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Assessment of the Short-finned Squid (*Illex illecebrosus*) in ICNAF Subarea 3 for 1978

by

G. V. Hurley and P. Beck
Fisheries and Marine Service, Newfoundland Environment Centre
St. John's, Newfoundland, Canada

Introduction

This paper represents a first attempt at using sequential population analysis to estimate the exploitation rate and late season rate of emigration of squid in ICNAF Subarea 3. Nearly 90% of the landings were from the Newfoundland inshore jigger fishery.

A spring random stratified survey yielded an early season abundance estimate. Squires (1957) showed that the average catch rate during this period may be used to predict yields to the inshore fishery later in the season. The average catch rate during the 1978 spring survey and the eventual yield to the inshore fishery were compared with historical data.

A late-season tagging study provided information on tag retention, migration and a crude estimate of the rate of exploitation.

C.P.U.E.

Catch per unit effort indices for three Newfoundland inshore sampling locations are summarized in Fig. 1. All values are standardized to numbers of squid per fisherman day for 2-week periods. Effort was calculated in two ways at Holyrood. The sample effort was collected on site by the local weighmaster. The other type of effort was derived from purchase slips, collected by the Economics Branch, Department of Fisheries and Oceans, which is a record of each sale of squid to a buyer.

A comparison of C.P.U.E. between sampling locations shows a similar trend in fluctuations of C.P.U.E. The most complete series of C.P.U.E. is the purchase-slip data from Holyrood. High early season C.P.U.E. declines abruptly over the first month for which data is available. This decline is followed by relatively low values of C.P.U.E. for the remainder of the fishing season with an apparent further decline in late season. The late season decline is probably explained by emigration from nearshore areas as suggested by other authors (Squires (1957) and Mercer (1973 b)) from an examination of sex ratios. Similarily during October and November 1978 we observed the percentage of males to decrease.

Effects of Environmental Factors on C.P.U.E.

Squires (1957) observed that more squid were jigged under the influence of offshore winds as opposed to onshore winds. From Fig. 2 it can be seen that the axis of lower Conception Bay opening to the open ocean runs northeast-southwest. The influence of wind vectors on catch rates of squid at Holyrood is shown in Fig. 3. The C.P.U.E. is from purchase-slip data. It may be seen that offshore southwest winds produced the highest catch rates at wind speeds of 41-50 km/hr. Unexpectedly, based on Squires (1957) observations, winds from the northeast quadrant were associated with the next highest catch rates observed but at slightly higher wind speeds. Winds from other quadrants produced poor yields. All catch rates were low or there was no data available at wind speeds greater than 60 km/hr. High wind speeds often make it impossible to jig squid in small boats for reasons of safety and comfort.

Squires (1957) postulated that certain environmental parameters such as water temperature and turbidity under the influence of local weather affected catch rates in the jigger fishery. Fig. 4 shows a thermograph tracing of water temperature over the fishing season at Holyrood recorded at a depth of 11.0 metres. Also daily C.P.U.E. is plotted. The inshore temperature preference of squid generally corroborates that observed by Squires (1957) of between 7 and 15°C. However, squid were caught also at temperatures outside this range. From Fig. 4 there is no obvious correlation between water temperature and daily fluctuations in C.P.U.E.

Unfortunately, there is insufficient data to test the hypothesis that turbidity is a controlling factor.

A multivariate analysis of the effects of various environmental paramters i.e. water temperature, tides, rainfall, phase of the moon etc. on daily C.P.U.E. will be done at a future date with data from more than one year.

Landings

Landings of squid for inshore Newfoundland regions are reported monthly by the Economics Branch, Department of Fisheries and Oceans. Offshore catches in Subarea 3 for 1978 are made available on a bi-weekly basis by the FLASH information system and catch reports of developmental charters.

Table 1 gives a summary of the Subarea 3 landings. The monthly inshore landings are summarized by region (Fig. 5) and broken down into bi-weekly landings by the ratio of average bi-weekly catch rates derived for each region. Where catch rates are not known it is assumed that half of the monthly landings were caught during each bi-weekly period.

In order to convert bi-weekly landings given in kilograms to number of animals landed, the average weight per animal (both sexes combined) was determined and divided into the landed weight. The resulting number of animals landed in each Newfoundland inshore region, the entire Subarea 3 offshore landings and the total bi-weekly number of animals landed in Subarea 3 are given also in Table 1.

Population Parameters

Natural Mortality Rate

The estimates of the life span of Illex range from less than one year to two years (Hurley and Waldron, 1978). Given a one-year life span and taking into account that in 1978 the fishery removed many individuals before they could attain the age of one, it may be reasonable to assume a mean life span of nine months. Therefore, a bi-weekly mortality rate can be calculated based on the mean life span of the population.

i.e. $$M = \frac{1}{L.S. \times 2} = 0.06 \qquad (1)$$

Sensitivity analysis of terminal F

A sequential population analysis was done following the method of Pope (1972) at varying values of a terminal F ranging from 0.1 to 0.5 using a constant M = 0.06. The resulting population estimates are given in Table 2.

Table 1. Estimate squid landings in numbers and weight during the 1978 fishing season (May-November) in Subarea 3.

