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Analysis of the snow crab population in northwestern Cape Breton, 1978

by

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Introduction

In the past few years, the yield obtained by the male only snow crab fishery in the northwestern Cape Breton has been increasing steadily. Together with the impressive catch rates, it suggests that the crab population is not optimally exploited and more fishermen could be admitted into the fishery. A decision on a suitable level of exploitation requires good estimates of standing stock, annual recruitment, growth, mortality and catchability of the gear.

For that purpose, a tag-recovery study combined with catch-effort data analysis was initiated in 1978. The results from the first year of monitoring are analyzed in this document.

State of the fishery

A total of 13 licensed boats from Pleasant Bay, Bay St. Lawrence and Chēticamp (Fig. 1) were fishing in the northwestern Cape Breton area. This area was restricted by regulation. Two boats from New Brunswick have been fishing outside it, in nearby locations. Their catch and fishing grounds are not considered here as being part of the northwestern Cape Breton fishery.

Limited by regulation, 12 boats were fishing 30 rectangular traps of 1.5 x 1.5 x 0.5 m and one was fishing 60 conical traps, height 60 cm, bottom and top diameters, 120 and 60 cm respectively. A season of 3 mo beginning on the last week of June and ending on the last day of September was accepted by the fishermen. Weather permitting, all boats were doing daily trips except on Sunday, hauling their traps once every day.

The fishing power has changed from approximately 212 rectangular traps, 125 conical traps and 60 wooden traps in 1977 to 360 rectangular traps and 60 conical traps in 1978. Together with this increase in effort, the catch increased substantially from 516 MT in 1977 to 1,941 MT in 1978. Limited information indicates that the overall CPUE in 1977 was approx. 59 kg/trap haul for the rectangular traps and 26 kg/trap haul for the conical traps. The higher overall CPUE of 73.6 kg/trap haul (rectangular traps) and 44.8 kg/trap haul (conical traps) in 1978 suggests either or both of the following: 1) a larger area was fished in 1978; or 2) crabs were more abundant in 1978.

Material and Methods

Log books were issued to each fisherman at the beginning of the fishing season. Details on catch, effort and location were recorded for every fishing day. In order to obtain cooperation and accurate data, logs were collected weekly by a permanent observer for most of the season. The observer was also responsible for getting the information on date, location and number of tag recoveries made by the fishermen.

Marking was done on commercial boats between July 1 and 12, during the second and third week of the fishing season. Male crabs were selected randomly from the traps, tagged and returned at sea as quick as possible. Eight trips were made in different locations in an attempt to accelerate the random distribution of the marked individuals on the fishing ground Fig. 1).

The tag used for population studies was a long yellow vinyl tubing tied around the body of the animal. A total of 3,951 crabs were marked. Of those, 1,398 were identified as old hard shells, and 996 as soft shells, including intermediates. Shell hardness for the remaining 1,557 was not recorded. All individual tags were numbered so that recoveries could be compiled in categories of shell hardness and size. Size frequencies of the marked individuals (Fig. 2) indicate that crabs in both shell conditions had a similar size distribution.

An approximate estimate of mortality caused by the tagging operation was obtained by placing 48 crabs marked with a sphyrion tag and 49 crabs unmarked in traps returned at sea and hauled back the following day.

Analysis of log book data

Catch and effort data were compiled on a weekly basis starting on June 22 (Table 1). To obtain a standardized total effort in each week, necessary for the analysis of the tag returns, the effort from the conical traps were transformed in rectangular trap units by dividing the weekly catch obtained in the conical traps by the CPUE value of the rectangular traps for the corresponding week. The resulting units of effort were added to the effort from the rectangular traps.

An estimate of usable stock (B) could be obtained by a Leslie analysis, plotting cumulative catch against CPUE by the rectangular traps (Fig. 3). The peculiar shape of the graph is reflecting a constant addition of biomass to the stock for the seven first weeks of the season. During this period, the presence of freshly molted crabs indicates that, despite the removal of approximately 1,250 MT by the fishery, recruitment and growth are aintaining the available biomass to almost the same level. We can see the CPUE decreasing slowly from 86.4 kg/trap haul to 71.7 kg/trap haul and then rising again to 80.7 kg/trap haul. After the seventh week of the season (3-9 August), all crabs in the catch had a shell more or less hardened, indicating that the molting period was over. From this time to the end of

September, the CPUE shows a constant linear decrease. Regression gives the linear equation: $CPUE_t = 142.63 - (4.73 \times 10^{-5})\ K_t$ (r^2 = 0.93). B can be estimated as the intercept on the x-axis which is 3,016 MT. Limits of confidence at a probability level of 95% are 2,722 MT and 3,533 MT. Substracting the total catch (Y), we calculate that 1,075 MT (35.6% of B), with limits of confidence of 780 MT (28.7%) and 1,592 MT (45.1%), were left on the ground at the end of the fishery.

If the natural mortality was not significant during the fishing season, we can estimate the rate of exploitation (u) from Y/B as being 0.644 with corresponding limits of confidence of 0.549 and 0.713.

The slope of the linear regression gives an estimate of catchability (q) by the rectangular traps of 4.73×10^{-5}. Assuming it is constant throughout the fishing season, we can calculate from any CPUE value the corresponding biomass (B_t) present on the fishing ground at that time from:

$$\frac{CPUE_t}{q} = B_t$$

A CPUE of 86.4 kg/trap haul, obtained in the first week of the season, corresponds to an available biomass of 1,827 MT (Table 1). Considering that through the fishing season, 3,016 MT was the total biomass usable by the fishery, we can calculate a net contribution of 1,189 MT from growth and recruitment. This is 65.1% of the initial available biomass and 39.4% of the total.

