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1997-98 BAY OF FUNDY SCALLOP STOCK ASSESSMENT: ANALYSIS OF THE AREA 4 SURVEY

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ABSTRACT

This document presents the results and preliminary analysis of the June 1997 scallop stock survey in Scallop Production Area 4 off Digby, Nova Scotia. The efficiency of the survey is evaluated and the numbers-at-age by stratum are presented. Survey biomass and abundance is calculated and used to estimate population biomass.

The 1997 survey identified a weak 1995 year class with the 1992 and 1993 year classes being above the average compared to similar ages from 1991 to 1997. The 1992 year class will enter the fishery in 1997 while the 1993 year class will not enter the fishery until 1998. These larger year classes have settled in the Centreville to Digby area, which has been closed to fishing since 1995. Population biomass estimates for the whole of Area 4 are 736 mt (lower and upper 95% confidence intervals (c.i.) of 655 and 819 mt) for the ages 5 and older (5+), while the 6+ biomass is estimated as 478 mt (95% c.i. 421, 542). Population biomass estimates for the portion of Area 4 which was open to fishing in 1996 (Digby to Parkers Cove) are 229 mt for the 5+ scallops and 143 mt for the 6+, reflecting the recruitment of the 1992 year class. These results are similar to those predicted from the 1996 survey (Kenchington et al. 1997).

RÉSUMÉ

Le présent document donne les résultats et présente une analyse provisoire du relevé du stock de pétoncle réalisé en juin 1997 dans la zone de production 4 au large de Digby (Nouvelle-Écosse). L'efficacité du relevé y est évaluée et l'on présente les effectifs selon l'âge par strates. La biomasse et l'abondance sont calculées et utilisées pour estimer la biomasse de la population.

Selon le relevé de 1997, la classe d'âge de 1995 est faible tandis que celles de 1992 et 1993 sont supérieures à la moyenne, comparativement à la période 1991 à 1997. La classe de 1992 sera recrutée par la pêche en 1997 tandis que celle de 1993 ne le sera qu'en 1998. Ces classes d'âges plus importantes se sont fixées dans la zone située entre Centreville et Digby, fermée à la pêche depuis 1995. La biomasse estimée de la population de toute la zone 4 est de 736 mt (intervalles de confiance de 95 % de 655 et 819 mt) pour les âges 5 et plus (5+). La biomasse des 6+ est estimée à 478 mt (int. de confiance de 95 % de 421 et 542 mt). La biomasse estimée dans la partie de la zone 4 ouverte à la pêche en 1996 (de Digby à Parkers Cove) est de 229 mt pour les 5+ et de 143 mt pour les 6+, ce qui reflète le recrutement de la classe de 1992. Les résultats obtenus sont semblables à ceux prévus suite au relevé de 1996 (Kenchington et coll., 1997).

Area 4: Digby Grounds

Introduction

On January 1,1997 an area based management plan was implemented for the Bay of Fundy. The bay is divided into 7 Scallop Production Areas (SPAs), largely based on the distribution of beds and the biology of the animals (Kenchington et al. 1997). Each area is managed by a TAC, minimum meat weight, corresponding minimum shell height, and a meat count. Scallop Production Area 4 off Digby, Nova Scotia is defined by the area inside a line joining the following points: 4448.8 N 6532.3 W to 4456.5 N 6536 W to 4437.3 N 6610 W to 4429.9 N 6606.5 W to place of origin (Fig. 1). Area 4 is equivalent to the former "Inside Zone" extended to 8 miles from shore. This Area roughly bisects a scallop bed which extends at least to the 16 mile line with overflow to the rest of Area 1.

The Digby scallop beds were fished according to seasonal zones from 1986 to 1996. The Inside Fishing Zone encompassed an area less than 6 miles from shore, from Parker's Cove to Centreville, and was closed by regulation from May 1 to September 30. The rest of the beds were seasonally unrestricted and are referred to as the Outside Zone. During this period, scallop abundance was highly variable. Two strong recruitment pulses (1984 and 1985 year classes) contributed to unprecedented high landings in 1988 through to 1991. While scallop abundance increased in many parts of the Bay due to these year-classes, the greatest concentration of scallops was centered on the Inside Fishing Zone, which is now subsumed by Area 4. However, heavy fishing and an unexplained mass mortality event abbreviated the life expectancy of these year classes. Landings have fallen each year since 1990 and are currently at very low levels. Recruitment has for the most part been poor since the 1984 and 1985 settlements, even when compared to those years which did not include the 1984 and 1985 year classes. In 1995, the Inside Zone regulation closure area was extended from Parkers Cove to Port Lorne beginning August 12, 1995, and neither area was opened in October. This was done to protect broodstock and the few pre-recruit scallops.

The part of Area 4 which was the former Inside Zone was not fished in 1996 except for a limited fishery in a portion of the Area from the Digby Gut to Port Lorne which was fished under a dockside monitoring condition from November 15 to December 15, 1996. The meat count for this area was 40/500 g. Fishing occurred from 6 to 8 miles until the establishment of the 8 mile Area on January 1, 1997. The November/December 1996 fishery in Area 4 landed 71.2 mt at low catch per unit effort (Kenchington et al. 1997).

Research Vessel Stock Surveys

As part of the annual scallop survey program, a stock survey of the Digby grounds was conducted in June 1997 using the research vessel "J.L. Hart" with 4 gang gear. The gear configuration consists of 76 cm inside width drags made of 7 rows of 4 mm steel wire rings 75 mm inside diameter, knit with rubber washers, 9 across and 3 on the side fastened to an angle iron

frame at the mouth and a piece of wood (2"x4") or plate steel at the tail end. This gear actively selects against small size scallops. Small scallops can avoid the drag path or if caught, escape through the steel rings (Robert and Lundy 1989). To estimate the relative abundance of small scallops (< 80 mm shell height) two drags were lined with 38 mm polypropylene mesh. However the abundance of scallops with shell height under 40 mm is not reliably estimated and can only be used as a qualitative index of recruitment. For analysis purposes the average number of scallops caught in unlined gear (> 80 mm) and the average number of scallops caught in lined gear (< 80 mm) were used and then prorated to conventional 7 gang gear to allow for annual comparisons.

The 1997 survey was of a stratified random design by area, with the number of stations allocated to each area dependent upon the variance observed in the stratum over the previous three years of survey data (i.e., 1993 to 1996; see Kenchington et al. 1997). A total of 100 survey stations were randomly assigned.

The location of the 1996 tows are shown in figure 2. At each station the shell height and meat weight of each animal was recorded. The shells were returned to the laboratory where they will be aged. Bottom temperature was recorded for each tow using a VEMCO digital sub-surface temperature recorder (Vemco Ltd., Shad Bay, N.S.). Note that the portion of Area 4 from 0 to 2 miles was not surveyed although commercial activity does take place there. This area will be surveyed in August when the lobster traps are removed.

Survey Efficiency

The efficiency of the survey design (stratified random) was evaluated by comparing it with a simple random sampling design (Smith and Gavaris 1993). The efficiency of a stratified random design is calculated as:

$$100*\{V(SRS)-V(STR)\}/V(SRS),$$

where V(SRS) = variance of simple random sampling mean and V(STR) = variance of stratified random mean. V(SRS)–V(STR) can be decomposed into two components:

1) Allocation of Stations: This component measures the contribution of the scheme for allocating the number of stations to each stratum. This term will be positive, zero, or negative depending upon whether the number of stations were allocated in proportion to the stratum variance, stratum size or in an arbitrary manner (Smith and Gavaris 1993).

2) Strata: This term determines whether the variance between strata is larger than that within strata. The larger this difference, the larger the amount of information that the strata boundaries contain with respect to the distribution of the scallops.

The 1996 Digby scallop survey was analyzed by age for these components. The analysis was performed on age group classes (pre-recruits ages 1–4, ages 5–7, ages 8+) and all ages combined. The allocation effect was negative in the case of these age groups, indicating that sample to strata allocation needed to be optimized to increase the overall efficiency of the design.

Survey Efficiency and Abundance Estimates Determined from the 1996 Research Vessel Survey

Ages	Str. Total	Str. Mean	SE (Mean)	Efficiency			
				Allocation	Strata	Total	Max. Effic.
1	163,740	0.85	0.54	15.80	1.40	17.19	76.95
2	1,564,478	8.09	2.41	5.75	4.74	10.49	63.02
3	9,898,502	51.18	14.19	-2.14	10.52	8.38	54.09
4	3,071,252	15.88	3.04	-23.29	-2.62	-25.90	23.54
5	3,355,169	17.35	3.01	-3.20	-6.83	-10.03	18.35
6	1,903,209	9.84	1.19	4.06	27.35	31.40	38.35
7	1,445,215	7.47	1.08	-7.10	29.57	22.47	48.25
8	1,163,238	6.01	0.70	-5.51	48.39	42.88	56.54
9	916,680	4.74	0.61	-10.73	17.43	6.69	28.91
10	2,785,321	14.40	2.40	-18.88	-5.00	-23.88	12.38
1–4	14,697,972	75.99	17.92	-3.41	6.36	2.96	48.24
5–7	6,703,593	34.66	4.40	-3.14	13.84	10.70	26.08
8+	4,865,239	25.15	3.18	-21.82	10.24	-11.58	28.15
All	26,266,803	135.80	19.90	-3.07	11.28	8.21	45.93

For the purposes of obtaining an estimate of stratified mean or total abundance from a stratified random design, the optimal allocation of tows to strata is to assign the number of tows proportional to the stratum standard deviation. That is the number of tows (n_h) in stratum h is equal to:

$$n_h = n\frac{A_h S_h}{\sum A_h S_h},$$

where n is the total sample size, A_h is the area of stratum h and S_h is the population standard deviation for stratum h. While we do not know the population standard deviation an average standard deviation for each stratum from the 1993 to 1996 surveys was used to obtain the n_h for the 1997 survey (see Kenchington et al. 1997 for a discussion of this approach). The proposed values for n_h are presented in the table below along with the allocation actually used, as well as the n_h using the observed values for S_h in 1997. The discrepancy between the proposed and the actual n_h for the Gulliver-Digby stratum was due to two extra sets being added for the collection of additional biological data. The largest discrepancies were between the actual n_h and those predicted from the observed 1997 standard deviations. In the case of all ages and ages 1 to 4 the Centreville stratum was more variable than expected given past experience, while the Parkers Cove stratum was less variable then expected.

Source of stratum sample sizes n_h	Centre.	Centre.-Gull.	Gulliver	Gull.-Digby	Digby	Digby-Delaps	Delaps	Parkers
Proposed	16	12	20	9	19	6	9	9
Actual Used	16	12	20	11	19	6	9	9
Observed (all ages)	28	11	17	15	16	7	4	4
Observed (1 to 4)	39	12	23	3	6	10	8	1
Observed (5 to 7)	18	8	16	21	25	5	5	4
Observed (8 plus)	18	8	14	22	14	2	12	8

How serious the above differences are can be evaluated by estimating the proportional increase in the minimum expected variance due to these differences. These proportional increases by stratum, and total over all strata, are given in the table below. The differences in n_h between the proposed and actual allocation would be expected to result in a 0.53% increase in variance — negligible for our purposes. However, using the observed standard deviations suggests that the differences in n_h for all of the age groups resulted in much larger expected increases. Note in particular that the difference in the expected variances for ages 1 to 4 resulted in a 126.65% increase in variance. The lowest increases were observed for the all age groups and ages 5 to 7.

The performance of the 1997 allocation scheme in terms of expected increase in minimum variance indicates that care must be taken in using past observed stratum standard deviations to estimate n_h. Unexpected changes in stratum variance with time can and do occur.

Source of n_h	Centre.	Centre.-Gull.	Gull.	Gull.-Digby	Digby	Digby-Delaps	Delaps	Parkers	Total
Actual used	0.00	0.00	0.05	0.44	0.05	0.00	0.00	0.00	0.53
Observed (all ages)	5.04	0.09	0.52	1.05	0.55	0.14	6.13	6.13	19.64
Observed (1 to 4)	13.30	0.00	0.38	20.92	27.61	1.57	0.12	62.75	126.65
Observed (5 to 7)	0.22	1.96	0.98	4.67	1.41	0.20	3.14	6.13	18.70
Observed (8 plus)	1.60	1.96	2.52	5.39	1.75	7.84	0.74	0.12	21.93

The second criteria for evaluating the 1997 allocation scheme is to compare the efficiency estimates with those from the 1996 survey (see above). In 1996 a large number of the allocation components were less than zero indicating suboptimal allocation of n_h to strata. The efficiency calculations for the 1997 survey in the table below show that the allocation components were greater than zero for ages 3 to 7, ages 1 to 4, 5 to 7, 8+ and all ages as a group. Indeed for all ages greater than 2 all of the total efficiencies were greater than zero indicating that the stratified design provided gains in precision over using a simple random sampling design. Therefore, while the

1997 allocation scheme didn't result in the estimates having the minimum variances, the allocation scheme and survey design still provided substantial increases in precision. Note that the actual efficiency of the estimated mean over all ages was much closer to the theoretical maximum in 1997 than in 1996.

Survey Efficiency and Abundance Estimates Determined from the 1997 Research Vessel Survey

Age	Str. Total	Str. Mean	SE(Mean)	Allocation	Strata	Total	Max. Effic.
1	75,090	0.39	0.13	-5.67	0.45	-5.22	35.23
2	230,688	1.19	0.20	-2.70	4.27	1.57	15.14
3	1,074,750	5.56	0.96	7.05	35.04	42.09	71.90
4	4,114,769	21.27	2.87	15.36	16.58	31.95	52.35
5	4,916,772	25.42	2.80	5.27	13.04	18.32	37.18
6	3,066,520	15.85	1.41	8.65	19.27	27.92	40.64
7	2,111,998	10.92	0.83	7.00	26.17	33.17	38.61
8	1,298,442	6.71	0.55	7.07	34.91	41.98	51.08
9	849,914	4.39	0.36	5.71	33.07	38.78	48.62
10	3,040,033	15.72	1.36	4.16	31.14	35.31	46.50
1–4	5,495,297	28.41	3.72	12.80	20.02	32.82	56.70
5–7	10,095,290	52.19	4.37	7.27	17.83	25.10	36.65
8+	5,188,390	26.83	1.91	4.42	39.63	44.05	54.10
All	20,778,977	107.43	7.42	9.87	29.69	39.57	48.44

Scallop Size and Spatial Distribution

The unstratified average number of scallops-at-age caught in the 1986-1996 stock surveys are given in Table 1. The 1997 catch-at-age was determined by using the 12 depth-defined growth curves presented in Kenchington et al. (1997). Comparison of the shell height meat weight relationship between the 1996 and 1997 survey data shows no significant differences between the curves. Therefore, the 1997 ageing data when completed is not expected to dramatically influence these results.

