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Status of snow crab (*Chionoecetes opilio*) stocks in the Gulf of St. Lawrence

by

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Introduction

The snow crab fishery in the Gulf of St. Lawrence was developed on a large commercial scale in 1967, after a period of experimental fishing and processing initiated by the Federal Department of Fisheries. The main fishing grounds were originally located northwest of Cape Breton Island and east of Gaspé peninsula from Gaspé Bay to the entrance of Baie des Chaleurs. In 1969 and 1970 the fishing grounds expanded from this latter location into the gullys nearby Orphan and Bradelle Banks toward Magdalen Islands. Starting in 1972, a small-scale fishery was developed by lobster fishermen off the northeastern coast of Cape Breton.

There are essentially two distinct snow crab fisheries; one pursued by New Brunswick and Quebec fishermen in the southwestern part of the Gulf, the other pursued around the northern coast of Cape Breton Island by local fishermen.

Fishermen from Quebec and New Brunswick are fishing on 13- to 26-m boats with standard 1.5 x 1.5 x 0.5 m traps built of steel rods covered with polypropylene netting (slightly larger traps are occasionally used). Fishing trips are one or two days long depending on the number of traps to haul and the distance to the fishing grounds.

In Cape Breton, fishermen have smaller boats, 7-13 m, and are doing 1-day trips exclusively. 1.5 x 1.5 x 0.5 m traps are common on the western side of the island, while Japanese conical traps and wooden traps of various shapes are used on the eastern side.

Biological studies were carried on at the beginning of the fishery until 1971. Log books were introduced in 1968 and, although interest dropped in 1971, some fishermen kept records every year since then.

Despite a growing importance of the snow crab fishery, particularly in the northeast New Brunswick, very few biological statistics of the snow crab population in the Gulf of St. Lawrence have been analyzed and interpreted. This document is an attempt to provide an assessment of the snow crab stocks and to orientate future work.

Catch and effort information

Official landings statistics are presented in Table 1 and Fig. 1 for Québec and the Maritimes. Landings from the southwestern Gulf (New Brunswick and Bonaventure and Gaspé-sud counties of Québec) and from the southeastern Gulf (P.E.I. and Inverness and Pictou districtq of N.S.) are for two distinct fisheries.

Information on fishing effort was available for New Brunswick and Quebec in terms of number of boats and number of traps (Table 2, Fig. 2). Unfortunately, number of traps used in Cape Breton is unknown.

Yield per effort (in kg per trap) in the southwestern Gulf for the period 1968-77 was calculated (Table 3) using total annual catch and total number of traps. Catch per unit of effort (kg/trap haul) estimates were also obtained from the literature and from fishermen log books for both parts of the Gulf (Table 4). Estimates were computed on a monthly basis and then combined in proportion to monthly landings for an annual average. Monthly estimates were not available every month of the fishery for each year, except for June, July and August. These were then combined and their averages over the years compared with the annual averages to give an indication on the accuracy of the annual CPUE estimates.

Graham-Schaeffer logistic model and Gulland-Fox exponential model were used to estimate the relation between catch and fishing effort (Fig. 3). A first estimation was made with yield per effort (kg/trap) data. Linear regression was made on Y/f against effort for the logistic model, and on $\log_e$ Y/f against effort for the exponential model (Fig. 4). Expected yield was then calculated for different effort levels for both models (Fig. 5). In the logistic curve, maximum yield (Y_s^A) is 7,348,958 kg and optimum effort (f_s^A) is 6,917 traps. The expoinential model predicts a maximum yield (Y_s^B) of 7,260,230 kg at an optimum effort (f_s^B) of 8,772 traps. Observed values are also indicated.

A second estimation of the relation between catch and effort was attempted with the same models, but using average CPUE (kg/trap haul) instead of Y/f (kg/trap). Figure 6 shows the data and the fitted regressions used to calculate the logistic and exponential curves (Fig. 7). In this case the maximum yield represents the average catch for one haul of all traps (f_s). The total annual catch would be obtained by multiplying by the average time traps are hauled in a fishing season. This information is not available. Optimum fishing effort with the logistic model is f_s^A = 13,062 traps and f_s^B = 20,404 traps with the exponential model.

These yield-effort relationships estimations are subjected to the assumption that annual hauling frequency was constant every year. Different frequencies will introduce error in the effort estimates which are in terms of total number of traps. Better fits would certainly be achieved with estimates of fishing effort in total number of trap hauls which, unfortunately are not available.

<u>Analysis of monthly CPUE estimates</u>

Monthly CPUE estimates for the southwestern Gulf were plotted against cumulative catches for 1968, 1969, 1970, 1971, 1973 and 1977 (Figs. 8a, 8b). According to Leslie method, fitting of a linear regression would yield estimates of total initial biomass (B_0) and of catchability (q). Natural mortality and recruitment affect the results both in a different direction. Recruitment is probably more important in this case, especially during the molting period which occurs in July-August generally. This probably explains the tendency of the CPUE estimates to stabilize or even increase during these months. Some of the first points, arbitrarily chosen, were then discarded for the linear regressions. The estimates obtained for B_0 indicate that the fishing grounds for snow crab in the southwestern Gulf can support a biomass of commercial crabs of over 10,000,000 kg (Table 5). By dividing total catch by total biomass, an estimate of fishing mortality (F) can be obtained (Table 5b). Estimates for F range from 0.46 in 1968 to 1.96 in 1977.

Leslie analysis was also performed with data for the southeastern Gulf (Fig. 9a, 9b). Resulting biomass estimates may indicate depletion of the stock from 1967 to 1970 (Table 6).

Accuracy in the monthly landings statistics and in the monthly CPUE estimates are prerequisite to the usefulness of this analysis. Unfortunately, the errors here are probably major, as indicated by the results for the southeastern Gulf in 1968, where the total catch exceeds the estimated total biomass.

Size frequencies analysis

Size frequencies obtained from a survey for snow crab in Chedabucto Bay, N.S., in 1976, indicated modes in their distribution. Separation into normal components was attempted with Harding-Cassie method (Figs. 10, 11, Table 7) and Bhattacharya method (Table 7). Percent increase in size from one mode to the next was calculated and linear regressions fitted to a plot of percent increase against size at molt (Fig. 12). Results obtained in the laboratory by Miller and Watson (1976) are indicated for comparison. The linear regressions on the results from the polymodal size distribution analysis suggest that molt would stop at a size between 140 mm and 160 mm. Very few crabs over 155 mm are in fact observed in the commercial fishery.

Size frequency histograms for crabs caught in the southwestern Gulf don't indicate any modes suggesting a polymodal distribution. But recent measurements made in the northern Cape Breton fishery suggest that there may be distinct modes in the size distributions (Fig. 13). Separation into normal components was attempted with NORMSEP computer program under the assumptions of 2 and 3 components (Table 8). Results for percent increase at molt, when the distributions were separated into 3 components, are similar to those obtained for Chedabucto Bay size distribution. It is therefore hypothesized that these modes in the size frequency distributions for Cape Breton represent molt classes.

Using the percentage contribution of each normal component in the total size distribution, the decrease from one to the next gives an estimate of total mortality (Z') for one molt duration (Tables 7, 9). These estimates equal annual mortality if molting frequency is once a year.

Similar mortality estimates may be obtained when analyzing size frequencies as catch curves (Ricker 1975, p. 60; Caddy 1976). Log_e of number at size are plotted against size (Figs. 14, 15). Choosing the initial value at the mode of the size distribution, one molt increment is calculated. In Fig. 14, results from previous polymodal distributions analysis were used to calculate the increase. In Fig. 15, Miller and Watson results were used. Linear regression is then performed for the values between and including these two sizes. Then the second value is used as initial size and a new molt increase is calculated. Linear regression is again performed between these two new values. The same process is repeated until the last size group is passed. From the regressions, numbers at size are obtained and their diminution can be used to calculate an estimate of Z'. In Fig. 15, an increase of 18.4% per molt as indicated by Miller and Watson, gives a size of over 160 mm after only two molts. Mortality estimates (Z') are indicated in Table 10. Results based on size increases at molt from polymodal analysis are more likely to be closer to reality.

The same procedure was applied to several size frequency distributions from different areas and different years. Results of the calculations are in Tables 11 and 12.

Beverton and Holt yield functions

When size at recruitment into this fishery (l_c) and maximum size (L_∞) can be estimated, their ratio may be used to plot the relation between yield (Y) and exploitation rate (E) in numbers of a year-class which will be caught during its fished lifespan. Legal minimum size of commercial crabs is 95 mm. Observations on culling by the fishermen indicate that 50% retention can be assumed to be at 90 mm. Since mesh size generally used on the traps in the Gulf of St. Lawrence is 91 mm, we can probably accept a full retention by the trap of all crabs 90 mm. Thus we accept l_c = 90 mm. Exceptionally do crabs exceed 155 mm in shell width. Results from polymodal size distribution indicated that 155 mm may be a size at which growth stops. We then tentatively set L_∞ at 155 mm. The ratio l_c/L_∞ is then 0.58. Yield functions for different M/K values from Beverton and Holt tables are plotted in Fig. 16. From them it appears that maximum yield is somewhere between E = 0.7 and E = 0.95 for M/K values of 0.50-2.00.

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Table 1. Snow crab (*C. opilio*) landings (kg) in the Gulf of St. Lawrence and eastern Cape Breton, N.S.

Year	Québec	New-Brunswick	New-Brunswick + Bonaventure and Gaspé-sud counties (Québec)	Nova Scotia	Prince-Edward-Island	P.E.I. + Inverness and Pictou districts (N.S.)	Total
1966	14 107	15 991	30 098	0	0	0	30 098
1967	6 396	152 390	158 786	253 342	45 587	298 721	457 715
1968	368 725	3 439 090	3 757 965	656 455	334 671	980 623	4 798 941
1969	1 456 032	6 320 050	7 144 772	87 989	31 463	119 452	7 895 533
1970	1 591 157	4 955 792	5 482 367	90 484	0	90 484	6 637 432
1971	827 171	4 603 242	5 388 093	0	0	0	5 430 413
1972	619 743	4 455 740	4 896 360	50 942	0	25 156	5 126 425
1973	896 888	5 913 041	6 743 840	121 882	0	39 059	6 931 811
1974	1 030 607	5 694 320	6 620 783	218 741	0	135 213	6 943 668
1975	600 466	4 049 672	4 630 179	378 883	0	303 979	5 029 021
1976	1 517 619	5 883 387	7 384 318	488 463	0	254 160	7 889 469
1977	2 082 475	7 451 539	9 450 029	776 992	0	516 177	10 227 021

Table 2. Estimates of the fishing effort by the New Brunswick and Quebec snow crab fishing fleets.

Year	New Brunswick			Quebec			Total estimated no. of traps
	Number of boats	Average no. of traps per boat	Total no. of traps	Number of boats	Average no. of traps per boat	Total no. of traps	
1967	10[a]	(30)[1]	(300)				(300)
1968	56[b]	35.0	1960[b]	9[a, b]	(30)	(270)	(2230)
1969	68[a]	45.4[c]	3087	17[d]	34.5	586[d]	3673
1970	55[e]	56.2[e]	3091	15[d]	48.3	725[d]	3816
1971	38[f]	67.1	2550[f]	6[d]	46.7	280[d]	2830
1972	42[f]	90.2	3790[f]	9[d]	57.3	516[d]	4306
1973	53[i]	109.1	5782[i]	9[d]	62.2	560[d]	6342
1974	85[f]	120.5	10245[f]	13[g]	(63)	(819)	(11064)
1975	64[f]	120.0	7680[f]	18[g]	63.1[g]	1136	8816
1976	62[f]	120.0	7440[f]	23[g]	82.6[g]	1900	9340
1977	72[h]	143.9	10361[h]	24[g]	(90)	(2160)	(12521)

[1] Numbers in brackets are personal estimates used for catch-effort analysis. Real values were not available.