Analysis of tagging data

1. Estimates of survival

Percentage of marked crabs remaining at the end of the fishing season were estimated using the Leslie graph technique. CPUE were obtained by dividing the number of recaptures (Table 2) by the total effort in rectangular trap units for each week (Table 1). When plotted against cumulative number of recaptures, the total number of marked crabs available to the fishery can be estimated by linear regression (Fig. 4-7). The last week data were excluded from the calculations since they seem abnormally high.

Two different regressions were performed on data for hard-shell, soft-shell, indeterminated and combined crabs marked with body tags. One includes all twelve data points, the other excludes the first two weeks data. The high values of these two weeks indicate probably that the crabs were not yet dispersed on the fishing ground. Furthermore, the catchabilities (q), which are estimated by the slope values, are much more similar to the one estimated from the catch and effort data of the fishery (4.73×10^{-5}) in the second regression (4.1, 4.2, 4.0 and 4.1×10^{-5}) than in the first (8.3, 6.7, 5.8 and 13.7×10^{-5}). For this reason, the estimates from the second regression will be used for future calculations.

To obtain the number of marked individuals surviving at the end of the fishing season (Table 3), the number of recaptures (R) is subtracted from the total number of marked individuals available to the fishery (M'). An instantaneous rate of total mortality or disappearance (Z') from the time of marking to the end of the season can be estimated from the survival rate.

2. Petersen estimate of biomass

The simple method of Petersen cannot be used for the whole period under study because recruitment is taking place during the first seven weeeks of the fishing season. As confirmed by the Leslie graph on Fig. 3, the situation is stabilized for the remaining weeks. A Petersen estimate of total biomass can thus be obtained for week 8 (B_8), using data from weeks 8 to 15 only:

$$B_8 = \frac{C_{8-15} \times M_8}{R_{8-15}} = \frac{631.2 \text{ MT} \times 1479}{533} = 1751.4 \text{ MT}$$

where C_{8-15} = total catch during weeks 8-15

M_8 = apparent total number marked less the recaptures up to week 8

R_{8-15} = total recaptures during weeks 8-15

This compares well with the estimate of 1,707 MT obtained for week 8 (Table 1) using the formula of page 4.

3. Estimates of mortality

A) Of the 48 crabs marked with sphyrion tags and left in traps at sea for 1 d, 6 were found dead, while 7 of the 49 unmarked crabs were dead. Being similar, these results can be combined and used to give a rough estimate of mortality caused by the action of handling crabs on board for marking and returning them at sea. Mortality rate was 7% for the hard-shell crabs and 18% for the soft-shell ones. Since we marked 59% of hard-shell and 41% of the soft-shell crabs, we can approximate to 11.5% the mortality rate of the total crabs marked with body tags (Table 3).

Subtracting this mortality factor (X) from the initial number marked

(M), the fraction of the remaining that is recaptured is an estimate of the fishing rate (Table 3). The difference between what should be left, after tagging mortality and fishing rate are subtracted, and what we estimate as remaining on the ground (M' - R), is what has disappeared from other causes such as natural mortality, molting, emigration and tag loss (X').

B) Tagging data can also be analyzed for mortality estimates using the following formula described in Gulland (1965):

$$\ln n_r = -(F+X)tr + \ln \frac{FNo}{F+X}\left(1-e^{-(F+X)t}\right)$$

where: t = length of the time interval

r = number of the interval, the first one being 0

n_r = number caught during the rth interval

No = initial number of marked individuals at beginning of first interval

F = instantaneous rate of fishing mortality

X = instantaneous rate of reduction of tags from other causes

When $\ln n_r$ is plotted against r, the result is a straight line, with a slope of $-(F+X)t$.

Since mixing of tagged crabs has occurred during the first 2 wk, only the data from the 11 following weeks have been used and the time intervals are then $t = 1/11$. No was estimated as M less tagging mortality and less the number of tags returned during the initial period of mixing. By iteration, an estimate of loss through other causes, X', was also removed from M.

Total "mortality" F+X can be estimated for this period from the value of the slope. We can also estimate F, using the intercept on the y-axis, which from the equation is

$$\ln \frac{FNo}{F+X}(1-e^{-(F+X)t}),$$

and solving for known values of F+X, No and t. The resulting estimates of F+X and F for hard-shell, soft-shell, indeterminated and total crabs marked with body tags are given in Table 4.

Several types of error that can affect these estimates do not apply or have been corrected here. Emigration is probably not a significant factor. Watson and Wells (1972) have demonstrated mainly short-distance movements in snow crab. Besides, the fishing ground for snow crab in this area is quite well delimited by the 50-fathom isobath beyond which environmental factors don't seem to be suitable for commercial size crabs.

Constant contact with fishermen and rewards ensured an almost complete reporting of recaptured tags which were obvious enough not to be overlooked.

Death of crab immediately after tagging has been taken into account before using the value for No in the equation.

The initial period of mixing of the tagged crabs with the untagged population was eliminated by removing the first 2-wk data points. As explained earlier, the values for q obtained with the remaining data seems to confirm that a uniform distribution has been reached by then.

Tags were fastened around the shell of the crabs in such a way that it was almost impossible for them to slip off. The elastic texture of the vinyl tubing also ensured a stable knot.

Molting which occurred during the fishing period has certainly caused several losses of tags. Such a factor should normally affect the total mortality but not that of fishing. In fact, it should be estimated by X, combined with natural mortality. Unfortunately, molting was not occurring at a steady rate throughout the experiment. It is thus likely to have affected the fishing mortality estimate (F) as well.

Discussion and Summary of 1978 Fishing Season

Approximately 1,827 MT was available to the snow crab fishery at the opening of the fishing season. Growth and recruitment has contributed a further 1,189 MT through molting that occurred until early August. From the total of 3,016 MT, the fishery has removed 1,941 MT or 65.1% in 15 wk with a total effort of 26,301 trap hauls (in rectangular trap units).

