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BAY OF FUNDY SCALLOP STOCK ASSESSMENT: AREAS 2, 3, 4, 5, 7

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ABSTRACT

This document presents the most complete data available on five fishing areas in the Bay of Fundy (Areas 2, 3, 4, 5, and 7). For each area the following information is provided.

- Description of the Area
- 1997 Interim Management Plan
- Fishing History of the Area
- Research Vessel Surveys
- Survey Efficiency (Area 4 only)
- Survey Abundance and Biomass Estimates
- Population Abundance and Biomass Estimates
- Ageing Data
- Meat Weight-Shell Height Regressions
- 1996 Fishing Activity
- Port Sampling of the Commercial Catch

In addition, Sections on (1) the Determination of Minimum Meat Weights/Counts using yield per recruit analyses and yield isopleths; (2) Application of Yield Determination to TAC Advice; and (3) 1996 Landing Statistics and Dollar Value are presented. This document is meant to provide a baseline for biological advice on the new fishing areas.

RÉSUMÉ

Le document présente les données les plus complètes qui soient disponibles sur cinq zones de pêche de la baie de Fundy (zones 2, 3, 4, 5 et 7). Pour chaque zone est présentée l'information suivante :

- une description de la zone
- le Plan intérimaire de gestion 1997
- un historique de la pêche dans la zone
- les relevés de navires de recherche
- l'efficience des relevés (pour la zone 4 seulement)
- des estimations de l'abondance et de la biomasse obtenues par relevés
- des estimations de l'abondance et de la biomasse des effectifs
- des données sur l'âge
- des régressions poids de la chair - hauteur de la coquille
- la pêche en 1996
- l'échantillonnage à quai des prises commerciales

Sont aussi incluses des sections sur la détermination du poids et du nombre minimums de chairs basée sur des analyses du rendement par recrue et des isoplètes du rendement, l'application de la détermination du rendement à la formulation de conseils sur les TAC, et des statistiques sur les débarquements de 1996 et leur valeur en dollars. Le document est destiné à servir de fondement pour les conseils biologiques portant sur les nouvelles zones de pêche.

Introduction

In 1997 an area based management plan was implemented for the Bay of Fundy. Previously the Bay of Fundy scallop fishery was a competitive fishery managed by gear, vessel and crew restrictions, minimum size and meat count regulations, and seasonal closures. In the new management plan the Bay is divided into 7 Areas (Fig. 1), largely based on the distribution of beds and the biology of the animals (Kenchington and Lundy 1993). Each area will be managed by a TAC, minimum meat weight, corresponding minimum shell height, and a meat count. The Full Bay licence holders may also operate on an ITQ system.

This document will provide data toward the management objectives for Areas 2, 3, 4, 5 and 7.

Area 2: Southwest Bank

Description of Area

Follow the International Boundary at latitude 4340 N to 4418 N 6718 W to 4418 N 6647 W to 4340 N 6647 W to place of origin (Fig. 2). The principal scallop bed in Area 2 is found on Southwest Bank, although scallops are also found in the northern portion of Area 2 on Northeast Bank.

1997 Interim Management Plan

TAC: 150 mt
Meat Count: 45/500 g
Minimum Meat Weight: 10 g (voluntary)
Shell Height Minimum: 95 mm
Season: All year except where restricted by industry overlap fishing agreements

Fishing History of the Area

Historically the scallop beds in Area 2 have not been heavily exploited. Class 1 (complete information) logbook records of the Full Bay licence holders from 1976 to 1991 do not show any fishing activity in this area (Kenchington and Lundy 1996). From 1992 to 1995 there are nineteen Class 1 log reports for Area 2, with the greatest activity seen in 1995 with 8 Class 1 log reports. In 1995 fishing was spread out through the area with two reports from Northeast Bank, three reports from south of Southwest Bank, and three reports from the southwest portion of Area 2 near the deep water Lurcher beds.

Research Vessel Stock Surveys

A stock survey of Southwest Bank was conducted for the first time during the last two weeks of August, 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) some 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.

All tows were 8 minutes in length. To eliminate the effects of tide and vessel speed on the area covered by the gear, the distance towed was determined either from latitude/longitude of the start and end of tow bearings, or from continuous recordings of location via a computer linked to navigation aids and standardized to a tow length of 800 meters (dragged area of 4256 sq. m). Data recorded for each tow were: 1) direction of tow (magnetic or true compass bearings), 2) depth (m), 3) weight of catch (kg) (individually for each drag), 4) types of substrate, and 5) shell heights in 5 mm intervals for all live and dead (empty paired shells) scallops fished were recorded individually for each drag. Scallops from 2 tows were collected for the calculation of meat weight-shell height regressions and for ageing (see below).

Eleven tows were randomly sampled on Southwest Bank (Fig. 3). The number of scallops per tow ranged from 0 to 627 resulting in the average number per standard tow of 249 ± 267. The animals are concentrated in the 4, 5, and 6 age groups which together account for 87% of the abundance.

Survey Numbers of Scallops per Tow on Southwest Bank by Age

					Age							
tow	1	2	3	4	5	6	4	8	9	10	11+	Total
1	3	16	4	41	405	93	11	0	1	13	20	607
2	0	0	6	159	226	194	35	0	0	0	7	627
3	0	0	0	2	0	0	0	0	0	2	16	20
4	3	9	29	208	171	27	0	0	0	3	36	486
5	0	0	14	158	170	82	7	0	0	0	3	434
6	0	0	0	3	0	0	0	0	0	0	0	3
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	27	76	4	0	0	0	0	11	118
10	0	0	0	2	0	0	0	0	0	0	0	2
11	8	32	29	55	183	100	11	1	2	0	15	436
Sum	14.0	57.0	82.0	655.0	1231.0	500.0	64.0	1.0	3.0	18.0	108.0	2733
Mean	1.3	5.2	7.5	59.5	111.9	45.5	5.8	.1	.3	1.6	9.8	248.5
s.d.	2.5	10.3	11.5	77.4	132.2	64.1	10.7	.3	.6	3.9	11.4	266.7

The spatial distribution of scallops, determined from the biomass surveys, have been presented in CAFSAC Advisory documents using a contouring approach since 1990 (Robert et al. 1990). The spatial distribution of the scallops is contoured using the ACON software package

(Black 1988) with data derived from Delaunay triangles and inverse distance weighted interpolation (Watson and Phillip 1985) as detailed in Robert et al. (1990). In brief, scallop density is integrated over a triangular area, the vertices of which are defined by nearest neighbour tow locations. The composite of triangles forms a polygon, the area of which is defined by the outlying tow locations which form the edge points (Fig. 3). The distribution of scallops in our survey area shows a concentration on the centre of the bank. These scallops are largely 5-7 year olds (Fig. 4) mixed with pre-recruits (Ages 1-4). There are very few animals over the age of 8 (Fig. 4).

