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An assessment of the stock of shrimp (Pandalus borealis) in the Esquiman Channel, Gulf of St. Lawrence

by

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1. History of the fishery

While the existence of shrimp fishing grounds in the deep water of the northern part of the Esquiman Channel has been known since 1958 (Squires, 1961), no attempt was made to commercially exploit the resource until 1970 when a joint effort by the Federal and Provincial governments and Fishery Products Ltd. established a shrimp processing plant at Port au Choix. At the same time three longliners were converted for shrimp trawling and these vessels quickly showed that a successful fishery was possible and during 1970 these three vessels were joined by others so that by the end of the year some 11 vessels were fishing for shrimps and a total landing of 159 metric tons was obtained. The fishery expanded rapidly in 1971 to some 21 vessels which landed 691 metric tons.

In 1972 a combination of factors caused a marked decline in the fishery. In 1972 the price of scallops rose from $1.00 to $1.75 per lb of shucked meats and new grounds for Icelandic scallops were discovered off Greenly Island on the Quebec shore at the southern end of the Belle Isle Strait and most shrimp fishing vessels converted to take part in this fishery which resulted in about 3/4 million lb of scallop meats being landed from the area. With the additional effect of an apparent lowered abundance of shrimps and low catches, only about five vessels prosecuted the fishery with any regularity, with landings dropping to 184 metric tons.

Since 1972, the fishery has expanded with the number of vessels participating in the fishery rising to a maximum of 39 in 1976. Prior to 1975, the shrimp fishery was unregulated. During 1975, at the instigation of the fishermen, steps were taken to institute a limited entry fishery and this became a fact in 1976 when the licensed fleet consisted of 39 eligible vessels (Fisher, 1977).

The fishery is one in which relatively small vessels participate and in 1976 the fleet consisted of vessels between 50' LOA and 65' LOA (Fisher, 1977). The small size of the vessels, together with the fact that the quality of shrimp landed deteriorates rapidly if held in ice for more than 1 or 2 days, has led to a fishing pattern whereby most vessels land daily and longer trips of 2 or 3 days duration are relatively rare and confined to times of fine weather in the summer. This means that the area of fishing is fairly limited and that it is only occasionally that fishing takes place south of latitude 50°N (Fisher, 1977).

2. Background material on shrimp biology and distribution

The shrimp species exploited in the Gulf of St. Lawrence, the great northern prawn, pink shrimp or *Pandalus borealis*, is a protandric hermaphrodite. Its life cycle is a relatively simple one though unusual for those who are more used to dealing with unisexual fish species. Eggs are carried on the parent female for a protracted period, the length of which appears to be related to environmental temperature conditions (Allen, 1959). In the Esquiman Channel area, egg laying starts in September and is completed by late November with the eggs being deposited and carried on the undersurface of the abdomen of the parent females. The eggs are carried and the females remain ovigerous until hatching starts in April-May, with all hatching completed by about mid-June.

The larvae which hatch from the eggs rise to the surface waters where they undergo several molts and, as immature shrimp, begin to make their appearance in the otter-trawl catches towards the end of their 1st year of life and throughout their 2nd year. By their 3rd year, most shrimps will be mature males and during the winter of their 3rd year many of the male shrimp will change into females so that by the following September they will be fully functional females which will become fertilized and lay eggs. The females may spawn more than once though they do seem to have a particularly high mortality rate shortly after the hatching of the larvae is completed. During the period while the change in sex is taking place, the individuals are called transitionals. Most transitionals are found in the January, February, March period and the numbers taper off so that none occur in the catches after about August. Fig. 1 shows diagrammatically the timing of the major phases of the life cycle and how these may be related to age.

As will be noted later, the fishery does not take many immature shrimp as only a few are recruited to the fishery at this stage of their life cycle. It seems that, though large numbers of males are taken in the fishery, they are not fully recruited until they have made the transition to become females. The pattern is not clear as seasonal changes in availability make abundance change difficult to analyze in terms of recruitment and mortality rates.

Shrimps can occur anywhere in the deep water that is found in the central part of the Esquiman Channel. They prefer relatively warm water (> 3°C) and it is presumed that, because there is a sharp thermal barrier of cold 0°C water throughout most of the year in the shallower depths, the shrimp are limited in their distribution to the warm (≃ 4^oC) water that remains at depths greater than about 100 fath. The biggest shrimp concentrations in the area occur in depths of 120-140 fath, though in the spring large numbers of ovigerous females may occur in depths shallower than this. In general, over most seasons of the year, smaller shrimps are found in the shallower part of their preferred depth range and larger ones in the deeper parts, though few shrimps are found at depths greater than about 150 fath.

3. Identity of the shrimp stock

While shrimp have been fished over a variety of areas in the Gulf of St. Lawrence, major commercial concentrations of shrimps are confined to a few relatively well-defined areas, the most important of which are as follows.

a) Area west of Anticosti in the general area offshore from Sept Iles, Quebec. This area is the mainstay of the shrimp fishery of Quebec and was the first of the Gulf shrimp fisheries to become established.

b) Area in the Mingan Channel north of Anticosti. This area has been fished by vessels from both Quebec and New Brunswick.

c) Esquiman Channel Area. Though shrimp occur over the whole of the area of the deepwater channel, the area of main concentration is at the northern end of the channel where the main fishery takes place.

d) Area in the main Laurentian Channel to the south and west of Anticosti.

