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A Review of Shrimp (*Pandalus borealis*) Biology and Environmental Changes in the Cartwright Channel (Division 2J), 1977-83

by

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ABSTRACT

Data from the shrimp fishery and research surveys in the Cartwright Channel were analysed to provide some indication of why the stock has declined over the period 1977 to 1983. The results suggest that the fishery was particularly responsible for the decline in abundance from 1977 to 1979. There appears to have been an overall decrease in bottom temperature from 1977 to 1983 which can reduce productivity by retarding growth and reducing fecundity. Reproductive potential in this area is also adversely affected by a comparatively high proportion of non-spawning females in most years.

Although fishing mortality was not significant after 1979, high total mortality was maintained due to increasing abundance of two important predators of shrimp, Greenland halibut and cod. The presence of these predators also might have dispersed concentrations of shrimp. Colder temperatures also might have provided a stimulus for dispersal or migration out of the area.

Management of the shrimp resource in the presence of significant environmental changes also is discussed.

RESUMÉ

Les données recueillies à même la pêcherie de crevettes et dans les relevés par navires de recherche dans le chenal Cartwright ont été analysées afin de déterminer les facteurs de déclin du stock entre 1977 et 1983. Les résultats donnent à penser que la pêche elle-même a été le principal responsable entre 1977 et 1979. De 1977 à 1983, il semble y avoir eu abaissement général de la température du fond, ce qui aurait causé une diminution de la productivité, en ralentissant la croissance et en abaissant la fécondité. En outre, le potentiel reproducteur dans cette région est défavorablement influencé par une proportion relativement forte, la plupart des années, de femelles non reproductrices.

Bien qu'après 1979, la mortalité par pêche n'ait pas été élevée, la mortalité totale s'est maintenue à un haut niveau par suite de l'augmentation de deux importants prédateurs des crevettes, le flétan du Groenland et la morue. Il se peut également que la présence de ces deux prédateurs ait contribué à la dispersion des concentrations. Enfin, des températures plus basses ont pu aussi être un stimulant à la dispersion ou à l'émigration hors de la région.

Nous examinons la gestion de cette ressource en crevettes face à d'importants changements de l'environnement.

INTRODUCTION

The existance of commercially exploitable concentrations of shrimp in the Cartwright Channel was confirmed through exploratory fishing in 1975 and 1976 (Sandeman 1978). The fishery essentially began in 1977 and continued up to and including 1979. Catch rates declined during this period and effort for the fleet was displaced farther north to the Hopedale Channel and Davis Strait where concentrations generally were higher. As a result of this shift in fishing effort, catches in the Cartwright Channel subsequently declined to very low levels from 1980 to 1983. During the period of low fishing mortality, stock size apparently has continued to decline. This was interpreted from decreasing biomass estimates derived from research surveys.

Biological data collected from 1977 to 1983 were analysed to reveal any changes that might have occurred during this period and which might be related to decreases in abundance and/or changes in distribution. Data on the distribution and abundance of predators also were examined and mean bottom temperatures at various depths were compared between years. Relationships observed in these analyses may be useful in evaluating the status of shrimp stocks in other areas. Since this is a 'first look' at such data, it is anticipated that discussion of the results will produce valuable suggestions concerning the direction of future research for shrimp stocks, generally.

CATCH AND CPUE

Shrimp catches in the Cartwright Channel increased from around 1400 tons (t) in 1977 to 1500 in 1978 and declined to around 1000 t in 1979 (Table 1). Since 1979, fishing effort in this area has been reduced and sporadic resulting in catches of 170, 67, 167, and 3 t for 1980-83 respectively.

CPUE as an index of abundance only was useful from 1977 to 1979 for the months of July to September (unweighted) and showed a decline of 33% over that period. The 1980 value for the same months was based on very little effort but indicated that the decline might have been slowing down. Catch rates in August and September actually were higher than in the same months for the previous year. Data in subsequent years were not based on sufficient fishing effort to continue the comparison.

Catch (kg) per hour fished (unweighted, July-September) and abundance index - Cartwright Channel.

	1977	1978	1979	1980
Standardized CPUE	641	535	427	382
Index	1.00	0.83	0.67	0.60

BIOMASS

The 1983 research survey revealed very low concentrations of shrimp in the areas sampled in previous years. Additional sets were made farther north over the saddle and produced some of the best shrimp catches (Fig. 1). Therefore, the stratified area was expanded over the saddle to include the grounds where this limited extra sampling was conducted (Fig. 2). The data from the expanded area (712.7 sq. n mi) produced an estimate of 1111 t (± 335 t) compared to 694 t (± 191 t) in the old stratification area (561.2 sq n mi) (Table 2).

Standardized surveys (gear, month, towing speed) have been conducted since 1979 and the results of the 1983 survey can be compared with those from earlier years (Table 3, Fig. 3A). Since 1980, there has been a continuous decline in the estimates for the areas surveyed and the biomass per sq. n. mile. Density was similar in 1979 and 1980 and, had a greater area been surveyed in the former, the biomass estimate would have been higher. Surveys in 1977 and 1978 were conducted in November and September respectively using a different vessel and gear. Sample sizes were low in these years and the estimates cannot be compared with the results from later surveys. If the catch rates discussed in the previous section are representative of changes in the stock from 1977 to 1979, the associated indices can be used to estimate density (biomass per sq. n. mi.) for 1977 and 1978.

	1977	1978	1979	1980	1981	1982	1983
CPUE Index	1.00	0.83	0.67				
Biomass (t)/ sq. n. mi.	9.88	8.20	6.62	6.69	4.71	3.81	1.56

These figures show a decline in shrimp density during the first three years of intensive fishing, some stability between 1979 and 1980, followed by another decline from 1980 to 1983 at a time when fishing effort was very low. Density in 1983 might have been as low as 16% of the 1977 level suggesting dispersal, but it is not certain how closely these density estimates relate to absolute abundance. Prior to 1983, very few shrimp were found outside the stratified area and, therefore, it is likely that overall abundance had declined as well. It should be noted, however, that abundance on the western slope of the channel cannot be estimated due to rough, untrawlable bottom.

PREDATOR ABUNDANCE

Bowering et al. (1983) showed that abundance of Greenland halibut in the Cartwright Channel varied between years from 1979 to 1982 and that extremely high abundance occurred in 1980. The results of the 1983 survey in the same area as in previous years showed that biomass increased from around 1400 t in 1981 to 3000 t in 1982 and to 3500 t in 1983 (Table 4, Fig. 3B).

Estimates for cod have been more variable but an increasing trend was apparent between 1979 and 1982 (Bowering et al. 1983). The 1983 estimate of approximately 400 t represents a decline of 60% from the high level observed in 1982 (Table 4, Fig. 3C).

The study by Bowering et al. (1983) also showed that, although Greenland halibut were more abundant, cod was the more important shrimp predator in 1981 due to more intensive and frequent feeding. Biomass estimates for both fish species were higher in 1982, increasing the potential for higher mortality through predation. Although abundance of cod was considerably reduced in 1983, abundance of Greenland halibut was much higher than in 1981, maintaining high predation potential. Greenland halibut abundance in 1983, however, was not as high as that observed in 1980.

REPRODUCTIVE POTENTIAL

A number of factors were observed to detect any changes in the reproductive potential of the stock during the period 1977-83. These include observations on fecundity, incidence of non-viable eggs, proportion of non-spawning females and proportion of females in the stock.