Month	Region	C/E 15 / (C/E 15 + C/E 30)	Landing (kg) Period Ending 15	30	Av. Wt/animal (g) (Both Sexes Comb.) Period Ending 15	30	Landing (No. of animals) Period Ending 15	30
May	2			1,097		50		21,940
	Offshore			400		50		8,000
	TOTAL							29,940
June	1	0.5	432.5	432.5	50	70	8,650	6,178
	2	0.5	23,907.0	23,907.0	50	70	478,140	341,528
	3	0.5	612.5	612.5	50	70	12,250	8,750
	Offshore		12,200	199,200	50	70	244,000	2,845,714
	TOTAL						743,040	3,202,170
July	1	0.5	155,676.0	155,676.0	104.4	111	1,491,149	1,402,486
	2	0.67	1,163,061	572,850	104.4	131.5	11,140,431	4,356,273
	3	0.5	90,405	90,405	104.4	115	865,119	786,130
	Offshore		278,000	539,110	104.4	115	2,662,835	4,687,913
	TOTAL						16,162,534	11,232,802
Aug.	1	0.5	1,500,660	1,500,660	170	148	8,827,411	10,139,594
	2	0.5	3,011,897	3,011,897	183.5	178.2	16,413,604	16,901,779
	3		728,042	1,047,671	147	178	4,919,202	5,885,792
	Offshore		687,830	1,865,450	147	178	4,679,115	10,480,056
	TOTAL						34,839,332	43,407,221
Sept.	1	0.57	4,353,438	3,573,751	175	215	24,896,788	16,622,098
	2	0.43	4,479,621	5,676,334	224	232	19,998,307	24,466,957
	3	0.53	1,613,202	1,487,179	185	191	8,956,645	7,786,278
	Offshore		108,300	222,600	185	191	585,405	1,165,445
	TOTAL						54,437,145	50,040,778
Oct.	1	0.76	1,647,309	520,203	248.3	257.8	6,634,349	2,017,855
	2	0.45	734,978	898,306	248.3	257.8	2,960,040	3,484,508
	3	0.50	449,283	449,283	248.3	257.8	1,809,438	1,742,760
	Offshore		107,700	47,400	248.3	257.8	433,750	183,864
	TOTAL						11,837,579	7,428,987
Nov.	1	0.5	23,027	23,027	253.2	237.1	90,943	97,119
	2	0.56	8,822	6,932	253.2	237.1	34,842	29,236
	3	0.5	11,785	11,785	253.2	237.1	46,542	49,703
	TOTAL						172,327	176,058

Table 2. Sensitivity of various population estimates to varying terminal F-values.

F	M	Population
0.05	0.06	1,945,144,406
0.1	0.06	1,112,281,152
0.15	0.06	834,851,840
0.20	0.06	696,349,184
0.25	0.06	613,365,248
0.30	0.06	558,153,472
0.35	0.06	518,811,136
0.40	0.06	489,388,288
0.45	0.06	466,576,384
0.50	0.06	448,393,216

Only catches for the period ending September 30 and earlier were input. During October and November Squires (1957) and Mercer (1973 (b)) and data from 1978 have suggested that emigration from inshore areas occurs. Therefore a sequential population analysis using catch data for this period may result in erroneous population estimates.

F vs Effort

In order to choose the optimal terminal F for the sequential population analysis an examination was made of the relation of F vs effort. F-values were derived from analyses run at different terminal F's ranging from 0.1 to 0.5. Bi-weekly effort is difficult to quantify as the landings were the result of both jigger and trawling fisheries. Since the jigger fishery was responsible for nearly 90 percent of the landings, effort values from the inshore jigger fishery were used in this analysis. As previously mentioned the most complete set of bi-weekly inshore C.P.U.E.-values (periods ending July 15 - Sept. 30) were available from Holyrood (Fig. 1). Effort values were calculated by dividing bi-weekly landings (Table 1) by the corresponding bi-weekly C.P.U.E.-values from Holyrood. The highest correlation coefficient (r = 0.9) was found using a terminal F = 0.1. The resulting geometric mean regression is shown in Fig. 6.

Sequential Population Analysis

The results of the sequential population analysis using a terminal F-value = 0.1 are given in Table 3. The analysis was initiated using catch data from period ending September 30 and earlier.

Stock projections and projected F-values were calculated for bi-weekly periods in October and November are listed also in Table 3. These projections were made iteratively using the following equations:

$$u = \frac{F}{F+M}\left(1-e^{-(F+M)}\right) \qquad (2)$$

AND

$$N_{t+1} = N_t\left(e^{-(F+M)}\right) \qquad (3)$$

Exploitation Rate

The exploitation rate was calculated using the equation

$$u = \frac{C}{N}$$ where C = summed bi-weekly catches

N = population estimate at the beginning of fishing season

$$\therefore \quad u = \frac{233,709,915}{1,112,281,152} = 0.21$$

Table 3. Projection of stock size and F-values in Subarea 3 for October and November 1978. (Analysis based on squid catches for twice-monthly periods with terminal F = 0.1 at end of September 1978 and M assured to be 0.06.)

Period ending		No. of animals Catch	Population	F
May	15-30	29,940	1,112,281,152	0.000
June	1-15	743,040	1,047,477,885	0.001
	16-30	3,202,170	985,756,442	0.003
July	1-15	16,162,534	925,242,924	0.018
	16-31	11,232,802	855,676,111	0.014
Aug	1-15	34,839,328	794,944,591	0.046
	16-31	43,407,216	714,840,951	0.065
Sep	1-15	54,437,152	631,087,516	0.093
	16-30	50,040,784	541,507,549	0.10
Oct	1-15	11,837,577	499,874,470)[1]	0.02)[2]
	16-31	7,428,987	466,079,867)[1]	0.01)[2]
Nov	1-15	172,327	438,775,112)[1]	0.0004)[2]
	16-30	176,058	413,057,583)[1]	0.0004)[2]

[1] Projected stock size
[2] Projected F-values

Estimation of late season rate of emigration

A rate of emigration may be estimated by subtracting the Z-value, derived from the late season projected numbers of squid, from the actual rate of decrease in numbers of squid.