Between each of these areas where the main concentrations of shrimps occur, the abundance of shrimps generally decreases. Furthermore, because the areas are quite widely separated and no information exists to suggest that there is any definite movements between the northern part of the Esquiman Channel and the adjacent areas of concentrations, it is convenient to regard the stock in this area as a unit stock. The limits defining the stock have arbitrarily been designated as the 100 fath contour to the north and east, the 49^oN latitude line to the south and the 60^oW longitude line to the west (Fig. 2). As mentioned previously, very little fishing actually occurs south of latitude 50^oN.

4. Catch, effort and catch/unit of effort

In 1971 and for the few vessels which fished shrimps in 1972, a logbook system was introduced which worked quite successfully until the time when most of the vessels converted from shrimp to scallop fishing. These logbooks provided effort data of hours fishing as well as providing more definite information on the locality of fishing and estimated catch and bycatch at that locality. Unfortunately, ours was not the only logbook which the fishermen were asked to complete and when I discovered that some fishermen were required to maintain as many as 5 or 6 different logbooks for different organizations I withdrew ours in favour of waiting till the official "Department of Fisheries" logbook which fishermen would be required to complete and which I understood to be forthcoming in the near future.

With only limited catch/hour data, we were forced to utilize effort data on a catch/day basis. As was mentioned previously, with the exception of a few vessels which may occasionally stay out overnight during the summer, it is the normal practice of the Port au Choix fleet to land their catch each day. Thus, use of the daily purchase slips of vessels which landed each day allows a mean monthly value of catch/day to be computed for that part of the fleet (most of it) for which daily landings records are available. The total days effort exerted by the fleet during each month was computed in the usual manner by dividing the total landings (equivalent to the total catch for shrimps) and compiled by the Economics and Intelligence Branch of the Fisheries Service by the already derived catch/day. This allowed an estimate of effort in days to be derived for most months (April-December) during the years 1971-77. Effort normally decreased quite markedly during November and December, partly because of the deterioration of weather conditions during the winter months and partly because the vessels were gradually being laid up for the winter. Usually only one or two vessels remained fishing through December and even into January when ice in the harbours finally closed fishing down till ice breakup which occurred in April or May.

Shrimps demonstrate a marked diel variation in availability to bottom otter trawls and in the Esquiman Channel shrimp fishing is normally carried out only during the hours of daylight. Thus it is apparent that a day's fishing in June or July, when the daylight period is 16 hours, is quite different to a day in December, when the daylight period is limited to about 8½ hours. To correct for this, the days fished in each month were adjusted to a standard day of 8 hours 25 minutes duration (using the day length at the 15th of each month) and, using these adjusted days, new estimates of catch/standard day obtained (Table 1).

An attempt was also made to incorporate an adjustment for windy weather during the month which might compensate for those days which wind might shorten the days fishing but this was not successful.

Use of data from 1971 when logbooks were kept by the majority of the fleet allowed a comparison to be made between catch/hour as obtained from the logbooks and catch/day estimates using the adjusted or not-adjusted values of effort. In a regression of c/hour against c/day, a correlation coefficient of 0.67 was obtained when unadjusted effort data were used as compared to 0.90 when catch/standard (8 h 25 min) day was used. Attempts at refining the data using a weather correction factor were not successful, with the correlation coefficient being 0.81 when the standardized data were further adjusted for weather.

5. General production models

Application of one of the variants of the general production type models is always an attractive first method of assessment because their demands on data are so limited. Also, for species where aging is difficult or confused, or those which are short lived and whose stocks are only subjected to a limited period of exposure to a fishery, such methods become even more attractive.

Annual catch, standardized effort and catch/effort are displayed in Fig. 3 for each year from 1971 to 1977. This figure immediately indicates that, in this fishery, we are faced with a situation which suggests that quite a dramatic increase in abundance of shrimps has taken place from 1972 to 1976 and, in spite of the fact that both catch and effort have tripled, the catch/effort has continued to rise. The customary plot of catch/effort against effort confirms our suspicions that the increase in abundance that has taken place during the period has completely overshadowed any effects that the fishery may have had in lowering the levels of stock abundance. This plot is shown in Fig. 4 and the positive slope indicates the non-applicability of these models under these circumstances.

6. Analytical models

The use of an analytical type model would seem to provide an obvious way to circumvent the problem of increased abundance noted above. The increased abundance would be included within the recruitment parameter of the model and, provided this (and the other parameters) could be quantified, derivation of sustainable yields under various management options might be possible.

Unfortunately, the technique I have been using for aging, while it appears to dissect the length frequencies in a most satisfying manner and produces a growth curve which appears to be most reasonable, it does not present the decline in numbers of a year-class through its life as a reasonably ordered progression. For this reason, an analysis using dynamic pool models is not presented at this time.

