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Soft-Shell Clam (*Mya arenaria*) Survey of Cole Harbour, Nova Scotia - 1984

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by

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ABSTRACT

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An assessment of the soft-shell clam (*Mya arenaria*) stock in Cole Harbour, Nova Scotia, was carried out in 1984. At the time of the survey, one area of the Harbour was legally open for shellfish harvesting and another was legally closed due to fecal coliform contamination. On the various flats of the open area, the standing stock of recruits 44-49 mm ranged between 0.01-1.8 t, and those ≥50 mm ranged between 0.09-10.7 t, totalling 7.6 and 32.1 t, respectively, and 39.8 t combined. On the flats in the closed area, the standing stock of recruits 44-49 mm ranged between 0.03-12.1 t, and those ≥50 mm ranged between 0.3-26.3 t, totalling 12.6 and 29.4 t, respectively, and 42.1 t combined. Total standing stock ≥44 mm for combined open and closed areas was 81.9 t. Growth rate analysis indicated that soft-shell clams reach a 44 mm shell length in approximately 5.2 yr and a 50 mm shell length in approximately 6.0 yr. Isopleths of clam density are presented for each area and indicate spatial overlap in the distribution of clams within the different shell length categories.

RÉSUMÉ

Woo, P. 1991. Soft-shell clam (*Mya arenaria*) survey of Cole Harbour, Nova Scotia - 1984. Can. Manuscr. Rep. Fish. Aquat. Sci. 2090: iv + 35 p.

En 1984, on a procédé à une évaluation du stock de myes (*Mya arenaria*) de Cole Harbour (Nouvelle-Écosse). La récolte des myes était alors légalement autorisée dans une partie du port tandis qu'elle était formellement interdite dans une autre partie de ce port en raison de contamination par des coliformes fécaux. Dans les divers gisements situés dans la zone ouverte à la récolte. Le stock permanent de recrues de 44 à 49 mm était de l'ordre de 0.01 à 1.8 t et celui des recrues ≥ 50 mm de l'ordre de 0.09 à 10.7 t, totalisant 7.6 t et 32.1 t respectivement et 39.8 t conjointement. Dans les gisements de la zone où la récolte était interdite, le stock permanent de recrues de 44 à 49 mm était de l'ordre de 0.03 à 12.1 t et celui des recrues ≥ 50 mm de l'ordre de 0.3 à 26.3 t, totalisant 12.6 t et 29.4 t respectivement et 42.1 t conjointement. Le stock permanent total des recrues de ≥ 44 m dans les deux zones était de 81.9 t. L'analyse du taux de croissance indiquait que la mye atteint une longueur de coquille de 44 mm en 5.2 ans environ et de 50 mm en 6 ans environ. On présente des isoplèthes de la densité des myes dans chaque zone, qui révèlent un chevauchement spatial dans la répartition des myes au sein des différentes catégories de longueur de coquille.

INTRODUCTION

The clam stock in Cole Harbour, on the eastern shore of Nova Scotia (Fig. 1), had, until this survey, never been assessed. In view of the increase, during the early 1980s, in the demand for soft-shell clams and the increased fishing pressure being exerted on stocks in this area, the Department of Fisheries and Oceans undertook a program to assess the Cole Harbour stock during the summer of 1984. The Harbour, which has an area of approximately 1617 ha, was found to contain an estimated 81.6 ha of clam flats. Although the clam population in Cole Harbour will probably have changed somewhat by the time this report is released, it is felt that the information contained herein will provide a useful baseline survey for future management of the resource. At the time of survey, approximately 28% of the flats were closed to commercial and recreational clam fishing due to bacterial contamination (Richard 1987). The closure was removed in 1989, and the entire 81.6 ha of flats may now be legally fished.

MATERIALS AND METHODS

For sampling and analytical purposes, discrete clam-bearing flats were designated as subareas. The subareas were selected after making initial reconnaissance forays to the "open" (fishing permitted) and "closed" (fishing illegal) areas to assess where live clams were to be found. Sampling was undertaken in 11 open subareas, designated Subareas A to K, and in four closed subareas, designated Subareas O to R (Fig. 2). The survey method and clam sampling procedures followed those previously described by Angus et al. (1985). A baseline was arbitrarily established at the point where live clams were first observed as one proceeded from shore. Transect lines were then extended from the baseline to the point where sediments were covered with water at low tide on the days of sampling (Appendix 1), or until the transect reached extremely soft muds where, on further sampling, no clams were found. Although the lowest tides on the day of sampling were used in establishing the seaward boundaries of the flats, these tides would seldom expose the entire flat; and, in consequence, all area estimates are minimums.

The size of each subarea was determined by planimetric estimation of the entire area over which transects were established. The term "surveyed area" is used to indicate the total area of the flat covered by transects, and visually determined to be clam habitat (Fig. 2). The term "sampled area" is used to indicate that portion of each surveyed area, over which sampling stations were finally established (Fig. 3, 7, 11, and 15).

In the sampled area, 0.1 m^2 substrate samples were collected at 20 m intervals at each station along parallel transects. Transects were 20 m apart, and aligned perpendicularly to the baseline. A total of 81.6 ha were surveyed, and 35.4 ha were sampled (Table 1).

The sampling method of Angus et al. (1985) was modified slightly in that in each of the 0.1 m^2 quadrates, dug to a depth of 20 cm, the upper 5 cm was separated from the lower 15 cm. Each sample was then screened through a 1 mm mesh sieve and the material retained for laboratory examination. In the laboratory, shell length (the longest axis) was measured to the nearest millimeter using vernier calipers. As the abundance and spatial distribution of clams recruiting to the fishery is of particular interest, sampled animals were grouped into three length categories: pre-recruits of $\leq$43 mm shell length, and recruits in the 44-49 mm and $\geq$50 mm shell length categories. Total recruits comprised all clams >44 mm in shell length. These categories were determined in consideration of current regional management initiatives which will introduce a 44 mm minimum harvestable size limit in 1991 and a possible return to the current 50 mm size limit in succeeding years. Abundance (number per square meter) for each category was determined for each station sampled. The percentage composition attributed to each of the shell length categories was obtained from frequency distributions established for each sampling station. Using these values and the estimated total number of individuals in a known sampling area, the density of clams (number per square meter) in each category was established and plotted. Density isopleths were drawn by eye to delineate areas of similar concentrations.

A random sample of 100 clams, combined from both areas, was used generate a von Bertalanffy growth curve following the procedures outlined in Mullen and Woo 1985. The equation, $L_t = L_\infty [(1-e) - ^{k(t-t_o)}]$, was then used to determine ages of recruitment for both the current and proposed size limits.

The same sample was also used to generate a straight-line regression of length against age and provide additional estimates of age of recruitment.

The standing stock (round fresh volume) was determined for both the 44-49 mm and ≥50 mm recruit size categories by using the mean size of all the animals in each of the respective shell length categories and the relationship between clam size (millimeter shell length) and number of clams per bushel as determined by Angus et al. (1985) (see Appendix 2). Standing stock expressed in terms of metric tons was subsequently determined by following conversion factors found in Hawkins and Rowell 1984.

The present legally harvestable size is ≥50 mm; but with the planned change in legal size to ≥44 mm in 1991, the recruit size categories may be combined to estimate the total recruits, which would have been available at the time of sampling had the lower size limit been in place.

RESULTS

ABUNDANCE AND DISTRIBUTION

The densities of recruit-sized soft-shell clams are shown, by area and subarea, in Table 2. In the open area, the density of 44-49 mm recruits ranged from 0.3-8.3/m^2, while those ≥50 mm ranged from 0.7-15.3/m^2. Subarea Q of the closed area had no recruits. In the remainder of the closed area the density of 44-49 mm recruits ranged from 0.6-6.6/m^2; those ≥50 mm, from 2.2-7.8/m^2. When the two recruit categories were combined as total recruits (individuals ≥44 mm shell length), the open area had densities as high as 22.6/m^2; the closed area, 14.4/m^2.

When the density ranges given in Table 2 are considered, the impression is that densities are lower in the closed area. However, this is a reflection of one or two high-density open subareas for each of the size categories. When the areas are considered as a whole, among the ≥44 mm and ≥50 mm recruit categories, respectively, the closed area contained 2.7 and 2.3 times the density, in bushels per hectare, found in the open area (Table 3). In the 44-49 mm category the ratio was 4.1:1. For total recruits (≥44 mm), densities in bushels per hectare were 24.9 and 67.0 for the open and closed areas, respectively. Mean density for total recruits for all areas combined was 36.8 bu/ha.

The mean percentages of each pre-recruit and recruit category in open, closed, and combined (total) areas are given in Table 4. The data show that pre-recruits comprised a higher percentage of the surveyed population than did recruits. In the open area, pre-recruits accounted for 78.7% of the total population; 44-49 mm recruits, 8.9%; and ≥50 mm recruits, 12.4%. In the closed area, pre-recruits accounted for 84.8% of the surveyed population; 44-49 mm recruits, 6.8%; and ≥50 mm recruits, 8.4%. Total recruits made up 21.3% and 15.2% of the population, respectively, in the open and closed areas. When the total area was considered, pre-recruits made up 80.4%, while recruits 44-49 mm and ≥50 mm, respectively, made up 8.3 and 11.3% of the population.

Spatial distribution, by size category, for the open area is presented in Fig. 4 to 6, 8 to 10, and 12 to 14, and for the closed area, in Fig. 16 to 18. In general, there is considerable overlap in the pattern of distribution within the subarea of the three size categories. Patchiness of distribution, however, tends to increase among clams in the larger size categories. Generally, where few or no clams occurred in one shell length category, clams were few or absent in the other shell length categories in the same location. The complete absence of recruits and the presence of pre-recruits in Subarea Q is an exception to the general pattern (Fig. 16, 17, and 18). However, although numerous, the pre-recruits were found over only a small part of the subarea.

The size-frequency distribution in the open and closed areas is virtually identical, with modes at roughly 19-20 mm and 43-46 mm (Fig. 19).

AGE OF RECRUITMENT

The von Bertalanffy growth equation, of the form $L_t = L_\infty [(1-e) - ^{k(t-t_o)}]$, when fitted to the length-at-age data, yielded the following values and 95% confidence limits for the three parameters: L_∞ = 147.10 ($\pm$67.69), k = 0.071 ($\pm$0.046), and t_o = -0.078 ($\pm$0.354) (Fig. 20). The length-at-age data when fitted to the von Bertalanffy, over the range of ages sampled, are essentially linear. The straight-line linear regression appeared to describe growth, within the range considered, just as adequately. The growth equation indicates that soft-shell clams in Cole Harbour reach the proposed 1991 recruit size of 44 mm (approximately 1-3/4 in.) in approximately 5.2 yr and the current recruit size of 50 mm (approx. 2 in.) in approximately 6.0 yr (Fig. 21).

STANDING STOCK

The standing stock for all recruit categories is given, in bushels and metric tons, in Table 5. In the open area, the standing stock of 44-49 mm recruits was 203.9 bu, or 7.61 t, and for recruits $\geq$50 mm 1174.6 bu, or 32.1 t. In the closed area, the standing stock of 44-49 mm recruits was 462.0 bu, or 12.6 t, and for recruits $\geq$50 mm 1078.9 bu, or 29.4 t. Total standing stock (individuals of $\geq$44 mm) in the open area was 1458.7 bu (39.8 t); in the closed area, 1540.8 bu (42.1 t).

DISCUSSION

CLAM ABUNDANCE AND DISTRIBUTION

Isopleths of clam density distribution for the shell length categories provide site-specific information on spatial recruitment patterns. For the Cole Harbour area in general, there is patchiness and spatial overlap among the shell length categories. Pre-recruits are found within areas numerically dominated by recruits. Subareas G, H, I, J, K, and R show markedly poor densities of all shell-length categories. These poor densities may be attributed to less-favourable sediment characteristics, such as the substrate being either much muddier or of finer sand than that in the surrounding subareas. These areas tended to support growths of marsh grass and razor clams (*Ensis directus*), flora and fauna not common on flats with abundant soft-shell clam populations.

The fact that there is spatial overlap, of comparable density levels, for the various size categories suggests that the combined results of recruitment, growth, and survival occur in patches, reflecting physical factors in the environment itself.

When compared with densities reported in several earlier surveys in other clam-producing areas of Nova Scotia and New Brunswick, the density of soft-shell clams in Cole Harbour is relatively low. Witherspoon (1982; 1983) found densities of 42-49 mm clams, in the eastern shore and in the Minas Basin of Nova Scotia, ranging from 40-300 bu/ha. In Charlotte County, New Brunswick, Robert and Smith (1980) found densities of >30 mm clams ranging from 74-338 bu/ha. Robert (1981) found densities of 0-323.8 bu/ha for 45 mm clams and 13-201 bu/ha for 51 mm clams in Prince Edward Island. These comparisons to the Cole Harbour data must be viewed with caution, since the methods used differed considerably in such things as sample size and sampling intensity. However, Angus et al. (1985), using the same survey methods as those employed in the present study, reports even lower densities for clams ≥43 mm in length from the Annapolis Basin. When adjusted for area, Angus et al. (1985) give mean densities for the open and closed areas of 19.1 and 30.2 bu/ha and an overall density of 26.7 bu/ha.