Fig. 7 shows the catch curve for Holyrood using different measurements of effort. If a regression line is fit through the late season natural log (C.P.U.E. - values) the resulting slope should be an estimate of Z. The equation of the line of best fit using purchase-slip effort is

$$y = 7.74 - 0.360\ x$$

$\therefore$ the estimate of Z = 0.360

From the sequential population analysis, projected bi-weekly stock size estimates were derived. The slope of the line of best fit through bi-weekly values of natural log (numbers of animals) should give the projected estimate of Z.

The equation of the line of best fit is

$$y = 20.04 - 0.05\ x$$

$\therefore$ the projected estimate of Z = 0.05

subtracting.

An estimate of the rate of emigration equals

$$0.36 - 0.05 = 0.31 \text{ or } 27\%.$$

Spring random-stratified survey

During June, 1978 a random-stratified survey was made along the outer slopes of the Grand Banks in ICNAF Subareas 3Ps, L, N. O. Fig. 8 shows the areas covered by the survey. The guidelines followed for the survey were as detailed by Pitt (1976).

An Engels high-opening bottom trawl was employed with an average wing tip to wing tip opening of 19.8 metres. The vertical opening of the net was 10.0 metres.

Calculations were based on survey sets made during daylight hours only. Fig. 9 illustrates the observation that squid move upward in the water column at night. Such a diel vertical migration would bias a biomass estimate if catches from nighttime sets were included.

Most of the sets producing relatively good catches of squid were made on the south-western slope of the Grand Banks i.e. 3Ps, 3O. Bottom water temperatures were noticeably colder on the northern and eastern part of the survey area (3L, N) than on the south-western slope (3Ps, O) (Fig.10). It may be that the relatively low bottom water temperatures (less than 5°C) accounted for the poorer catches in 3L, N. This is consistent with the findings of Mercer (1973 (a)).

The results of the population and biomass estimates are summarized in Table 4. Areas of relatively high concentrations of squid (3Ps, O) for the June period were in the same areas which produced the highest catches in the commercial offshore fishery later in the season.

Table 4. Population and biomass estimates for squid from June random survey in 1978. (Upper and lower confidence limits are given for each ICNAF Division.)

ICNAF	Population (No. of animals)	Upper	Lower	Biomass (kg)	Upper	Lower
3L	902,925	3,062,799 (-)	1,256,948	64,483	192,468 (-)	63,501
3N	866,559			66,766		
3O	31,173,920	68,322,048 (-)	5,974,208	1,787,476	3,814,891 (-)	239,939
3Ps	20,395,632	69,923,856(-)	29,132,592	1,087,541	3,556,970(-)	1,381,888
Total	52,436,120			3,006,266		

Perhaps more important than the population estimate produced by the random-stratified survey is the comparison of the average catch rate over the same period with the eventual inshore landings.
Squires (1957, 1959) and Hodder (1964) showed that the average catch rate during this period may be used to predict the yield to inshore fishery later in the season. Table lists known early season catch rates and yearly landings from 1946-58 and 1978. The data from 1946-1952 is Table III (from Squires, 1957) and from 1953-1958 is Table I (from Squires, 1959). The values given for 1978 were based on catches from the southwest slope of the Grand Banks (3Ps, O, N). The high-lift Engels trawl was assumed to be three times as efficient as the smaller trawl used in previous years.

Since 1958, the introduction of the Japanese drum jigger has greatly improved the catching ability of inshore Newfoundland fishermen. This greater gear efficiency plus the increased value of squid in 1978 from sales for human consumption probably accounts for the disproportionate inshore landings in 1978 compared with landings in other years listed in Table 5.

In 1978 there was a relatively high early season catch rate offshore followed by substantial landings inshore later in the season. Therefore, based on the data for 1978 the original hypothesis put forward by Squires (1959) that early season catch rates offshore correlate with landings by the inshore fishery later in the season still holds true.

Table 5. Incidental early season captures of squid by the Investigator II on the Grand Bank, 1946-58 and reported occurrence of squid inshore (from Squires, 1957, 1959). Also captures of squid from June survey 1978 on southwest slope of the Grand Banks (3Ps, O, N). 1978 catch figure corrected for gear efficiency.

Year	Dates Fished	Total Trawling Time (hours)	Percentage Trawling time in which Squid taken	No. of Squid /100 hrs Trawling	Landed Squid (millions of lbs.)	Relative Abundance
1946	May & June	81	10	385		Moderate numbers
1947	May & June	91	3	70+		Very abundant
1948	May & June	67	1	3		Scarce
1949	June	31	0	0		Few
1950	June	24	14	95		Moderate numbers
1951	May	21	42	5,683		Very abundant

Table 5. (cont'd)

Year	Dates Fished	Total Trawling Time (hours)	Percentage Trawling time in which Squid taken	No. of Squid /100 hrs Trawling	Landed Squid (millions of lbs.)	Relative Abundance
1952	May & June	22	21	3,523		Abundant
1953	May 5-12: 23-29 June 18-26	53.0	15.7	68	10	Abundant
1954	May 8-17 May 30-June 1 June 22-29	43.8	44.2	4,212	15	Very abundant
1955	May 17-23 June 13-19	34.3	26.2	1,024	15	Very abundant
1956	May 12-19 May 31-June 8 June 20-27	43.7	9.2	1,554	17	Very abundant
1957	May 19-24 June 11-15 June 25-July 1	35.1	11.4	330	6	Abundant
1958	April 30-May 8 May 18-24 June 25-July 1	44.0	4.5	30	2	Few
1978	June 3-June 20	59	43	5,728	87	Very abundant

Tagging

Introduction

Tagging operations were undertaken during late October - early November in lower Conception Bay, Newfoundland. Over 3,000 squid were tagged during this period using three different types of tags. A summary of these tag releases is reported in ICNAF Circular Letter 79/3. We hoped to obtain information on migratory patterns, growth, tag retention time and estimates of exploitation rate by the fishery. In 1965, over 400 squid were tagged in Conception Bay (Fleming, 1966). There were no tag returns. These squid were tagged with anchor tags in the tail fin area. In 1971 there was an 18.7 percent return on 402 tag releases at Holyrood. Some squid retained the metal clip tags for as long as two months.

