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A Two-dimensional Systematic Survey of the Iceland Scallop, *Chlamys islandica* in the Strait of Belle Isle

by

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ABSTRACT

The use of a systematic lattice sampling scheme to obtain estimates of exploitable scallop (*Chlamys islandica*) biomass in the Strait of Belle Isle is investigated here. Problems in variance estimation, which heretofore limited the use of this method for the enumeration of animal population are also discussed.

RESUME

Nous examinons ici un schéma d'échantillonnage systématique en treillis pour estimer la biomasse exploitable des pétoncles (*Chlamys islandica*) du détroit de Belle-Isle. Nous considérons également les problèmes que pose l'estimation de la variance, problèmes qui, jusqu'à maintenant, avaient limité l'utilisation de cette méthode dans le dénombrement d'une population animale.

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INTRODUCTION

A fishery for the Iceland scallop developed in the northeastern Gulf of St. Lawrence in 1969. Annual landings during the first six years of the fishery ranged from 151 mt in 1971 to 2342 mt in 1972 with a mean at 847 mt. There was no active fishery for the mollusc between 1975 and 1978 (inclusive). The fishery resumed in 1979 when 430 mt were taken. Landings increased to 1022 and 1380 mt in 1980 and 1981 (provisional) respectively with landed value for the two parts combined exceeding 2M dollars. The recent resurgence of fishing in this area has renewed our interest in this stock, particularly from the point of carrying out suitable assessments and developing appropriate management regimes for the fishery.

In 1980 and 1981 sample surveys based on a systematic lattice design were carried out over the main fishery area with two objectives in mind, 1) to explore and determine the spatial structure of the scallop population and 2) to assess the suitability of using this type of sampling design for stock management purposes.

The main advantage being sought here by applying a systematic scheme, aside from ease of design and the fact that little 'a priori' information is required (in contrast to stratified designs), is that under certain conditions this design provides more precise estimates of the population mean than random or random-stratified schemes (Cochran 1977). The major drawback in using this method is that there is no general estimator of this precision. Methods of dealing with this problem for the case at hand are discussed.

METHODS

I. Survey Design

The procedures involved in setting up a systematic lattice design are described in Smith and Naidu (1981). Briefly, the area to be sampled is divided up into a $N_1 \times N_2$ rectangular lattice with $N_1 = K_1 n_1$, rows and $N_2 = K_2 n_2$ columns, (K_1, K_2, n_1, n_2 all integers) such that there are $N = N_1 N_2$ possible sample units of equal size available. The sample positions are obtained by randomly choosing integers i' and j' from the ranges 1,..., K_1 and 1,..., K_2 respectively. The sample will then consist of those units identified by the $n_1 \times n_2$ combinations of the row indices i', i' + K_1, i' + $2K_1$,..., i' + $(n_1-1)K_1$ and column indices j', j' + K_2, j' + $2K_2$,..., j' + $(n_2-1)K_2$. The structure of the sample will be aligned in both directions, aligned in one direction only or unaligned, depending upon the choice of i' and j'. The advantages and disadvantages of using any one of these three alignments are discussed in Bellhouse (1977).

The survey that was carried out deviated from this ideal structure in that the sample area was not rectangular, but the general procedure still applies. The fishing (sample) area was delineated based on information gathered from all the fishermen actively prosecuting the scallop fishery.

Initially the sample units were defined to be the area covered by a ½ mile tow with the dredging gear and hence, under the restriction of the time available the sample grid was set up in the following manner. Eleven latitudinal transects, each spaced one nautical mile apart (K_1 = 639), were run in the target area (Figure 1). Fishing stations were assigned at ½ mile intervals along these lines. Fishing stations in water less than 30 fms (55 m) were deleted from the lattice since no commercial fishing occurred at those depths. Preliminary studies indicated that at a standard tow speed of 3.0 knots the dredging gear tended to "bulldoze" when dragging over a distance of a ½ mile and therefore the sample units were reduced to the area covered in a 0.25 mile (0.46 km) tow (K_2 = 4). The total number of stations available in the survey area is 290,745 of which 455 were contained on the eleven transects chosen. Using the value of K_2 = 4,103 stations were occupied in 1980 (Figure 1, closed circles). In 1981 operational constraints imposed principally by inclement weather reduced the coverage to 59 stations (Figure 1 open circles) and therefore K_2 = 8 for the survey. The total number of stations occupied along each transect in the two surveys is summarized in Table 1.

Both surveys were conducted during July-August with the 18.6 m government research vessel, the M.V. MARINUS.

All tows were made with a gang of four toothless Digby buckets (effective mouth opening of 2.9 m), mounted on a single tow bar. Dredges were equipped with 2½" (6.4 cm) rings and carried a 1" (2.5 cm) nylon net liner on the inside of the bag to increase retention of smaller scallops. The liner was inspected frequently and repaired or replaced as necessary.