POPULATION STRUCTURE

The overall similarity of the length-frequency curves for the open and closed areas (Fig. 19) suggests that the factors governing recruitment, growth, and survival are similar in the two areas. When the density and biomass results are also considered, it appears that while the overall pattern of annual recruitment in both areas is very similar, either the level of recruitment is generally lower in the open, more seaward, area of the Harbour, or survival is generally lower in this area. The similarity between open and closed areas in length frequencies for clams ≥50 mm, which were already recruited to the fishery under the current size limit, is particularly interesting. One would expect to see a reduction in the frequency of commercial sizes in the open area, which can be - and is - regularly fished, relative to that in the closed area, where no legal fishery exists at the time of the survey. The data may be interpreted as indicating that either the commercial fishery has had little impact or that there is equally heavy exploitation of both areas.

AGE OF RECRUITMENT

The von Bertalanffy growth equation does not provide a good fit to the data, the 95% confidence intervals being very large for all parameters. Over the range of ages sampled, growth appears to be essentially linear. Since the range in size-at-age is relatively small up to Age 6, it is unlikely that the size-at-age derived from the equation for clams up to Age 6 will be significantly in error.

Clams in Cole Harbour reach the proposed and current commercial size limits of 44 and 50 mm in 5.2 and 6.0 yr, respectively. This indicates more rapid growth to recruitment size than that for other flats in the Scotia-Fundy Region. Along the outer coast of Nova Scotia, in Three Fathom Harbour and Clam Harbour, Mullen et al. (1985) found growth to 50 mm required 6.2 yr, while Witherspoon (1982) found clams in Chezzetcook and Harrison Beach required 8 yr to reach this size. In the Annapolis Basin, Bay of Fundy, Angus et al. (1985) determined that it took 7.5 yr to reach 50 mm. Robert (1981) examined data for 25 flats in Prince Edward Island and found that clams took between 3 and 6 yr to reach 44 mm and from 3 to 8 yr to reach 50 mm. Newell et al. (1986) indicated that in Maine, U.S.A., clams took between 3-6 yr to reach 50 mm. It appears that environmental conditions for clam growth are very favourable in Cole Harbour, or possibly that the stock in this Harbour is considerably different genetically in its growth response than clams in other areas of the Region.

STANDING STOCK

Historically, the open area has supported both a commercial and a recreational fishery. The 1989 opening of the previously closed area should, unless total effort increases, reduce fishing pressure on those open areas discussed in this report. The author's data indicate that the standing stock of recruits in the formerly closed area, having 2.3-4.1 times the density of clams in the historically open area, could support a substantial fishing effort. While the similarities in population structure for the two areas suggest historically similar fishing impact, as a result of illegal fishing, the much higher densities of recruit-sized clams in the closed area indicate that the level of this illegal fishing may not have been as high as generally believed. Alternatively, recruitment to the population and/or survival may generally be greater in the inner areas of the Harbour.

SUMMARY

1. The growth rate of clams in Cole Harbour is the highest reported for the Scotia-Fundy Region - 44 mm shell length being attained in 5.2 yr; 50 mm, in 6.0 yr. Other areas, such as Prince Edward Island and Maine, appear to have better growth conditions than Cole Harbour. Clams in Prince Edward Island require 3-8 yr to reach 50 mm in length; those in Maine, 3-6 yr.

2. Densities of recruit-sized clams appear to be somewhat lower, even in the closed areas, than reported for some other Atlantic Canada clam flats, although comparisons are difficult because of variations in the size classes included, sampling regimes, etc.

3. Densities of recruits are considerably higher in the closed area - 2.7 and 2.3 times higher, respectively, for the $\geq$44 and $\geq$50 mm recruiting size classes. For the smaller recruits, in the 44-49 mm size category, the ratio is even greater, being 4.1:1.

4. Total standing stock of recruits $\geq$50 mm (approx. 2 in.) was 61.5 t, while that for recruits $\geq$44 mm (1.75 in) was 81.9 t. Standing stocks of recruits in the open and closed areas were virtually equal.

5. Population structure and distributional data indicate consistent recruitment to the population and spatially consistent recruitment patterns.

6. Overlapping spatial density distributions among the pre-recruit and recruit categories indicate stable physical and environmental conditions acting as a control on clam distribution throughout the Harbour.

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Table 1. Aerial coverage of the study areas within Cole Harbour, Nova Scotia.

Location		Surveyed[1] (hectares[3])	Sampled[2] (hectares[3])
Open:	A	7.3	4.2
	B	1.4	1.4
	C	3.8	3.8
	D	0.9	0.9
	E	2.5	2.4
	F	4.8	4.8
	G	4.8	3.2
	H	18.6	4.6
	I	4.2	1.8
	J	8.1	1.5
	K	2.2	0.6
Subtotal:		58.6	29.2
Closed:	O	19.3	4.4
	P	1.2	0.6
	Q	1.7	0.4
	R	0.8	0.8
Subtotal:		23.0	6.2
Grand total:		81.6	35.4

[1]Surveyed area refers to the estimated total area of the clam flat exposed at the low tide level on the day of study.
[2]Sampled area refers to that portion of the surveyed area covered by sampling stations.
[3]1 ha = 10,000 m^3.

Table 2. Number of recruits per square meter in the open and closed areas of Cole Harbour, Nova Scotia.

Location		Recruits (44-49 mm)	Recruits (≥50 mm)	Total recruits (≥44 mm)
Open:	A	2.6	3.3	5.9
	B	0.6	2.6	3.2
	C	1.0	1.8	2.8
	D	8.3	5.7	14.0
	E	6.7	5.3	12.0
	F	2.0	2.8	4.8
	G	0.3	1.1	1.4
	H	0.6	0.8	1.4
	I	1.1	2.7	3.8
	J	0.4	0.7	1.1
	K	7.3	15.3	22.6
Range:		0.3-8.3	0.7-15.3	1.1-22.6
Closed:	O	2.0	4.2	6.2
	P	6.6	7.8	14.4
	Q	0.0	0.0	0.0
	R	0.6	2.2	2.8
Range:		0-6.6	0-7.8	0-14.4

Table 3. Densities in bushels per hectare for each recruit category in the open and closed areas of Cole Harbour, Nova Scotia. Mean bushels per hectare (bu/ha) for all recruits ≥44 mm in shell length are also given for the combined area. The ratio of closed to open areas densities is also presented.

		Recruit categories		
		44-49 mm	≥50 mm	≥44 mm
bu/ha:	Open area	4.9	20.0	24.9
	Closed area	20.1	46.9	67.0
Ratio (bu/ha):	Closed:Open	4.1:1	2.3:1	2.7:1

Table 4. Percentages of pre-recruits and recruits in the open and closed areas of Cole Harbour, Nova Scotia.

Area	Pre-recruits (≤43 mm)	Recruits		Total recruits (≥44 mm)
		44-49 mm	≥50 mm	
Open	78.7	8.9	12.4	21.3
Closed	84.8	6.8	8.4	15.2
Total	80.4	8.3	11.3	19.6

Table 5. Estimated standing stock of soft-shell clams in the surveyed area.

Survey area		Recruits 44-49 mm bu/ha	Recruits 44-49 mm Total bu	Recruits 44-49 mm t	Recruits ≥50 mm bu/ha	Recruits ≥50 mm Total bu	Recruits ≥50 mm t	Total recruits (≥44 mm) Total bu/ha	Total recruits (≥44 mm) Total bu	Total recruits (≥44 mm) Total t
Open:	A	9.1	66.4	1.8	21.0	153.0	4.2	30.1	219.7	6.0
	B	2.0	2.8	0.01	280.1	392.1	10.7	282.1	394.9	10.8
	C	3.2	12.2	0.3	13.1	49.8	1.4	16.3	61.9	1.7
	D	29.1	26.2	0.7	36.4	32.8	0.9	65.5	59.0	1.6
	E	23.1	57.8	1.6	35.7	89.3	2.4	58.8	147.0	4.0
	F	6.7	32.2	0.9	18.3	87.8	2.4	25.0	120.0	3.3
	G	1.0	4.8	0.1	8.9	42.7	1.2	9.9	47.5	1.3
	H	2.1	39.1	1.1	5.6	104.2	2.8	7.7	143.2	3.9
	I	3.7	15.5	0.4	26.7	112.1	3.1	30.4	127.7	3.5
	J	1.5	12.2	0.3	6.3	51.0	1.4	7.8	63.2	1.7
	K	6.7	14.7	0.4	27.2	59.8	1.6	33.9	74.6	2.0
Total:			283.9	7.61		1174.6	32.1		1458.7	39.8
Closed:	O	23.0	443.9	12.1	49.9	963.1	26.3	72.9	1407.0	38.4
	P	13.9	16.7	0.5	86.8	104.2	2.8	100.7	120.8	3.3
	R	1.8	1.4	0.03	14.5	11.6	0.3	16.3	13.0	0.4
Total:			462.0	12.63		1078.9	29.4		1540.8	42.1

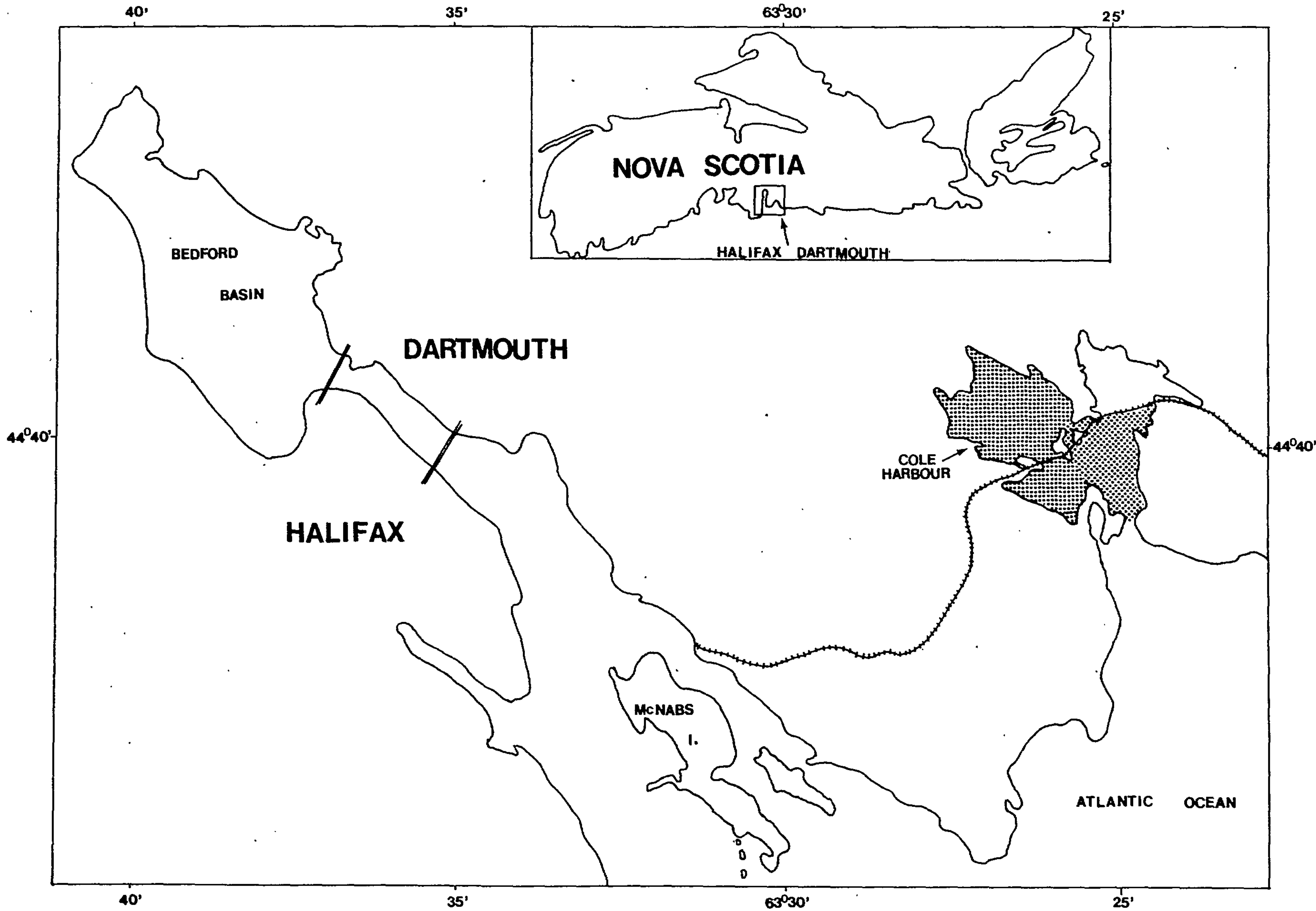


Fig. 1. Clam-producing area (shaded) - Cole Harbour, Nova Scotia.