Sources:
[a]Watson, J. 1970.
[b]Savoie, R. 1969.
[c]Degrace, R. 1969.
[d]Anonymous 1974, Bureau de la statistique du Quebec.
[e]Landry, L. P. 1970.
[f]Anonymous, 1977, Snow crab advisory committee-Gulf, C. Cormier (Chairman).
[g]Quebec Department of Fisheries, pers. comm.
[h]Personal observations.
[i]Branch, J. 1973.

Table 3. Yield per effort in kg/trap from the snow crab fishery in the southwestern Gulf opf St. Lawrence.

Year	Y (Catch, kg)	f (Effort, traps)	Y/f (Yield per effort, kg/trap)
1968	3,757,965	2,230	1,685.2
1969	7,144,772	3,673	1,945.2
1970	5,482,367	3,816	1,436.7
1971	5,388,093	2,830	1,903.9
1972	4,896,360	4,306	1,137.1
1973	6,743,840	6,342	1,063.4
1974	6,620,783	11,064	598.4
1975	4,630,179	8,816	525.2
1976	7,384,318	9,340	790.6
1977	9,450,029	12,521	754.7

Table 4. Catch per unit of effort (CPUE) in kg/trap haul from the snow crab fishery in the Gulf of St. Lawrence.

	South-western Gulf				South-eastern Gulf			
	June-July-August average		Total average		June-July-August average		Total average	
Year	CPUE (Kg/trap haul)	No. of Trap hauls	CPUE (Kg/trap haul)	No. of Trap hauls	CPUE (Kg/trap haul)	No. of Trap hauls	CPUE (Kg/trap haul)	No. of Trap hauls
1967	—	—	—	—	41.65	1,393	43.10[a, b]	3,876
1968	33.57	14,456	30.32[c]	25,960	53.12	2,148	50.76[c]	2,777
1969	33.42	17,447	38.28[c, d]	21,694	43.29	1,645	48.72[c]	2,022
1970	54.25	27,626	52.22[c, e]	45,364	17.35	1,034	18.73[c]	1,325
1971	48.98	2,012	47.51[c]	2,893	—	—	—	—
1972	42.18	833	42.18[c]	833	—	—	—	—
1973	23.31	8,844	19.74[c]	13,713	—	—	—	—
1974	25.67	1,584	25.80[c]	1,584	—	—	—	—
1975	35.88	3,951	31.88[c]	3,951	—	—	—	—
1976	23.25	2,967	23.01[c]	3,873	—	—	—	—
1977	30.66	133,182	29.38[c]	159,825	—	—	—	—

Sources: [a]Simpson and Simpson, 1967
[b]Judson, Ms. 1967
[c]Fishermen's log books
[d]Savoie, R., Ms. report 1969
[e]Landry, L. P., Ms. report 1970

Table 5. a) Resulting parameters from lienar regressions performed on monthly cumulative catches and CPUE from the southwestern Gulf of St. Lawrence (Leslie analysis).

Year	Initial biomass B_0 (Kg)	Catchability q
1968	10,187,207	3.6644×10^{-6}
1969	10,332,076	5.4713×10^{-6}
1970	10,975,008	9.3103×10^{-6}
1971	6,982,992	13.560×10^{-6}
1973	8,433,607	3.3607×10^{-6}
1977	11,008,339	8.7845×10^{-6}

b) Fishing mortality estimates (F) from Leslie analysis results on initial biomass (B_0) and from total annual landings (Y) from the southwestern Gulf of St. Lawrence.

Year	Total catch (kg) Y	Initial biomass (kg) B_0	Y/B_0	Fishing mortality F
1968	3,757,965	10,187,207	0.3689	0.46
1969	7,144,772	10,332,076	0.6915	1.18
1970	5,482,367	10,975,008	0.4995	0.69
1971	5,388,093	6,982,992	0.7717	1.48
1973	6,743,840	8,433,607	0.7996	1.61
1977	9,450,029	11,008,339	0.8584	1.96

Table 6. a) Resulting parameters from lienar regressions performed on monthly cumulative catches and CPUE from the southeastern Gulf of St. Lawrence (Leslie analysis).

Year	Initial biomass B_o (kg)	Catchability q
1967	449,101	1.1433×10^{-4}
1968	637,335	1.0948×10^{-4}
1969	281,160	1.7088×10^{-4}
1970	132,129	1.8223×10^{-4}

b) Fishing mortality estimates (F) from Leslie analysis results on initial biomass (B_o) and from total annual landings (Y) from the southeastern Gulf of St. Lawrence.

Year	Total catch (kg) Y	Initial biomass (kg) B_o	Y/B_o	Fishing mortality F
1967	298,721	449,101	0.6652	1.10
1968	980,623	637,335	____	___
1969	119,452	281,160	0.4249	0.55
1970	90,484	132,129	0.6848	1.15

Table 7. Mortality estimates (Z) using results from Harding-Cassie and Bhattacharya analysis of size frequencies of snow crab males caught in Chedabucto Bay, 1976.

Sample 1 (N=630)			Sample 2 (N=3024)					
Harding-Cassie			Harding-Cassie			Bhattacharya		
Mean (mm)	Number	Z	Mean (mm)	Number	Z	Mean (mm)	Number	Z
			57.5	212		66.5	212	
					—			—
70.0	302		73.0	1452		77.5	1270	
		0.13			0.18			—
92.5	265		93.0	1210		93.5	1361	
		1.65			2.25			2.02
111.5	51		113.0	127		114.5	181	
		1.99			1.71			1.80
126.5	7		129.0	23		128.5	30	

N.B. These annual mortality estimates are obtained under the assumptions that each mode in the size frequencies are molt classes and that molting frequency is once a year.

Table 8. Separation of size frequency distributions from Cape Breton, 1977, using NORMSEP (Computer program separating polymodal frequency distributions into normal components).

				First mode		Second mode		Third mode	
No. of components	Zone	Month	Sample Size	Average size (mm)	Contribution (%)	Average size (mm)	Contribution (%)	Average size (mm)	Contribution (%)
2	8	July	345	102.3	56.9	115.5	43.1	—	
		August	3426	102.2	65.4	115.6	34.6	—	
		September	528					—	
	9	August	1148					—	
	Combined	July	404	102.2	52.5	115.6	47.5	—	
		August	4574					—	
3	8	August	3426						
		September	528	103.5	72.2	120.0	25.3	135.0	2.5
	9	August	1148	102.3	25.4	117.4	74.6	135.0	0.03
	Combined	July	404						
		August	4574	102.3	69.3	120.0	24.0	130.5	6.8

Table 9. Mortality estimates (Z) and percentage increase at molt using results from NORSEP analysis of size frequency distributions of male snow crabs from Cape Breton, 1977.

		Distributions with 2 components				Distributions with 3 components			
Zone	Month	Mean size (mm)	Number	Z'	% at molt	Mean size (mm)	Number	Z'	% at molt
8	July	102.3	196	0.27	12.9		———		
		115.5	149				———		
	August	102.2	2240	0.64	13.1		———		
		115.6	1186				———		
	September	———				103.5	381	1.04	15.9
						120.0	134	2.33	12.5
						135.0	13		
9	August	———				102.3	292	—	14.8
						117.4	856	—	15.0
						135.0	(0.3)		

Table 10. Mortality estimates (Z) from catch curve analysis based on size frequency of crabs landed in New-Brunswick, 1977.
A)Size increases at molt based on polymodal size frequencies analysis.
B)Size increases at molt based on 18.4% from Miller and Watson, 1976.

Arbitrary molt group	Shell width (mm)	Log_eN (from regressions)	(N)	Z'
A) Initial value: m(0)	115	8.31	4064.3	
(Mode)				1.16
After 1 molt: m(1)	130 (115 + 13%)	7.15	1274.1	
Initial value: m(1)	130	7.34	1542.3	
				2.13
After 1 molt: m(2)	140.3 (130 + 8%)	5.21	183.6	
Initial value: m(2)	140.3	5.01	149.9	
				2.11
After 1 molt: m(3)	147 (140.3 + 5%)	2.90	18.1	
B) Initial value: m(0)	115	8.34	4564.0	
(Mode)				2.13
After 1 molt: m(1)	136.2 (115 + 18.4%)	6.29	540.8	
Initial value: m(1)	136.2	6.40	602.0	
				7.60
After 1 molt; m(2)	161.3 (136.2 + 18.4)	-1.26	0.3	

Table 11. Mortality estimates ($\hat{Z}$) from catch curve analysis based on size frequencies of snow crabs.

Southwestern Gulf	Year	Arbitrary molt group (shell width, mm)	$\hat{Z}$
Watson & Simpson, 1969; Baie des Chaleurs; N=1286	1966	110	
			0.56
		110 + 15% = 126.5	
			2.27
		125.5 + 9% = 137.9	
Watson & Simpson, 1969; Baie des Chaleurs; N=1440	1968	115	
			0.92
		115 + 13% = 130.0	
			1.32
		130 + 8% = 140.3	
Watson & Simpson, 1969; Gaspé Bay, October; N=2226	1968	105	
			1.51
		105 + 16% = 121.8	
			1.85
		121.8 + 10% = 134.0	
Watson, unpublished; Gaspé Bay; N = 3464	1969	110	
			0.71
		110 + 15% = 126.5	
			1.40
		126.5 + 9% = 137.9	
			1.29
		137.9 + 7% = 147.5	
Watson, unpublished; Orphan Bank; N=1993	1969	120	1.05
		120 + 11% = 133.2	
			2.84
		133.2 + 7% = 142.5	
Watson, unpublished; Orphan Bank; N=1158	1970	110	0.33
		110 + 15% = 126.5	
			1.41
		126.5 + 9% = 137.9	
			1.39
		137.9 + 7% = 147.5	

Table 11. (Continued)

Southwestern Gulf	Year	Arbitrary molt group (shell width, mm)	Z
Watson, unpublished; Bradelle Bank; N=921	1970	105	
			0.41
		105 + 16% = 121.8	
			0.38
		121.8 + 10% = 134.0	
			1.72
		134.0 + 7% = 143.4	
Lamoureux & Dubé, 1976; Baie des Chaleurs; N=10659	1975	105	
			0.79
		105 + 16% = 121.8	
			2.18
		121.8 + 10% = 134.0	
			1.39
		134.0 + 7% = 143.4	
Lamoureux & Dubé, 1976; Gaspé Bay; N=1453	1975	100	
			1.02
		100 + 18% = 118	
			1.93
		118 + 12% = 132.2	
Stasko, 1975; Bradelle Bank, July; N=1640	1975	110	
			1.36
		110 + 15% = 126.5	
			1.83
		126.5 + 9% = 137.9	
Personal data; Baie des Chaleurs, October; N=358	1976	110	
			0.48
		110 + 15% = 126.5	
			1.41
		126.5 + 9% = 137.9	
			1.01
		137.9 + 7% = 147.6	
Personal data; Orpahn Bank, October; N=1644	1976	115	
			1.07
		115 + 13% = 130.0	
			2.23
		130.0 + 8% = 140.3	

Table 12. Mortality estimates ($\hat{Z}$) from catch curve analysis based on size frequencies of snow crab (size increases at molt based on polymodal size frequencies analysis).