1) FECUNDITY - Samples of ovigerous female shrimp were available from September 1978 (n = 45), November 1979 (n = 47), September 1982 (n = 87) and October 1983 (n = 81). Shrimp were preserved individually in 10% formalin. Eggs were removed from the pleopods, spread on a Petrie dish and dried overnight in a Thelco precision oven at 60°C. They were then separated and counted by hand. Carapace lengths were measured to the nearest 0.1 mm using Vernier calipers. Slopes and intercepts for number of eggs vs carapace length in each year were estimated by linear regression. Relationships were compared by analysis of covariance and t-tests. Although data of this type are generally described exponentially, the linear model is used here because log-log transformation did not improve the r^2 values or the distribution of residuals.

Relationships for each year (Fig. 4) do not show any trends although the analysis of covariance shows statistical difference between years (Table 5). T-tests showed no difference between the 1978 and 1982 samples or between the 1979 and 1983 samples (Table 6). All other comparisons were statistically different ($\alpha = 0.05$).

The 1979 and 1983 data indicated lower fecundity at most lengths compared to 1978 and 1982. It must be pointed out, however, that the 1979 and 1983 samples were taken in November and October respectively, compared to September in the two other years and egg loss likely occurred over the season.

The coefficients of determination show that the data were more variable each year from 1978 to 1983, ranging from 0.81 in the former to 0.51 in the latter. This increase in variation may have no biological significance but it could reflect a general instability in conditions affecting the stock over this period.

Although efforts were made in each year to sample a wide range of sizes for female shrimp, the largest sizes obtained progressively decreased from 1978 to 1983. If these samples are representative in that the abundance of larger females has been declining, then reproductive potential might have decreased over the period because of the lower fecundity observed for the smaller females. Any such decrease, however, could be offset by increased abundance of smaller females in the stock.

2) <u>INCIDENCE OF NON-VIABLE EGGS</u> - Frequently, eggs which are white in color and noticeably swollen are encountered among the other 'normal' eggs in the clutch. These eggs are considered to be non-viable and, although included when enumerating the number of eggs per female, must be considered separately when determining 'effective' fecundity. The condition likely results from infection by a parasitic dinoflagellate reported by Stickney (1978) for *P. borealis* in the Gulf of Maine.

The data show that in 1979, there was a much higher proportion of non-viable eggs in the samples than in the three other years.

Year	1978	1979	1982	1983
Total eggs observed	41,217	67,612	31,129	97,687
No. non-viable	228	3,903	320	689
% non-viable	0.55	5.77	1.03	0.71

It is possible that more 'diseased' eggs developed over the season and that this is reflected in the November 1979 sample. However, considering that the percentage is much higher than in October of 1983, some increased egg mortality is indicated for 1979.

3) <u>PROPORTION OF NON-SPAWNING FEMALES</u> - Examination of shrimp samples from 1977 to 1983 showed that in any year, a certain proportion of females and transitionals would not spawn. Most of these were females which had spawned in the previous year. The proportions of non-spawners were calculated for each year from the available samples. During June and July, non-spawners were interpreted to include transitionals and females with small, undeveloped ovaries. Eggs are layed in August and September and any females without eggs and with small ovaries or any transitionals with small ovaries were considered as non-spawners. Later in the year (e.g. November), more transitionals with small ovaries appeared but these represented the younger male group which had begun changing sex. These late season transitionals with small ovaries were excluded from the calculations.

Year	1977	1978	1979	1980	1981	1982	1983
Females and transitionals	173	664	1120	1152	386	616	674
Non-spawners	39	40	322	192	16	139	155
% non-spawners	22.54	6.02	28.75	16.67	4.15	22.56	23.00

The proportion of non-spawners varied between years but showed no trend. Reliability in the high value obtained in 1977 is questionable due to the low sample size. Before pooling the data for each year, individual samples were compared and showed inconsistency. Therefore, it was felt that pooling was appropriate to increase sample size, providing a more representative picture for each year. In years where sample size was relatively small (i.e. 1977 and 1981) the data may not be reliable.

Spawning failure in 1979 (28.75%) appeared to be considerably greater than in the two adjacent years. Samples for 1982 and 1983 indicate a spawning failure greater than 20%, less than in 1979 but greater than most other years. Certainly for most years, the proportion of non-spawning females was higher than observed for shrimp stocks in other areas (e.g. Gulf of St. Lawrence and Davis Strait).

Comparison with commercial sampling data is not possible because the breakdown by sex is not provided in routine sampling for length. Length frequencies were available, however, for October and November 1980, a time when all females that were capable of reproducing had laid their eggs. These data showed that up to 33% of females and transitionals would not reproduce compared to 16.67% from the biological samples. Because the samples were taken late in the season, it is likely that some new transitionals are included, thus inflating the estimate. Although the research data must be considered more reliable, the commercial samples confirm the relatively high proportion of non-spawning females.

4) PROPORTION OF FEMALES IN THE STOCK - A fishery directed at larger, female shrimp likely will result, over time, in a reduction in the proportion and abundance of females in the stock. If it is assumed that the estimates of shrimp biomass and density indices presented above represent abundance to some extent, then stock size, generally, has been declining. Data from research surveys from 1979 to 1983 were analysed to determine any changes in the proportion of females over that period.

Length frequencies from the research survey catches were used to construct a total length frequency for the available stock. Surveys were stratified by depth, covering the main area of shrimp concentration. Frequencies were adjusted to the total catch weight in each set and combined over all sets in the survey. This resulted in total length frequencies for the research catch in each year which were used to interpret changes in the proportion of females and transitionals.

The proportions at length were calculated from sex and maturity data obtained during the period (Fig. 5). All data were pooled to reduce variation within and between years. Average length of females and transitionals also was computed for each year.

Year	1977	1978	1979	1980	1981	1982	1983
% Females and transitionals	58	73	57	49	40	44	35
Average length (mm)	25.81	25.24	24.25	24.24	24.08	24.25	24.18

The surveys in 1977 and 1978 were conducted in November and September respectively and results may not be directly comparable to the July surveys from 1979 onward. Since 1979, at least, there has been a decline in the proportion of transitional and female shrimp in the catches from these surveys which might reflect conditions in the stock, as well. The proportion of transitionals and females in 1983 was 61% of the 1979 level and likely less than this compared to actual levels in 1977 and 1978.

Average length decreased between 1977 and 1979 when fishing effort was high. Although sampling was conducted at different times in each year (November, September and July respectively), lengths are comparable because it is assumed that little or no growth occurs in July, just prior to egg laying and no growth occurs while females are ovigerous. Average length from the July surveys show that the size of females and transitionals has remained fairly consistent (approx. 24.2 mm) from 1979 to 1983.

In summary, overall reproductive potential likely has decreased since 1977, based on the four factors considered above. Although fecundity data did not show a declining trend, the fecundity/length relationship has become more variable, possibly reflecting instability in conditions affecting the stock. Also, there has been a reduction in the abundance of large females as demonstrated through efforts to sample from as wide a size range as possible. This is supported by an observed decrease in the size of transitional and female shrimp from research length frequencies during 1977 to 1979. Since the stock likely consists of smaller females, reduced fecundity is implied because smaller females carry less eggs. The incidence of non-viable eggs and the proporiton of non-spawning females were higher in 1979 than in other years and, assuming some stock/recruitment relationship, might have resulted in reduced stock size in later years. The proportion of non-spawning females was comparatively high in most other years, as well, indicating that the reproductive capacity for the stock is lower than observed for some other stocks. The proportion of females in the stock also appears to have declined and this, coupled with reduced abundance and fecundity, would result in lower productivity. This, again, assumes some self-sustaining characteristics of the stock. Recruitment from other areas, either passive or active, remains unknown.