7. Biomass surveys

Methods

The distribution of shrimp in the Esquiman Channel is clearly limited to these areas where relatively warm 4°C water is present throughout the year. Such water occurs only in the deepest water in the Gulf of St. Lawrence and thus shrimps do not normally occur at depths shallower than about 100 fath. Thus, in designing a survey plan, it was possible to limit the survey to depths of 100 fath and greater.

Observations on commercial shrimp vessels in the area showed that smaller shrimps were often more plentiful in the shallower 100-120 fathom zone than in deeper zones and this differential distribution of year-classes suggested that the distribution of shrimps would be relatively homogeneous within depth zones and that a random sampling survey stratified by depth would provide a suitable survey design. Hence, the area of the Esquiman Channel greater than 100 fath and bounded to the south by 49°N latitude and to the west by 60°W longitude lines was arbitrarily divided into 24 strata based on depth intervals of 20 fathoms.

Random starting positions for each set were generated throughout the survey area by computer and these positions were plotted till each stratum received an allocation of sets approximately proportional to its area. As might be expected from such a random selection process, a few sets occurred very close to other sets and some areas were devoid of sets. Arbitrary adjustments were made such that, except where strata were narrow because of rapid depth change, no sets were nearer than about 3 miles to each other and a few extra sets were included where obvious bare patches were noted. These adjustments and extra sets totaled less than 10% of the total sets. Fig. 1 shows the stratification scheme used and the distribution of the random set positions used in the 1972 survey. In the other surveys the same stratification scheme was used though, of course, the random set positions were different.

In each survey, trawling was carried out only during daylight hours and care was taken that all the sets of half hour duration were as similar as possible with respect to net and towing parameters. The net used was a standard No. 36 shrimp net with 1½-inch mesh throughout and with the codend lined with ½-inch mesh nylon netting. A warp length to depth ratio of 3:1 was used throughout the survey. Bottom temperatures were measured after each set.

For each set, not only were the weights of shrimp caught recorded, but a random sample of about 400 shrimps was measured (carapace length). Also, representative samples from each depth zone were preserved for detailed examination (sex and maturity) at the Station.

A total of four such surveys have been carried out, one in each of the following years: 1972, 1973, 1975 and 1976. In 1973, the survey did not cover the whole area but was restricted to the area north of latitude 50°N. To allow the results from the 1973 survey to be used in a between-year comparison, the biomass values have been calculated for the surveys in 1972, 1975 and 1976 for the area north of latitude 50°N as well as the total area.

Results

The catches obtained in each stratum have been multiplied up to provide an estimate of minimum trawlable biomass for each stratum and strata have then been combined to provide estimates of minimum trawlable biomass for each depth zone as well as for the total area (Table 2). The increase in biomass from 1972 to 1976 is readily apparent in both the total area and the area north of 50°N latitude where almost all the fishery takes place.

These estimates of total biomass demonstrate the general increase in abundance of the stock and should correlate with the indices of abundance obtained from the commercial fleet. Fig. 4 shows the regression of biomass as estimated for the area north of 50°N latitude by the stratified random surveys on the catch/standard day obtained by the commercial fleet. (To smooth out small irregularities in the monthly catch/effort values, the average of the month in which the survey took place, the month before and the month after have been used.) With the commercial fleet operating in the more restricted depth zone 120-140 fath, an improved correlation might be expected if the biomass estimate for this depth zone was used in the regression and indeed this was so though the improvement was only slight (r^2 = 0.67 for the latter, 0.64 for the former).

8. Conclusions

After the survey in 1972, I ventured the advice that a total allowable catch of about 5,000,000 lb (2268 tons) might be a reasonable figure for the total area of the Esquiman Channel. This has never been attained though catches of over 3,000,000 lb have been obtained from a much smaller part of the area to which almost all commercial exploitation has been restricted.

With the increase in abundance that has occurred since 1972, it would seem clear that our advice from the viewpoint of the shrimp stock could indicate a TAC for the total area of the Esquiman Channel of at least 20 million lb (9072 metric tons) (35% of the minimum trawlable biomass) or for the area north of the 50^{o}N latitude of at least 8.75 million lb (3962 metric tons).

Recruitment in 1977 appears to be good and, as the size distribution presented in Fig. 6 suggests, abundance should likely remain high for 1978 and 1979.

With a limited entry fishery in place, this increased TAC might allow an expansion of vessels allowed to fish in the area; however, it should be emphasized that the increase in abundance that has occurred is likely to be only a temporary phenomenon and that a return to diminished stock size as was present in 1972 could occur at any time and at this time is not predictable. Furthermore, following the recent economic assessment that has been carried out on this fishery (Fisher, 1977), the implications of an expanded fishery deserve careful scrutiny.

9. References

Allen, J. A. 1959. On the biology of *Pandalus borealis* with reference to a population off the Northumberland coast. J. Mar. Biol. Assoc. U.K. 38: 189-220.

Fisher, C. F. 1977. An economic assessment of the Newfoundland shrimp fishery. Economics and Intelligence Branch, Fisheries and Marine Service, St. John's, Nfld. MS 116 pp.

Squires, H. J. 1961. Shrimp survey in the Newfoundland fishing area, 1957 and 1958. Bull. Fish. Res. Board Can. No. 129, 29 pp.

