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An Assessment of the Labrador Shrimp Fishery

by

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Introduction

The shrimp (Pandalus borealis) fishery in areas of the Labrador (Fig. 1) was regulated by total allowable catch during 1978, the second year of sustained exploitation through the course of the fishing season. These catch quotas were based on information presented by Sandeman (1978) which included 1977 research and commercial data.

During 1978 considerable data were collected in each month of the season through an intensive observer programme. Various vessels engaged in the exploitation of this species were sampled from July to December. Additionally, a shrimp research survey was conducted in September and October in the areas of commercial fishing activity and beyond.

This paper represents an attempt to transform available relevant information concerning this fishery over its brief history into some meaningful conclusions which will aid in the management of the Labrador shrimp in 1979. It is imperative at this point to emphasize that data available for employment in accepted analytical models are, indeed, limited. Much of the information can be regarded as interpretive but should receive due consideration in the total assessment of these areas.

Cartwright Channel

Fishing patterns and catch per unit effort

Only two vessels fished consistently over the season in both 1977 and 1978. Comparisons for the two years are limited to the activities of these vessels as a means of standardizing unit of effort and relative fishing efficiency.

The shrimp season began in the Cartwright Channel in mid July, 1977 (Fig. 2) and experienced high but wildly fluctuating catch rates. These rates dropped steadily reaching a low of less than 200 kg per hour in early October. Consequently, effort was displaced north to the Hopedale Channel. Towards the end of November (and the fishing season) catch rates

increased sharply to levels experienced at the beginning of the season, although limited effort at this time may place the level of resurgence in some question. The total catch obtained for the 1977 effort was approximately 1200 m tons (Table 1).

Fishing resumed in early July 1978 but the success witnessed the previous year was not at first evident. The steady decline evident in 1977 did not occur in 1978 and by early August catch rates, if anything, had increased slightly averaging approximately 700 kg per hour and surpassing the declining rates of 1977. An abrupt decline did occur in mid September to levels around 300 kg per hour. The quota had been taken by this time and the area was officially closed on October 18, the total catch almost reaching 1400 m tons (Table 1). As a result, no effort was forthcoming from the end of the year to corroborate the resurgence indicated in 1977.

Figure 3 shows the pattern of fishing for the whole fleet in 1978 which confirms observations from the standard vessels. Learning factors can explain, perhaps, the slight differences in catch rate levels and the slower rate of decline witnessed in September. The figure also shows that effort was concentrated in deeper waters after catch rates declined. Most fishing occurred around 440 m from July to early September but mean depth increased to approximately 480 m until the close of the season.

A monthly summary of catch rates and total seasonal catches are presented in Table 1.

Shrimp size distribution

Commercial length frequency distributions are compared for similar periods in 1977 and 1978 (Fig. 4). The fishery in the former year concentrated on two size (age) groups, the smaller of which supported the fishery in 1978. Abundance levels of shrimp in the smallest size mode in 1977 appears to have increased in 1978 for the period of comparison. The growth of the smaller shrimps over the year is also evident as the modal length shifts from 19 to 21 mm carapace length. The 17 mm mode evident in 1978 data occurs at levels of abundance similar to the 19-20 mm mode of 1977. This may suggest reasonable recruitment in 1979, depending on partial recruitment values.

Figure 5 consists of representative commercial length frequencies for 1978 corresponding to periods of change in fishing depth indicated in Fig. 3. Shrimp from the 20-21 mm mode dominated the distribution during periods of high catch rates. When rates declined, increasing percentages of larger shrimp were evident and in the September period, with catch rates very low, larger shrimp (modal at 25 mm) predominated in the deeper water.

Figures 6 and 7 are constructed from data collected on research cruises in October-November 1977 and September-October 1978. The latter falls into the time of lowest abundance for the season. Shrimp in November 1977 were concentrated between depths of 300 to 450 m whereas in 1978 dispersal was considerably greater. A comparison of these figures indicates the relative abundance by stratum in terms of number caught per hour. Best concentrations

in September 1978 occurred between 450 and 550 m, confirming the observations from commercial data. However, while larger shrimp are evident in abundance in deeper strata there is no sign of the size-group represented most frequently in the catches (Fig. 5). Depths shallower than 240 m could not be sampled due to rough bottom.

The diel variations in shrimp abundance may be characterized by disproprotionate densities of ovigerous females in daylight hours and darkness (Jones and Parsons, 1978). A literature survey by MacLaren Marex, Inc. (1978 unpublished) provides information which suggests that ovigerous females migrate very little and that smaller P. borealis have a greater tendency to migrate vertically than larger animals. If ovigerous females do not undertake the extensive vertical migrations of the smaller non-ovigerous animals the pattern should be indicated in length frequency data. Figure 8 reflects an atypical situation in which the two frequencies shown are antithetic. It is also an accepted fact that catch rates at night are lower because of this vertical movement. This is indicated in the figure for August 1978 but not so in September.

Biomass Estimates and Calculation of Total Allowable Catch

Stratification for the Cartwright Channel was accomplished through the use of soundings and positions (Satellite Navigation) taken onboard the A.T. CAMERON in September-October 1978. The interpretation of these records is presented in Fig. 9, Table 2. A minimum trawlable biomass estimate for 1978 was obtained by the swept volume method. Biomass was calculated similar to the method of Sandeman (1978) except the speed of tow was considered to be 3.5 knots. This has the effect of lowering the estimates. Minimum trawlable biomass in September 1978 was estimated at approximately 900 m tons (Table 2). This figure was calculated using catches taken in both daylight and darkness. When calculated separately the biomass was usually slightly higher in similar strata using night catches only. Since the availability of shrimp during the survey was very low, this estimate, covering depths from 240 to 570 m, cannot be considered reliable. No reasonable method of adjusting to periods of high densities was determined.

The 1977 survey results were applied to the revised stratification scheme in the absence of good data for 1978. The results of this exercise are also presented in Table 2. The figure of 2,800 m tons is almost twice that indicated in the previous assessment. The former calculation includes depth strata which Sandeman considered outside the range of commercial activity in 1977 and for which no estimate of area could be obtained. If these strata are excluded the estimate of minimum biomass drops to 1,041 m tons, less than one-half the other.

Interpretations of catch levels from 1978 data were not considered but the 1977 estimates have been revised and may reflect the virgin biomass condition facilitating revised catch estimates. In any case, 1,179 m tons caught in 1977 must be added to the biomass estimate. Calculations are made using revised figures for those strata used by Sandeman (1978) and for

all strata surveyed in the 1977 cruise. The options given below are those considered by the Invertebrates and Marine Plants Subcommittee.

	Strata of Sandeman	All strata
Minimum biomass	1,041 m tons	2,811 m tons
1977 catch	1,179	1,179
Estimate of B_0	2,220 m tons	3,990 m tons

Option I

$Y = 0.5\ MB_0$
$= 0.5 \times 1.0 \times 2{,}220$
$= 1110$ m tons

$Y = 0.5\ MB_0$
$= 0.5 \times 1.0 \times 3{,}990$
$= 1995$ m tons

$M = 1.0$

Option II

$C = \frac{B_0 F}{Z}(1-e^{-Z})$

$= \frac{2{,}220 \times 0.35}{1.35}(1-e^{-1.35})$

$= 426$ m tons

$C = \frac{B_0 F}{Z}(1-e^{-Z})$

$= \frac{3{,}990 \times 0.35}{1.35}(1-e^{-1.35})$

$= 766$ m tons

$F = 0.35$
$M = 1.0$

Option III

$C = \frac{B_0 F}{Z}(1-e^{-Z})$

$= \frac{2{,}220 \times 0.5}{0.85}(1-e^{-0.85})$

$= 748$ m tons

$C = \frac{B_0 F}{Z}(1-e^{-Z})$

$= \frac{3{,}990 \times 0.5}{0.85}(1-e^{-0.85})$

$= 1344$ m tons

$F = 0.5$
$M = 0.35$

Option IV

$Y = 40\%\ \bar{B}$[1]

$= 0.4 \times 2{,}220$

$= 888$ m tons

$Y = 40\%\ \bar{B}$[1]

$= 0.4 \times 3{,}990$

$= 1596$ m tons

Review of depths fished in 1977 reveals that some fishing did occur between 310 and 350 meters, although vessels fishing the complete season usually frequented waters of 350 to 450 meters. The A.T. CAMERON fished this area at a time when most effort was being expended in the Hopedale Channel. It is obvious from Figure 6 that greatest densities at this time

[1] For these calculations $\bar{B} = B_0$

occurred in the 313 to 348 m stratum and comprised size distributions comparable to those of the commercial catches. It is not unreasonable to include this biomass in considering levels of T.A.C. at the same time voicing concern for the inadequacy of sampling data and inherent errors in the swept volume method.

Catches from the Cartwright Channel in 1977 and 1978 were roughly 1,200 and 1,400 m tons, respectively. Most of the catch was taken before the season was half complete. The years subsequent to the first year of a fishery would be expected to produce lower catch rates before levelling off under stable conditions. Except for the first month of the fishery, 1977 and 1978 monthly catch rates can be considered comparable (Table 1).

An additional estimate of biomass in 1978 was obtained from a commercial vessel fishing this channel in August (Table 3). Assuming the vessel fished areas of shrimp concentrations, this estimate of 1,780 m tons at least indicates that the 2,800 m tons determined for 1977 survey data may be a reasonable estimate of mean biomass. The swept-volume method was again employed.

A compromise TAC will be indicated around 1,400 mt. This compromise recognizes the underestimate of population size as well as the need to preserve a significant spawning stock biomass.

Hopedale Channel

Fishing patterns and catch per unit effort

The standard vessels used in interpretation of catch per unit of effort for the Cartwright Channel were used in this area as well to compare 1977 and 1978 (Fig. 10).

In mid August 1977, the effects of the decline in catch rate from the Cartwright Channel forced vessels to move to the more northerly grounds. Rates increased by roughly 200 kg per hour with the shift in fishing area and remained the same until the end of September. At the same time, brief visits to the Cartwright Channel indicated the decline was continuing in that region. During October to mid-November catch rates in the Hopedale Channel dropped to levels around 300 kg per hour, still a little better than the southern region. By the end of November catch rates had risen again to levels experienced at the start of the season. The total catch for the year reached 1,500 m tons.

Early 1978 was characterized by a lack of fishing effort in the area, despite good catch rates obtained very early in the season. With favourable conditions in the Cartwright Channel there was no need to change grounds. When rates finally did decline in the southern area short visits to the Hopedale Channel produced very poor results in contrast to the 1977 pattern, however, actual levels of shrimp abundance are uncertain due to low effort at this time. Closure of the Cartwright Channel in mid October forced all vessels into the northern area where catch rates fluctuated around 500 kg per hour until the end of November.

Figure 11 presents the information for the whole fleet during 1978 and supports the interpretation presented above. In addition, indications are that at the end of the year the resurgence evident in 1977 had recurred and although only one vessel fished in December 1978, her catch rates reached highest levels ever recorded for the area. The total catch for this channel in 1978 was 2,225 m tons, approximately one-half the T.A.C. The monthly summary of catch rates and total catch for the season are given in Table 1.

Figure 11 also shows the changing pattern of fishing depths over the 1978 season. Fishing began in depths of 400 m but when the fleet concentrated effort in this region in mid October, depths between 280 and 380 m were preferred. At the end of the year the only vessel that remained active in the fishery experienced good catch rates over a wide variety of depths.

Shrimp size distribution

A comparison of 1977 and 1978 commercial length frequencies for similar periods is presented in Figure 12. Again, the two size (age) groups evident in the Cartwright Channel maintained the fishery in 1977. The younger of these dominated the 1978 season but the relative abundance of this mode increases only slightly from the previous year for that particular time interval. Recruitment levels indicated around 17 mm carapace length from the Cartwright Channel are not represented so strongly in this example.

Figure 11 indicates a number of periods during the season when the depth of fishing concentration changed. Length frequencies for some of these periods are presented in Figure 13. Evident here is the increase in sizes of shrimp caught as fishing depth increased from early November to late December. The lack of detail in the last figure is a function of fishing over a wide depth range. No commercial data are available from the period of low concentration. Research data at this time indicate that concentrations of shrimp characteristic of commercial catches were found in depthsof 170 to 240 m (Fig. 15), the zone not fishable in the Cartwright Channel. It should be noted that this distribution was only obvious in the northern end of the Hopedale Channel. Shrimp found in depths of limited commercial activity occurred in very low densities and were typically larger (modal at 24 mm), the distribution ranging from 19 to 28 mm.

Research data from November 1977 and September 1978 are presented in Figures 14 and 15. Shrimp were found in greatest abundance in depths of 350 to 450 m in November 1977 compared to 170 to 300 in September 1978. The apparent reversal in depths of greatest concentration between the two channels may be somewhat anomalous since the 170-240 m zone could not be fished in the Cartwright Channel.

An examination of commercial length frequencies on a day-night basis reveals no difference in the distributions in terms of size or proportion of ovigerous females (Fig. 16). Catch rates in November 1978 are typically higher during daylight but in December no obvious difference is discernable.

Biomass Estimates and Calculation of Total Allowable Catch

Data concerning bottom topography for the Hopedale Channel was obtained during the research vessel cruise in September 1978. Details of the area are shown in Figure 17, Table 4. The minimum trawlable biomass estimated for 1978 (2059 m tons) is also unreliable considering the very low abundance levels observed at the time of the survey. A total of 12 depth strata were sampled in 1978 in comparison to only 5 for 1977. For these reasons the 1977 data were revised using the 1978 stratification scheme (Table 4). The estimated minimum trawlable biomass of 5669 m tons is approximately one-half that indicated in the previous assessment. The revised estimate covers depths from approximately 275 to 450 m all of which were fished commercially in 1977.

A total catch of 1,502 m tons must be added to the revised biomass estimate to arrive at an approximation of virgin biomass, i.e. 7171 m tons. Using this figure the options calculated for the Cartwright Channel can be applied to the Hopedale Channel as well.

Option I $Y = 0.5\ MB_0 \quad M = 1.0$

$= 0.5X1X7171$

$= 3586$ m tons

Option II $C = \frac{B_0F}{Z}(1-e^{-Z}) \quad F = 0.35 \quad M = 1.0$

$= \frac{7171X0.35}{1.35}(1-e^{-1.35})$

$= 1377$ m tons

Option III $C = \frac{B_0F}{Z}(1-e^{-Z}) \quad F = 0.5 \quad M = 0.35$

$= \frac{7171X0.5}{0.85}(1-e^{-0.85})$

$= 2415$ m tons

Option IV $Y = 40\%\ \bar{B}$[1]

$=0.4X7171$

$= 2868$ m tons

A compromise T.A.C. would be approximately 2,500 m tons.

[1] For this calculation $\bar{B} = B_0$

Landings totalled 1,500 m tons in 1977 and 2,225 m tons in 1978. The Cartwright Channel has been fished first until catch rates drop as in 1977 or until the quota is taken as in 1978. Most effort in 1978 was directed in the Hopedale Channel in the second half of the season.

In December 1978, a commercial vessel fished the northern Hopedale Channel (Area 1, Fig. 17) at a variety of depths and maintained good fishing rates. An estimate of biomass of 4,000 m tons (Table 5) compares with the survey estimate of 2,500 m tons in 1977 for similar strata. If the same proportions apply then an estimate of minimum trawable biomass in December 1978 would be 9000 m tons for the whole Hopedale Channel. This is considerably higher than the 7171 m tons indicated as a virgin biomass in 1977. It should be noted however, that estimates from commercial data can result in over-estimates of biomass. Commercial vessels concentrate effort in areas of shrimp abundance and considerable error could occur when extrapolating over the whole area. Nevertheless, as the possibility of an underestimate of virgin biomass is apparent, the higher option of T.A.C. should be considered.