Materials and Methods

Animals were captured using the Japanese drum jigger. All animals were tagged in the collar area, measured for mantle length and returned quickly to the water.

Results

Of 3,184 squid tagged there were 1,011 tags (32%) recovered from the commercial fishery. Table 6 gives a breakdown of the tag returns for each type of tag used and the number of days at large for the tagged squid. The length of time at large for the tagged squid ranged from the same day as tagging took place to thirty days after tagging. Of the 3,184 squid tagged, 3,051 were tagged using either the anchor or metal clip tags. The percent tag returns for both these tags were 32.8 and 26.4 respectively. The average percent tag returns for all types of tags was 31.3.

A crude estimate of the rate of exploitation may be made over the tagging period using tag return information. The estimate would likely be a minimum estimate as some tags may not have been returned. In Table 6 it may be noted that there is a high percentage return of tags for a short time after tagging. This is probably due to the tagged squid not having had enough time to mix with the rest of the population.

Discounting those squid recaptured on the same day or one day after tagging, a crude estimate of the rate of exploitation over the tagging period is

$$\mu = \frac{\Sigma Ri}{\Sigma Ti} = \frac{745}{3184} = 0.22$$

where R_i = recapture for each tag type
T_i = total squid tagged for each tag type.

This estimate is less than that calculated from the sequential analysis. Emigration from the tagging area during October and November and the low effort exerted by the fishery over this period may account for the relatively lower value.

Migration

Tagging operations in lower Conception Bay were carried out at two locations, Holyrood and Harbour Main (Fig. 11). Table 7 summarizes the extent of squid migration between the two tagging sites. There were 16 squid tagged in Harbour Main, recaptured in Holyrood. Only one squid tagged in Holyrood was recaptured in Harbour Main. This difference is probably due to the greater fishing effort in Holyrood rather than a net immigration into Holyrood.

The elaped time between capture and recapture varied from 2 - 29 days. The swimming distance between the two locations was approximately 10 km.

Table 6. Summary of tag returns from squid tagging experiments in Newfoundland area in the fall of 1978.

Type of Tag	No. Squid Tagged	Number of days at large																															Total Return	Tags Not Dated
		Same Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
Anchor		49	279	90	72	57	57	55	11	17	16	22	6	17	5	1	1	0	1	0	2	0	3	13	0	30	8	0	0	1	1	1	8.15	13
Percent	Return	1.9	11.3	3.6	2.9	2.3	2.3	2.2	0.5	.7	.7	.9	.2	.7	.2	.04	.04	0	.04	0	.1	0	.1	.5	0	1.2	0.3	0	0	.04	.04	.04	32.8	
Metal Clip	588	12	39	21	24	15	20	5	9	0	4	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	154	2
Percent	Return	2.0	6.6	3.6	4.1	2.6	3.4	0.9	1.5	0	.7	.2	.2	.2	0	0	0	0	0	0	0	0	.2	0	0	0	0	0	.2	0	0	0	26.4	
Orange Ribbon	33	0	2	2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	7	0
Percent	Return	0	6.1	6.1	3.0	0	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.0	0	0	0	0	0	0	21.2	
Yellow Ribbon	100	6	0	0	1	7	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Percent	Return	6.0	0	0	1.0	7.0	4.0	2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.0	
TOTAL	3,184																																31.3% 996	

Table 7. Squid migrations from tagging in the Newfoundland area in the fall of 1978.

Tag Type	Date Tagged	Place Tagged	Date Caught	Place Caught	Elapsed Time
Anchor	Oct. 26/78	Harbour Main	Nov. 1/78	Holyrood	7 days
"	"	"	Nov. 11/78	"	17 days
"	"	"	Nov. 1/78	"	7 days
"	"	"	Nov. 7/78	"	13 days
"	Oct. 27/78	"	Nov. 3/78	"	7 days
"	"	"	Nov. 3/78	"	7 days
"	"	"	Nov. 3/78	"	7 days
"	"	"	Nov. 1/78	"	5 days
"	"	"	Nov. 1/78	"	5 days
"	"	"	Nov. 6/78	"	10 days
"	"	"	Nov. 1/78	"	5 days
"	"	"	Oct. 30/78	"	3 days
"	"	"	Nov. 25/78	"	29 days
"	"	"	Nov. 3/78	"	7 days
"	Oct. 28/78	"	Nov. 22/78	"	26 days
"	"	"	Oct. 30/78	"	2 days
"	Oct. 29/78	Holyrood	Nov. 7/78	Harbour Main	9 days

Discussion

The calculated rate of exploitation for squid in ICNAF Subarea 3 was below the optimal rate for squid of 0.4 suggested in ICNAF Sum. Doc. 78/VL/3.

The stock projection gives a minimum estimate of the spawning escapement (413,057,583 animals).

Tagging methodology seems to insure relatively long term tag retention for future studies.