The total average number of scallops per standard tow caught during the survey (Table 1) has declined dramatically since the peak of the fishery in 1988 and 1990 and remains low in 1997. There is very little change in the numbers between 1996 and 1997 in Area 4. The average number of scallops per standard tow by shell height increment is illustrated in figures 3 and 4 from 1981 to 1997. The magnitude of the 1984 and 1985 year classes relative to the years previous and following can readily be seen (note histogram of the average over the time series on the bottom of the figure on each page). Examination of the relative frequencies of these same data permits the identification of year classes through the time series. The mode seen in 1986 can be followed through until 1990; similarly the recent recruitment pulses seen in 1994 and 1995 can be tracked to 1997. If we exclude the exceptional years (i.e., 1986-1989) from the calculation of the average (Fig. 5) we can see that in the current year survey the number of animals less than 70 mm and greater than 95 mm shell height was below average, while the number from 70 to 95 mm shell

height was above average. This above average peak reflects the strong 1993 year class which can be tracked from the 1995 survey numbers (Fig. 5). The same pattern is seen when only the data from 1990 to 1997 is used (Fig. 6).

The spatial distribution of scallops was contoured using the ACON software package with data derived from Delaunay triangles and inverse distance weighted interpolation (see Kenchington et al. 1997 for details). The distribution of all scallops caught, prorated for gear width and tow length, is shown in figure 7. The greatest concentration of scallops in Area 4 is in the area off Centreville and Gulliver's Head (Fig. 7). This is the area where the pre-recruit scallops (Fig. 8) are also concentrated (animals less than 75 mm shell height). The pre-recruit scallops are dominated by the 1993 year class the distribution of which is illustrated in figure 9a (Age 4). This year class was detected in the 1995 survey and has not changed it's distribution since that survey (Fig. 9b). The 1995 year class is weak (Fig. 9a; Age 2) but extends across the whole of Area 4 in contrast to the 1994 year class which was also weak but was concentrated in the Centreville to Digby area being locally abundant.

The distribution of recruited scallops over 75 mm shell height is shown in figure 10. The greatest concentrations are seen in the Centreville to Digby area which was closed to fishing in 1995 and 1996. The 1992 year class is the strongest of the recruited year classes in this area (Fig. 11; Age 5). This year class was first identified as being an above average year class in the 1994 survey. The distribution of the animals has not changed from the 1994 survey to the present. That is the animals have remained concentrated in the Centreville to Digby area. There are very few animals above Digby and very few over the age of 6 (Fig. 11).

The percentage of clappers (dead paired shells) was low at 4.3%, a decline from 1996 (Table 1) and similar to levels observed in 1986 and 1987. Of these, 72% were larger scallops over 100 mm shell height and located primarily in the area between Digby and Delaps Cove where the concentrated fishing activity took place in late 1996 (Kenchington et al. 1997).

Area 4 Total Mortality (Z), Fishing Mortality (F) and Percent Exploitation were determined from the survey numbers between the 4+/5+, 5+/6+ and 6+/7+ age groups assuming a natural mortality (M) of 0.1:

Age 4+/5+

Year	Total Mortality (Z)	Fishing Mortality (F)	Exploitation Rate (%)
1991-1992	.47	.37	29.5
1992-1993	.14	.04	3.7
1993-1994	.42	.32	26.1
1994-1995	.25	.15	13.3
1995-1996	.14	.04	3.7
1996-1997	-.04	-	-

Age 5+/6+

Year	Total Mortality (Z)	Fishing Mortality (F)	Exploitation Rate (%)
1991-1992	.50	.40	31.5
1992-1993	..25	.15	13.3
1993-1994	.45	.35	28.2
1994-1995	.40	.30	24.7
1995-1996	.24	.14	12.4
1996-1997	.11	-	-

Age 6+/7+

Year	Total Mortality (Z)	Fishing Mortality (F)	Exploitation Rate (%)
1991-1992	.53	.43	33.4
1992-1993	.32	.22	18.8
1993-1994	.43	.33	26.8
1994-1995	.49	.39	30.8
1995-1996	.27	.17	14.9
1996-1997	.12	-	-

Estimates of total mortality from the surveys indicate the much higher mortality experienced by all age groups in 1991 and the older age groups in the later years. The lower mortality rates estimated in 1995-96 are in accordance with the lower landings noted for that period. Average Fishing Mortality has been greater on the older animals 6+/7+ through this time frame (average 0.31 as opposed to 0.18 on the 4+/5+ group). The decrease in exploitation of the 4+/5+ group from 1995 to 1996 may reflect the change to a lower meat count for this Area. The total mortality was negligible in the 1997 survey and estimates of F and Exploitation Rate could not be calculated. This is consistent with the closure of the area from Digby to Centerville where the greater portion of the abundance lies.

Survey Abundance and Biomass Estimates

In order to estimate the number of scallops in Area 4, simple aerial expansion of the survey data was applied. The average number of scallops per standard tow (dragged area of 4256 sq. m) was determined for each Stratum and then multiplied by the total area of the Stratum divided by the area covered by the tow. The resulting abundance estimate by age is indicated in the table below. All ages were derived from the new stratum specific growth curves (Kenchington et al. 1997) applied to length frequencies prorated to the set level.

Number of Scallops by Age (1991-1997) Estimated from the Research Vessel Surveys

Ages	1991	1992	1993	1994	1995	1996	1997
1	73,460	147,451	615,822	1,617,751	1,671,046	163,740	75,090
2	1,316,809	416,505	986,784	1,567,175	4,720,913	1,564,478	230,688
3	763,566	1,625,118	1,092,193	2,299,523	2,137,649	9,898,503	1,074,750
4	2,258,636	1,516,133	1,693,424	1,161,824	2,887,432	3,071,252	4,114,769
5	**4,877,939**	1,955,354	**2,963,224**	1,425,631	2,172,890	3,355,169	4,916,772
6	5,462,157	**3,303,893**	**2,415,578**	**1,710,889**	**1,628,083**	1,903,209	3,066,520
7	**5,274,969**	3,038,622	**2,287,274**	**2,076,055**	**1,430,482**	**1,445,215**	2,111,998
8	3,918,353	**2,837,477**	2,172,270	**1,616,374**	**987,747**	**1,163,238**	**1,298,442**
9	2,468,693	2,007,098	**1,592,955**	1,186,287	**811,758**	**916,680**	**849,914**
10+	4,340,078	4,736,876	5,508,006	4,250,205	3,400,901	2,785,321	3,040,033
Total	30,754,661	21,584,527	21,327,530	18,911,715	21,848,900	26,266,805	20,778,977
4+	28,600,825	19,395,452	18,632,732	13,427,265	13,319,293	14,640,084	19,398,449
5+	26,342,189	17,879,320	16,939,308	12,265,441	10,431,861	11,568,832	15,283,680
6+	21,464,250	15,923,966	13,976,084	10,839,810	8,258,970	8,213,664	10,366,908
7+	16,002,093	12,620,073	11,560,506	9,128,921	6,630,887	6,310,454	7,300,388

The survey number of scallops by year is estimated for each age group in the Table above. Year-classes are marked in bold. Year classes can be tracked quite well through the matrix - many cohorts can be followed from at least age 5 to age 9. Age 10 is a plus group and therefore will not show the further changes on a cohort-by-cohort basis. The 1993 year-class is the largest seen at age 3 to date in this short survey series. The estimated numbers at age 5+ in 1997 is higher than the levels observed for this age group in 1994 and 1995 due to the recruitment of the above average 1992 year class. The total numbers in 1997 are down slightly due to the low level of recruitment in the age 1 to 3 groups. This data is also illustrated in figure 12 where a histogram of the mean from 1991 to 1997 for each age is also drawn. The 1997 population is below average for all ages except the age 4 and 5 scallops (Fig. 12).

The abundance of animals by age and stratum is given in the table below. It can be seen that the majority of the animals are in the strata below Digby.

Numbers of Scallops-at-Age for each of the Strata in the Area 4 Survey. Bold-faced Numbers indicate Strata with the Majority of the 1993 and 1992 Year-Classes.

Age	Centre.	Centre-Gull.	Gull.	Gull.-Digby	Digby	Digby-Delaps	Delaps	Parkers
1	9,671	0	18,052	10,550	14,252	22,565	0	0
2	44,695	22,028	57,535	5,416	24,024	14,667	46,850	15,473
3	647,137	70,629	175,067	12,607	29,135	40,230	90,203	9,742
4	**981,069**	44,340	**1,324,485**	213,126	308,142	279,034	**486,175**	78,398
5	582,568	365,158	**1,152,345**	**774,577**	**1,324,857**	301,438	295,138	120,691
6	716,960	248,174	581,369	523,154	494,187	126,333	195,966	180,378
7	521,416	230,670	366,574	307,759	318,383	92,775	123,557	150,864
8	355,192	155,925	205,575	245,515	106,053	19,374	75,017	135,792
9	224,443	83,018	137,261	160,306	93,410	14,538	27,565	109,373
10	950,719	324,777	405,554	419,905	407,741	58,057	299,407	173,874

The numbers of scallops caught in the survey were converted to weight caught in order to estimate biomass. Meat weights from the survey were estimated using the stratum specific growth curves to estimate average weight-at-age (Kenchington et al. 1997).

Estimated Total Meat Weight (mt) from Survey with 95% Upper and Lower Bounds using a BWR Bootstrap (1000 replications) and Percentile Confidence Intervals (Smith 1997)

Year	Total	lower	Upper	5+ Total	lower	Upper	6+ Total	lower	Upper
1991	438	369	511	419	349	487	372	312	436
1992	299	253	329	283	241	313	264	224	291
1993	288	249	332	273	233	314	244	211	280
1994	215	178	253	197	164	235	184	149	220
1995	194	166	223	162	136	189	141	119	166
1996	230	189	278	172	142	208	138	114	169
1997	236	208	262	206	183	229	164	144	186

The biomass of Ages 5+ was estimated as 206 mt with the lower and upper bounds estimated by the bootstrap method as (95%): 183 and 229 mt. The total biomass estimates for the population with bootstrap confidence intervals was 236 mt with lower and upper bounds of 208 and 262 mt, respectively.

Population Biomass Estimates

The estimates of the scaling factor for converting survey to population (i.e., $1/q$) was established in Kenchington et al. (1997) for this area from the means over the period 1991 to 1995. The estimates of average $1/q$ were then used to convert total meat weight from the survey to population estimates.

Estimates of $1/q$ from Survey Population Estimates and Predicted Population Numbers

Ages	1991	1992	1993	1994	1995	Mean
5+	3.40	6.00	2.45	2.86	3.11	3.57
6+	3.52	3.89	2.54	1.92	2.71	2.92

Meat weights from the survey were estimated using the stratum specific growth curves to estimate average weight-at-age as above. Growth curves were derived from observations during the 1996 survey and they were used to estimate weight-at-age for all years. The resultant population meat weights are presented below.

Estimated Total Meat Weight (mt) for the Area 4 Population using ($1/q$) Scaling Factors of 3.57 and 2.92 for 5+ and 6+ Estimates, Respectively

Year	5+ Total	lower	Upper	6+ Total	lower	Upper
1991	1495.83	1245.93	1738.59	1086.24	911.04	1273.12
1992	1010.31	860.37	1117.41	770.88	654.08	849.72
1993	974.61	831.81	1120.98	712.48	616.12	817.60
1994	703.29	585.48	838.95	537.28	435.08	642.40
1995	578.34	485.52	674.73	411.72	347.48	484.72
1996	614.04	506.94	742.56	402.96	332.88	493.48
1997	736.00	655.00	819.00	478.00	421.00	542.00

Biomass estimates (mt) for the fished area of Area 4 only were similarly calculated should only this portion of Area 4 be opened for fishing in 1997:

Metric Tonnes of Meat		
	1996	1997
5+ (survey) =	69	64
(1/q corrected) =	246	229
6+ (survey) =	53	49
(1/q corrected) =	155	143

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Table 1. 1986-97 Digby Stock Survey. Average Number of Scallops-at-Age Prorated to a Seven-gang Digby Drag.