Dredges were hauled up at the end of each tow and the catch was "bushelled" into baskets and weighed to the nearest pound. Shell-height measurements (to the nearest mm) were performed on either the whole catch, or a random subsample, depending on the amount caught and anticipated arrival time at the next station. When subsamples were employed, counts were made of all animals not measured.

Marked sounder records with start and finish positions were brought back to the lab to ensure that tows were in fact 0.25 nautical miles in length. When deviant, catches were adjusted accordingly based on the observation made during the preliminary trials that the amount caught was found proportional to distance towed.

II. Estimation

The estimators of the mean and population total are straight forward, that is:

$$\overline{Y}_{syst} = \frac{1}{n_1 n_2} \sum_{i=1}^{n_1} \sum_{j=1}^{n_1} Y_{ij}, \qquad (1)$$

$$Y_{syst} = N\,\overline{Y}_{syst}. \qquad (2)$$

The above formula for the mean is the general equation for the case of a rectangular lattice but is modified for our design since the transects are not of equal length to:

$$\overline{Y}_{syst} = \left(\sum_{i=1}^{n_1} n_{2i} \right)^{-1} \sum_{i=1}^{n_1} \sum_{j=1}^{n_{2i}} Y_{ij} \qquad (3)$$

The population total formula remains the same. As discussed in Smith and Naidu (1981) the sampling variance of $\overline{Y}_{syst}$ (V_{sy}) for a rectangular lattice is defined to be:

$$V_{sy} = \frac{1}{K_1 K_2} \sum_{l=1}^{K_1} \sum_{s=1}^{K_2} (\overline{Y}_{l,s} - \overline{Y})^2, \qquad (4)$$

where $\overline{Y}_{l,s}$ denotes a particular mean obtained from one of the $K_1 K_2$ possible samples and $\overline{Y}$ is the mean of the whole population. Since from any one systematic sample we will have only one value for $\overline{Y}_{l,s}$ the variance cannot be estimated by using equation 4. Three approaches are available to circumvent this problem. The first assumes that the population units are in random order and therefore the estimator reduces to that used in random sampling. In sampling natural populations (see references in Cochran 1977 and Jumars et al. 1977) it has been observed that samples taken close together in space are more likely to be similar in value than those taken farther apart due to there being spatial autocorrelation present or a trend or both. The second approach assumes some model to take these effects into account in order to devise an appropriate estimator of the variance (Cochran 1977, Heilbron 1978, Smith and Naidu 1981). The third approach uses a hybridization of a systematic scheme with some other method but has yet to be extended to the lattice situation (Stephan 1969, Singh and Singh 1977, Zinger 1980).

In this paper we will consider the first two approaches listed above.

RESULTS

The numbers and weights of scallops caught in the 1980 and 1981 surveys are listed in Table 2. The relative positions of the 1980 samples and the associated observed values are presented in Table 3a and 4a.

Before the variance of the mean of these observations can be estimated the null hypothesis of randomness of the sample values must be tested. This is carried out by applying the spatial autocorrelation tests developed by Cliff and Ord (1973) (also see Jumars et al. 1977 for applications of these tests to benthic sampling data). These tests which were developed for demographical and earth sciences problems are weighted forms of Moran's "I" and Geary's "C" statistics both of which have seen use in the ecological literature for summarizing dispersion and diversity patterns. Since Cliff and Ord (1973) discuss the statistics and their properties we will not dwell on these aspects here. Instead we will present the forms of the statistics I and C used here and briefly review their interpretation.

Define,

n = number of samples,

y_{ij} = variate value of the ij th sample (in the grid),

$Z_{ij} = Y_{ij} - \bar{y}$,

$$W = \sum_i^n \sum_j^n \sum_k^n \sum_l^n W_{ijkl} \quad \text{where } i \neq k \text{ and } j \neq l$$

$$I = \left(\frac{n}{W}\right) \frac{\sum_i^n \sum_j^n \sum_k^n \sum_l^n W_{ijkl} \; Z_{ij} \; Z_{kl}}{\sum_i^n \sum_j^n Z_{ij}^2} \quad \text{where again } i \neq k,\ j \neq l,$$

and,

$$C = \left(\frac{n-1}{2W}\right) \sum_i^n \sum_j^n \sum_k^n \sum_l^n \frac{W_{ijkl} \, (X_{ij} - X_{kl})^2}{\sum_i \sum_j Z_{ij}^2} \quad (i \neq k,\ j \neq l)$$

The weighting factor W_{ijkl} in the above formulae is defined in such a way as to provide all the spatial information assumed in the model being entertained under the alternative hypothesis. The null hypothesis for both of the test statistics above is that there is no spatial autocorrelation present i.e. the values are in random order. Under this null hypothesis the expected values of I and C are $-(n-1)^{-1}$ and 1 respectively. The significance of the differences from these expected values are tested assuming a Gaussian distribution for I and C (Cliff and Ord 1973). Positive autocorrelation is determined when the observed value of the test statistic I is greater than the expected value and C is smaller than the expected. Negative autocorrelation is indicated when the reverse is observed.