The presence of one dominant size class on the bank is reflected in the shell height frequency distribution (Fig. 5). This population would appear to have resulted from good recruitment from the 1989, 1990, and 1991 year-classes, with poor recruitment prior and subsequent to those years. The number of clappers is relatively high at approximately 17% with the greatest numbers appearing in the most abundant size frequencies (Fig. 5).

Survey Abundance and Biomass Estimates

The portion of Area 2 surveyed was too small for the calculation of abundance and biomass estimates. Until more fishery data is available to better delineate the scallop beds in this Area, it is unlikely that further survey work will be carried out by the Department of Fisheries and Oceans.

Ageing Data

Scallops were collected for ageing on Southwest Bank during the August 1996 research vessel survey (August 19 to 30). Fifty scallops were randomly sampled from each of 2 tows. A total of 100 scallops were aged in the lab and only the age of the animal and the shell height were recorded.

A single von Bertalanffy function was used to describe the growth of the scallops. The function is expressed as $L_t=L_{inf}\,(1-\exp\,(-k(t-t_0)))$, where, L_t is length at age, L_{inf} is the asymptotic length, k is the growth coefficient, and t_0 is the age at which length is 0. Functions were fit using the Levenberg-Marquardt method for computing parameter estimates using program NLR of the SPSS Release 4.0 software package (SPSS Inc. 1990). At each iteration, the estimates were evaluated against a set of control criteria. In these analyses, all iterations were stopped because the relative reduction between successive residual sums of squares was less than 1.000E-08. r^2 values were calculated as: 1 minus the residual sum of squares/corrected sum of squares.

Area 2	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
Southwest Bank	100	134.543 (3.953)	0.15102 (0.0198)	-1.835 (0.558)	0.94

This curve was used to convert the shell height data from the survey to numbers-at-age.

Meat Weight-Shell Height Regressions

Samples were collected (see Ageing Data above) for calculating the relationship between shell height and meat weight. The wet weight of the adductor muscle was recorded to 0.01 g. Data were used to calculate linear regressions, by area, of the ln (meat weight) on ln (shell height).

The function is expressed as ln (meat weight)=b*ln (shell height) +c, where, b is the slope of the line, and c is the intercept. Functions were fit using program REGRESSION of the SPSS Release 4.0 software package (SPSS Inc. 1990). The regression model was not forced to pass through the origin. The regression model was significant, that is, the slope was significantly different from 0. The resultant parameters of the regression model are listed below:

Area 2	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
Southwest Bank	100	1.312 (0.182)	-4.290 (0.815)	0.35	5.8 g

Plots of the expected values (from the regression model) against observed values show that the model tends to under-estimate meat weight when the shell height is greater than 100, and to over-estimate meat yield in the middle of the shell height distribution, i.e. between 70 and 100 mm shell height. Scatterplots of the data show that the variability in meat weight is large in the animals over 100 mm shell height, and marked at lower shell heights. This is the cause of the low r^2 value and appears to be the result of poor growth conditions on the bank. The meat weight of a 100 mm shell is the lowest of those reported for Areas 3, 4 and 5 (see below).

Area 3: Brier Island and Lurcher Shoal

Description of the Area

All area inside a line joining the following points: 4418 N 6647 W to 4418 N 6624 W to 4414.2 N 6624 W, to 4405.2 N 6612.5 W then following the coast south to latitude 4340 N then to 4340 N 6647 W to place of origin (Fig. 1). The scallops are distributed over the entire Area with the exception of the northwest corner.

1997 Interim Management Plan

TAC: 237 mt
Meat Count: 45/500 g
Minimum Meat Weight: 10 g (voluntary)
Shell Height Minimum: 95 mm
Season: Closed January 1, 1997 to May 31, 1997 and November 1, 1997 to December 31, 1997

Fishing History of the Area

Historically the scallop beds in the lower Bay of Fundy have not supported an extensive, stable fishery, as have the beds off Digby, N.S. The scallop beds below Brier Island and areas to the south above 43°40' N, were heavily exploited in the 1950's and 1960's (Jamieson and Lundy 1979). In the 1970's, scallop fishing on these grounds was both minimal and sporadic, and the stocks were considered to have been depleted by the earlier over-fishing. However, at the end of the decade catches increased as both the offshore and Bay of Fundy fleets fished these beds. Most of this effort was incidental to concentrated effort expended on German Bank (4Xq) and beds south of Lurcher Shoal. Fishing continued in this fashion through to the end of 1986. Since 1990 these beds have been annually exploited by the Full Bay fleet (Kenchington and Lundy 1991). In May of 1991 most of the fleet moved off the Digby grounds to the Brier Island beds and areas in the upper reaches of Lurcher Shoal. A large proportion of the fleet fished there until the opening of the Inside Fishing zone off Digby in October, 1991 (Lundy and Kenchington 1992). Landings from the Brier Island and Lurcher Shoal grounds increased each year from 1990 to 1994. In 1994, a minimum of 75% of Bay of Fundy catches were from the beds below Brier Island. However, in 1995, landings showed a decline of approximately 45% from 1994. Preliminary landings for 1996 show a further decline over 1995.

Area 3 Landings (000s metric tons meats)

Year	88-90 AVE	1991	1992	1993	1994	1995	1996
Total	0.00	0.45	0.83	0.99	1.38	0.92	0.20*

*very preliminary

The increased scallop fishing effort in this area led to gear conflicts with the lobster fishery, resulting in portions of the bed being closed during the lobster season. During 1994, a Variation Order was effected which closed a large portion of these beds from November 19, 1994 to May 31, 1995. In 1995 a similar but slightly larger area was closed from November 21 to December 31 (Variation Order 95-164) and from January 1 to February 28 (Lurcher Shoal Variation Order 96-005) and May 31, 1996 (Brier Island Variation Order 96-005). In 1996 the entire area was closed from November 14, 1996 to May 31, 1997 (Variation Order 1996-210), although an earlier opening of a portion of the area on May 9 is currently under consideration.

Research Vessel Stock Surveys

The Department of Fisheries and Oceans has conducted eight surveys of the Brier Island stocks. Surveys were conducted in 1982 and 1983, and from 1991-1996. The 1982 and 1983 stock assessment surveys were catch stratified and are not considered further here (Robert et al. 1985a). Survey results from 1991-1994 are discussed in Kenchington et al. (1995b). Survey results from 1995 are presented in Kenchington and Lundy (1996).