	Age (years)											
	2	3	4	5	6	7	8	9	10+	Total	No. of Stations	% Clappers
Inside 6 mile (Centreville to Hampton)												
1986	591	186	18	10	16	17	10	9	17	874	48	2.4
1987	457	373	727	253	18	10	8	7	22	1875	38	2.2
1988	52	298	662	788	527	55	12	7	19	2420	45	34.2
1989	7	98	86	292	288	159	49	16	13	1008	59	66.5
1990	1	4	22	53	53	70	49	21	18	291	57	29.4
1991	3	4	6	15	32	29	24	17	24	154	38	11.8
1992	2	4	8	7	13	18	21	17	24	114	42	10.4
1993	5	7	5	12	15	15	15	13	31	118	38	12.5
1994	10	9	9	6	8	12	13	11	19	99	42	5.3
1995	25	6	12	15	12	9	9	7	19	114	37	10.8
1996	3	25	19	12	17	10	8	7	16	117	37	7.9
Area 4												
1996	3	29	32	12	17	12	9	7	15	136	44	
1997	2	6	22	26	16	11	7	4	16	110	102	
Outside 6 mile (Centreville to Hampton)												
1986	230	26	17	33	38	38	31	21	30	464	72	5.0
1987	51	355	296	31	31	26	18	11	22	841	81	4.7
1988	11	94	178	715	87	30	19	10	15	1159	59	25.3
1989	2	12	39	187	177	94	17	5	8	541	51	58.1
1990	1	8	20	71	68	53	32	13	13	279	79	28.8
1991	2	3	6	25	44	47	41	27	27	222	62	12.6
1992	2	6	14	18	38	46	33	20	25	202	48	5.2
1993	2	2	5	21	27	22	20	14	23	136	62	10.8
1994	5	15	7	11	15	21	19	13	16	122	54	9.5
1995	9	8	10	13	14	15	14	10	13	106	63	5.2
1996	2	10	17	11	16	14	11	7	9	97	63	8.1

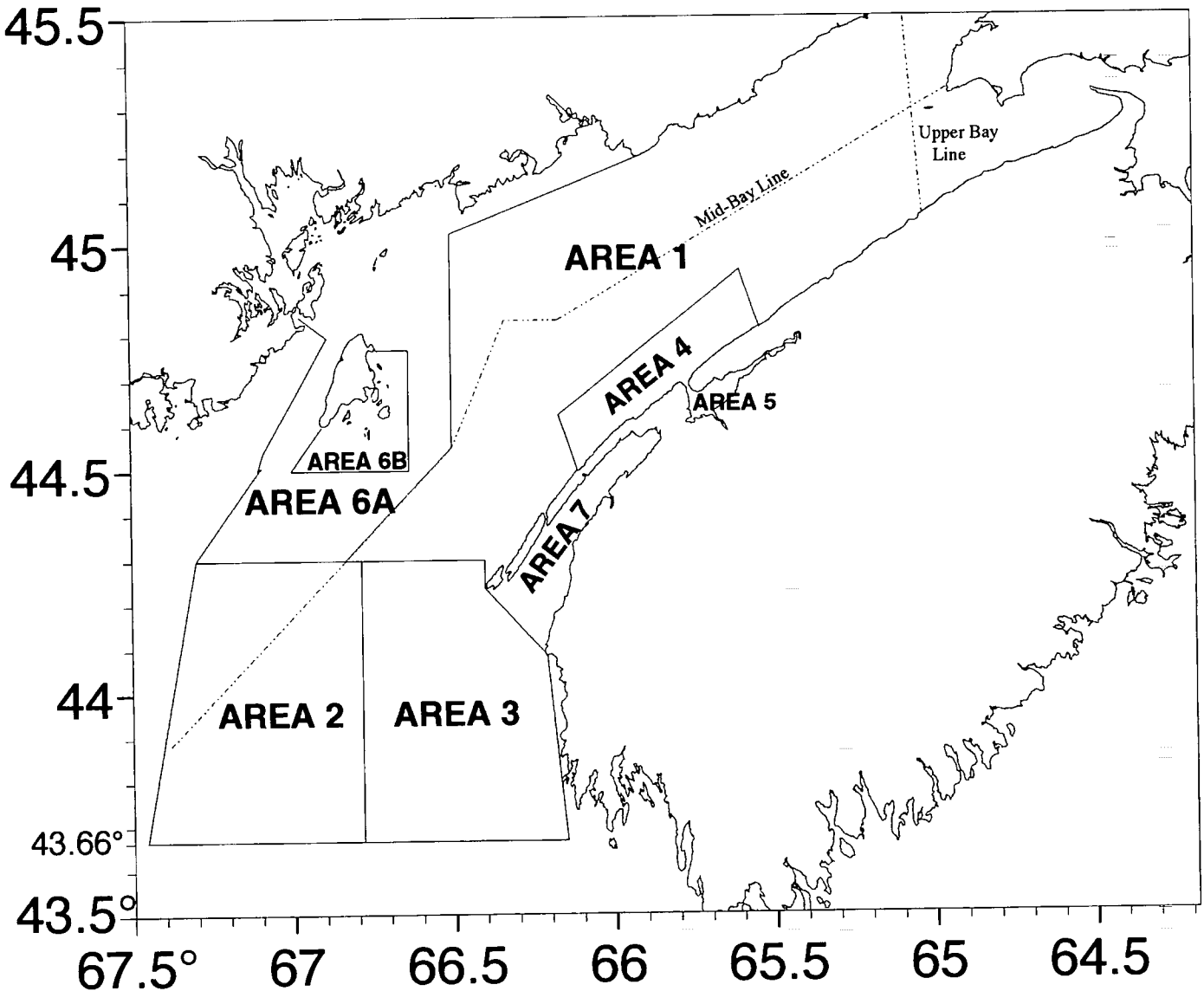


Figure 1. Scallop fishing areas in the Bay of Fundy.

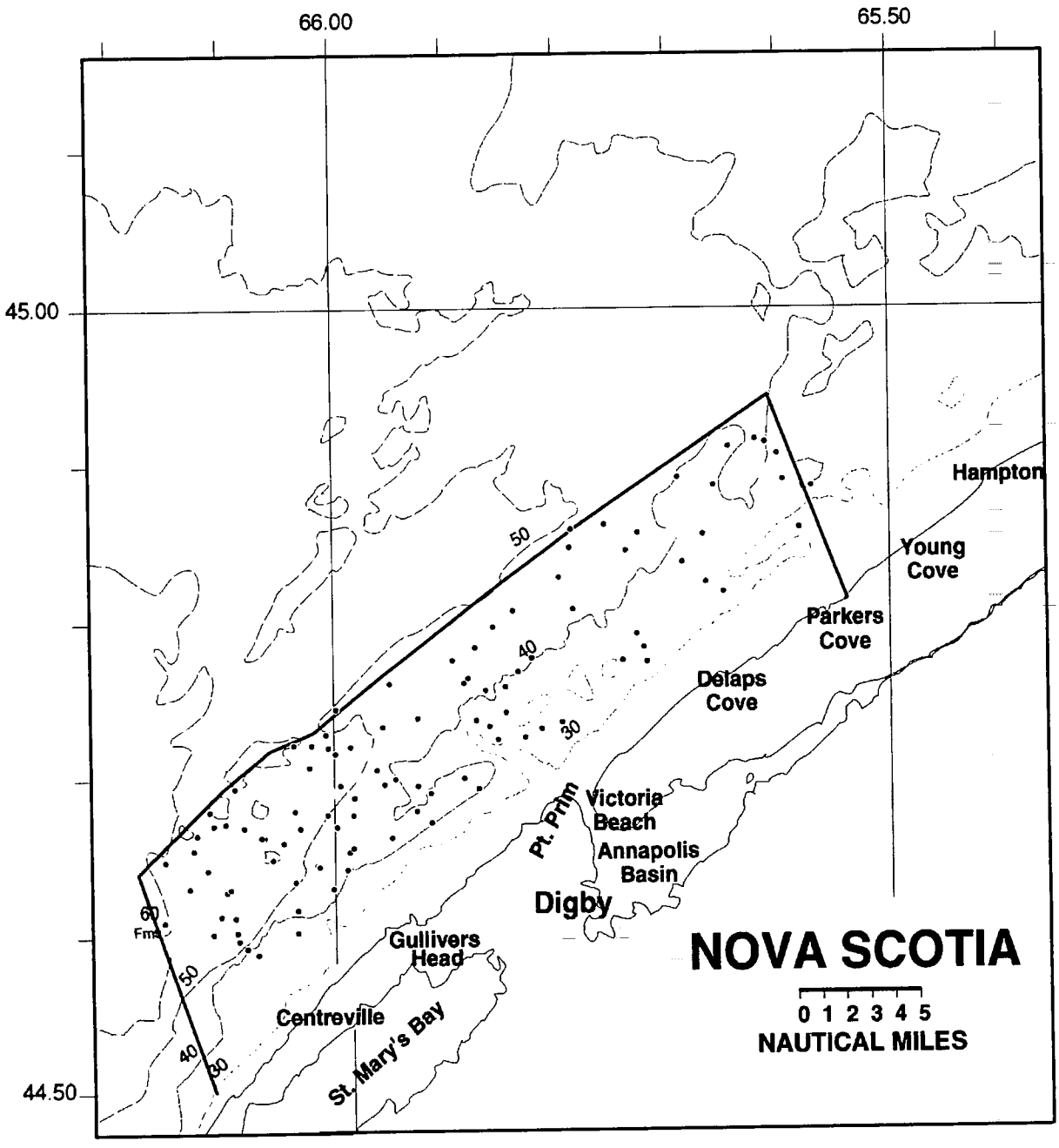


Figure 2. Location of tows in the 1997 scallop survey of Area 4.

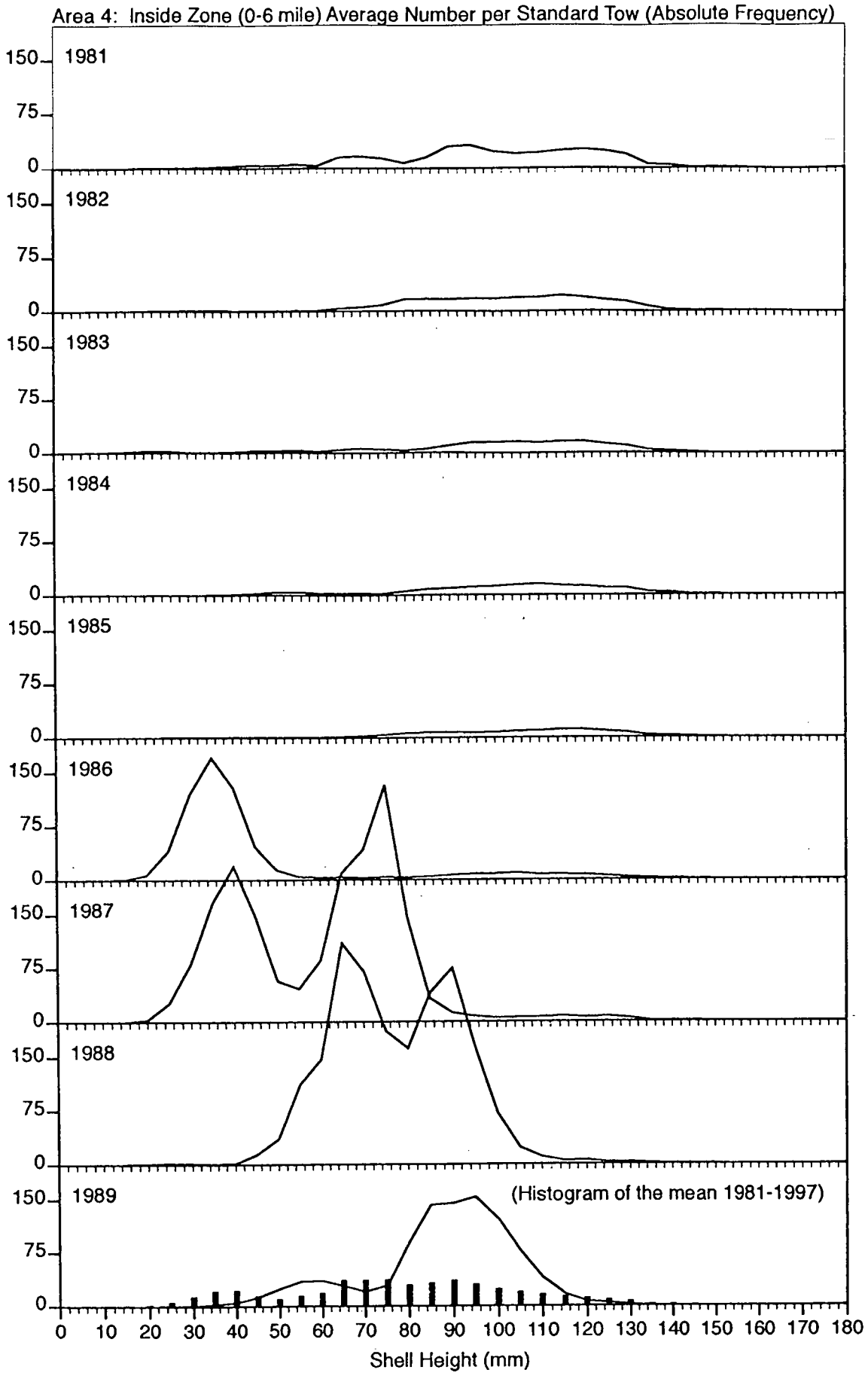


Figure 3. Shell height frequency distribution (absolute numbers) of the unstratified average number of scallops per standard tow (1981 to 1997) with a histogram of the mean from 1981 to 1997.

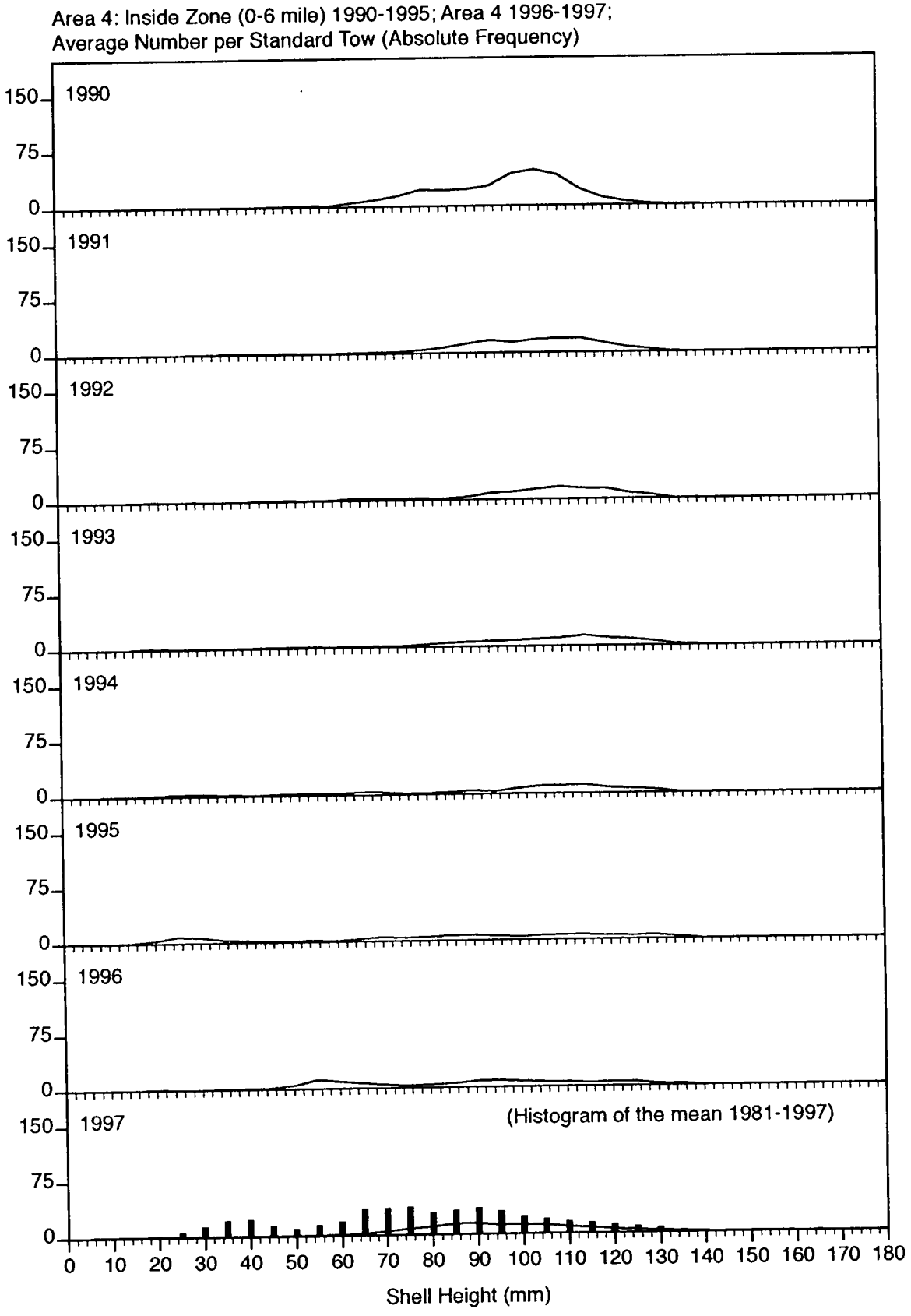


Figure 3.
(cont'd) Shell height frequency distribution (absolute numbers) of the unstratified average number of scallops per standard tow (1981 to 1997) with a histogram of the mean from 1981 to 1997.