Cape Breton, N. S.	Year	Arbitrary molt group (shell width, mm)	$\hat{Z}$
Watson & Simpson, 1969; Chéticamp; N=859	1967	120	
			2.01
		120 + 11% = 133.2	
Watson & Simpson, 1969; Chéticamp; N=526	1968	120	
			0.49
		120 + 11% = 133.2	
			0.86
		133.2 + 7% = 142.5	
Personal data; eastern Cape Breton;	1977	100	
			1.90
		100 + 18% = 118	
			1.39
		118 + 12% = 132.2	
			1.46
		132.2 + 8% = 142.7	
Personal data; western Cape Breton	1977	100	
			0.44
		100 + 18% = 118	
			1.36
		118 + 12% = 132.2	
			2.78
		132.2 + 8% = 142.7	

Figure. 1

Annual snow crab landings in the Gulf of St.Lawrence and eastern Cape Breton,N.S.

A - Total (New-Brunswick + Quebec + Nova Scotia + P.E.I.)

B - New-Brunswick + Bonaventure and Gaspe-sud counties (Quebec) (Western Gulf)

C - P.E.I. + Inverness and Pictou districts(N.S.) (Eastern Gulf)

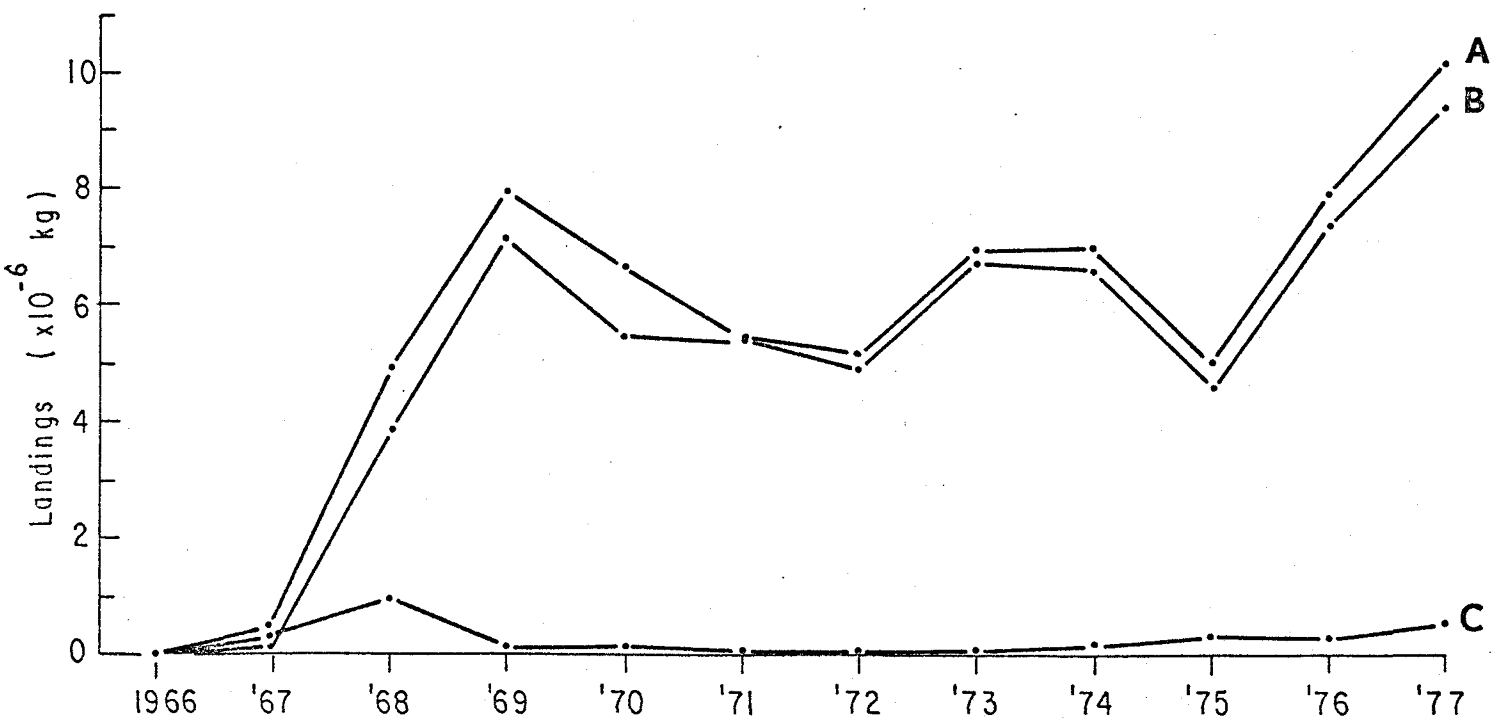


Figure.2.

Annual fishing efforts by New-Brunswick and Quebec snow crab fishery fleets.

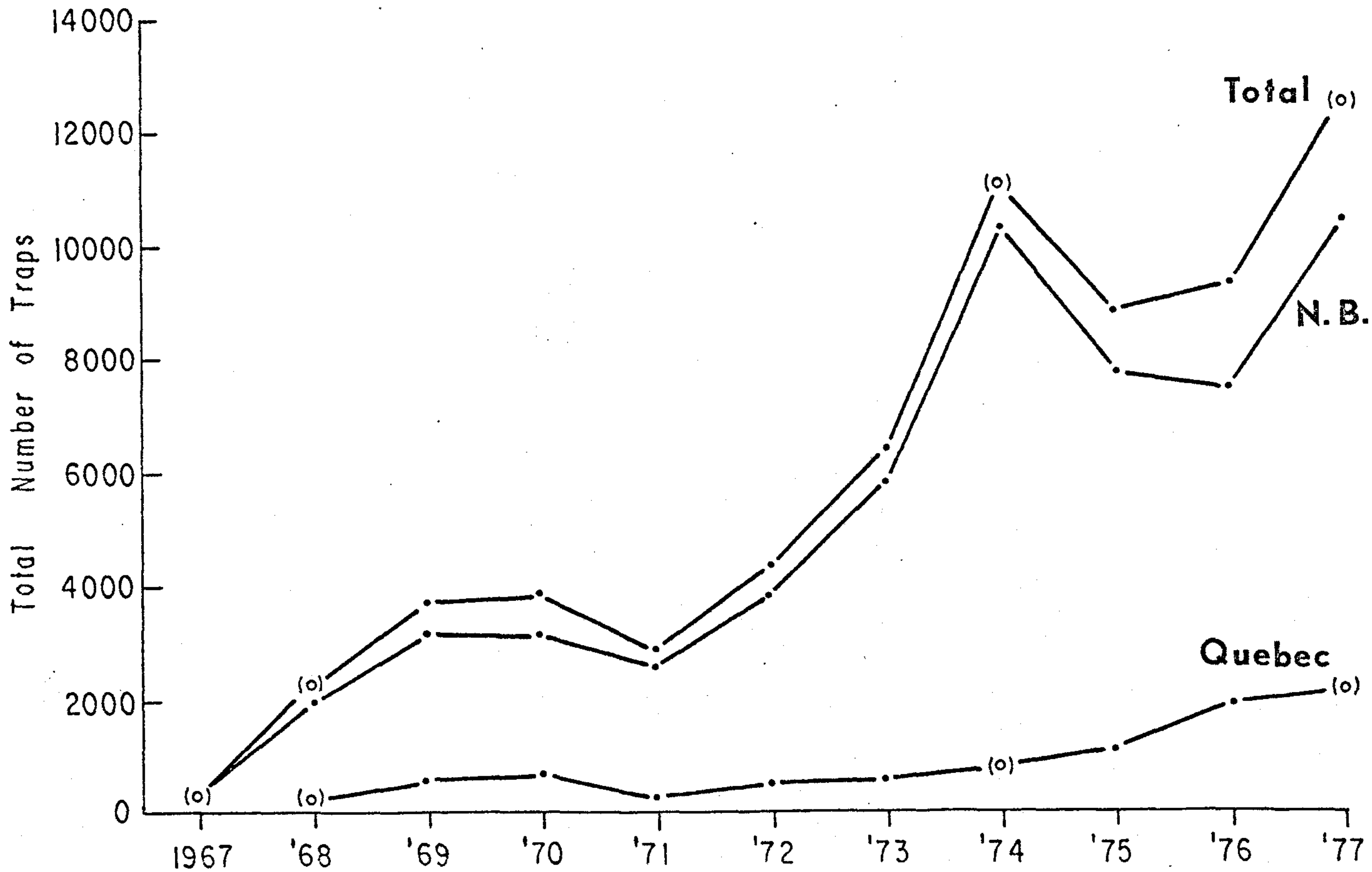


Figure.3.
Catch against effort from the snow crab fishery in the south-western Gulf of St.Lawrence

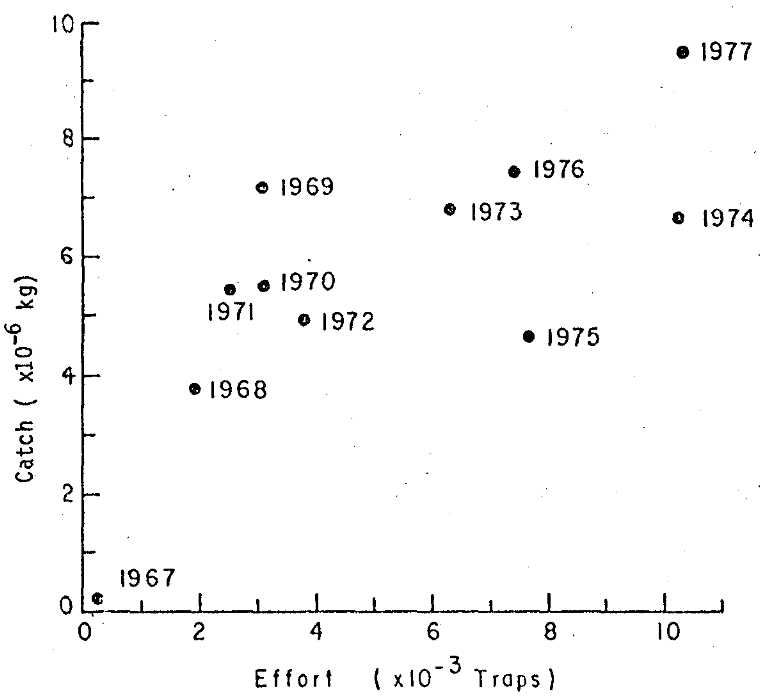


Figure 4.
Relationship between effort and y/f in the south-western Gulf of St.Laurence snow crab fishery for Graham-Schaeffer logistic model (linear regression) and for Gulland-Fox exponential model (exponential regression)