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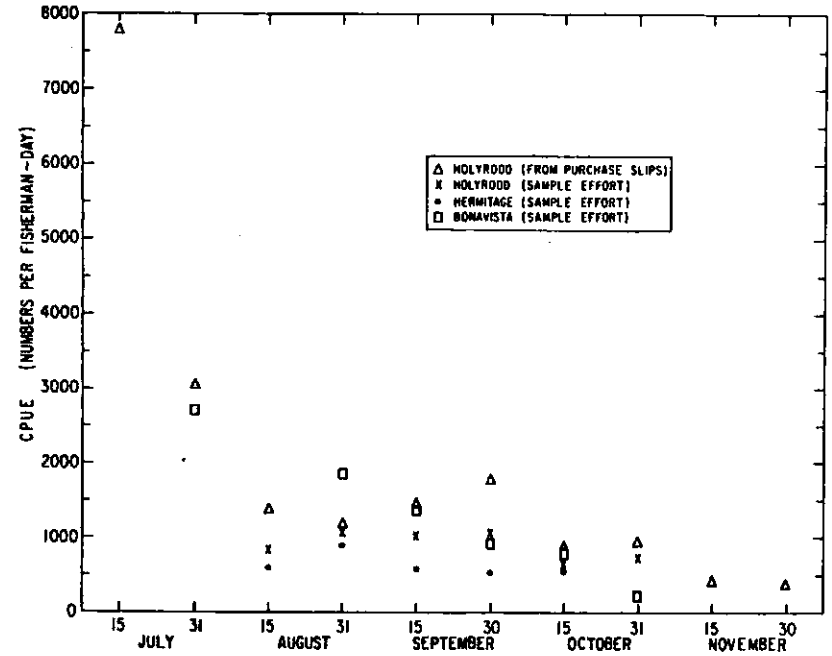

Fig. 1. C.P.U.E. (Numbers per fisherman-day) from various inshore Newfoundland locations in 1978.

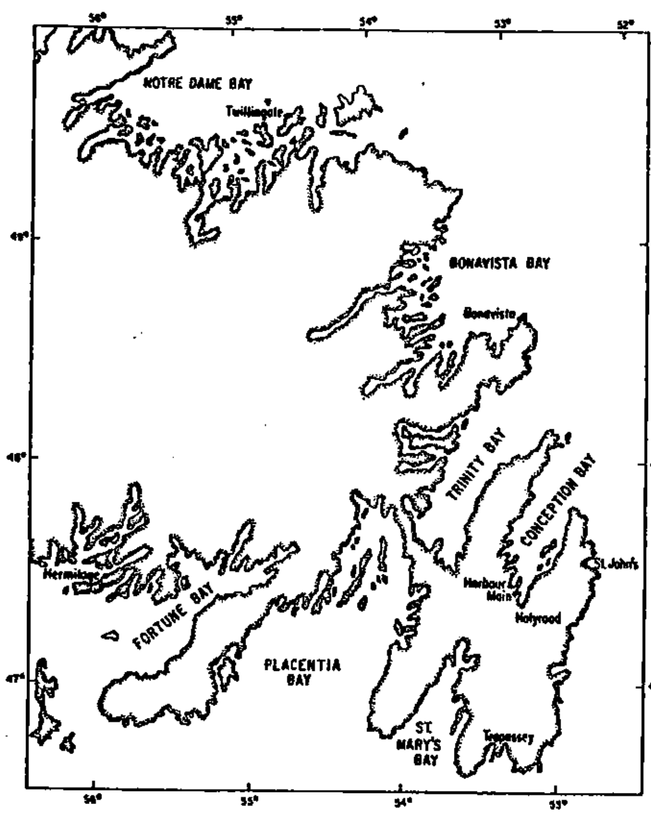

Fig. 2. Map of eastern Newfoundland showing inshore sampling locations.

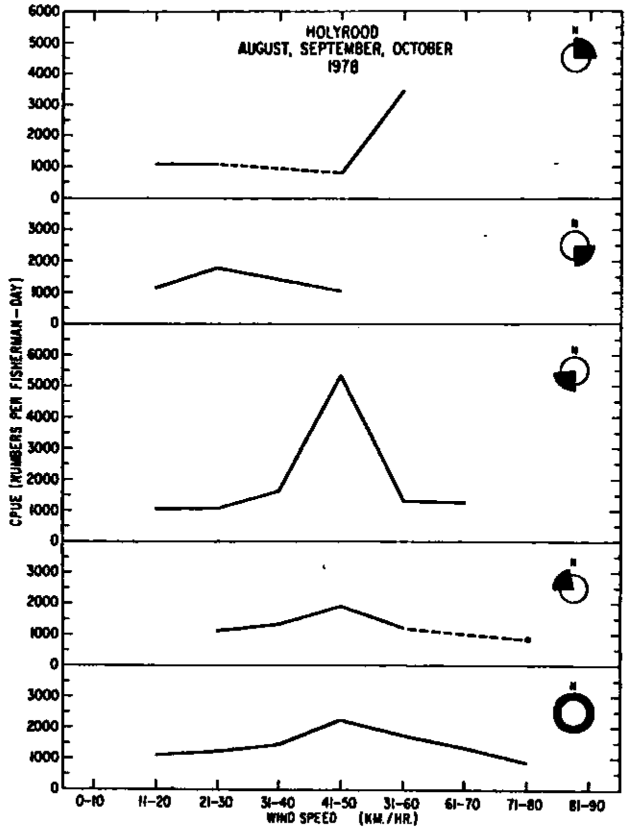

Fig. 3. C.P.U.E. (Number per fisherman-day) versus wind vectors at Holyrood for August, September, October, 1978.