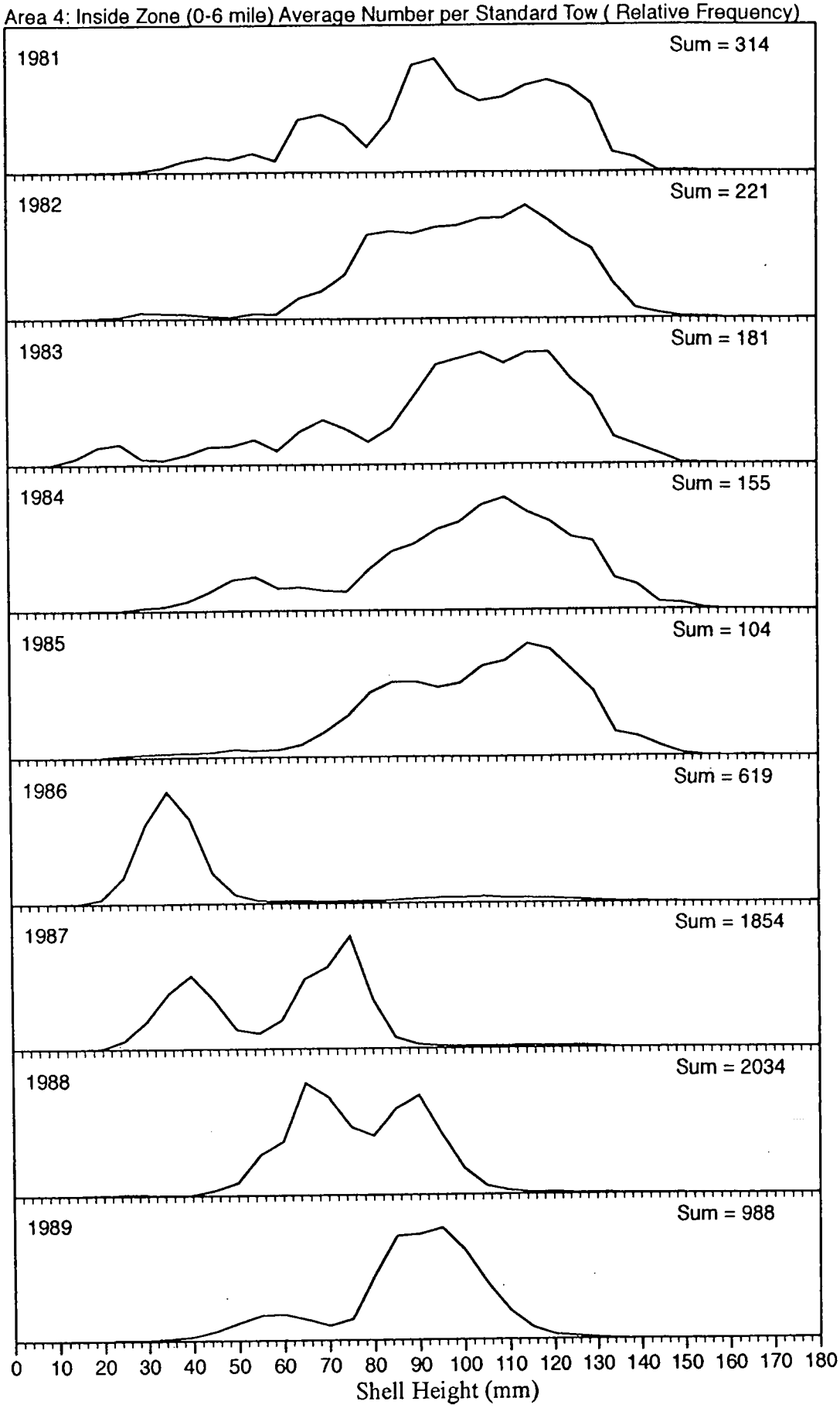


Figure 4. Shell height frequency distribution (relative numbers) of the unstratified average number of scallops per standard tow (1981 to 1997).

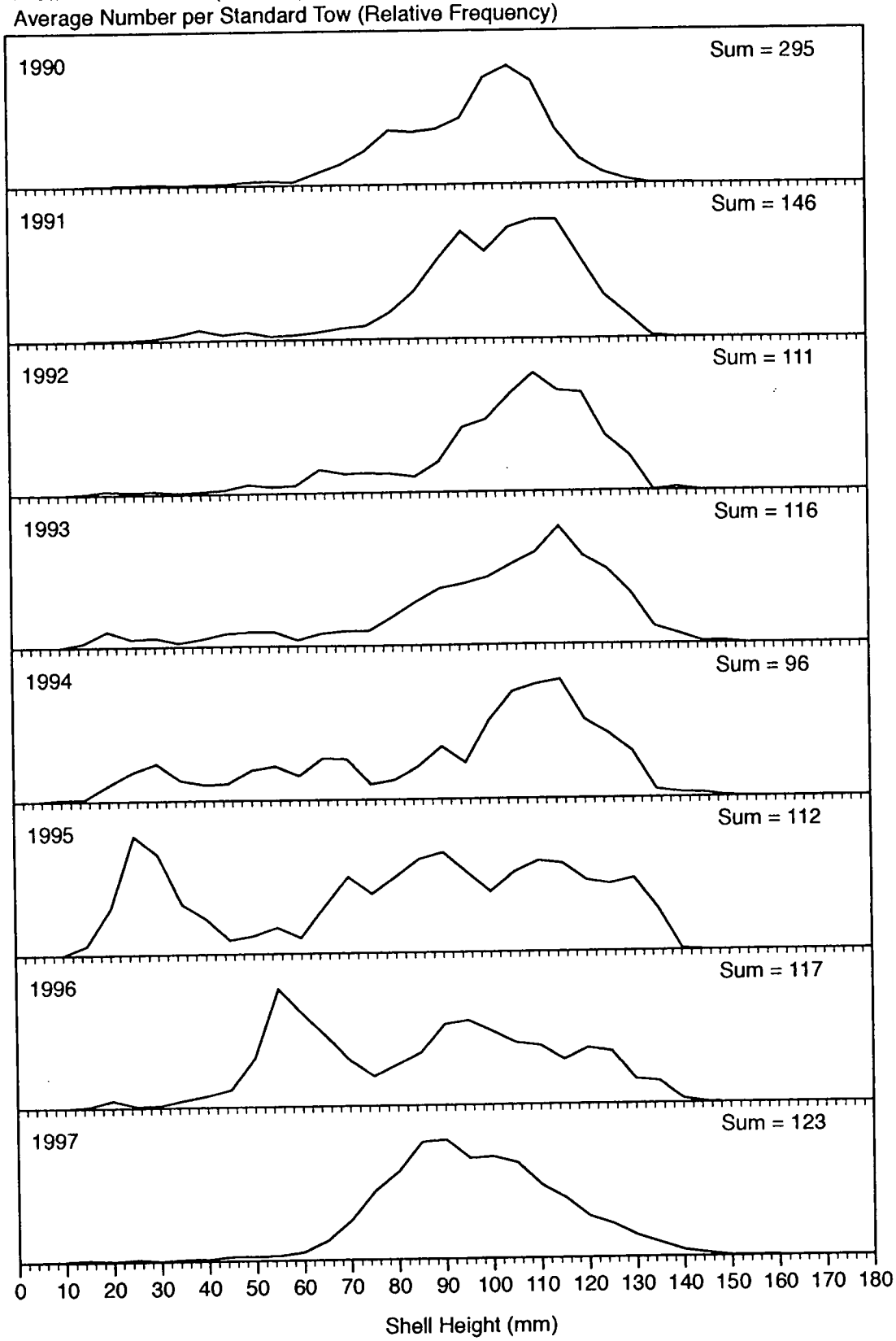


Figure 4.
(cont'd) Shell height frequency distribution (relative numbers) of the unstratified average number of scallops per standard tow (1981 to 1997).

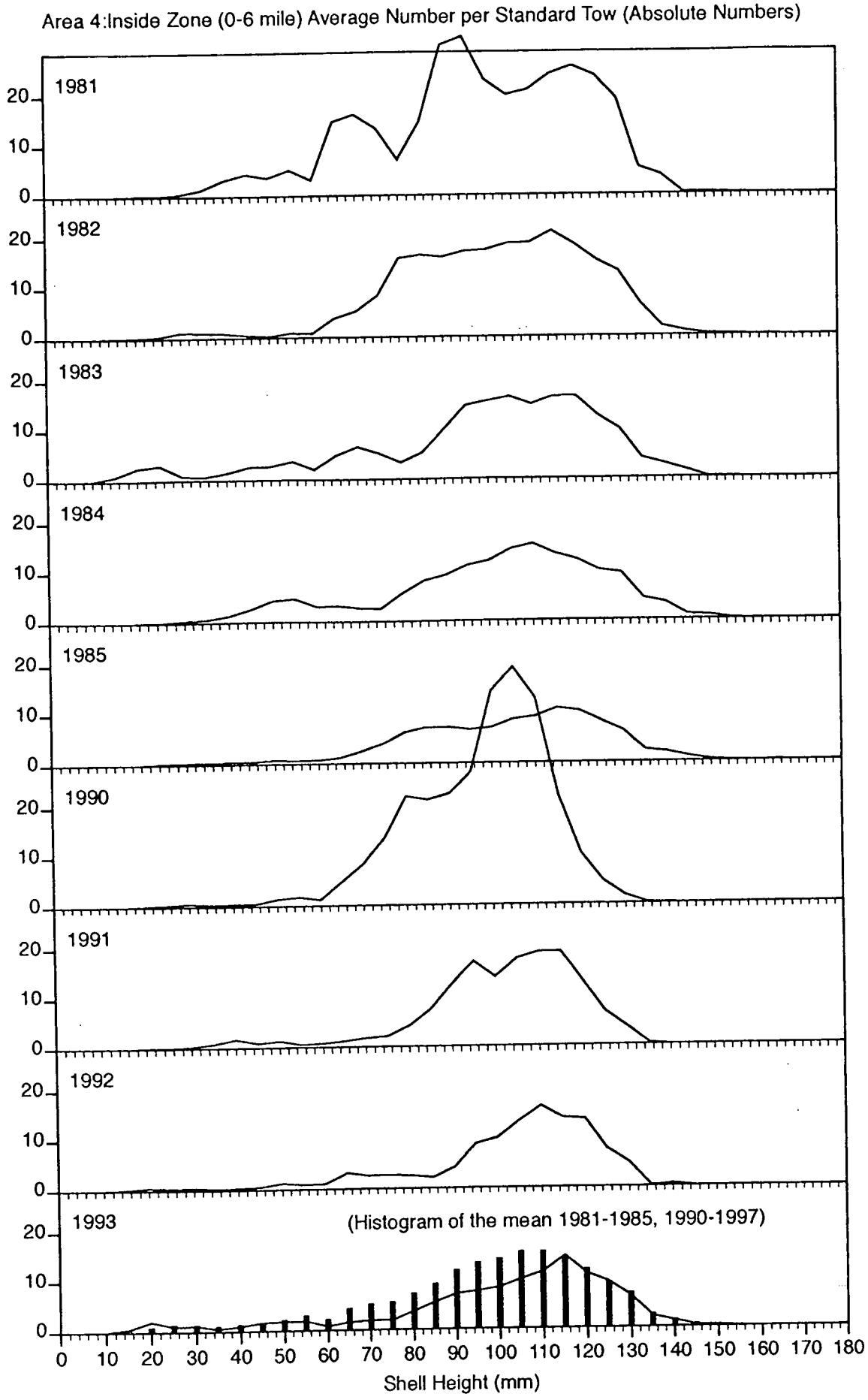


Figure 5. Shell height frequency distribution (absolute numbers) of the unstratified average number of scallops per standard tow (1981 to 1985, 1990 to 1997). A histogram of the mean over this time period is presented.