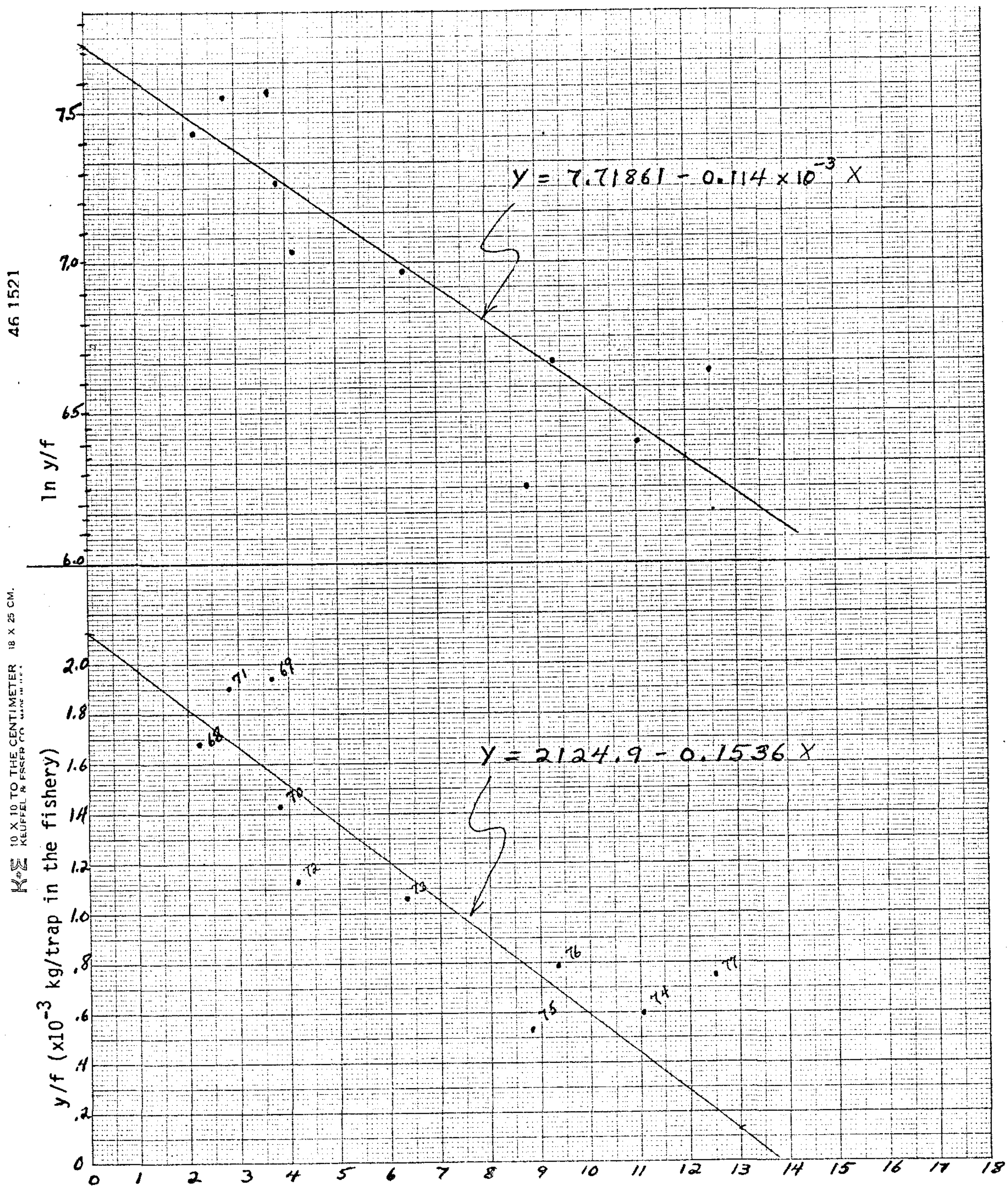


Figure 5.
Plot of yield against fishing effort and fitting equations A) $y/f = 2124.9 - 0.1536f$ (Graham-Schaeffer model) ; and B) $\log_e y/f = 7.71861 - 0.114 \times 10^{-3} f$ (Gulland-Fox exponential model)

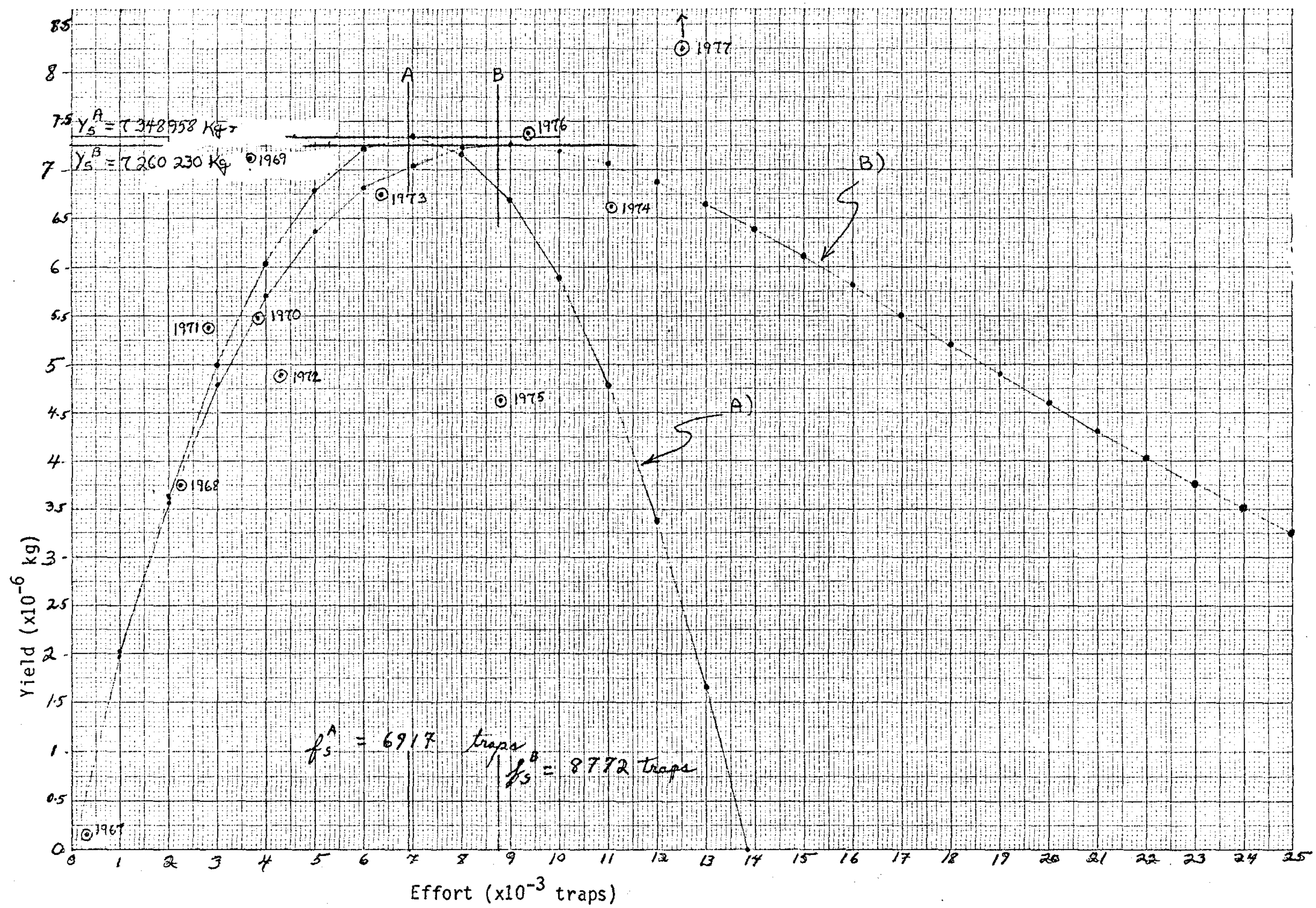
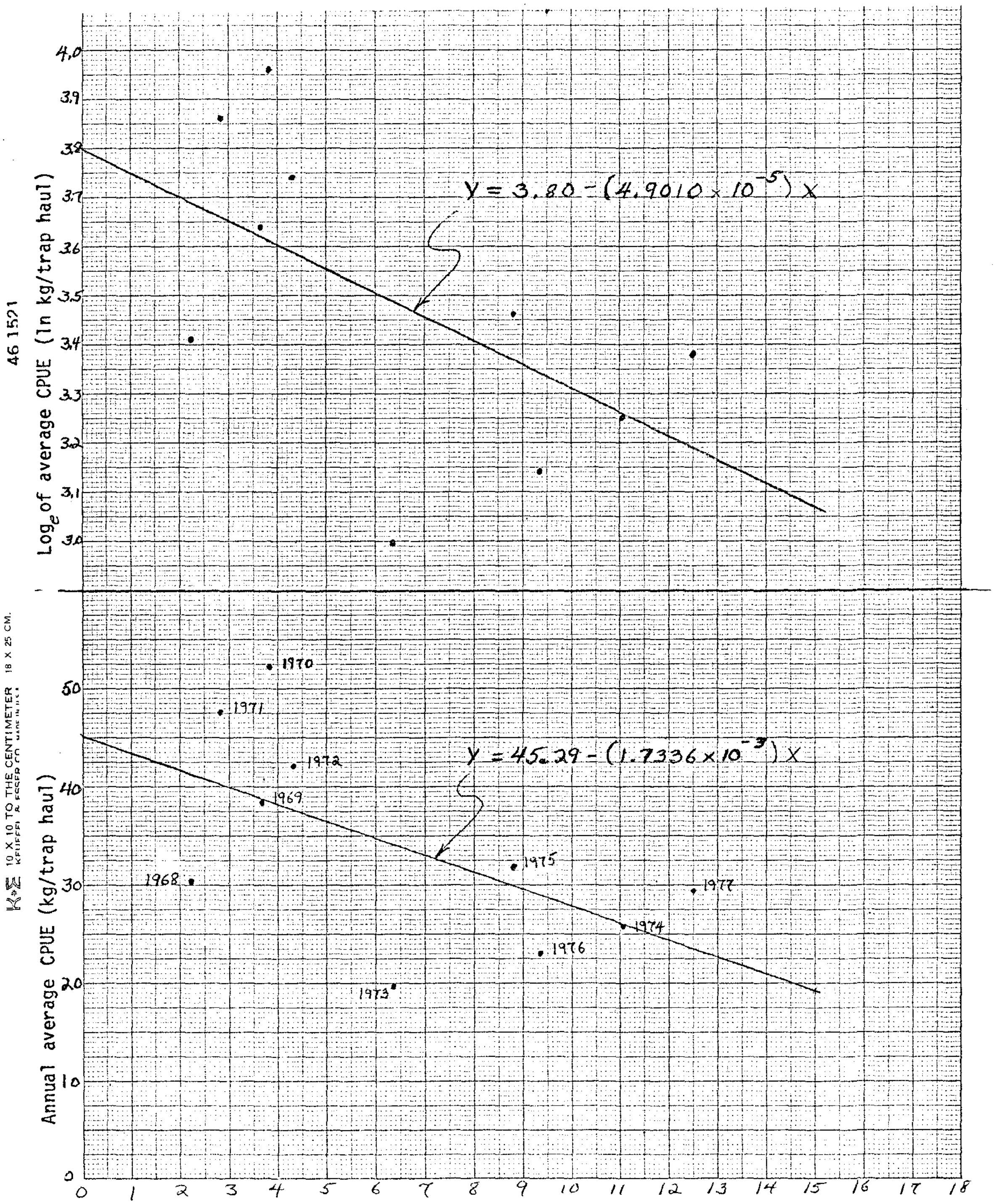


Figure 6.
Relationship between effort and CPUE in the south-western Gulf of St.Lawrence snow crab fishery for Graham-Schaeffer logistic model (linear regression) and for Gulland-Fox exponential model (exponential regression)



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1521

Figure 7.
Plot of yield against fishing effort and fitting equations A) CPUE = 45.29 - 1.833 x 10^{-3} Effort (Graham-Schaeffer model) ; and B) $\log_e$ CPUE = 3.80 - 4.901 x 10^{-5} Effort (Gulland - Fox model)