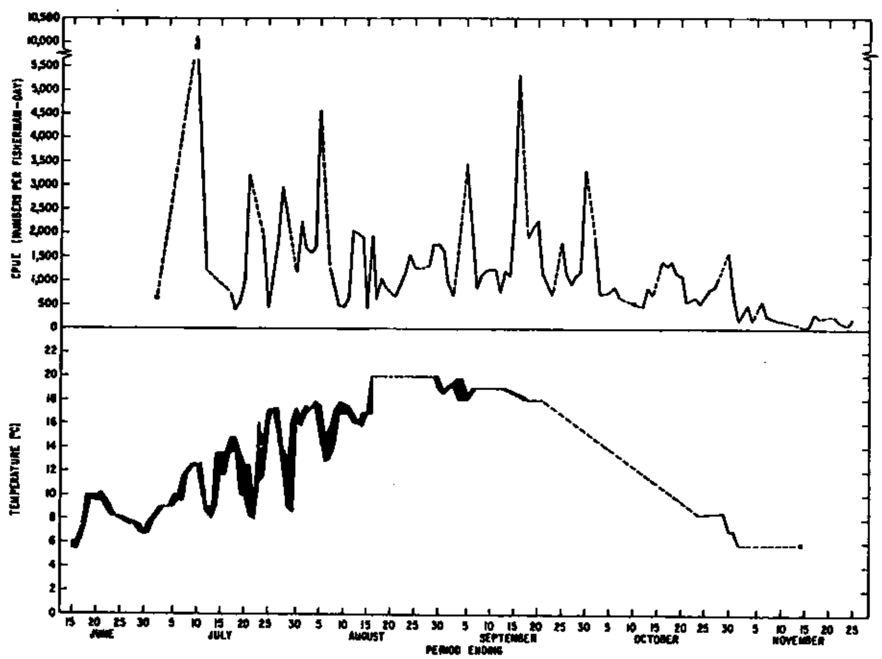

Fig. 4. C.P.U.E. (Numbers per fisherman-day) versus water temperature (^{o}C) over fishing season at Holyrood, 1978.

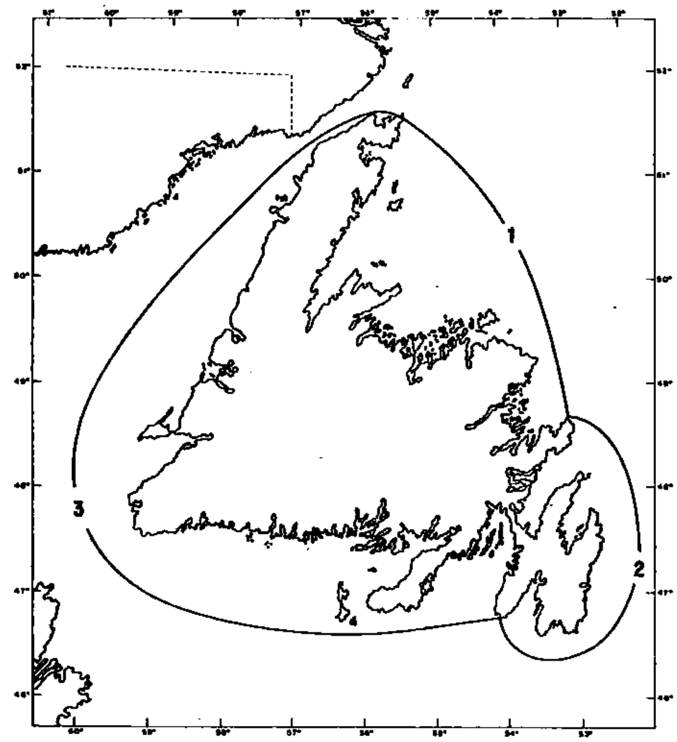

Fig. 5. Map of Newfoundland showing inshore regions.

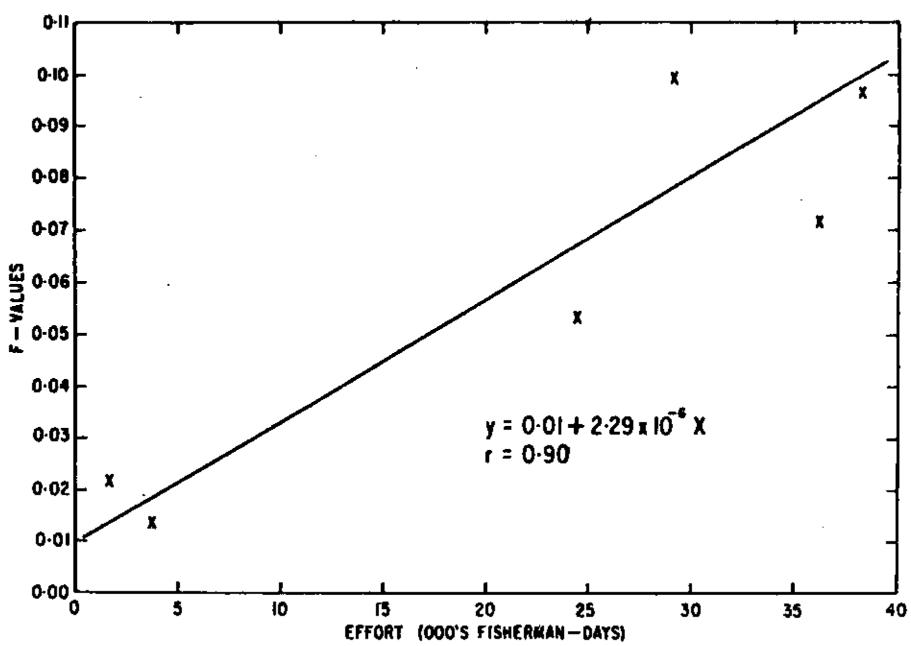

Fig. 6. F versus Effort.