Since the validity of the test results depend upon the choice of the W_{ijkl} values used we define our alternative hypothesis in an analagous manner to that used in Cliff and Ord (1973) for autoregressive models of the Gaussian-Markov type. That is since adjacent sample units were equidistant along one direction only, the tests of the relationships were subdivided into the orientations where equal distances between samples were obtained. These relationships were denoted by describing them as movements undertaken by chess pieces on a chess board in combination with compass directions, e.g. Rook (E-W) denotes relationships between samples along a transect and Rook (N-S) relationships between samples across transects. Bishop moves were along the diagonally arranged samples. The weights were defined as follows:

W_{ijkl} = 1/d, where d is the total number of joins between adjacent samples.

The tests were carried out separately for samples one and two sample units apart and extended to three if the results were significant at the second order difference. The results of the tests for 1980 for both numbers and weights are presented in Table 5. From these results we can see that there is evidence of positive autocorrelation along transects (Rook E-W) for both numbers and weights when samples are 1 and 2 nautical miles apart. Further there also seems to be a like relationship along the diagonal denoted by Bishop (SE-NW) when samples are $2\sqrt{2}$ miles distant (order = 2) and $3\sqrt{2}$ miles distant (numbers only, order = 3). The 1981 results are not presented due to the conclusions being the same with the exception that only the test for the first order distance ($\sqrt{2}$ miles) was significant for the Bishop (SE-NW) test.

Although these tests indicate that there is enough evidence to reject the null hypothesis of random arrangement along transects and along one diagonal they do not by themselves prove that spatial autocorrelation is the only factor at work here. One of the assumptions required to use the variance estimator studied in Smith and Naidu (1981) which assumes spatial autocorrelation, is that there be stationarity present (interpreted to mean absence of trend here). In Table 3b we have depicted the positions of observations of numbers of scallops caught in the 1980 survey whose values are greater than the mean (1) and less than the mean (-1). From this table we can see that there is a definite trend in the data such that sample values from the more southerly areas (top of table) tend to be greater than the mean and the northerly areas less than the mean in value. This pattern is again seen for the weights observed (Table 4b) and is also present in 1981 (Tables 6a and 6b) although less well defined probably due to there being fewer samples taken.

To deal with this trend we considered conceptualizing the data in the following manner (after Tukey 1977);

DATA = FIT + Residual

If we can determine the "Fit" or trend in the data and remove it successfully then the stationarity assumption may be met. The variance then would be obtained from the residuals. Since the trend appears to be non-linear in form it was decided not to employ linear regression techniques to find a fit instead we decided to use the smoothing techniques described in Tukey (1977). Since the autocorrelation tests indicated that between transects samples appeared to be uncorrelated the smoothing was carried out along transects. The diagonal results obtained from the autocorrelation tests were assumed to be confounded by the trend.

Smoothing the transect sequences was carried out as follows: 1) smooth points by replacing each point with the median of it and the two adjacent points, continuing this operation until no further changes occur in the sequence then, 2) smooth the sequence further by taking a running average 3 points at a time but giving the point which is being replaced a weight of 0.5 and the adjacent points a weight of 0.25. This latter process is referred to as "Hanning" in Tukey (1977). When the smoothed sequences were plotted against the actual values for each transect (too many plots to reproduce here) it was found that a great deal of the trend was accounted for. The residual component was obtained by subtracting the "Fit" from the data and then we tested for the presence of the trend noted earlier by tabling the values according to their position and value in relation to their mean. These results are included as Tables 7 and 8. It appears from these tables that the original pattern is no longer present and therefore we will assume that any obvious trends no longer exist.

The next thing to determine is whether or not there is any spatial autocorrelation present in the detrended data. Again applying the tests using the I and C statistics we find that positive spatial autocorrelation only exists now for Rook's relationship (E-W) order = 1 for numbers caught in 1980. There is some consistency in this result when compared to the results in 1981 as the test for Rook (E-W) order = 2 (1980) is testing the same distance measure as is in 1981 order = 1 since the samples taken were spaced twice as far and both tests indicated the null hypothesis could not be rejected. With the exception of numbers in 1980 there is no evidence to reject the null hypothesis of randomness for the other variates that were measured and therefore it appears that the autocorrelation pattern noted in the original was mainly due to the trend observed. The variances of the means for these results can be estimated under the assumption of randomness by the following formula:

$$V_{sy} = \mathrm{Var}(\bar{y}) = \left(\frac{N-n}{Nn}\right) S^2$$

where S^2 is the sample variance of the residuals.