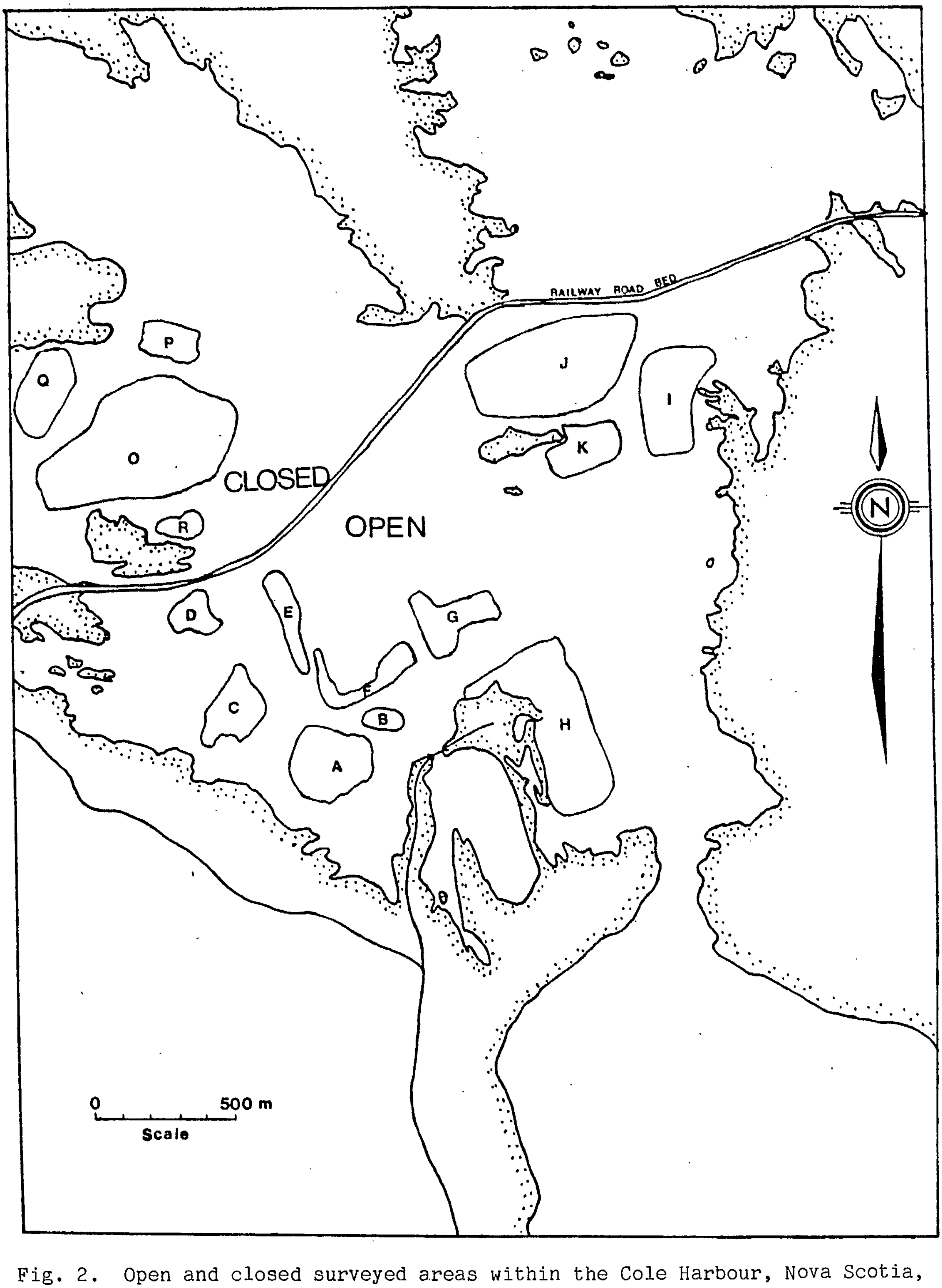


Fig. 2. Open and closed surveyed areas within the Cole Harbour, Nova Scotia, area.

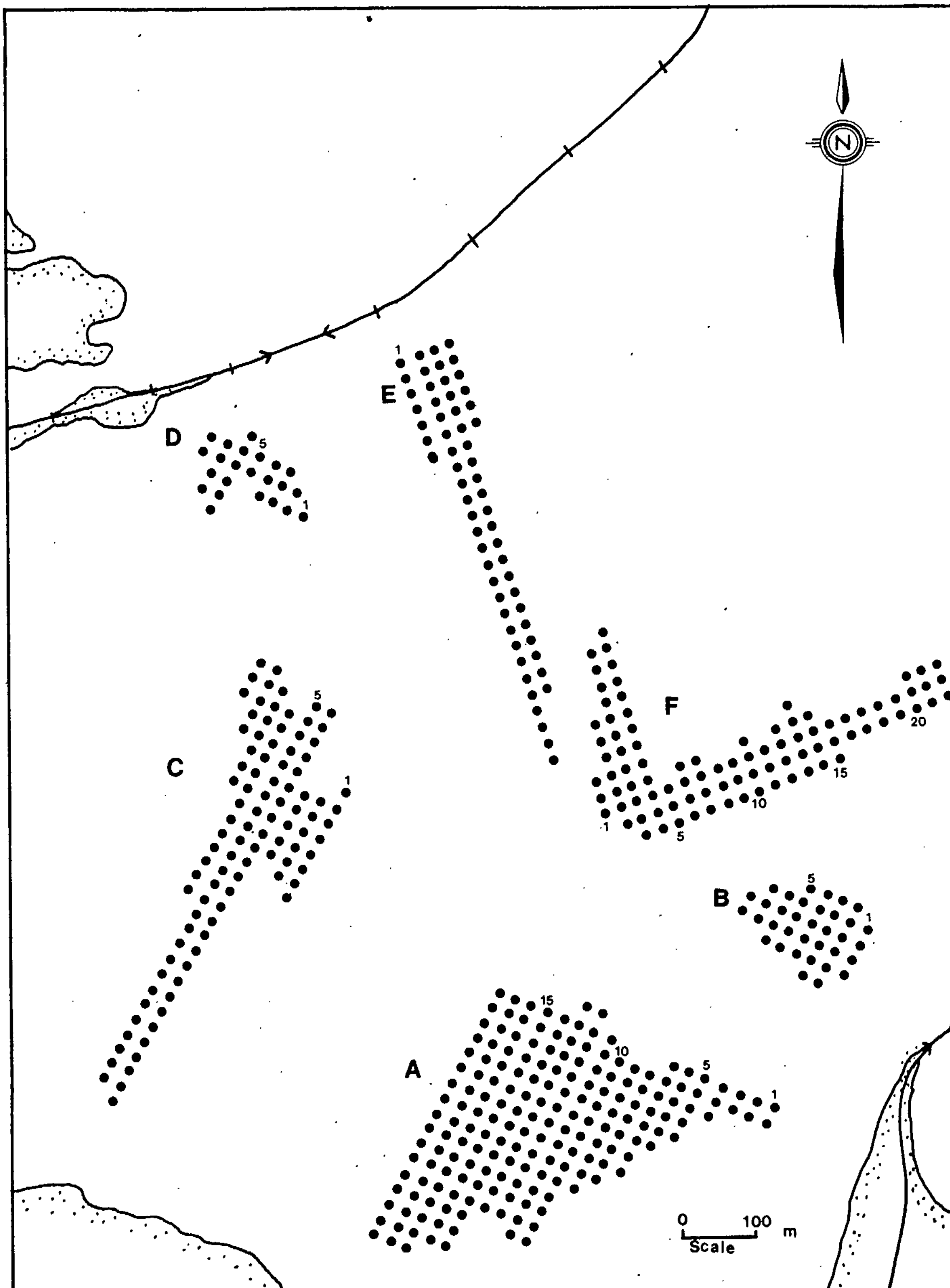


Fig. 3. Sampling station distribution for open Subareas A to F, Transect 22.

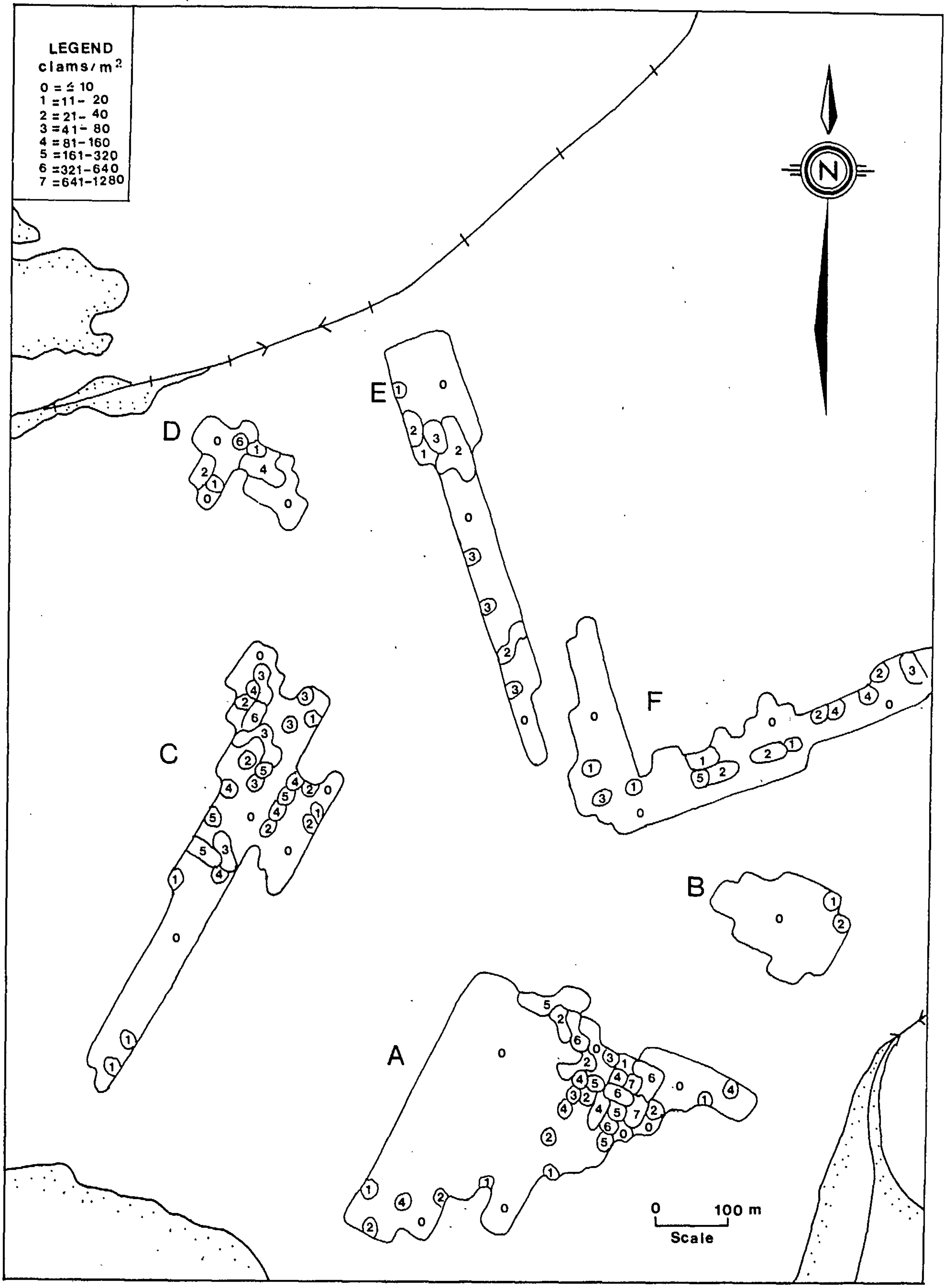


Fig. 4. Isopleths of clam density distribution for open Subareas A to F Transect 22, Pre-recruits (≤43 mm).