Size frequency of crabs caught in August can be used to calculate a relative contribution from both recruitment of new individuals and growth of commercial ones to the biomass increase observed in the summer. Size of soft-shell crabs (assumed to have molted) were back-calculated by 18.4% (Miller and Watson 1976). Weight before and after back-calculation was obtained from $W = .00018\ S^{3.16}$ (Sandeman, cited by Miller and Watson 1976).

This procedure reveals that the total weight increment of the recently molted crabs represents 32.6% of the weight of the sample. Similarly, our estimate of 1,189 MT increase over a total of 3,016 MT available is 39.4%

A weight increase from recruitment can be estimated from the individuals falling under the size limit of 95 mm when back-calculated. The difference in weight for the others gives the increase from growth of crabs already available to the fishery. The proportions obtained are 84% from new recruits and 16% from growth.

We then assume that 84% of 1,189 MT or 999 MT was the recruitment, and 16% or 190 MT was growth of the initial stock.

From the analysis of log books we estimated an exploitation rate (Y/B) of 0.644 with limits of confidence of 0.549-0.713. Corresponding values for F are 1.03 and 0.78-1.25. These are somewhat overestimated since without natural mortality, which is not taken into account here, the total available stock (B) would have been higher.

In Table 3, summarizing the tagging results, the rates of exploitation (R/M') were 64.6%, 61.7%, 69.3% abd 65.3% for hard-shell, soft-shell, indeterminated and total crabs respectively. Corresponding values for F are 1.04, 0.96, 1.18 and 1.06.

The rate of disappearance from molting and natural mortality is at a minimum for the hard-shell crabs. A possible hypothesis would be that these crabs have reached a terminal molt stage or at least have a very low proportion of molting. This seems to be reflected by the somewhat higher percentages of tag returns among the large size classes of hard-shell crabs (dots in Fig. 2). The rate of disappearance of 1.6% would then be attributed to natural mortality only. The instantaneous rate multiplied by 4 to extrapolate for 1-yr period would be 0.065.

Estimation of mortality rates with Gulland's equation is reliable under the assumption that fishing rate was constant throughout the experiment. Unfortunately, weather conditions tend to be worst at the end of the fishing season, resulting in a reduction of the effort toward the end of the season (Table 1). The effect on the returns would introduce an overestimation. These estimates, nevertheless, serve to set upper limits of 1.24 for F and 0.84 for X.

In conclusion, F value is between 0.78 and 1.25, most probably close to 1.00. This corresponds to an exploitation rate of 63%.

Tentative Forecast for 1979

In 1978, the fishery has left on the ground approximately 1,075 MT, with limits of confidence of 780-1,592 MT. Since most of the suitable bottom for snow crab has been exploited in 1978, a significant contribution of biomass from an untouched area is not expected in 1979. Natural mortality rate (M), tentatively estimated at 0.065, would reduce this stock to 1,024 MT (743-1,516 MT) after 9 mo.

Unaccounted molting, before the end of June, would increase the standing crop available for the opening of the fishing season.

It is unlikely that the fishery has a negative effect on recruitment. Only male snow crabs are harvested and their culling size is well above the size at maturity. Instead, it probably enhances the productivity of the population by reducing the competition for food. Recruitment is subject to environmental conditions, and basic knowledge and data are not available to predict its level for 1979.

Assuming a similar situation as in 1978, approximately 1,000 MT will be recruited to the fishery during the season. A further 16% of 1,024 MT, or 164 MT (limits of 119-243 MT) will be added by growth of the initial standing stock, for a total exploitable stock of 2,188 MT (limits of 1,863-2,759 MT).

References

Gulland, J. A. 1965. Manual of methods for fish stock assessment. Part 1. Fish population analysis. FAO Fish. Tech. Paper No. 40, Revision 1.

Miller, R. J., and J. Watson. 1976. Growth per molt and limb regeneration in the spider crab, *Chionoecetes opilio*. J. Fish. Res. Board Can. 33: 1644-1649.

Watson, J., and P. G. Wells. 1972. Recaptures and movements of tagged snow crabs (Chionoecetes opilio) in 1970 from the Gulf of St. Lawrence. Fish. Res. Board Can. Tech. Rep. 349.

Table 1. Catch and effort statistics for the snow crab fishery in northwestern Cape Breton, 1978.

Week period	Effort (trap hauls) 1.5x1.5x 0.5 m	conical	combined[1]	CPUE (kg/trap haul) 1.5x1.5x 0.5 m	Catch (MT)	Estimated biomass (MT)
1. 22-28 June	1683	510	1986	86.4	171.6	1827
2. 29-5 July	1930	410	2182	85.3	186.2	1804
3. 6-12 July	2339	460	2652	81.7	216.5	1728
4. 13-19 July	1964	400	2238	72.5	162.3	1533
5. 20-26 July	1882	380	2146	71.7	153.9	1516
6. 27-2 August	2527	480	2803	77.4	217.2	1637
7. 3-9 August	2277	400	2508	80.7	202.5	1707
8. 10-16 August	991	160	1071	80.7	86.3	1707
9. 17-23 August	1541	320	1721	72.9	125.4	1542
10. 24-30 August	1164	210	1282	68.9	88.2	1457
11. 31-6 September	1535	320	1701	62.7	106.7	1326
12. 7-13 September	1086	200	1183	59.7	70.7	1263
13. 14-20 September	668	210	765	51.8	39.7	1095
14. 21-27 September	1647	80	1681	55.4	93.2	1172
15. 28-3 October	382	0	382	55.0	21.0	1163
Total	23616	4540	26301	-	1941.3	-

[1]See explanations in text on how efforts from both types of trap were combined.