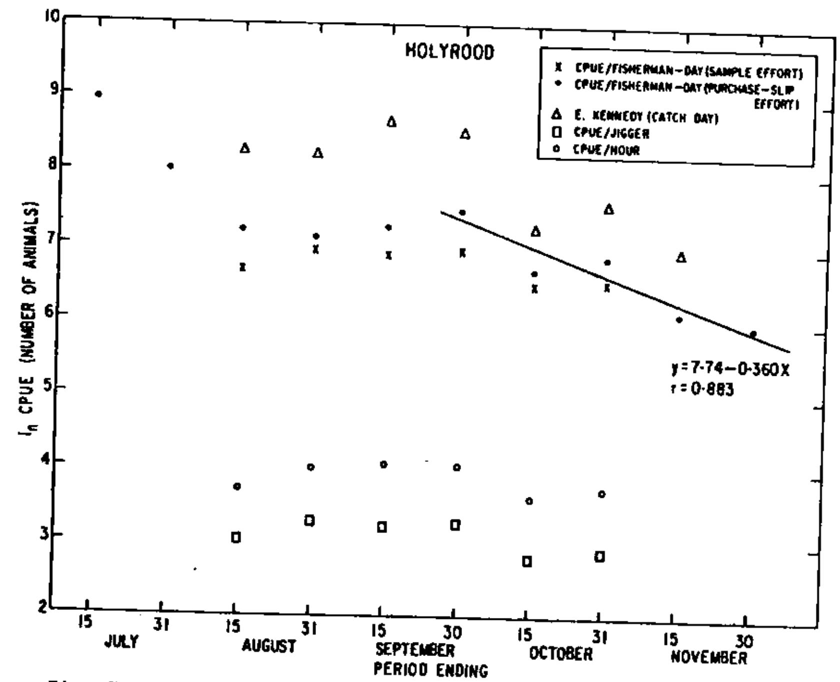

Fig. 7. Catch curve described by various indices of C.P.U.E. at Holyrood.

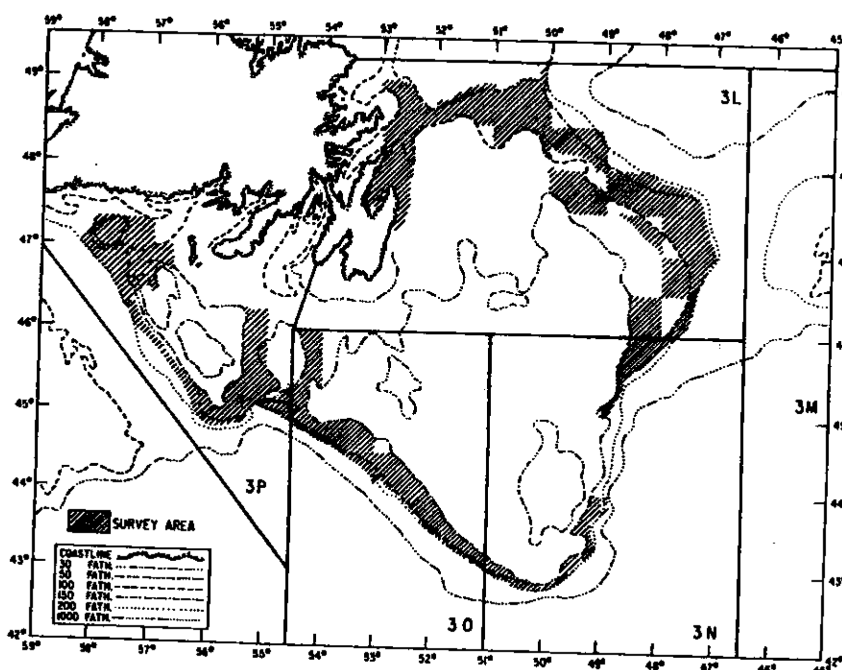

Fig. 8. Map of Grand Banks showing area covered by spring random-stratified survey.

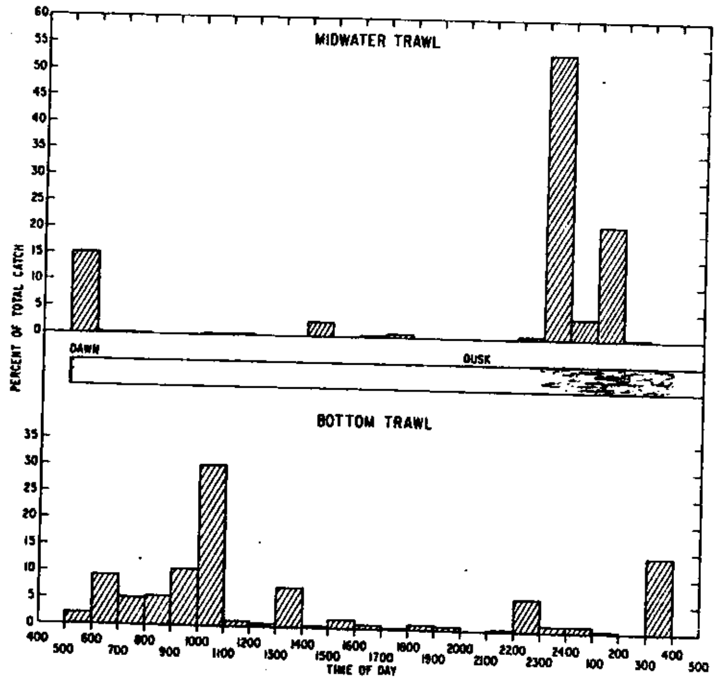

Fig. 9. Diurnal variation in catches from bottom and midwater trawls during spring random-stratified survey.