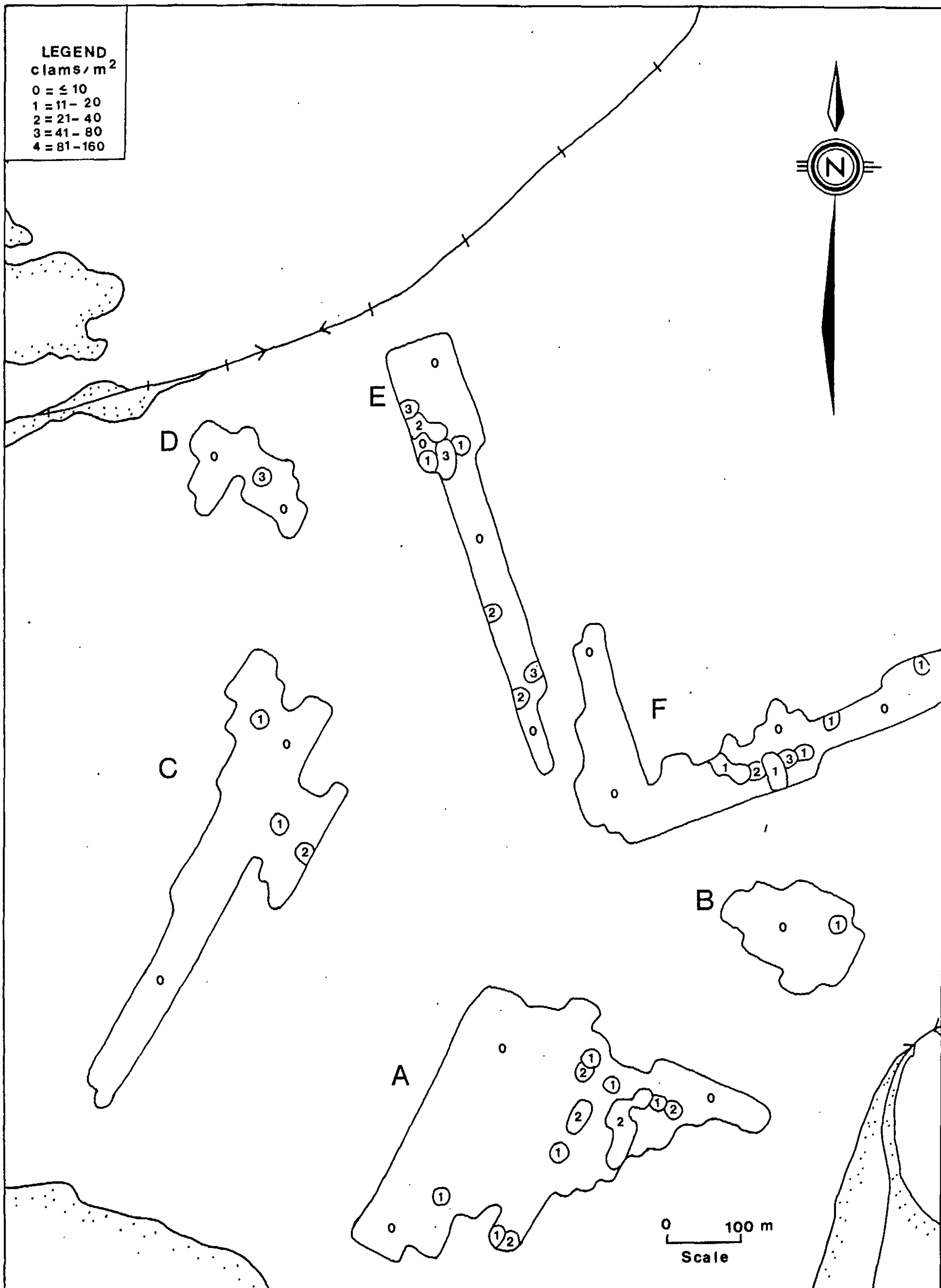


Fig. 5. Isopleths of clam density distribution for open Subareas A to F Transect 22, Recruits 44 to 49 mm.

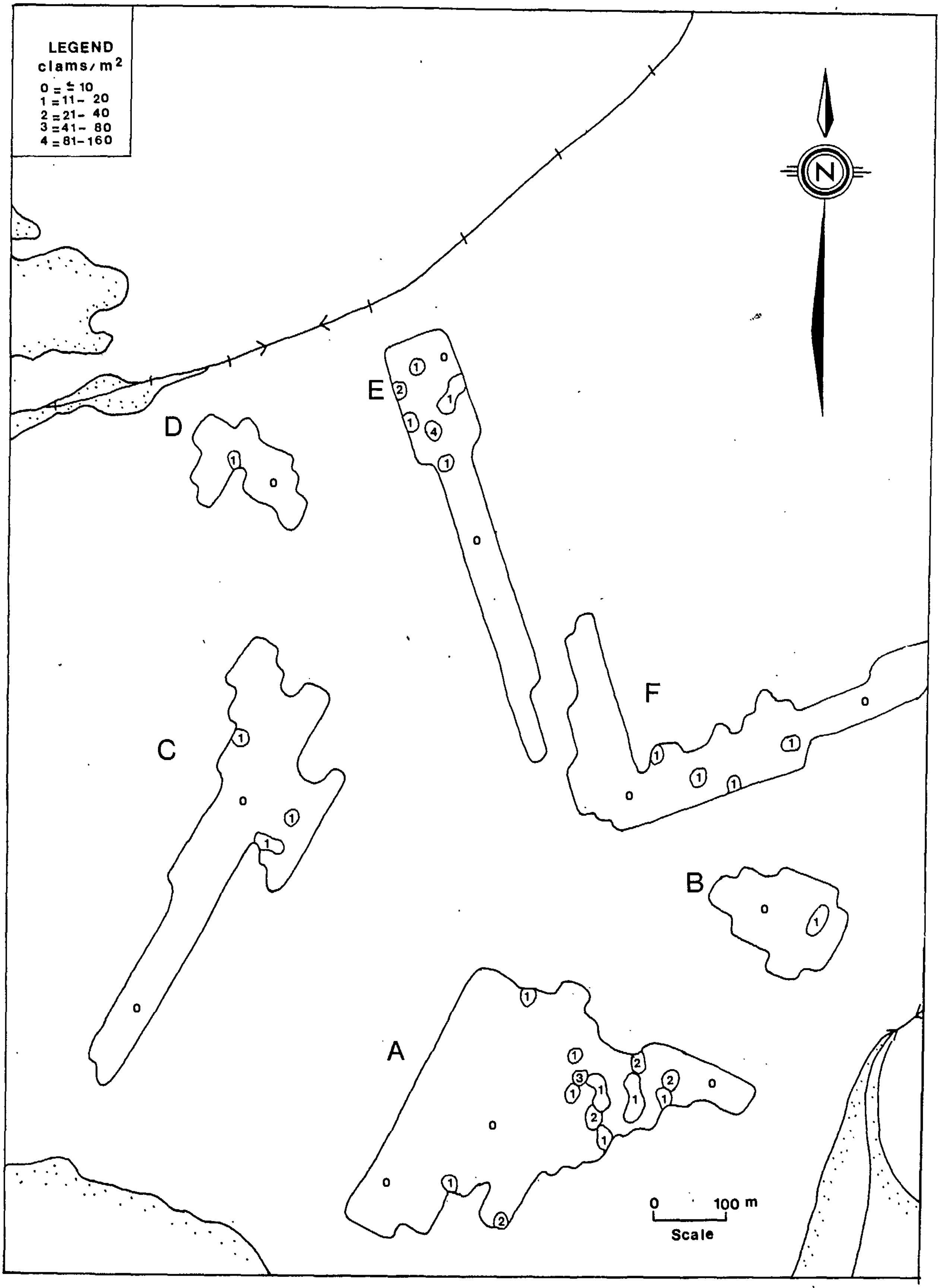


Fig. 6. Isopleths of clam density distribution for open Subareas A to F Transect 22, Recruits ≥50 mm.

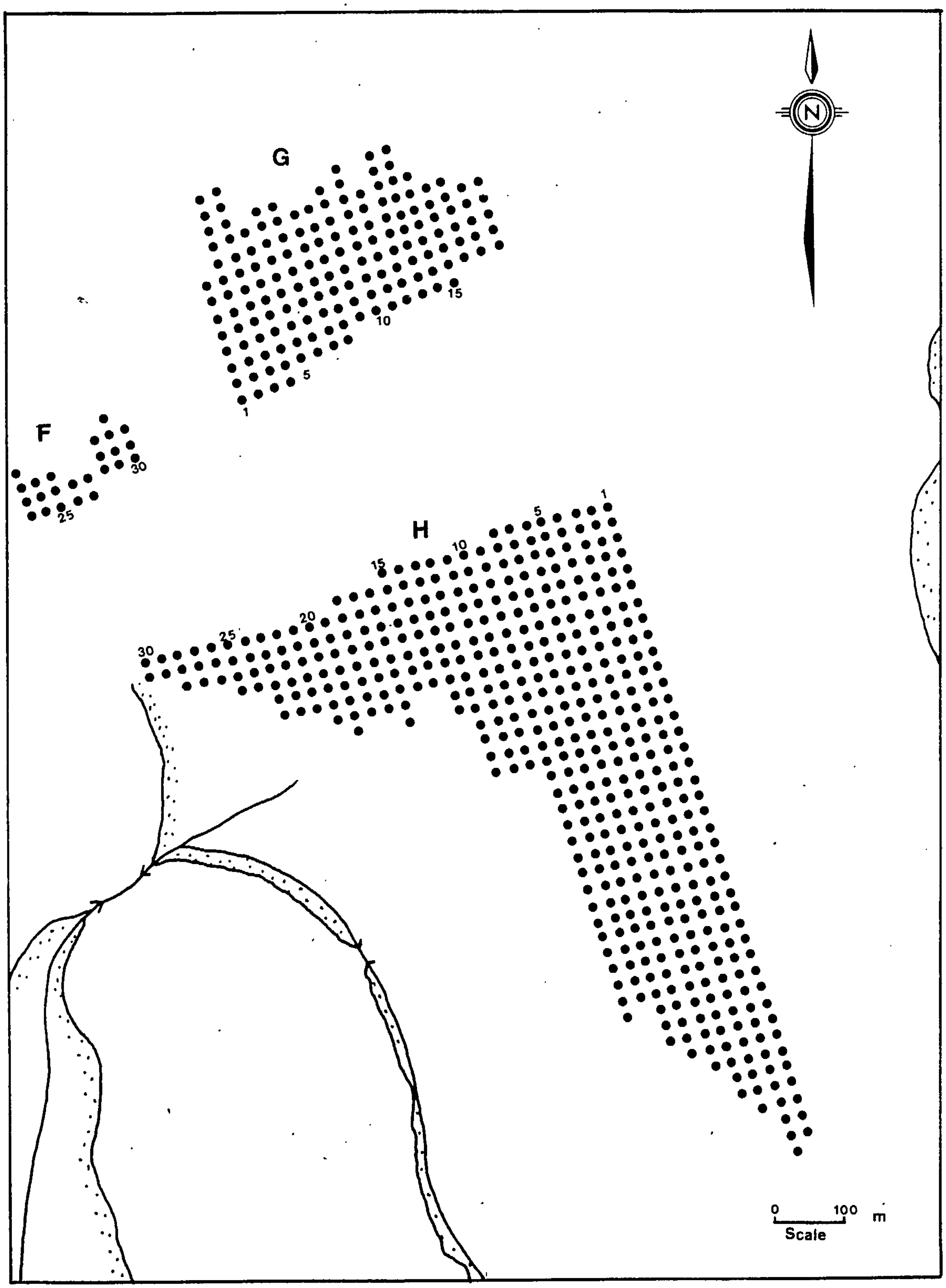


Fig. 7. Sampling station distribution for open Subareas F to H.