Table 2. Number of tag returns from the snow crab fishery in northwestern Cape Breton, 1978.

Week period	Total	Hard-shelled	Soft-shelled	Indeterminated
3. 6-12 July	437	178	67	192
4. 13-19 July	320	138	84	98
5. 20-26 July	183	85	47	51
6. 27-2 August	194	106	40	48
7. 3-9 August	110	56	27	27
8. 10-16 August	70	38	21	11
9. 17-23 August	70	30	19	21
10. 24-30 August	85	44	24	17
11. 31-6 September	111	54	33	24
12. 7-13 September	46	24	8	14
13. 14-20 September	24	13	3	8
14. 21-27 September	88	38	25	25
15. 28-29 September	39	22	7	10

Table 3. Survival and mortality estimates from the tagging study.

Estimates	Total crabs	Hard-shell crabs	Soft-shell crabs	Indeterminated
-Initial number marked - (M):	3951	1398	996	1557
-Mortality (nb.) from marking - (X): (rate observed experimentally)	454 (.115)	98 (.07)	179 (.18)	179 (.115)
-Actual number marked - (M-X):	3497	1300	817	1378
- Apparent number marked - (M'): (limits of confidence at P = .05)	2723 (2048->3951)	1279 (948->1398)	656 (432->996)	788 (668->1557)
-Number recaptured - (R):	1777	826	405	546
-Rate of fishing - (R/M-X):	.508	.635	.496	.396
-Rate of fishing - (R/M'):	.653	.646	.617	.693
-Estimated number remaining - (M'-R):	946 (271->2174)	453 (122->572))	251 (27->591)	242 (122->1011)
-"Survival" rate - (S' = M'-R/M-X):	.271 (.077->.622)	.348 (.094->.440)	.307 (.033->.727)	.176 (.089->.734)
Instantaneous rate of "total mortality for the 13-week period - (Z' = - ln S'):	1.30 (.47-2.56)	1.06 (.82-2.36)	1.18 (.32-3.41)	1.74 (.31-2.42)
Disappearance (nb.) from other causes - (X' = M - X - R - (M'-R)):	774	21	161	590
-Rate of disappearance from other causes - X'/M-X:	.221	.016	.197	.428

Table 4. Mortality estimates from the tagging data using Gulland's equation, where ln of recaptures is plotted against the number of the time interval in which they were made.

Mortality estimate	Total crabs	Hard-shell crabs	Soft-shell crabs	Indeterminated
Z = F + X	1.58	1.56	1.94	1.38
F	1.13	1.13	1.24	0.54
X	0.45	0.43	0.70	0.84

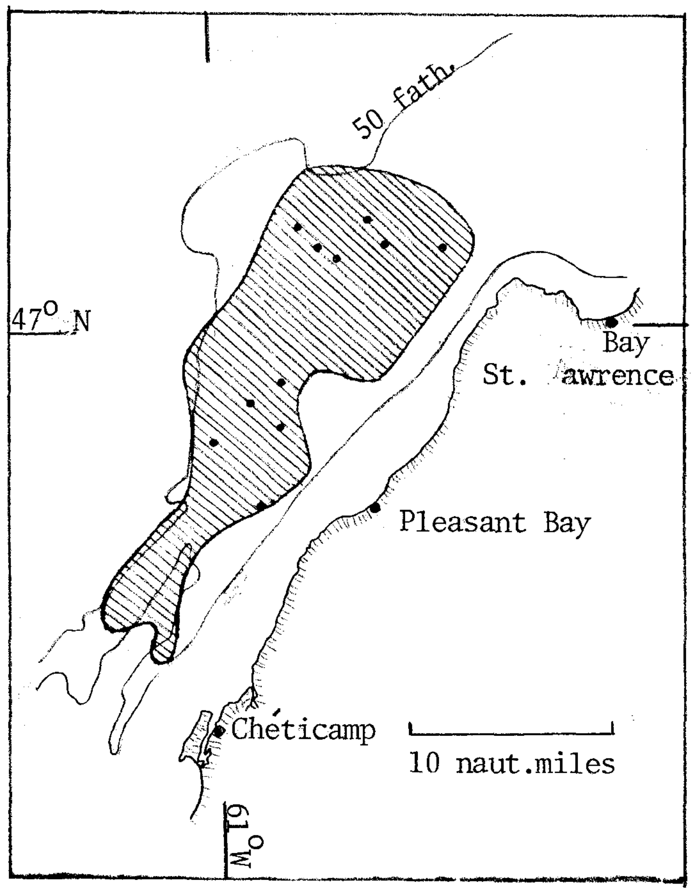

Fig. 1. Location of the north-western Cape Breton snow crab fishery. Shaded area indicates where the boats where fishing in 1978. The dots are approximative places where the marked crabs were released.