TEMPERATURE

Bottom temperatures were taken intermittently at selected fishing stations in 1977 using a manual bathythermograph. From 1978 to 1983, temperatures were taken at most fishing stations using expendable bathythermographs (XBT). Mean bottom temperatures and ranges for each depth stratum were plotted for each year (Fig. 6). Data for the more shallow strata (<300 m) are lacking up to 1981. Depths greater than 300 m were sampled in most years, these being the depths where shrimp were most abundant. Between 300 and 400 m, there was a decrease in mean bottom temperature from 1977 to 1980 (Table 7). Temperatures were more stable between 400 and 500 m (2-3°C) but a slight decrease can be seen. At depths greater than 500 m, temperatures remained relatively constant around 3°C from 1977 to 1981.

In 1981, there was an increase in mean temperature in most strata less than 500 m. Temperatures in 1982 decreased at all depths, and the decrease was more pronounced in more shallow water. Some recovery was observed in most strata in 1983 (detailed profile in Fig. 7) but not to the levels observed prior to 1982. With the exception of 1981, there has been on overall decrease in bottom temperature in the Cartwright Channel between 1977 and 1983.

This trend in temperatures can be related to some of the factors discussed in previous sections. Based on the July survey results, 1979-83, shrimp usually were most abundant in depths greater than 400 m. In 1979, abundance was particularly high between 450 and 550 m while in most other years biomass was spread over a wider area and depth range (Bowering et al. 1983).

Distribution in 1981, however, was more concentrated in slightly shallower water, 400-500m. This was likely due to the warmer temperatures encountered in 1981 at these depths.

Bottom temperatures in shrimp depths of 2.3°C and less in 1982 (Table 7) may have resulted in a dispersal of shrimp over a much larger area or provided a stimulus for migration out of the area. Certainly, there was no evidence that shrimp were concentrating in the depths of warmest temperature (i.e. 500-550 m). Although temperatures, on average, increased slightly in 1983, shrimp density and abundance appeared to continue to decline. Evidence of dispersal was provided by the relatively high shrimp catches obtained on the Cartwright Saddle, compared to earlier years.

Predator abundance also may be related to changes in temperature. Abundance of Greenland halibut was high in 1980 , the year in which lowest temperatures were recorded since 1977. Abundance declined in 1981, the warm year, but increased again in the cold year of 1982. Temperatures in 1983 remained cold compared to the earlier years and abundance of Greenland halibut was maintained at a high level.

Although biomass estimates of cod are more variable than those for Greenland halibut, at least one observation can be made which might be related to temperature. Cod in this area are usually more abundant in shallower, colder water. Abundance of cod was highest in 1982 when the coldest temperatures were recorded but declined in 1983, a slightly warmer year.

The concentration of shrimp in more shallow water in 1981 might account for the relatively high estimate of cod biomass in a warm year, assuming a significant predator-prey interaction exists. Confidence in the mean estimate, however, is very low.

There is no evidence in the data to indicate that the decreasing trend in temperature has reduced fecundity but, as noted previously, the fecundity/length relationship over the same period has become less well-defined. Also, colder temperatures usually result in slower growth rates which may account, in part, for the reduced abundance of large females. In this way, overall stock productivity could be reduced because growth is retarded and smaller females carry fewer eggs. Unfortunately, data on the age and growth of individual cohorts are not available to substantiate this possibility.

No clear relationship exists between temperature and the proportion of non-spawning females. In 1981, the warm year, only 4.15% of the transitionals and females in the sample were non-spawners compared to over 20% in the colder years, 1982 and 1983. However, proportions are quite variable between samples within years and the total sample size in 1981 (n = 386) may not be representative.

The effects of temperature on growth also can be interpreted by observing the changes in the average length of transitionals and females. No relationships can be seen between the average length and temperature in each year but a pattern emerges by comparing the length in year i with the temperature in year i-1. Temperature generally declined up to 1980 and, in

1981, the average length of transitional and females in the samples was the smallest observed, 24.08 mm. Warmer conditions existed in 1981 and average length in 1982 increased to 24.25. Temperatures in 1982 were colder and average length in 1983 dropped to 24.18.

It must be noted that both length and temperature are mean values with associated variance. The comparison of point estimates for both may be misleading but as a first attempt at interpreting these types of data, the observations are interesting, at least.

DISCUSSION

Recent events in the Cartwright Channel and the possible effects on the shrimp stock can be reviewed under the general categories of mortality, reproductive potential and environment. The three are not independent, rather they are highly interactive. Mortality has two components, natural and fishing, which have varied in importance in this area during the review period. Reproductive potential is dependent on stock size and environmental conditions. It is considered to be important because the stock is assumed to be, to some extent, self-sustaining. This assumption must be made mainly because alternate recruitment mechanisms are unknown. Environmental conditions relate to the physical environment (i.e. bottom temperatures) and biological environment (i.e. predators, parasites).

An intensive fishery for shrimp occurred from 1977 to 1979, directed primarily toward the larger (female) animals. Population size usually decreases under controlled exploitation until a new equilibrium is attained. This likely accounts for part of the observed decline in the abundance index of 33% during this period. Fishing pressure was directed toward the larger, female shrimp, thus reducing reproductive capacity. Although very little effort was expended after 1979, the effects of fishing during the previous years might have carried through to 1980 or longer. From 1977 to 1983, there was an overall decrease in bottom temperatures from research survey data which could have further affected productivity by retarding growth and consequently, reducing fecundity. If in 1979, the incidence of non-viable eggs and the proportion of non-spawning females actually were higher compared to other years, then the effective fecundity in that year and stock size in subsequent years would have been reduced. Also, it is important to note that, compared to some other stocks, reproductive capacity appears less in the Cartwright Channel due to a high proportion of non-spawning females in most years, possibly related to low temperatures. Similar observations on reduced reproductive potential have been made by Squires (1968) - south and east coasts of Newfoundland, Couture (1970) - le fjord du Saguenay, Quebec and Berenboim (1982) - Barents Sea.

Although fishing mortality was considerably reduced in 1980, total mortality remained high because of the high abundance of Greenland halibut. In 1981 and 1982, abundance of cod increased and studies have shown that cod consume more shrimp per unit biomass than Greenland halibut. Therefore, despite the decline in abundance of the latter from the 1980 level, mortality through predation by cod remained high in 1981 and 1982. Survey results in

1983 showed that abundance of Greenland halibut again had increased since 1981. In addition to reducing stock size by predation, these species also may disperse concentrations of shrimp, resulting in lower densities. This has been observed for cod/shrimp interactions at Iceland (Skúladottir, pers. comm. in Fréchette and Parsons, 1983). Changes in predator abundance in the Cartwright Channel show some relationship to changes in bottom temperatures in the area. Predator abundance generally was higher in colder years.

The decline in temperature from 1977 to 1980 was followed by an observed increase in 1981. Shrimp were found to be more heavily concentrated in more shallow water in that year and may have become more available as prey for cod. In 1982, temperatures were very cold compared to other years and the low estimates of biomass and density might be indicators of dispersal as well as reduced abundance. Temperatures in 1983 were warmer than in the previous year but, in most depths, less than in years prior to 1982. Biomass and density again were lower in 1983. Relatively large catches of shrimp on the Cartwright Saddle provided additional evidence of dispersal.

CONCLUSIONS

The demise of the shrimp stock in the Cartwright Channel as a commercially exploitable unit can be related through circumstantial evidence to three major events; the fishery from 1977 to 1979, the increases in abundance of Greenland halibut and cod since 1979 and the general decline in bottom temperatures at shrimp depths from 1977 to 1983. All three have contributed to a continued decrease in overall stock productivity, both individually and interactively. Fishing mortality, natural mortality through predation and declining temperatures also appear to have contributed to a dispersal of shrimp concentrations as well as a reduction in abundance.

