: 4RST Redfish nominal catches (t) by division, region and month in 1985.

MONTH	4R				4S				4T				4RST TOTAL
	CAN-N	CAN-M	CAN-Q	TOTAL	CAN-N	CAN-M	CAN-Q	TOTAL	CAN-N	CAN-M	CAN-Q	TOTAL	
J	0	1007	0	1007	0	18	0	18	0	0	0	0	1025
F	0	347	0	347	0	0	0	0	0	0	0	0	347
M	0	0	0	0	0	0	1	1	0	0	0	0	1
A	117	1	0	118	0	0	10	10	0	0	11	11	139
M	175	165	11	351	2	726	672	1400	0	94	315	409	2160
J	33	668	267	968	0	171	378	549	0	257	1043	1300	2817
J	180	890	230	1300	0	572	741	1313	0	440	716	1156	3769
A	466	844	33	1343	136	969	167	1272	0	264	28	292	2907
S	601	894	587	2082	201	774	1179	2154	0	76	300	376	4612
O	730	2240	100	3070	263	1054	1405	2722	2	84	223	309	6101
N	162	377	109	648	141	1373	548	2062	0	1	187	188	2898
D	149	196	20	365	0	674	0	674	0	0	0	0	1039
TOTAL	2613	7629	1357	11599	743	6331	5101	12175	2	1216	2823	4041	27815

Table 3: 4RST Redfish nominal catches by gear, tonnage class, division and region in 1985.

GEAR	TON CLASS	4R				4S				4T				
		CAN-N	CAN-M	CAN-Q	TOTAL	CAN-N	CAN-M	CAN-Q	TOTAL	CAN-N	CAN-M	CAN-Q	TOTAL	TOTAL
OTB	1	0	278	0	278	0	0	0	0	0	0	3	3	281
	2	0	6	0	6	0	0	9	9	0	0	30	30	45
	3	0	384	0	384	0	5	33	38	0	68	57	125	547
	4	2286	3837	1357	7480	465	2713	4598	7776	2	1065	2659	3726	18982
	5	327	2531	0	2858	278	1980	0	2258	0	0	0	0	5116
	UNK	0	0	0	0	0	0	0	0	0	0	2	2	2
ST	1	0	8	0	8	0	0	6	6	0	0	0	0	14
	2	0	12	0	12	0	0	54	54	0	0	1	1	67
	3	0	113	0	113	0	286	389	675	0	8	20	28	816
	4	0	0	0	0	0	99	0	99	0	74	0	74	173
OTM	5	0	447	0	447	0	1248	0	1248	0	0	0	0	1695
SDN	3	0	0	0	0	0	0	0	0	0	1	0	1	1
GNS	NS	0	10	0	10	0	0	9	9	0	0	31	31	50
LLS	1	0	1	0	1	0	0	0	0	0	0	12	12	13
	2	0	0	0	0	0	0	1	1	0	0	1	1	2
PTB	3	0	0	0	0	0	0	2	2	0	0	7	7	9
DRB	3	0	2	0	2	0	0	0	0	0	0	0	0	2
TOTAL	—	2613	7629	1357	11599	743	6331	5101	12175	2	1216	2823	4041	27815

Table 4: 4RST Redfish. Percent landings according to Tonnage Class.

TC	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1	0	0	0	0	0	0	0	0	0	1	0	3	9	0	0	0	0	0	0
2	10	7	3	4	4	2	1	1	2	2	4	4	2	2	2	2	1	1	0
3	54	52	31	28	28	18	10	11	13	17	39	27	22	10	26	15	10	4	5
4	36	41	62	57	59	49	41	53	41	22	50	53	63	82	67	76	75	80	69
5	0	0	4	11	10	31	47	33	44	57	6	13	3	5	5	7	13	15	25
6	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Table 5: 4RST Redfish - Percent landings according to gear.

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
OTB	100	100	100	100	92	50	23	36	36	39	67	66	54	48	63	100	99	98	94
OTM	0	0	0	0	8	50	77	65	65	62	33	31	36	52	36	0	0	1	6
SDN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GNS	0	0	0	0	0	0	0	0	0	0	1	2	9	0	0	0	0	0	0
MIS	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Table 6: Summary of redfish (1985) length frequency sampling effort.

Division	Males	Females	Unsexed[a]	Total
		Scotia-Fundy Sea Samples - 3 samples		
4R	346	254	-	600
		Quebec Sea Samples - 46 samples		
4R	971	445	-	1,416
4S	1,875	1,998	1.338	5,211
4T	1,286	1,775	-	3,061
		Gulf Port Samplers - 39 samples		
4R	907	940	-	1,847
4S	2,902	3,825	-	6,727
4T	714	401	-	1,115
		Quebec Port Samples - 14 samples		
4R	46	72	132	250
4S	978	1,316	194	2,488
4T	608	544	152	1,304
Totals	10,633	11,570	1,816	24,019

[a] Unsexed samples not included in catch at age calculations.

Table 7: Commercial sampling of 4RST redfish and nominal catches for 1984. Fish measured males - females/followed by nominal catch (t).

	4R			4S			4T		
MONTH	OTB	ST	OTM	OTB	ST	OTM	OTB	ST	OTM
J	290-285/491			0 - 0 / 747		113/96/0			
F	637-364/289		140-105/30						
M	0 - 0 / 12								
A	0 - 0 / 6			0 - 0 / 2	0 - 0 / 5		0 - 0 / 1		
M	569-584/1200			1586-1259/1939	0 - 0 / 34		278-155/308		
J	817-697/2291	0 - 0 / 38		983-534/1067	0 - 0 / 171		1228-738/1300	0 - 0 / 1	0 - 0 / 245
J	887-628/2450	0 - 0 / 9		828-605/1245	326-436/183		1692-1699/1386	0 - 0 / 10	
A	1208-995/1392	0 - 0 / 14		1185-1352/702	793-1117/326		1093-1172/2649	0 - 0 / 3	
S	515-619/1744	0 - 0 / 3	0 - 0 / 5	807-1028/1593	297-518/267	199-135/0	537-724/930	0 - 0 / 7	0 - 0 / 5
O	330-335/342	0 - 0 / 11	0 - 0 / 201	1226-1735/1576	1123-478/174	0 - 0 /341	360-401/1644	0 - 0 / 1	
N	102-148/828	0 - 0 / 11		1131-1213/2015			0 - 0 / 945	0 - 0 / 1	
D	307-442/784	0 - 0 / 3		217-276/190			0 - 0 / 915	0 - 0 / 2	

Table 8: Commercial sampling of 4RST redfish and nominal catches for 1985. Fish measured males - females/followed by nominal catch (t).

	4R			4S			4T		
MONTH	OTB	ST	OTM	OTB	ST	OTM	OTB	ST	OTM
J	346-254/684		0 - 0/323	0 - 0/18					
F	0 - 0 /347								
M					0 - 0 /0.7	0 - 0/181			
A	0 - 0 /117		0 - 0/1	96-155/0	0 - 0 /9.6		0 - 0/9.7		
M	0 - 0 /350.2	0 - 0 /1		145-206/1144.8	0 - 0 /73.9		137-188/397.8	0 - 0 /1.1	
J	0 - 0 /941	52-72/24		555-687/412	240-157/137.8		1215-618/1295.2	0 - 0 /3	
J	121-131/1279.1	0 - 0 / 20		542-769/1090.2	364-444/221.1		670-1727/1142.7	0 - 0 /4.4	370-169/0
A	141-136/1315.9	0 - 0 / 25		539-709/1062.3	191-243/205.4		0 - 0/272.3	0 - 0 /5.4	
S	876-397/2056.5	0 - 0 / 22		1477-1440/2033	210-324/115.3	0 - 0/2	148-103/351.1	0 - 0 /13.1	
O	166-258/3008.7	0 - 0 / 13	0 - 0/46	537-724/2654.1	0 - 0 /66.6		0 - 0/230.6	0 - 0 /75.4	
N	141-128/620.5	0 - 0 / 25		695-815/1229.2	0 - 0 /4.1	0 - 0/829	79-151/187.6		
D	0 - 0 /285.4	0 - 0 / 3	0 - 0/77	0 - 0 /438.1		0 - 0/236			

Table 9: Yearly 4RST redfish catch rates from 1981 to 1985.

Year	1981	1982	1983	1984	1985
			Gulf PEI + NB (CAN-M) + Quebec (CAN-Q) TC-4 Vessels		
t/h	1.56	1.14	1.28	1.06	0.90
t/day	16.87	17.95	17.15	15.00	12.07
			Non-Gulf Newfoundland (CAN-N) + Nova Scotia (CAN-M) TC-4 Vessels		
t/h	0.89	0.83	0.57	0.62	0.47
t/day	11.73	13.33	8.11	8.59	6.46
			Non-Gulf Newfoundland (CAN-N) + Nova Scotia (CAN-M) TC-5 Vessels		
t/h	2.23	1.47	1.17	1.58	1.41
t/day	31.33	16.84	15.11	21.35	18.66

Table 10: Directed landings and effort for 4RST redfish from 1981-1985.

Year	1981	1982	1983	1984	1985
Gulf PEI + NB (CAN-M) + Quebec (CAN-Q) TC-4 Vessels					
Landings (t)	5517	17612	16619	21327	13072
Effort (h)	3538	15408	13009	20079	14682
Effort (days fished)	327	981	969	1422	1095
Non-Gulf Nova Scotia (CAN-M) + Newfoundland (CAN-N) TC-4 Vessels					
Landings (t)	786	1360	1687	2500	3231
Effort (h)	882	1639	2974	4052	6726
Effort (days fished)	67	102	208	291	482
Non-Gulf Nova Scotia (CAN-M) + Newfoundland (CAN-N) TC-5 Vessels					
Landings (t)	847	1796	2871	4377	5020
Effort (h)	380	1223	2461	2776	3564
Effort (days fished)	27	106	190	205	269

Table 11: Number of 30 degree quadrats in which 75% of the effort was exerted by the commercial fishery from 1975-1985. Gulf = PEI + NB + Que. Non-Gulf = NS + Nfld.

YEAR	QUEBEC TC-4	GULF TC-4	NON-GULF TC-4	NON-GULF TC-5
1975	10	-	-	-
1976	7	-	-	-
1977	5	-	-	-
1978	10	-	-	-
1979	6	-	-	-
1980	5	-	-	-
1981	4	-	-	-
1982	6	-	-	-
1983	6	-	-	-
1984	9	12	3	5
1985	13	14	3	4

Table 12: Comparison of abundance indices of Divs. 4RST redfish between 1984 and 1985 from commercial and research vessel sampling.

INDEX	1984	1985	RATIO 1985/1984
Quebec commercial CPUE (area with 75% effort)	1.17	0.83	0.70
R/V biomass estimates (all ages)	473,209 t	486,222 t	1.03
R/V biomass estimates (adults 10+)	443,710 t	315,251 t	0.71
R/V catch/tow (kg) (area with 75% effort)	388	220	0.57
Standardized CPUE	1.20	0.95	0.79

Table 13: CAN-N OTB Tonnage Class 4 Vessels directing for 4RST Redfish

MONTH	1984		1985	
	NUMBER OF BOATS FISHING	NUMBER OF BOATS WITH HI-LIFT TRAWLS	NUMBER OF BOATS FISHING	NUMBER OF BOATS WITH HI-LIFT TRAWLS
J	0	0	0	0
F	0	0	0	0
M	0	0	0	0
A	0	0	3	1
M	5	3	3	1
J	5	3	2	1
J	4	3	3	1
A	4	3	4	1
S	0	0	5	2
O	0	0	3	1
N*	0	0	3	1
D*	0	0	3	1

*Note: no log book data for the months Nov. and Dec., so the ratios were assumed.

Table 14: Comparison of catch rates (t/h) calculated from the multiplicative model for adjusted and unadjusted data with all runs weighted by effort.

Year	Unadjusted	Adjusted CAN-(M+Q) TC-4	Adjusted CAN-(M+Q) TC-4,TC-5	Adjusted CAN-(M+Q) TC-4,TC-5 CAN-N TC-4,TC-5
1959	0.760	0.749	0.746	0.759
1960	0.781	0.771	0.770	0.780
1961	0.758	0.750	0.749	0.758
1962	0.563	0.557	0.557	0.564
1963	1.093	1.079	1.076	1.094
1964	1.151	1.134	1.129	1.151
1965	1.276	1.254	1.250	1.275
1966	1.460	1.432	1.431	1.458
1967	1.689	1.660	1.657	1.691
1968	1.605	1.579	1.574	1.608
1969	1.115	1.096	1.098	1.115
1970	0.920	0.912	0.904	0.933
1971	0.879	0.873	0.868	0.887
1972	0.988	0.966	0.971	0.960
1973	0.872	0.851	0.850	0.870
1974	0.618	0.611	0.601	0.623
1975	0.593	0.601	0.578	0.609
1976	0.736	0.721	0.712	0.728
1977	0.619	0.603	0.609	0.618
1978	0.720	0.702	0.709	0.719
1979	0.830	0.809	0.814	0.830
1980	1.160	1.132	1.140	1.162
1981	1.381	1.322	1.326	1.348
1982	1.587	1.271	1.265	1.283
1983	1.552	1.289	1.251	1.305
1984	1.476	1.197	1.183	1.213
1985	1.134	0.952	0.937	0.923

Table 15: Analysis of variance for Division 4RST redfish adjusted for TC-4 vessels CAN-M+Q

Multiple R 0.762
Multiple R squared 0.581

ANALYSIS OF VARIANCE

Source of Variation		Degrees of Freedom	Sums of Squares	Mean Squares	F - Value
Intercept		1	79.45	79.45	
Regression		41	250.00	6.10	56.06
Gear	Type 1	5	135.30	27.06	248.79
Months	Type 2	8	10.54	1.32	12.11
Divisions	Type 3	2	6.11	3.06	28.10
Years	Type 4	26	109.80	4.22	38.82
Residuals		1659	180.50	0.11	
Total		1701	509.90		

Table 16: Variability for multipicative model weighted by effort. Coding by gear, months, division and year are indicated from 1959-1985 with data adjusted for TC-4 (M+Q) vessels.

REGRESSION COEFFICIENTS

Category	Variable	Coefficient Log Scale	Standard Error	Number of Observations
Gear				
	Intercept	-0.340	0.085	1701
CAN-M+Q OTB4	-	-0.000	-	-
CAN-M+Q OTB5	1	0.438	0.041	181
CAN-M+Q+N OTM5	2	1.092	0.033	191
CAN-N OTB4	3	0.170	0.022	372
CAN-N OTB5	4	0.273	0.059	128
CAN-M+Q OTM4	5	0.699	0.030	188
Month				
January	-	0.000	-	-
Feb.-March	6	-0.011	0.077	74
April	7	-0.125	0.089	57
May	8	-0.329	0.064	128
June-July	9	-0.325	0.056	387
Aug.-Sept.	10	-0.316	0.056	411
Oct.	11	-0.400	0.058	220
Nov.	12	-0.442	0.059	196
Dec.	13	-0.389	0.062	139
Division				
4R	-	0.000	-	-
4S	14	0.002	0.018	633
4T	15	-0.212	0.030	290
Year				
1959	-	0.000	-	-
1960	16	0.030	0.102	26
1961	17	0.002	0.102	19
1962	18	-0.291	0.133	20
1963	19	0.365	0.096	33
1964	20	0.417	0.113	24
1965	21	0.515	0.089	30

Cont'd

Table 16: Cont'd.

REGRESSION COEFFICIENTS

Category	Variable	Coefficient Log Scale	Standard Error	Number of Observations
Year				
1966	22	0.648	0.082	49
1967	23	0.796	0.086	51
1968	24	0.745	0.075	66
1969	25	0.379	0.071	81
1970	26	0.195	0.069	103
1971	27	0.151	0.070	94
1972	28	0.253	0.071	140
1973	29	0.126	0.070	163
1974	30	-0.205	0.071	149
1975	31	-0.222	0.071	165
1976	32	-0.039	0.087	67
1977	33	-0.217	0.090	39
1978	34	-0.065	0.093	33
1979	35	0.078	0.093	22
1980	36	0.414	0.095	28
1981	37	0.569	0.094	33
1982	38	0.527	0.079	77
1983	39	0.542	0.080	51
1984	40	0.468	0.075	66
1985	41	0.238	0.075	49

Table 17: 4RST redfish catch rate standardized to Maritimes and Quebec OTB-4 Otter trawlers, adjusted for the shift to Engle High lift trawls.

		Catch Rate			
Year	Total Catch(t)	Proportion	Mean(t/h)	Standard Error	Effort (h)
1959	16978	0.392	0.749	0.063	22668
1960	12218	0.390	0.771	0.070	15842
1961	10391	0.394	0.750	0.071	13863
1962	6585	0.211	0.557	0.071	11820
1963	19794	0.361	1.079	0.098	18350
1964	29700	0.162	1.134	0.123	26194
1965	48827	0.243	1.254	0.106	38974
1966	65215	0.332	1.432	0.108	45531
1967	70036	0.260	1.660	0.134	42183
1968	90963	0.395	1.579	0.108	57607
1969	88875	0.494	1.096	0.069	81073
1970	87588	0.553	0.912	0.055	96028
1971	79406	0.530	0.873	0.053	90962
1972	80329	0.742	0.966	0.062	83127
1973	130164	0.834	0.851	0.054	152999
1974	63489	0.790	0.611	0.038	103883
1975	65401	0.783	0.601	0.039	108845
1976	37983	0.705	0.721	0.049	52684
1977	15840	0.497	0.603	0.050	26281
1978	13591	0.588	0.702	0.061	19367
1979	15034	0.610	0.809	0.071	15580
1980	14832	0.804	1.132	0.102	13102
1981	20549	0.699	1.322	0.117	15544
1982	26429	0.786	1.271	0.091	20801
1983	24505	0.828	1.281	0.092	19004
1984	35780	0.832	1.197	0.00	229887
1985	27827	0.864	0.952	0.064	29235

Average C.V. for the Mean: 0.079.

Table 18: Commercial age length key for male redfish caught in Division 4RST in 1984.

Fork Length	Numbers at Age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Total
10	2																																				2
11	2	2	1																																		5
12		11																																			11
13		13	2	1																																	16
14		1	8		1																																10
15			8	6	2																																16
16			1	5																																	6
17			1	5	2																																8
18					3																																3
19					1																																1
20					7	10	1																														18
21					3	15	4																														22
22					1	14	8	1	1																												25
23						2	11	10	2	1																											26
24							3	16	8	3																											30
25							2	17	16	9	1																										45
26								9	17	12	5	2																									45
27								3	1	21	7	4																									36
28										3	10	12	5																								30
29										2	4	17	12	2																							37
30											1	9	20	7	3	1				1																	42
31												3	12	8	6	1	1				1	1															33
32													4	8	8	4	2	1	1		1	2		1		1											33
33															2	3	3	3	4	1	3		1	2	3	1		1									27
34																1	1	4	4	7	4	4	4	5	2	1	1										38
35																				2		7	10	6	3	1	2										31
36																				2	2	3	6	4	4	1	5	1	1			1					30
37																				1	2	3	2	5	4		4	2									23
38																						1			3	3	7	3	2								19
39																						1			1	3	4	4		1							14
40																									2		4	3	2	1							12
41																										2		2	1		1				1		7
42																										1	3	1	1	1	1						8
43																																1		1			2
44																									1			1									2
45																														1							1
46																													1								1
Total	4	27	21	17	20	41	29	56	45	51	28	47	53	25	19	10	7	8	9	14	13	22	23	24	22	14	31	17	8	4	2	2	0	1	1		715

Table 19: Commercial age length key for female redfish caught in Division 4RST in 1984.