Stock surveys (1991-1996) were conducted during the last two weeks of August or the first week of September, using the research vessel "J.L. Hart" with 4 gang gear as for Area 2.

From 1991-1994 a uniform 2 mile interval grid system was set over Brier Island Ledge and Lurcher Shoal aligned to the most easterly point of the survey area. This system was used because initially no log information was available with which to catch stratify the grounds. At each grid intersection a tow was made, provided the bottom was suitable. In 1995, the area covered was expanded, based on cumulative logbook information since 1991. A 2.5 mile grid was used to accommodate the larger survey area. In 1996, as in 1995, a 2.5 mile grid pattern was repeated with additional stations added to the west. 113 stations were surveyed in total.

At each station the shell height and meat weight of each animal was recorded. The shells were returned to the laboratory where they were later aged.

The average number of scallops-at-age caught in the 1991-1996 stock surveys are given below. The numbers presented in these tables differ from those published in Kenchington and Lundy (1996) as the new growth curves were used and pre-recruits from the lined buckets were estimated as the number less than or equal to 80 mm shell height as opposed to the 4 years used in previous analyses (see below). The 1996 catch-at-age was also determined directly from the raw data, as all scallops in the survey were aged (see below).

From 1991 to 1993 the survey was discontinuous between the two grounds. From 1995 to 1996 the survey area was continuous between Brier Island and Lurcher Shoal and so the area allocation was defined as above 44°N for Brier Island, and above 43°40'N and below 44°00'N for Lurcher. The total average number of scallops per standard tow caught during the survey has declined dramatically since 1992 and 1993 and remains low in 1996 after a sharp decline in 1995. On the Brier Island beds, the dominant age class is still that which first appeared in the survey in 1992 as 2.5 year old scallops, and there are few pre-recruit scallops. On the Lurcher Shoal beds, the 4 year old age group is numerically the most dominant, and the average total number of scallops in the catch is 2.2 x greater than that on the Brier Island beds. The older animals have been fished down but are still present on both beds in moderate numbers.

Survey Mean Numbers-at-Age per Standard Tow for Brier Island (north of 44° latitude)
Calculated with 1997 Growth Curves

Year	Age 1	2	3	4	5	6	7	8	9	10+	4+	5+	6+	Total	No. Stations
1991	9	23	7	11	11	5	7	4	2	22	62	51	40	101	28
1992	398	200	26	22	18	9	11	7	4	26	97	75	57	718	23
1993	9	92	181	122	58	22	10	7	4	24	247	125	67	529	32
1994	15	48	39	140	49	14	9	7	4	19	242	102	53	344	35
1995	2	9	4	7	14	9	5	4	3	14	56	49	35	71	42
1996	1	6	5	7	7	10	8	4	2	10	48	41	34	60	45
1996*		6	6	4	8	10	7	4	3	9	45	41	33	57	45

* actual ages from survey

Survey Mean Numbers-at-Age per Standard Tow for Lurcher Shoal (south of 44° latitude)
Calculated with 1997 Growth Curves

Year	Age 1	2	3	4	5	6	7	8	9	10+	4+	5+	6+	Total	No. Stations
1991	18	46	10	21	43	15	4	2	1	10	96	75	32	170	31
1992	98	28	66	57	49	26	10	6	5	15	168	111	62	360	24
1993	28	451	194	141	88	36	20	16	11	24	336	195	107	1009	49
1994	32	19	67	112	63	30	14	10	6	16	251	139	76	369	61
1995	6	17	15	32	41	25	12	10	7	17	144	112	71	182	60
1996	1	2	26	24	23	17	10	8	5	10	97	73	50	126	68
1996*		2	26	28	24	15	10	7	5	9	98	70	46	126	68

*actual ages from survey

The spatial distribution of scallops, determined from the biomass surveys, was contoured using the ACON software package with data derived from Delaunay triangles and inverse distance weighted interpolation (see Area 2 : Southwest Bank above, for details).

The largest concentrations of scallops are in the deeper water off Lurcher Shoal (Fig. 6). The pre-recruit scallops are also found in this area, and to the west of Lurcher Shoal (Fig. 7). There are some small scallops on the Brier Island bed toward St. Mary's Bay. The 5 to 7 (Fig. 7) and 8+ age groups (Fig. 7) are also concentrated in the deeper water where the yield is poor. The distribution of individual age groups is plotted in figure 8. The youngest year-class born in 1994 and age 2.5 in the survey have largely settled on the eastern edge of the Brier Island beds. This is a good growth area and the yield from these pre-recruits will be important for the revitalization of this subarea. Our survey gear does not sample this size class very effectively and so there is some hope that a strong age 3.5 group will appear in the 1997 survey.

The incidence of "clappers" (paired empty shells) on both beds has increased in the surveys from lows of less than 2.5% from 1991 to 1993, to 16% in 1994 and 17.1% in 1996. Most of the clappers in 1994, 1995, and 1996 are on the Lurcher bed, however, there was a sharp increase in clappers on the Brier Island bed from 1995 to 1996 (8.1% to 12.8%).

Percent Clappers (Paired Empty Shells) in Survey Catch

	1991	1992	1993	1994	1995	1996
Brier Island	0.9	1.4	2.0	5.4	8.1	12.8
Lurcher	1.3	1.6	2.3	20.5	16.8	18.3

The size frequency distribution of the total number of live animals and clappers caught during the survey is illustrated in figure 9. The clappers do not seem to be concentrated in any one size class and are spread evenly over the size distribution, with greater numbers in the larger size classes of live animals.

The catch per unit effort of the research vessel was 4.83 kg/hr on Brier Island, 6.52 kg/hr on Lurcher Shoal and 5.88 kg/hr over the whole area. This calculation was based on the weight of the total number of animals > 80 mm caught in the unlined buckets prorated to 7 gangs and 8 minute tows.

The similarity of survey areas in 1994 through 1996 allowed the calculation of Fishing Mortality estimates (*F*) on each of the beds (see below). The estimates were based on the exploited age groups, ages 4+ to 6+, and assuming a Natural Mortality (*M*) of 0.1 (Merrill and Posgay 1964). The exploitation of the Brier Island beds was significantly lower from 1995 to 1996 than from 1994 to 1995 in both age groups, while exploitation of the Lurcher Shoal beds was slightly lower from 1995 to 1996 in the age 4+/5+ calculations and slightly higher in the age 5+/6+ calculations than in the previous year. Unfortunately the 1996 log data was not available at the time of assessment and so there is no independent conformation of these figures. The high percentage of clappers could be due to either incidental Fishing Mortality, or to an increase in Natural Mortality. The mortality and exploitation values were also calculated using an *M* based on the number of clappers (cf. Kenchington et al. 1995a). The percentage of clappers (*Cl*) in the catch was converted to a Natural Mortality estimate (*M*) by the formula: $Cl=1-e^{-M}$. The Natural Mortality on the Brier Island beds would be 0.14 based on a figure of 12.8% clappers. Similarly *M* for Lurcher Shoal is 0.20.