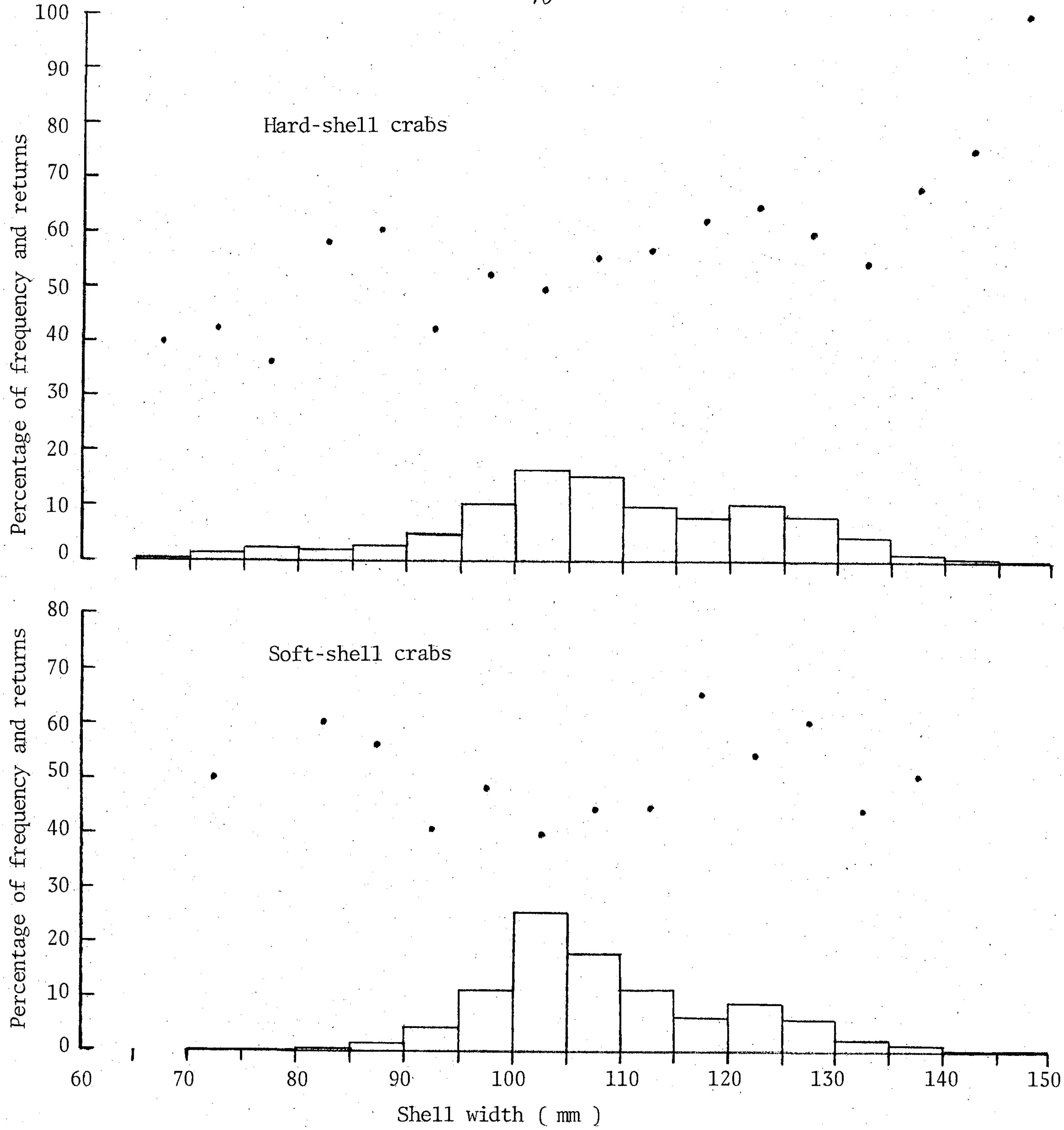

Fig. 2. Size frequencies and percent of returns in each size class for hard-shell and soft-shell crabs marked with body tags .