Fork Length	Numbers at Age																																				Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	
10	2																																				2
11	2	2	1																																		5
12		11																																			11
13		13	2	1																																	16
14		1	8		1																																10
15			8	6	2																																16
16				2	2																																4
17				2	2																																4
18				1	3																																4
19					4																																4
20					7	5																															12
21					7	6		1																													14
22					5	6	5	2																													18
23					1	5	12	6	3																												27
24							6	4	3																												13
25							1	11	10	3	1																										26
26							1	6	13	6	1	1																									28
27								3	7	13	9	2	1																								35
28									2	6	13	6	2																								29
29											8	15	9																								32
30											5	16	13	2																							36
31												8	8	4	5						1																26
32												1	9	14	11	1	1																				37
33													3	2	7	13	2	2	1	1	1	2	1	1		2											38
34														1	1	5	9	4	9	1	3	3			1		1										38
35															1	1	3	4	8	7	11	3	2	2	1												43
36																	1	2	3	3	1	7	2	1	5		1	1									27
37																		1		3	2	4	7	9	8	2	7	1									44
38																				1		1	2	6	14	2	3	1		1	1						32
39																						1	1	5	5	6	12	2	3	1							36
40																							1	5	7	2	6	8	1	2	2						34
41																									6	2	4	2	3	2	1						20
42																							1	2	1	1	2	1	3	4	2						17
43																								1	1	1	2	1		5							11
44																								1	1		2	3	1	3	3	1					15
45																								1			1		2	2	1	1					8
46																								1	1				1	1					1		5
47																								1					1			2					4
48																											1				2						3
49																																1					1
50																								1				1								1	3
51																											1										1
52																												1									1
Total	4	27	19	12	34	22	25	33	38	28	37	49	45	23	25	20	16	13	21	16	19	21	17	37	51	18	43	22	15	21	12	5	0	0	1	1	790

Table 20: Commercial age length key for male redfish caught in Division 4RST in 1985.

Fork Length	Numbers at Age																																					Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	
11	1																																					1
12		6																																				6
13		7	10	1																																		18
14		2	24	5																																		31
15			14	32	7																																	53
16				2		1																																3
17				3	2																																	5
18					4																																	4
19				1	7	2																																10
20					2	3	2																															7
21					1	18	6	2	1																													28
22						8	17	3	1																													29
23						4	19	7																														30
24						3	6	14	6	1																												30
25							1	10	15	3	1																											30
26								4	7	10	6	1	1		1																							30
27									6	13	7	4			1																							31
28								1		1	13	10	2	2																								29
29											2	14	11	3	1																							31
30												2	14	13		1																						30
31												1	7	14	5	3					1																	31
32													3	8	4	2	3	1	3	2	1	1	1	1														30
33													1	2	3	4	5	2	3	4	1	1	3	1														30
34															1		1	2	2	4	2	8	6	2	2	1												31
35																	1	1		2		3	12	4	2	3			1									29
36																					3	2	4	7	8	5					1							30
37																			1				3	2	1	10	6	5		1	1							30
38																								2	2	9	2	9	1	1	1	1	1					29
39																							1	1	1	3	5	7	9		2							29
40																								2	1	5	2	7	4	6	3	1						31
41																									1	1	1	5	1	2	3		2					16
42																									1	1	2	4	1	3	3							15
43																										1	1	2		2		2			1			9
44																												1	1	1	1	1						5
45																										2		1			2							5
46																																	2					2
48																																					1	1
49																																	1					1
51																															1							1
Total	1	15	48	44	23	39	51	41	36	28	29	32	39	42	16	10	10	6	9	12	8	15	30	22	19	41	19	41	18	16	18	5	6	0	1	0	1	791

Table 21: Commercial age length key for female redfish caught in Division 4RST in 1985.

Fork Length	Numbers at Age 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	Total
11	1																																					1
12		6																																				6
13		7	10	1																																		18
14		2	24	5																																		31
15			14	32	7																																	53
16				1	2																																	3
17					3																																	3
18				2	4	2																																8
19					4		1																															5
20					4	5																																9
21					5	20	4																															29
22						19	13																															32
23						9	16	2	2		1																											30
24							17	9	3	1																												30
25							5	16	7	2																												30
26							2	5	13	6	3	2																										31
27								2	11	14	3																											30
28									2	11	13	4	1																									31
29										2	7	13	8																									30
30											9	9	10	1																								29
31												5	16	8																								29
32													5	21	4		1																					31
33														3	13	3	5		3		1																	28
34															1	3	7	7	4	6	1	1			1													31
35														1		1	1	3	4	5	6	4	4	1		1												31
36																		1			7	5	10	5	1	1			1									31
37																			1			3	4	12	1	7		1										29
38																						1	3	4	4	11	4	2										29
39																									2	12	5	8	1	1								29
40																								1	3	11	2	8	2	2	1							30
41																								1	3	8	2	5	4	1	4		2					30
42																									1	2	3	11	4	5	3			1				30
43																										1	2	5	5	7	2	4		2				28
44																									1		1	6	2	4	4	3	1	1				23
45																												1	3	3	1	3	2	1			1	15
46																										1		2	1	3	2	1			1			11
47																												1	1					1	1	2		6
48																													1		1							2
49																											1						1		1			3
51																												1					1					2
Total	1	15	48	41	29	55	58	34	38	36	36	33	40	34	18	7	14	11	12	11	15	14	21	24	17	55	20	51	25	26	18	11	7	6	3	2	1	887

Table 22: Catch at age calculations for 1984 Division 4RST redfish, based on landings of 35780 t sexes combined.

	AVERAGE		CATCH		
AGE	WEIGHT	LENGTH	MEAN	STD. ERR.	C. V.
5	0.068	16.657	50.335	12.769	0.254
6	0.122	20.214	601.847	68.804	0.114
7	0.138	21.156	724.961	75.869	0.105
8	0.174	22.811	466.844	57.407	0.123
9	0.227	24.955	964.451	109.596	0.114
10	0.247	25.679	986.118	105.448	0.107
11	0.289	27.159	2114.752	278.225	0.132
12	0.334	28.448	3263.500	454.858	0.139
13	0.377	29.604	9333.348	895.899	0.096
14	0.408	30.422	12523.815	1097.354	0.088
15	0.444	31.275	7041.288	911.882	0.130
16	0.465	31.732	6194.095	863.842	0.139
17	0.510	32.694	3226.953	555.061	0.172
18	0.535	33.208	2038.161	438.392	0.215
19	0.565	33.838	1539.703	350.674	0.228
20	0.573	33.974	2104.581	383.566	0.182
21	0.598	34.468	1744.516	339.656	0.195
22	0.562	33.762	2151.079	429.061	0.199
23	0.612	34.744	2649.994	427.480	0.161
24	0.652	35.558	2001.521	313.915	0.157
25	0.687	36.035	2590.426	367.558	0.142
26	0.742	36.915	3092.484	368.522	0.119
27	0.709	36.290	1313.144	285.093	0.217
28	0.796	37.883	2219.387	268.749	0.121
29	0.820	38.226	1030.276	200.586	0.195

Table 23: Catch at age calculations for 1985 Div. 4RST redfish based on landings of 27816 t.

	AVERAGE		CATCH		
AGE	WEIGHT	LENGTH	MEAN	STD. ERR.	C. V.
5	0.068	16.633	195.136	69.487	0.356
6	0.087	18.023	568.566	77.147	0.136
7	0.151	21.713	1070.225	110.669	0.103
8	0.182	23.162	1843.251	153.216	0.083
9	0.218	24.630	1964.290	203.297	0.103
10	0.242	25.538	2000.073	210.089	0.105
11	0.277	26.717	1830.201	205.873	0.112
12	0.328	28.207	2724.003	318.644	0.117
13	0.363	29.246	4127.939	484.764	0.117
14	0.408	30.400	7521.699	720.551	0.096
15	0.444	31.269	8946.995	776.070	0.087
16	0.490	32.242	3796.265	576.301	0.152
17	0.497	32.460	1679.514	408.171	0.243
18	0.535	33.204	2209.735	440.150	0.199
19	0.576	34.011	1256.263	292.166	0.233
20	0.553	33.563	1684.430	375.184	0.223
21	0.563	33.839	1627.111	327.549	0.201
22	0.597	34.376	1474.874	318.323	0.216
23	0.617	34.855	1621.823	294.374	0.182
24	0.635	35.215	2397.067	324.117	0.135
25	0.691	36.112	1814.446	271.838	0.150
26	0.732	36.794	982.803	194.363	0.198
27	0.804	37.933	2279.898	243.963	0.107
28	0.866	38.906	601.839	118.593	0.197
29	0.913	39.580	1068.878	136.686	0.128

Table 24: 4RST redfish catch at age for 1972 - 1985.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5	142	273	170	355	7359	3801	3368	2266	125	1	1	33	50	195
6	1272	639	698	620	1482	2119	2656	2378	285	4	1	89	602	569
7	784	3112	292	290	1073	824	511	2233	2728	308	73	1	725	1070
8	944	2380	444	401	372	669	280	2899	7800	2586	782	71	467	1843
9	1887	803	510	448	188	620	800	2373	7926	10810	3714	612	964	1964
10	4297	3434	216	286	44	416	708	2753	5723	11974	4482	1499	986	2000
11	2938	8043	403	161	146	409	491	1902	2141	7276	9824	3452	2115	1830
12	6366	2497	463	329	125	236	372	1838	1516	5222	9607	6626	3263	2724
13	2588	12850	2240	974	383	171	131	931	853	3449	8634	7192	9333	4128
14	14034	7060	5381	1654	716	177	131	510	532	2085	6833	6083	12524	7522
15	7971	76633	6364	2956	1836	79	153	326	531	1219	5198	6205	7041	8947
16	66593	8222	28739	4572	3913	123	86	346	265	940	2298	5753	6194	3796
17	5102	88382	7953	25149	4025	509	247	887	306	328	1761	3076	3227	1680
18	7659	5583	37269	5771	15842	379	1003	1131	300	401	681	1265	2038	2210
19	4299	9916	2989	41020	3380	2959	1399	2392	500	973	924	914	1540	1256
20	3697	7166	3387	4156	16519	1273	3621	1943	1601	858	1015	922	2105	1684
21	2471	4548	1371	3453	1533	5259	1294	3376	921	1133	808	735	1745	1627
22	2598	4333	1233	3489	2131	2519	3468	1542	2446	1192	1017	747	2151	1475
23	2366	4934	471	2634	1431	2314	4425	3048	1348	2120	1370	1160	2650	1622
24	1168	1306	1168	1632	1317	1814	1027	1013	2219	1235	2060	948	2002	2397
25	5840	2277	825	1356	543	1160	725	869	822	1555	1021	2320	2590	1814
26	1	7963	1815	1186	430	1027	222	905	505	826	1362	450	3092	983
27	1	1	5844	2080	408	229	222	506	298	458	686	1960	1313	2280
28	1	1	1	7259	659	515	315	522	234	262	550	580	2219	602
29	1	1	1	1	2370	196	103	102	78	136	250	563	1030	1069

Table 25: Divs. 4RST redfish weights at age for 1972-1985.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.049	0.068	0.068
6	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.085	0.085	0.075	0.122	0.087
7	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.165	0.118	0.115	0.138	0.151
8	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.219	0.197	0.159	0.174	0.182
9	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.205	0.263	0.245	0.194	0.227	0.218
10	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.243	0.293	0.287	0.258	0.247	0.242
11	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.282	0.32	0.317	0.312	0.289	0.277
12	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.322	0.346	0.345	0.339	0.334	0.328
13	0.362	0.362	0.362	0.362	0.362	0.362	0.362	0.362	0.362	0.388	0.377	0.373	0.377	0.363
14	0.403	0.403	0.403	0.403	0.403	0.403	0.403	0.403	0.403	0.406	0.387	0.408	0.408	0.408
15	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.454	0.42	0.441	0.444	0.444
16	0.482	0.482	0.482	0.482	0.482	0.482	0.482	0.482	0.482	0.465	0.483	0.45	0.465	0.49
17	0.521	0.521	0.521	0.521	0.521	0.521	0.521	0.521	0.521	0.502	0.478	0.472	0.51	0.497
18	0.559	0.559	0.559	0.559	0.559	0.559	0.559	0.559	0.559	0.535	0.529	0.504	0.535	0.535
19	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.596	0.522	0.479	0.453	0.565	0.576
20	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.569	0.492	0.556	0.573	0.553
21	0.665	0.665	0.665	0.665	0.665	0.665	0.665	0.665	0.665	0.552	0.518	0.552	0.598	0.563
22	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.698	0.621	0.527	0.541	0.562	0.597
23	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.613	0.567	0.576	0.612	0.617
24	0.759	0.759	0.759	0.759	0.759	0.759	0.759	0.759	0.759	0.626	0.602	0.582	0.652	0.635
25	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.682	0.652	0.621	0.687	0.691
26	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.815	0.757	0.666	0.732	0.742	0.732
27	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.841	0.782	0.753	0.718	0.709	0.804
28	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.869	0.771	0.908	0.796	0.866
29	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.889	0.879	0.835	0.763	0.82	0.913

Table 26: Calibrations of 5+ Biomass versus CPUE indicating optimization points at various levels of fishing (F) and natural mortalities (M). Population numbers (billions) from cohort are indicated Population Biomass in thousand metric tons is also given. PR fully recruited at age 15.

M = 0.10
F_t = 0.02
Pop. No. = 5.2
Pop. Bio. = 1762
Corr. R. = 0.82
Int.($x10^3$)= 44.0

M = 0.07
F_t = 0.04
Pop. No. = 2.6
Pop. Bio. = 893
Corr. R= 0.82
Int. ($x10^3$)= 35.1

M = 0.05
F_t = 0.05
Pop. No. = 2.1
Pop. Bio. = 714
Corr. R = 0.80
Int.($x10^3$)= 26.0

M = 0.04
F_t = 0.06
Pop. No. = 1.7
Pop. Bio. = 597
Corr. R = 0.78
Int.($x10^3$)= 36.4

M = 0.03
F_t = 0.06
Pop. No. = 1.7
Pop. Bio. = 595
Corr.R = 0.79
Int.($x10^3$)= 22.9

M = 0.02
Ft = 0.07
Pop. No. = 1.5
Pop. Bio. = 520
Corr. R = 0.75
Int.($x10^3$)= 32.4

Table 27: Population numbers estimated from cohort analysis for Division 4RST redfish at $F_t = 0.07$ and M = 0.02.

POPULATION NUMBERS ($x10^3$)

I	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5 I	69049	66800	112045	218398	254135	173737	122823	84905	92295	99036	130193	124824	84103	28235
6 I	43210	67541	65207	109658	213722	241817	166533	117056	80980	90344	97074	127614	122320	82388
7 I	45386	41095	65571	63225	106873	208022	234931	160606	112384	79095	88551	95150	124999	119302
8 I	39962	43711	37201	63984	61686	103695	203087	229773	155215	107458	77224	86725	93265	121806
9 I	41379	38236	40489	36024	62320	60096	100979	198789	222353	144419	102770	74920	84938	90956
10 I	54055	38691	36684	39182	34867	60900	58292	98187	192503	210101	130857	97058	72831	82301
11 I	66820	48731	34525	35743	38123	34133	59282	56437	93518	183025	194086	123829	93652	70412
12 I	80967	62588	39803	33443	34876	37224	33053	57622	53436	89546	172197	180516	117959	89703
13 I	57947	73061	58876	38556	32455	34062	36253	32030	54661	50877	82603	159276	170382	112393
14 I	238077	54237	58892	55493	36828	31433	33218	35406	30474	52734	46455	72419	149002	157768
15 I	57724	219468	46174	52398	52756	35390	30635	32431	34200	29344	49626	38770	64963	133652
16 I	320164	48690	139252	38959	48434	49894	34611	29877	31466	32997	27556	43497	31859	56705
17 I	66487	247893	39585	108041	33661	43601	48784	33841	28943	30580	31413	24735	36940	25096
18 I	48671	60120	155482	30928	81003	29009	42234	47574	32293	28067	29650	29047	21200	33013
19 I	29371	40124	53402	115505	24602	63715	28060	40404	45512	31356	27114	28389	27220	18762
20 I	19835	24533	29512	49385	72606	20768	59524	26119	37236	44116	29772	25662	26922	25156
21 I	13665	15782	16953	25574	44293	54814	19097	54760	23678	34914	42393	28178	24242	24304
22 I	13331	10948	10966	15259	21649	41898	48522	17437	50333	22297	33101	40753	26892	22034
23 I	8032	10495	6442	9529	11503	19111	38574	44128	15565	46915	20676	31438	39207	24230
24 I	10017	5530	5402	5848	6732	9859	16442	33429	40236	13923	43887	18910	29667	35807
25 I	50434	8662	4128	4138	4116	5295	7867	15099	31764	37243	12424	40979	17597	27098
26 I	7	43654	6236	3229	2714	3497	4042	6994	13940	30322	34966	11167	37870	14684
27 I	8	6	34906	4316	1991	2235	2411	3742	5959	13164	28904	32925	10501	34059
28 I	6	7	5	28428	2171	1548	1964	2144	3167	5546	12450	27652	30332	8993
29 I	9	5	6	4	20679	1476	1007	1613	1584	2872	5177	11659	26530	27535
5+I	1374612	1270608	1097744	1185249	1304796	1367227	1432224	1460402	1483696	1510290	1551116	1576093	1565391	1466394
6+I	1305563	1203808	985698	966852	1050662	1193491	1309402	1375497	1391401	1411254	1420923	1451269	1481288	1438159
7+I	1262353	1136267	920491	857194	836940	951674	1142868	1258441	1310421	1320911	1323850	1323655	1358968	1355771
8+I	1216967	1095172	854920	793969	730067	743652	907938	1097835	1198037	1241816	1235299	1228505	1233969	1236469

Table 28: Mean Population biomass for Division 4RST redfish estimated from cohort analysis at $F_t = 0.07$ and $M = 0.02$.