For the numbers caught in 1980 we will use a modified form of the sample-based approximation to the unconditional expected value of the true variance studied in Smith and Naidu (1981). To use this we will assume that a Markov stationary model describes the autocorrelation pattern seen in the residuals. The estimate of the variance is obtained by the following formula:

$$V_{sy} = \left(\frac{N-1}{N}\right) S^2 \left\{1 - \frac{1}{N(N-1)} \sum_{\nu} A_{\hat{\rho}o,v} - \frac{n-1}{n} + \frac{1}{n^2} \sum_{\nu} B\, \hat{\rho}_{o,k_2v}\right\}$$

where N,n, and S^2 are as previously defined. The values $\hat{\rho}_{o,v}$ and $\hat{\rho}_{o,k_2v}$ represent the estimated autocorrelations between samples along transects between population units "v" units apart and population units K_2v units apart (i.e. sample units) respectively, as per Smith and Naidu (1981). As we are assuming a Markov - stationary model we define $\rho_{o,v} = \rho^v$ and $\hat{\rho}_{o,k_2v} = \hat{\rho}^{k_2v}$. Since the presence of positive autocorrelation was found to be significant at order = 1 for numbers caught we use this estimate ($\hat{\rho}^{K_2v} = \hat{\rho}^4 = 0.8425$) to find our estimates for $\hat{\rho}^v$. It should be noted that the estimated autocorrelation for order = 2 was $\rho^8 = 0.6572$ which although not significant when tested is still close to, what would be expected under this kind of model ($(\rho^4)^2 = 0.7098$). We define B in the above equation to be the number of samples which contribute to this autocorrelation (i.e. 2 x (n-11v) assuming $\rho_{o,k_2v} = \rho_{o,-k_2v}$) and A is an analogous quantity for the population units i.e. B = 2 ($N-K_2n_1v$).

The results of these calculations for the variances and the means for numbers and weights for 1980 and 1981 are presented in Table 9.

DISCUSSION

This is certainly not the first application of a systematic type of sampling scheme to marine data but it is the first time that we know of where the use of spatial information has been made when sampling this type of material. We know of three studies previous to our own where systematic sampling has been studied in order to determine if the scheme will provide more precise estimates of the population mean than random or stratified type of designs. Two of these studies, namely Venrick (1978) and Lenarz and Adams (1980) use empirical results to compare the precision obtained from each type of scheme. In both studies the precision of the mean was estimated assuming random order although in the first case there was a definite trend in the data and in the second the sample was assumed to be the population and a quasi-subsampling approach was carried out.

Estimation of the variance by a subsampling approach was investigated in Smith and Naidu (1981) and was found to be a very inefficient estimator.

The approach taken here to deal with the trend noted in the data may not be accepted by some due to the lack of rigour of the smoothing techniques. Explanatory variables such as depth and/or position were considered as possibilities for a least squares type of trend surface curve, but the apparent lack of a relationship exhibited when the variate values were plotted against depth and the arbitrariness of using the positions deterred us from continuing in this direction for the moment. Although we would agree that this line should be pursued farther it is still important to emphasize how powerful the smoothing techniques were in picking out the trends along the transects. The trends extracted from each transect did not parallel each other but instead showed definite individual patterns.

From the results of the survey in Table 9 we note that 95% confidence intervals (calculated assuming a Gaussion distribution for $\overline{Y}_{st}$) for the estimated mean numbers of scallops do not quite overlap although the confidence intervals for the estimated mean weight per tow do. We can assume therefore given the distributional assumption the survey results indicate that the population size (numbers or weights) has changed very little between the two years.

In order to express these results in terms of estimated exploitable biomass we must take the efficiency of the sampling gear into account. It has been shown that the efficiency of scallop dredges varies with the type of bottom over which fishing takes place. Dickie (1955) found that the efficiency (or captures of sea scallops Placopecten magellanicus by means of recapturing tagged individuals, with commercial gear (2 5/8" rings) varied on the order of 5% for rough inshore areas to 12% for the smoother offshore areas. Overall efficiency for this study is assumed to be 15% and therefore total biomass is estimated to be 16,433 mt and 20,000 mt for 1980 and 1981 respectively. Comparison of these estimated total weights to the landings reported by the commercial fishery for 1980 and 1981 (1092 and 1488 mt respectively) indicate that the amount removed was on the order of 6.65% and 7.44% respectively for the two years.

The gear efficiency assumed here is probably a conservative estimate and for the present we feel that the biomass estimates herein derived are to be used as relative indices of abundance rather than absolute estimates.

As a final note we would like to draw the readers attention to the fact that coefficients of variation (i.e. SE/$\overline{Y}_{st}$) range from 7.6% to 5.4% for our data.