Hawke Channel

General

Commercial fishing has been limited in the Hawke Channel and in 1978 only 0.8 m tons were reported from the area. The T.A.C. was set at 800 m tons. Before 1976 much of the exploratory work was done in this area but in 1977 and 1978 commercial vessels favoured the higher catch rates obtained in two more northerly channels.

In 1977 the M/V FREIDRICK BUSSE fished in the vicinity of 53°10'N, 53°45'W and obtained reasonable catch rates (Table 6). The M/V G.C. SUROIT fished 7.5 hours on October 6, 1978 and obtained a catch rate of approximately 110 kg per hour fished. This occurred during a period of low abundance for all areas. During the same period, the catch rate in the Hopedale Channel was as low as 100 kg per hour and in the Cartwright Channel as low as 200 kg per hour.

Research sampling in the area during 1978 (Fig. 18) confirmed low abundance levels in this area as well. Best concentrations occurred between 250 and 350 m. The shallow water concentrations exhibited in the northern Hopedale Channel (Fig. 15) did not occur in areas sampled. Most striking in this situation is the relatively high proportion of shrimp in the 16-17 mm mode. It is atypical from the other areas in that in strata of greatest shrimp concentration it forms the most prominent mode.

Biomass Estimates and Calculation of Total Allowable Catch

Stratification of the Hawke Channel (Fig. 19) has been facilitated by recent morphological surveys in the immediate area (Warren, 1976). Data collected by the A.T. CAMERON in 1975 gives reasonable coverage of the area

and these data have been applied to the stratification scheme as an indicator of possible levels of virgin biomass (Table 7). As no commercial catch has been reported for ICNAF Subarea 2 in 1975 there need be no further adjustment before calculations of T.A.C.

Option I $Y = 0.5\ MB_0$ $M = 1.0$

$= 0.5X1X5000$

$= 2500$ m tons

Option II $C = \frac{B_0F}{Z}(1-e^{-Z})$ $F = 0.35$ $M = 1.0$

$= \frac{5000x0.35}{1.35}(1-e^{-1.35})$

$= 960$ m tons

Option III $C = \frac{B_0F}{Z}(1-e^{-Z})$ $F = 0.5$ $M = 0.35$

$= \frac{5000x0.5}{0.85}(1-e^{-0.85})$

$= 1684$ m tons

Option IV $Y = 40\%\ B_0$

$= 0.4X5000$

$= 2000$ m tons

The compromise situation for the above options indicate a T.A.C. of approximately 1800 m tons by averaging the four results.

If this suggestion is carried forward to 1979 then it is understood that the stock has not experienced significant changes in abundance and that natural mortality and recruitment levels have been counteracting processes since that time.

Observations on by-catches and discarding

The small mesh gear used in shrimp fisheries is known to result in by-catches of various finfish species and quite often the younger year-classes of these. Cod, redfish and Greenland halibut are the major

commercially-valuable species caught as by-catch. Various others including eelpouts, wolffish, skate, arctic cod and Greenland sharks are taken as well in smaller quantities. The methods of handling the catch onboard these shrimp vessels does not afford easy estimation of by-catch. Observers have supplied some very rough estimates of by-catches and discarding practices.

Most finfish is discarded, however at least one vessel began processing some commercially valuable fish when shrimp catch rates were lowest. As a rule, these vessels are not equipped to handle quantities of groundfish.

Usually, less than 8% of the total catch is represented by all species of by-catch combined although Greenland halibut reached as high as 21% of the total catch in the Cartwright Channel in October. Individual sets, however, may produce considerable by-catch. During August in the Hopedale Channel 1000 kg of cod represented 37% of a total catch and in November 3000 kg of redfish and Greenland halibut comprised 49% of the weight of all species. Reports indicate that the incidence of Greenland sharks increased in the month of December in the Hopedale Channel. At least one occurred in most sets, the highest number reported being ten in one set.

Enumeration of small fish is very difficult under existing conditions. Juvenile Greenland halibut often occur as a by-catch but actual amounts have not been estimated.

A small amount of shrimp discarding does occur at sea. What little information is available suggests that around five per cent of the shrimp catch may be discarded on vessels using the shrimp sorter. This discard comprises very small and damaged shrimp. It can be reasonably assumed that the greater the by-catch the greater the amount of shrimp damage.

Discussions

Fishing Patterns

The Labrador shrimp fishery is characterized by catch rates with extreme day-to-day variations which suggest that:

(1) Shrimp concentrations are extremely sensitive to fishing pressure and that profitable catch rates can only be achieved by some shift in fishing efforts to areas of higher density. These shifts may be slight in the case of the Cartwright Channel or large as exhibited in the Hopedale Channel.

or

(2) Day-to-day extremes in catch rates may be a function of environmental stimuli such as light intensity.

or

(3) A combination of a number of factors including the above.

Whatever the reasons for these highly fluctuating catch rates, the situation indicates the need for intensive sampling when utilizing the swept-volume method. Increased sampling should help lower the variance used in these estimations and provide greater confidence in the results achieved.

Shrimp abundance throughout the season is obviously variable. Summer and winter months typically provide good catch rates while the intervening autumn months show a distinct decline in abundance. This situation implies two possible scenarios:

(1) Fishing activity has resulted in a wide dispersal of the resource.

or

(2) Environmental factors affect the seasonal abundance of shrimp.

A number of criteria support the second of these possibilities. Catch rates in the Hawke Channel, otherwise unfished in 1978, indicate low abundance levels at a time when exploited areas experienced the same condition. In 1977 vessels displaced from the Cartwright Channel because of low catch rates made periodic returns to the area only to find that abundance was still low despite the removal of fishing effort. Indications are that catch rates improve towards the end of the season, regardless of fishing activity. Smidt (1976) states that the largest diel vertical migration occurs in autumn when variation in light intensity is maximal. Light conditions in the Labrador are somewhat comparable to those of the Davis Strait. Extreme vertical migrations would tend to decrease daily catch rates in a bottom trawl fishery. Concentrations in shallow water of the Hopedale Channel in 1978 may suggest this type of migration or indicate the level of temporary pelagic existence. No information is available to suggest that shrimp at this time are dispersed vertically in the water column. In fact, temperature barriers should discourage this (see section below).

Nothing is known of shrimp distribution throughout the winter and spring. Vessels begin to abandon fishing in late November when weather conditions are harsh. Consequently, no catch and effort data are available from January to June. Any vessel with the capability to fish the resource in non-traditional months should be encouraged to do so, temporarily, at least. The observer programme initiated in 1978 should be continued in 1979.

Interpretation of Length Frequency Data

Length frequencies for both commercial and research data for 1977 and 1978 indicate that shrimp in all areas of the Labrador possibly comprise one stock. Since the channels or troughs are geographically isolated, it is reasonable to treat the areas as separate units for management purposes as fishing dynamics differ in each area. The similarity of modal groups would also tend to suggest that the population in all areas may result from a common spawning stock in either Hopedale Channel or areas north.

Distribution of length in all areas show varying signs of the appearance of the 16-17 mm length group. With limited data available for comparison between 1977 and 1978, it is difficult to predict what this indicated recruitment will mean in 1979. It has been pointed out that the time period compared between years for the Cartwright Channel indicates

levels of commercial significance. In the Hopedale Channel levels are not as clear but in the Hawke Channel research data indicate this mode is dominant in zones of highest concentration. It is apparent also from comparison of length frequencies from research data with those of commercial landings that the selectivities of the two trawls used does not differ much despite small mesh throughout the research trawl and a cod end liner.

At a glance, the day-night comparisons of shrimp catches seems confusing certainly during the period of low abundance. Data presented here infer that the per cent of ovigerous females in the catch may not always follow the expected rule even though catch rates during the day may be higher. It is also suggested that catch rates during daylight hours are by no means invariably higher than those obtained at night.

As the ageing technique has not yet been refined no attempt has been made in this analysis to determine age structure of the stock.

Environmental Indicators

The effect of temperature on shrimp populations has been accepted as an important controlling factor. This concept was discussed by the Invertebrates and Marine Plants Subcommittee, and the concern that 'stocks' of shrimp in the Labrador Sea may not exist in the steady state is a real one, and although it is difficult to demonstrate long-term trends in environmental conditions in these areas it is possible to develop some concept of the short-term.

Figures 20, 21 and 22 present the limited hydrographic data available for these areas. Bottom temperatures in the Hopedale Channel show little change between 1977 and 1978. There is an absence of 4°C water in 1978 and the 3°C Isotherm is somewhat deeper. Bottom temperatures between 2.5 and 3°C have been characteristic of the Cartwright Channel in 1977 and 1978. Again in 1978, 4°C water is not evident and the 3° isotherm is much deeper. Figure 22 shows thermographic profiles during the period 1973 to 1978 for the Hawke Channel. The years 1973 and 1978 appear the coldest although depth comparisons are not ideal. It would appear from length frequencies obtained in 1977 that many of the shrimp in the larger size group were hatched in 1973 or earlier. A recent research survey to shrimp grounds in the Davis Strait produced its largest catch (479 kg/30 min) in 2.8°C (Fig. 23) a temperature comparable to areas of commercial concentration in the Labrador area.

Temperature data from research surveys in 1977 and 1978 would indicate better conditions for dispersal in the earlier year with 3 and 4°C water in abundance. In fact, the opposite occurred. Shrimp distribution was widespread in 1978 at a time when temperature would seemingly favour concentration in deeper and warmer waters.

Haynes & Wigley (1969) suggests that temperature affects, among other things, the number of eggs produced by female shrimp. If the Labrador Channels are experiencing a cooling effect then this could be reflected in fecundity levels. Egg counts and regression of fecundity on carapace length

are available from the Hawke Channel for 1974, 1975 and 1977 (Fig. 24). 1978 samples have not yet been analyzed. Analysis of covariance for available data (Table 8) suggests no significant difference in either the rate of egg production or the mean number of eggs produced at acceptable levels of testing.

There is no available evidence to indicate a definite cooling trend in the Labrador areas, at least in the short-term. However, we need only to look at the experience of other shrimp fisheries to appreciate the abruptness of imminent collapse. Constant monitoring of such a sensitive environment relationship is imperative if we wish to avoid or simply detect approaching disaster.

Effort Limitation

The implementation of total allowable catches for an area supplies a reference point from which the effort to obtain that catch can be calculated. Table 9 indicates the number of vessel days required to catch the suggested quota for each Channel. This exercise assumes that the average shrimp trawler can fish at least 100 days during a six month season. It also assumes that the daily catch rate observed over the 1978 season will closely approximate the 1979 level. Catch per day for the Hawke Channel (Table 6) is calculated from six days of fishing by the M/V FREIDRICK BUSSE in August 1977, the only available data. Vessel days indicated are 394.79 for the Hopedale Channel, 195.22 for the Cartwright Channel using the higher T.AC. of 1400 m tons or 111.56 days using the lower T.A.C. of 800 m tons and 294.44 for the Hawke Channel (Table 9). The total vessel days for all areas is estimated at 884.45 for the higher total and 800.79 for the lower. Allowing 100 days per vessel, this would imply that 8 to 9 vessels could take the suggested T.A.C.'s in 1979. If, in reality, the catch rate in the Hawke Channel is lower, additional days would be added.

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Table 1. CPUE (wt. per hour fished) 1977-78. All vessels

	1977					1978				
Month	Catch (lbs.)	Catch (kgs.)	Effort (Hrs.)	C/E (lbs.)	C/E (kgs.)	Catch (lbs.)	Catch (kgs.)	Effort (hrs.)	C/E (lbs.)	C/E (kgs.)
				Cartwright Channel						
July	634,130	287,640	406.0	1,562	708	343,500	155,811	325.0	1,057	479
Aug.	1,182,428	536,346	938.0	1,261	572	884,547	401,228	630.8	1,402	636
Sept.	567,247	257,302	593.5	956	434	1,575,443	714,616	1,788.7	881	400
Oct.	31,696	14,377	79.3	400	181	216,210	98,072	401.7	538	244
Nov.	163,022	73,946	105.7	1,542	700	-	-	-	-	-
Dec.	21,275	9,650	21.5	990	449	-	-	-	-	-
Total[1]	2,599,798	1,179,261	2,144.0	1,213	550	3,019,700	1,369,727	3,146.2	960	435
Total[2]	2,354,513	1,068,000	2,144.0	1,098	498	3,115,100	1,413,000	3,146.2	990	449
				Hopedale Channel						
July	-	-	-	-	-	304,945	138,322	179.0	1,704	773
Aug.	241,408	109,502	179.3	1,346	611	203,037	92,097	168.5	1,205	547
Sept.	560,868	254,408	436.8	1,284	582	153,451	69,605	214.2	716	325
Oct.	1,059,559	480,613	1,419.6	746	339	1,613,099	731,697	1,465.9	1,100	499
Nov.	1,449,700	657,580	929.5	1,560	707	1,882,627	853,954	1,643.5	1,145	520
Dec.	-	-	-	-	-	748,080	339,327	401.0	1,866	846
Total[1]	3,311,535	1,502,102	2,965.2	1,117	507	4,905,239	2,225,002	4,072.1	1,205	546
Total[2]	3,417,130	1,550,000	2,965.2	1,152	523	4,071,896	1,847,000	4,072.1	1,000	454

[1] Based on catches from vessel logs.
[2] Based on statistics from landings.

Table 2. Minimum Trawlable Biomass - Research Data

Cartwright Channel

Stratum	Depth M	Depth FMS	Sq. Naut. Mi. Area	1977 Biomass (m. tons)	No. Sets	1978 Biomass (m. tons)	No. Sets
1	276-311	151-170	54.1			26	2
2	313-348	171-190	83.7	1747	3	51	3
3	349-384	191-210	31.0	449	2	23	2
4	385-421	211-230	34.2	282	1	49	5
5	422-457	231-250	36.5	310	1	62	4
6	459-494	251-270	59.7	23	1	412	7
7	496-530	271-290	88.8			76	2
8	532-567	291-310	28.2			195	2
TOTAL			416.2	2811	8	894	27

Table 3. Minimum Trawlable Biomass - Commercial Data

Cartwright Channel August 1978

Stratum #	Effort Hrs	Catch kgs	Catch/Hr. kgs.	No. of Units	Biomass kgs
4	5.3	2,200	415.1	660.1	274,016
5	115.4	76,249	660.7	704.5	465,470
6	49.0	25,269	515.7	1,152.3	594,246
7	3.5	909	259.7	1,714.0	445,123
					1,778,855 kg.
					3,921,664 lbs.

Speed of Tow 3.5 knots
Sweep of Net 90 feet
1 unit = 0.051809 sq. N. mi.

Table 4. Minimum Trawlable Biomass - Research Data

Hopedale Channel

Stratum	Depth M	Depth FMS	Sq. Naut. Mi. Area	1977 Biomass m tons	No. of Sets	1978 Biomass m tons	No. of Sets
101	166-201	91-110	61.29			239	1
102	203-238	111-130	48.65			215	1
103	240-274	131-150	44.44			97	1
104	276-311	151-170	38.83	160	1	386	1
105	313-348	171-190	38.83	267	3	49	2
106	349-384	191-210	40.70	812	3	10	*
107	386-421	211-230	37.89	631	3	3	1
108	422-457	231-250	39.30	645	3	84	1
109	459-494	251-270	41.64			13	1
110	496-530	271-290	109.94			34	*
111	532-567	291-310	51.46			207	1
204	276-311	151-170	290.06	176	3	178	1
205	313-348	171-190	174.04	553	3	221	*
206	349-384	191-210	134.74	1161	2	34	2
207	386-421	211-230	94.97	731	4	12	1
208	422-457	231-250	147.84	63	2	115	2
209	459-494	251-270	161.87			37	3
210	496-530	271-290	167.95			52	4
211	532-567	291-310	168.42			28	2
212	569-603	311-330	163.27			45	1
305	313-348	171-190	30.41	232	1		
306	349-384	191-210	23.39	132	1		
307	386-421	211-230	18.71	59	1		
308	422-457	231-250	18.25	47	1		
TOTAL			2146.89	5669	31	2059	26

* Assumptions of homogeneity expanded to adjacent stratum.