Mortality and Exploitation Levels for Area 3: Brier Island and Lurcher Shoal

Age 4+/5+					
Subarea	Total Mortality (Z)	Fishing Mortality (F)		Exploitation	
		M=.1	M=.14	M=.1	M=.14
Brier Island					
1994-1995	1.60	1.50	1.46	74.8%	72.8%
1995-1996	0.31	0.21	0.17	18.1%	14.6%
		M=.1	M=.2	M=.1	M=.2
Lurcher					
1994-1995	.81	0.71	0.61	48.7%	41.5%
1995-1996	.68	0.58	0.48	42.1%	34.8%

Mortality and Exploitation Levels for Area 3: Brier Island and Lurcher Shoal (cont'd)

Age 5+/6+					
Subarea	Total Mortality (Z)	Fishing Mortality (F)		Exploitation	
		M=.1	M=.14	M=.1	M=.14
Brier Island					
1994-1995	1.07	0.97	0.93	59.6%	57.1%
1995-1996	0.37	0.27	0.23	22.6%	19.2%
		M=.1	M=.2	M=.1	M=.2
Lurcher					
1994-1995	0.67	0.57	0.47	41.5%	34.3%
1995-1996	0.81	0.71	0.61	48.7%	41.8%

The relative abundance of pre-recruit (ages 1 to 4) to adult scallops is shown in figure 10 for Brier Island and Lurcher Shoal. The decline in both groups of scallops is readily seen. The high number of pre-recruit scallops in 1992 on Brier Island and 1993 on Lurcher, were heavily fished at low yield (Kenchington et al. 1995b).

Survey Abundance and Biomass Estimates

The Brier Island/Lurcher survey was a fixed station design and as a result the estimation theory is more problematic than when random surveys are used. While estimates of means and total numbers are unbiased, variance estimates require some model for the spatial distribution of the animals. Preliminary analysis using geostatistical methods (variograms, kriging) were inconclusive with respect to finding strong spatial autocorrelation in the data. Therefore only the mean, total abundance and total biomass were calculated from the survey data.

The survey area was divided into Brier Island area and Lurcher Shoal subareas with the 44° N line (Kenchington and Lundy 1996). The mean catch-at-age per standard tow was calculated for each area. The surface area within each management area was estimated and converted to total number of standard tows. Total numbers were then calculated as the mean catch-at-age times the total number of standard tows in each area. These estimates are given in the table below.

Biomass-at-age estimates were calculated in a similar manner the abundance estimates, with mean weights-at-age calculated separately for the two management areas and multiplied by total numbers in each area to get total biomass. Mean weight-at-ages (in g) for the two areas were:

Brier Island :

1	2	3	4	5	6	7	8	9	10
0.11	0.97	2.8	5.72	8.17	10.19	11.99	13.58	14.73	19.09

Lurcher:

1	2	3	4	5	6	7	8	9	10
0.18	1.06	2.89	4.65	6.63	8.34	9.54	10.62	11.86	15.52

	Brier Island			Lurcher Shoal		
	Mean (nos)	Total (nos)	Biomass (kg)	Mean (nos)	Total (nos)	Biomass (kg)
1	1.07	288,484	32	0.71	190,056	35
2	5.52	1,481,396	1,441	2.50	670,479	708
3	5.46	1,465,733	4,108	25.65	6,888,624	19,885
4	6.87	1,845,138	10,562	24.24	6,509,512	30,282
5	7.02	1,886,018	15,404	23.01	6,180,158	4,098
6	10.05	2,699,659	27,509	16.74	4,496,998	37,497
7	7.56	2,031,048	24,348	10.34	2,777,802	26,498
8	4.18	1,122,388	15,246	7.93	2,129,946	22,629
9	2.22	595,392	8,768	4.95	1,329,130	15,764
10	9.66	2,594,727	49,537	10.44	2,803,857	43,521
1-4	18.92	5,080,751	16,142	53.09	14,258,670	50,910
5-7	24.64	6,61,672	67,262	50.10	13,454,959	104,979
8+	16.06	4,312,507	73,551	23.32	6,262,934	81,914
All	59.61	16,009,983	156,954	126.51	33,976,561	237,804

The survey total fishable biomass (Age 5+) in Area 3 is approximately 327.7 mt. The survey total number of animals available to the fishery (Age 5+) is approximately 25 million (24,692,072).

Population Abundance and Biomass Estimates

The abundance and biomass figures calculated from the survey data underestimate the population abundance and biomass by the catchability of the survey (q). In order to determine the catchability of the survey, we expressed the catch, C as function of mortality and population size based on the commercial catch-at-age,

$$C = N(F / Z)(1 - exp(-Z))$$

where N is population size, F is fishing mortality and Z is total mortality. Given the total mortalities estimated from the surveys we can predict $\hat{N}$ for an observed catch, assuming a specific natural mortality M. That is,

$$\hat{N} = \frac{C}{(F / Z)(1 - exp(-Z))}$$

The ratio of the predicted N with the survey estimate of N should give us an estimate of the catchability to the survey. If this factor is stable over time then it can then be used to scale the estimated total meat weights from the survey to population meat weight estimates.