MEAN POPULATION BIOMASS (KG)

I	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5 I	6146	5940	9976	19445	22313	15310	10792	7463	8218	8825	11601	6055	5660	1894
6 I	4341	6855	6614	11151	21718	24551	16846	11815	8243	7603	8169	9473	14738	7072
7 I	6013	5281	8745	8431	14212	27749	31366	21316	14837	12896	10341	10834	17029	17755
8 I	6607	7111	6187	10672	10290	17294	33957	38201	25308	23016	14985	13647	16026	21781
9 I	8204	7678	8166	7266	12629	12134	20413	40104	44315	36170	24472	14331	18980	19417
10 I	12477	8886	8799	9392	8383	14601	13938	23288	45617	59182	36538	24599	17689	19477
11 I	18240	12441	9583	9957	10623	9472	16482	15488	25808	56818	59348	37711	26491	19057
12 I	24777	19550	12615	10609	11099	11829	10477	18073	16791	29766	57150	59461	38461	28683
13 I	20298	23791	20695	13642	11563	12177	12970	11311	19436	18870	29180	57473	61826	39642
14 I	92144	20189	22400	21808	14550	12506	13228	14024	12052	20773	16446	27998	57605	62188
15 I	23514	78114	18812	22323	22731	15505	13403	14152	14882	12912	19527	15524	26969	56750
16 I	136160	21199	59280	17470	22160	23781	16496	14174	14952	14972	12616	18058	13180	26572
17 I	32953	103215	18276	48908	16296	22358	25100	17225	14850	15117	14443	10819	17819	11928
18 I	24741	31692	75188	15453	40256	15949	23094	26013	17789	14759	15349	14174	10677	16891
19 I	16020	20590	30615	55072	13488	36711	16138	23124	26707	15951	12637	12525	14788	10335
20 I	11188	12942	17350	29526	39938	12570	36036	15698	22755	24608	14252	13870	14663	13304
21 I	8151	8797	10701	15666	28651	34317	12139	34923	15282	18768	21532	15196	13826	13086
22 I	8276	5931	7141	9278	14207	28069	32310	11506	33926	13337	17002	21627	14352	12580
23 I	4893	5598	4482	5876	7782	12952	26236	30771	10752	27821	11215	17594	22938	14297
24 I	7076	3639	3599	3743	4542	6699	11962	24736	29389	8238	25535	10619	18493	21744
25 I	37006	5818	2884	2661	2993	3656	5849	11435	24458	24615	7684	24470	11058	17907
26 I	6	31880	4252	2087	2010	2380	3170	5267	11042	22412	22601	7928	26661	10279
27 I	7	5	26539	2625	1480	1763	1913	2898	4836	10012	21290	22697	6897	26187
28 I	5	6	4	21086	1560	1090	1544	1602	2613	4657	9290	24595	23013	7448
29 I	7	4	5	3	17130	1210	840	1374	1360	2440	4175	8591	21115	24041
5+I	509251	447150	392906	374149	372605	376632	406701	435982	466218	504536	497378	499867	530955	520313
6+I	503105	441210	382930	354704	350292	361322	395909	428518	457999	495711	485777	493812	525294	518419
7+I	498764	434355	376316	343554	328573	336771	379063	416704	449756	488108	477608	484340	510556	511347
8+I	492751	429075	367572	335123	314361	309022	347696	395388	434919	475213	467267	473506	493528	493592

Table 29: Fishing mortalities estimated from cohort analysis for Division 4RST redfish at F_t = 0.07 and M = 0.02.

FISHING MORTALITY

I	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5	0.002	0.004	0.002	0.002	0.030	0.022	0.028	0.027	0.001	0.000	0.000	0.000	0.001	0.007
6	0.030	0.010	0.011	0.006	0.007	0.009	0.016	0.021	0.004	0.000	0.000	0.001	0.005	0.007
7	0.018	0.080	0.005	0.005	0.010	0.004	0.002	0.014	0.025	0.004	0.001	0.000	0.006	0.009
8	0.024	0.057	0.012	0.006	0.006	0.007	0.001	0.013	0.052	0.025	0.010	0.001	0.005	0.015
9	0.047	0.021	0.013	0.013	0.003	0.010	0.006	0.012	0.037	0.079	0.037	0.008	0.012	0.022
10	0.084	0.094	0.006	0.007	0.001	0.007	0.012	0.029	0.030	0.059	0.035	0.016	0.014	0.025
11	0.045	0.182	0.012	0.005	0.004	0.012	0.008	0.035	0.023	0.041	0.052	0.029	0.023	0.027
12	0.083	0.041	0.012	0.010	0.004	0.006	0.011	0.033	0.029	0.061	0.058	0.038	0.028	0.031
13	0.046	0.196	0.039	0.026	0.012	0.005	0.004	0.030	0.016	0.071	0.112	0.047	0.057	0.038
14	0.061	0.141	0.097	0.031	0.020	0.006	0.004	0.015	0.018	0.041	0.161	0.089	0.089	0.049
15	0.150	0.435	0.150	0.059	0.036	0.002	0.005	0.010	0.016	0.043	0.112	0.176	0.116	0.070
16	0.236	0.187	0.234	0.126	0.085	0.002	0.003	0.012	0.009	0.029	0.088	0.143	0.219	0.070
17	0.081	0.446	0.227	0.268	0.129	0.012	0.005	0.027	0.011	0.011	0.058	0.134	0.092	0.070
18	0.173	0.098	0.277	0.209	0.220	0.013	0.024	0.024	0.009	0.015	0.023	0.045	0.102	0.070
19	0.160	0.287	0.058	0.444	0.149	0.048	0.052	0.062	0.011	0.032	0.035	0.033	0.059	0.070
20	0.209	0.350	0.123	0.089	0.261	0.064	0.063	0.078	0.044	0.020	0.035	0.037	0.082	0.070
21	0.202	0.344	0.085	0.147	0.036	0.102	0.071	0.064	0.040	0.033	0.019	0.027	0.075	0.070
22	0.219	0.510	0.121	0.263	0.105	0.063	0.075	0.094	0.050	0.056	0.032	0.019	0.084	0.070
23	0.353	0.644	0.077	0.327	0.134	0.130	0.123	0.072	0.092	0.047	0.069	0.038	0.071	0.070
24	0.125	0.273	0.246	0.331	0.220	0.206	0.065	0.031	0.057	0.094	0.049	0.052	0.071	0.070
25	0.124	0.309	0.225	0.402	0.143	0.250	0.098	0.060	0.026	0.043	0.087	0.059	0.161	0.070
26	0.146	0.204	0.348	0.464	0.174	0.352	0.057	0.140	0.037	0.028	0.040	0.042	0.086	0.070
27	0.127	0.175	0.185	0.667	0.232	0.109	0.098	0.147	0.052	0.036	0.024	0.062	0.135	0.070
28	0.189	0.149	0.216	0.298	0.366	0.410	0.177	0.282	0.078	0.049	0.046	0.021	0.077	0.070
29	0.120	0.239	0.179	0.283	0.123	0.144	0.109	0.066	0.051	0.049	0.050	0.050	0.040	0.070
15+	0.193	0.370	0.205	0.257	0.146	0.057	0.050	0.051	0.032	0.035	0.051	0.068	0.097	0.070

Table 30; Biomass estimates in kg per standard 1.75 nautical mile and population biomass calculated in metric tons for 1984 and 1985 obtained by the Lady Hammond research surveys.

Strata	Depth Range (fathoms)	Strata Area (Sq. N. Mi.)	1984 Standard Catch per tow (1.75 N.mi. kg/tow)	1985	1984 Biomass(t) per Stratum	1985
820	51-100	396	1.19	8.54	39.90	286.61
821	"	371	1.30	13.76	40.73	432.53
822	"	946	3.79	14.99	303.55	1201.49
823	"	162	3.60	21.51	49.43	295.27
824	"	244	139.90	54.75	2892.80	1132.02
825	"	1156	0.00	217.96	0.00	21352.37
826	"	902	N/S	0.00	N/S	0.00
827	"	942	N/S	49.26	N/S	3932.30
828	"	710	N/S	0.61	N/S	36.68
829	"	785	N/S	36.89	N/S	2454.37
830	"	559	209.68	88.62	9933.00	4198.12
831	"	351	N/S	32.94	N/S	979.97
832	"	1155	N/S	16.99	N/S	1663.04
401	101-150	159	487.89	79.05	6574.15	1065.19
402	"	265	365.56	406.19	8209.53	9122.10
403	"	347	0.00	136.31	N/S	4008.45
811	"	439	414.79	201.99	15431.56	7514.77
812	"	1355	230.80	273.58	26502.70	31415.35
813	"	1154	11.66	54.54	1140.14	5333.78
814	"	300	98.75	385.03	2510.72	9789.02
815	"	1285	140.98	308.92	15352.21	33640.48
816	"	1467	69.26	182.65	8610.57	22707.32
817	"	1063	187.10	114.09	16854.42	10278.17
818	"	630	291.28	300.84	15551.31	16061.79
819	"	420	520.52	405.99	18526.84	14450.42
404	151-200	231	826.69	402.85	16183.49	7886.31
405	"	431	327.96	251.02	11978.71	9168.74
406	"	752	637.11	222.43	40602.39	14175.35
801	"	354	138.56	125.48	4156.85	3764.40
805	"	1680	7.89	63.86	11236.15	9091.91
806	"	620	172.15	229.26	9044.92	12046.12
807	"	691	391.59	1589.12	22931.40	93057.88
808	"	708	244.41	275.32	14664.84	16519.19
809	"	451	647.58	269.86	24750.90	10314.27
810	"	223	525.07	628.08	9923.02	11869.68
407	201+	681	486.41	233.96	28071.81	13502.21
408	"	797	209.05	201.65	14120.03	13619.68
802	"	399	51.38	138.88	1737.39	4696.00
803	"	2034	127.30	229.20	21942.67	39508.06
804	"	726	384.67	394.15	23666.81	24250.39

Total Biomass Sampled Strata	403534.96t	486821.80 t
Total Biomass Sampled > 100f	390275.54	448856.64
Adjusted Total Biomass	473208.92	486821.80

Table 31: 4RST redfish mean weight (kg), mean length (cm) and population number estimates at age determined from 1984 R/V survey data based on a total weight of 473,209 t.

AGE	AVERAGE WEIGHT	AVERAGE LENGTH	CATCH NUMBERS (x103) MEAN	STD.ERR.	C.V.
2	0.016	10.358	97809	15321	0.157
3	0.027	12.151	195724	16501	0.084
4	0.028	13.629	86394	14536	0.168
5	0.056	15.607	46497	7154	0.154
6	0.089	18.027	61771	6716	0.109
7	0.135	20.978	27212	2714	0.100
8	0.172	22.710	15569	2003	0.129
9	0.215	24.504	22620	2169	0.096
10	0.238	25.365	20505	2054	0.100
11	0.282	26.901	26459	3208	0.121
12	0.335	28.447	39195	5283	0.135
13	0.378	29.631	108510	10328	0.095
14	0.409	30.438	144084	12645	0.088
15	0.445	31.300	81048	10496	0.129
16	0.467	31.766	72250	10049	0.139
17	0.513	32.740	39177	6660	0.170
18	0.538	33.268	25039	5280	0.211
19	0.568	33.891	19415	4332	0.223
20	0.575	34.018	26708	4764	0.178
21	0.603	34.548	22283	4193	0.188
22	0.567	33.844	27128	5209	0.192
23	0.615	34.781	32656	5215	0.160
24	0.658	35.644	25337	3955	0.156
25	0.714	36.399	34532	4693	0.136
26	0.758	37.131	40531	4694	0.116
27	0.726	36.549	17401	3627	0.208
28	0.818	38.157	30264	3602	0.119
29	0.847	30.572	13652	2535	0.186
30	0.973	40.399	6392	1490	0.233
31	1.051	41.341	6300	1406	0.223
32	1.064	41.411	3398	1082	0.318
33	1.080	41.466	12123	587	0.484
34					
35	1.113	43.000	168	183	1.091
36	1.447	46.000	2067	213	1.030
37	1.331	44.665	244	185	0.758
TOTAL:			1,417,746		

Table 32: 4RST redfish mean weight (kg), mean length and population number estimates at age determined from 1985 R/V survey data based on a total weight of 486,822 t.

	AVERAGE		CATCH NUMBERS (x103)		
AGE	WEIGHT	LENGTH	MEAN	STD.ERR.	C.V.
2	0.025	11.000	58361	439	0.008
3	0.037	12.602	322827	32619	0.101
4	0.049	13.904	682987	44356	0.065
5	0.066	15.489	703551	114451	0.163
6	0.086	16.976	592269	85146	0.144
7	0.103	17.896	136791	72543	0.530
8	0.183	22.103	44054	7612	0.173
9	0.236	24.294	22545	2347	0.104
10	0.262	25.190	17244	1965	0.114
11	0.306	26.595	12736	1582	0.124
12	0.366	28.259	19899	2437	0.122
13	0.405	29.306	30201	3710	0.123
14	0.453	30.505	66747	6154	0.092
15	0.495	31.416	67689	6577	0.097
16	0.538	32.287	32428	5027	0.155
17	0.546	32.525	15819	3763	0.238
18	0.583	33.211	21280	4159	0.195
19	0.626	34.008	12873	3016	0.234
20	0.606	33.643	17230	3724	0.216
21	0.613	33.845	17696	3560	0.201
22	0.656	34.507	15765	3262	0.207
23	0.673	34.917	18706	3377	0.181
24	0.690	35.270	31518	4100	0.130
25	0.750	36.187	24887	3548	0.143
26	0.796	36.935	14824	2607	0.176
27	0.860	37.881	35249	3570	0.101
28	0.921	38.798	10394	1844	0.177
29	0.965	39.430	18944	2227	0.118
30	0.995	39.744	7064	1362	0.193
31	1.070	40.806	4913	993	0.202
32	1.044	40.486	5099	1079	0.212
33	1.159	41.890	1182	414	0.350
34	1.247	42.944	1775	544	0.306
35	1.297	43.315	411	195	0.473
36	1.738	47.870	192	150	0.782
37	1.646	47.000	53	52	0.975
38	1.579	47.078	169	55	0.324
TOTAL:			3086466		

Table 33: Numbers at length and numbers at age of 4RST redfish estimated from the 1984 Lady Hammond research vessel survey.

LENGTH	NUMBER PER THOUSAND OF SEX COMBINED	MALE	FEMALE	AGE	NO PER THOU	BIOMASS
10	44.265	45.671	42.889	2	68.992	1605
11	61.809	62.898	60.743	3	138.059	5195
12	70.847	71.031	70.667	4	60.940	3309
13	48.469	48.301	48.633	5	32.797	2621
14	31.014	30.429	31.587	6	43.571	5487
15	31.336	30.318	32.332	7	19.195	3664
16	16.649	15.132	18.134	8	10.982	2671
17	11.295	12.774	9.847	9	15.955	4860
18	7.381	8.791	6.002	10	14.464	4889
19	10.267	12.314	8.262	11	18.663	7473
20	13.290	16.908	9.749	12	27.647	13141
21	12.489	14.656	10.367	13	76.540	41068
22	9.123	11.612	6.686	14	101.633	58949
23	8.331	10.830	5.885	15	57.169	36083
24	9.425	11.948	6.955	16	50.963	33713
25	10.630	14.003	7.327	17	27.634	20082
26	12.648	15.940	9.424	18	17.662	13478
27	14.699	17.809	11.653	19	13.695	11025
28	27.716	38.309	17.344	20	18.839	15367
29	48.241	70.847	26.108	21	15.718	13432
30	83.236	102.183	64.684	22	19.135	15381
31	85.358	91.342	79.499	23	23.034	20084
32	79.575	71.626	87.358	24	17.872	16676
33	61.155	48.819	73.232	25	24.358	24644
34	44.398	39.286	49.404	26	28.000	30708
35	32.887	28.767	36.920	27	12.274	12631
36	26.712	21.541	31.775	28	21.347	24748
37	24.267	14.221	34.102	29	9.630	11558
38	19.655	8.786	30.298	30	4.509	6220
39	17.088	6.635	27.323	31	4.444	6624
40	10.560	2.828	18.131	32	2.397	3616
41	5.517	1.444	9.506	33	0.855	1309
42	4.038	0.771	7.236	34	0.000	0
43	1.505	0.479	2.510	35	0.118	187
44	1.608	0.479	2.713	36	0.146	299
45	0.986	0.164	1.790	37	0.172	325
46	0.742	0.026	1.443			
47	0.221	0.031	0.408			
48	0.258	0.000	0.511			
49	0.091	0.033	0.147			
50	0.218	0.016	0.416			
51	0.000	0.000	0.000			
52	0.000	0.000	0.000			

Table 34: Numbers at length and numbers at age of 4RST redfish estimated from the 1985 Lady Hammond research vessel survey.

LENGTH	NUMBER PER THOUSAND OF SEX COMBINED	MALE	FEMALE	AGE	NO PER THOU	BIOMASS
11	18.909	18.953	18.867	2	18.909	1476
12	51.617	51.499	51.729	3	104.597	11955
13	110.610	109.830	111.350	4	221.291	33212
14	154.417	152.411	156.321	5	227.954	46562
15	152.511	151.211	153.744	6	191.898	50757
16	140.806	141.553	140.097	7	44.321	14063
17	90.901	92.100	89.763	8	14.274	8047
18	54.354	54.211	54.490	9	7.305	5324
19	21.053	20.889	21.209	10	5.587	4521
20	8.078	8.184	7.978	11	4.127	3898
21	5.983	5.544	6.399	12	6.447	7287
22	6.181	5.908	6.441	13	9.785	12218
23	5.575	5.674	5.481	14	21.626	30208
24	7.725	7.709	7.740	15	21.932	33525
25	5.145	4.990	5.291	16	10.507	17443
26	3.976	4.552	3.430	17	5.125	8637
27	3.452	4.959	2.022	18	6.895	12399
28	5.479	7.912	3.171	19	4.171	8061
29	8.382	12.323	4.644	20	5.583	10449
30	14.912	19.658	10.409	21	5.734	10851
31	18.310	21.203	15.565	22	5.108	10343
32	21.776	21.845	21.710	23	6.061	12593
33	17.646	16.918	18.338	24	10.212	21762
34	13.895	12.510	15.208	25	8.064	18677
35	13.806	13.278	14.306	26	4.803	11796
36	10.480	10.162	10.782	27	11.421	30324
37	9.996	8.651	11.272	28	3.368	9573
38	8.022	6.265	9.689	29	6.138	18277
39	5.081	3.273	6.795	30	2.289	7026
40	4.112	2.320	5.812	31	1.592	5255
41	2.964	1.875	3.997	32	1.652	5323
42	1.691	0.598	2.728	33	0.383	1370
43	0.622	0.109	1.109	34	0.575	2214
44	0.623	0.314	0.916	35	0.133	533
45	0.378	0.259	0.492	36	0.062	333
46	0.093	0.061	0.124	37	0.017	88
47	0.056	0.008	0.101	38	0.055	267
48	0.135	0.078	0.188			
49	0.216	0.187	0.244			
50	0.026	0.016	0.035			
51	0.006	0.000	0.011			

Table 35: Comparison of population parameters obtained by various methods for Divisions 4RST redfish.