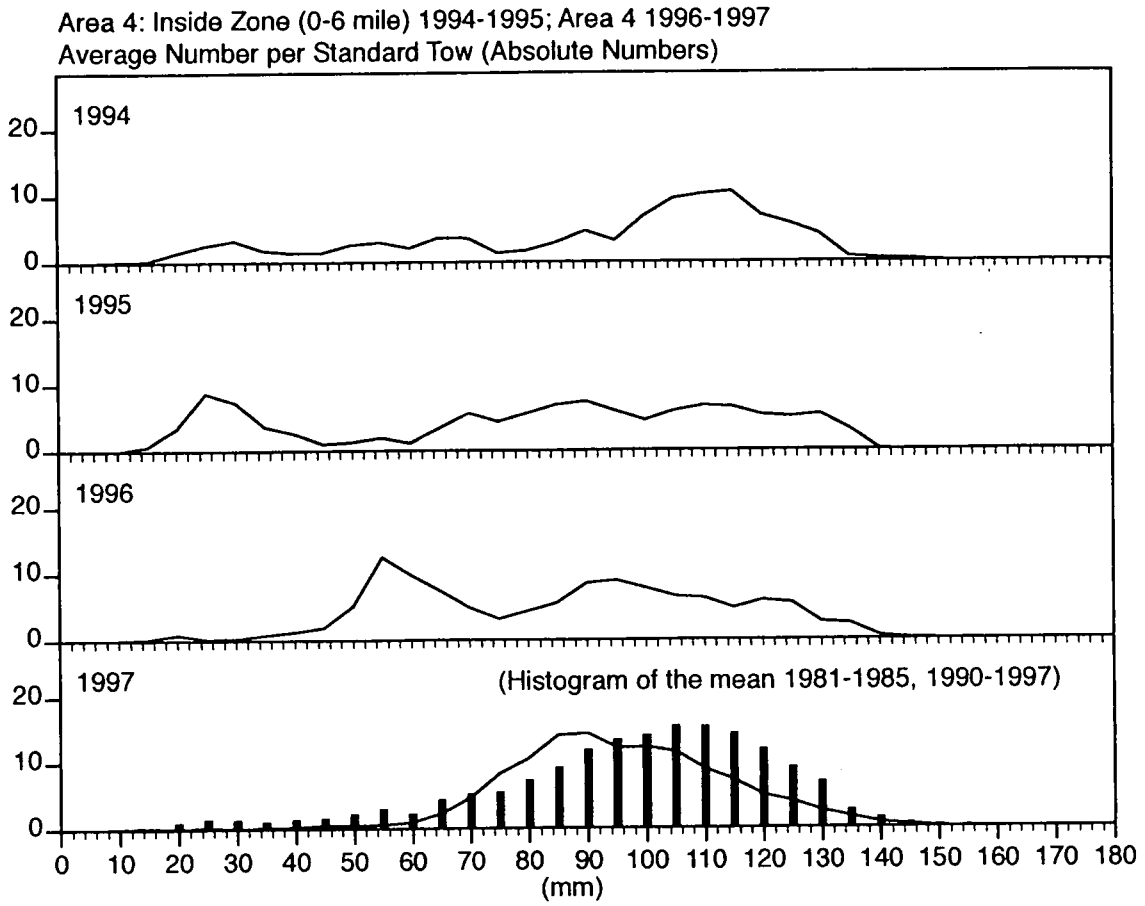


Figure 5.
(cont'd). Shell height frequency distribution (absolute numbers) of the unstratified average number of scallops per standard tow (1981 to 1985, 1990 to 1997). A histogram of the mean over this time period is presented.

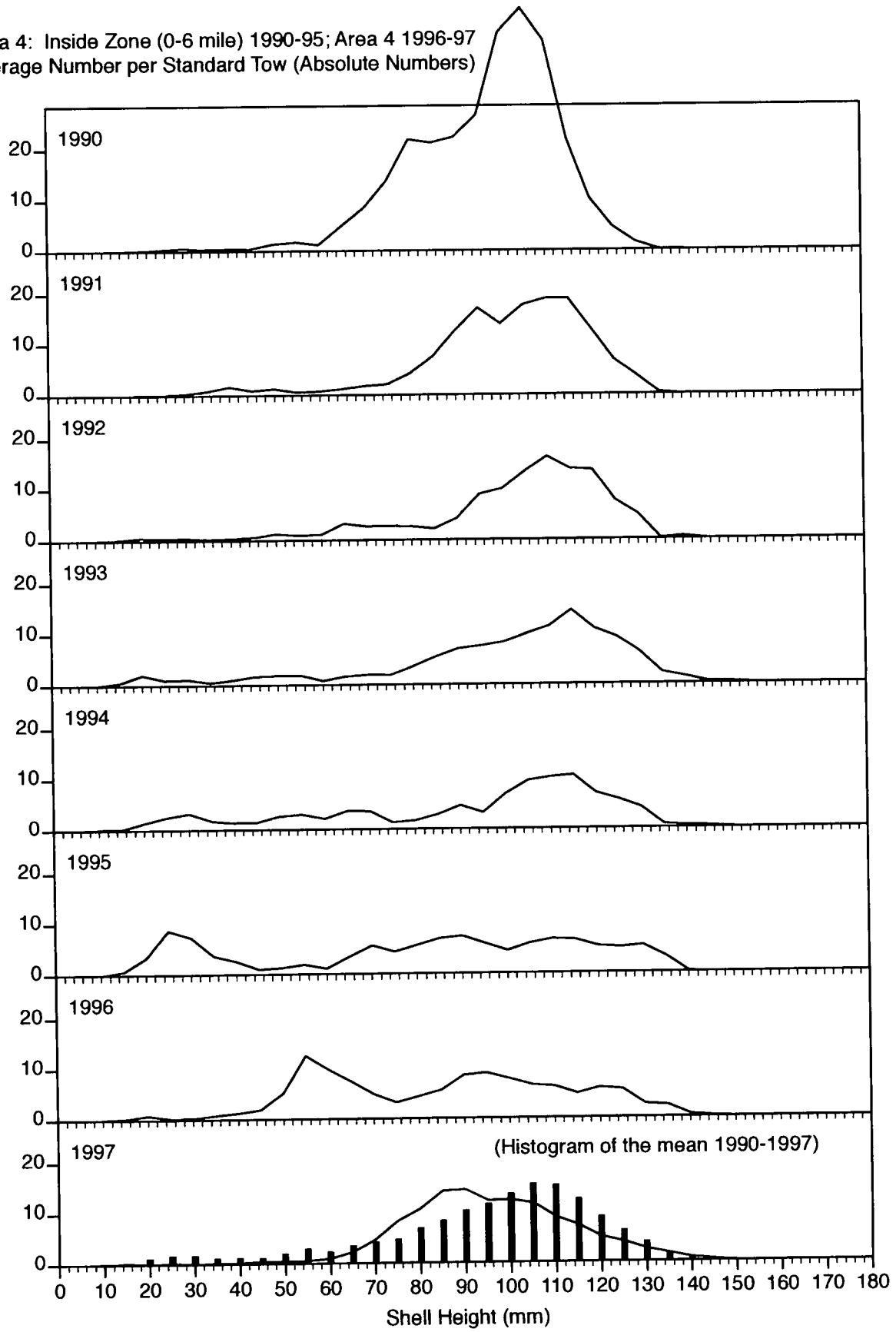


Figure 6. Shell height frequency distribution (absolute numbers) of the unstratified average number os scallops per standard tow (1990 to 1997) with a histogram of the mean.

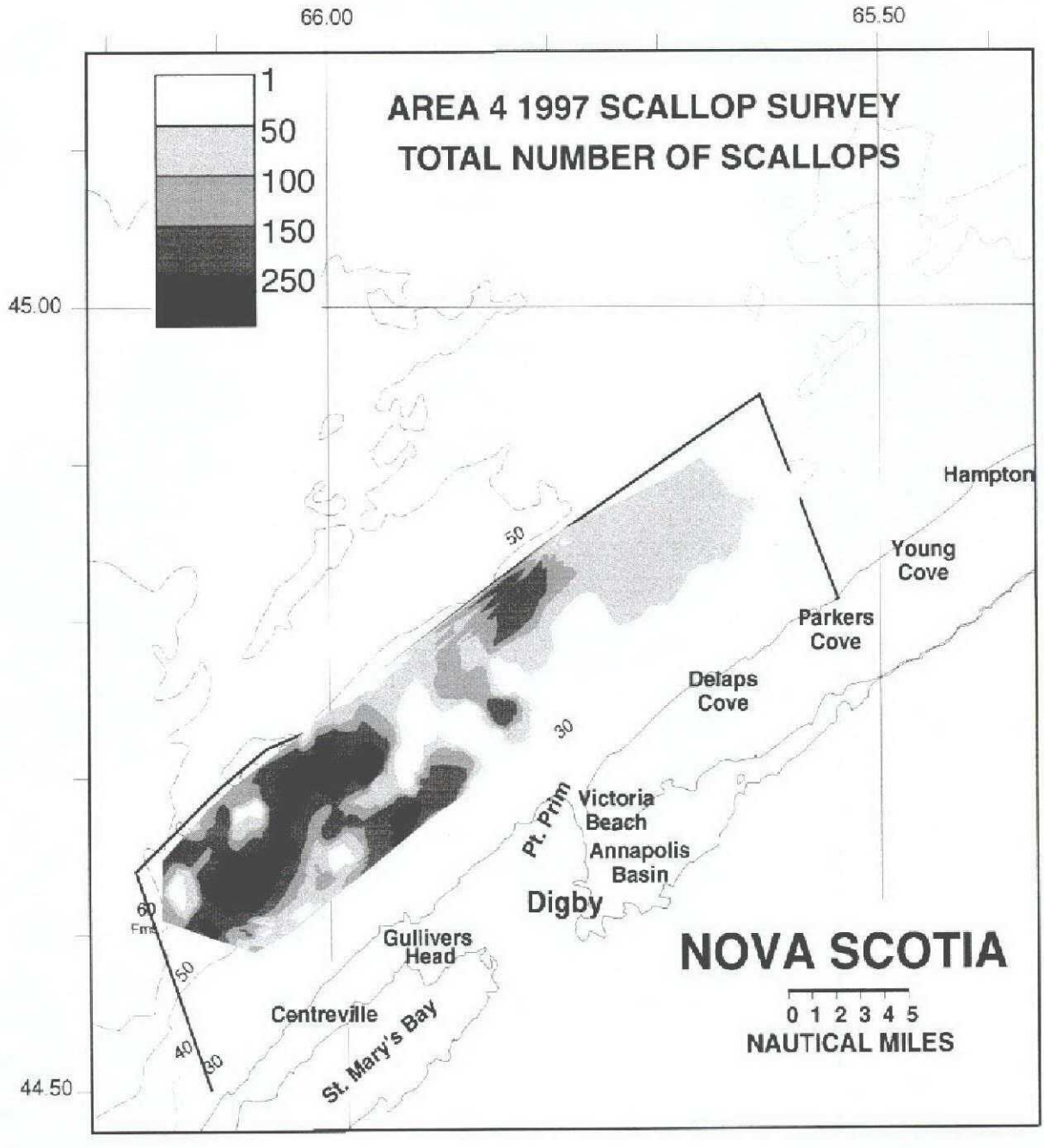


Figure 7. Spatial distribution of scallops (numbers per m^2) in Area 4. All scallops caught, prorated for gear width and tow length are included.

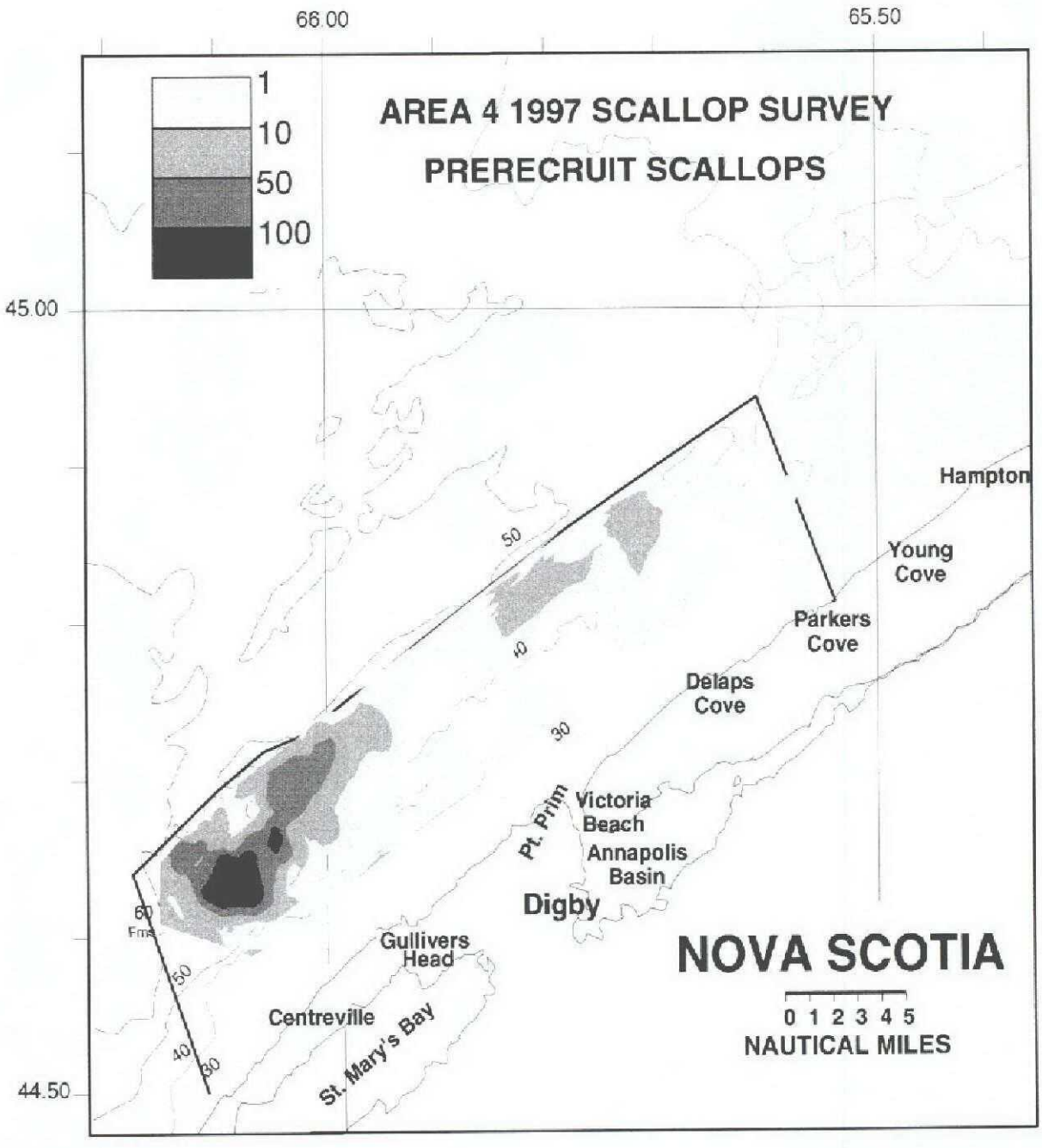


Figure 8. Spatial distribution of prerecruit (<80mm shell height) scallops (numbers per m^2) in Area 4. All prerecruit scallops caught, prorated for gear width and tow length are included.