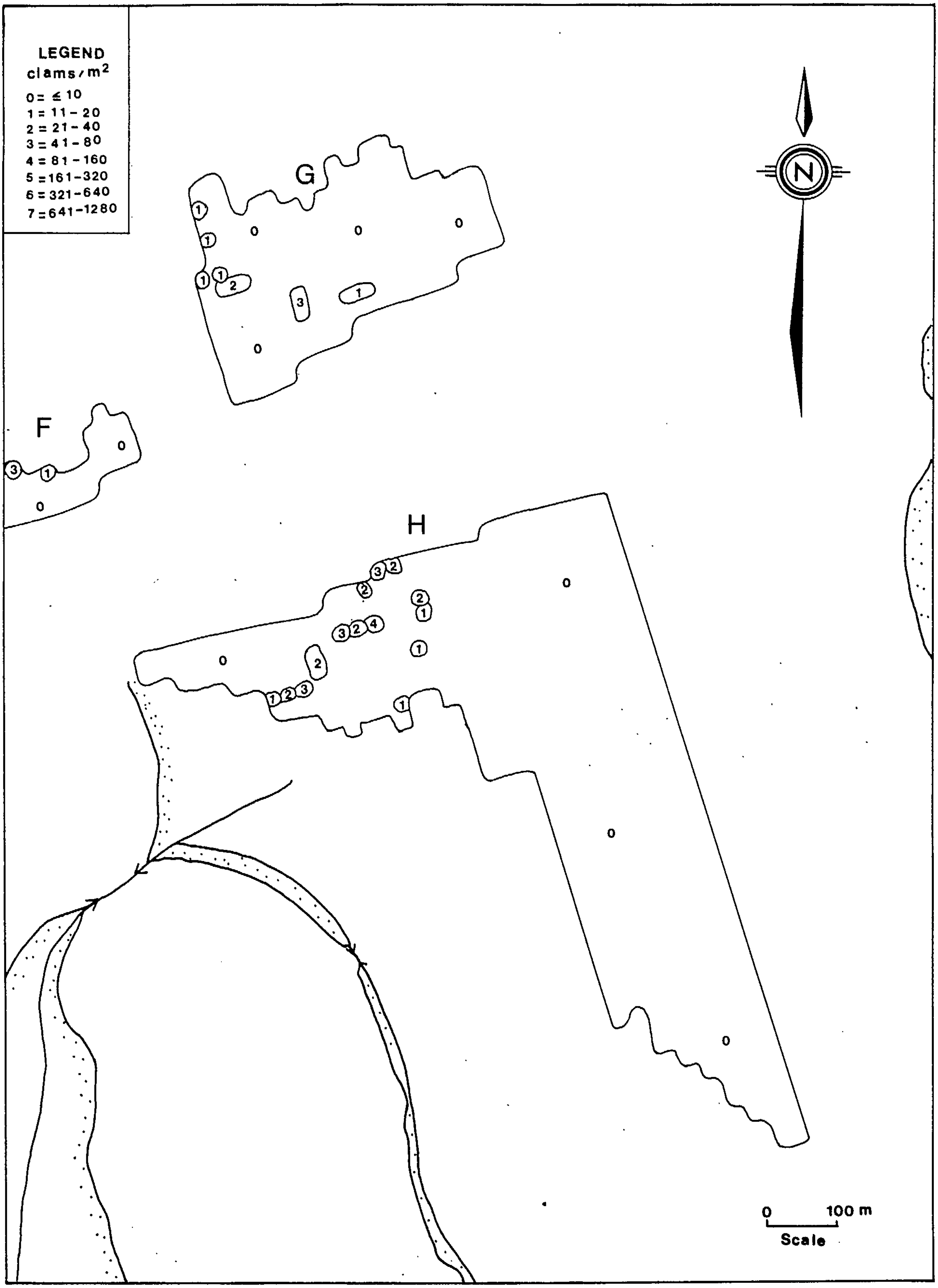


Fig. 8. Isopleths of clam density distribution for open Subareas F to H, Pre-recruits (≤43 mm).

Fig. 9. Isopleths of clam density distribution for open Subareas F to H, Recruits 44 to 49 mm.

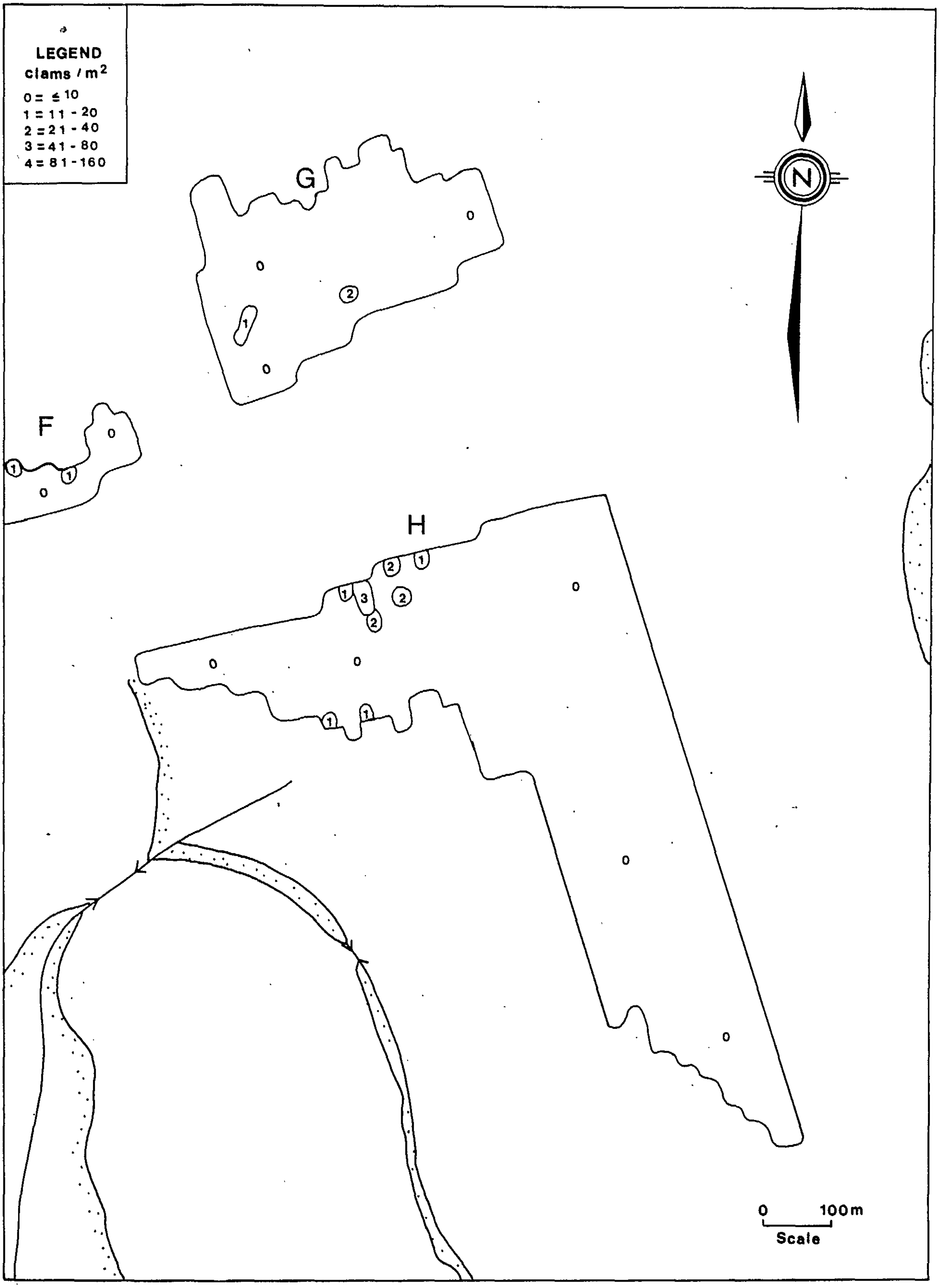


Fig. 10. Isopleths of clam density distribution for open Subareas F to H, Recruits ≥50 mm.

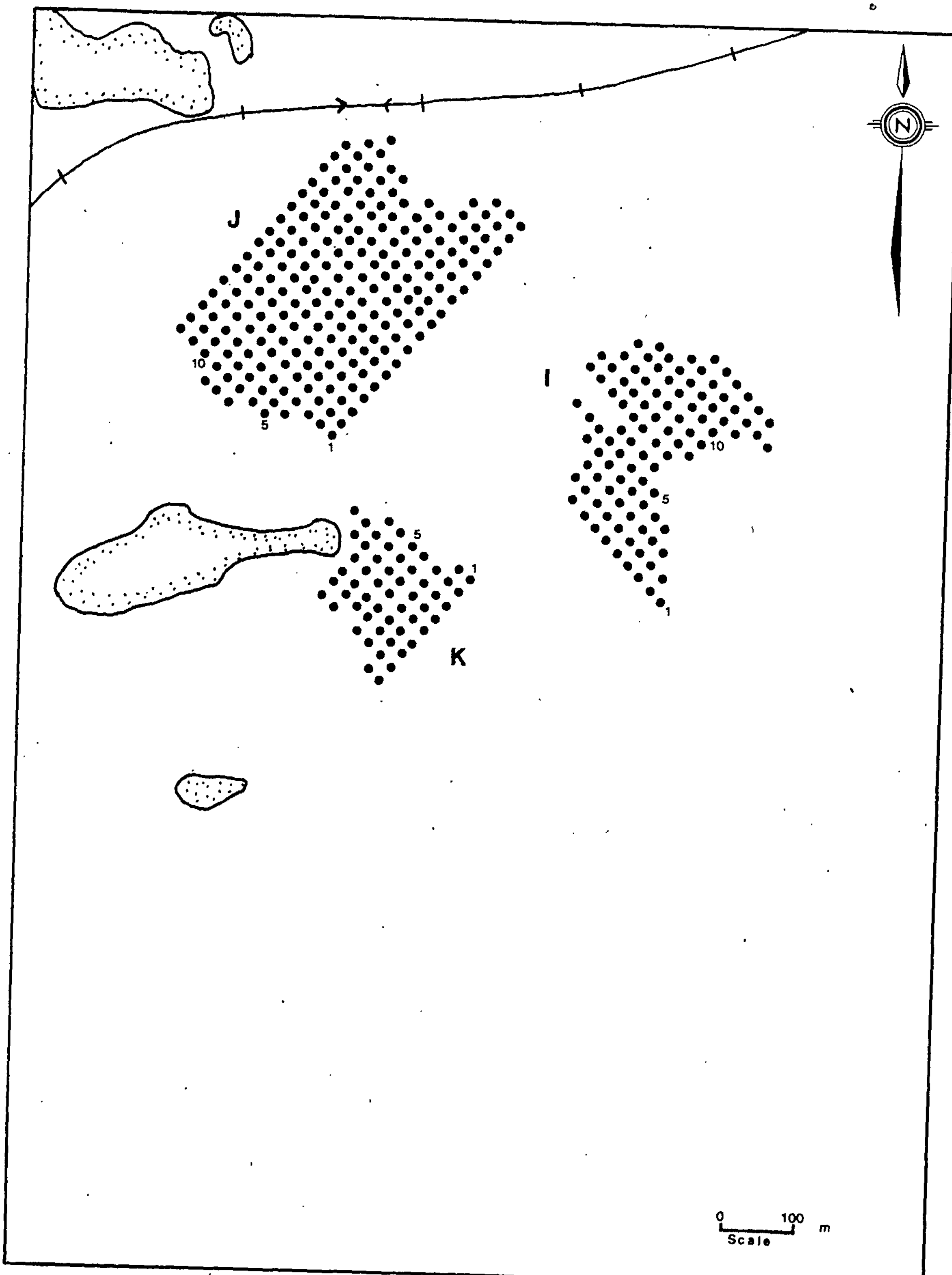


Fig. 11. Sampling station distribution for open Subareas I to K.

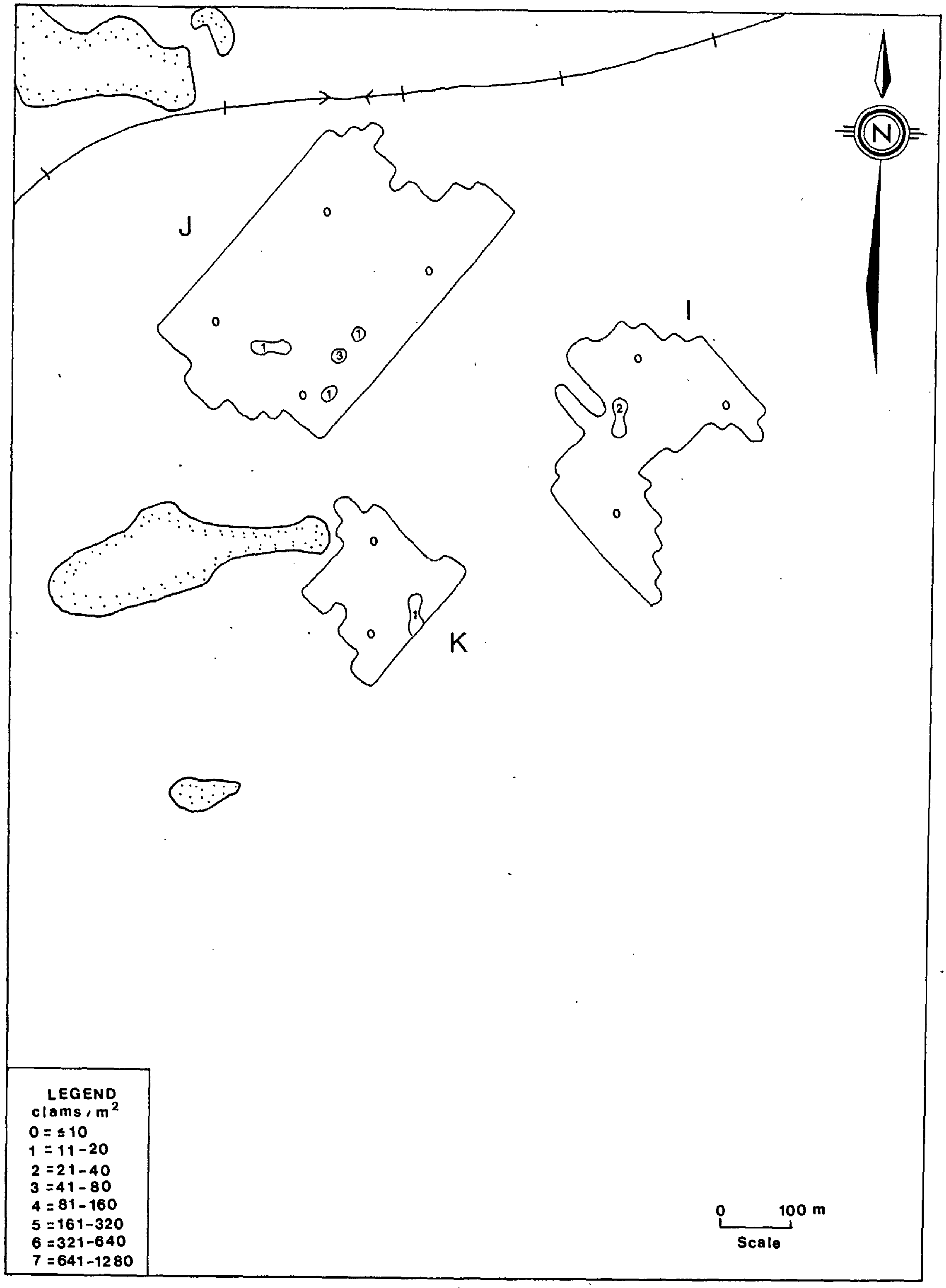


Fig. 12. Isopleths of clam density distribution for open Subareas I to K, Pre-recruits (≤43 mm).