Survey Mean Catch-at-Age for Brier/Lurcher Subareas Combined, with Total Mortality Estimates (Z) on the 4+/5+ and 5+/ 6+ year old Age Groups

Year	1	2	3	4	5	6	7	8	9	10	4+	5+	6+	Z4/5	Z5/6
1991	13	35	9	16	28	10	5	3	2	16	80	64	36	-0.16	0.06
1992	245	112	47	40	34	18	10	7	5	20	134	94	60	-0.22	0.03
1993	20	309	189	133	76	30	16	13	8	24	300	167	91	0.88	0.91
1994	26	30	57	122	58	24	12	9	5	17	247	125	67	1.06	0.80
1995	4	14	10	21	30	18	9	8	5	16	107	86	56	0.58	0.69
1996	1	4	18	17	17	14	9	6	4	10	77	60	43		

Size compositions from port sampling of the commercial catches are sparse and do not allow for characterizing the catch separately for Brier Island and Lurcher Shoals. The commercial catch-at-age derived from this data is represented below:

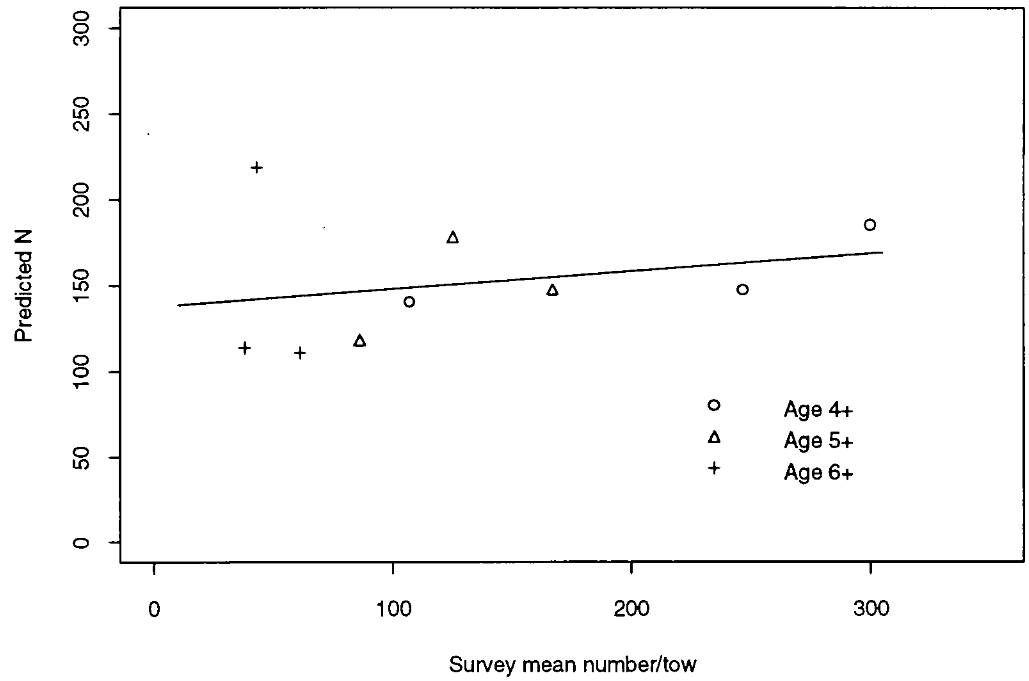
Commercial Catch-at-Age for the Scallop Fishery in Area 3 (Brier Island/ Lurcher Shoals)

Age	1991	1992	1993	1994	1995
1	0	0	0	0	0
2	0	0	0	0	0
3	1066	278	1042	33	0
4	16035	5337	17588	1008	669
5	**19917**	20013	27778	7636	3624
6	5272	**17847**	19016	13285	7677
7	1703	9675	**10088**	14221	8228
8	1015	4615	6276	**11667**	6975
9	805	2463	4052	8730	**6202**
10+	2824	6231	11232	30461	17588
5+	31536	60845	78443	85998	50295
6+	11619	40832	50665	78362	46671

Despite the limited data available, the commercial catch-at-age matrix permits the following of cohorts through time in many cases.

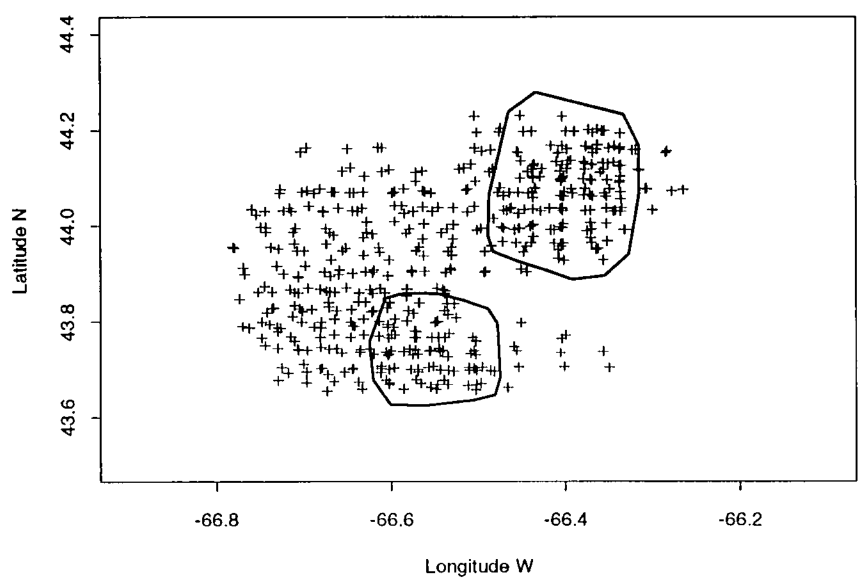
The regression of the estimated population size using the above catch equation and total mortality estimates from the surveys with survey population numbers from the Brier Island/Lurcher Shoal (Area 3) survey is illustrated below. The solid line represents the regression equation for all three age groups combined. The intercept of this line was significantly different from zero while the slope was not. The average $1/q$ ($\times 10^6$) for age groups 4+, 5+ and 6+ were 0.87, 1.14 and 1.94 , respectively.

Regression of Survey Numbers Against Predicted Numbers



Given that the area covered by the Area 3 survey has expanded over time, using all six years to calculate Z values and $1/q$ is problematic. One approach is to define an common area covered in all six years and use only the tows made in this area. Such an area is illustrated below, and includes all tows made in 1991 and 1992 and encompasses between 39 and 51 tows each year for 1993 to 1996.

Common Positions used to Calculate Total Mortality
and Catchability Coefficients for Area 3 Survey