A shrimp fishery in the absence of significant environmental changes (biotic and abiotic), can be sustainable for a number of years. This has been demonstrated for stocks in the Gulf of St. Lawrence and Davis Strait. Even the Hopedale Channel stock has been successfully fished since 1977, although effort has been quite variable from year to year. If increases in predator abundance and/or changes in water temperature can be predicted with some degree of reliability, then management advice should change from the 'sustainable' concept to one which maximizes returns from the resource over a short period. However, predictability of environmental events is usually difficult to achieve, even with an extensive time-series data base. Another problem is the inherent fear of being wrong and the associated consequences (economic, social and biological).

Management decisions for many fisheries based on biological input usually lean towards conservation, especially in cases where problems in interpreting the data arise. This is likely the best approach for most species, but for shrimp, sensitivity to the environment also must be considered. Conservation then may be considered in perspective.

Annual July research surveys to the Cartwright Channel since 1979 have provided useful data on the shrimp stock, particularly during the period when fishing mortality was very low. Interest in the Labrador shrimp stocks began in the Hawke Channel in the early 1970's, but concentrations in this area have been very low since the July surveys were initiated. Data are not sufficient to conduct a similar review for that area but the fact that abundance apparently has declined in the absence of a fishery should be considered along with the more detailed observations for the Cartwright Channel.

Concentrations of shrimp in the Labrador Channels appear to be sensitive to environmental changes. Fisheries are difficult to maintain under such conditions and equally difficult to manage. One must determine the threshold where fishing effort and environmental pressures are sufficiently balanced to ensure enough resource for future years and, at the same time, be able to make correct management decisions should unprecedented changes in these factors occur. If recent events in the Hawke and Cartwright Channels are part of a trend which is continuing in a general northward direction, it is quite probable that shrimp stocks in other areas also will decline to levels which are commercially unacceptable.

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Table 1. Catch (kg) and catch per hour fished adjusted to tonnage class 5 vessels, 1977-83, Cartwright Channel (monthly values compiled from available vessel logs).

Month	1977		1978		1979		1980		1981		1982		1983	
	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE
June							23,134	212			113,580	382	2,790	111
July	311,838	834	155,813	479	147,498	730	11,770	453	6,875	262				
Aug.	514,633	624	399,501	664	148,268	318	22,465	368	5,035	155	1,020	322		
Sept.	234,037	465	638,159	463	353,821	235	55,919	326	907	202			160	53
Oct.	14,378	187	45,439	264			405	73						
Nov.	73,616	802					3,535	135						
Dec.	9,650	566									28,710	380		
Total[a]	1,158,152	614	1,238,912	500	649,587	299	117,228	294	12,817	203	143,310	381	2,950	105
Total[b]	1,414,000		1,521,000		1,034,000		170,000		67,419		167,196		3,000[c]	

[a]Totals from available vessel logs.

[b]Totals from reported landings.

[c]Preliminary.

Table 2. Minimum trawlable biomass - 1983 research - Cartwright Channel.

Stratum	Depth (m)	Area (sq. n. mi.)	No. sets	Biomass (t)
A. Expanded Stratification				
701	251-300	57.8	3	20
702	301-350	89.7	3	41
703+704+705	<300	86.5	5	0
706	301-350	45.7	6	16
707	351-400	36.0	5	66
709	451-500	53.9	6	198
710	501-550	89.7	7	129
711	451-500	15.6	4	12
712	>550	41.3	5	108
807	350-400	66.9	2	97
708+808	400-450	92.3	8	237
809	450-500	37.3	2	186
Total		712.7	56	1,111
95% C.I. Upper				1,446
95% C.I. Lower				775
B. Old Stratification				
Same as above for strata 701-702				
+708	400-500	45.0	7	103
Total		561.2	51	694
95% C.I. Upper				885
95% C.I. Lower				503

Table 3. Biomass estimates (tons) and 95% confidence intervals for shrimp, 1979-83, Cartwright Channel.

Year	Mean[a]	Upper	Lower	Area (sq. n. mi.)	n	Biomass per sq. n. mi.
1979	1,892	2,879	904	286	22	6.62
1980	2,789	3,422	2,157	417	37	6.69
1981	2,367	3,380	1,355	503	49	4.71
1982	1,916	2,867	965	503	42	3.81
1983	1,111[b]	1,446	775	713	56	1.56
	694[c]	885	503	561	51	1.24

[a]1978-81 estimates are derived from systematic line surveys.
1982-83 estimates are derived from stratified random surveys.

[b]Expanded stratification.

[c]Old stratification.

Table 4. Biomass estimates (tons) and 95% confidence intervals for Greenland halibut and cod, 1979-83, Cartwright Channel.

Year	Greenland halibut			Cod		
	Mean	Upper	Lower	Mean	Upper	Lower
1979	1,739	2,685	793	224	426	62
1980	5,332	6,189	4,476	331	502	160
1981	1,367	2,042	710	751	1,403	99
1982	3,061	3,934	2,188	1,017	1,414	620
1983	3,538	4,420	2,656	413	633	193

Table 5. Analysis of covariance for fecundity/length data, Cartwright Channel, 1978-83.

Source	DF	SS	MS	F	Pr>F	r^2	C.V.
Model	7	26268777.42	3752682.49	115.76	0.0001	0.76	13.06
Error	252	8169339.37	32418.01		$\sqrt{MSE}$		Count Mean
Corrected total	259	34438116.78			180.05		1378.41
Length	1	25050638.07		772.74	0.0001		
Area	3	584002.97		6.00	0.0007		
Length x Area	3	634136.38		6.52	0.0004		

Table 6. T-tests for samples included in analysis of covariance in Table 5.

Year	Average No.	Pr>|t| H_0: Mean = 0	P>|t| H_0: Mean (i) = Mean (j) 1978	1979	1982	1983
1978	1446.87	0.0001	•			
1979	1308.05	0.0001	0.0004	•		
1982	1408.35	0.0001	0.2759	0.0037	•	
1983	1349.03	0.0001	0.0092	0.2561	0.0427	•

Table 7. Mean bottom temperatures (°C) by depth stratum, Cartwright Channel, 1977- 83.

Stratum	Depth (m)	1977	1978	1979	1980	1981	1982	1983
701	251-300				0.0	1.3	0.4	0.6
702	301-350		1.4		0.9	2.2	0.6	0.8
703	251-300	2.7				1.2	-0.3	0.9
704	<250			0.5		1.1	-1.3	-1.1
705	251-300	2.7	0.5	0.5		2.0	-0.5	-0.1
706	301-350	2.7	2.0	1.5	1.2	2.3	0.6	1.2
707	351-400	3.1	2.5	2.3	1.8	2.4	1.3	1.8
708	401-450		2.4	2.5	2.2	2.8	1.7	2.0
709	451-500		3.0	2.9	2.5	2.8	2.0	2.3
710	501-550	3.1	3.1	3.1	2.9	3.0	2.3	2.6
711	451-500			3.0	2.9	2.8	2.0	2.5
712	>550				3.0	2.8	2.2	2.4