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Table 1. Number of stations occupied along each transect during the two survey years.

Transect No.	No of stations occupied 1980	1981	Totals
1	7	5	12
2	0	5	5
3	8	5	13
4	8	4	12
5	10	5	15
6	12	6	18
7	13	7	20
8	13	6	19
9	13	7	20
10	12	6	18
11	7	3	10
Totals	103	59	163

Table 2. Numbers and (weights) of scallops caught per tow in 1980 and 1981.

Transect No.	Station No.	1980	1981
1	208	106(9.1)	
	209		154(12.1)
	210	115(9.1)	
	212	147(11.3)	
	213		242(19.9)
	214	95(8.2)	
	216	154(11.3)	
	217		211(16.3)
	218	206(16.3)	
	220	222(17.2)	
	221		367(25.9)
	225		110(7.3)
2	229		444(32.3)
	233		319(24.5)
	237		325(25.0)
	241		248(19.9)
	245		67(6.3)
3	001		107(8.3)
	002	187(13.6)	
	004	246(18.2)	
	005		22(1.3)
	006	279(20.0)	
	008	233(20.4)	
	009		83(5.7)
	010	414(36.7)	
	012	151(13.6)	
	013		179(14.3)
	014	38(2.7)	
	016	282(20.9)	
	017		200(13.2)
4	28	104(8.2)	
	29		71(5.8)
	30	77(5.9)	
	32	105(8.6)	
	33		39(2.7)
	34	44(2.7)	
	36	50(4.5)	
	37		227(21.4)
	38	28(2.3)	
	40	20(0.9)	
	41		5(0.5)
	42	212(19.5)	
	44	7(0.5)	
	45		118(10.6)
	46	16(0.9)	
	48	110(9.5)	

Table 2. continued

Transect No.	Station No.	1980	1981
	49		258(21.4)
	50	79(7.7)	
	52	152(15.0)	
	53		109(7.2)
	54	204(15.4)	
5	56	182(18.1)	
	57		139(10.1)
	58	111(6.4)	
	60	157(10.9)	
	61		242(15.7)
	62	259(21.3)	
6	64	62(5.0)	
	65		207(14.3)
	66	218(18.1)	
	68	83(5.4)	
	69		320(28.0)
	70	180(14.1)	
	72	99(5.9)	
	73		103(8.4)
	74	106(7.3)	
	76	142(10.9)	
	77		49(3.8)
	78	4(0.5)	
	80	56(5.0)	
	81		128(10.7)
	82	2(0.5)	
	84	7(0.5)	
	85		148(13.4)
	86	9(0.7)	
7	88	33(2.3)	
	89		39(3.6)
	90	195(15.9)	
	92	30(2.3)	
	93		74(6.1)
	94	102(7.3)	
	96	24(1.8)	
	97		39(3.9)
	98	78(5.9)	
	100	83(7.7)	
	101		11(1.0)
	102	84(6.8)	
	104	36(1.8)	
	105		71(7.1)
	106	23(1.4)	
	108	41(2.7)	
	109		108(9.7)

Table 2. continued

Transect No.	Station No.	1980	1981
	110	16(1.4)	
	112	52(4.5)	
	113		48(4.3)
8	114	75(5.9)	
	116	25(2.3)	
	117		46(4.3)
	118	15(0.9)	
	120	128(9.5)	
	121		8(0.9)
	122	78(7.7)	
	124	23(1.4)	
	125		69(7.8)
	126	68(6.4)	
	128	38(3.2)	
	129		53(5.8)
	130	79(7.3)	
	132	81(8.6)	
	133		91(9.8)
	134	124(11.3)	
	136	272(23.6)	
	137		65(6.6)
	138	278(22.7)	
9	140	47(5.4)	
	141		113(7.7)
	142	22(2.7)	
	144	151(14.5)	
	145		185(15.2)
	146	98(10.4)	
	148	65(6.4)	
	149		96(9.5)
	150	46(5.4)	
	152	28(3.2)	
	153		112(8.5)
	154	74(6.8)	
	156	124(10.9)	
	157		76(5.3)
	158	103(9.5)	
	160	25(2.3)	
	161		82(6.4)
	162	47(5.0)	
	164	29(2.7)	
	165		57(4.5)
10	168	120(13.6)	
	169		86(7.1)
	170	53(6.8)	
	172	114(15.0)	

Table 2. continued

Transect No.	Station No.	1980	1981
	173		81(6.8)
	174	97(11.8)	
	176	92(11.3)	
	177		113(10.2)
	178	52(7.7)	
	180	13(1.8)	
	181		128(12.6)
	182	55(6.4)	
	184	122(13.2)	
	185		94(9.1)
	186	107(11.3)	
	188	86(8.2)	
	189		110(10.6)
	190	59(5.9)	
	192	68(7.3)	
	193		108(11.6)
	194	102(10.9)	
	196	122(12.3)	
	197		19(3.0)
	198	42(5.0)	
	200	34(4.5)	
	201		27(3.5)
	202	11(1.8)	
	204	43(4.5)	