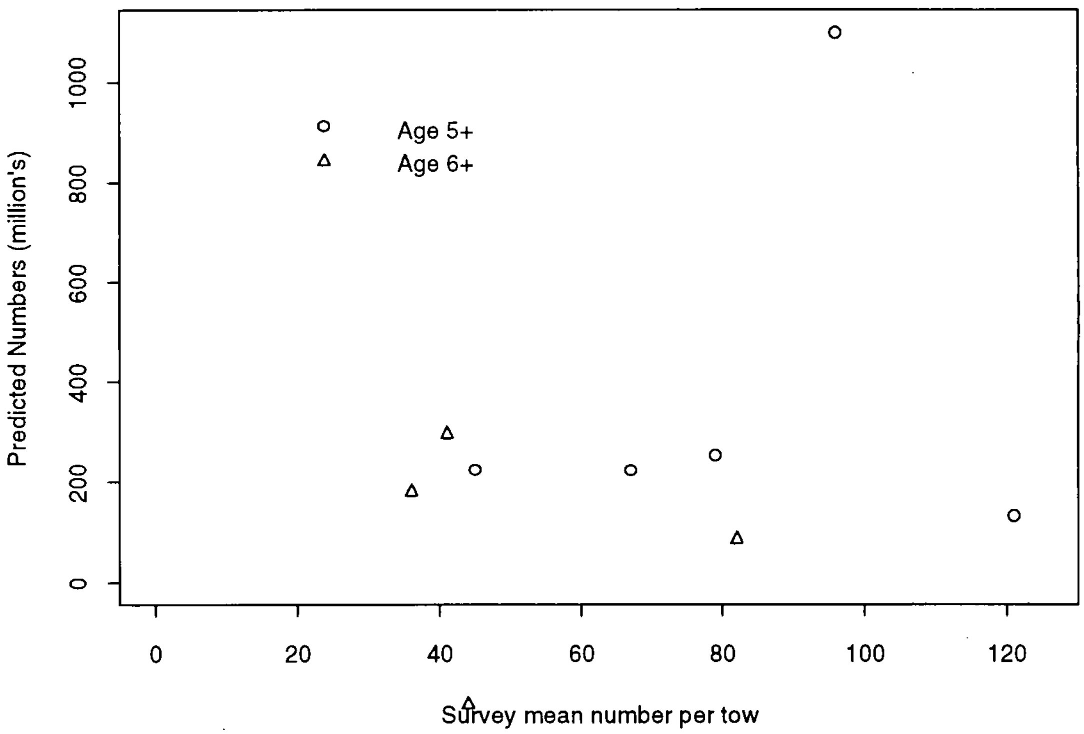


New survey catch-at-age matrices were calculated using only the tows in the common area described above:

Survey Mean Catch-at-Age and Total Mortality Estimates for Brier/Lurcher Combined using only the Areas Common for all Survey Years

	1	2	3	4	5	6	7	8	9	10	4+	5+	6+	Z4/5	Z5/6
1991	23	37	7	19	35	15	8	4	2	15	98	79	44	0.02	0.24
1992	314	47	41	38	34	20	12	7	5	18	134	96	62	0.10	0.16
1993	11	72	84	45	39	22	16	11	8	25	166	121	82	0.91	1.08
1994	35	15	11	55	26	11	9	5	4	12	122	67	41	1.00	0.62
1995	7	9	4	2	9	9	5	5	4	13	47	45	36	0.29	0.37
1996	2	5	24	7	4	7	7	5	3	9	42	35	31		

Regression of Survey Numbers Against Predicted Numbers from Common Area Only



The regression of the estimated population size using the catch equation above and total mortality estimates from the surveys with survey population numbers from the Brier Island/Lurcher Shoal (Area 3) survey is plotted above for the common survey area. Note that a data point for the Age 6+ group falls outside of the positive quadrant. There does not appear to be any consistent relationship between the survey population and associated total mortality estimates and the catch numbers, when common areas surveyed each year are used.

In conclusion, the estimates of q do not appear to be reliable with our present set of data.

Ageing Data

Scallops were collected for ageing during the August 1996 research vessel survey (August 19 to 30). All animals landed were ultimately aged with the exception of those in tow 88, which were subsampled randomly. Previous analyses (Roddick et al. 1994) have shown that recording shell height-at-age from multiple rings on the same shell produces a bias in the growth curve toward slower growing animals. In these analyses only the age of the animal and the shell height were recorded. A total of 5475 animals were aged. These growth curves reflect the height distribution of the population at the time of sampling.

Six von Bertalanffy functions were used to describe the growth of the scallops in Area 3, calculated as in Area 2.

An analysis of the residual sums of squares was used to determine if fitting multiple growth curves to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Many combinations of curves were evaluated based on divisions of the data set into 50 m depth intervals and two locations, Brier Island and Lurcher Shoal. There were only 7 animals in water less than 50 m on Lurcher Shoal, so this function was not included in the evaluations. There was no significant difference ($F=1.5$, $P>0.05$) between the functions used to describe the deep water Brier Island growth (i.e., between animals living at depths greater than 150 m and those at depths between 101 and 150 m), and so a single curve was used. The use of six curves was a significant improvement ($F=79.03$, $P<0.01$) over the use of a single curve, or of a single curve by area or depth. The resultant parameters of the von Bertalanffy models are listed below:

Area 3 Subareas	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
Brier Island < 50m	185	153.678 (4.587)	0.19404 (0.01426)	0.1930 (0.1041)	0.93
Brier Island 51-100m	680	135.924 (0.975)	0.26030 (0.00656)	0.3105 (0.0479)	0.94
Brier Island > 100m	430	129.655 (1.069)	0.25662 (0.01015)	0.1309 (0.1153)	0.87
Lurcher <100m	1536	138.806 (0.969)	0.21068 (0.00524)	-0.3040 (0.0639)	0.93
Lurcher 101-150m	2349	120.654 (0.457)	0.31576 (0.00622)	0.2328 (0.0509)	0.88
Lurcher > 150m	295	119.229 (0.952)	0.28774 (0.01242)	-0.0789 (0.1241)	0.92

The parameters of the growth functions differ from a previously published curve for this area (Robert et al. 1986), particularly with regard to L_{inf} which was high at 155.775. However, the 1986 curve was produced with data from scallops collected largely in shallow water, and included animals from German Bank (M. Lundy, pers. comm.). The shallow water Brier Island samples show a similarly high L_{inf}, but this is atypical of Area 3 as a whole.

For some purposes a general growth curve is of more use than a group of specific growth curves (e.g., in calculating a yield per recruit model for the whole of Area 3). The growth curve coefficients for Area 3 are given below:

Von Bertalanffy Growth Coefficients for Area 3

Area 3	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
	5474	127.1990 (0.3506)	0.2786 (0.0032)	0.1964 (0.0273)	0.90

Meat Weight-Shell Height Regressions

Samples were collected (see Ageing Data above) for calculating the relationship between shell height and meat weight. The wet weight of the adductor was recorded to 0.01 g. Data were used to calculate linear regressions, by area, of the ln (meat weight) on ln (shell height).