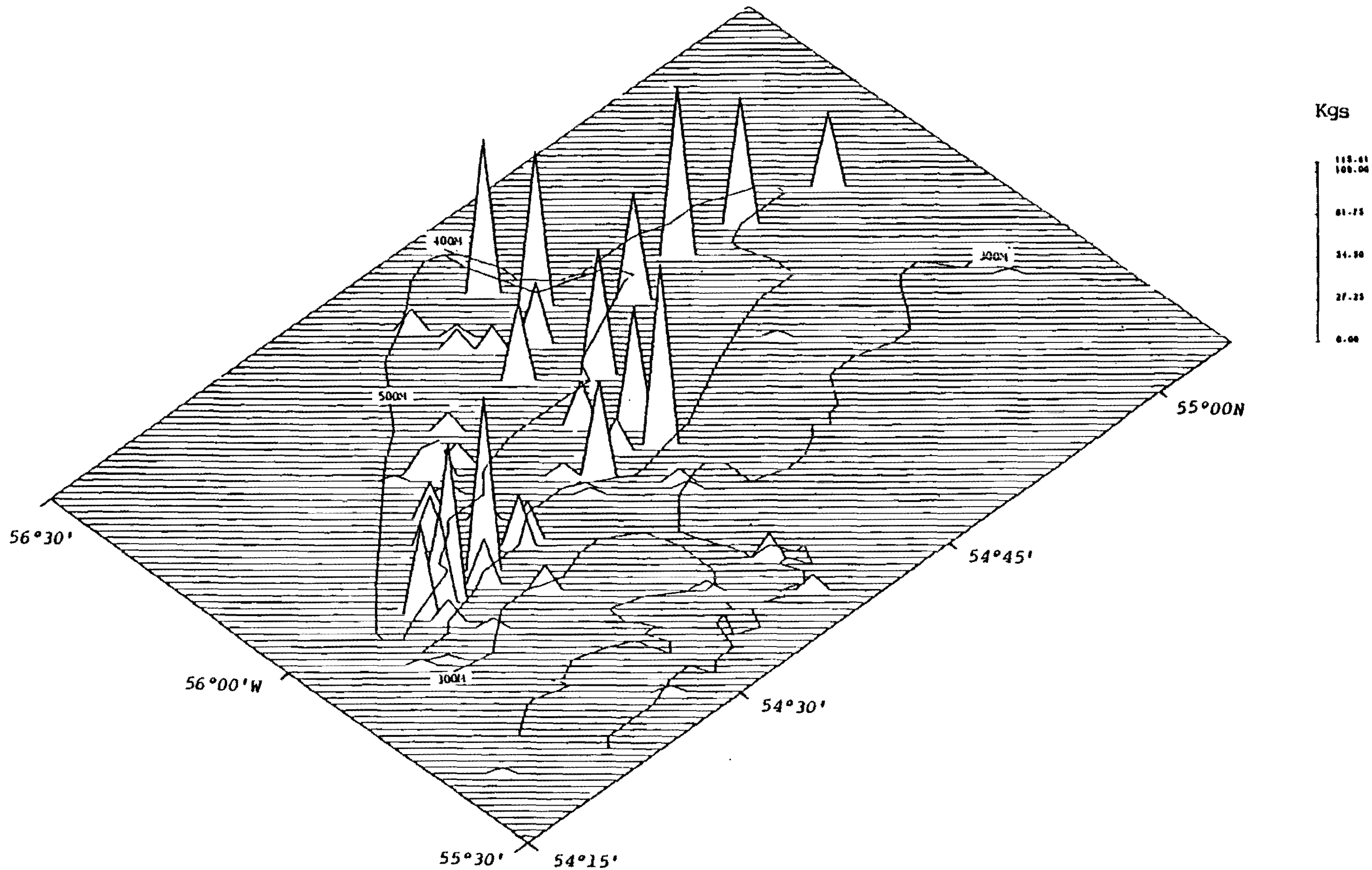


Fig. 1. SHRIMP CATCHES PER 30 MIN TOW   CARTWRIGHT   GADUS81 1983

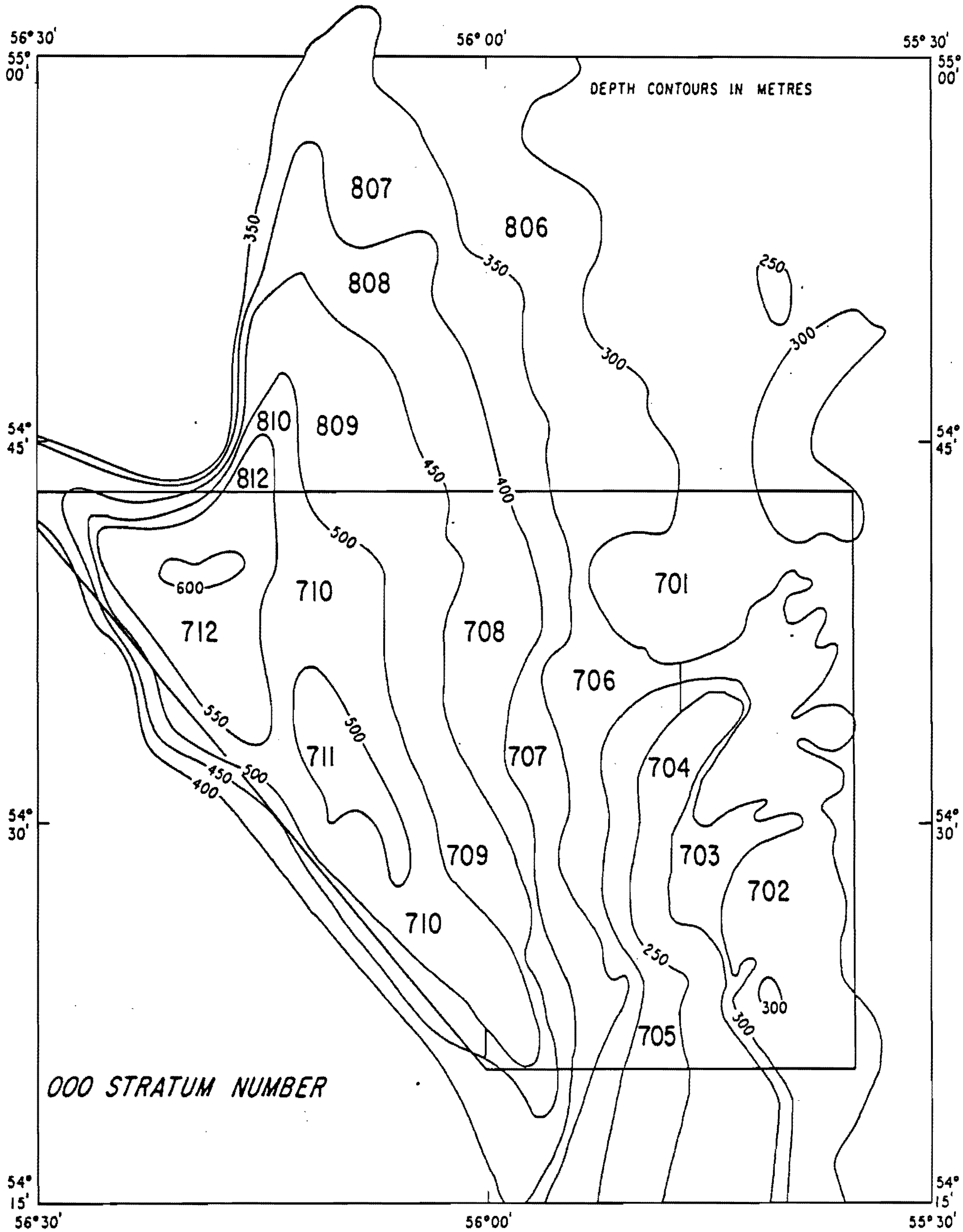


Fig. 2 Stratification of the Cartwright Channel.