Table 5. Minimum Trawlable Biomass - Commercial Data.

Hopedale Channel Zone 1, December 1978

Stratum #	Effort Hrs	Catch kgs	Catch/hr. kgs	No. of Units	Biomass kgs	
4	22.1	42,320	1,914.9	749.48	1,435,186	
5	19.5	15,900	815.4	749.48	611,126	
6	25.9	25,095	968.9	785.58	761,146	4,128,775
7	158.5	137,890	870.0	731.34	636,266	
8	56.1	50,665	903.1	758.56	685,051	
9	71.0	42,640	600.6	803.72	482,715	
10	44.0	28,945	657.8	2,122.03	1,395,868	
				TOTAL	6,007,358 kgs	
					13,243,821 lbs	

Speed of Tow 3.5 knots
Sweep of Net 90 feet
1 unit = 0.051809 sq. mi.

Table 6. Catch per unit effort Hawke Channel 1977

M/V FREIDRICK BUSSE

Date	No. of Sets	Depth m	Hours Fished	Shrimp Catch kgs	Catch/hr. kgs	Catch/hr. lbs
20/8/77	3	400-487	6.8	968	142	313
21/8/77	6	380-500	14.7	8,295	566	1,248
22/8/77	7	405-440	18.6	8,866	477	1,052
23/8/77	8	405-440	16.7	10,001	601	1,325
24/8/77	7	420-440	17.4	7,620	438	966
25/8/77	2	400-435	5.0	930	186	410
TOTAL	33	380-500	79.2	36,680	463	1,021

Table 7. Minimum Trawlable Biomass - Research Data

Hawke Channel Sept. 14 - Oct. 1, 1975

Stratum No.	Depth		Area Sq. Naut. Miles	No. of Sets	Biomass (m tons)
	M	FMS			
4	301-340	165-186	92.5	1	219
5	341-380	187-208	326.5	8	1,994
6	381-420	209-229	277.4	3	1,283
7	421-460	230-252	143.4	3	567
8	461-500	253-273	375.5	4	460
9	501-540	274-295	354.7	2	373
10	541-580	296-317	203.8	4	103
TOTAL			1,773.8	25	4,999

Table 8. Shrimp comparison of fecundity against length, Hawke Channel 1974 - 1977.

Analysis of Covariance

	DF	Sum of squares	Mean square
Within	58.	0.24181528D+07	0.41692290D+05
Reg Coef	2.	0.28770279D+05	0.14385139D+05
Common	60.	0.24469231D+07	0.40782051D+05
Adj Means	2.	0.17934290D+06	0.89671448D+05
Total	62.	0.26262660D+07	

Comparison of slopes.F # 0.35
Probability of random occurance # 0.715

Comparison of adjusted means, F # 2.20
Probability of random occurence # 0.118

Table 9. Calculation of effort limits for the Labrador area.

Area	Days Fished 1978	Shrimp Catch Kg 1978	Catch per Day Kg. 1978	Suggested T.A.C. 1979	No. of vessel days 1979
Hopedale Channel	244	2,225,002	9,118.86	3600	394.79
Cartwright Channel	191	1,369,727	7,171.35	1400	195.22
				800	111.56
Hawke Channel [1]	6	36,680	6,113.33	1800	294.44
					884.45 TOTAL
					800.79[2]

[1] Catch per day calculated using 1977 commercial data.

[2] Total using the lower T.A.C. level for the Cartwright Channel.

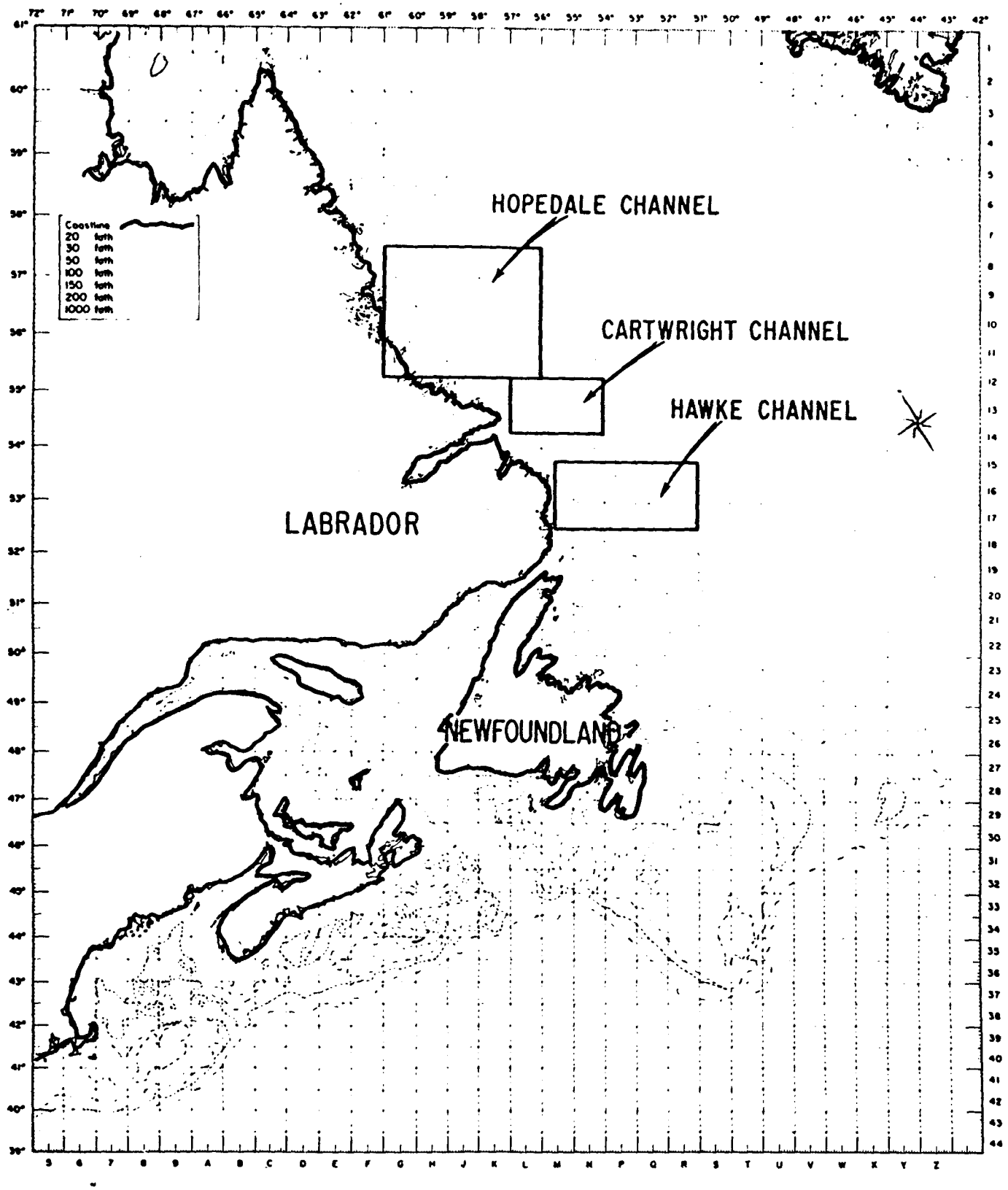

Fig. 1. Chart showing the principal shrimp fishing grounds in the Labrador area. (From Sandeman, 1978)

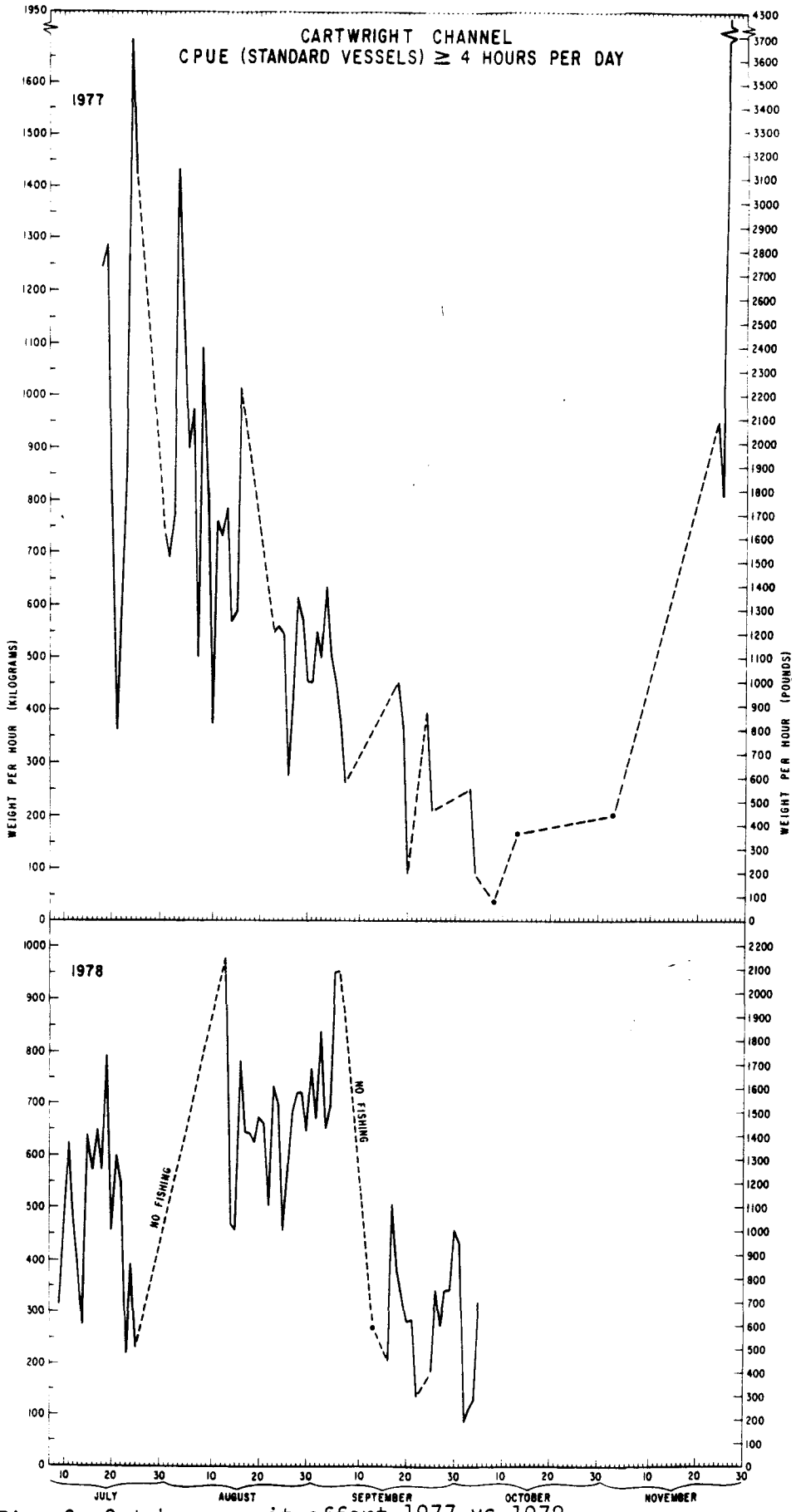

Fig. 2 Catch per unit effort 1977 vs 1978

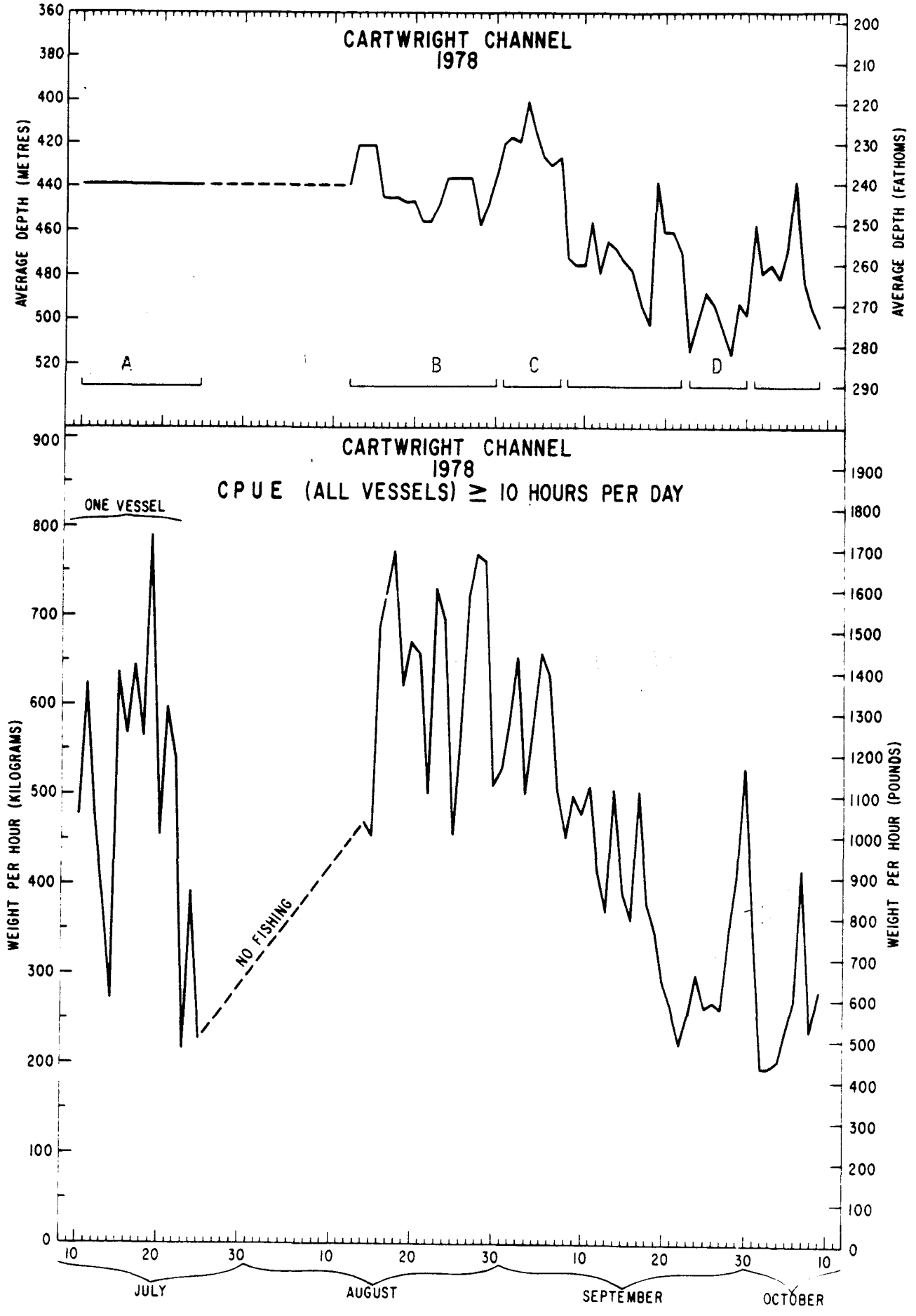

Fig. 3. Catch per unit effort and depths fished, 1978. A - D refer to periods for which length frequencies are available.