Fishing Mortality for 1985

Tuning VPA	0.07
Non-linear production model	0.07

Exploitation Fishing Mortality

Thompson and Bell $F_{0.1}$	0.098 ≅ 0.10
2/3 effort MEY from non-linear production model	0.098 ≅ 0.10

Population Biomass for 1985

R/V Survey	486,000 t
Cohort analysis ($M=0.02$, $F_t=0.07$)	520,000 t
Non-linear Production model	498,000 t

Projected Exploitable 5+ Biomass

	1986	1987
From Cohort model ($M=0.02$)	39,000 t	39,000 t
From Non-linear Production model	50,000 t	50,000 t

Catch Rates

Standardized CPUE for 1985	0.95 t/h
2/3 effort MEY (1959-1985)	1.37 t/h

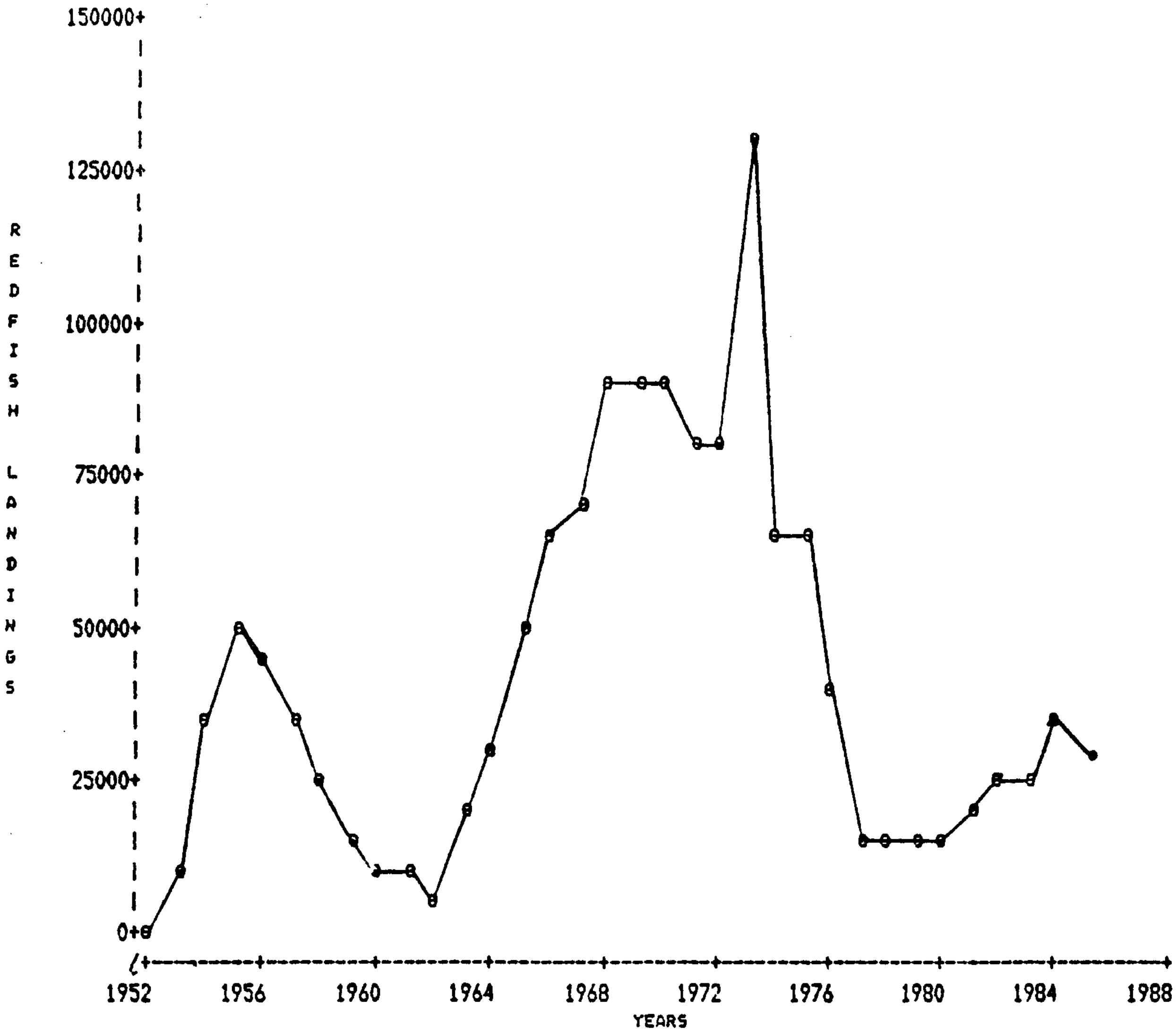
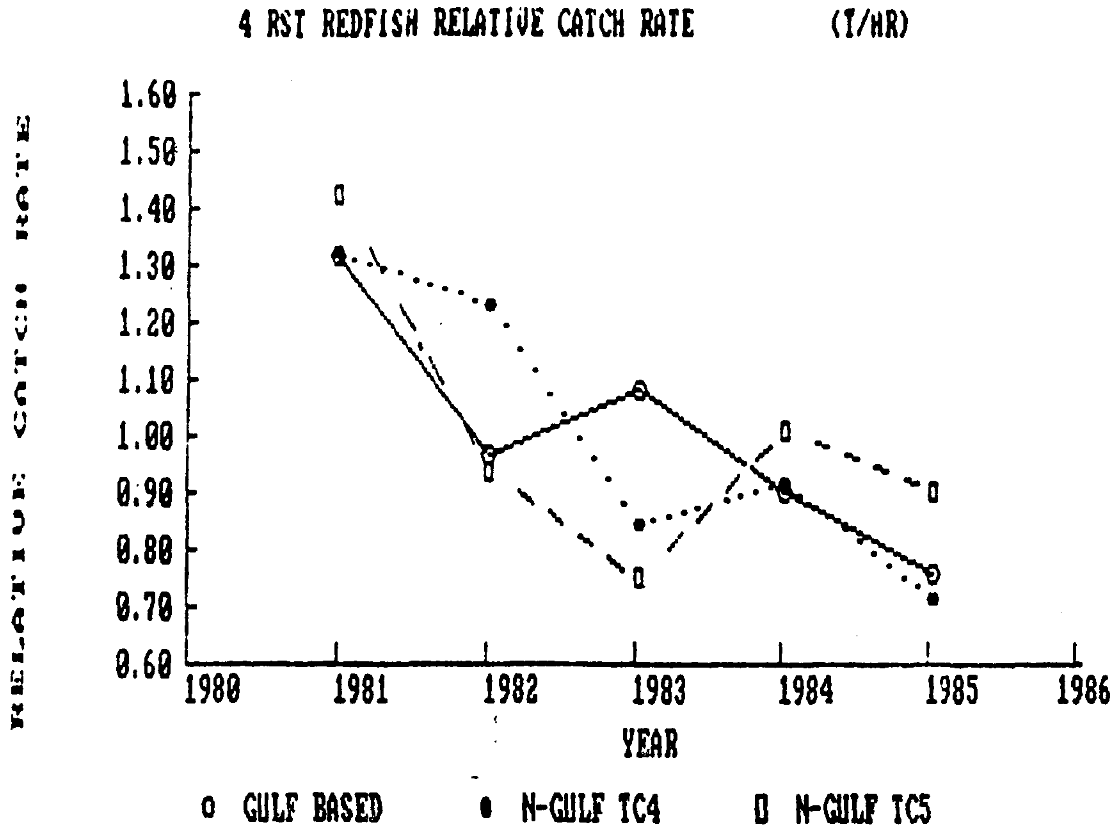


Figure 1. 4RST redfish total nominal catches (t) for 1952-1985.



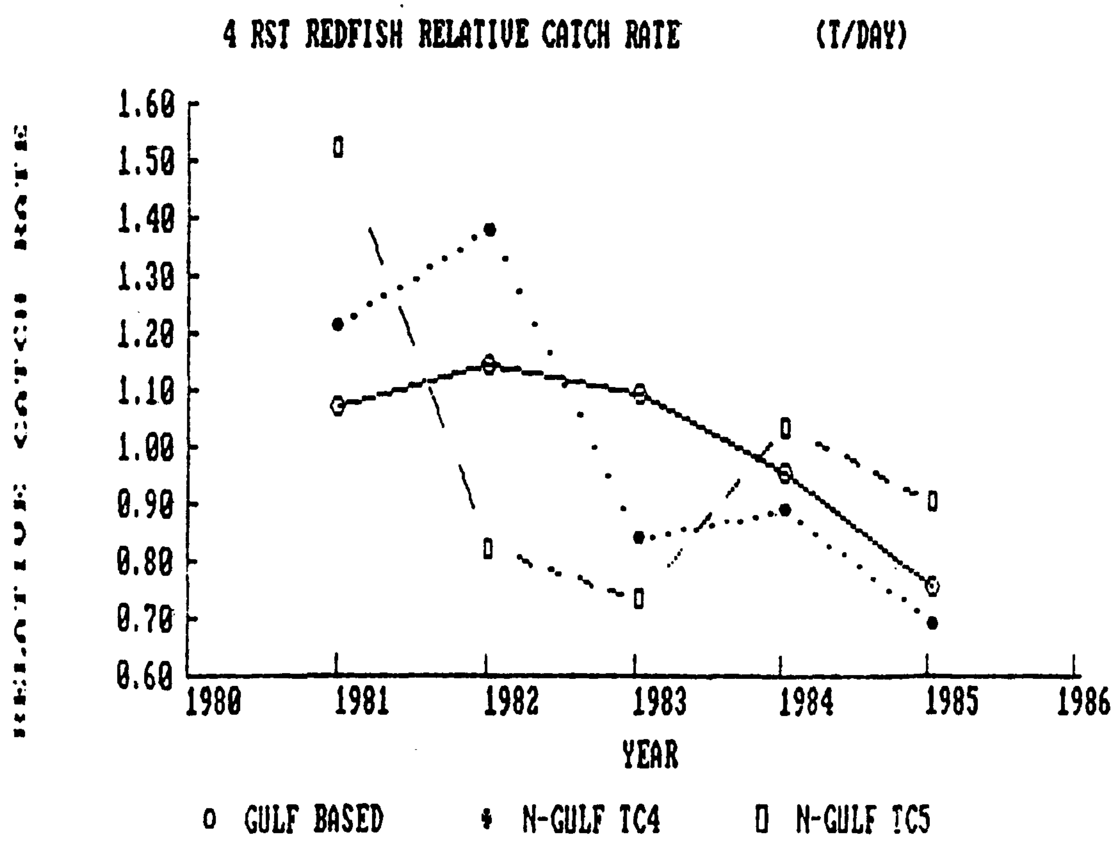


Figure 2. Comparison of 4RST redfish catch rates of Gulf-based vessels versus non-Gulf based vessels, 1980-1985.

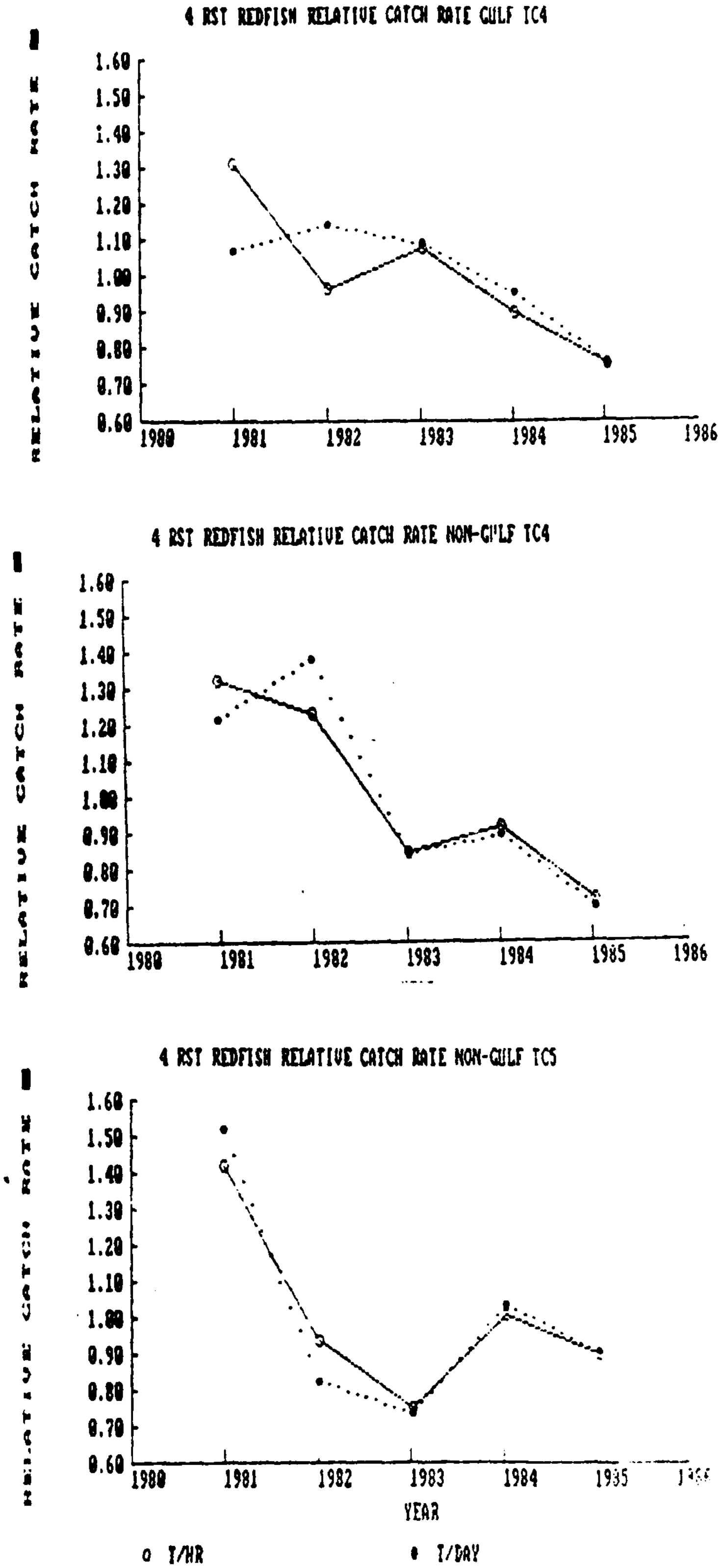


Figure 3. Comparison of 4RST redfish catch rates of Gulf versus non-Gulf tonnage class 4 and 5 fishing vessels, 1980-1985.

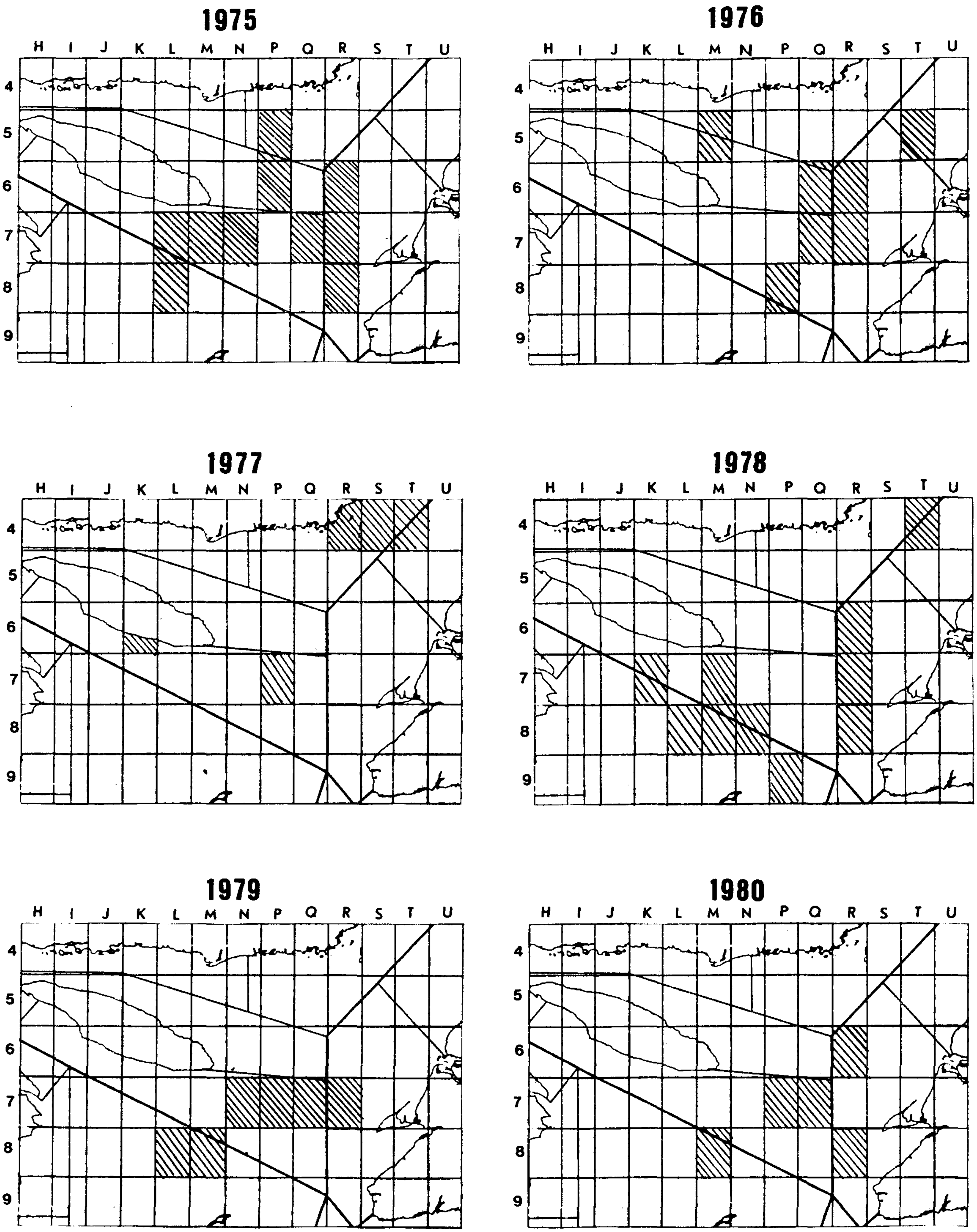


Figure 4. Distribution of 75% of commercial fishing effort for Quebec based vessels from 1975-1985.

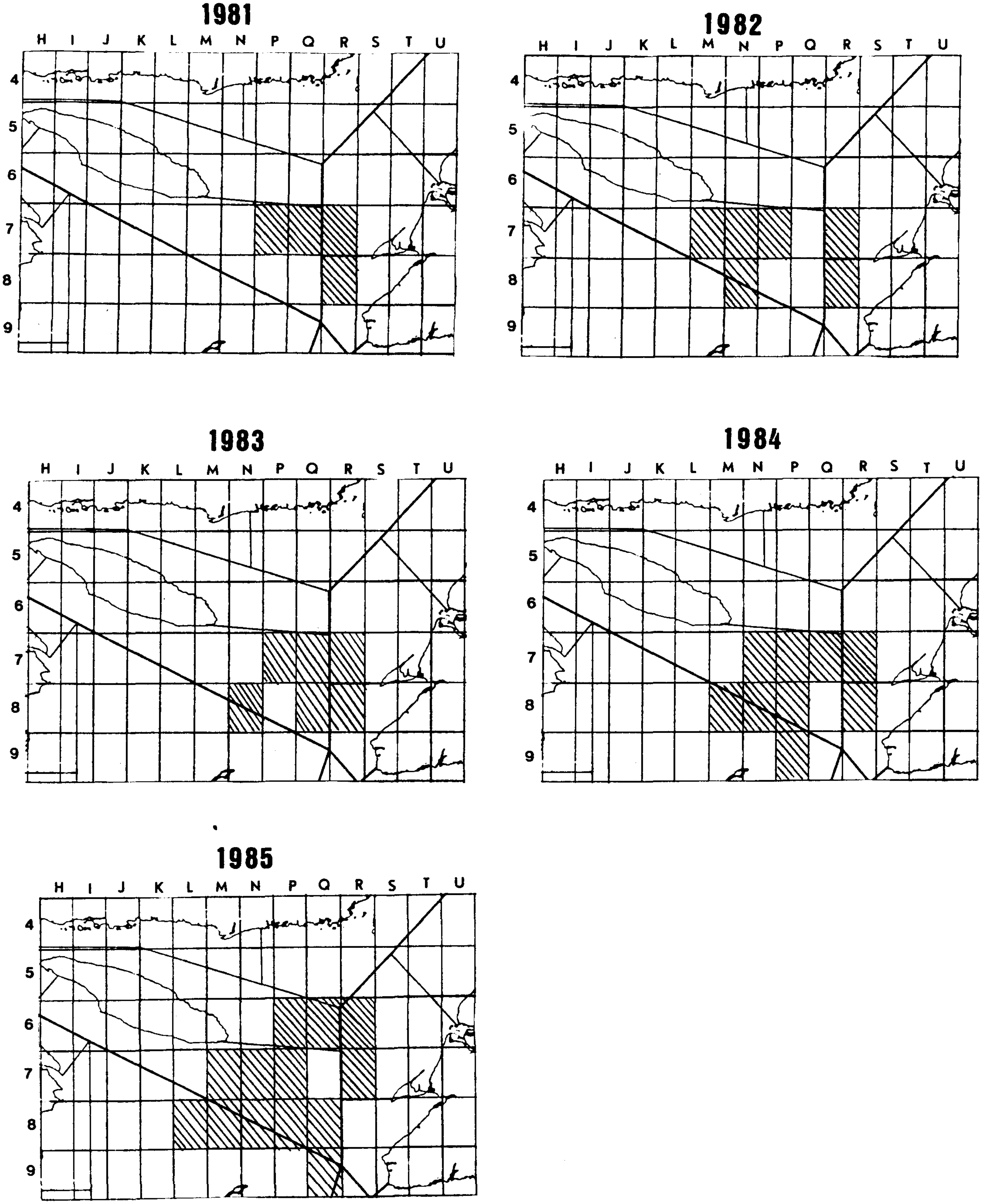


Figure 4. Distribution of 75% of commercial fishing effort for Quebec based vessels from 1975-1985.