Table 3.(a) Schematic representation of numbers of scallops caught 1980

Transect																										
1									106		115		147		95		154		206		222					
2																										
3							187		246		279		233		414		151		38		282					
4						212		20		28		50		44		105		77		104						
5							7		16		110		79		152		204		182		111		157		259	
6				9		7		2		56		4		142		106		99		180		83		218		62
7	33		195		30		102		24		78		83		84		36		23		41		16		52	
8		278		272		124		81		79		38		68		23		78		128		15		25		75
9	47		22		151		98		65		46		28		74		124		103		25		47		29	
10		59		86		107		122		55		13		52		92		97		114		53		120		
11	68		102		122		42		34		11		43													

Table 3(b) Position of observations greater than (1) or less than (-1) the mean in value. Mean 97.981

Transect																										
1									1		1		1		-1		1		1		1					
2																										
3							1		1		1		1		1		1		-1		1					
4						1		-1		-1		-1		-1		1		-1		1						
5							-1		-1		1		-1		1		1		1		1		1		1	
6				-1		-1		-1		-1		-1		1		1		1		1		-1		1		-1
7	-1		1		-1		1		-1		-1		-1		-1		-1		-1		-1		-1		-1	
8		1		1		1		-1		-1		-1		-1		-1		-1		1		-1		-1		-1
9	-1		-1		1		-1		-1		-1		-1		-1		1		1		-1		-1		-1	
10		-1		-1		1		1		1		-1		-1		-1		-1		-1		1		-1		
11	-1		1		1		-1		-1		-1		-1													

Table 4. (a) Schematic representation of weights of scallops caught - 1980 (x10).

Transect													
1	91	91	113	82	113	163	172						
2													
3	136	182	20	204	367	136	27	209					
4	195	09	23	45	27	86	59	82					
5	05	09	95	77	15	154	181	64	109	213			
6	07	05	05	5	05	109	73	59	141	54	181	5	
7	23	159	23	73	18	59	77	68	18	14	27	14	45
8	227	236	163	86	73	32	64	14	77	95	09	23	59
9	54	27	145	104	64	54	32	68	109	95	23	05	27
10	59	82	113	132	64	18	77	113	118	15	68	136	
11	73	109	123	5	45	18	45						

Table 4.(b) Position of observations greater than (1) or less than (-1) the mean in value . Mean ≐ 8.479

Transect														
1					1	1	1	-1	1	1	1			
2														
3				1	1	1	1	1	1	-1	1			
4				1	-1	-1	-1	-1	1	-1	-1			
5				-1	-1	1	-1	1	1	1	-1	1	1	
6			-1	-1	-1	-1	-1	1	-1	-1	1	-1	1	-1
7	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	
8	1		1	1	1	-1	-1	-1	-1	-1	1	-1	-1	-1
9	-1	-1	1	1	-1	-1	-1	-1	1	1	-1	-1	-1	
10		-1	-1	1	1	-1	-1	-1	1	1	1	1	-1	
11	-1	1	1	-1	-1	-1	-1							

Table 5. Results of autocorrelation tests for numbers and weights of scallops caught in 1980 survey.

		Numbers		Weights	
Relation	Order	Test Statistics	p Level	Test Statistics	p Level
Rook (E-W)	1	I = 0.4827***	$p<0.0005$	I = 0.4333***	$p<0.0005$
		C = 0.5044***	$p<0.0005$	C = 0.5589***	$p<0.0005$
	2	I = 0.3648***	$p<0.0005$	I = 0.2879***	$0.0005<p<0.0005$
		C = 0.5985***	$p<0.0005$	C = 0.6933***	$0.0005<p\ 0.0005$
Rook (N-S)	1	I = 0.0246	$0.25<p<0.40$	I = -0.0302	$0.40<p<0.40$
		C = 1.0580	$0.25<p<0.40$	C = 1.0903	$0.25<p<0.40$
	2	I = 0.0039	$0.40<p$	I = -0.0144	$0.40<p$
		C = 0.9024	$0.25<p<0.40$	C = 0.9451	$0.25<p<0.40$
Bishop (SW-NE)	1	I = 0.0797	$0.10<p<0.25$	I = 0.0364	$0.25<p<0.40$
		C = 0.8584	$0.10<p<0.25$	C = 0.9258	$0.25<p<0.40$
	2	I = -0.0075	$0.40<p$	I = -0.0302	$0.40<p$
		C = 1.0549	$0.25<p<0.40$	C = 1.0903	$0.25<p<0.40$
Bishop (SE-NW)	1	I = 0.0370	$0.25<p<0.40$	I = 0.0146	$0.40<p$
		C = 0.8743	$0.10<p<0.25$	C = 0.9432	$0.25<p<0.40$
	2	I = 0.1989**	$0.025<p<0.05$	I = 0.1682*	$0.05<p<0.10$
		C = 0.8182*	$0.05<p<0.10$	C = 0.8611	$0.10<p<0.25$
	3	I = 0.1049	$0.10<p<0.25$		
		C = 0.7903*	$0.05<p<0.10$		