Table 1. Shrimp - 4R - Basic Catch/Effort Statistics (standard days).

	lb			mt	
Year	Catch	Catch/day	Days	Catch	Catch/day
1970	350535			159	
1971	1523395	595	2559	691	270
1972	405650	386	1050	184	175
1973	1146403	553	2074	520	251
1974	1309545	823	1592	594	373
1975	3015925	929	3245	1368	422
1976	3293706	941	3501	1494	427
1977	2297194	758	3029	1042	344

Table 2. Estimates of minimum trawlable biomass obtained in each depth zone of the survey area in each year.

	Depth	N of 50^{o}N		Whole area		
		Biomass (tons)	Biomass ('000 lb)	Biomass (tons)	Biomass ('000 lb)	
1972 (October)	100-120	374	823	1011	2229	
	120-140	2661	5866	5288	11659	
	140-160	1120	2469	2051	4522	
	> 160	232	513	247	544	
		4387	9671	8597	18954	211
1973 (November)	100-120	1430	3153			
	120-140	3834	8452			
	140-160	1773	3908			
	> 160	401	884			
		7438	16397			345
1975 (August)	100-120	1545	3406	6055	13349	
	120-140	5615	12379	13036	28738	
	140-160	1030	2271	2832	6244	
	> 160	233	514	297	655	
		8423	18570	22220	48986	356
1976 (August)	100-120	2415	5324	6043	13322	
	120-140	5877	12957	14298	31521	
	140-160	2741	6043	5407	11919	
	> 160	287	633	219	484	
		11320	24957	25967	57246	344

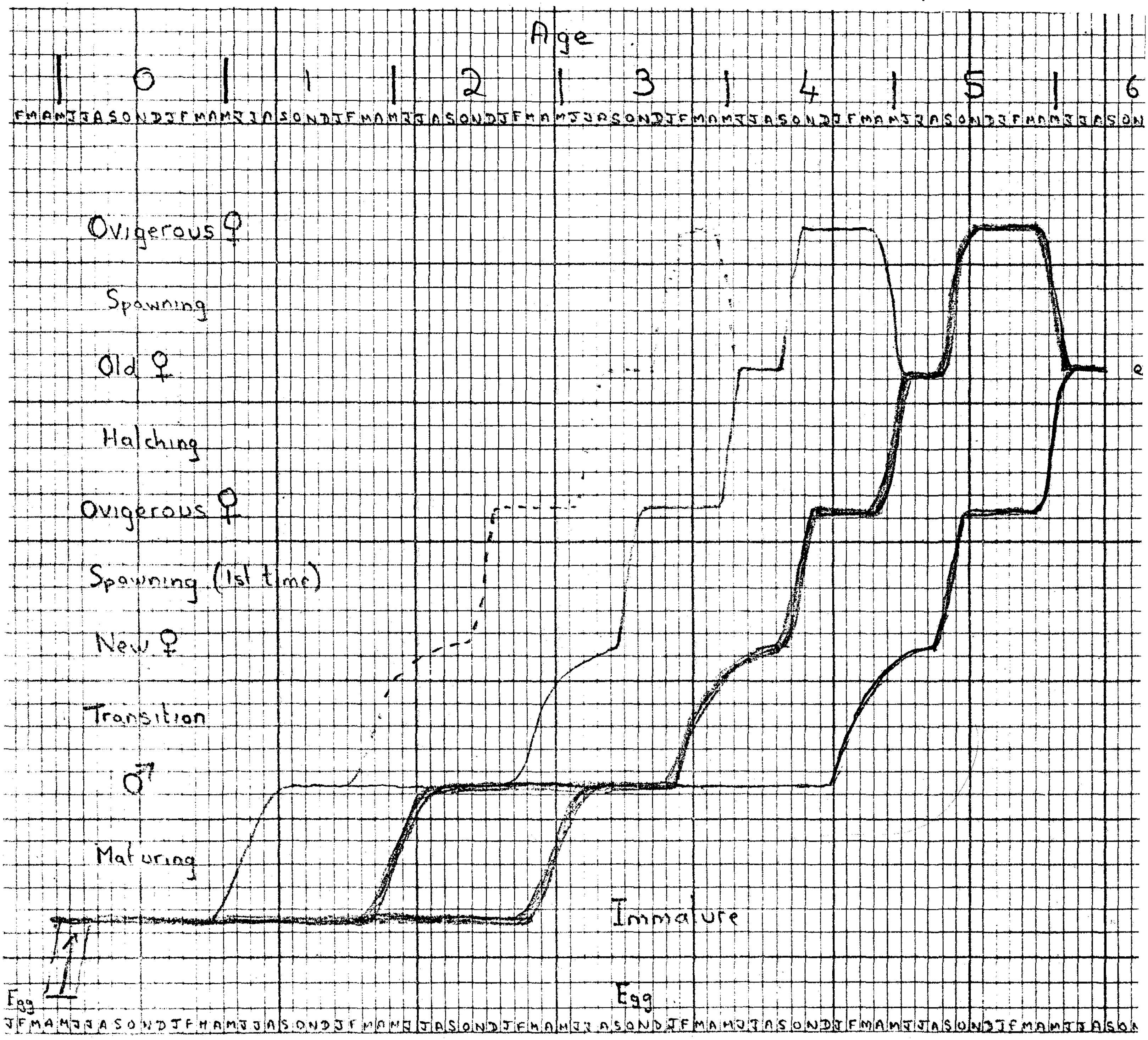

Fig. 1. Diagram showing timing of the major phases of the life cycle.