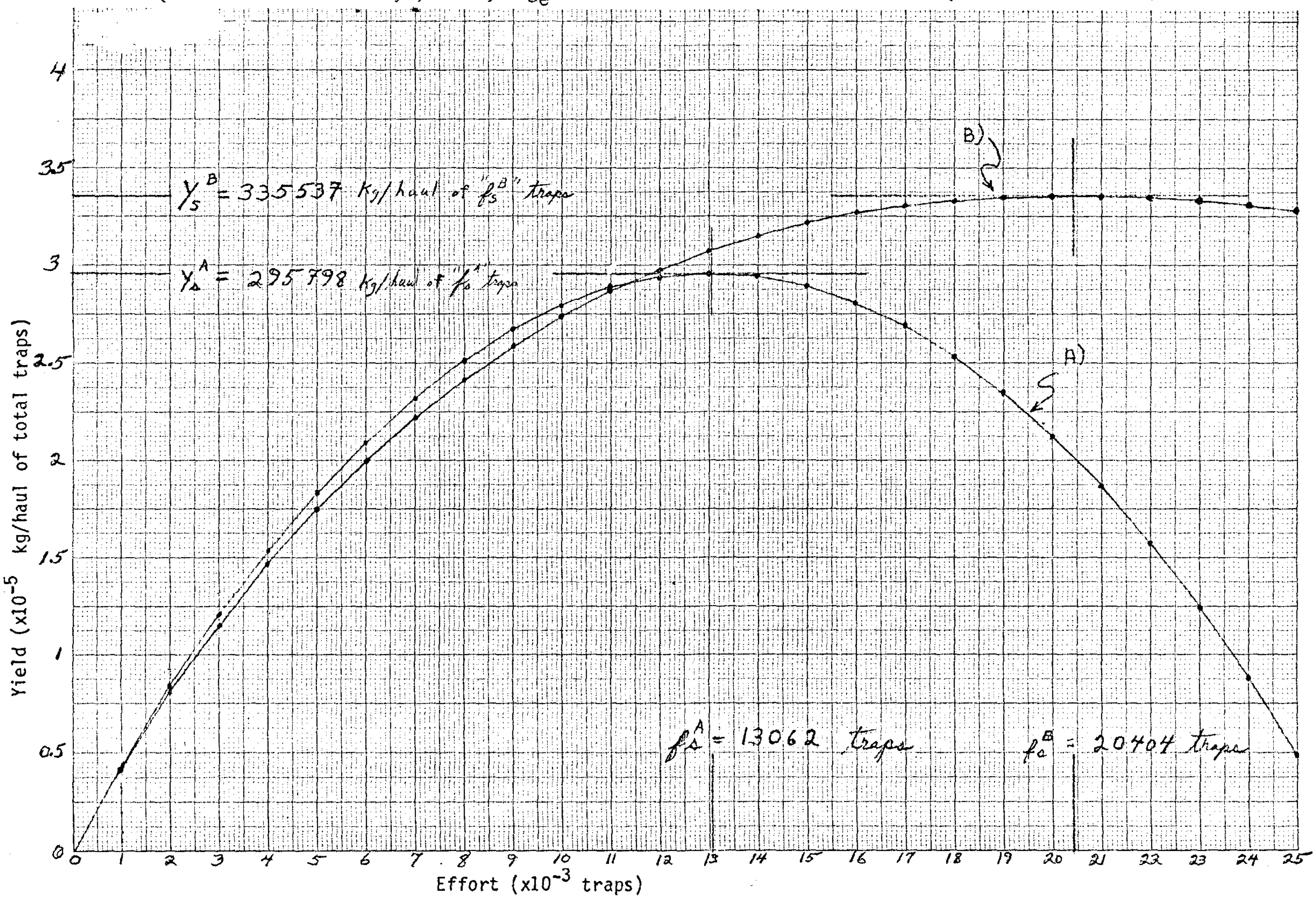


Figure 8a. Catch per unit of effort against cumulative catch in the southwestern Gulf for several years. Linear regressions for Leslie analysis.

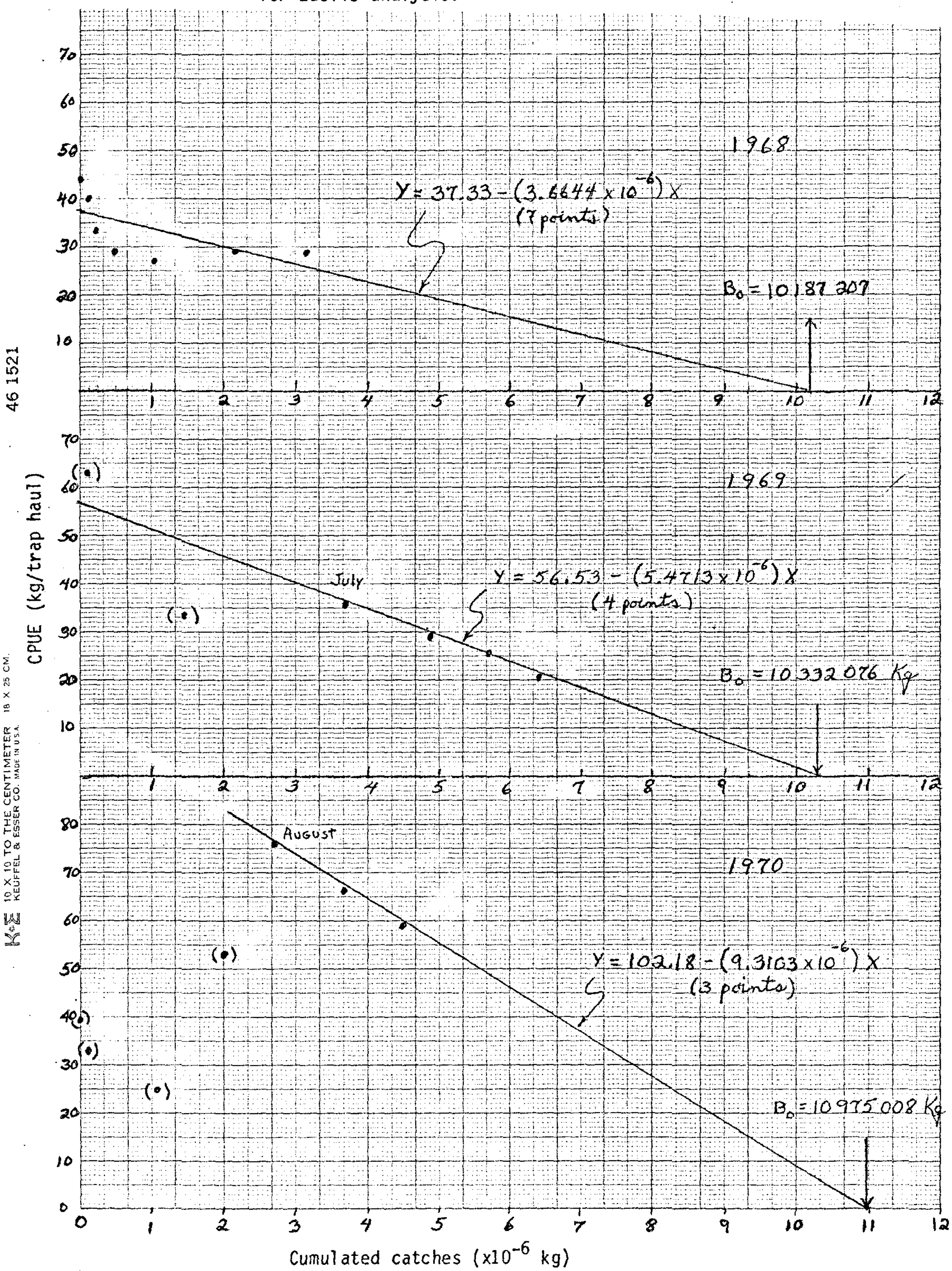


Figure 8b.
Catch per unit of effort against cumulative catch for Leslie analysis (continued).

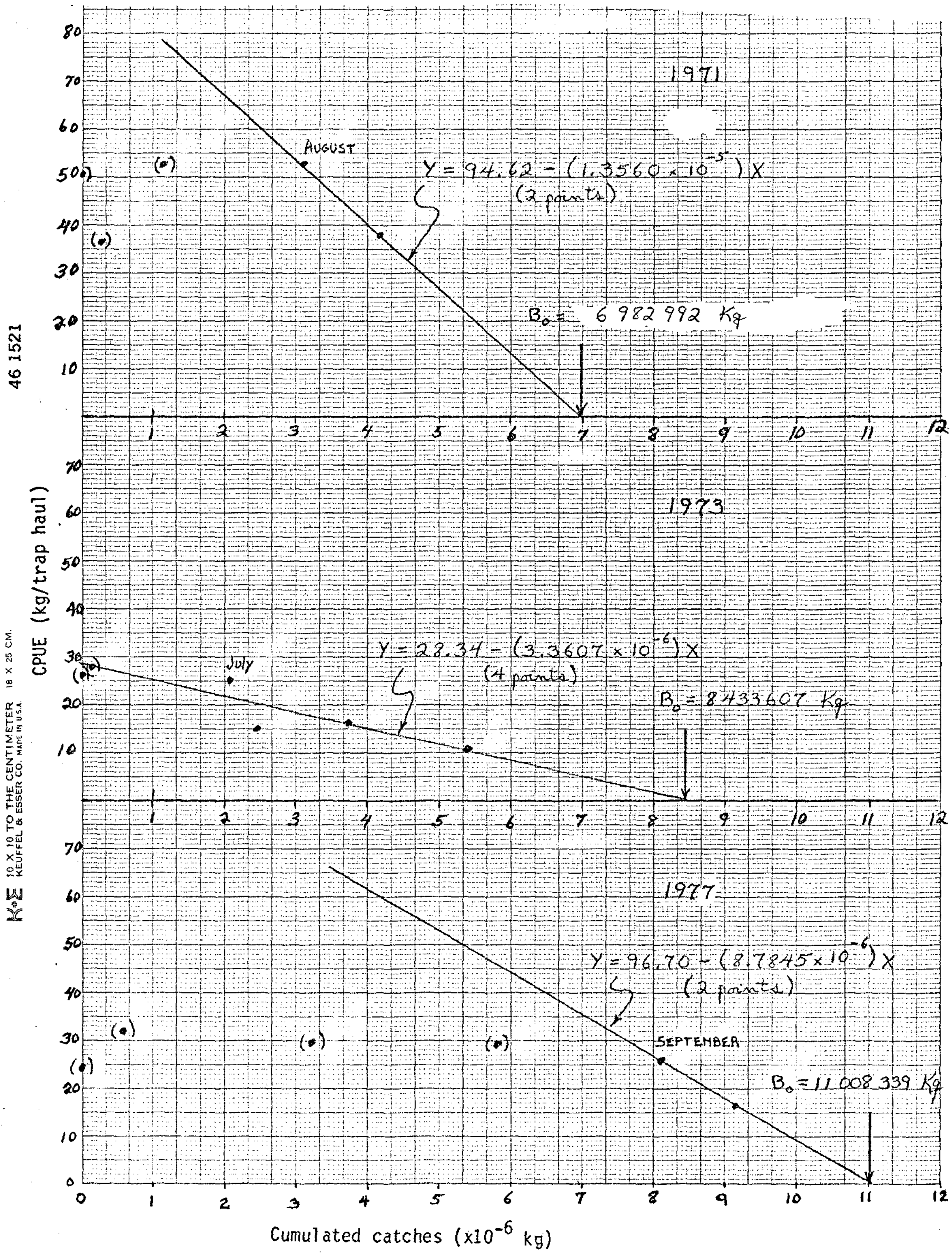


Figure 9a.
Catch per unit of effort against cumulative catch in the southeastern Gulf for 1967-1968. Linear regressions for Leslie analysis.