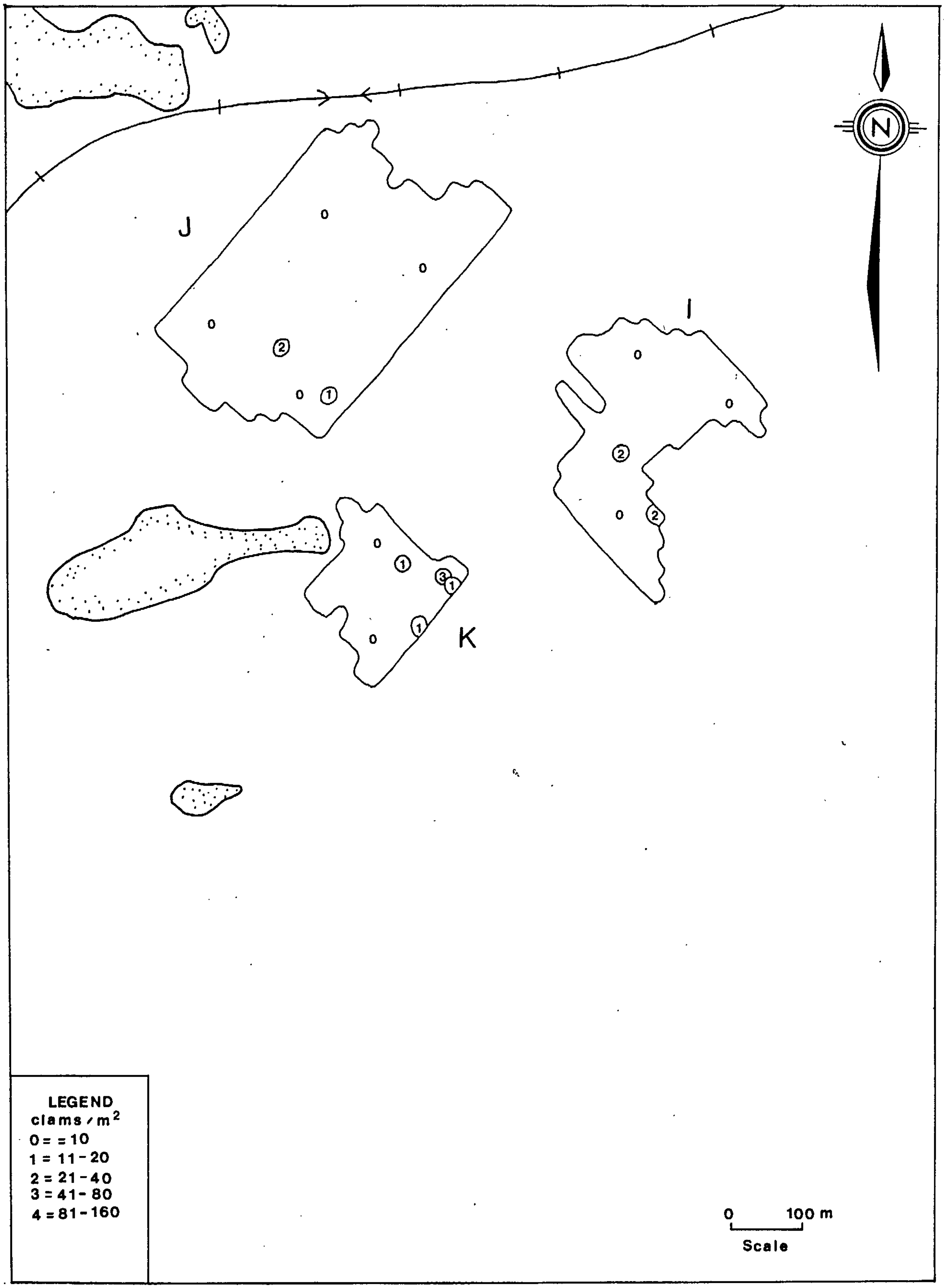


Fig. 13. Isopleths of clam density distribution for open Subareas I to K, Recruits 44 to 49 mm.

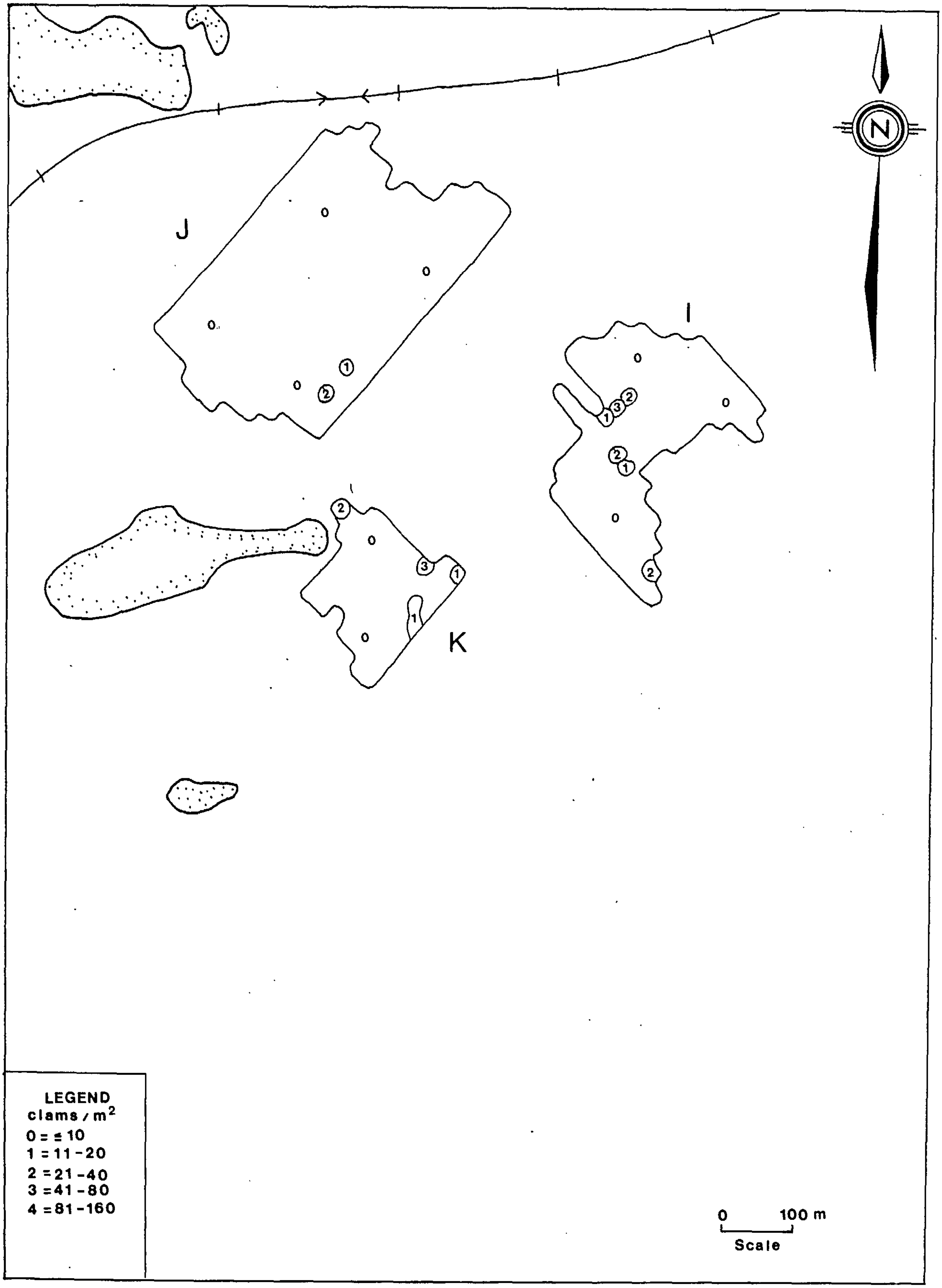


Fig. 14. Isopleths of clam density distribution for open Subareas I to K, Recruits >50 mm.

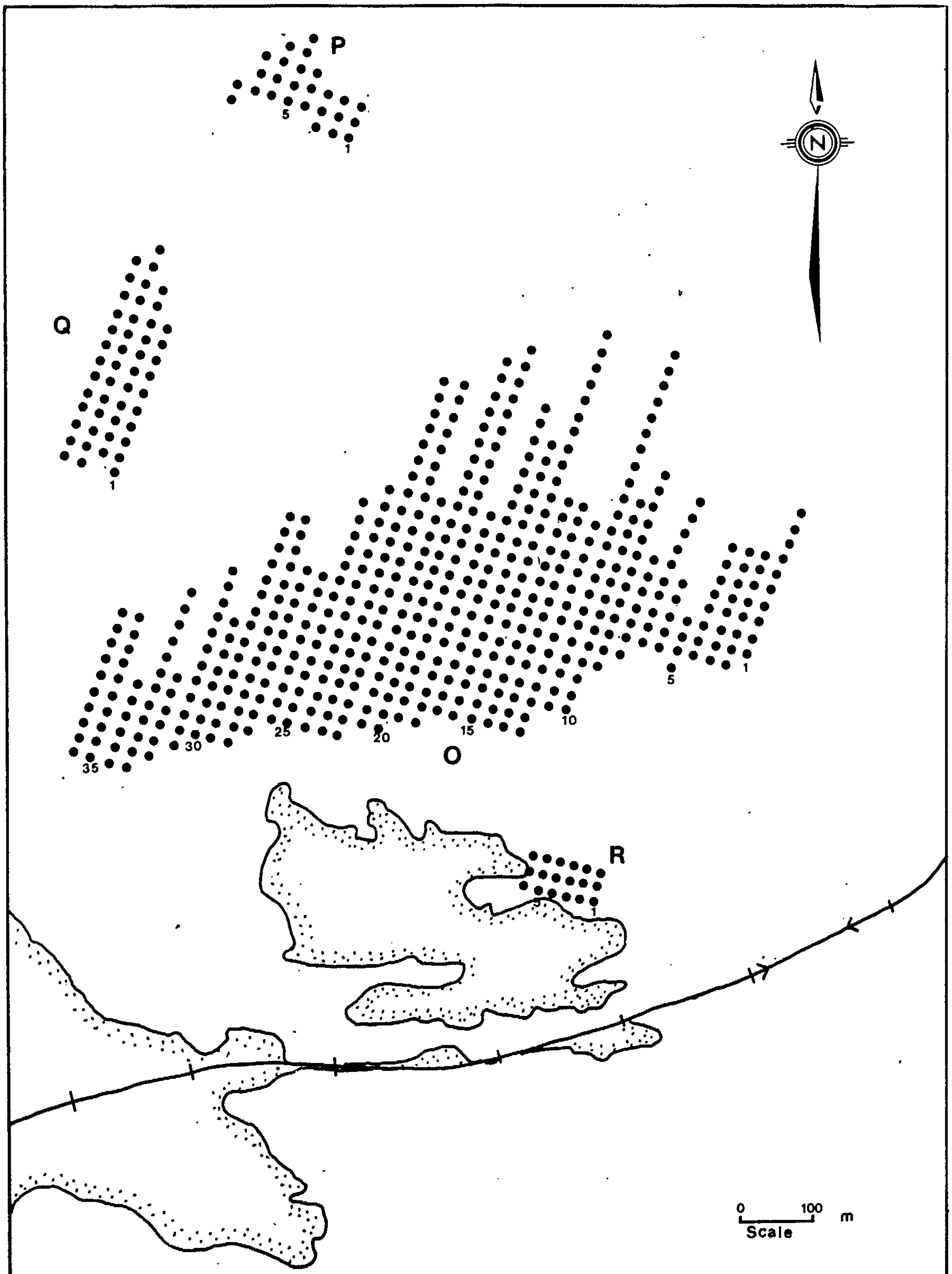


Fig. 15. Sampling station distribution for closed Subareas O to R.