The function is expressed as ln (meat weight)=b*ln (shell height) +c, where, b is the slope of the line, and c is the intercept. Functions were fit using program REGRESSION of the SPSS Release 4.0 software package (SPSS Inc. 1990) as for Area 2 above. The regression model was not forced to pass through the origin. Each regression model was significant, that is, the slope was significantly different from 0. An analysis of the residual sums of squares was used to determine if fitting multiple regressions to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Combinations of functions were evaluated to determine whether one growth curve per subarea or per depth could be used or whether different subarea/depth functions were required. The use of 6 functions was a significant improvement over the use of a single function, or of a single function by area or depth or combination of depth within area with the exception of the deep water Lurcher Shoal animals. There was no significant difference ($F=0.17$, $P>0.05$) between the regression models produced for Lurcher Shoal scallops at depths of 101-150 m and at depths of greater than 150 m. The resultant parameters of the regression models are listed below.

Plots of the expected values (from the regression model) against observed values show that the Brier Island shallow water models for the < 50 m, 51-100 m, and 101-150 m functions tend to over-estimate meat weight when the shell height is less than 65, 70 and 80 mm respectively, and under-estimate meat weight when the shell height is greater than 65, 70 and 80 mm respectively. The Brier Island function for depth >150 m does not show any strong deviation between the observed and expected values. The Lurcher models also tend to over-estimate meat yield when shell heights are less than 135 mm (shallow water < 100 m) and 88 mm (deep water > 100 m); at shell heights greater than these values, the estimates from the model are under-estimated.

Area	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
Brier Island < 50m	185	2.899 (0.040)	-10.986 (0.176)	0.97	10.6g
Brier Island 51-100m	680	2.775 (0.030)	-10.528 (0.137)	0.93	9.54g
Brier Island 101-150m	371	2.827 (0.101)	-10.956 (0.474)	0.68	7.9g
Brier Island > 150m	59	3.048 (0.075)	-11.777 (0.332)	0.97	9.6g
Lurcher < 100m	1536	2.979 (0.026)	-11.569 (0.118)	0.90	8.6g
Lurcher > 100m	2644	2.786 (0.030)	-10.813 (0.135)	0.77	7.5g

Meat yield is best on the shallow water Brier Island beds, and poorest in the deep water off Lurcher Shoal. These models differ from those published in Kenchington and Lundy (1996) where only specific stations were analyzed for meat weight data, and represent a more comprehensive modeling of yield relationships in this area. The present coverage should be more representative of the area/depth strata as there was no subsampling. One peculiarity is the model for the Brier Island scallops at depths greater than 150 m. This model gives a large meat weight for a 100 mm shell height (i.e., 9.6 g) in comparison with the other deep water samples. These animals came from a single tow (number 43) which occurred on a slope. The depth change was 50 to 70 fathoms over 1 mile. The slope water may provide food sources through turbulence which are not generally available at these depths on flatter contours. The tow itself followed the depth contour and did not follow the slope. The mean, standard deviation and minimum and maximum values for meat weight, shell height and age are given below for each area/depth stratum:

Statistics for Meat Weight, Shell Height and Age by Area/Depth Stratum

Variable	Mean	Std Dev	Minimum	Maximum	N
Brier Island ≤ 50m					
MEATWT	9.08	7.34	.1	29.6	185
SHELLHT	84.12	33.10	24	151	185
AGE	4.98	2.98	1	15	185
Brier Island 51-100m					
MEATWT	10.26	6.12	.1	41.2	680
SHELLHT	96.91	25.48	23	155	680
AGE	6.07	3.06	1	19	680
Brier Island 101-150m					
MEATWT	11.47	4.47	.2	29.8	371
SHELLHT	111.72	13.07	31	151	371
AGE	8.64	2.76	1	20	371
Brier Island < 150m					
MEATWT	6.77	4.11	.1	22.6	59
SHELLHT	84.81	21.47	26	134	59
AGE	4.97	2.59	1	15	59
Variable	Mean	Std Dev	Minimum	Maximum	N
Lurcher Shoal ≤ 100m					
MEATWT	8.07	4.65	.2	34.6	1536
SHELLHT	94.32	17.24	28	158	1536
AGE	5.55	2.34	1	19	1536
Lurcher Shoal >100m					
MEATWT	7.29	3.49	.1	24.0	2644
SHELLHT	95.72	15.15	20	145	2644
AGE	6.02	2.53	1	18	2644

In some uses, generalized meat weight-shell height relationship models are more useful than a series of models (e.g., in calculating yield per recruit models for the whole of Area 3). The meat weight-shell height regression parameters for Area 3 are given below:

Area 3	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
	5474	2.791 (0.016)	-10.757 (0.071)	0.85	8.1g

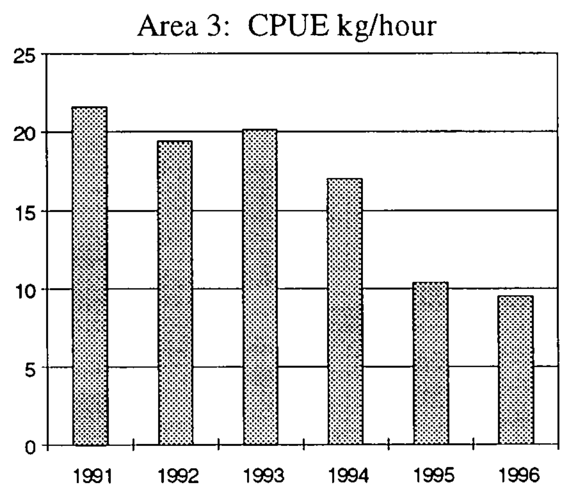
1996 Fishing Activity

Estimates of the proportion of the catch removed from Area 3 have not been calculated as the log records have not been processed at the time of writing due to late receipt. The available logs were screened for Class 1 (complete) data so that preliminary catch per unit effort (CPUE) and days fished could be calculated. CPUE in Area 3 was 9.52±3.84 kg/hour with a minimum of 3.74 kg/h and a maximum of 25.4 kg/h. These preliminary Class 1 log records totaled 403 "days" fished.

Catch per unit effort was the lowest on record for this Area in 1996. The summary statistics for CPUE from 1991 to 1996 are shown below (Area 3 CPUE 1991-1995 recalculated from Kenchington and Lundy 1996):

CPUE kg/h

Year	Brier Island	Lurcher Shoal	Combined Area 3
1991	17.7	30.2	21.6
1992	20.0	18.9	19.4
1993	17.2	23.0	20.1
1994	17.0	16.9	17.0
1995	10.6	10.4	10.4
1996	-	-	9.5



The commercial CPUE statistics for the whole area are higher than those from the research vessel survey (5.88 kg/h), however exploitation rates indicate that the fleet targeted the Lurcher scallops which had a higher CPUE than the Brier Island scallops in the survey (see above).