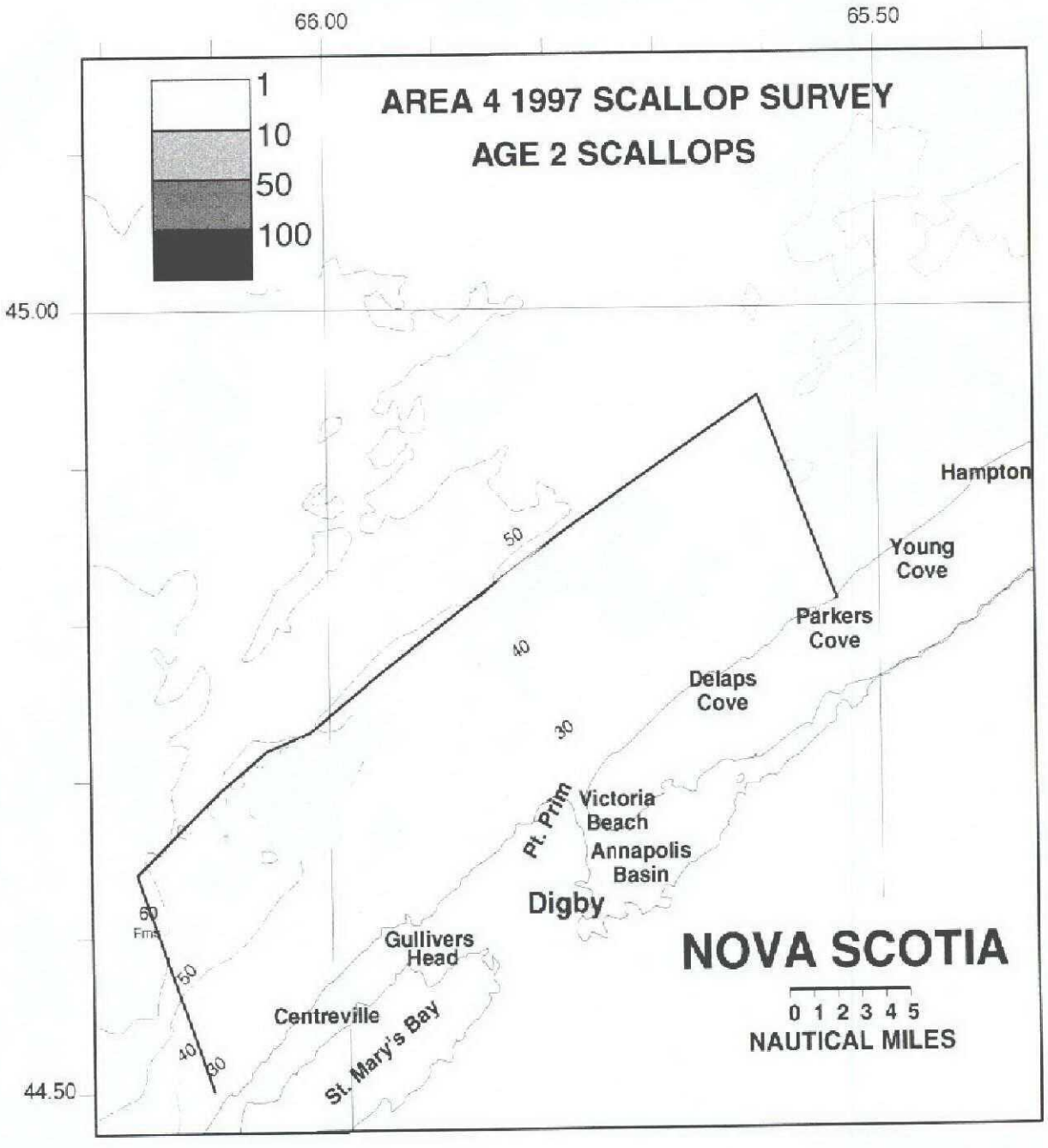


Figure 9a. Spatial distribution of prerecruit (<80 mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops at age are prorated for gear width and tow length.

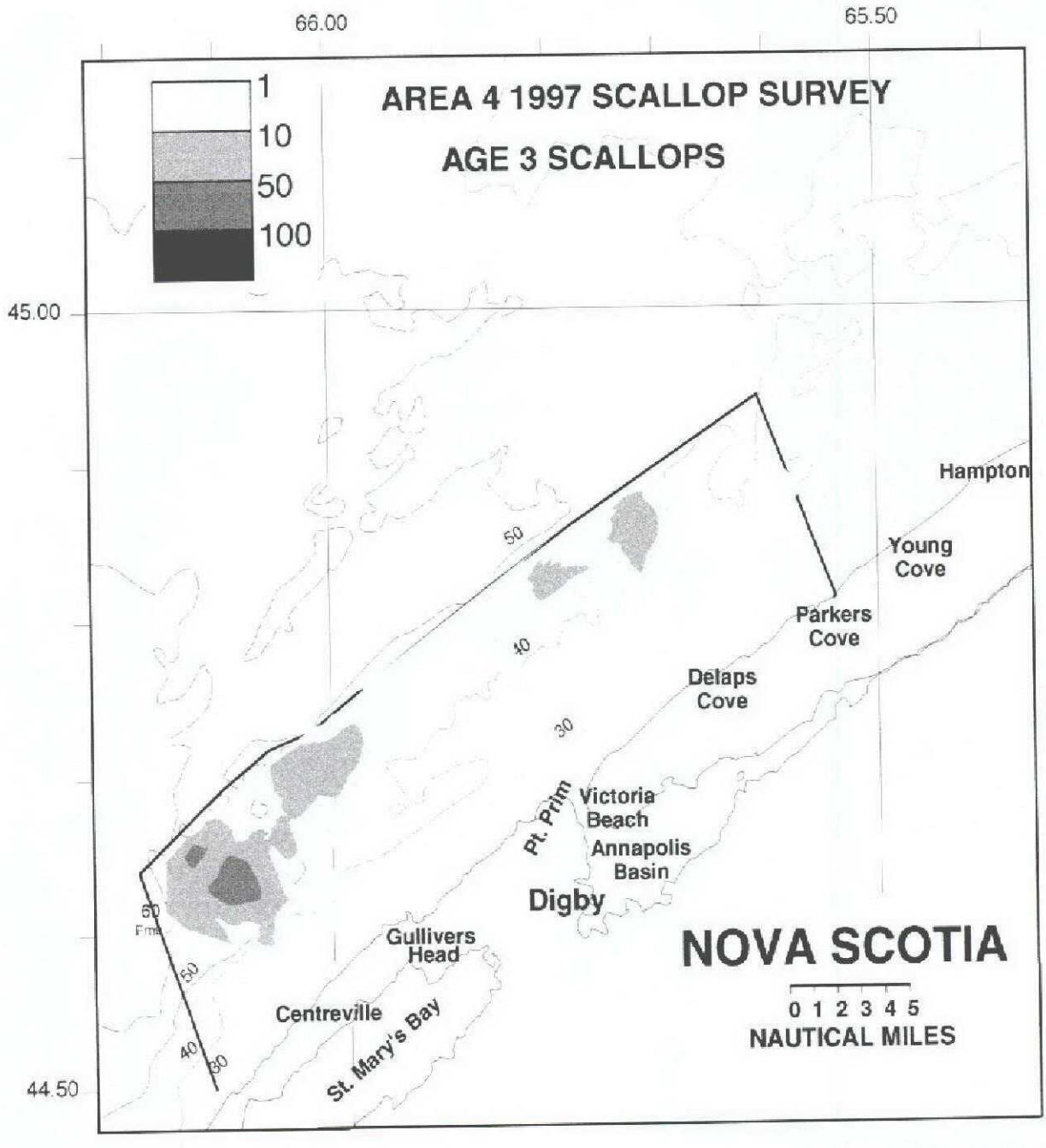


Figure 9a cont'd. Spatial distribution of prerecruit (<80 mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops at age are prorated for gear width and tow length.

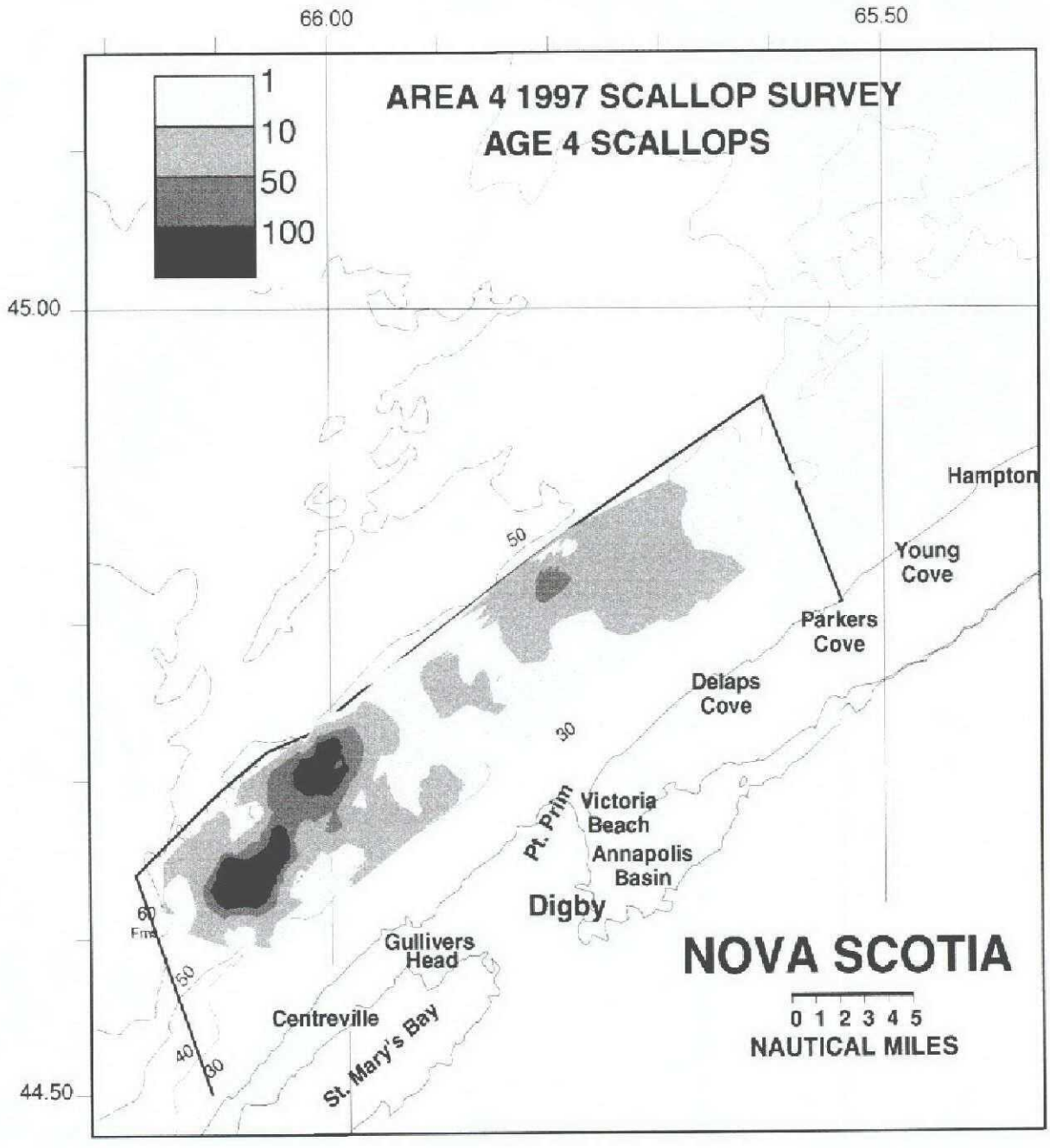
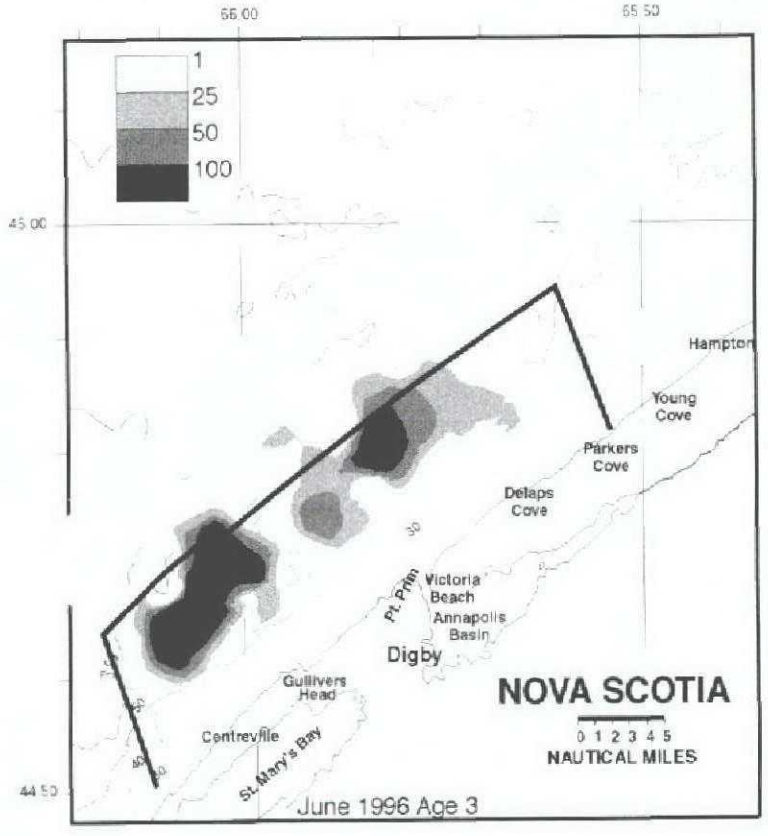


Figure 9 cont'd. Spatial distribution of prerecruit (<80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops at age are prorated for gear width and tow length.