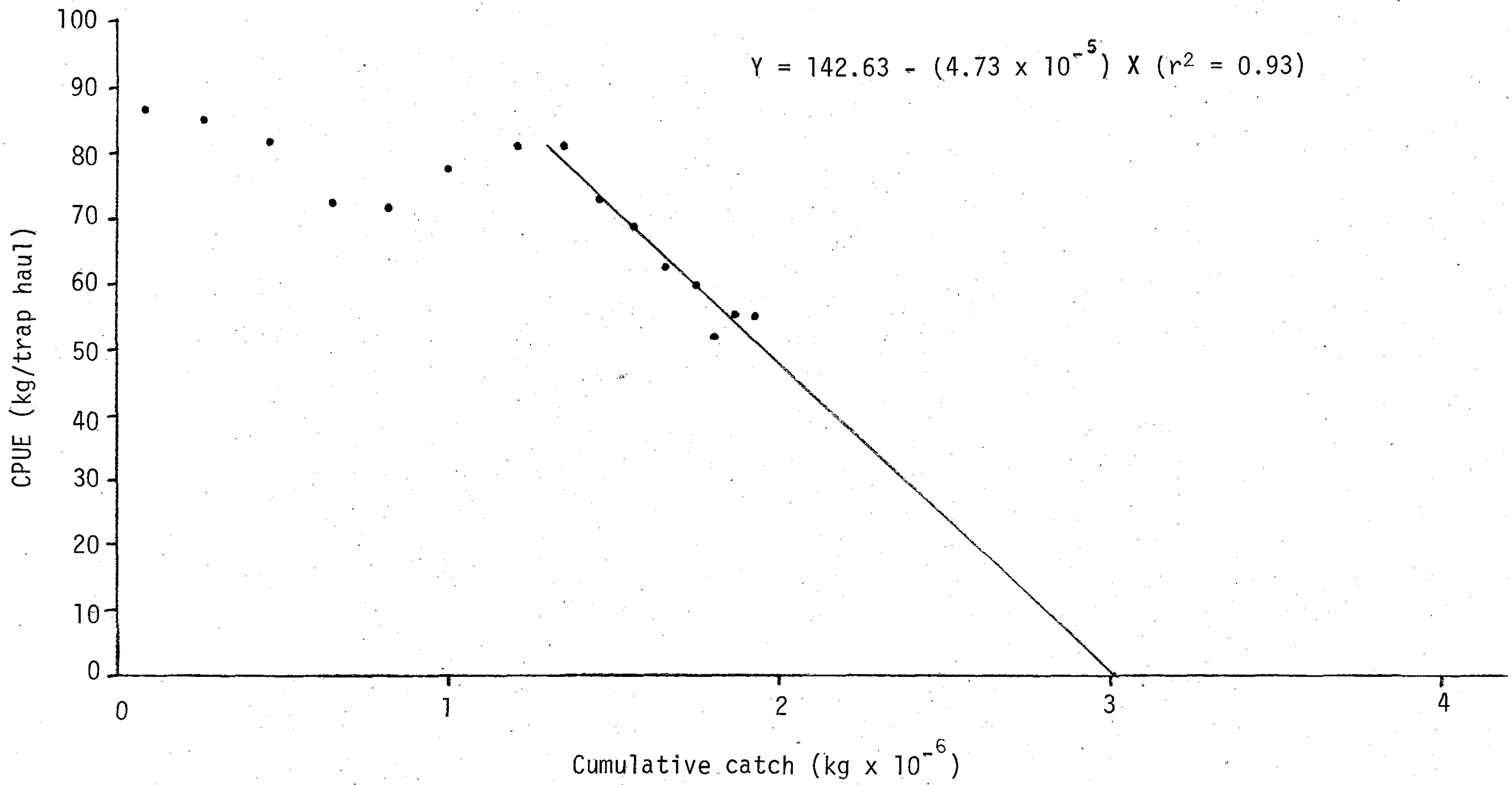

Fig. 3. Leslie graph of weekly catches of snow crab from the northwestern Cape Breton in 1978. CPUE values are from the rectangular 1.5 x 1.5 x 0.5 m traps.

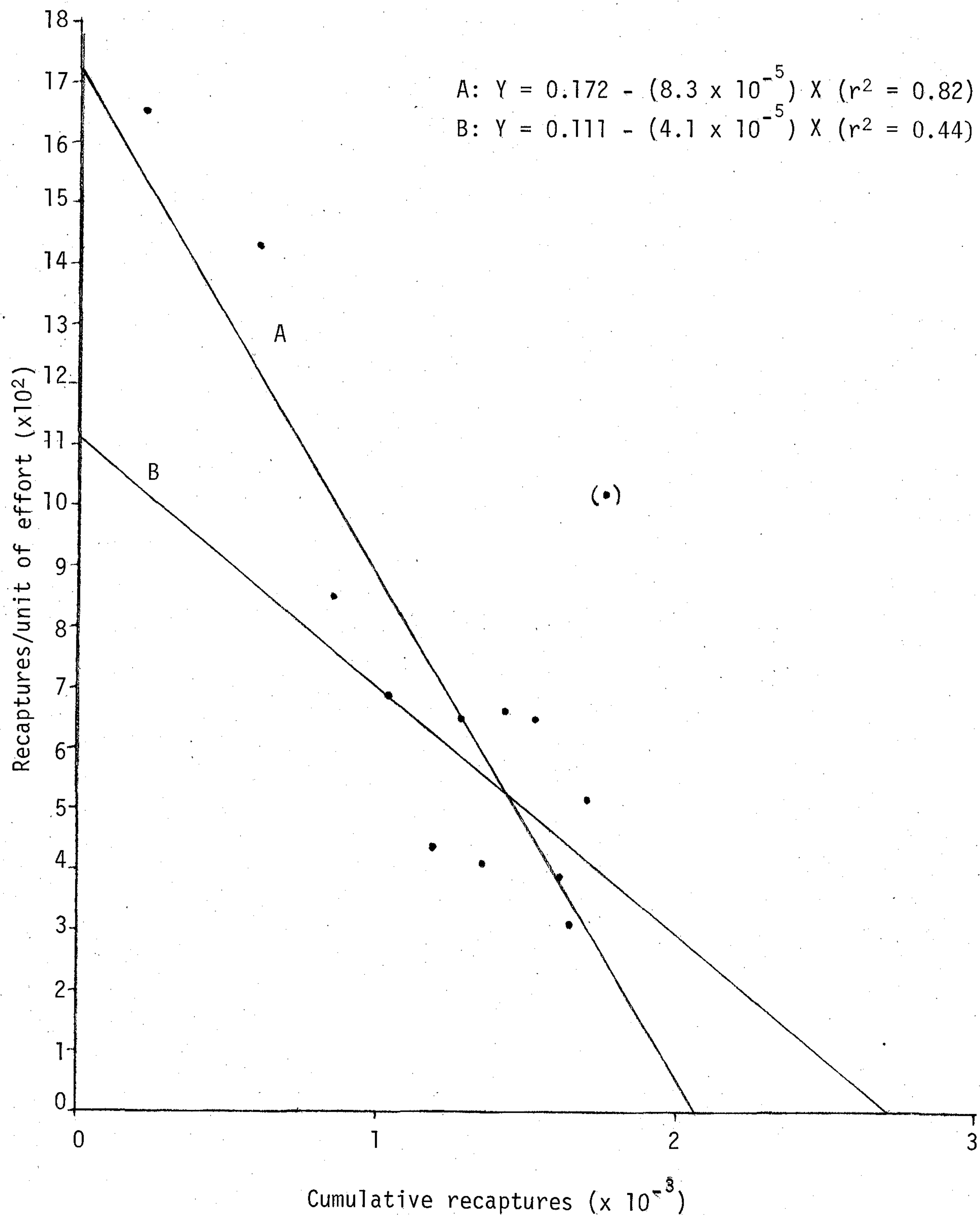

Fig. 4. Leslie graph for recaptures of total marked snow crabs.