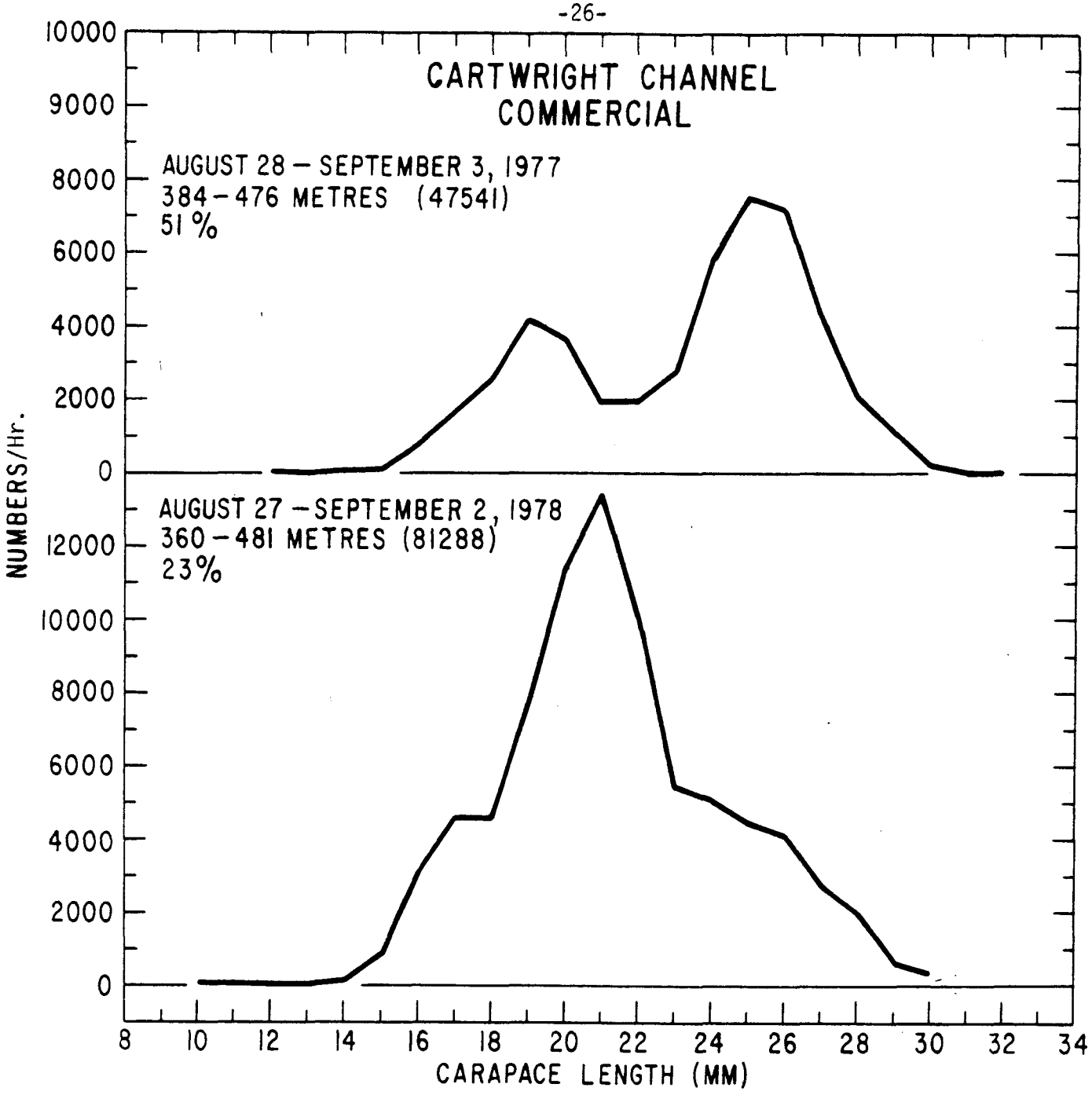

Fig. 4. Comparison of length distributions 1977 and 1978 (number caught per hour). % ovigerous indicated.

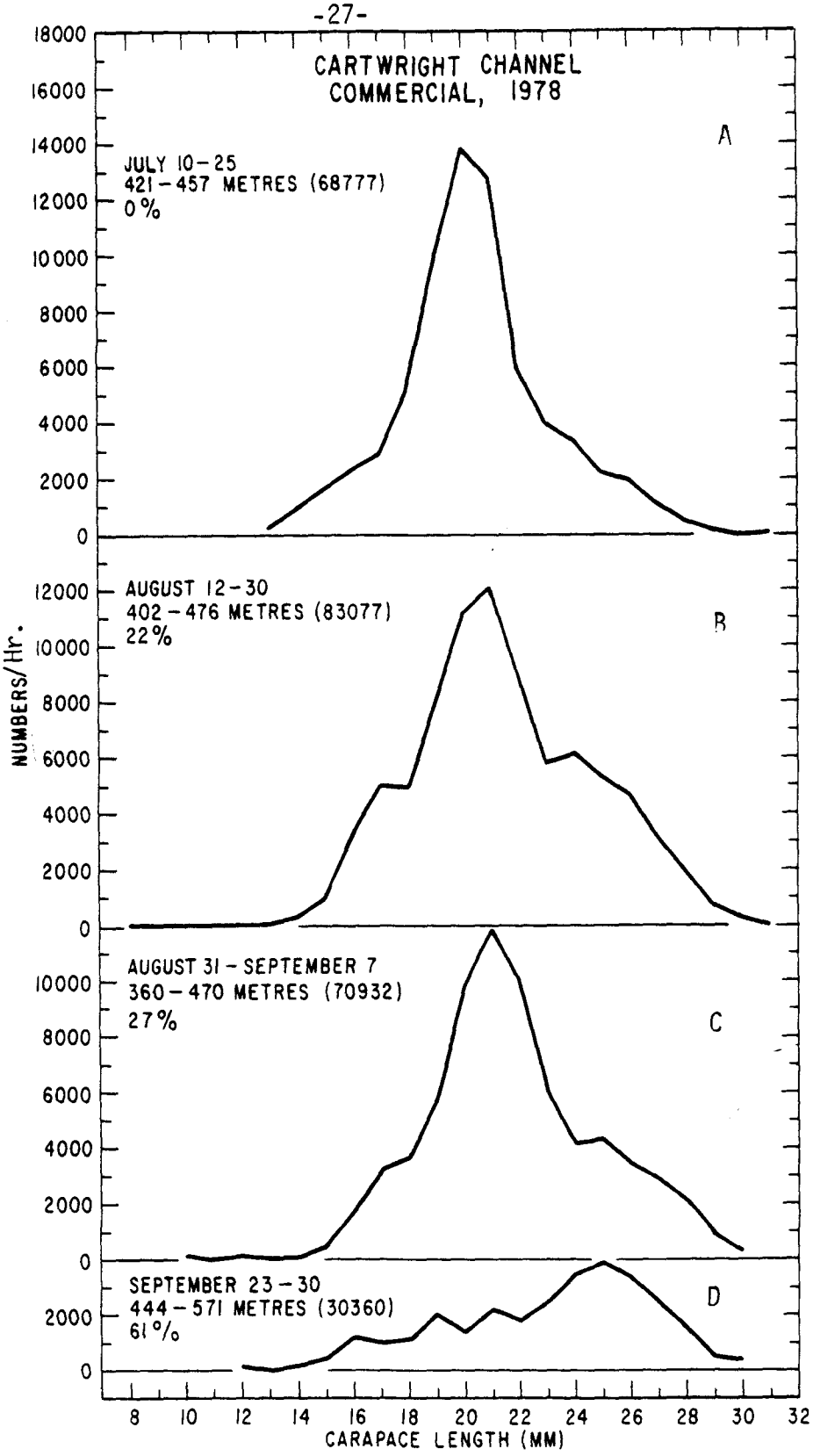

Fig. 5. Commercial length frequencies 1978 (number caught per hour). Letters A - D denote time intervals indicated in Fig. 3.

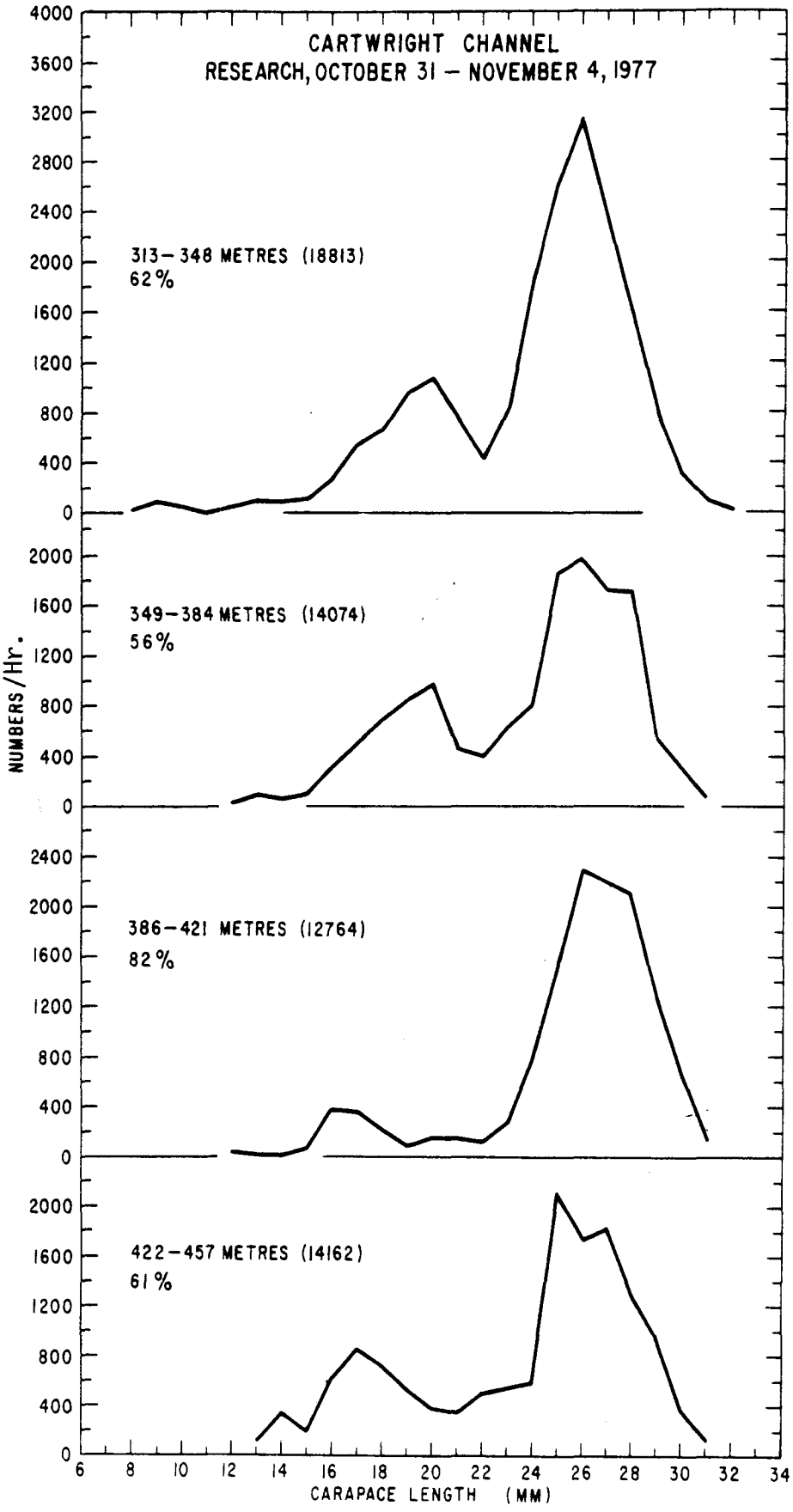

Fig. 6. Research length frequencies, 1977 (number caught per hour). % ovigerous indicated.

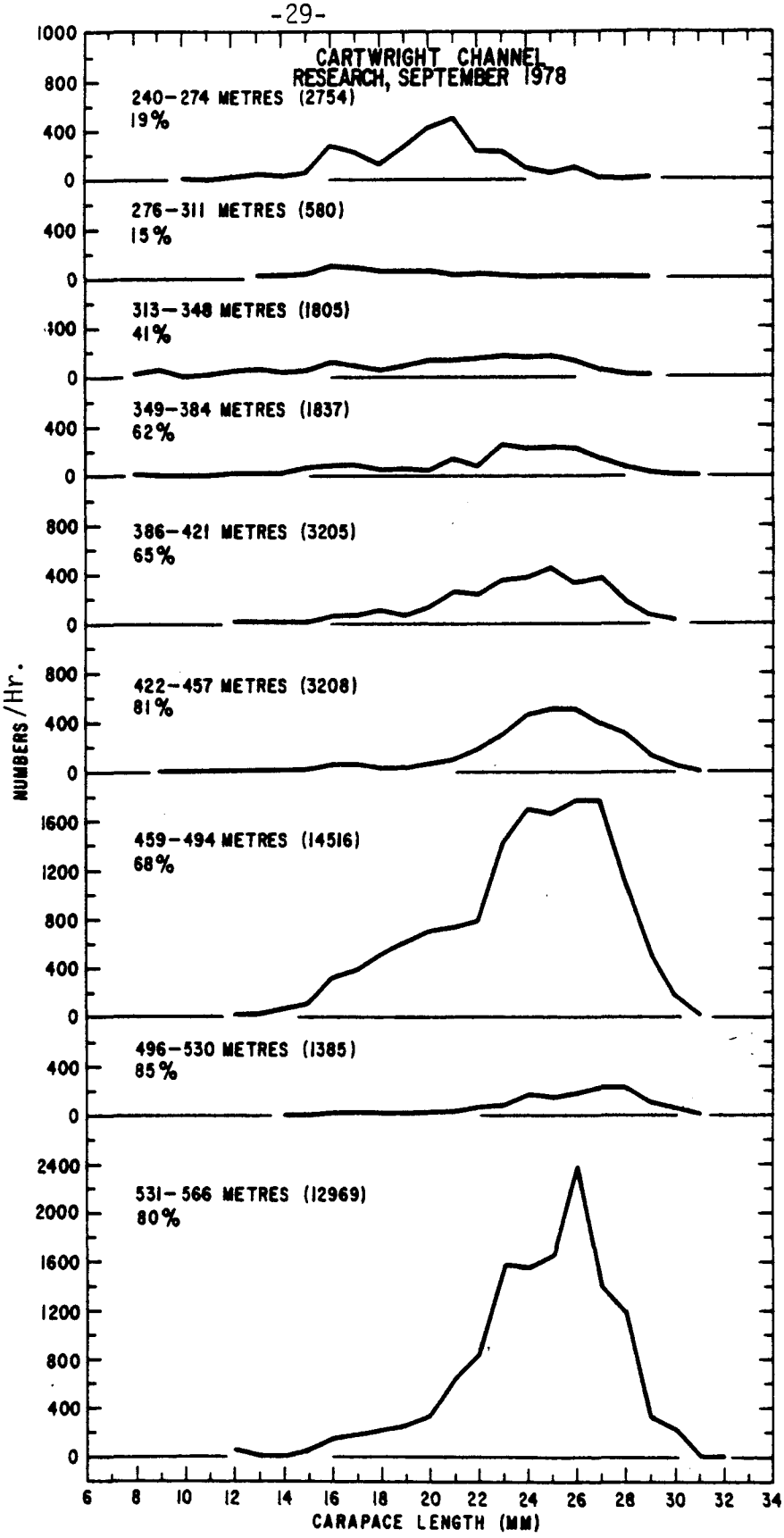

Fig. 7. Research length frequencies, 1978 (Number caught per hour).