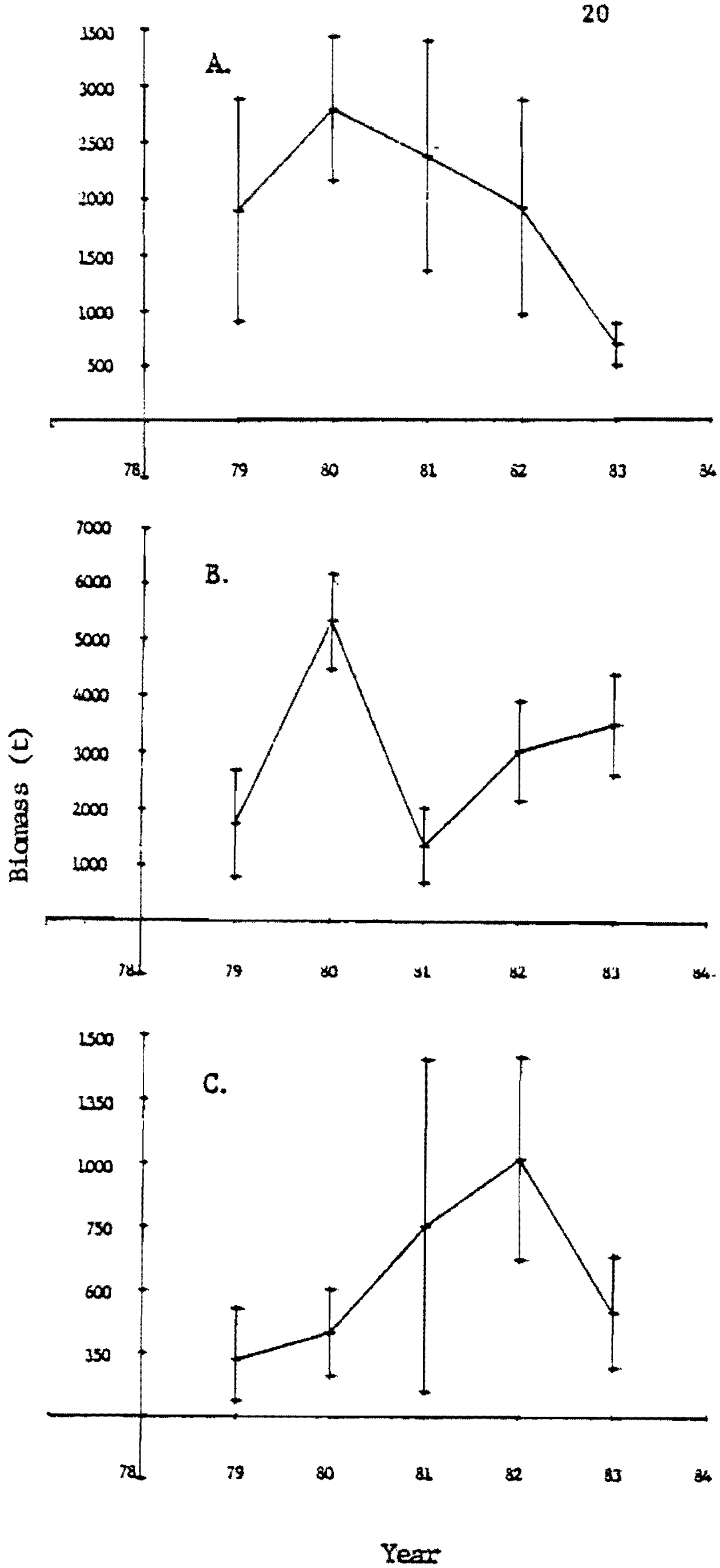


Fig. 3. Mean estimates of biomass and 95% confidence intervals for (A) Shrimp, (B) Greenland halibut, and (C) Cod in the Cartwright Channel, 1979–1983.

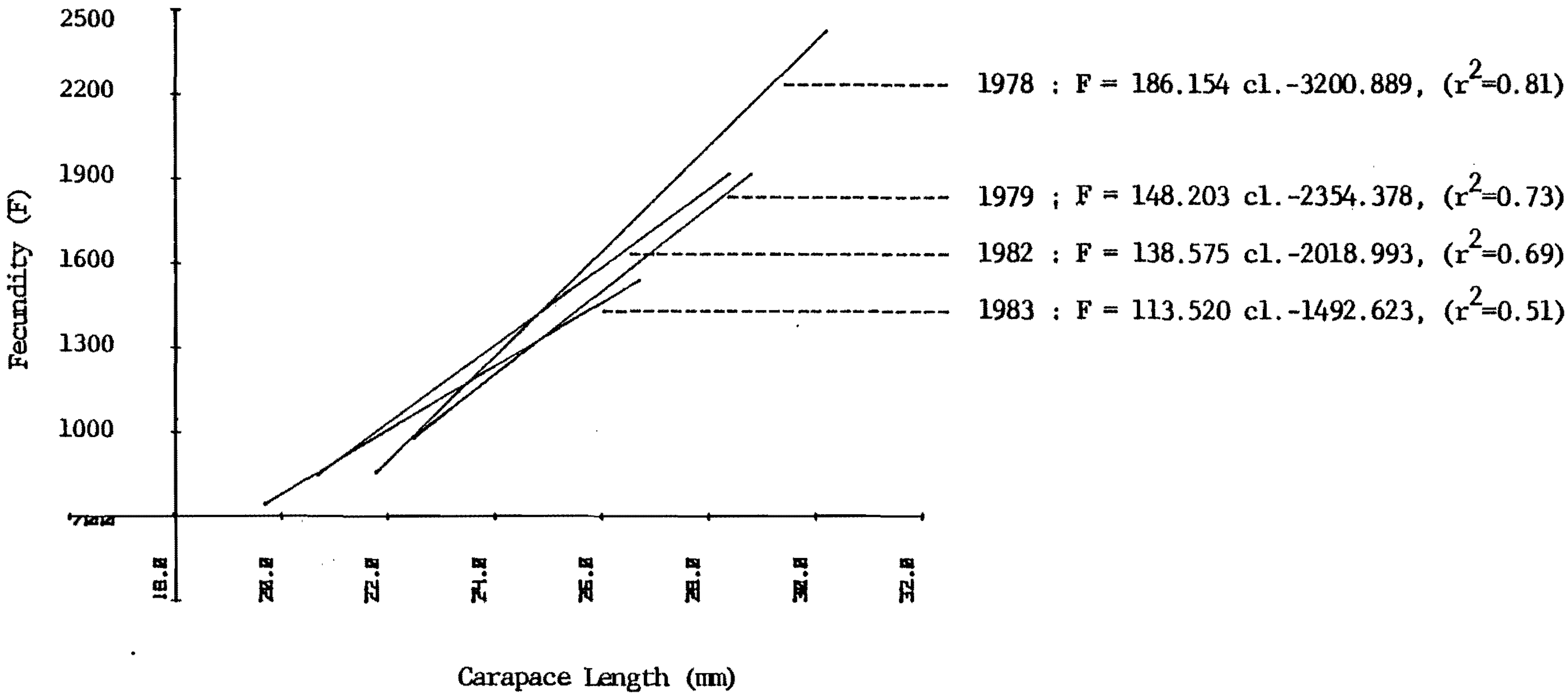
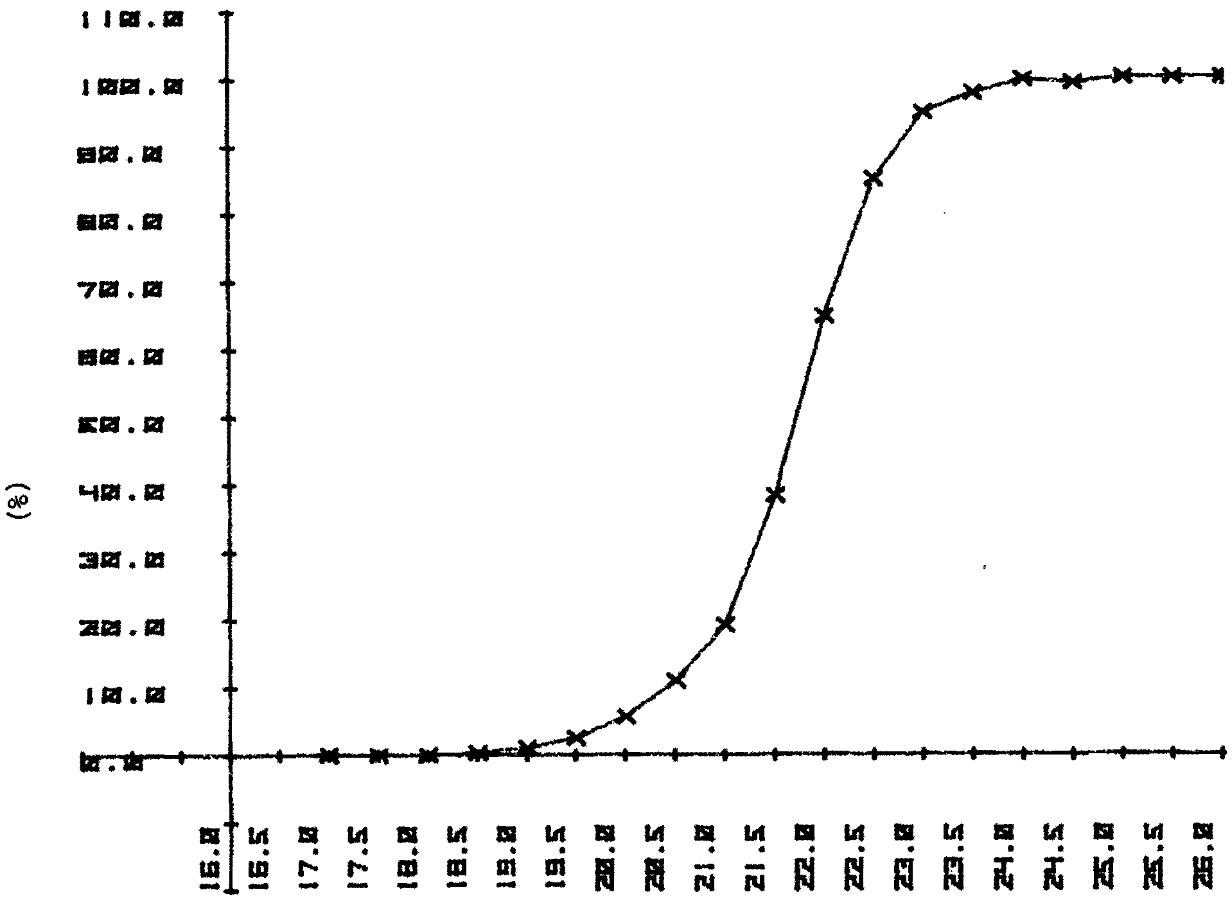