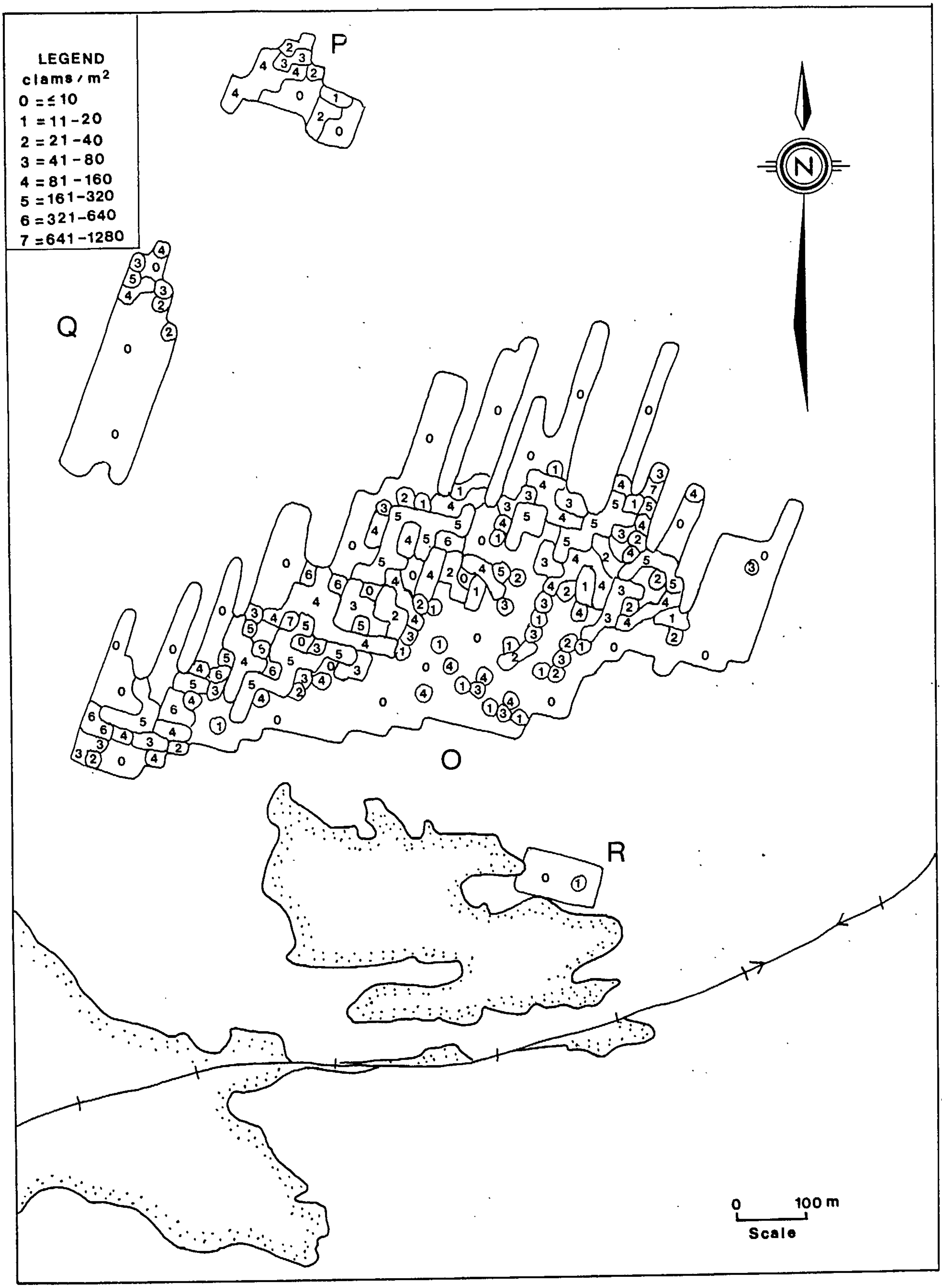


Fig. 16. Isopleths of clam density distribution for closed Subareas O to R, Pre-recruits (≤43 mm).

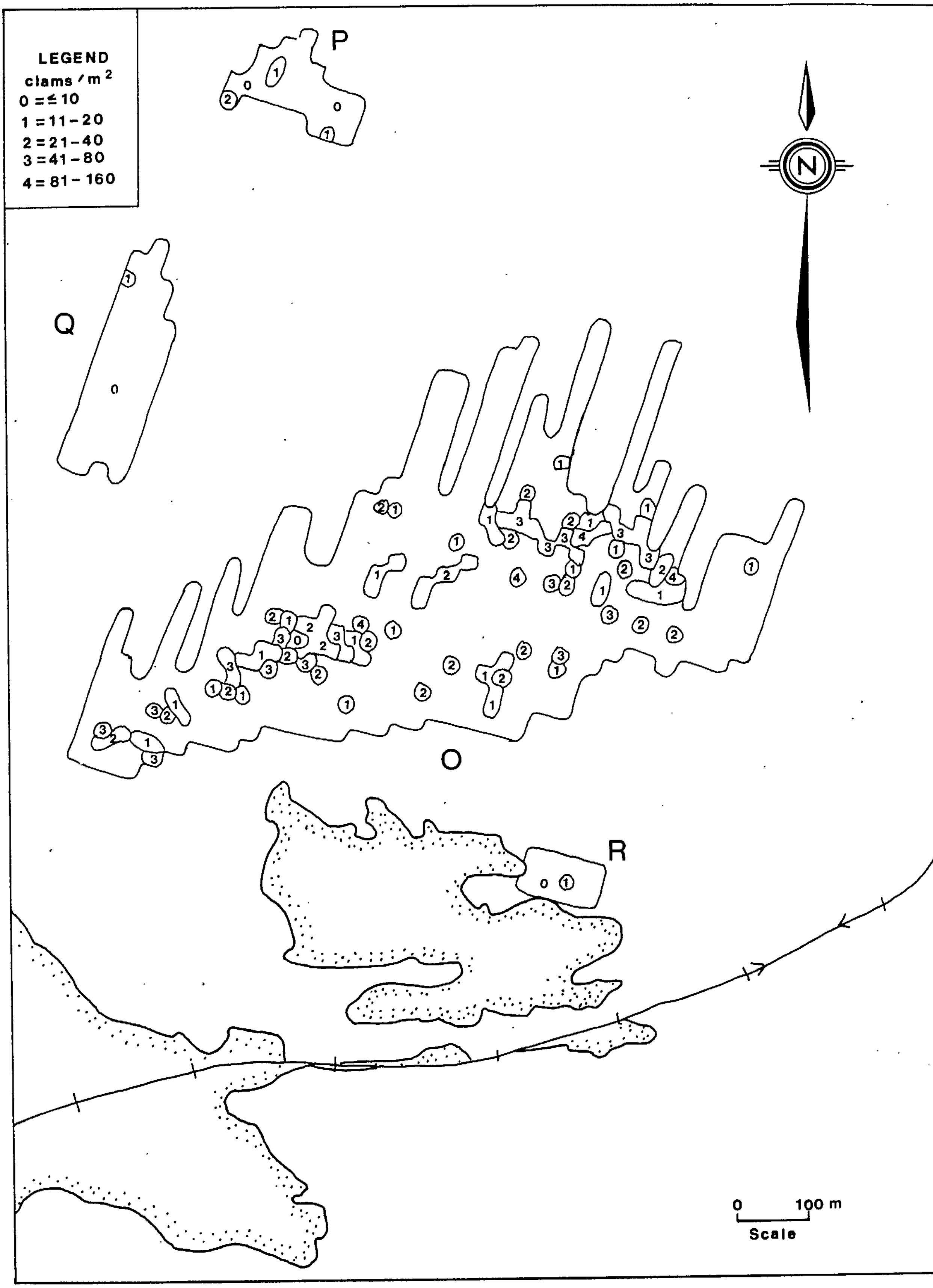


Fig. 17. Isopleths of clam density distribution for closed Subareas O to R, Recruits 44 to 49 mm.

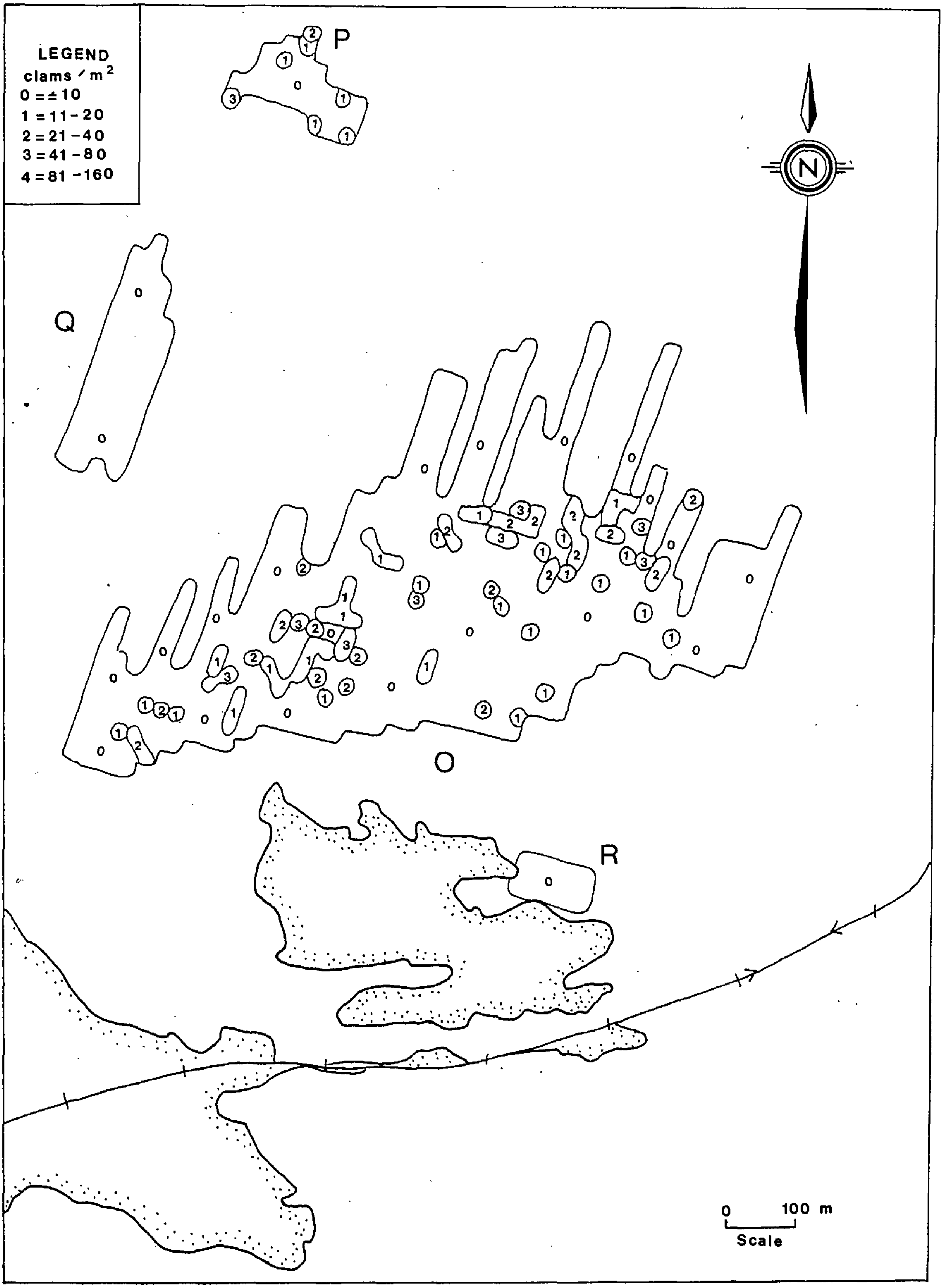
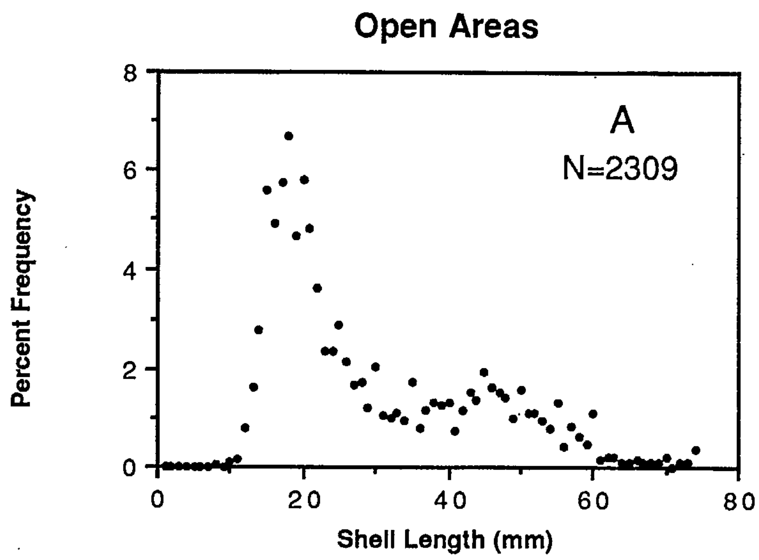


Fig. 18. Isopleths of clam density distribution for closed Subareas O to R, Recruits >50 mm.