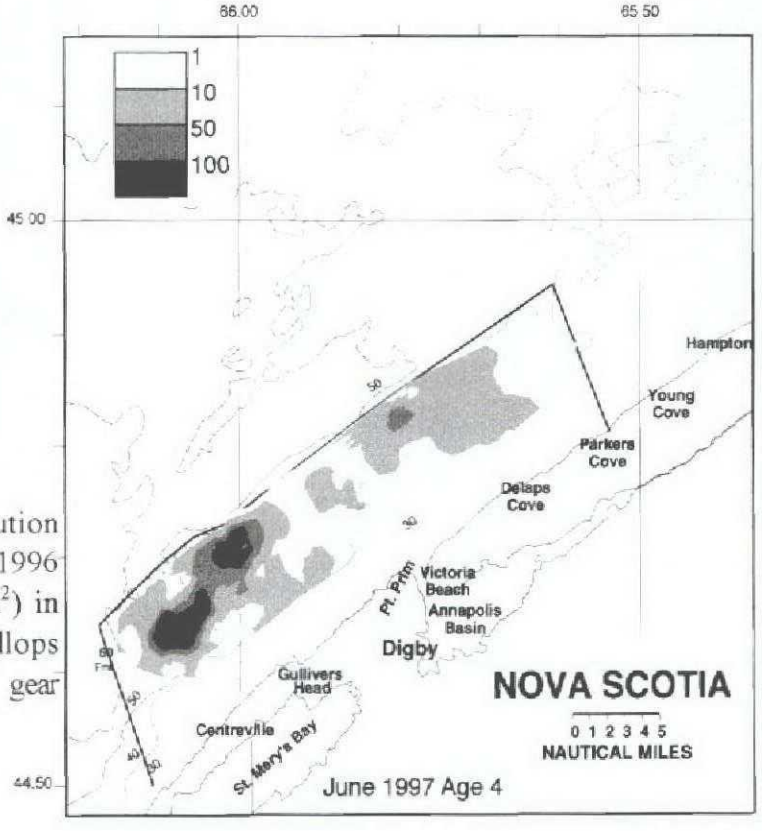


Figure 9b. Spatial distribution of the 1993 year class in 1996 and 1997 (numbers per m^2) in Area 4. The number of scallops at age are prorated for gear width and tow length.

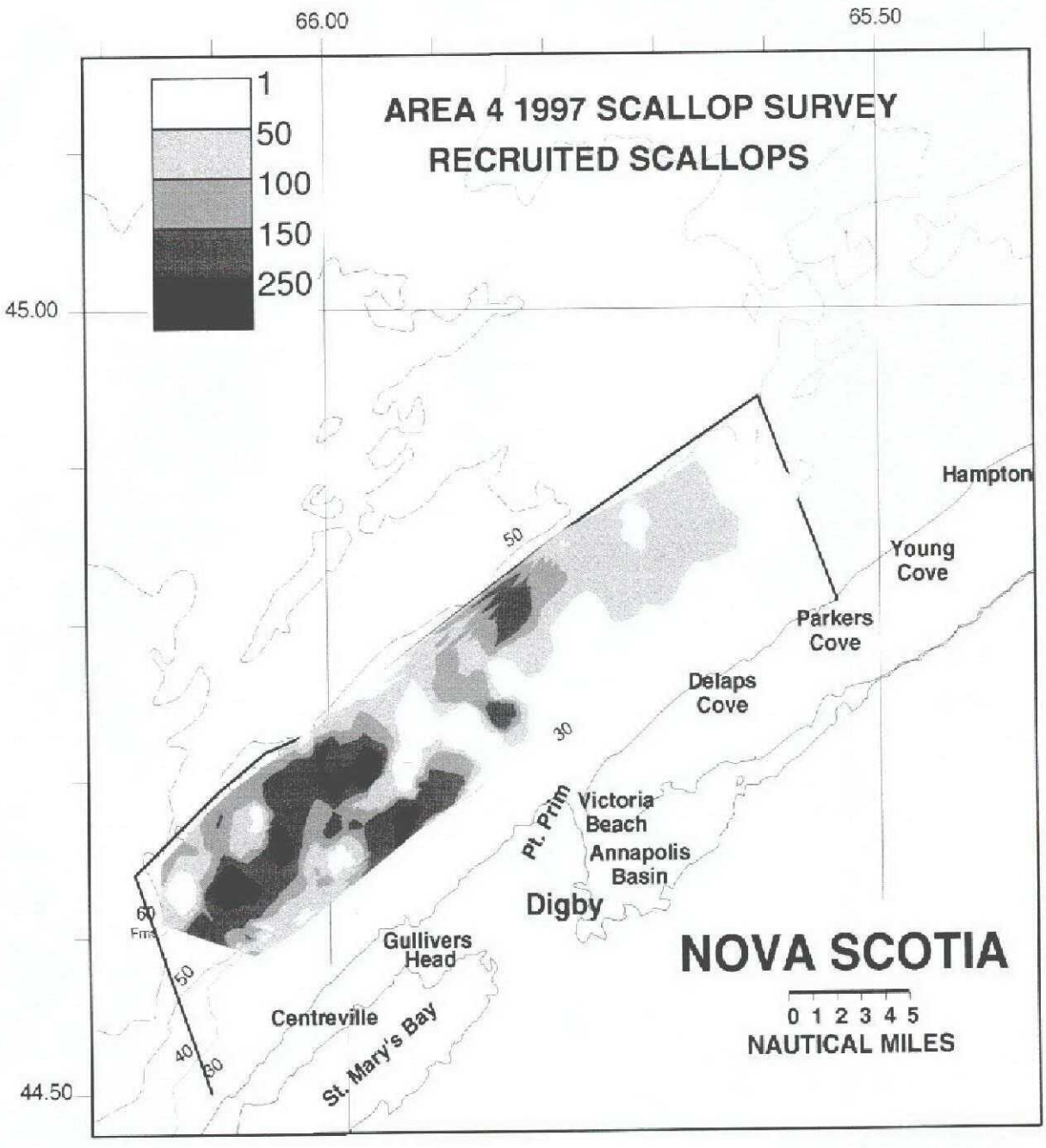


Figure 10. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) in Area 4. The number of scallops are prorated for gear width and tow length.

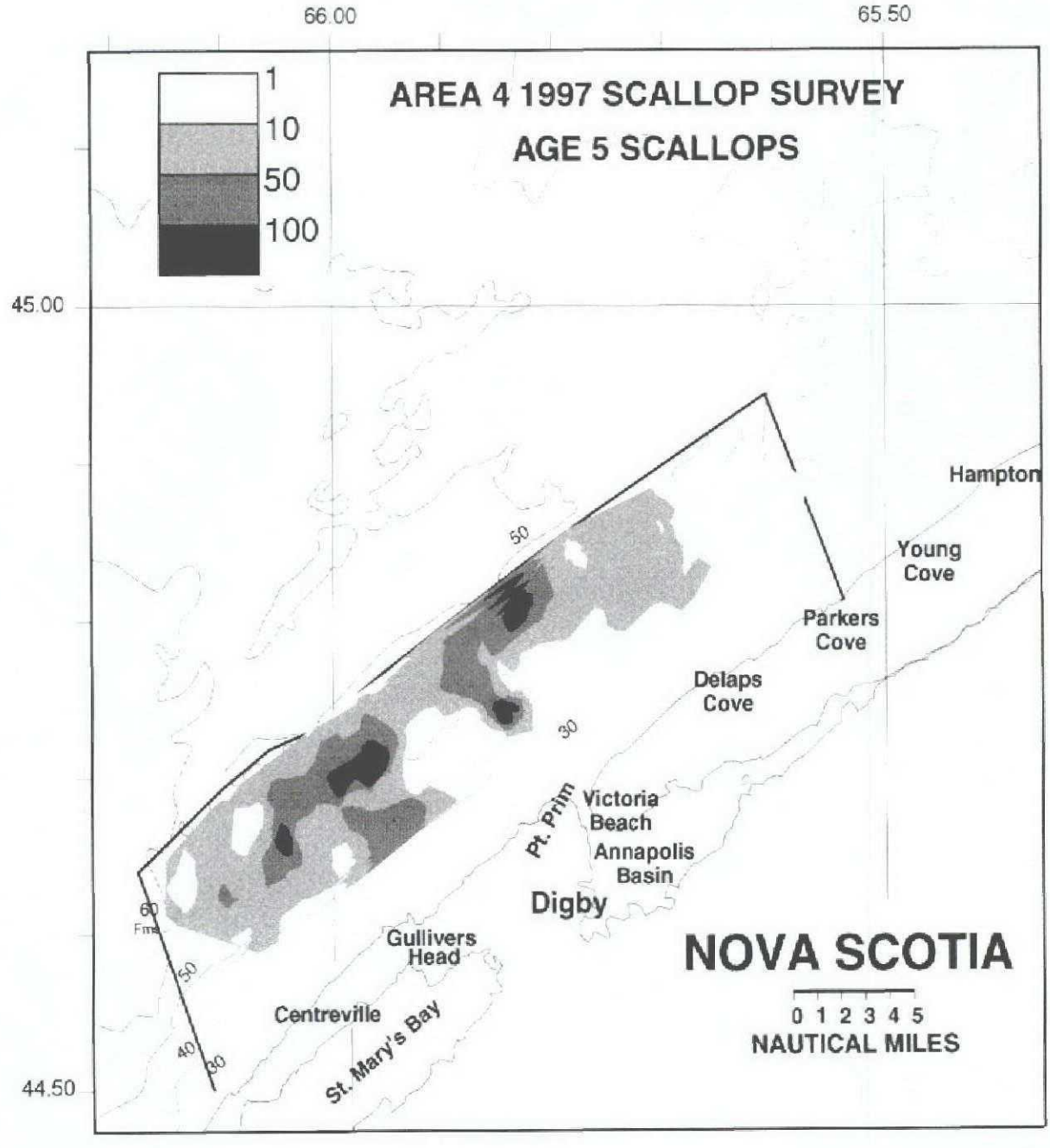


Figure 11. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops by age are prorated for gear width and tow length.

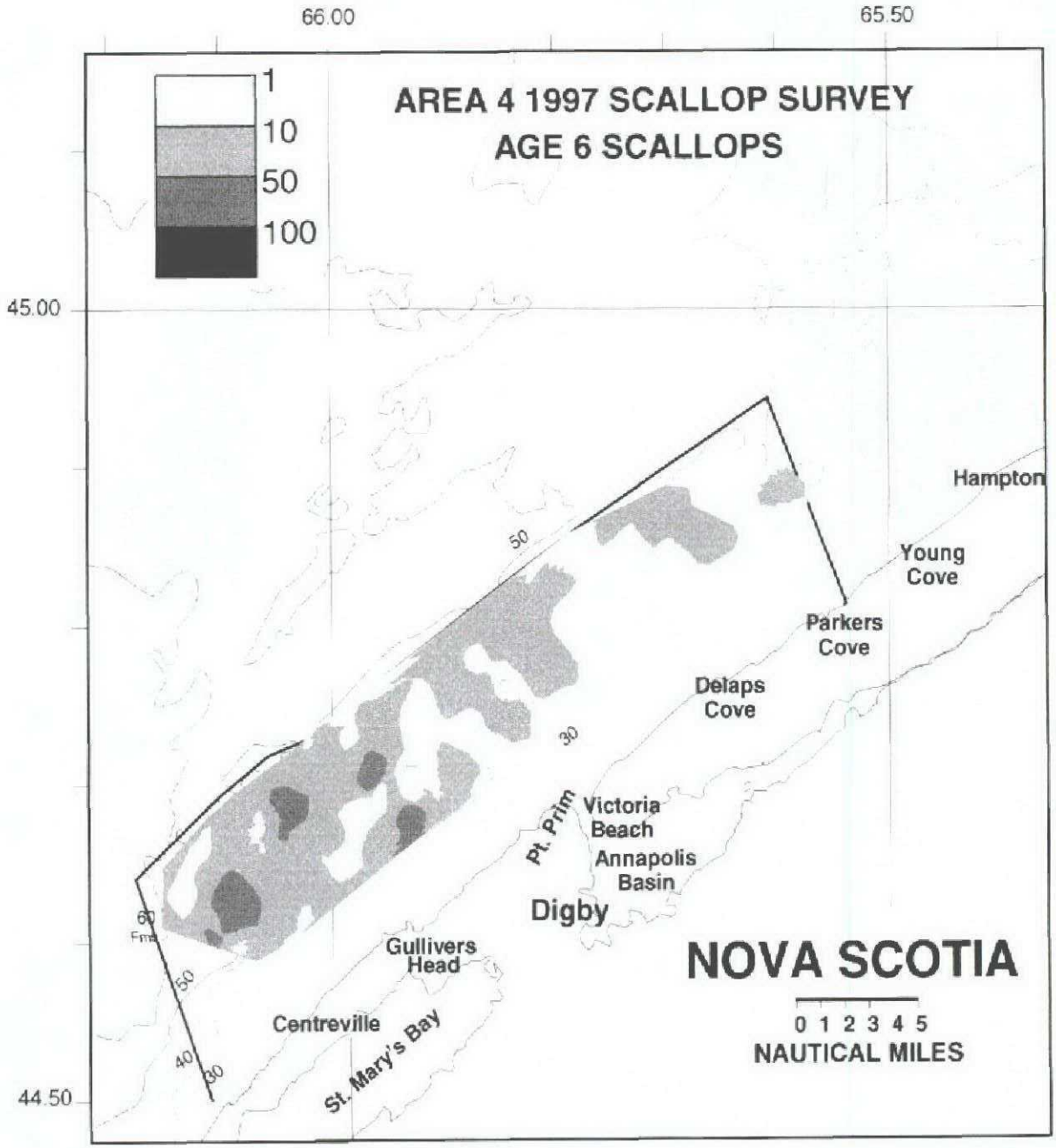


Figure 11 cont'd. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops by age are prorated for gear width and tow length.