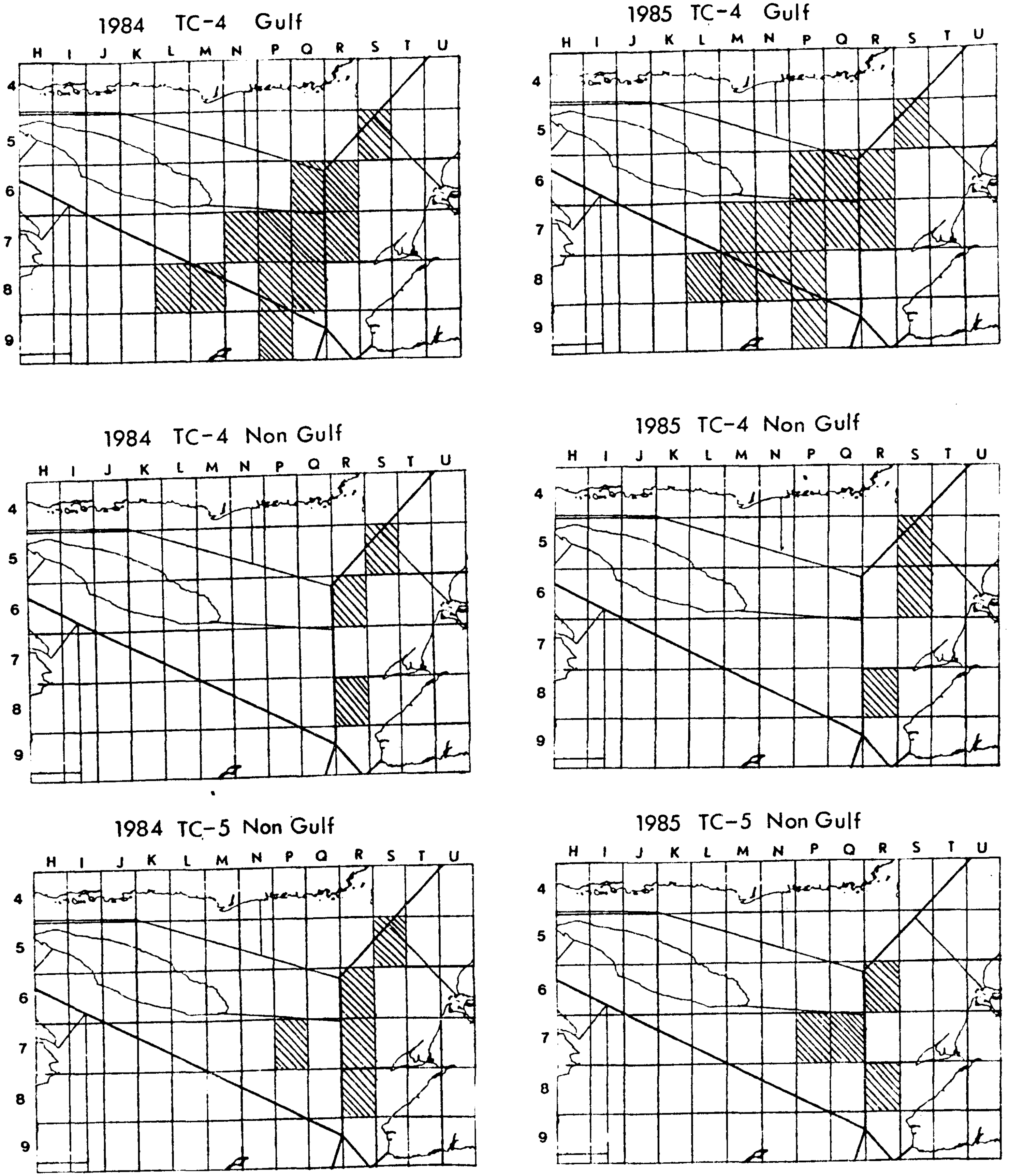


Figure 5. Distribution of 75% of commercial fishing effort for Gulf (PEI,NB,Que.) TC-4 and non-Gulf (NS, Nfld.) TC-4 and 5 vessels.

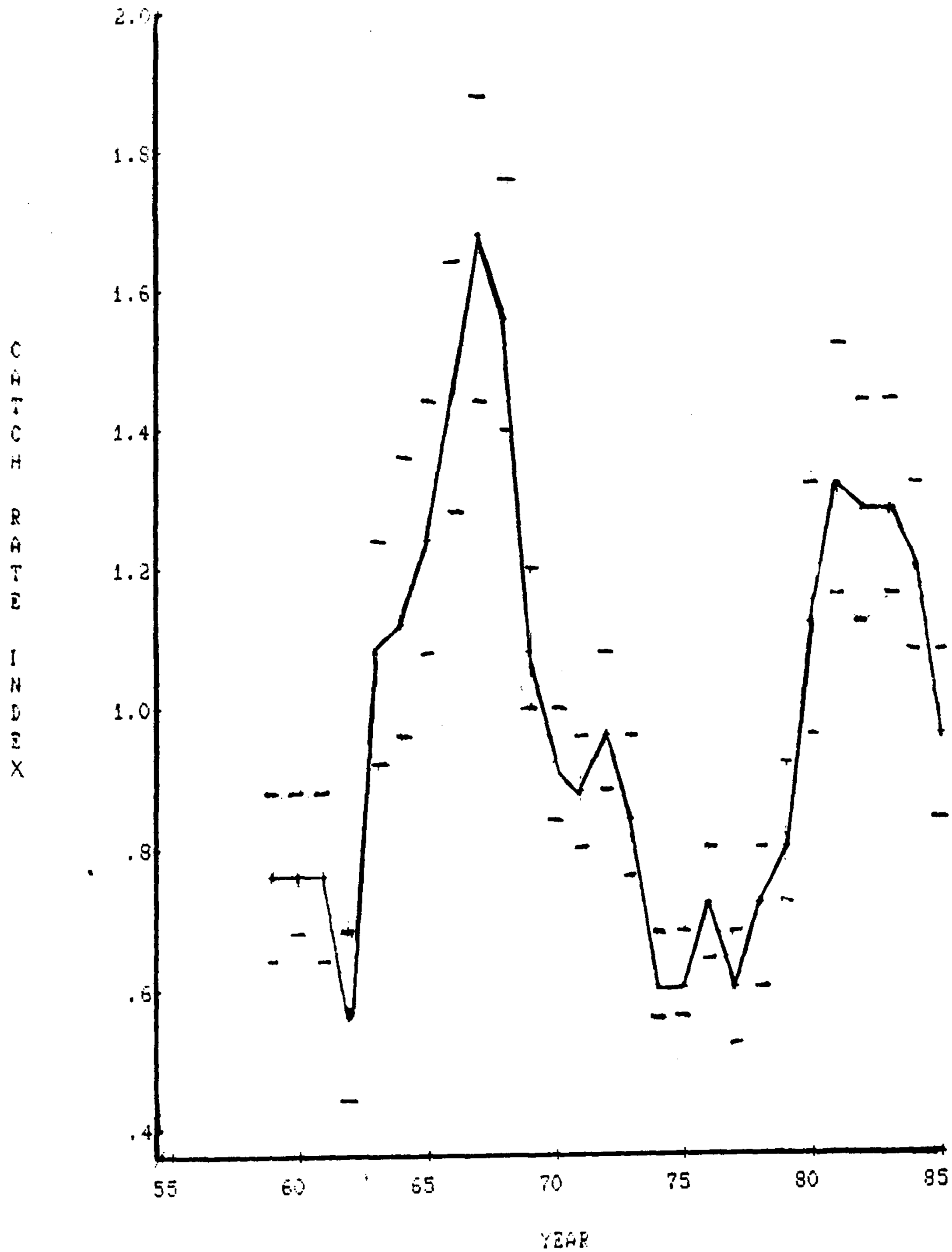


Figure 6. 4RST redfish standardized CPUE for 1959-1985 with approximate 90% confidence interval.

Figure 7: 4RST redfish sample combinations used to calculate the 1984 composite length frequencies for each sex. Length frequency samples "S" were combined and weighted by monthly catch weights "CW", gear types are bottom trawls (OTB), shrimp trawls (ST), and midwater trawls (OTM).

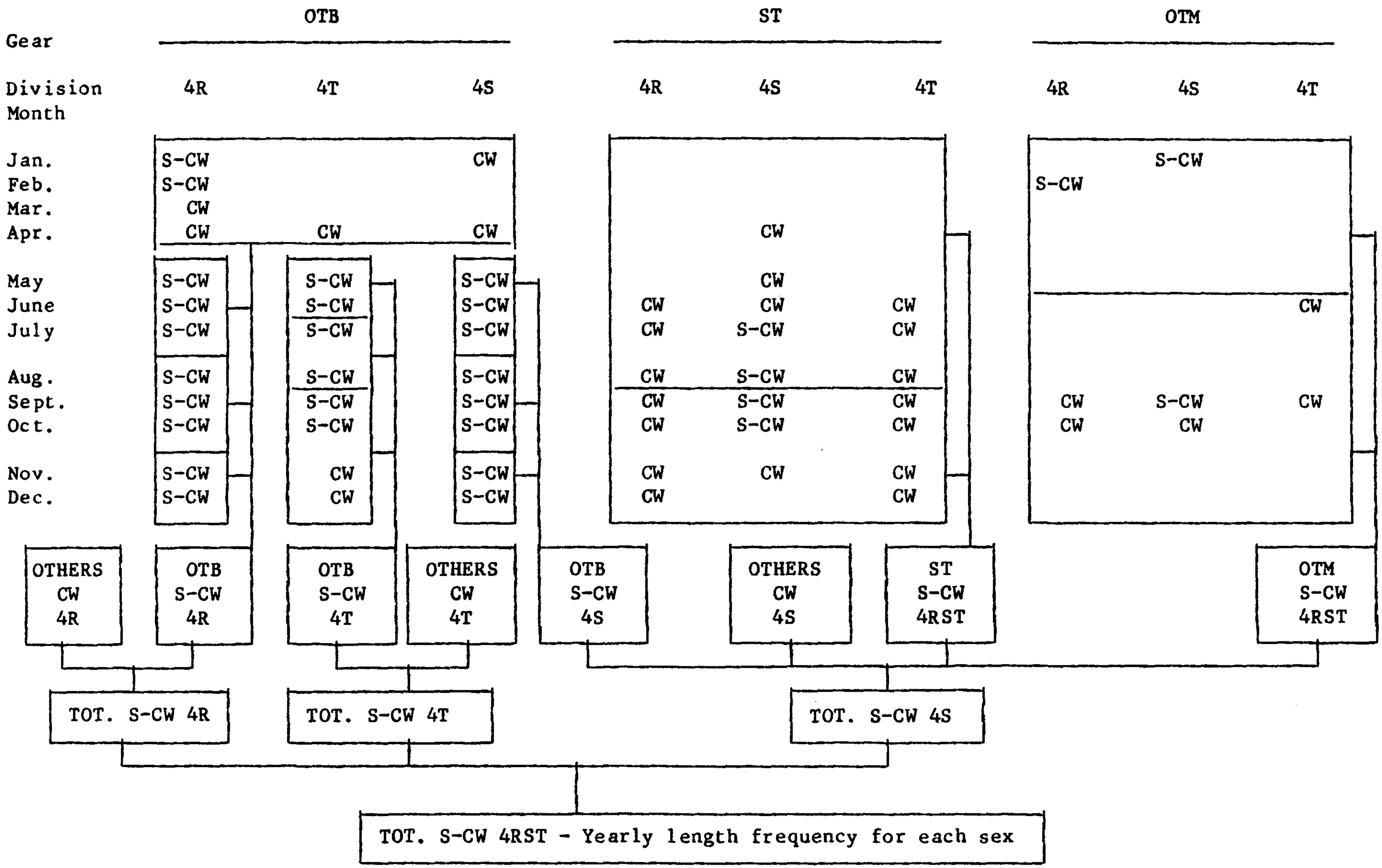
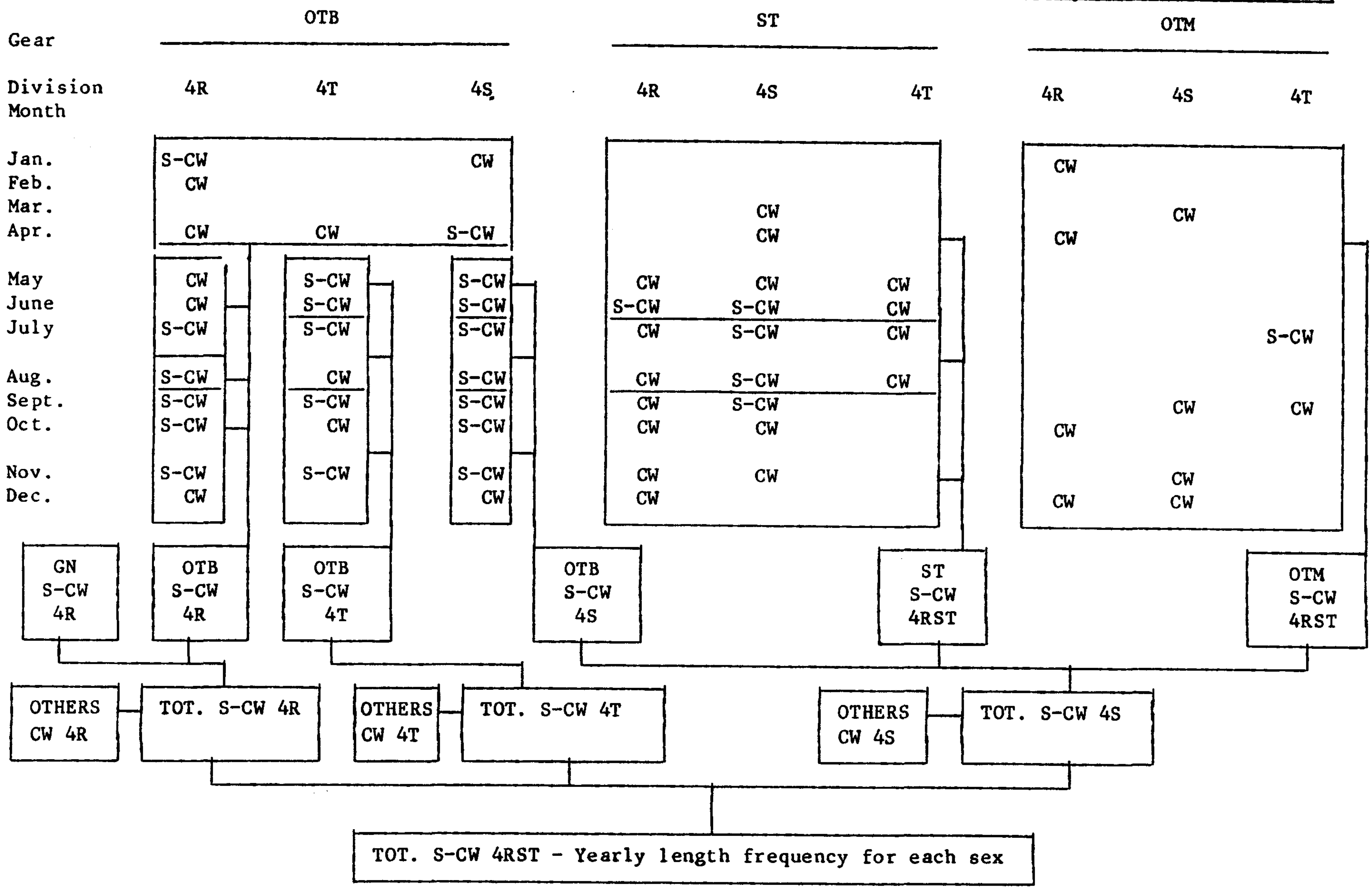


Figure 8 : 4RST redfish sample combinations used to calculate the 1985 composite length frequencies for each sex. Length frequency samples "S" were combined and weighted by monthly catch weights "CW", gear types are bottom trawls (OTB), shrimp trawls (ST), and midwater trawls (OTM).