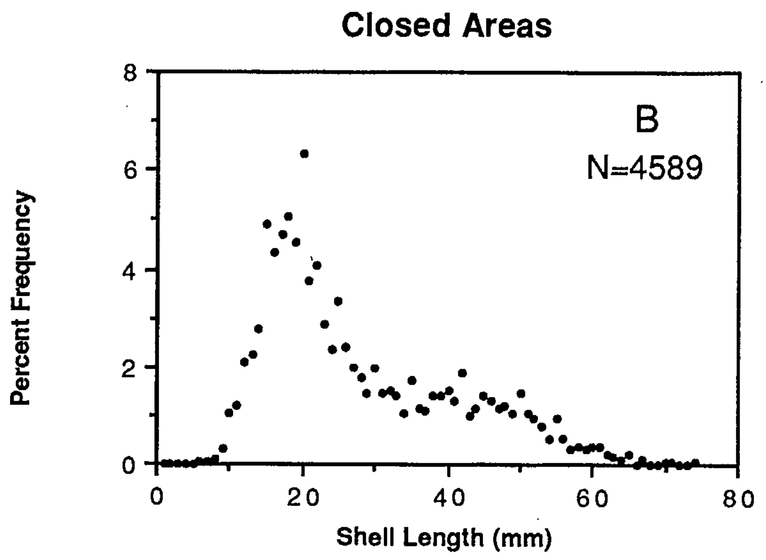


Fig. 19. Percent frequency of clams in areas open (A) and closed (B) to harvest at the time of the survey.

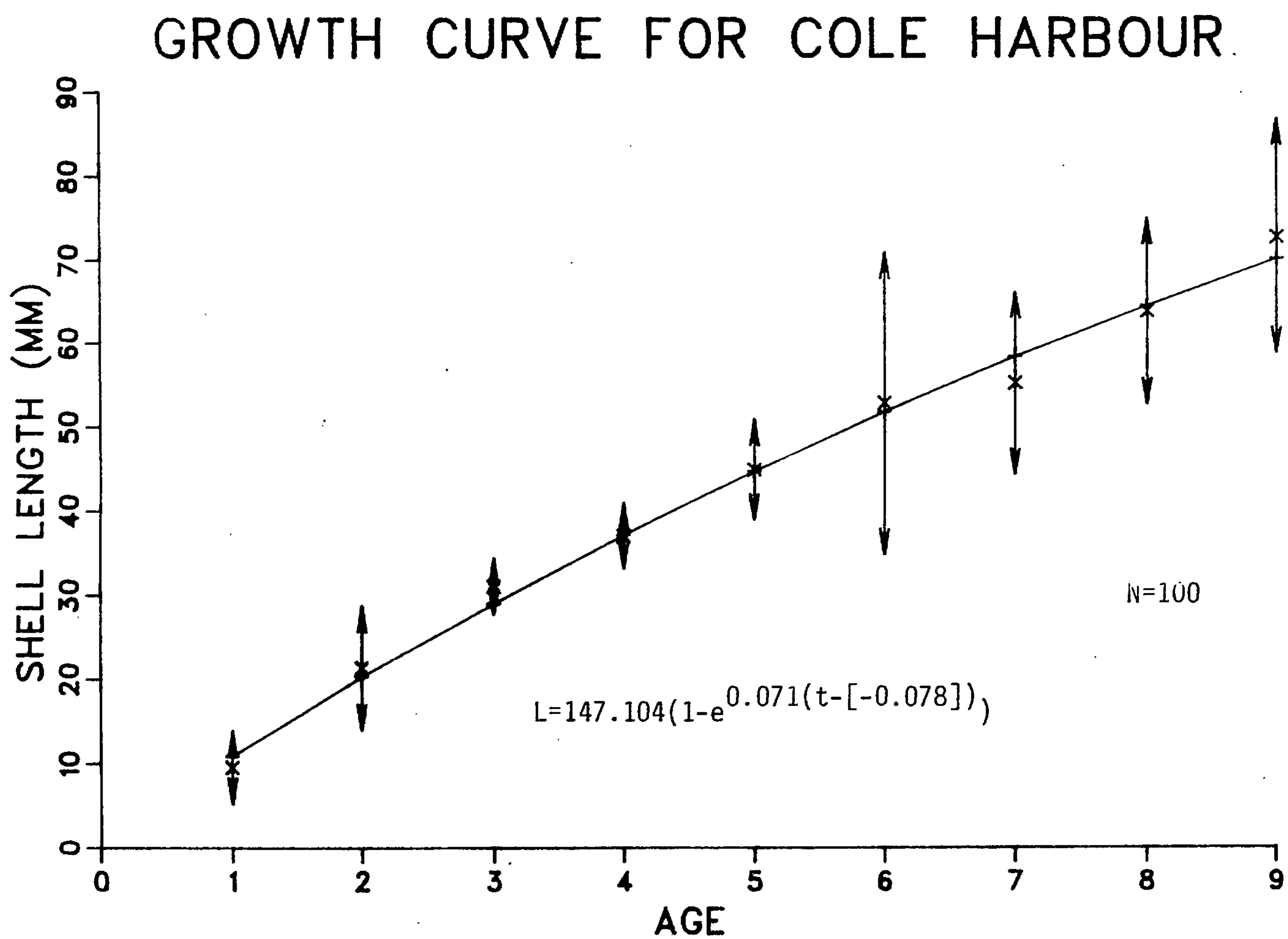


Fig. 20. Growth curve for Cole Harbour, Nova Scotia, fitted by the von Bertalanffy growth equation. Means and ranges are indicated.

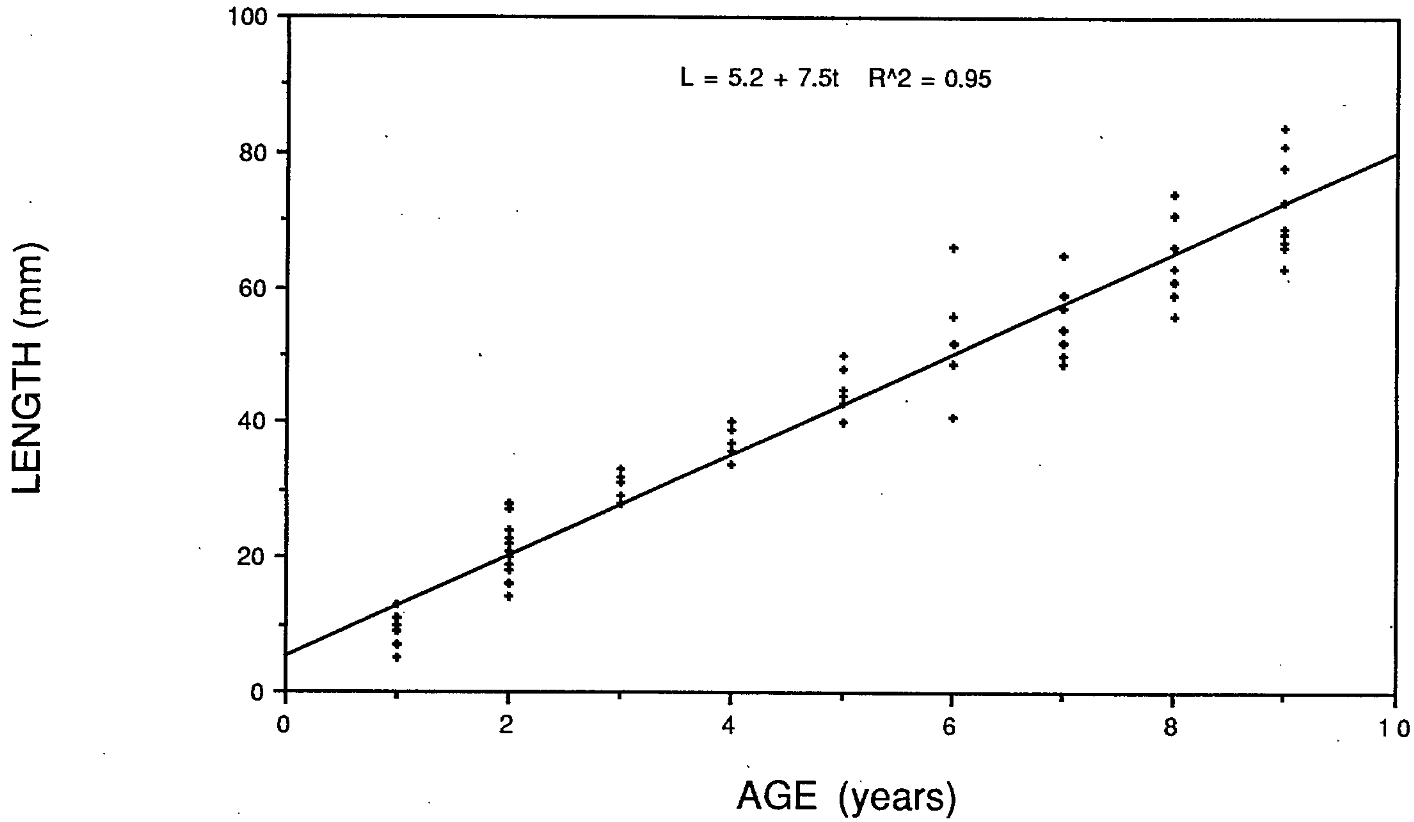


Fig. 21. Growth of Cole Harbour, Nova Scotia, clams fitted by a straight-line regression. Mean length and ranges are indicated.

Appendix 1. Cole Harbour, Nova Scotia, tides on survey dates.

Area	Survey date (1984)	Low tide time (h)	Tide level (m)
A	August 14	17:01	2.4
A	15	17:41	2.4
A	16	18:16	2.5
		06:11	2.4
A	17	19:01	2.5
A	20	08:46	3.0
C	21	09:51	3.0
C	22	10:56	2.9
D	23	11:46	2.8
E	27	15:41	1.8
F	28	16:21	1.7
F	29	17:26	1.6
F	30	18:21	1.7
G	30	18:21	1.7
H	Sept. 10	15:16	2.2
H	11	15:51	2.2
I	13	17:01	2.2
I	17	07:06	3.0
J	18	08:06	3.2
O	19	09:21	3.2
Q	24	14:21	1.8
O	25	15:21	1.5
O	26	16:01	1.3
O	27	17:01	1.3
		06:06	1.9
O	29	18:51	1.6
O	Oct. 01	08:16	2.7
O	02	19:21	2.9
O	03	10:21	3.0
Q	04	11:16	3.0
P	18	09:31	3.3
P	19	10:16	3.2
Q	22	13:16	2.1

Appendix 2a. Data used in calculating the relationship[1] between clam length (in millimeters) and total number of clams in 1 bu.

Size range (mm)	Clams/bu[2]		Size range midpoint (mm)
	Counted[2]	Predicted	
0-20	23,815	22,070	15[3]
21-30	13,862	11,522	25
31-40	5,405	6,015	35
41-50	2,545	3,140	45
51-60	1,481	1,639	55
61-70	851	856	65
71-80	555	447	75

[1]Relationship: $\ln y = a + bx$ ($a = 10.977$; $b = -0.065$)
$\ln y = 10.977 - 0.065x$
$r^2 = 0.95$
$n = 7$

where x = clams per bushel; and
y = clam length in millimeters.

[2]Number of clams to occupy 1 bu.

[3]15 mm was selected as a midpoint in this range as there were very few clams of less than 10 mm.

Appendix 2b. Sample calculation using 44-49 mm size clams in Subarea A.

In Subarea A, 4.2 ha (42,000 m^2) of clam flats were sampled. The size range of the clams was 44-49 mm. The midpoint of the clams was 46.5 mm. There were 2.6 clams per square meter.

By using the equation from Appendix 2a, the number of clams per bushel at 46.5 mm size is determined to be 2,864.

- 2.6 clams x 42,000 = 109,000 clams
- 109,000 clams/2,864 clams = 38.06 bushels
- 38.06 bu/4.2 = 9.1 bu of clams per hectare in Subarea A.