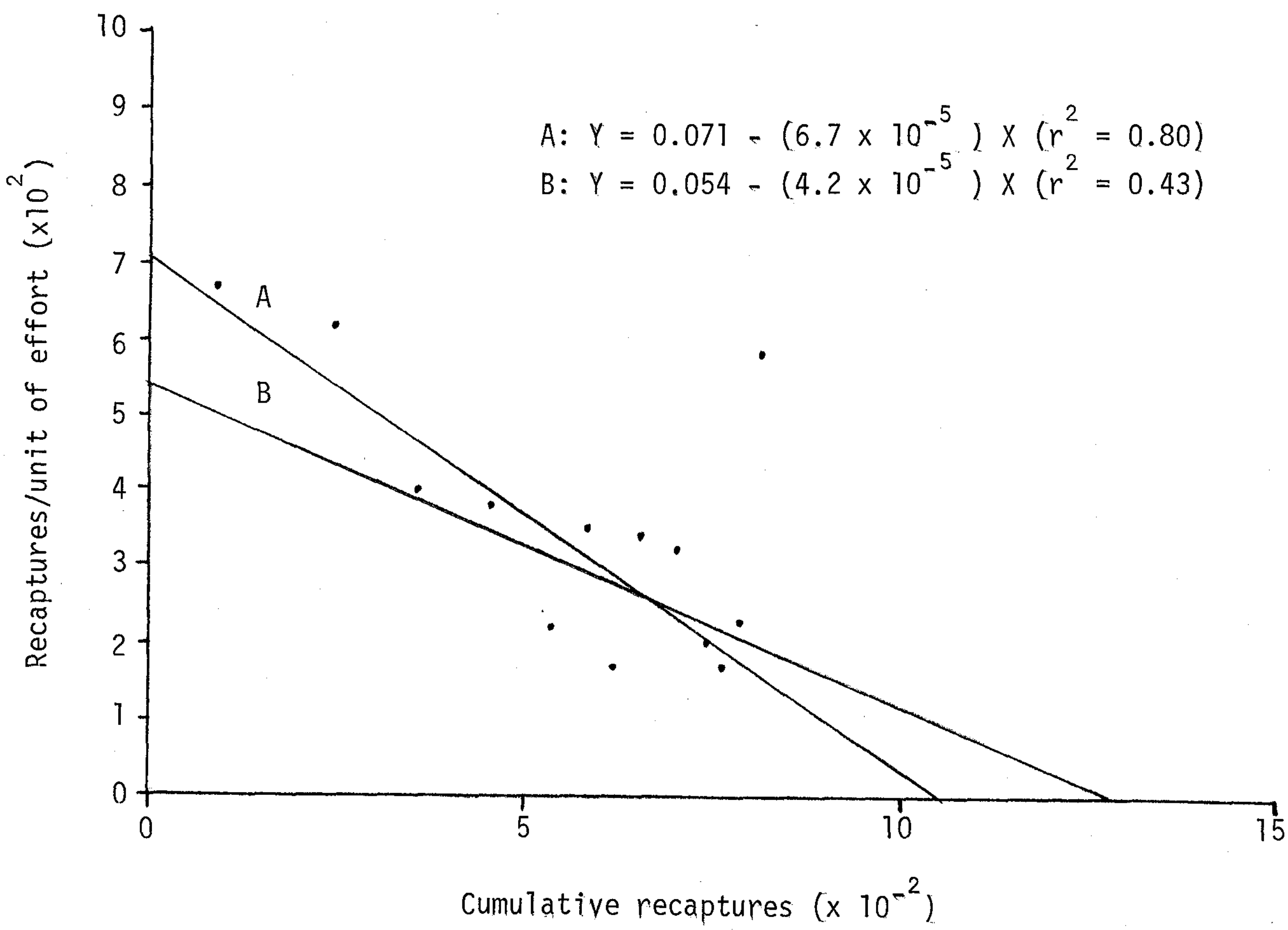

Fig. 5. Leslie graph for recaptures of marked hard-shell crabs.