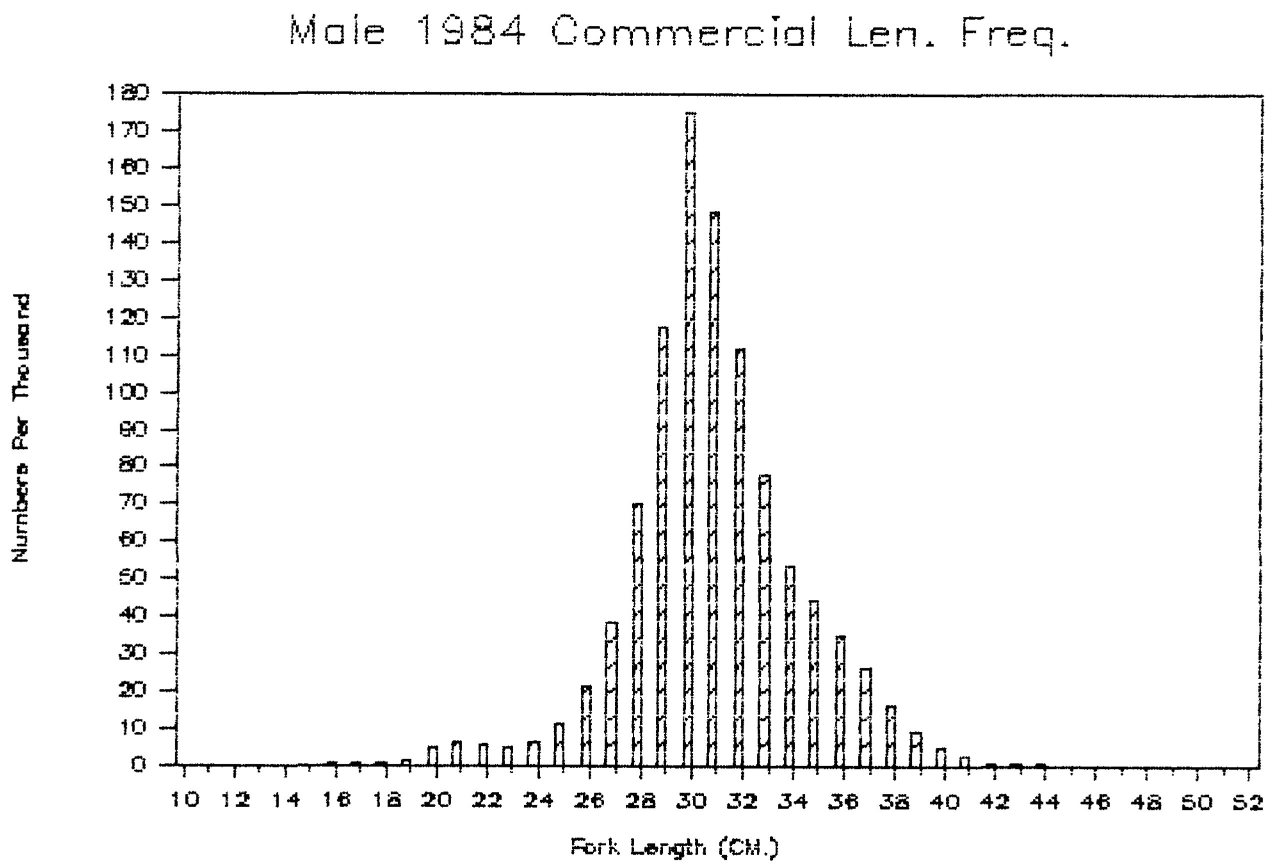


Figure 9, 1984 yearly length frequency for male Div. 4RST redfish (range 16-47 cm)

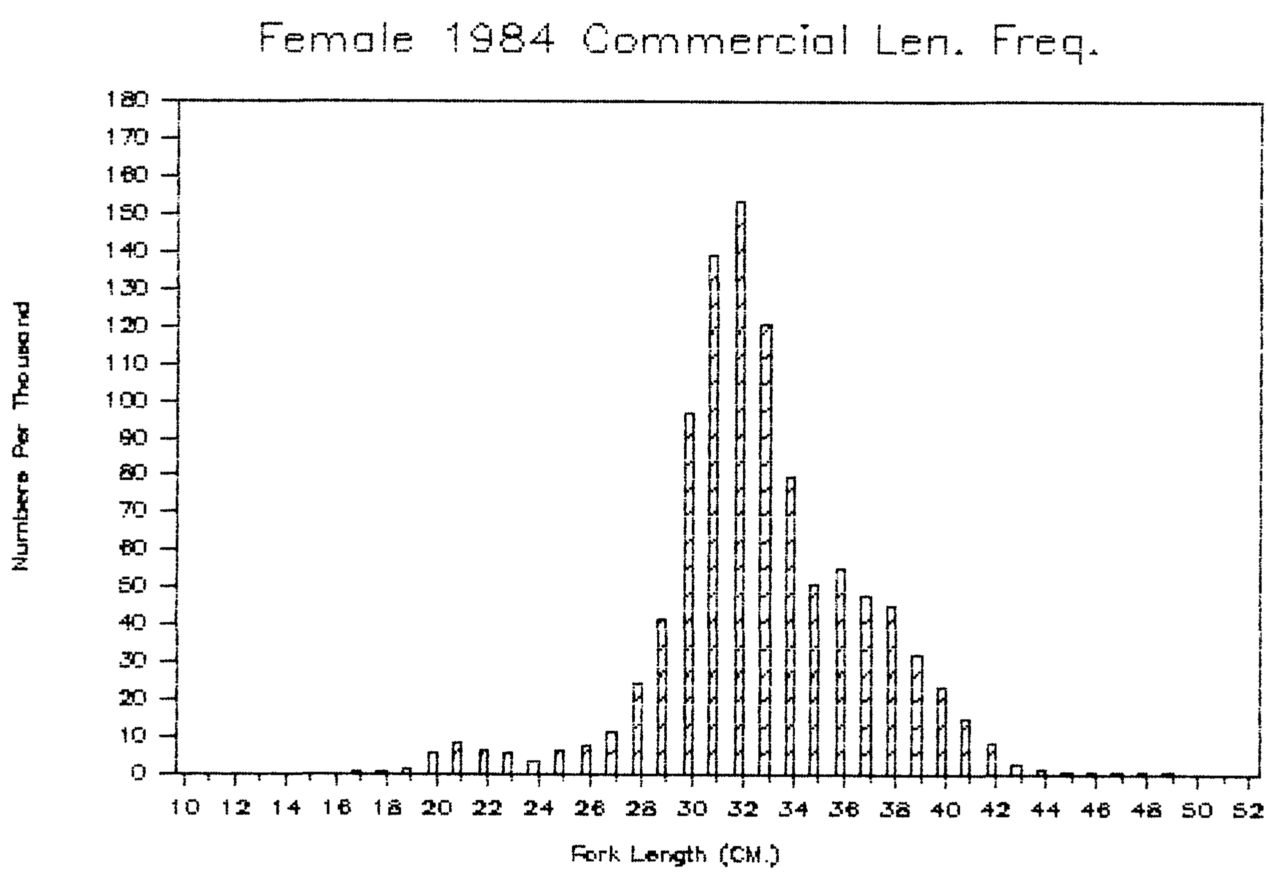


Figure 10, 1984 yearly length frequency for female Div. 4RST redfish (range 16-52 cm)

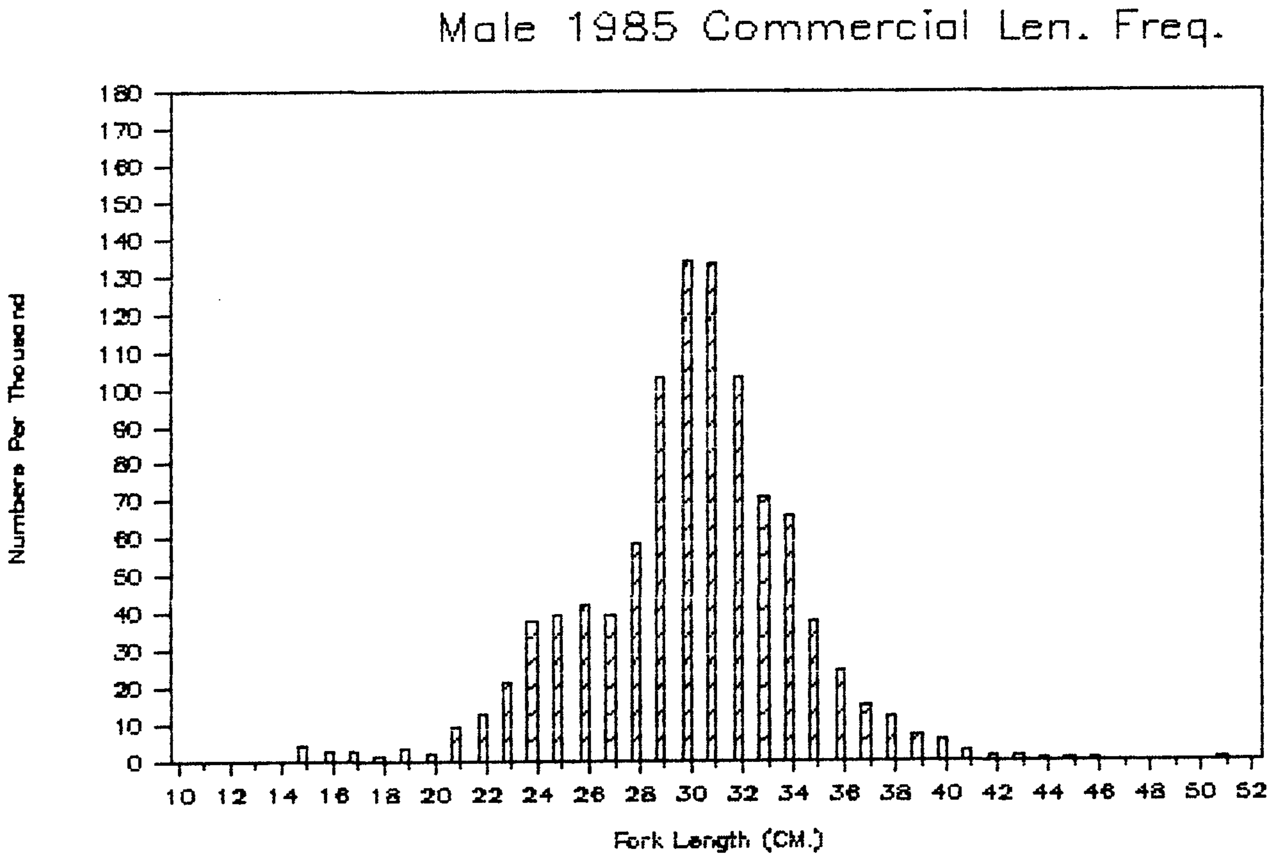


Figure 11. 1985 yearly length frequency for male Div. 4RST redfish (range 14-51 cm).

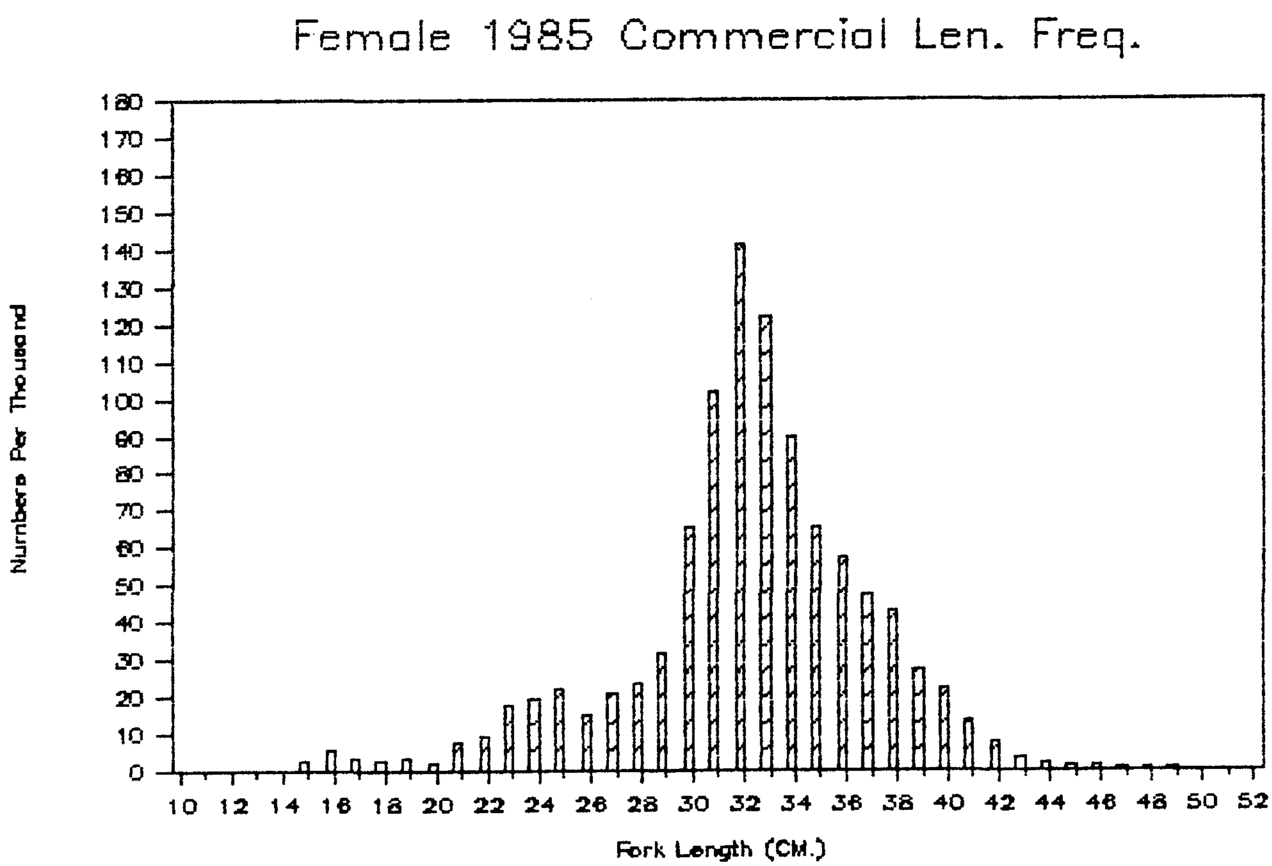


Figure 12. 1985 yearly length frequency for female Div. 4RST redfish (range 15-51cm).

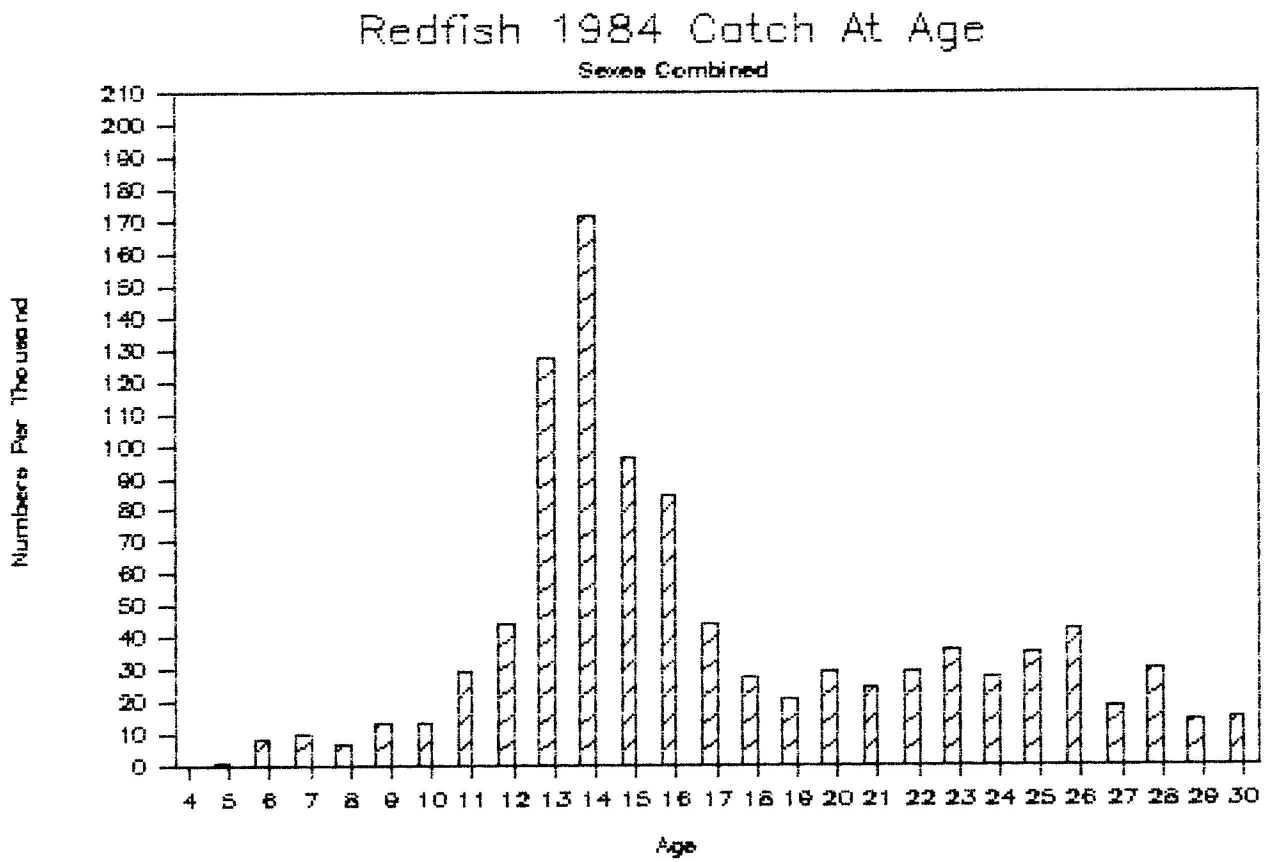


Figure 13. Catch at age for Div. 4RST redfish for 1984, sexes combined.

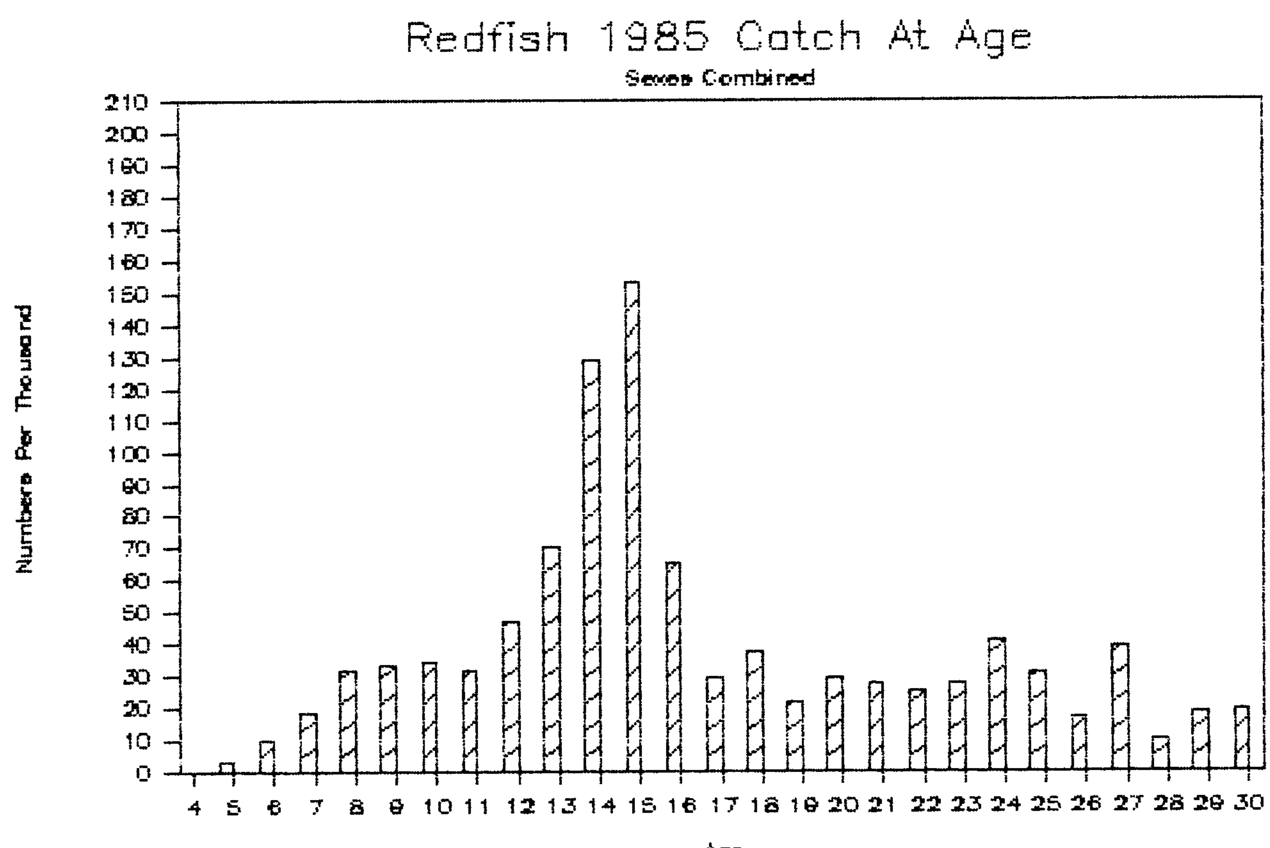


Figure 14. Catch at age for Div. 4RST redfish for 1985, sexes combined.