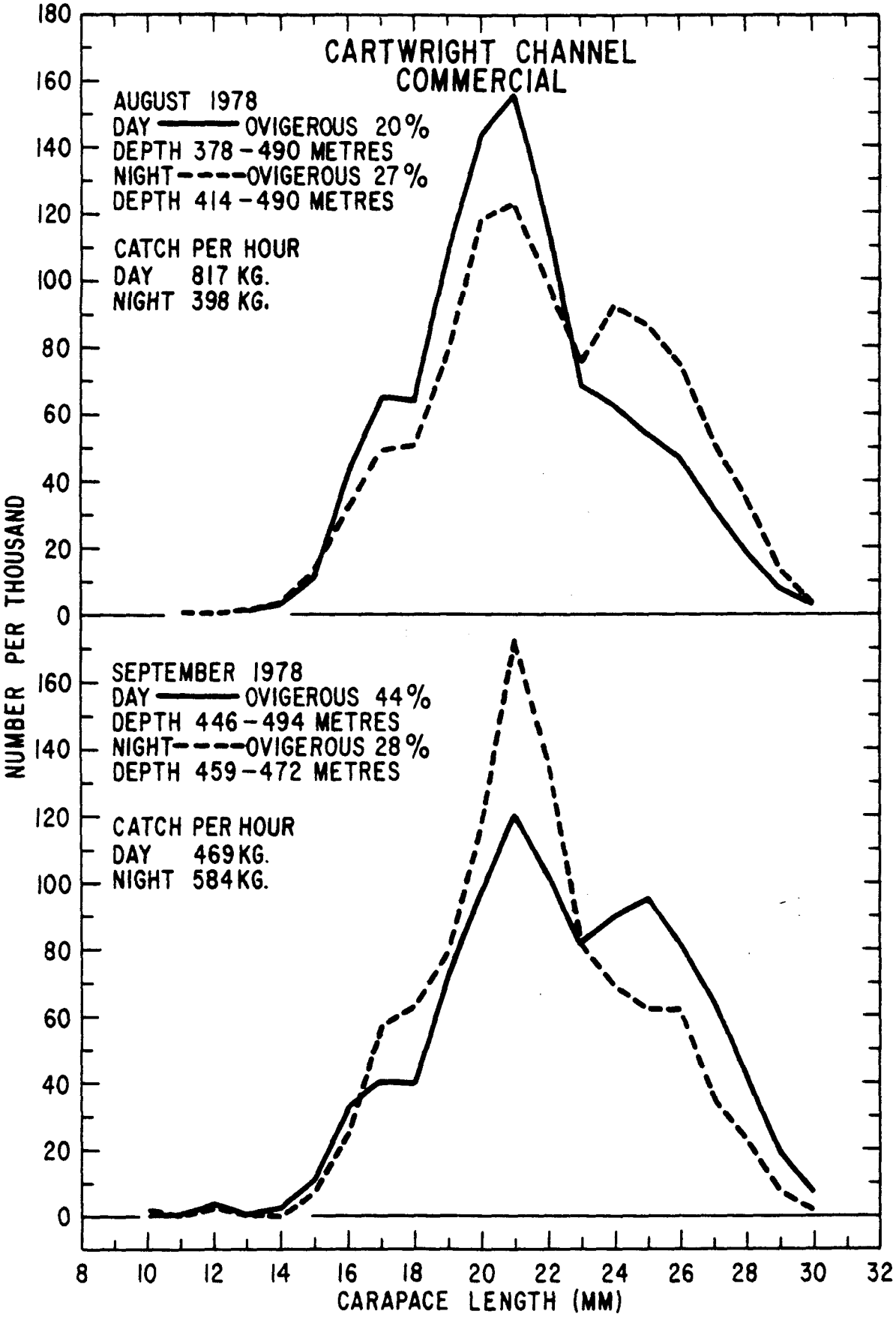

Fig. 8. Day - night comparison, 1978.

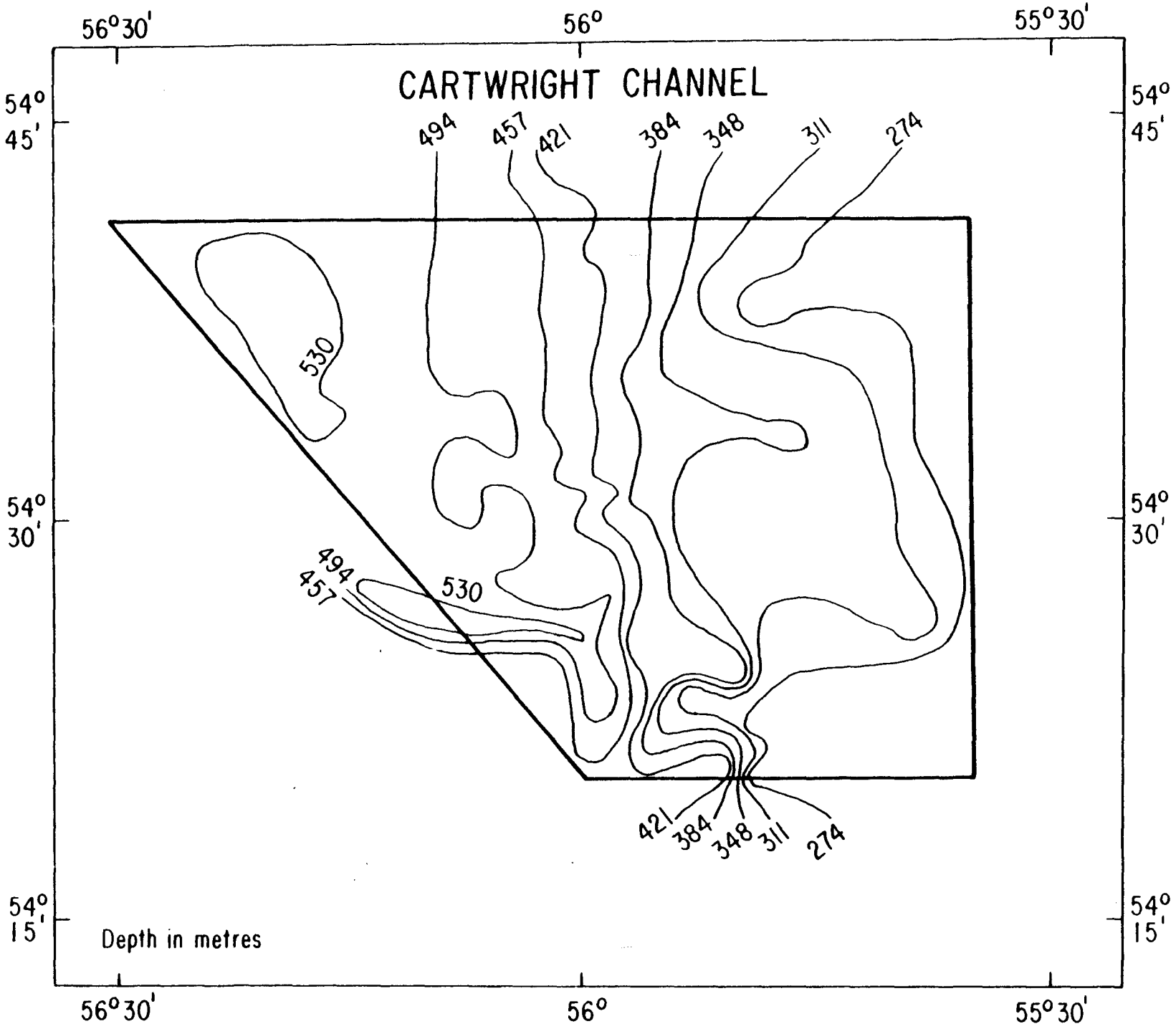

Fig. 9. Stratification of the Cartwright Channel.

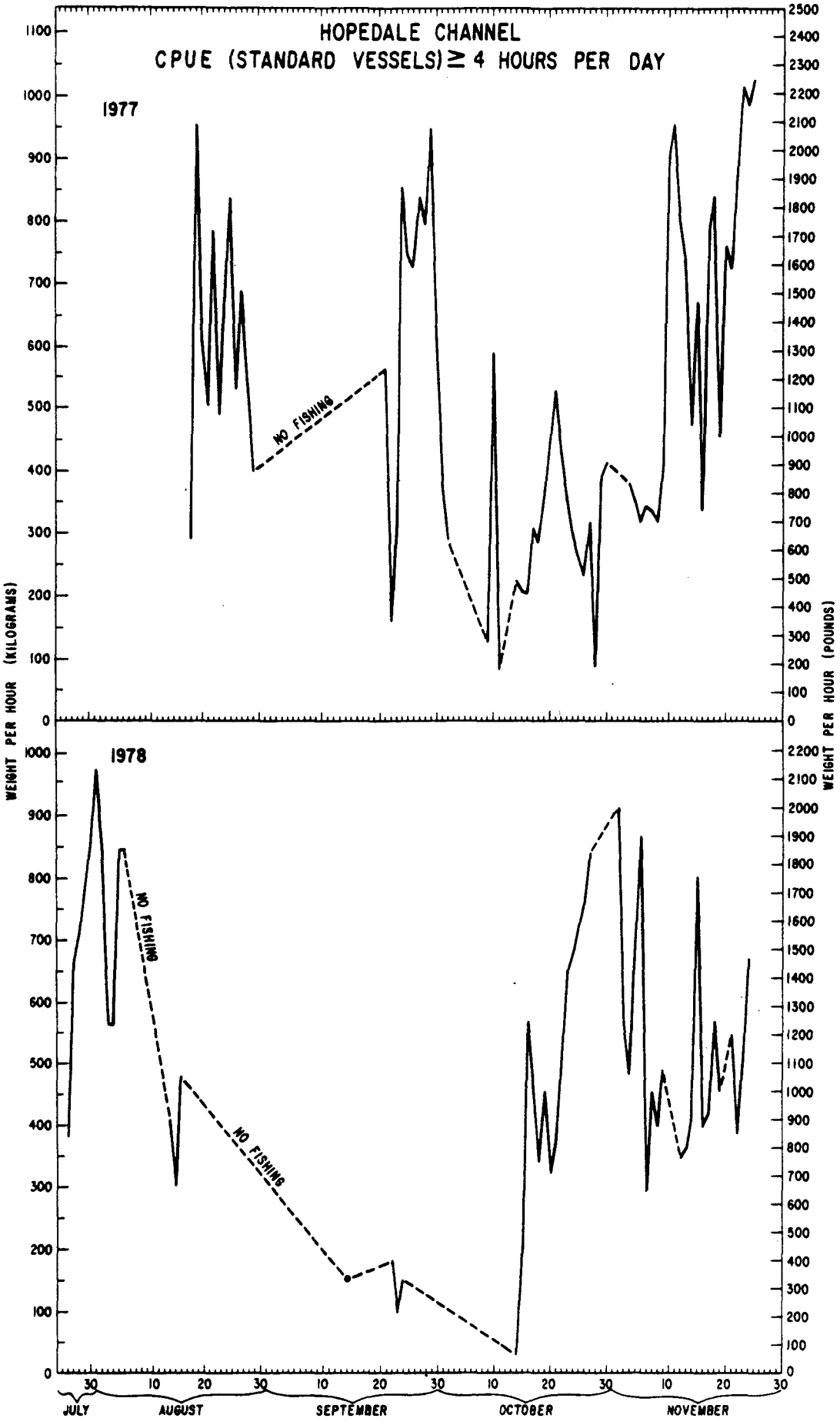

Fig. 10. Catch per unit effort 1977 vs 1978.

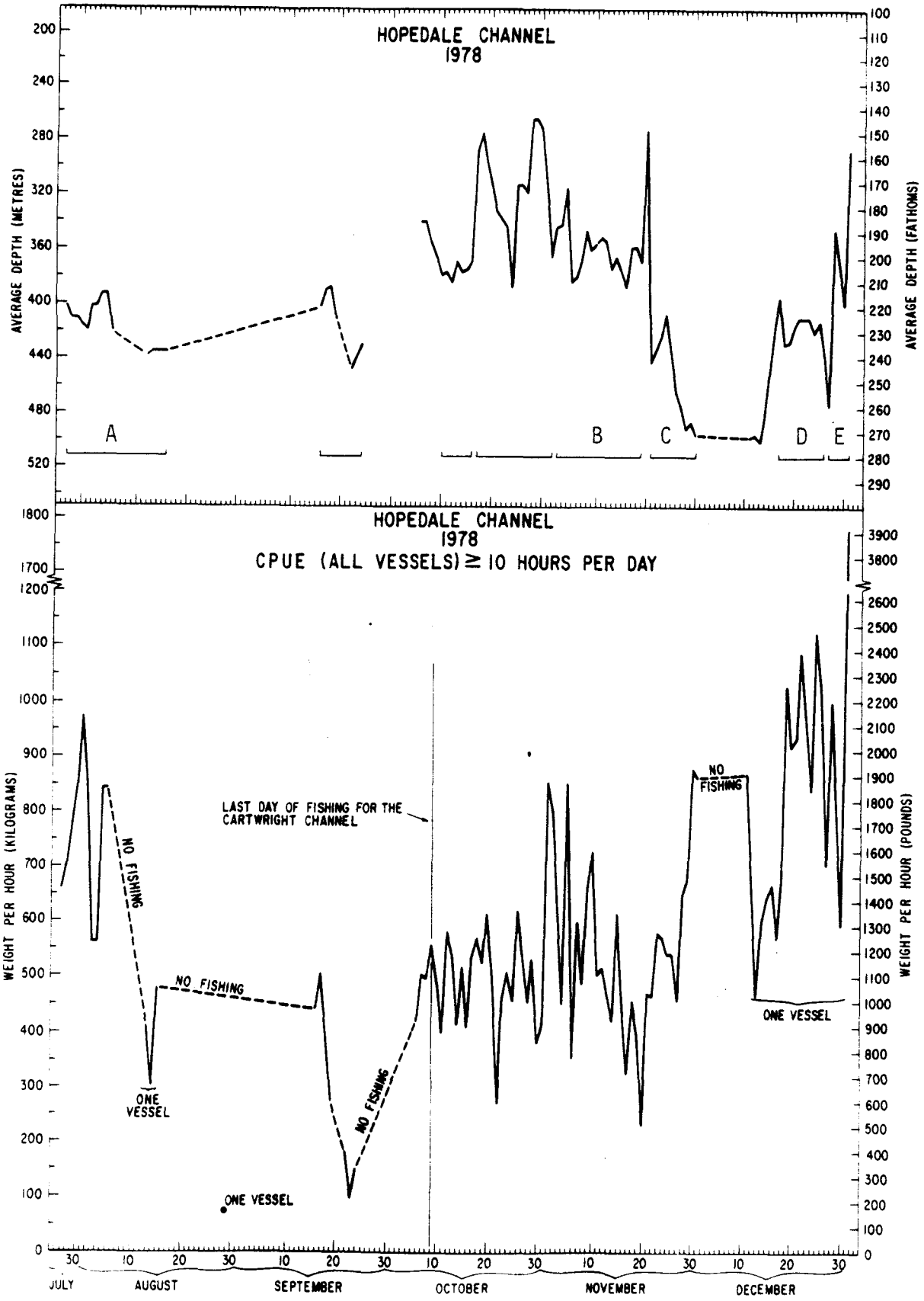

Fig. 11. Catch per unit effort and depths fished, 1978. A - E refer to period for which length frequencies are available.