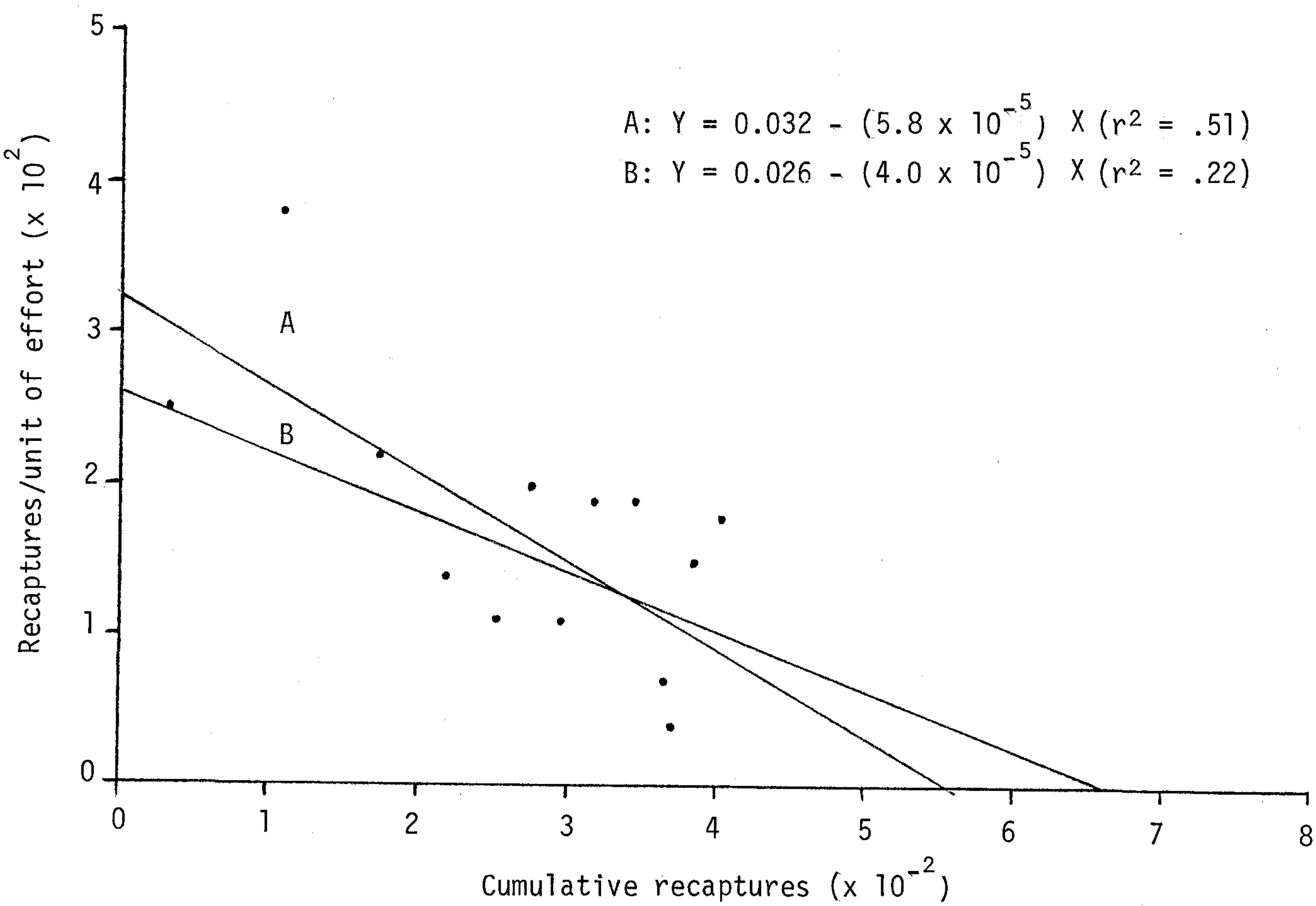

Fig. 6. Leslie graph for recaptures of marked soft-shell crabs.

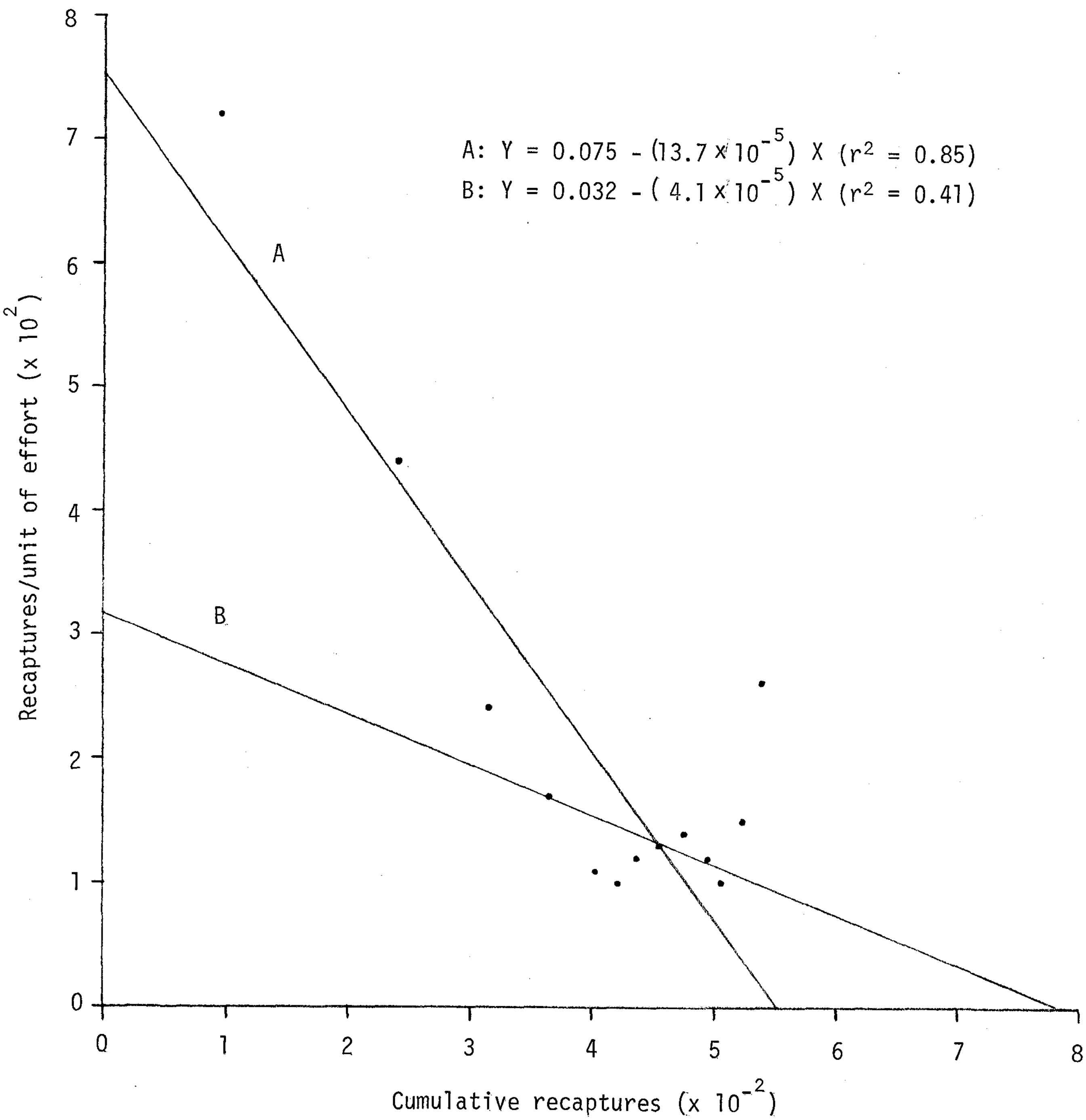

Fig. 7. Leslie graph for recaptures of marked indeterminated crabs.