Fig. 4. Shrimp fecundity vs carapace length, Cartwright Channel.



Carapace Length (mm)	% ⚥ & ♀
17.0	0.0
17.5	0.0
18.0	0.0
18.5	0.3
19.0	1.1
19.5	2.5
20.0	5.6
20.5	10.9
21.0	19.1
21.5	38.2
22.0	64.7
22.5	85.0
23.0	94.8
23.5	97.7
24.0	99.7
24.5	99.2
25.0	100.0
25.5	100.0
26.0	100.0

Fig. 5. Percent transitionals and females at length, Cartwright Channel, 1977-1983 combined.

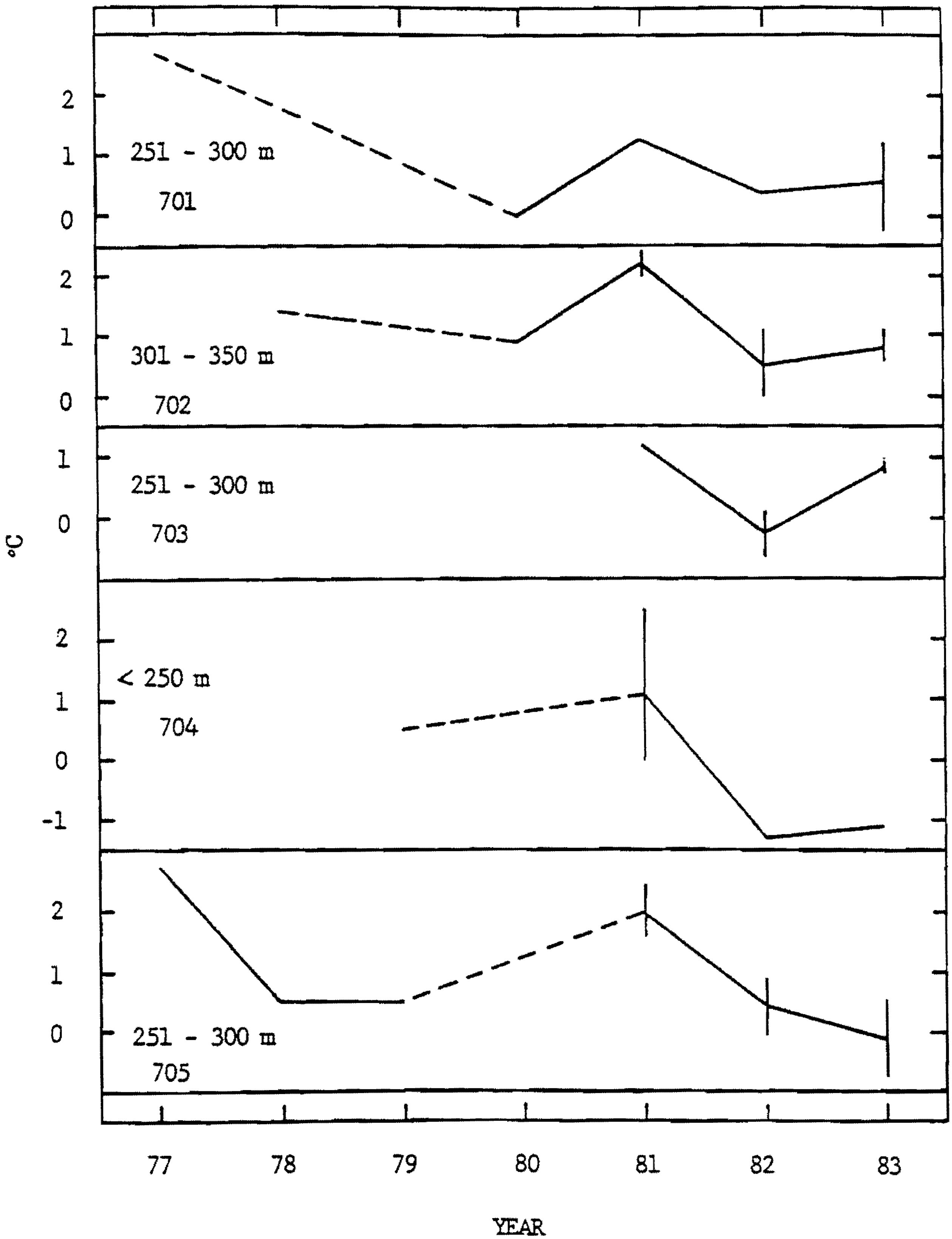
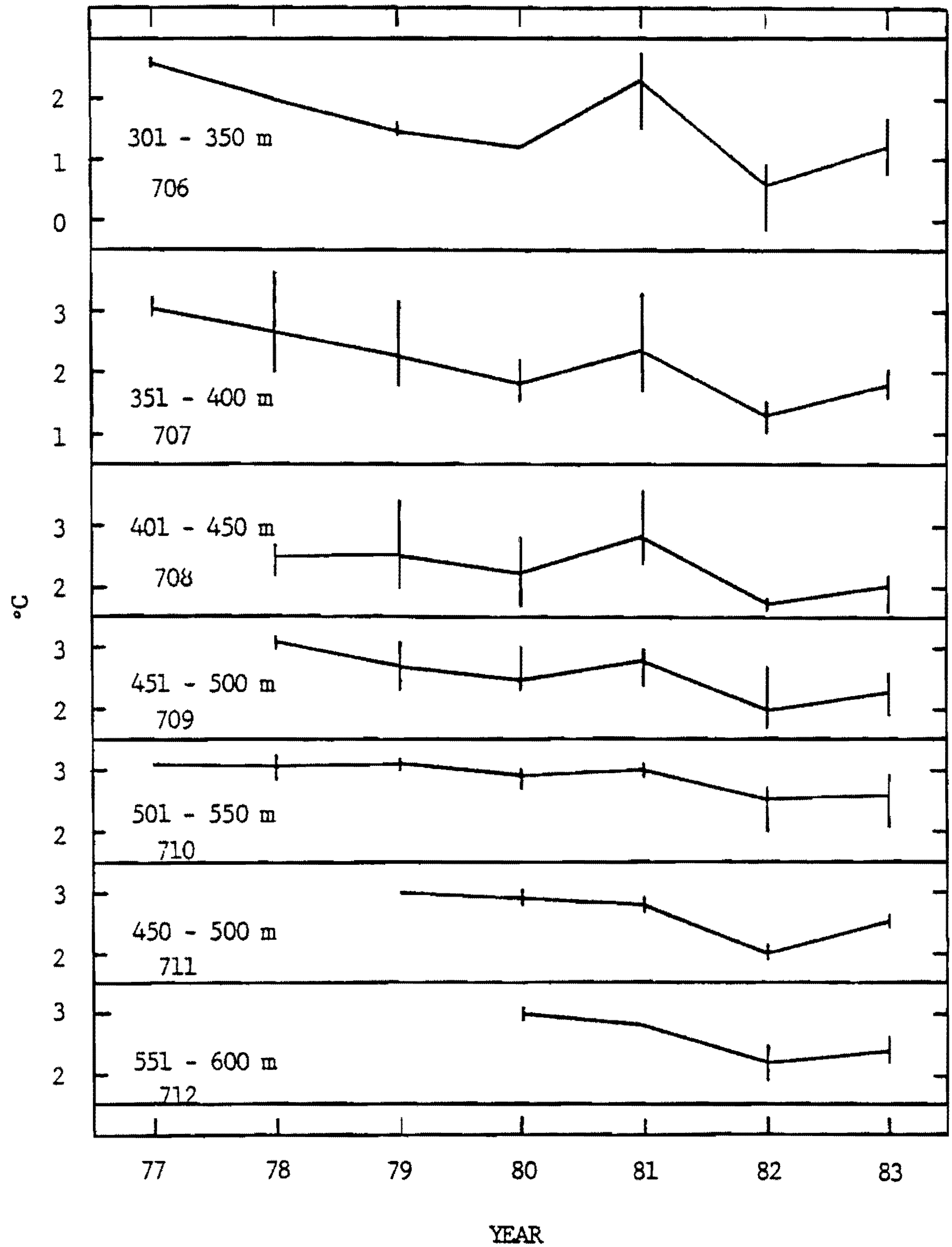