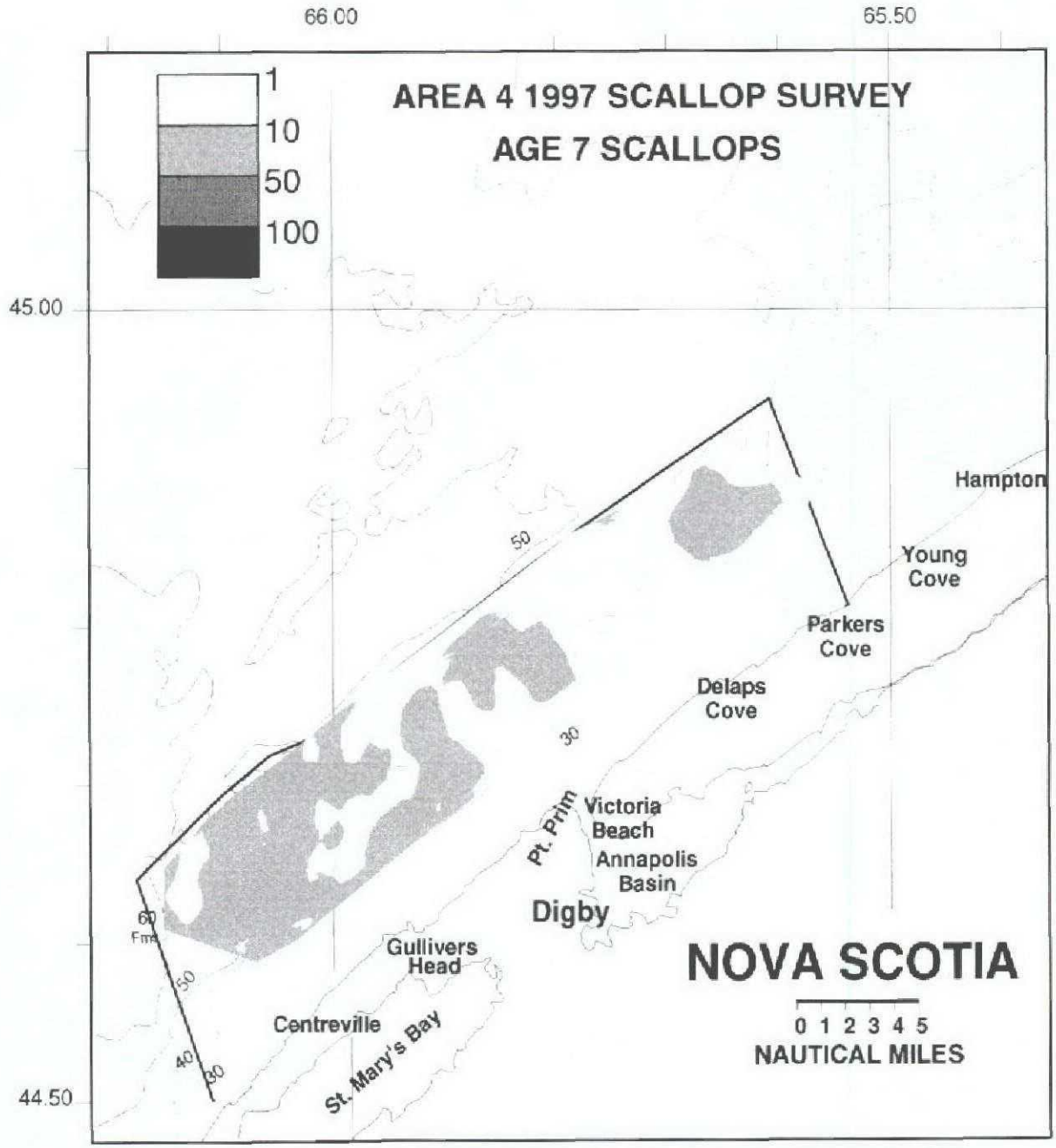


Figure 11 cont'd. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops by age are prorated for gear width and tow length.

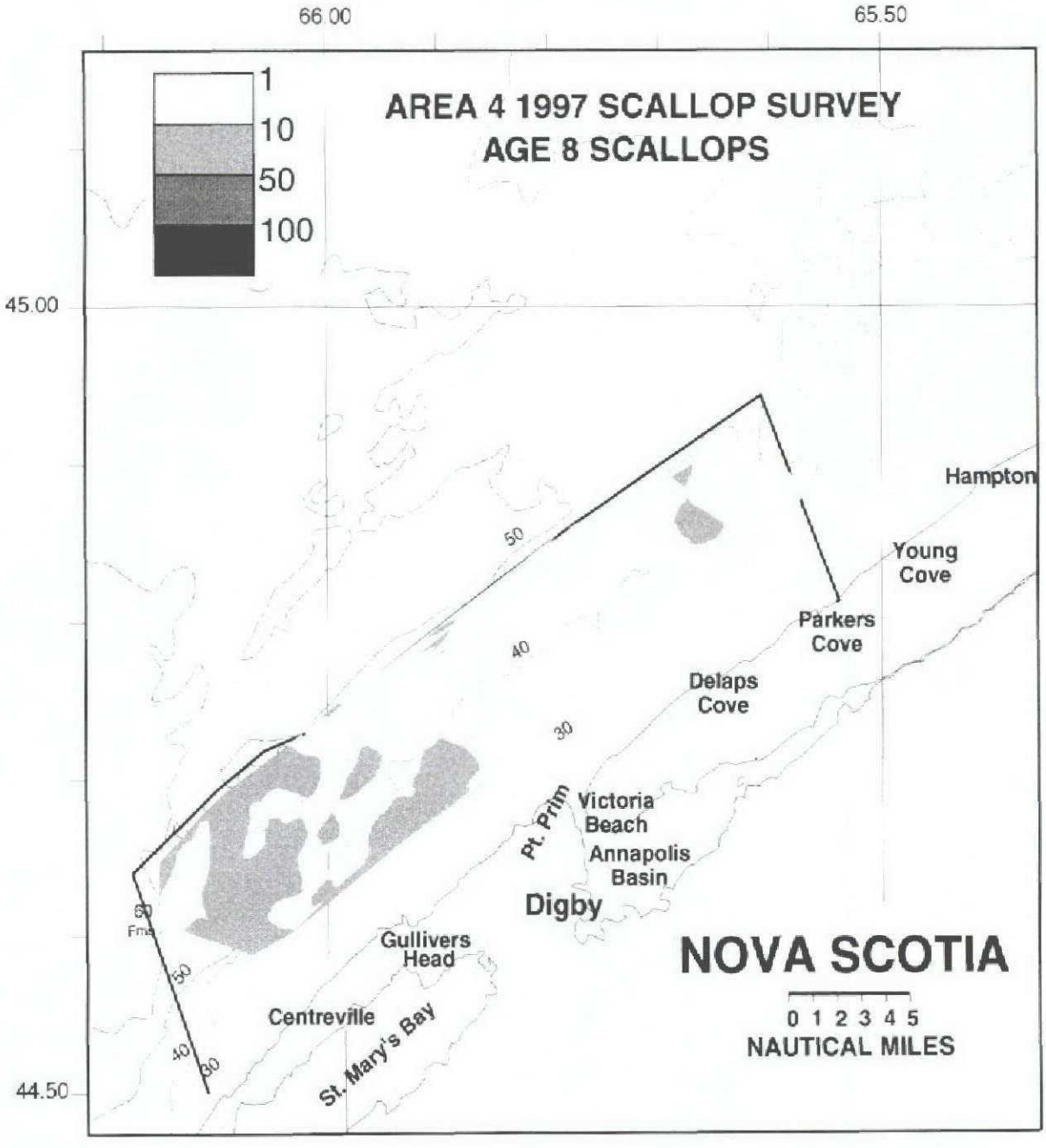


Figure 11 cont'd. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops by age are prorated for gear width and tow length.

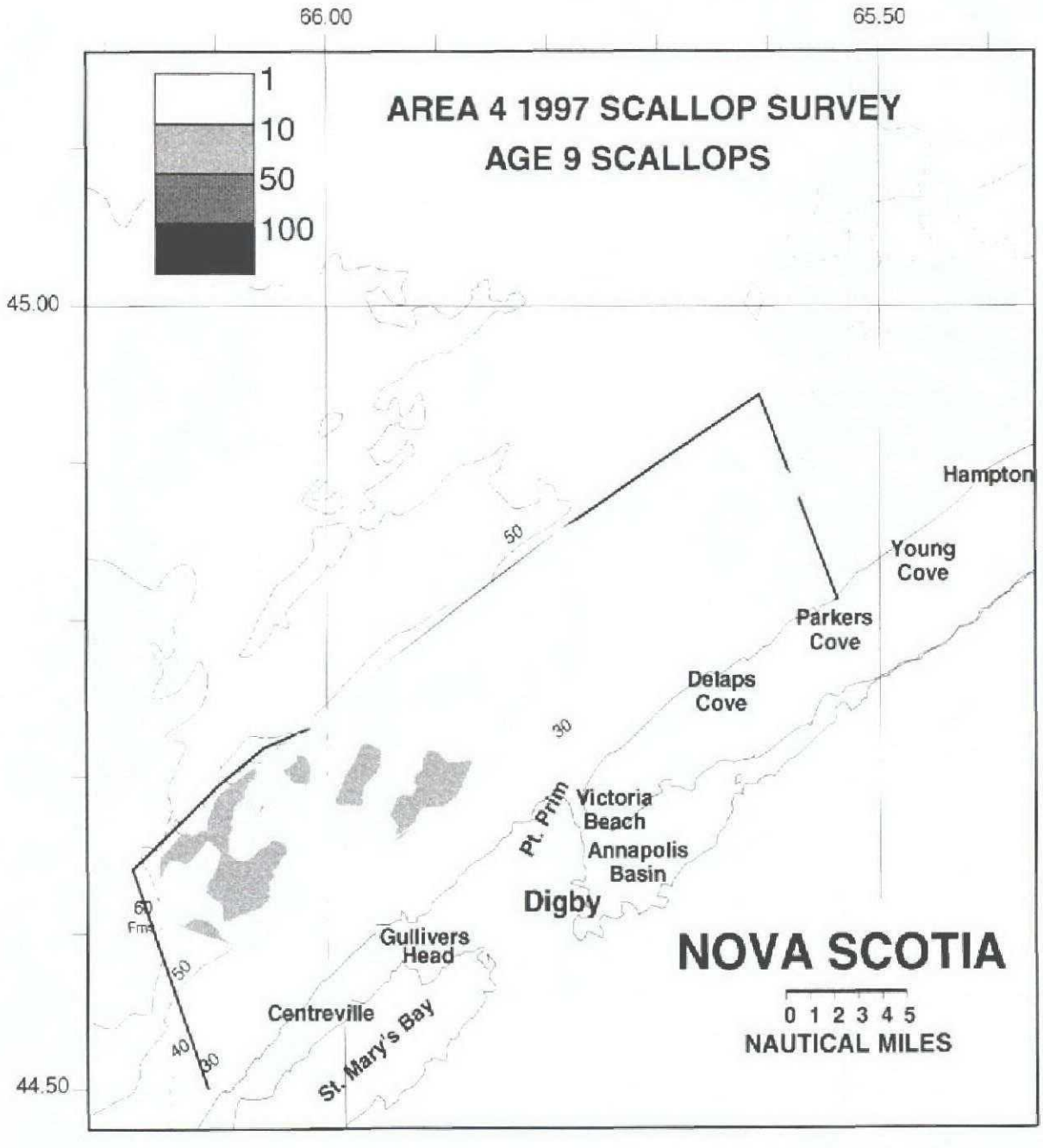


Figure 11 cont'd. Spatial distribution of recruited (>80mm shell height) scallops (numbers per m^2) by age in Area 4. The number of scallops by age are prorated for gear width and tow length.

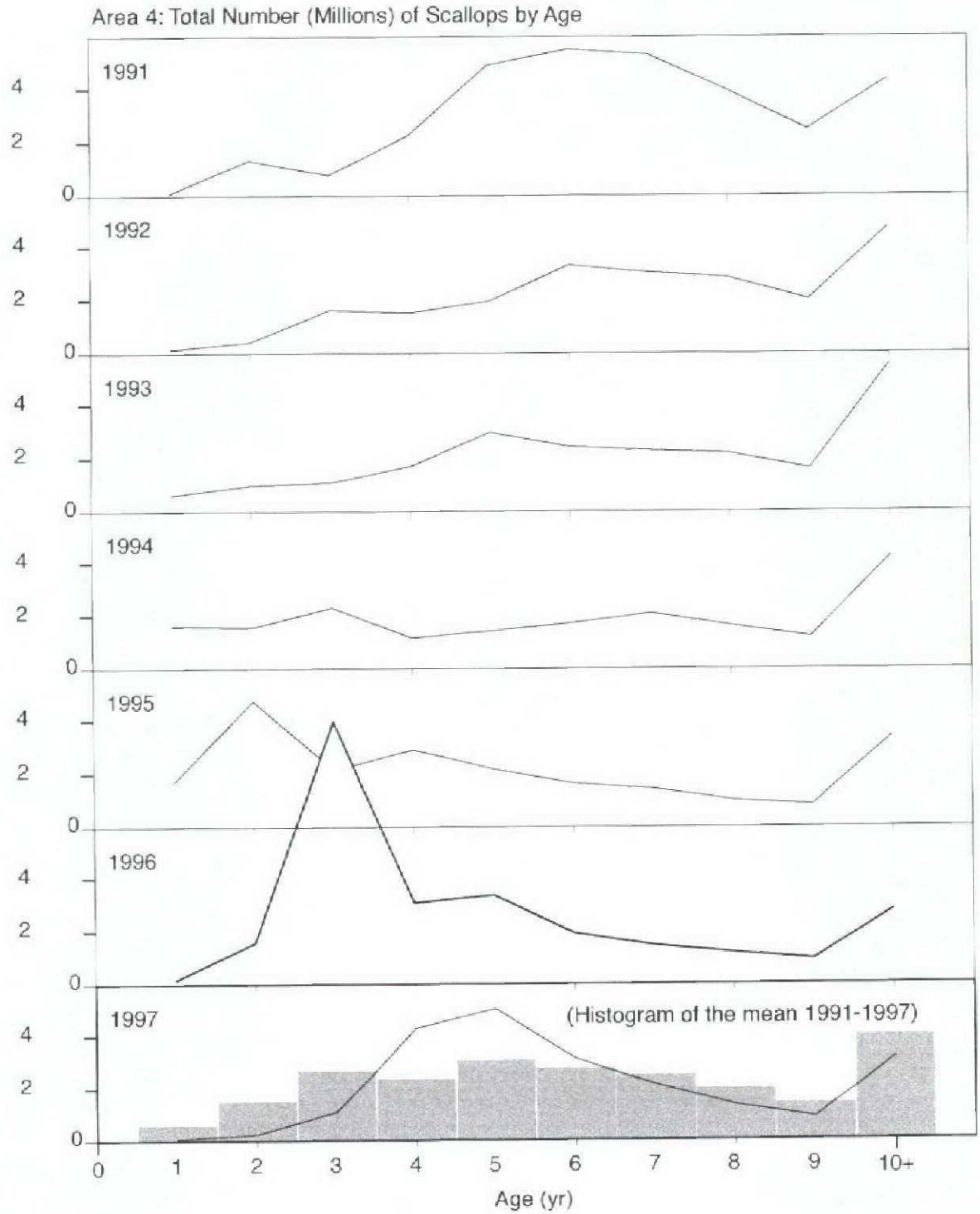


Figure 12. Frequency distribution of the number of scallops (millions) by age (1991 to 1997) determined from the research vessel survey using the stratified means for Area 4. These numbers are scaled up to produce population numbers (see text).