$$E[I] = \frac{-1}{(n-1)}$$

$$= -0.0098$$

$$E[C] = 1.0$$

*significance at 10%
**significance at 5%
***significance at < 5%

Table 6. (a). Position of observations (numbers) greater than (1) or less than the mean in value from 1981 survey (mean = 126,271)

Transect																								
1								1				1				1				1				-1
2					-1				1				1				1				1			
3				-1				-1				-1				1				1				
4					-1				1				-1				-1							
5						-1				1				-1				1				1		
6			1				1				-1				-1				1				1	
7	-1			-1				-1				-1				-1				-1				-1
8		-1			-1				-1				-1				-1				-1			
9	-1			1				-1				-1				-1				-1				-1
10		-1			-1				1				-1				-1				-1			
11	-1			-1				-1																

Table 6.(b) Position of observations (weights) greater than (1) or less than the mean in value from 1981 survey (mean = 10.319).

Transect																								
1								1				1				1				1				-1
2					-1				1				1				1				1			
3				-1				-1				-1				1				1				
4					-1				1				-1				-1							
5						1				1				-1				-1				1		
6			1				1				-1				-1				1				1	
7	-1			-1				-1				-1				-1				-1				-1
8		-1			-1				-1				-1				-1				-1			
9	-1			1				-1				-1				-1				-1				-1
10		1			-1				1				-1				-1				-1			
11	1			-1				-1																

Table 7. (a). Position of residuals (numbers) greater than (1) or less than (-1) the mean in value 1980.

Transect																										
1									-1		-1		1		-1		-1		-1		-1					
2																										
3							-1		1		1		-1		1		-1		-1		1					
4						1		-1		-1		-1		-1		1		-1		-1						
5							-1		-1		1		-1		-1		1		1		-1		-1		1	
6				-1		-1		-1		1		-1		1		-1		-1		1		-1		1		-1
7	-1		1		-1		1		-1		-1		1		1		-1		-1		-1		-1		1	
8		-1		1		-1		-1		-1		-1		-1		-1		1		1		-1		1		1
9	-1		-1		1		1		-1		-1		-1		-1		1		1		-1		1		-1	
10		-1		-1		1		1		-1		-1		-1		-1		-1		1		-1		-1		
11	-1		1		1		-1		-1		-1		-1													

Table 7. (b) Position of residuals (weights) greater than (1) or less than (-1) the mean in value 1980

Transect																										
1									-1		-1		1		-1		-1		1		-1					
2																										
3							-1		-1		-1		1		1		-1		-1		1					
4						1		-1		-1		1		-1		1		-1		-1						
5							-1		-1		1		-1		1		1		1		-1		-1		1	
6				-1		-1		-1		1		-1		1		-1		-1		1		-1		1		-1
7	-1		1		-1		1		-1		-1		1		1		-1		-1		-1		-1		-1	
8		-1		1		-1		-1		-1		-1		-1		-1		1		1		-1		-1		1
9	-1		-1		1		1		-1		-1		-1		-1		1		1		-1		-1		-1	
10		-1		-1		-1		1		-1		-1		-1		-1		-1		1		-1		-1		
11	-1		1		1		-1		-1		-1		-1													

Table 8. (a). Position of residuals (numbers) greater than (1) or less than (-1) the mean in value (1981).

Transect																									
1									-1				1				-1				1				-1
2						-1				1				1				-1				1			
3					1				-1				-1				1				-1				
4						-1				1				-1				-1							
5							-1				1				-1				-1				1		
6				1				-1				-1				-1				1				-1	
7	-1				1				-1				-1				1				1				-1
8		-1				1				-1				-1				-1				-1			
9	-1				1				-1				-1				-1				-1				-1
10		-1				-1				1				1				-1				-1			
11	1					-1				-1															

Table 8. (b) Position of residuals (weights) greater than (1) or less than (-1) the mean in value 1981.

Transect																									
1									-1				1				-1				1				-1
2						-1				1				1				-1				1			
3					1				-1				-1				1				-1				
4						-1				1				-1				-1							
5							-1				1				-1				-1				1		
6				1				-1				-1				-1				1				-1	
7	-1				1				-1				-1				1				1				-1
8		-1				1				-1				1				-1				-1			
9	-1				1				-1				-1				-1				-1				-1
10		-1				-1				1				-1				-1				-1			
11	1				-1				-1																

Table 9. Results of Iceland scallop surveys in the northeastern Gulf of St. Lawrence in 1980 and 1981.