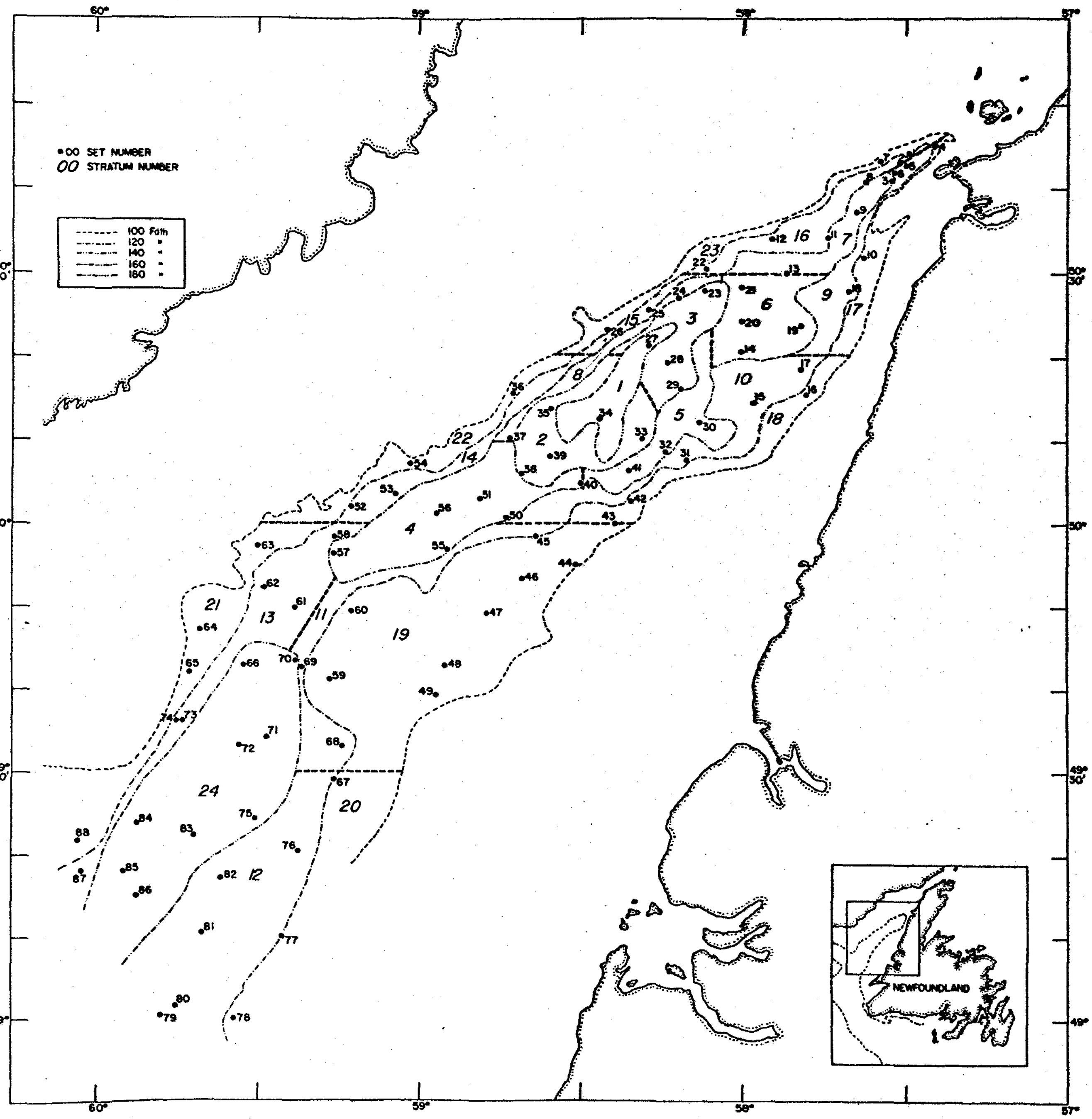

Fig. 2. Stratification scheme used for biomass surveys and individual random set positions used on the 1972 survey.