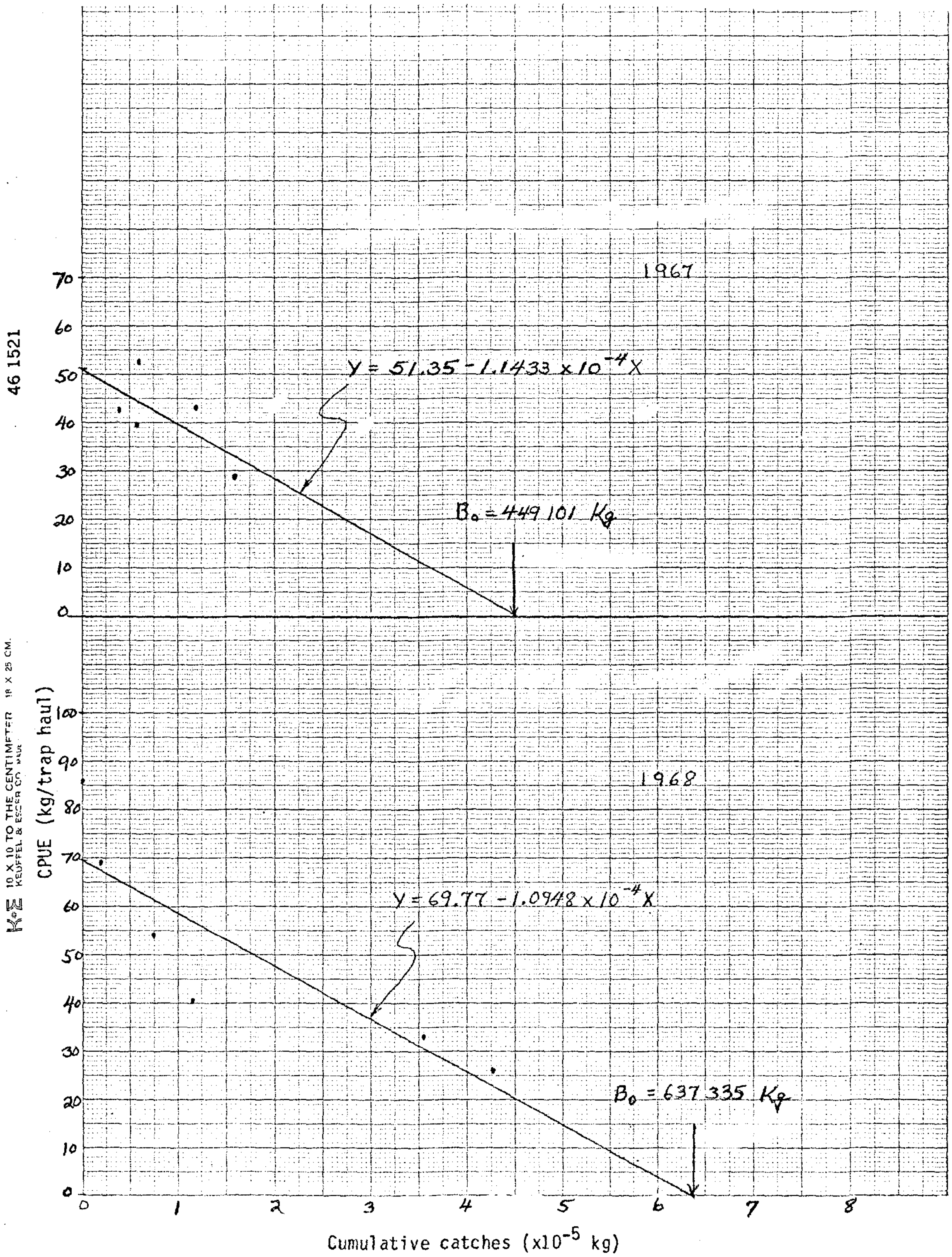


Figure 9b.
Catch per unit of effort against cumulative catch in the southeastern Gulf for 1969 and 1970. Linear regressions for Leslie analysis.

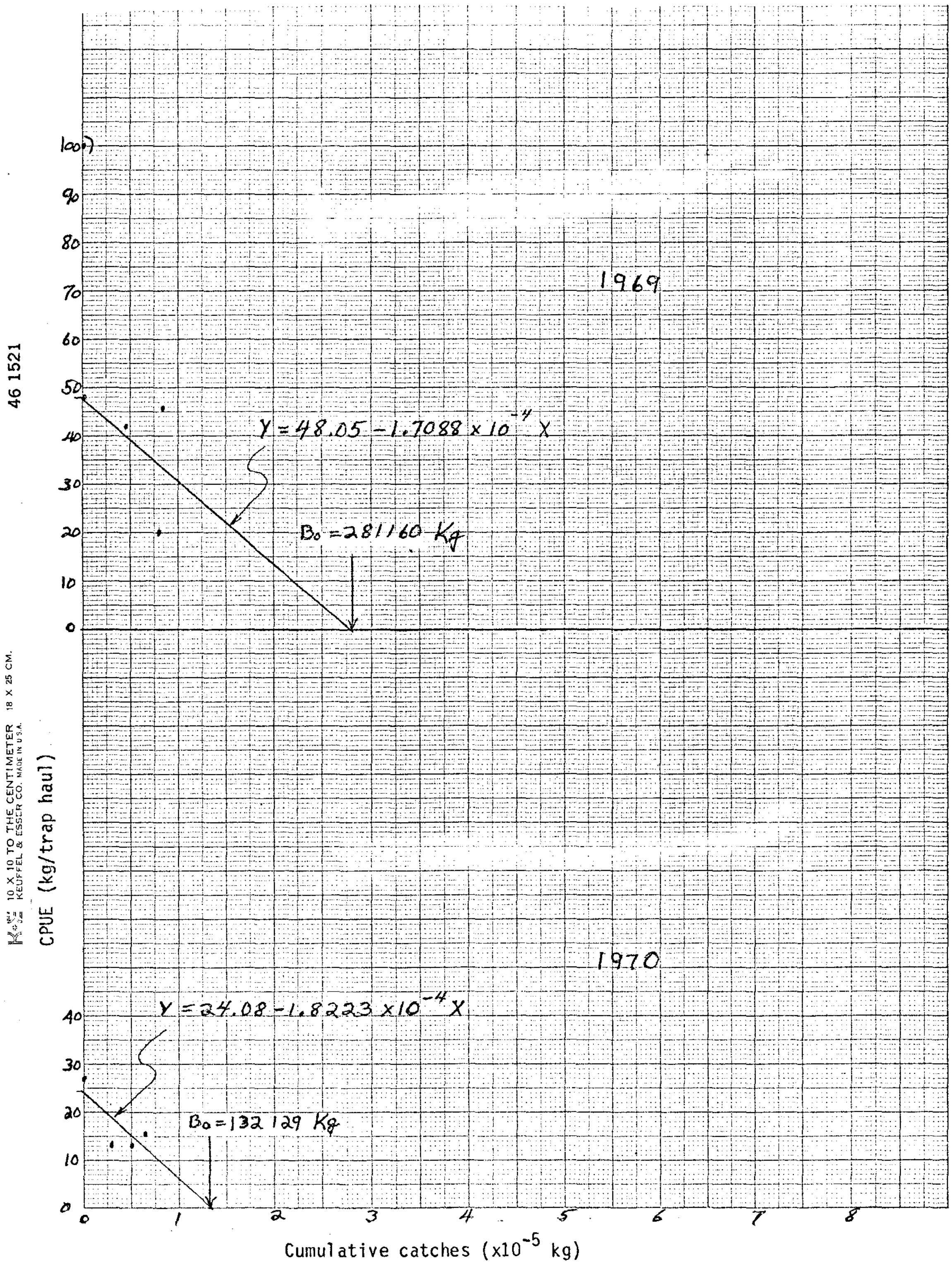


Figure 10.
Harding-Cassie analysis of size frequency for 630 hard-shell snow crab males caught in Chedabucto Bay, N.S., July 9 - 29, 1976.

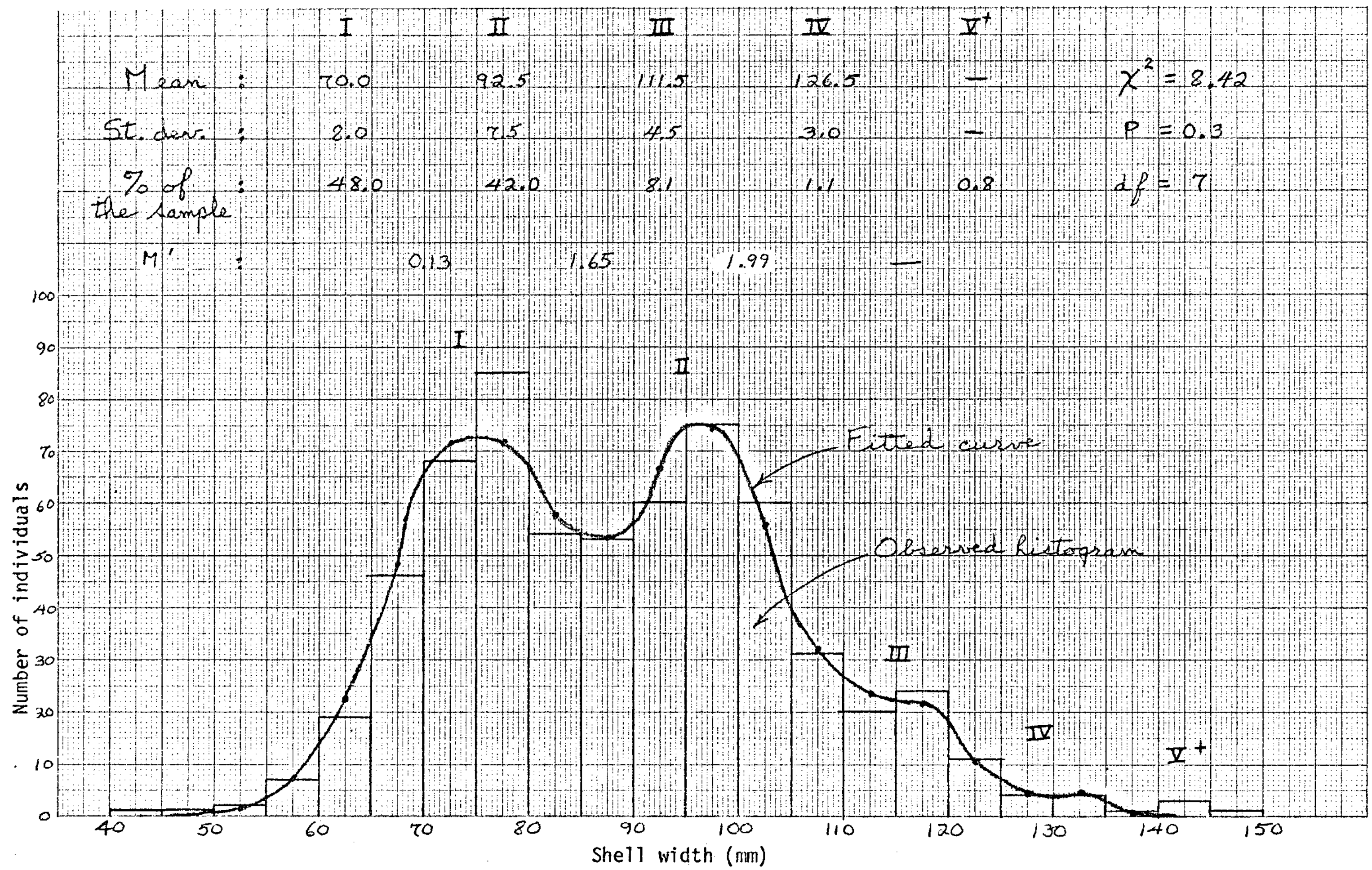


Figure 11.

Harding-cassie analysis of size frequency for 3024 snow crab males caught in Chedabucto bay, N.S., July-August 1970.