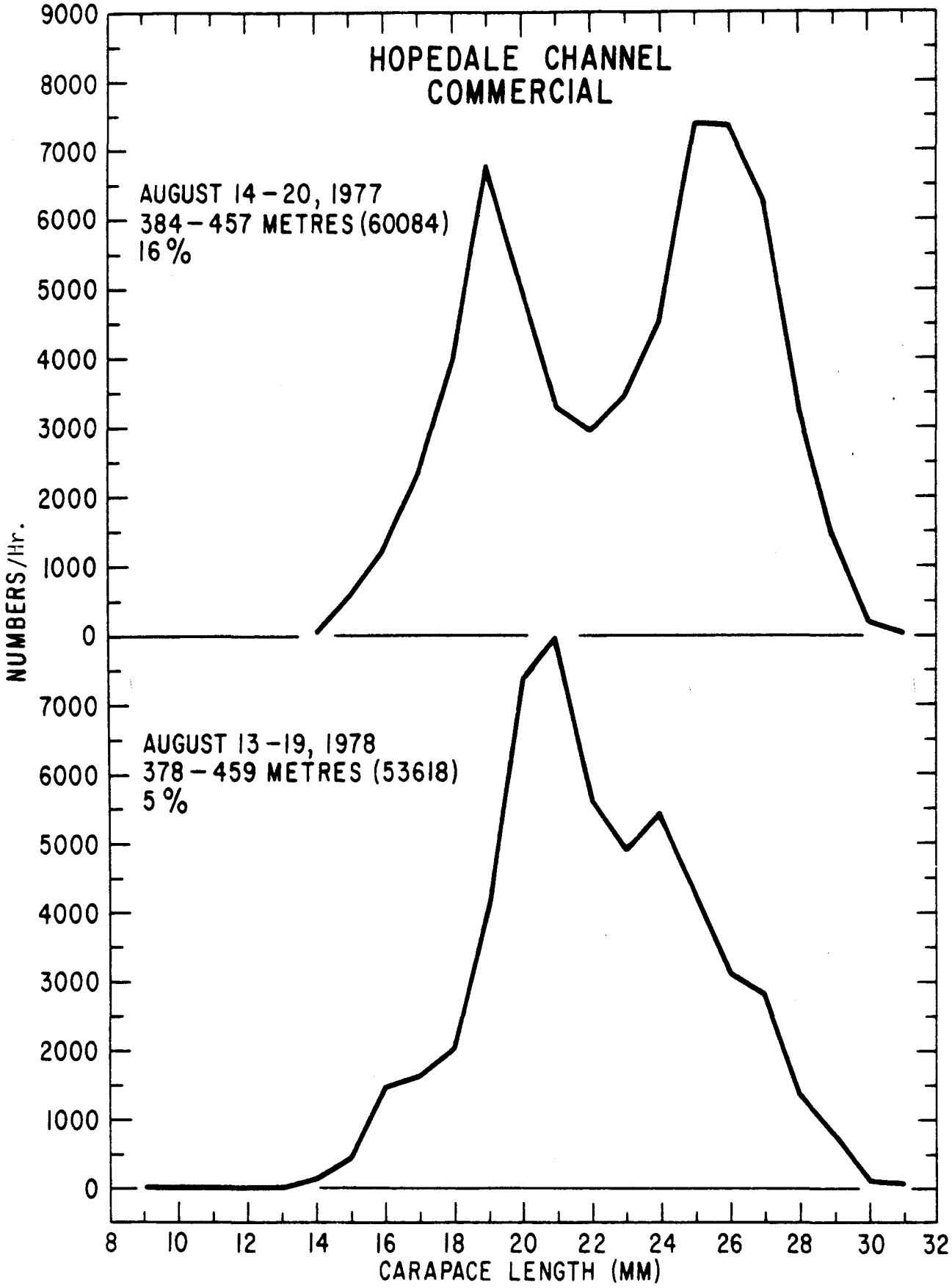

Fig. 12. Comparison of length distribution 1977 and 1978 (number caught per hour). % ovigerous indicated.

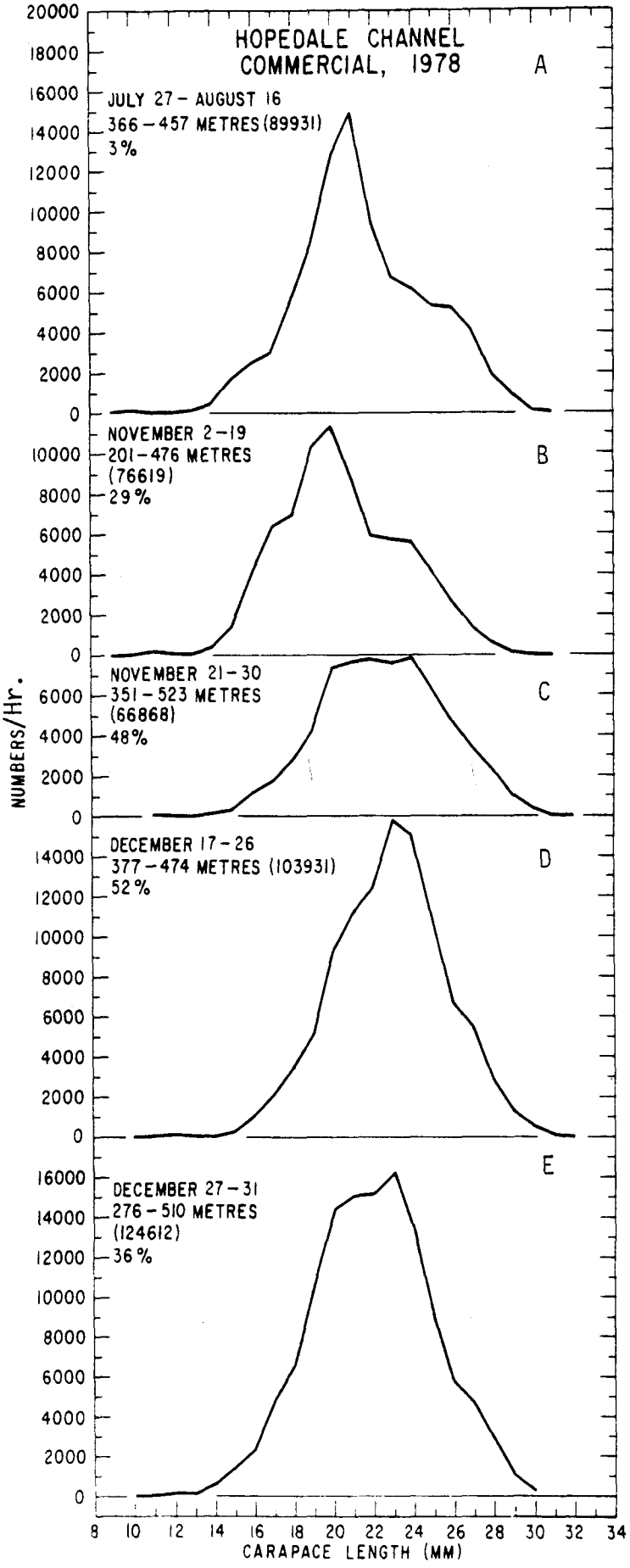

Fig. 13. Commercial length frequencies 1978 (number caught per hour). Letters A - E denote time intervals indicated in Fig. 11.

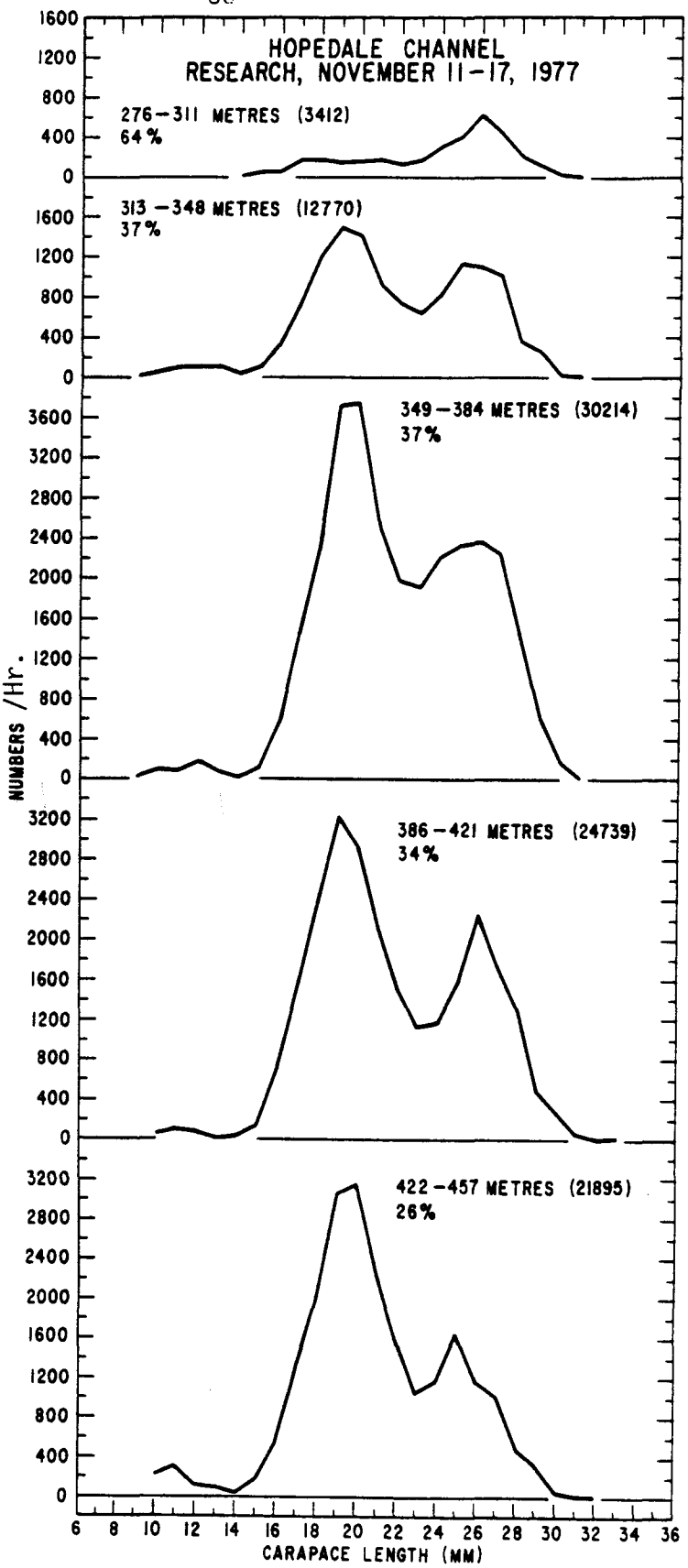

Fig. 14. Research length frequencies, 1977 (number caught per hour). % origerous indicated.

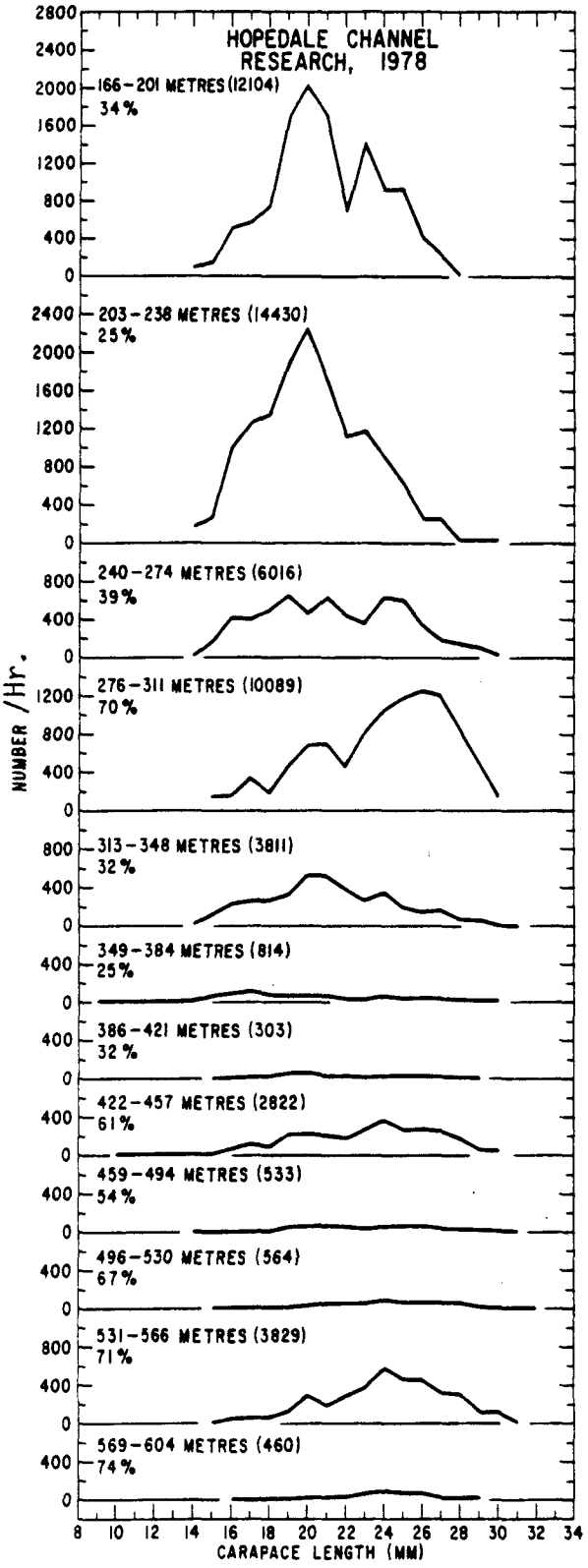

Fig. 15. Research length frequencies, 1978 (number caught per hour). % origerous indicated.

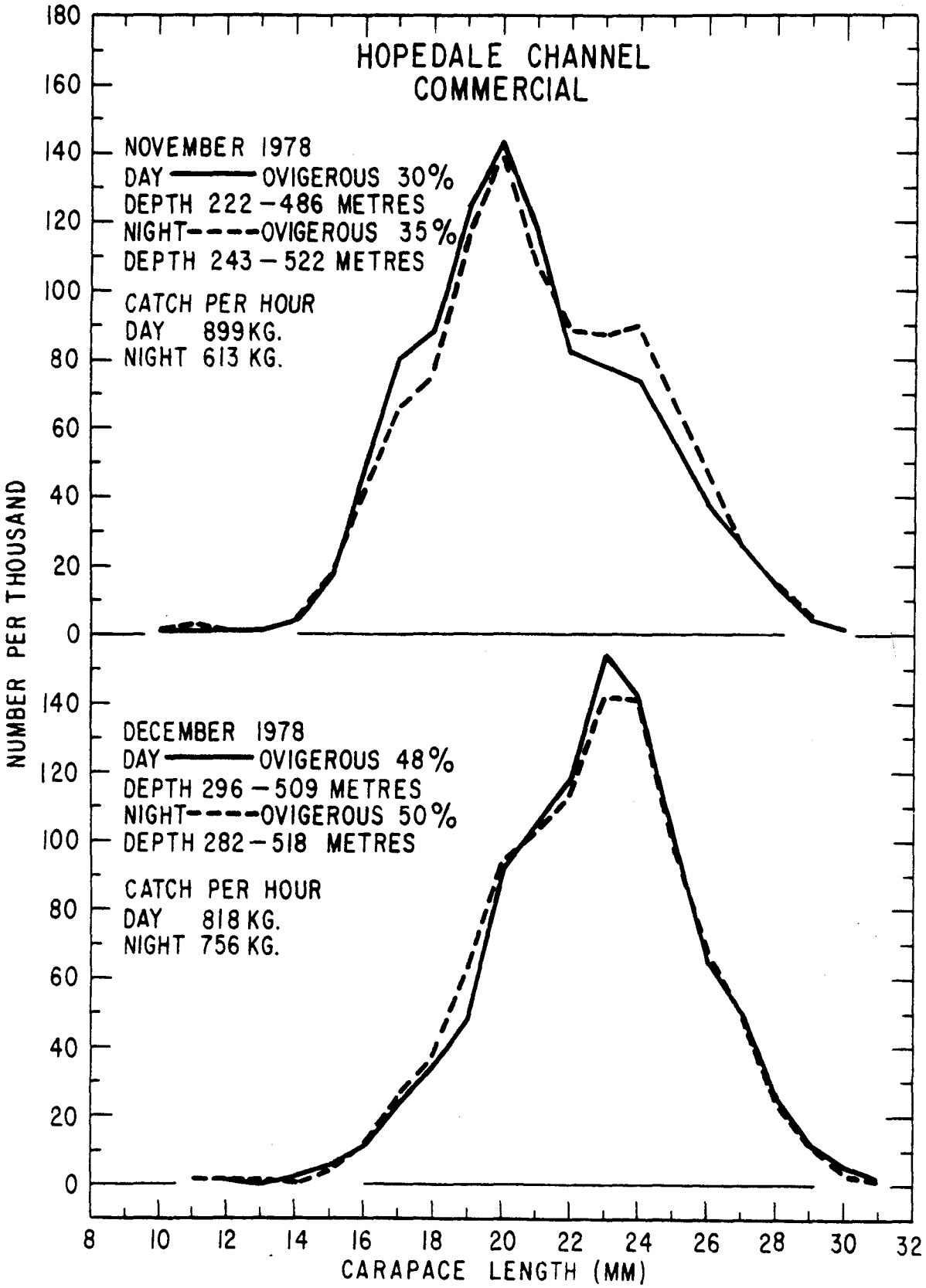

Fig. 16. Day-night comparison, 1978.