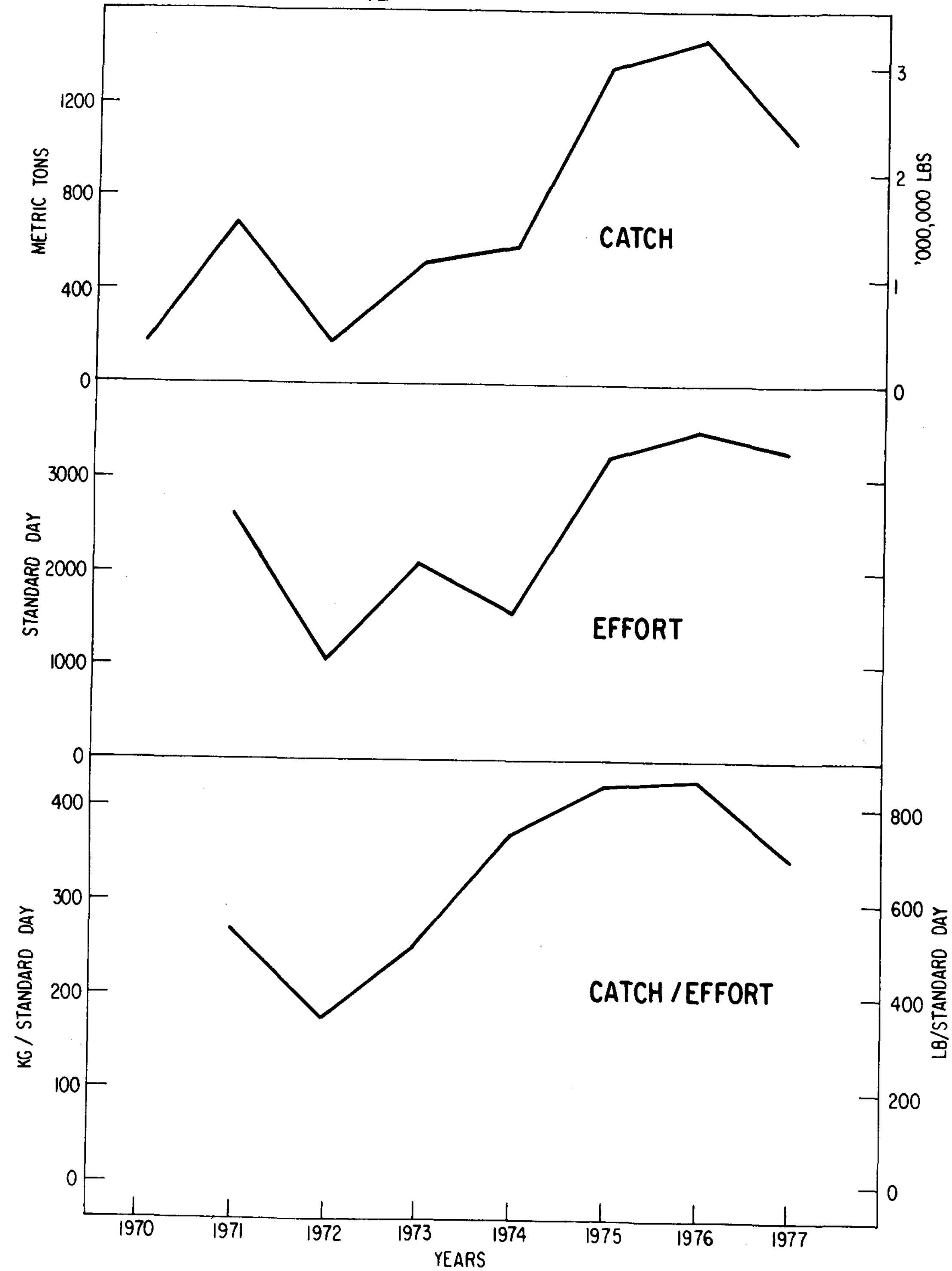

Fig. 3. Basic annual statistics - Esquiman Channel.