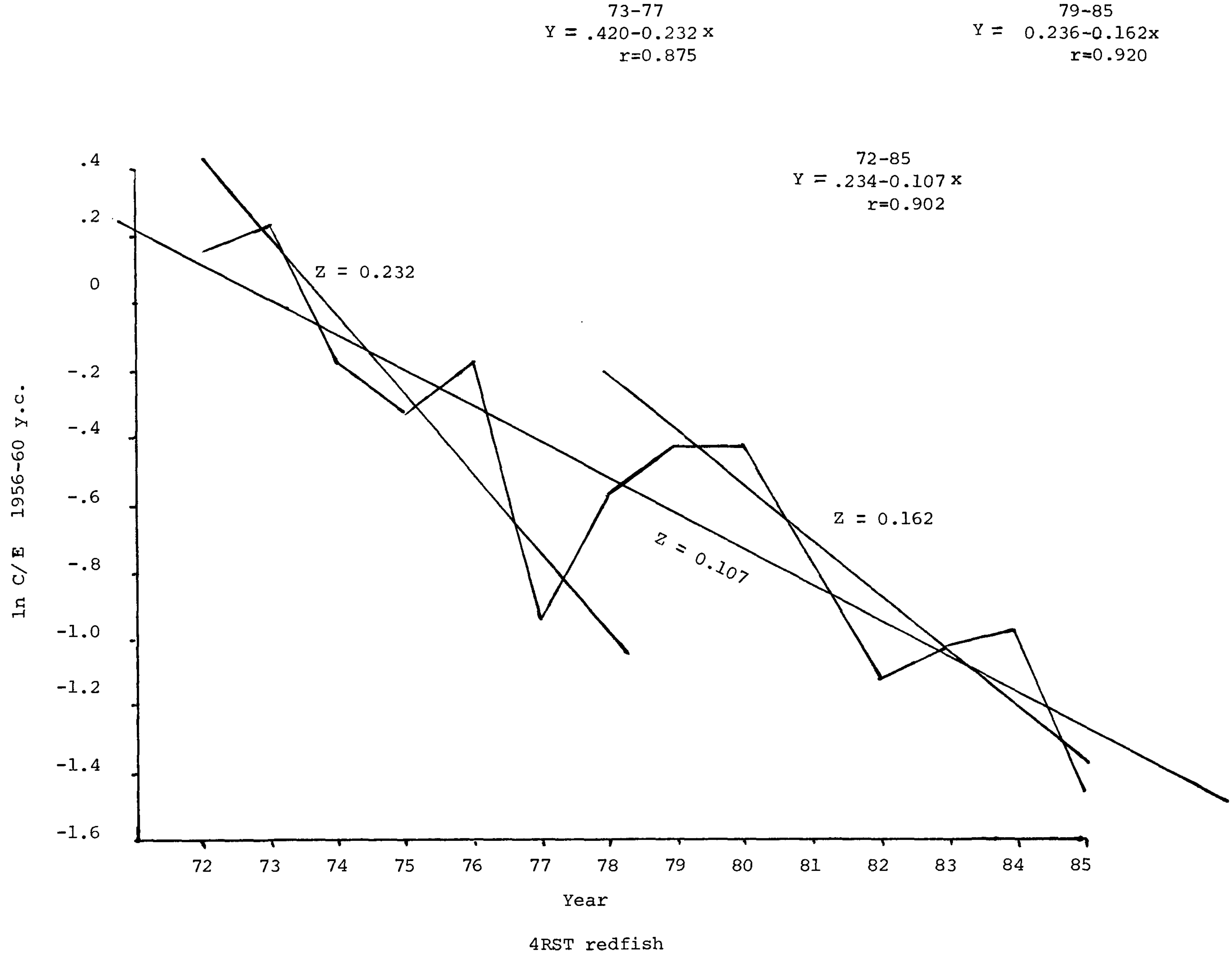


Figure 15. Calculations of total mortality (Z) by the regression of the natural logarithm of catch divided by effort for the 1956-1960 year classes versus years.

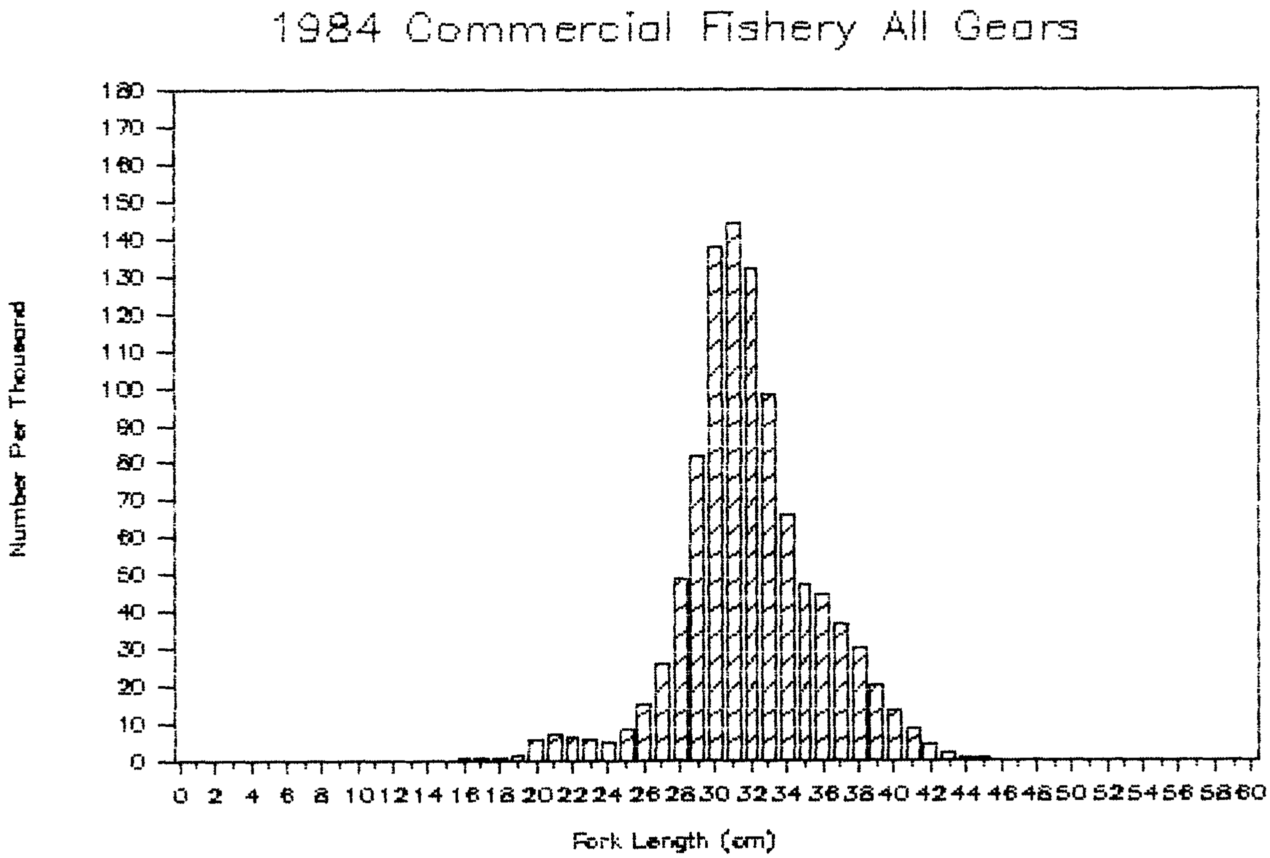


Figure 16. 1984 Commercial length frequency for Div. 4RST redfish, sexes combined.

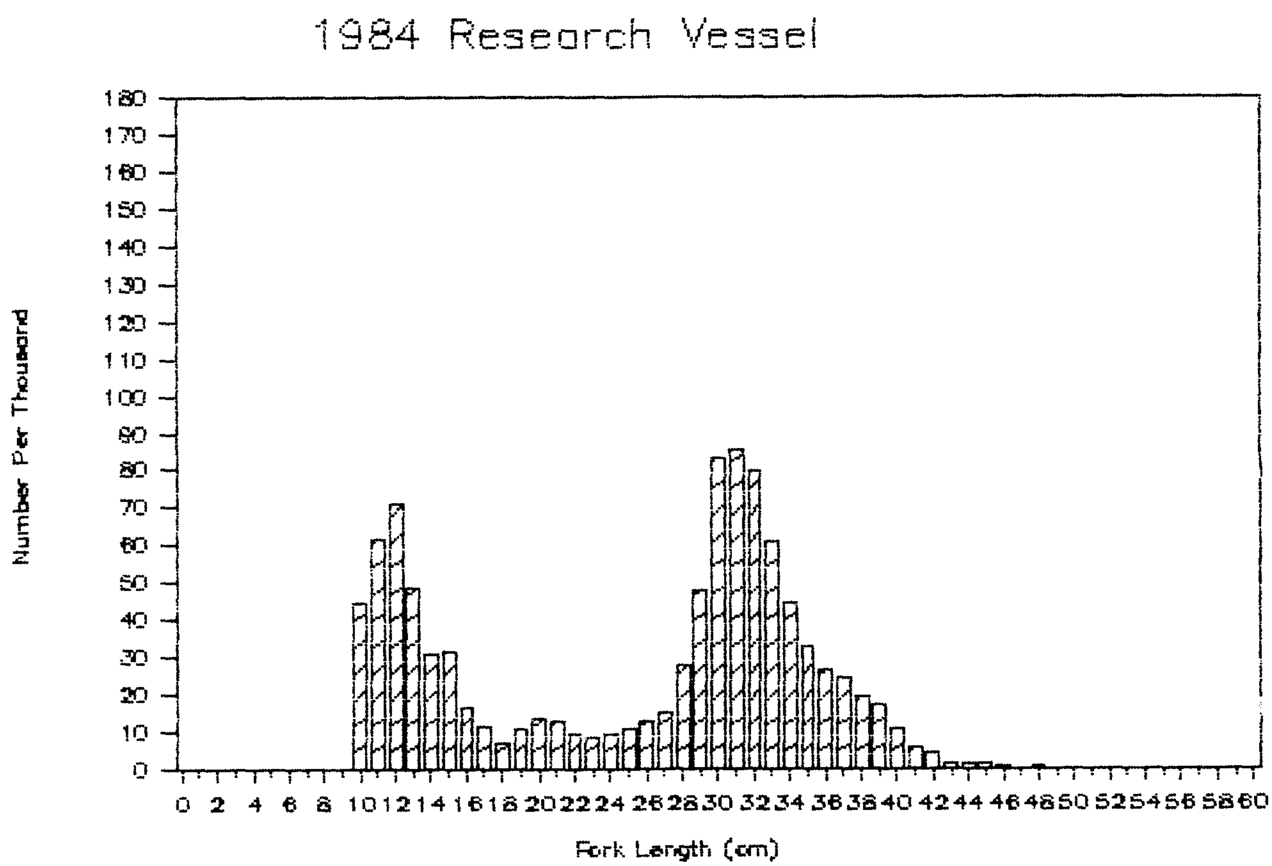


Figure 17. 1985. 1984 research survey length frequency for Div. 4RST redfish, sexes combined.

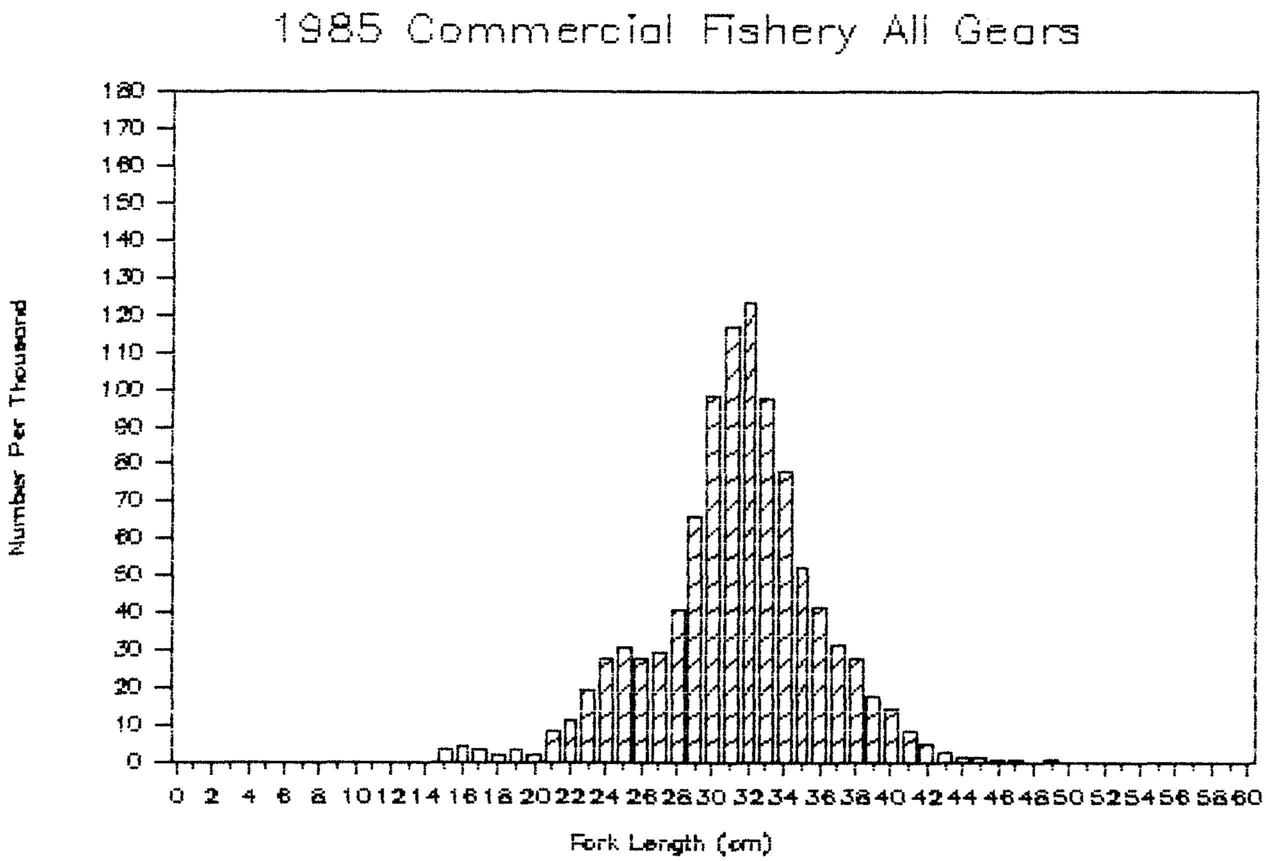


Figure 18. 1985 Commercial length frequency for Div. 4RST redfish, sexes combined.

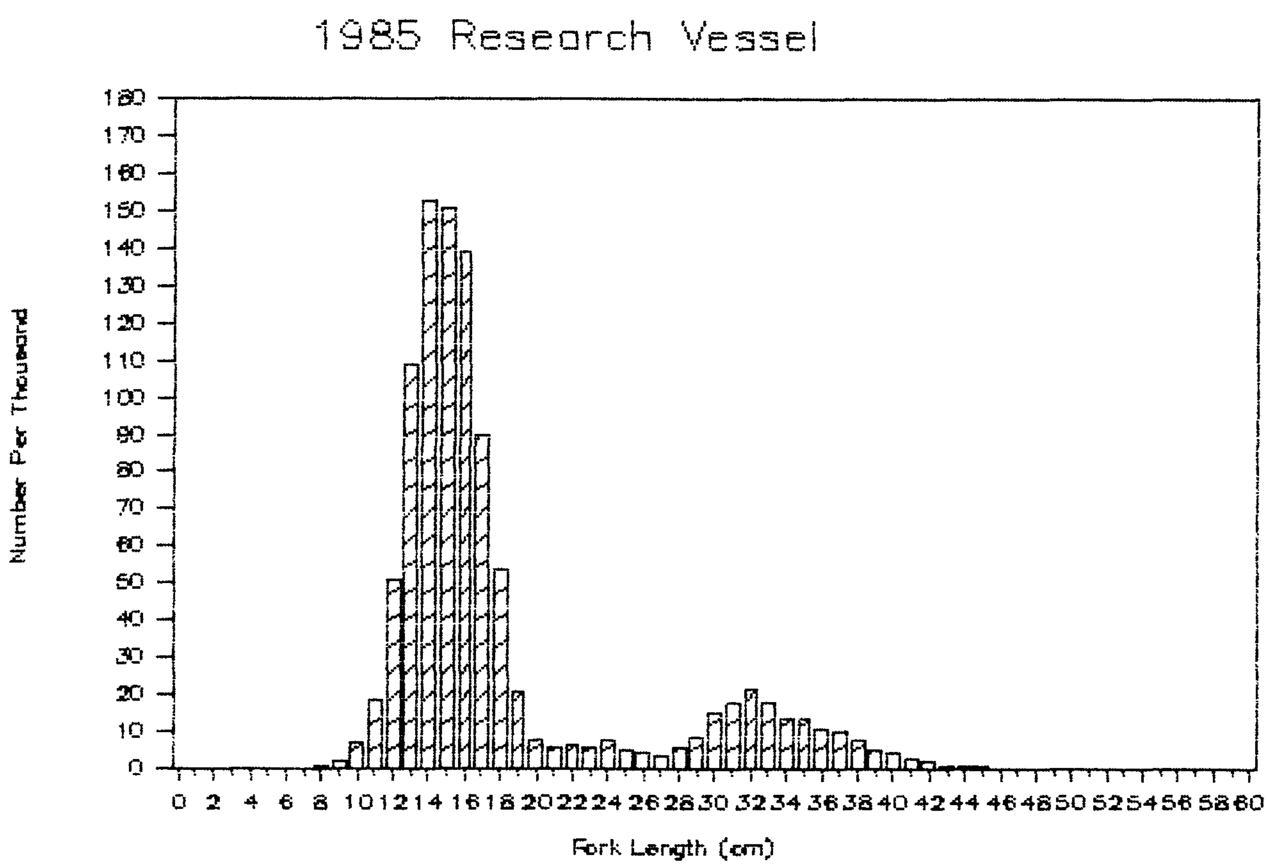


Figure 19. 1985 research survey length frequency for Div. 4RST redfish, sexes combined.