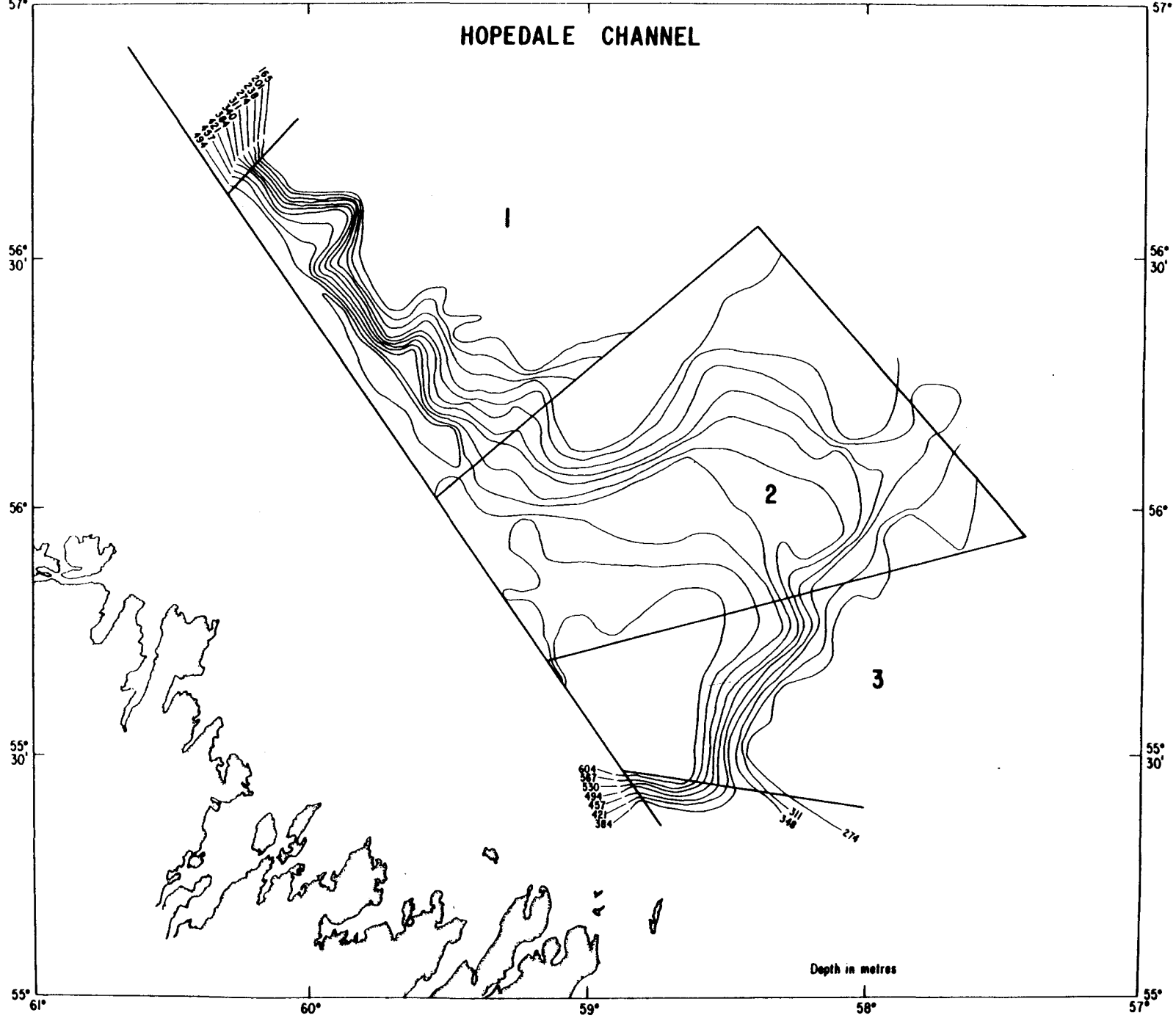

Fig. 17. Stratification of the Hopedale Channel.

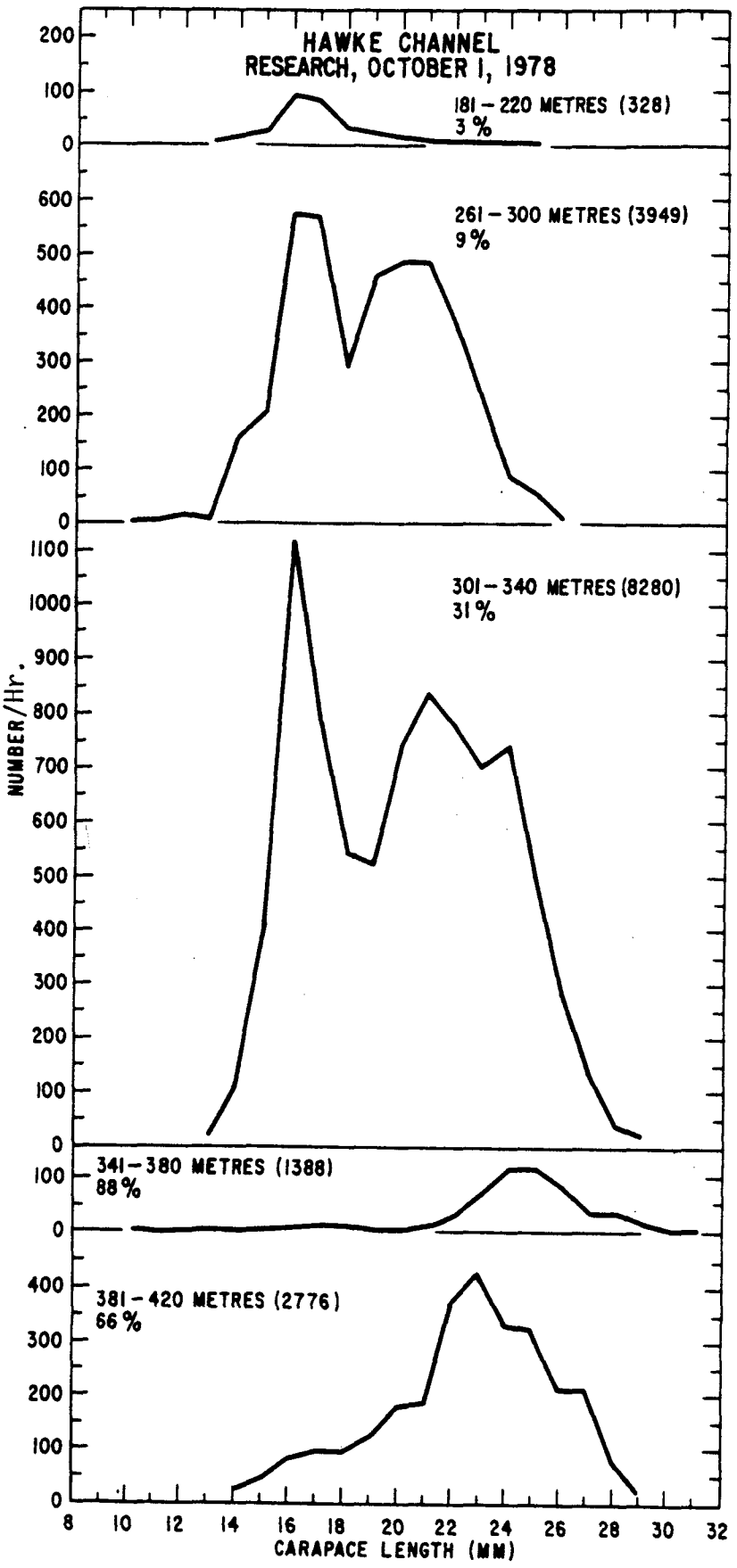

Fig. 18. Research length frequencies 1978 (number caught per hour). % origerous indicated.

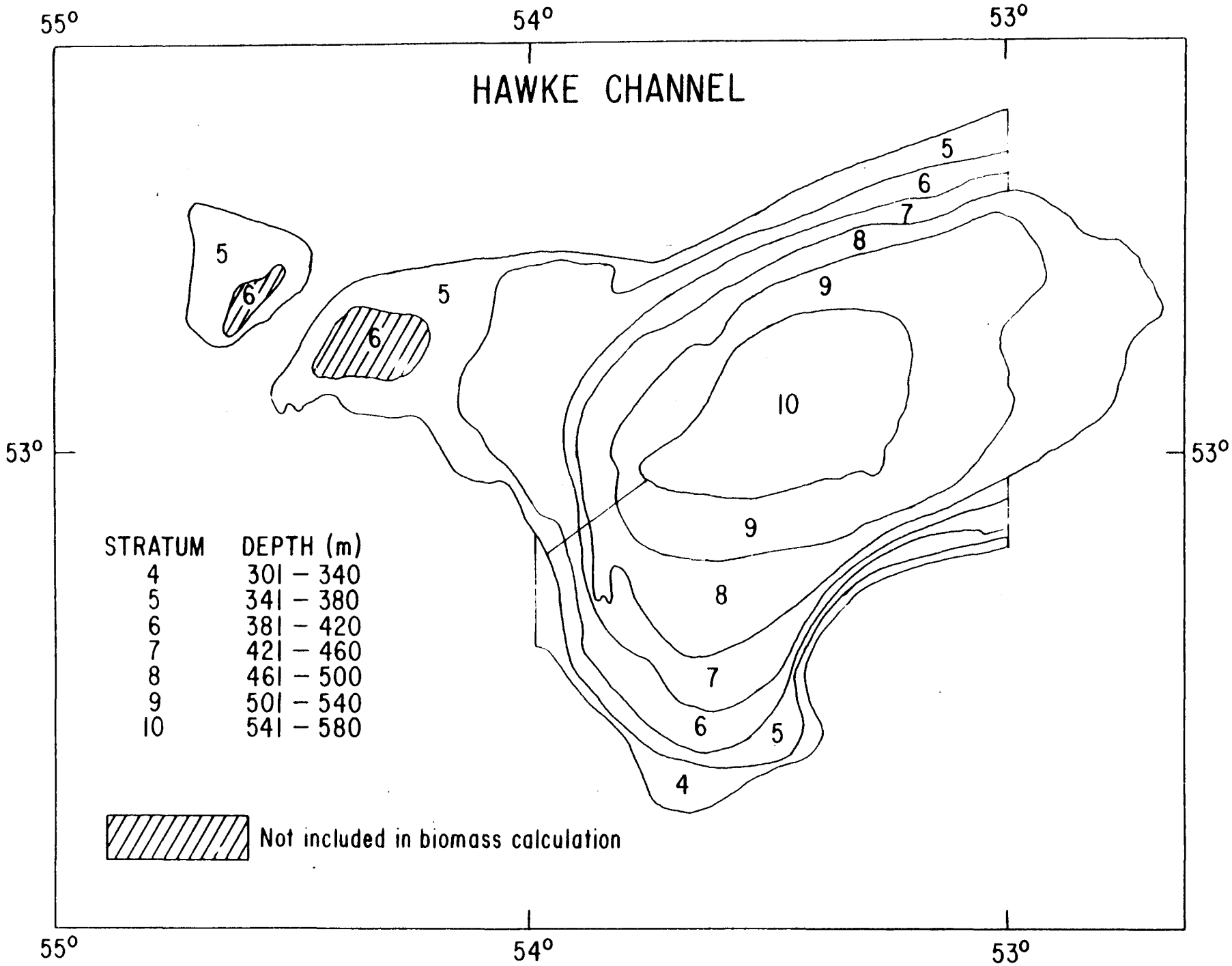

Fig. 19. Stratification of the Hawke Channel.

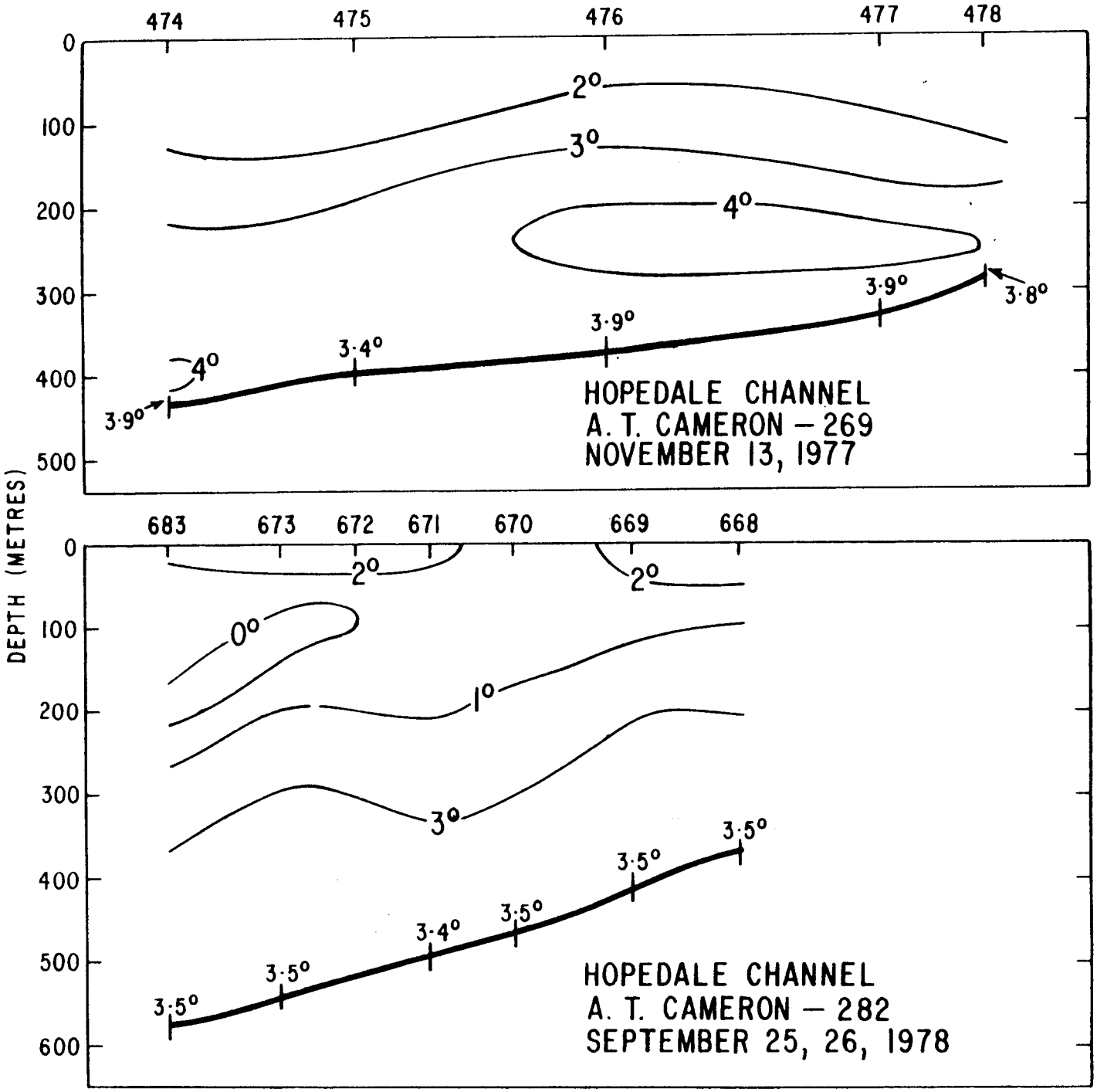

Fig. 20. Hydrographic sections Hopedale Channel 1977-1978.