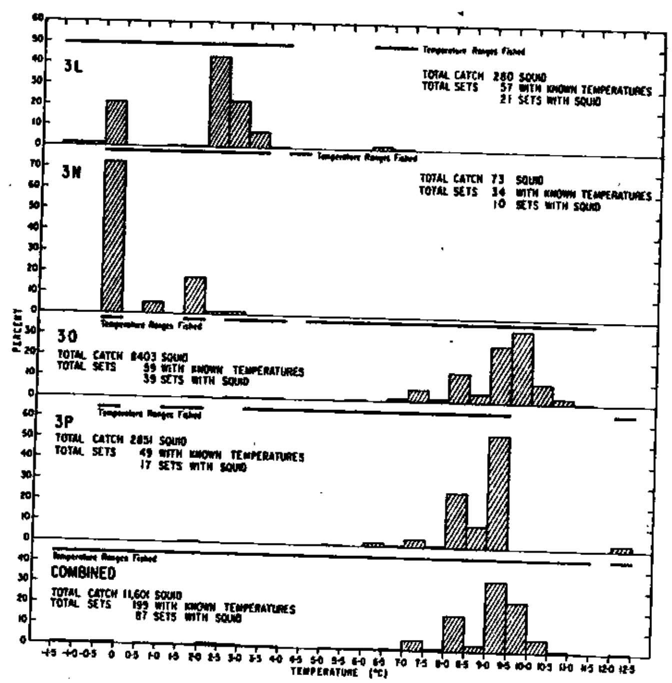

Fig. 10. Percent catch versus temperature (^{0}C) during spring random-stratified survey for ICNAF Subareas 3L, N, O, P.

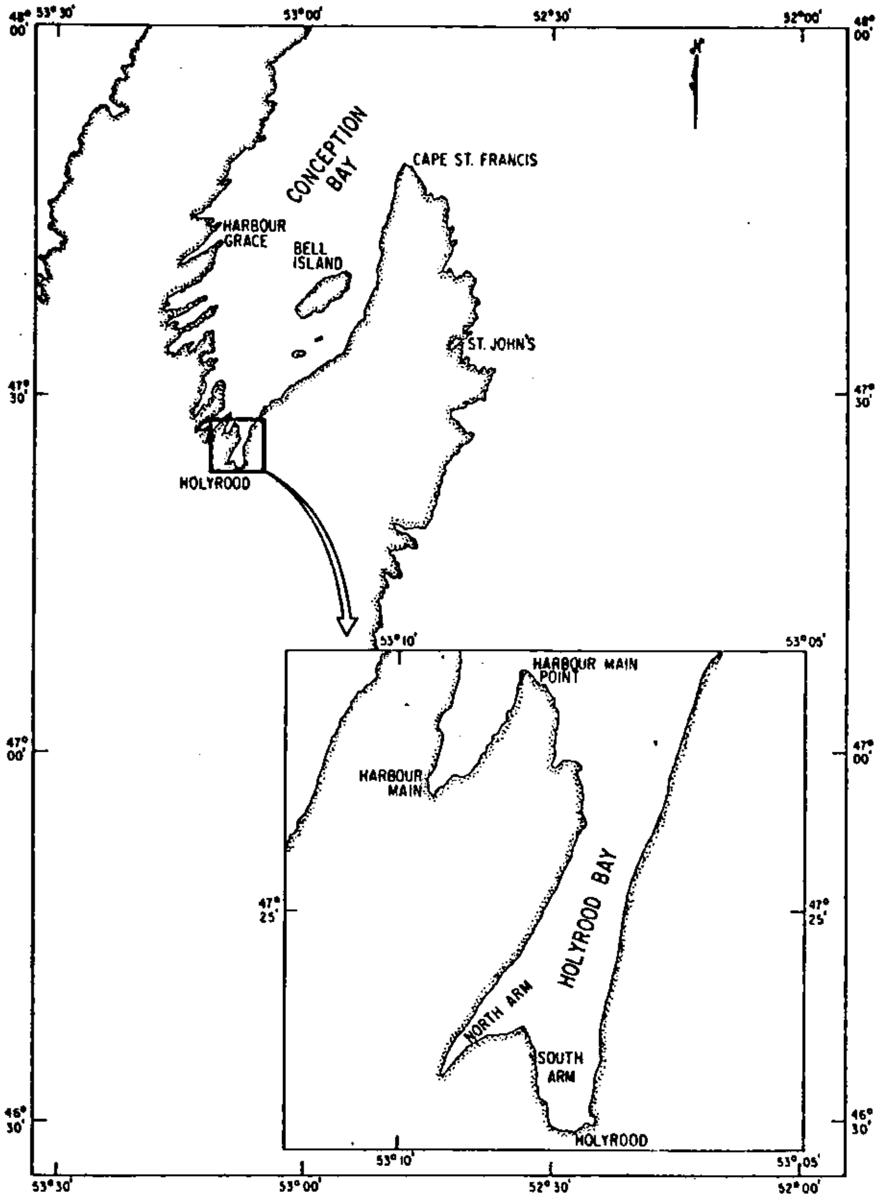

Fig. 11. Map of Conception Bay, Newfoundland showing locations of tagging in 1978.