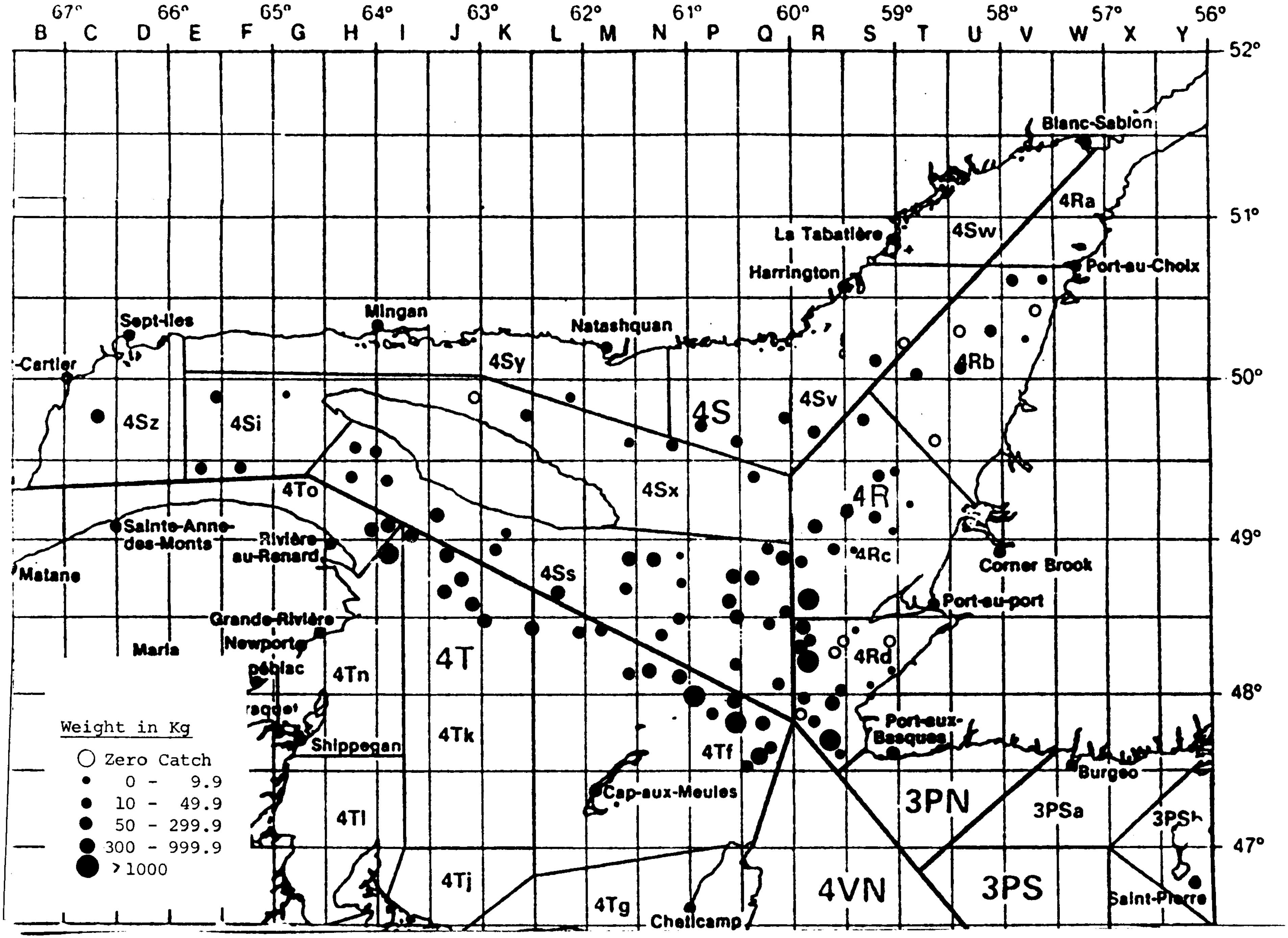


Figure 20. Redfish distribution in 4RST determined by the Lady Hammond in July, 1984.

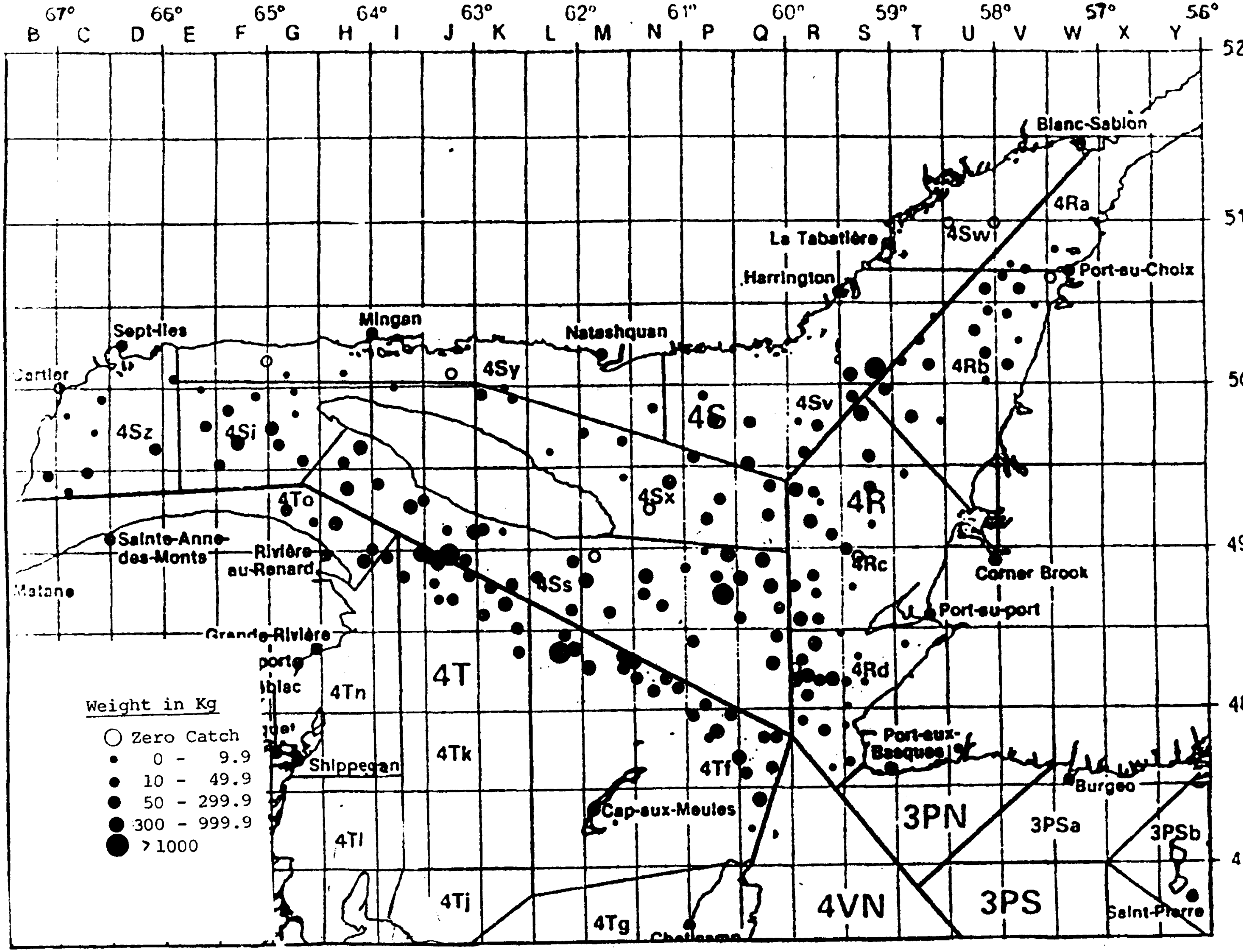


Figure 21. Redfish distribution in 4RST determined by the Lady Hammond in August, 1985.

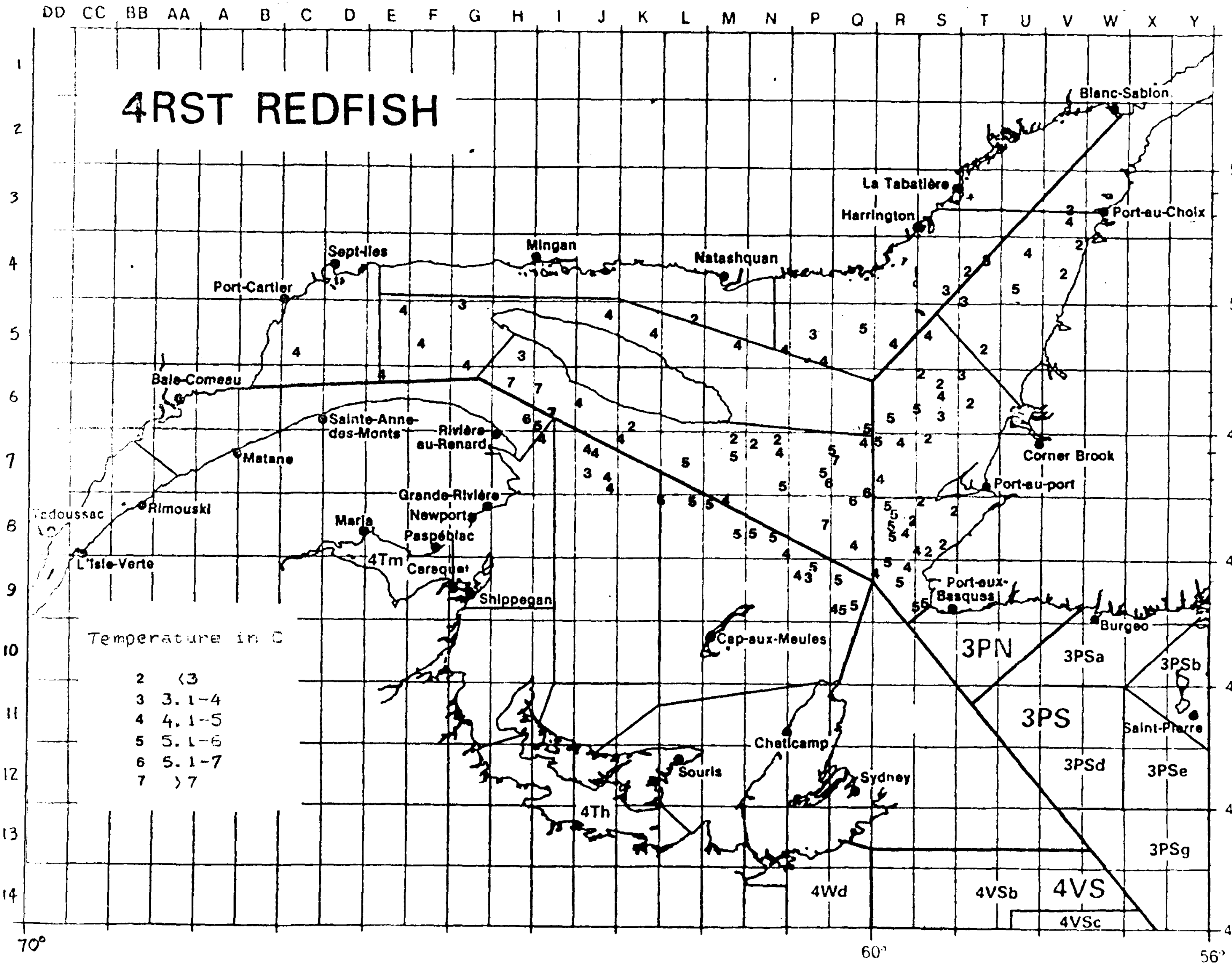


Figure 22. Bottom temperatures taken during the Lady Hammond cruise in July, 1984.

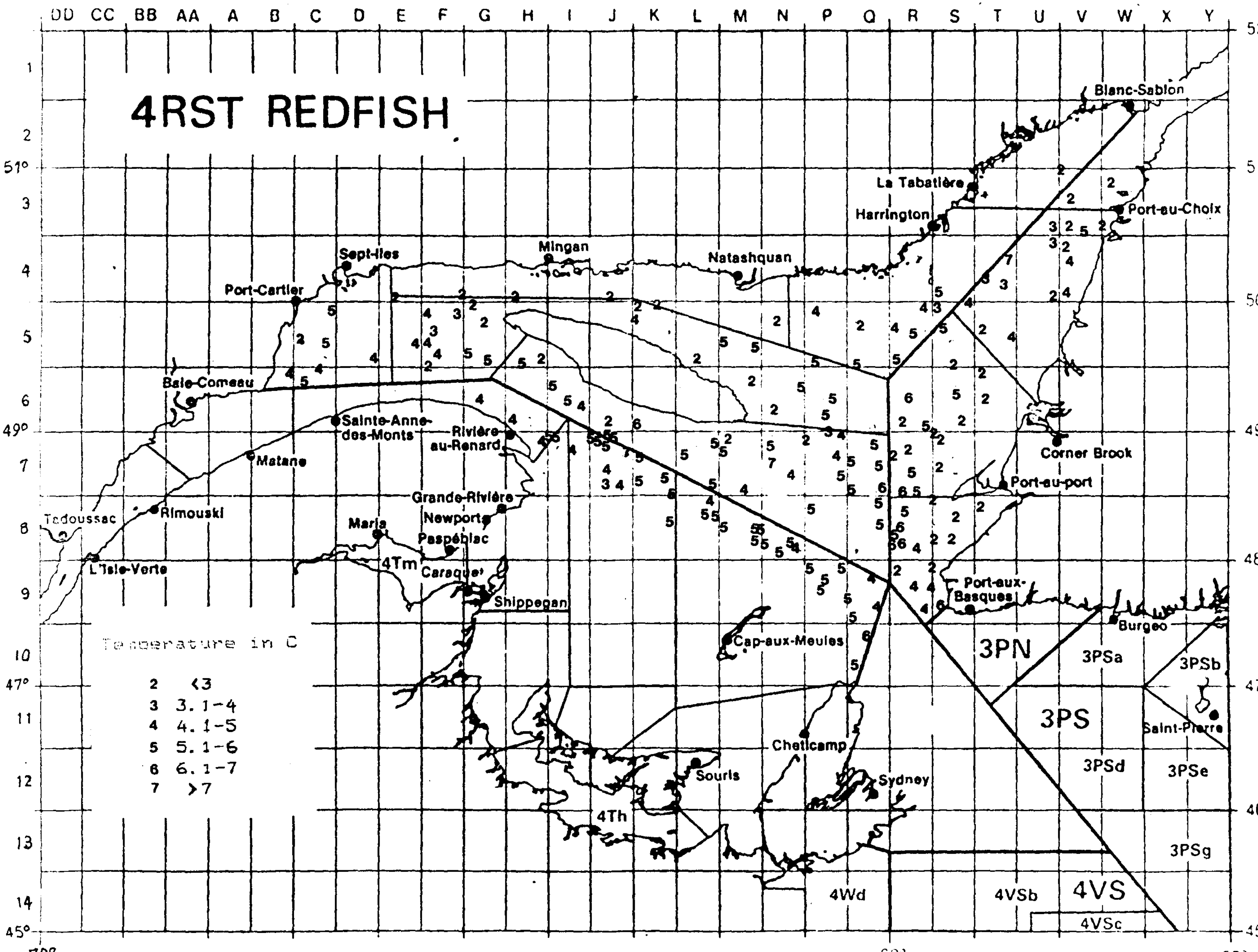


Figure 23. Bottom temperatures taken during the Lady Hammond cruise in August, 1985.

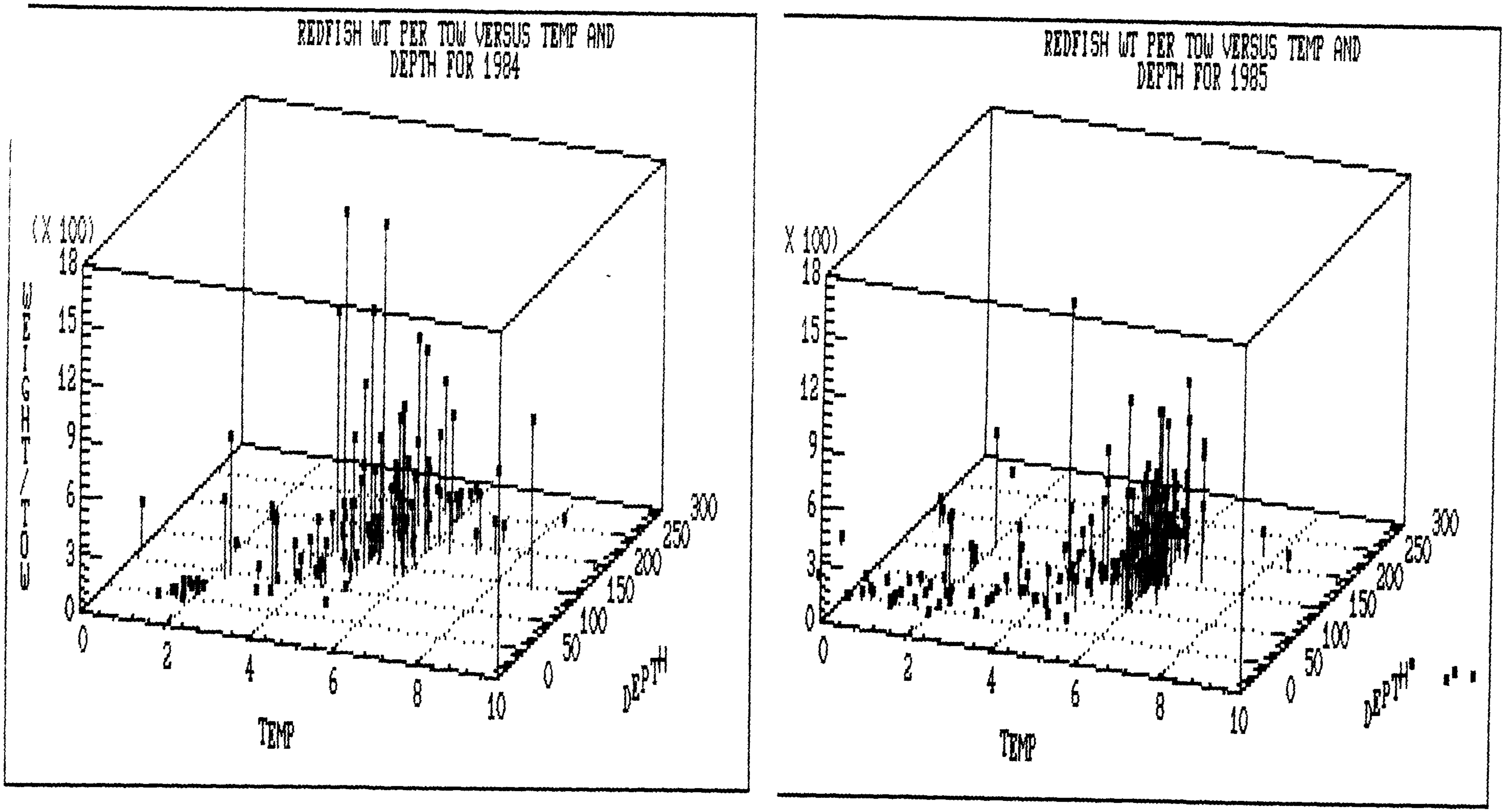


Figure 24. Three dimensional plots of Division 4RST redfish weight (kg) per tow versus temperature and versus depth in fathoms for 1984 and 1985.