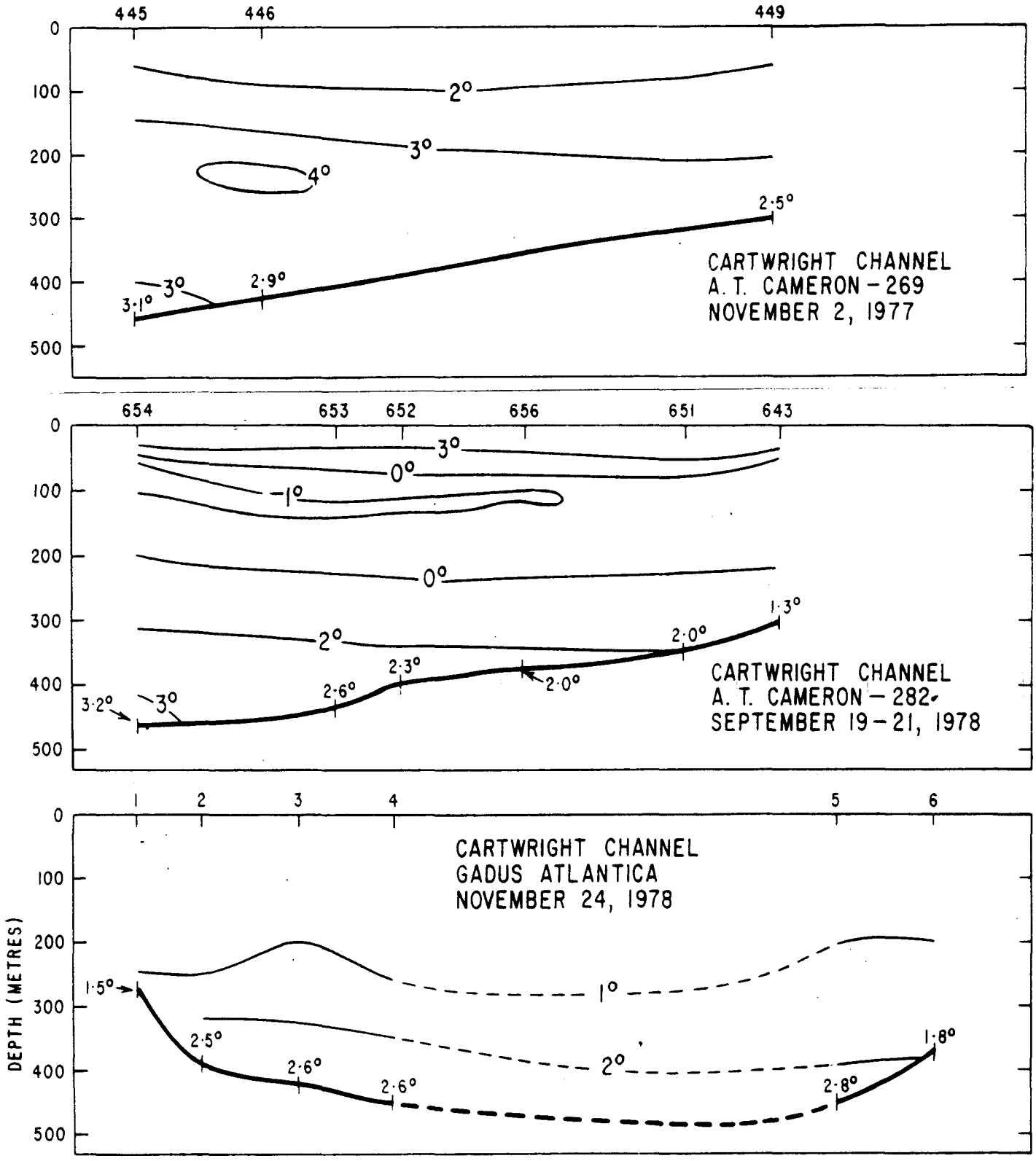

Fig. 21. Hydrographic sections Cartwright Channel 1977-1978.

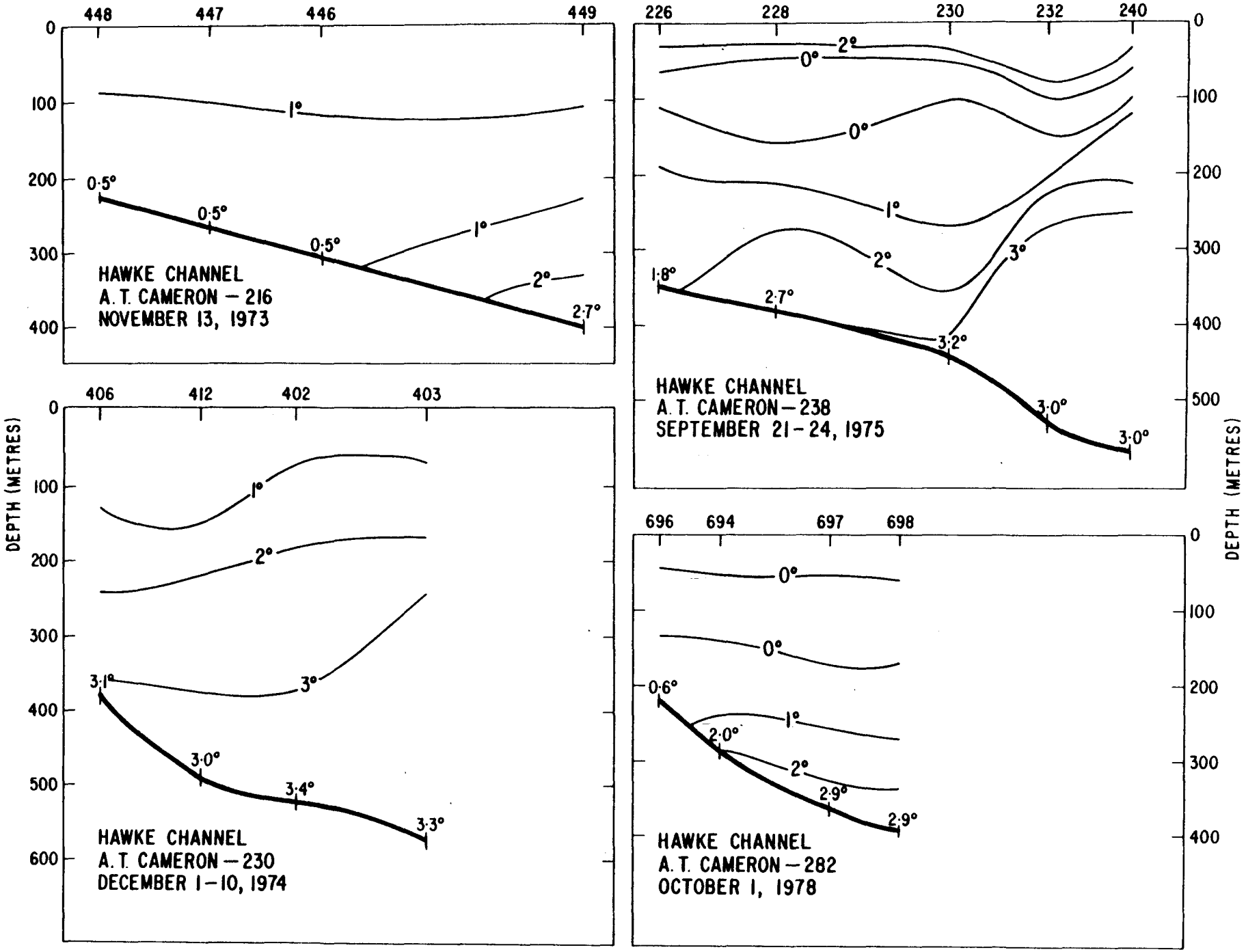

Fig. 22. Hydrographic sections Hawke Channel 1973-1978.

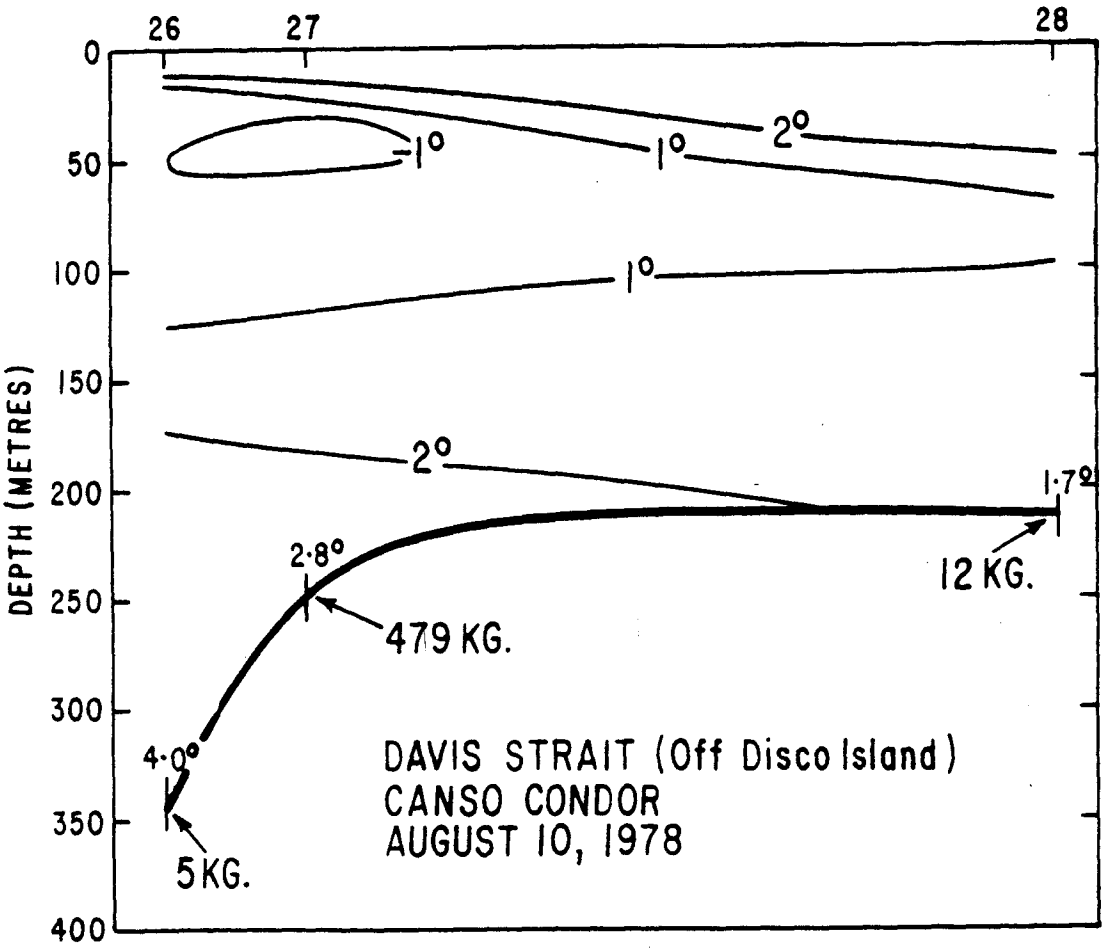

Fig. 23. Hydrographic Section Davis Strait 1978.

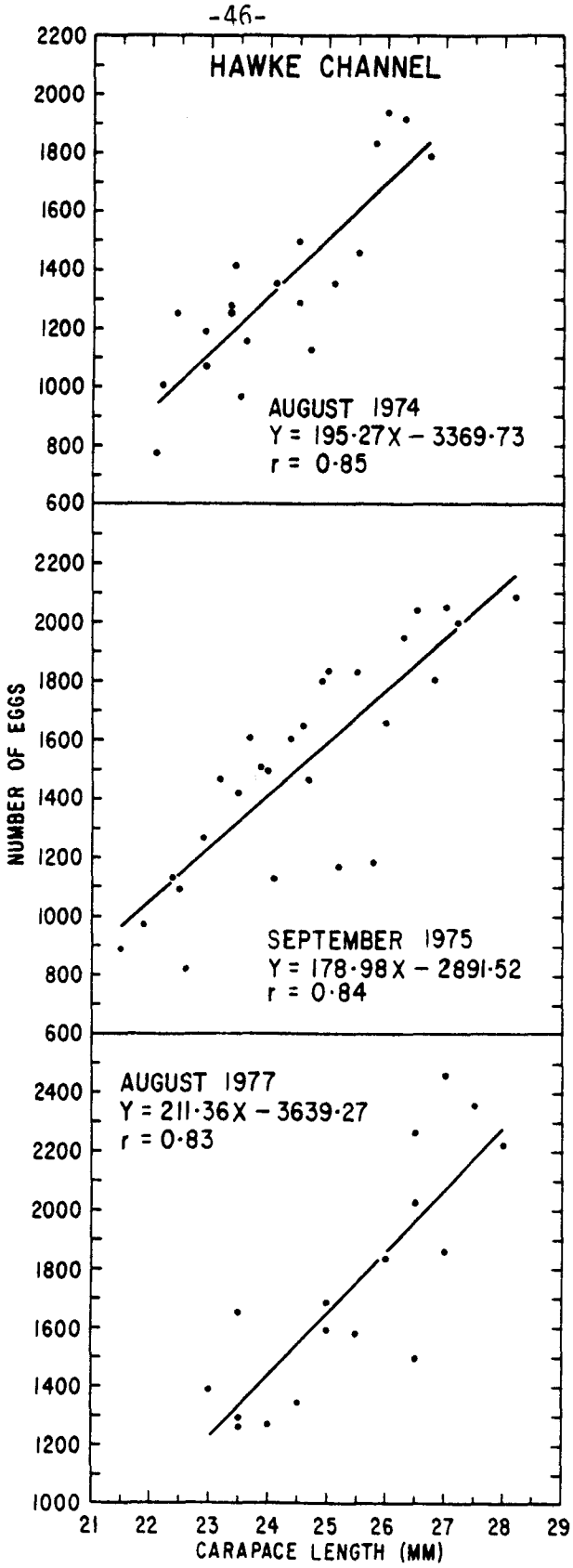

Fig. 24. Regression of egg counts against carapace length - Hawke Channel.