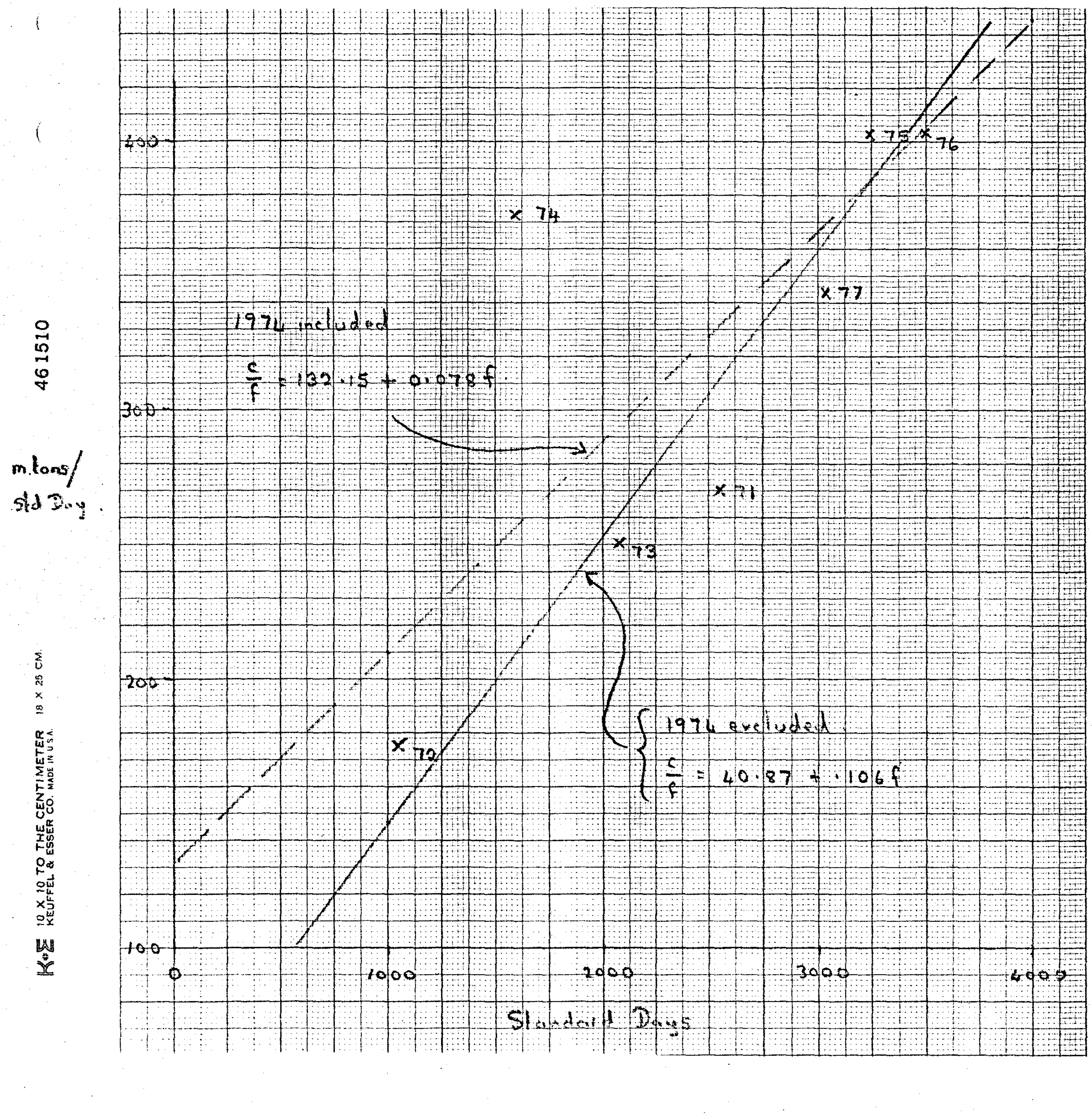

Fig. 4. Regressions of catch/standard day on standard days.