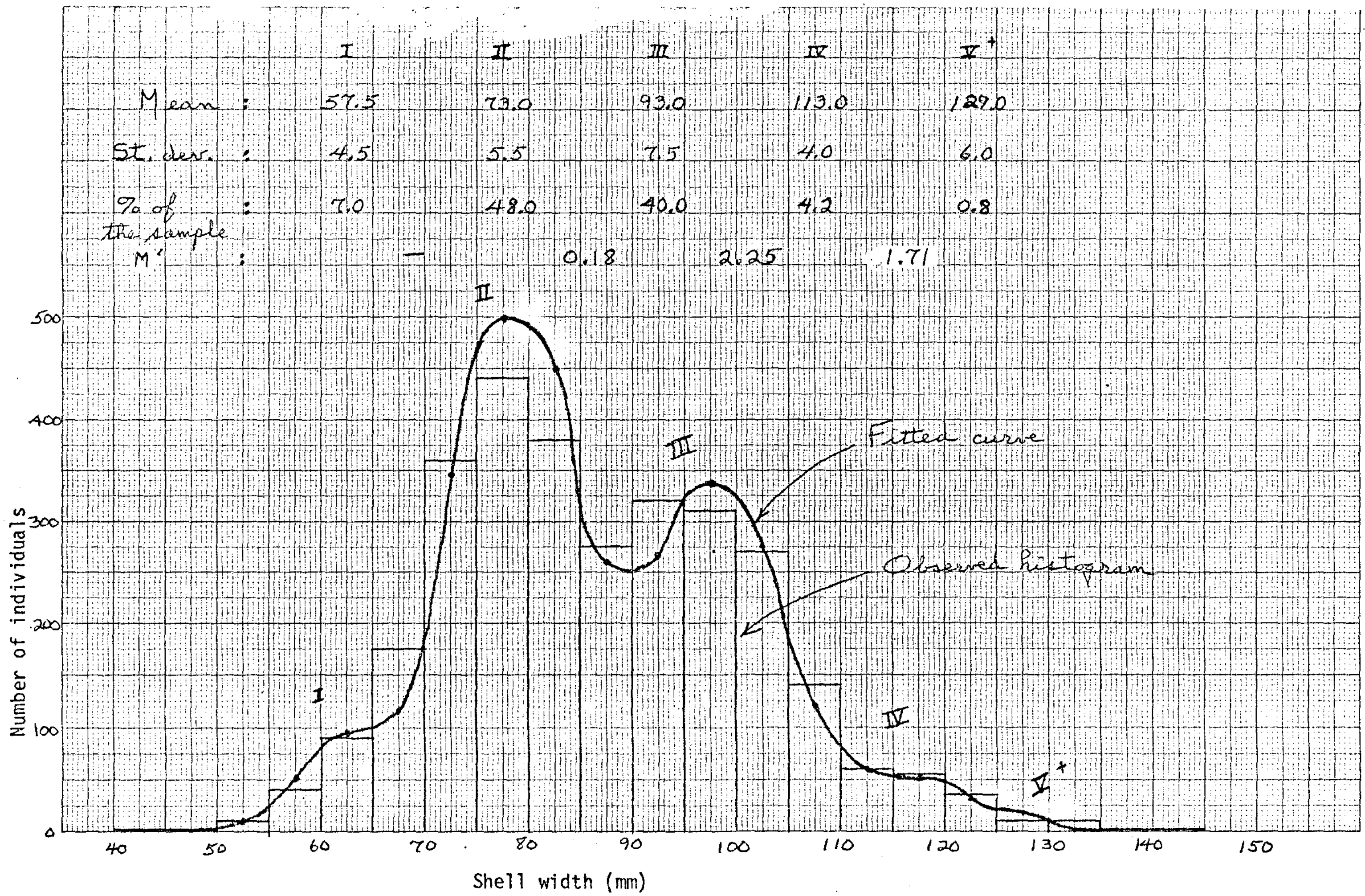


Figure 12.
Percentage increase per molt against pre-molt size from Miller & Watson and from polymodal size frequencies analysis on 1976 Chedabucto bay samples.

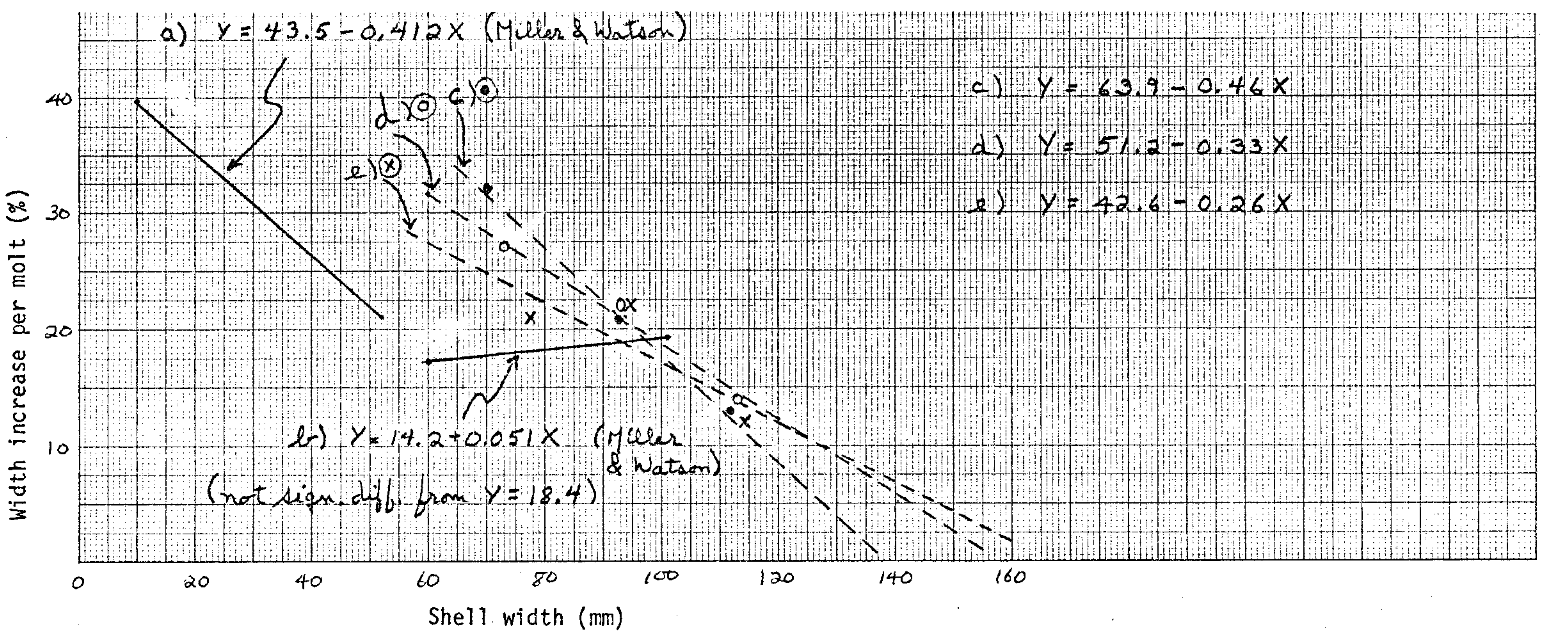
a) %increase for 131 male and female juveniles (10 - 52 mm premolt sizes) observed in the laboratory (Miller and Watson, 1976)

b) % increase for 18 mature males (60 - 101 mm) observed in the lab. (Miller and Watson, 1976)

c) % increase from Harding Cassie analysis (sample 1)

d) % increase from H.-C. analysis (Sample 2);

e) %increase from Bhattacharya analysis (Sample 2)



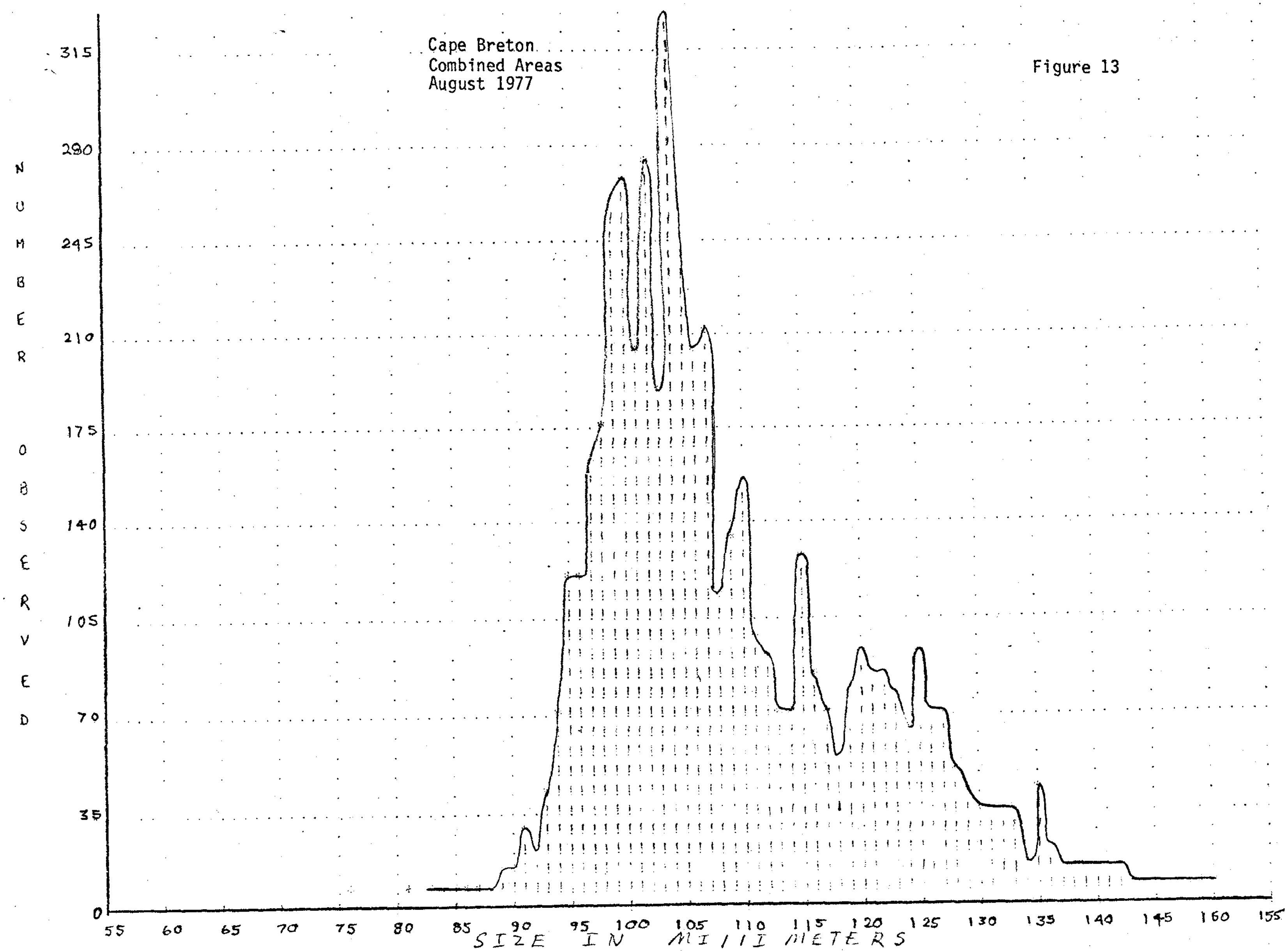

Cape Breton
Combined Areas
August 1977
Figure 13
NUMBER OBSERVED
315
280
245
210
175
140
105
70
35
0
55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 160 155
SIZE IN MILLIMETERS

Figure 14.
Catch curve with size frequency of crabs landed in New-Brunswick,1977. Monthyl size frequencies are weighted and combined in proportion of monthly landing values. Increase per molt are based on polymodal size frequencie analysis.