	1980	1981
A. Numbers		
$\overline{Y}st$	97.9	126.3
Vsy	55.8	46.3
S.E. ($\overline{Y}st$)	7.47	6.80
95% C.I. for mean	83.0-112.9	112.6-139.8
MIB (nos)	28.5 m	36.7 m
B. Weights		
$\overline{Y}st$	8.48	10.32
Vsy	0.195	0.328
S.E. ($\overline{Y}st$)	0.441	0.572
95% C.I. for mean	7.60-9.36	9.20-11.43
MIB (MT)	2,465	3,000
At 15% gear efficiency (MT)	16,436	20,002
At 20% gear efficiency (MT)	12,326	15,001

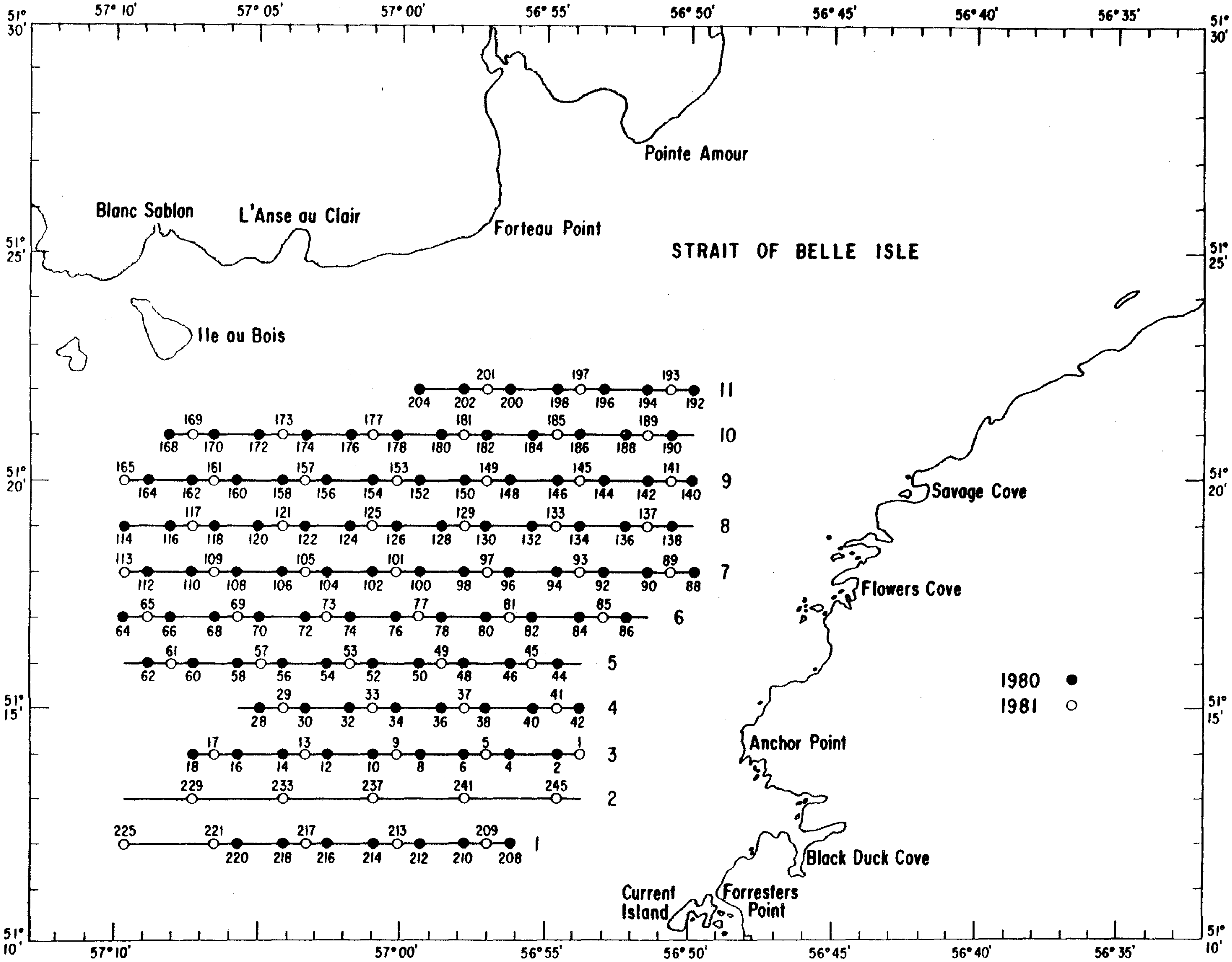

Fig. 1. Distribution of fishing stations