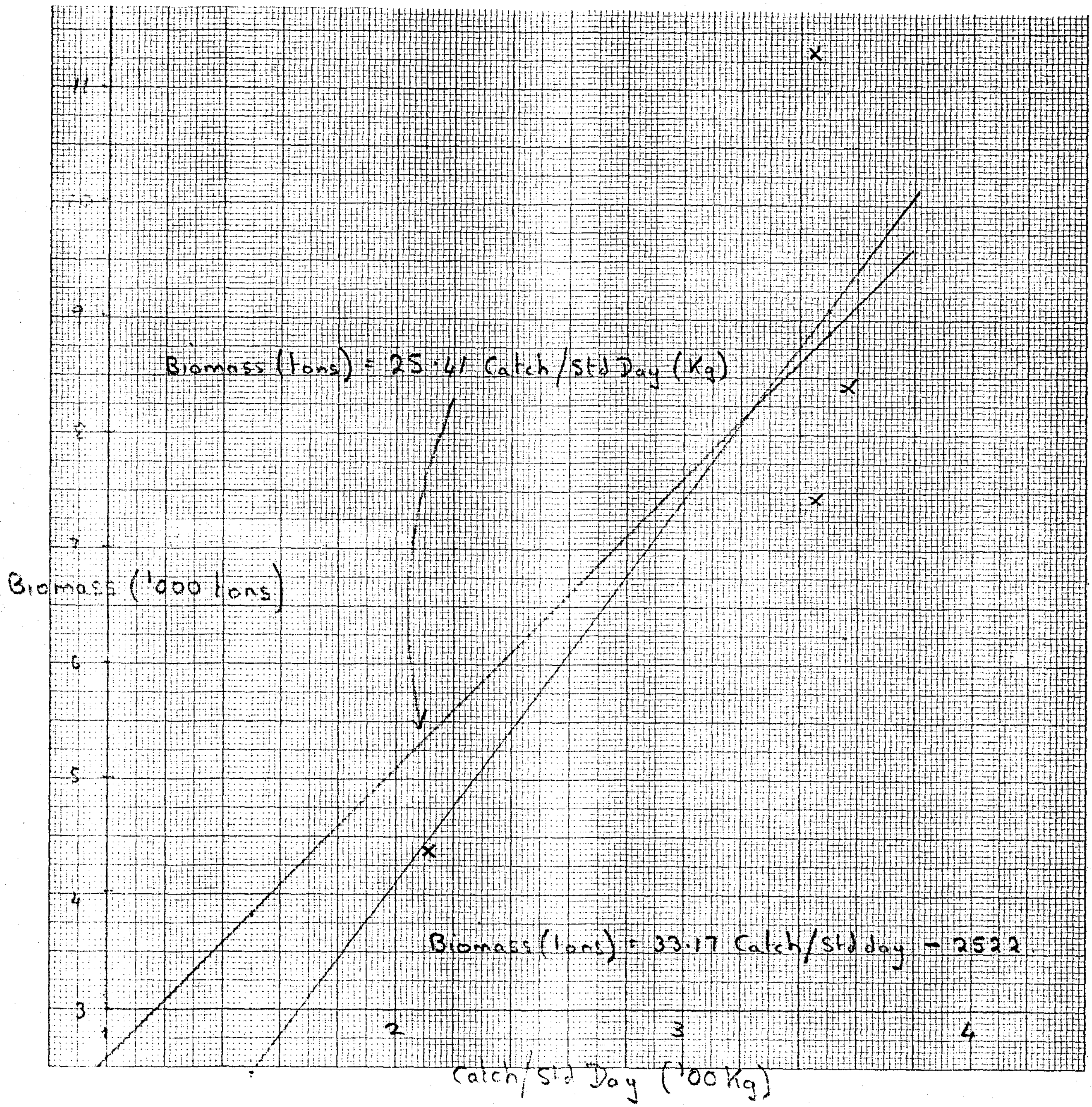

Fig. 5. Biomass in area north of $50^{O}N$ as function of catch/standard day obtained by the commercial fleet.

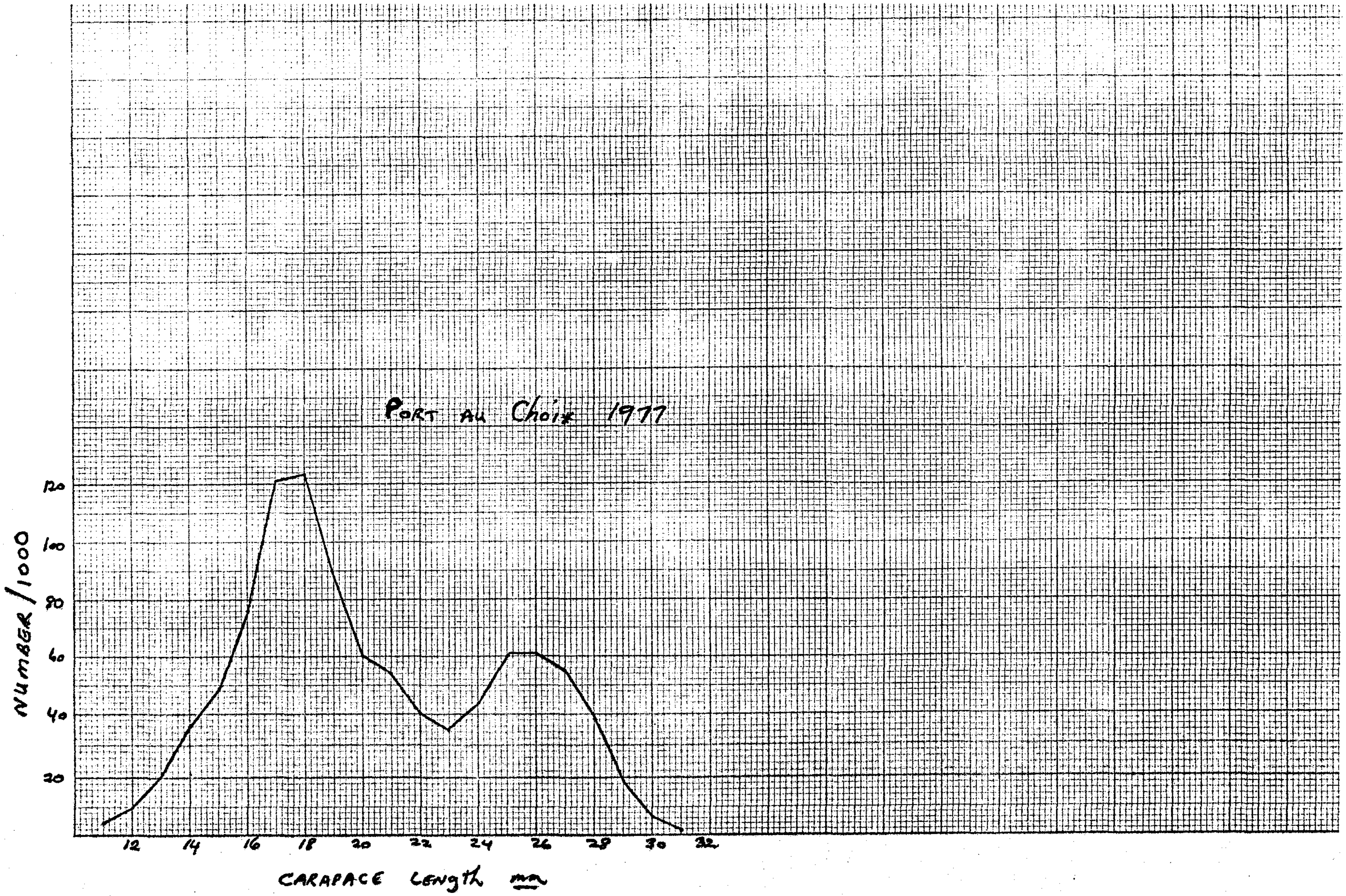

Fig. 6. Size distribution of shrimps caught in commercial fishery, Port au Choix, all months combined.