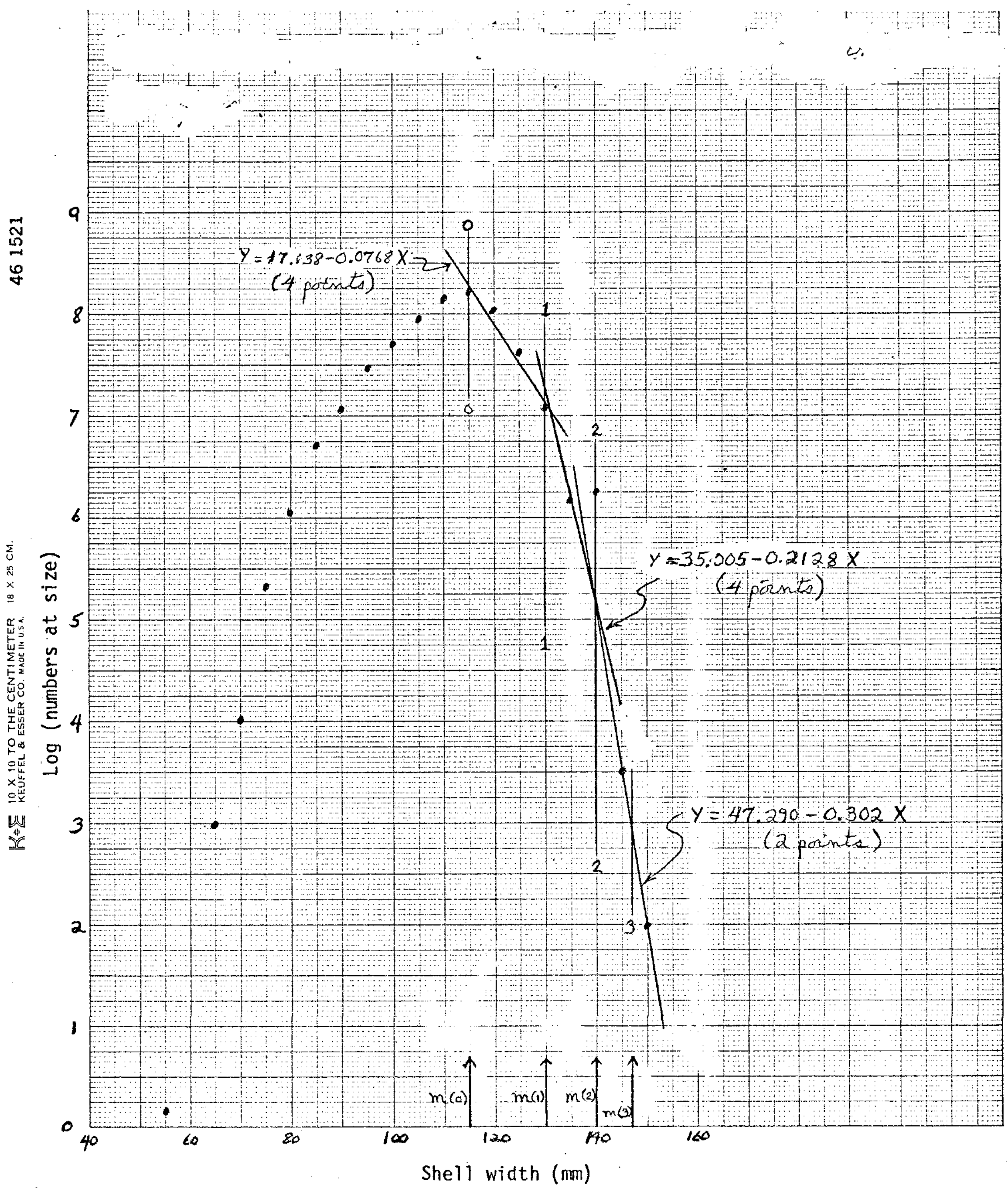
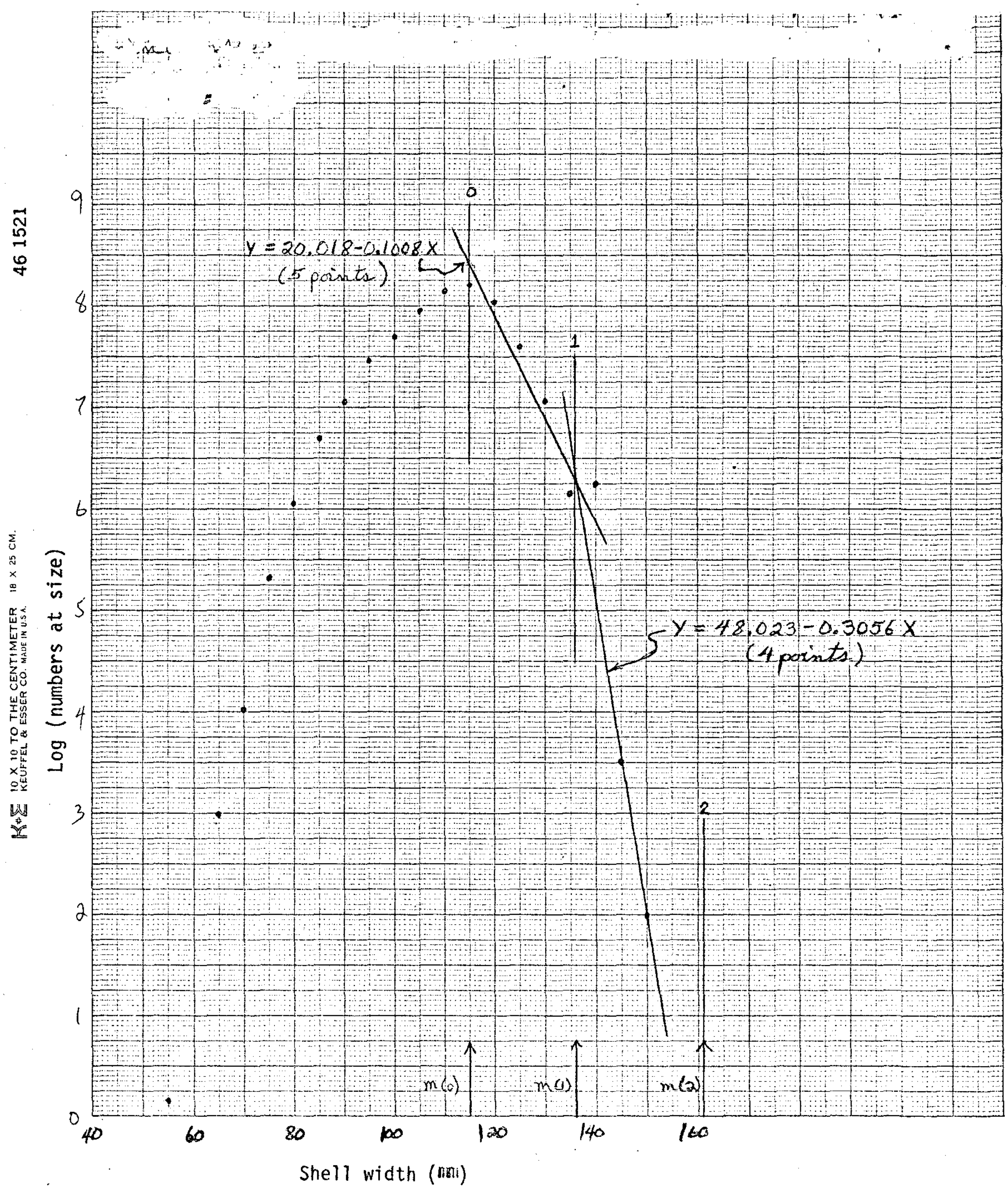


Figure 15.
Catch curve with size frequency of crabs landed in New-Brunswick, 1977.Monthly size frequencies are weighted and combined in proportions of monthly landin values. Increases per molt are based on 18.4% increase (Miller and Watson).Table 3



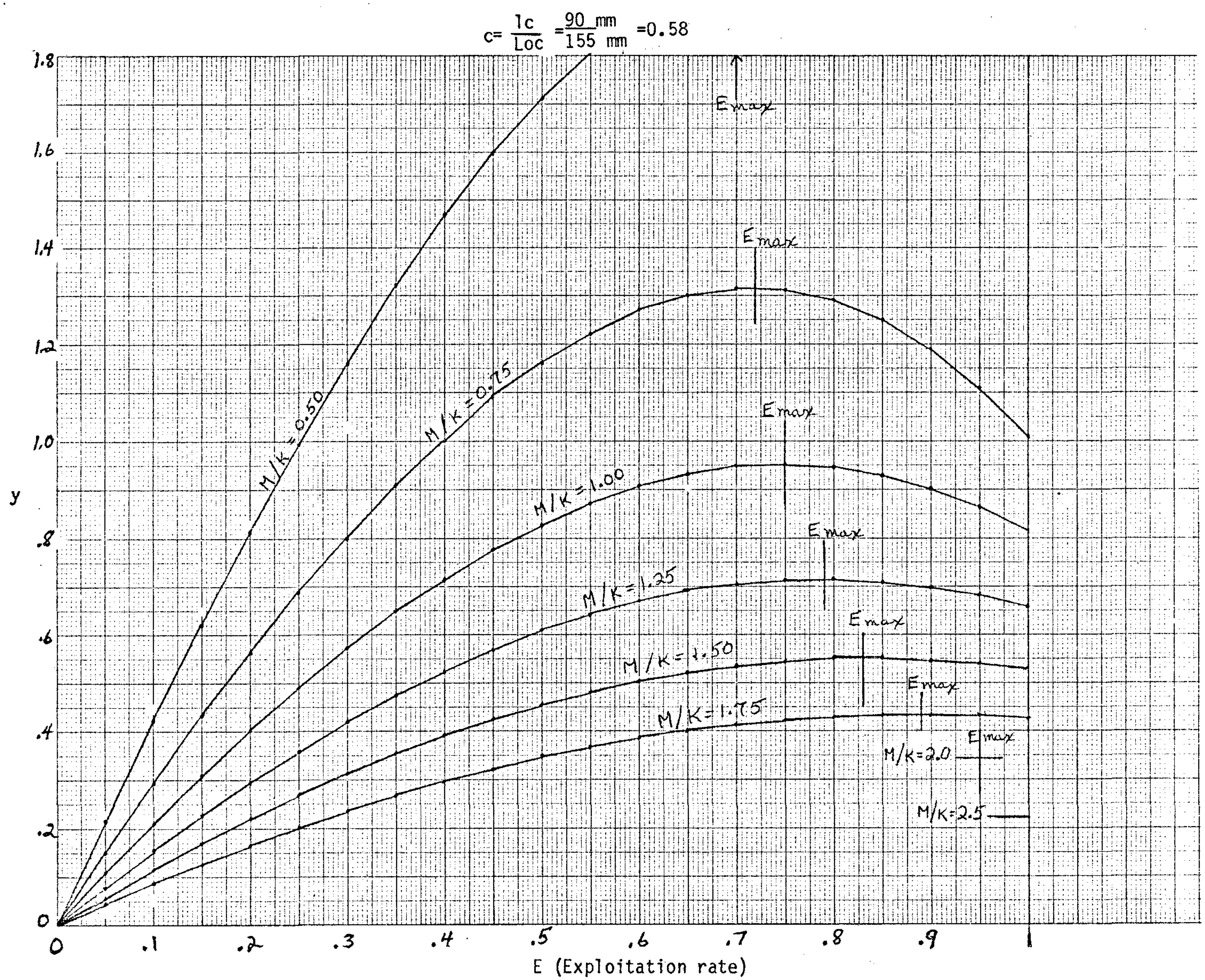


Figure 16.
Yield functions from Beverton and Holt tables for the snow crab fishery in the Gulf of St.Lawrence.