Fig. 6 Mean bottom temperatures and ranges by depth stratum, 1977-1983, Cartwright Channel.



301 - 350 m
706
351 - 400 m
707
401 - 450 m
708
451 - 500 m
709
501 - 550 m
710
450 - 500 m
711
551 - 600 m
712
°C
77
78
79
80
81
82
83
YEAR

Fig. 6 (cont'd)

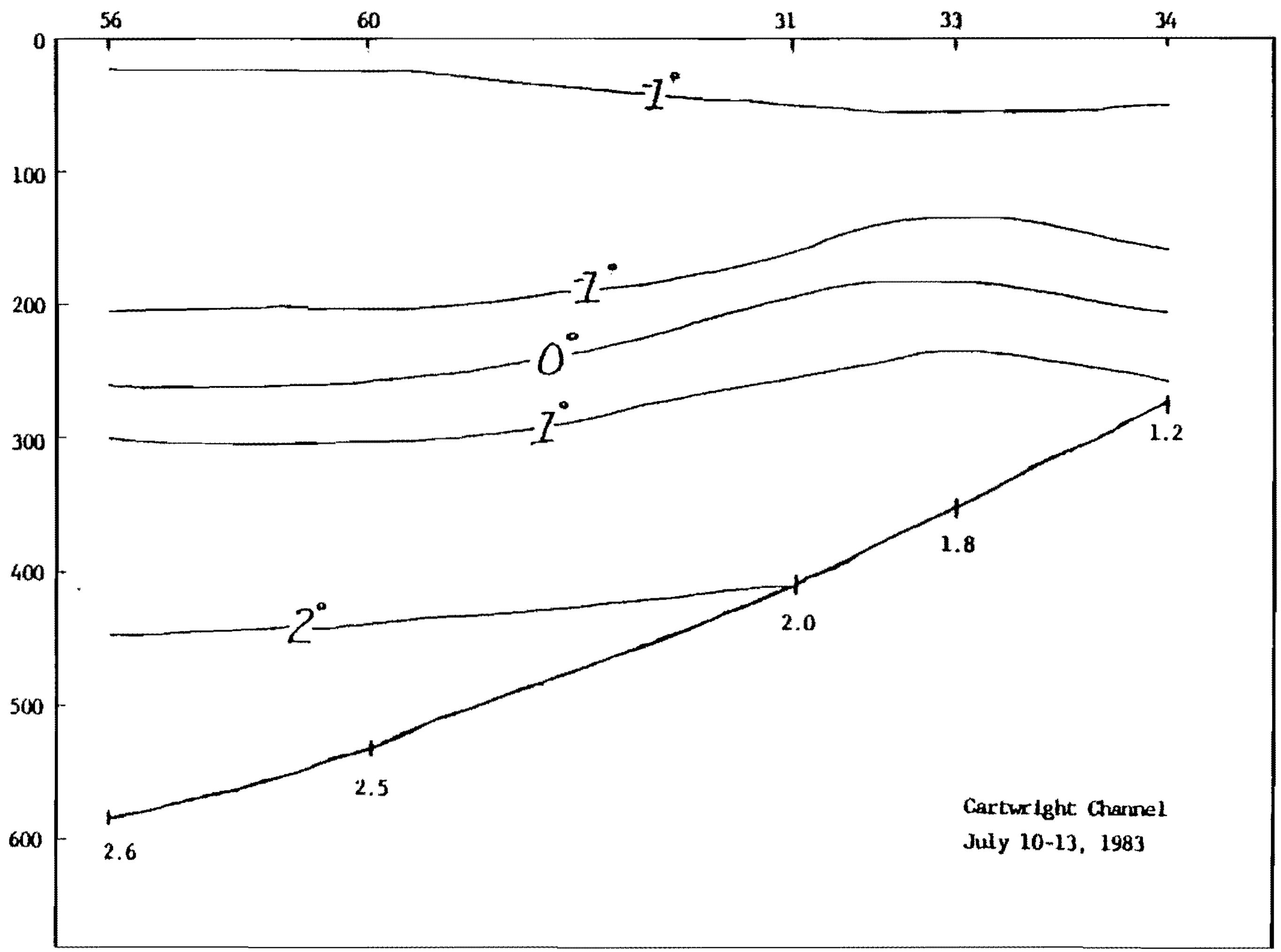


Fig. 7 Hydrographic Section, Cartwright Channel, 1983.