Port Sampling of Commercial Catch

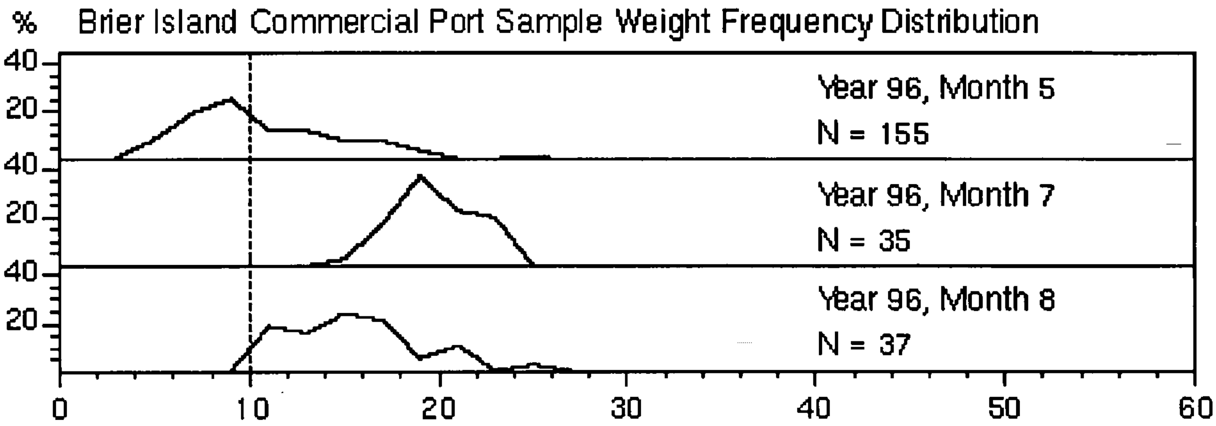
Port sampling of the commercial catch has been carried out from Digby, and Yarmouth, N.S. When a vessel lands, two samples of approximately 500 grams each are removed from the catch, and date, vessel, location and depth fished are recorded. The catch muscle is then removed from the adductor muscle and each adductor muscle is weighed and recorded for each of the two samples. This separation of the muscles is done because the catch muscle is not always attached to the adductor, as a result of processing. The contribution of the catch muscle to the total weight is later prorated. In 1995, a total of 104 samples were collected from 9 vessels, with 59% of the samples coming from 2 vessels. This was a decrease in the number of samples, and the number of vessels sampled from 1994, and an increase in the percentage coming from 2 vessels. In 1996 a total of 1174 samples were collected from 27 vessels, with 26% of the samples coming from 2 vessels, 1174 of these samples were collected from Area 3. The locations of these samples are shown in figure 6. Three of the samples came from an area which was not covered in the survey. The increase in our coverage in 1996 is due to the addition of 2 port sampling contracts, one in the Digby area, and one in the Yarmouth area.

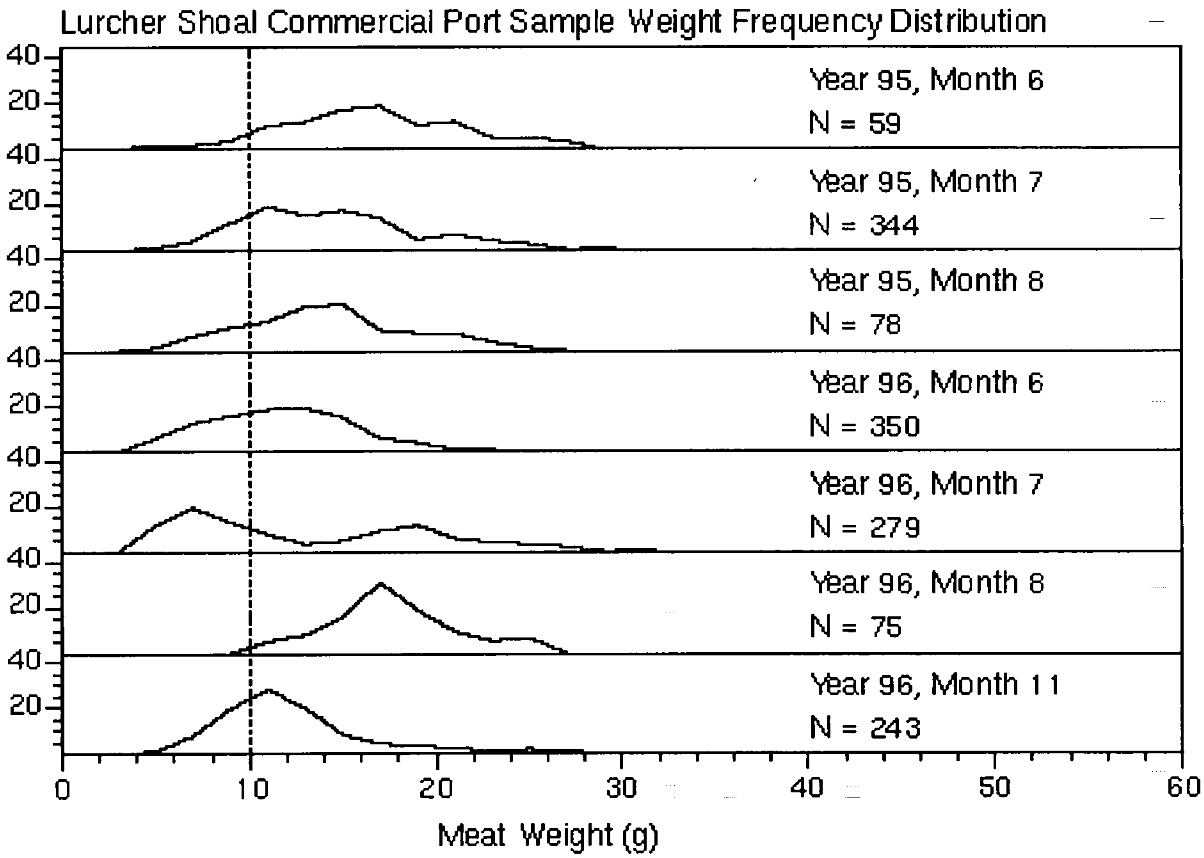
The mean, standard deviation and range of meat weights are calculated on a monthly basis when data is available. A "meat count" of the sample is then calculated by dividing 500 (g) by the mean meat weight (g). The meat count regulation for this area was 50 meats per 500 g in 1996. The mean meat weight (g) per month and associated statistics are given below. These data do not include the weight of the catch muscle, however, this has been calculated as 5-7% of the total (e.g. 4 g meat could have been landed as a 4.28 g meat with catch on). Also, fishermen do not remove the entire muscle when "shucking" the meat. A portion of the muscle is commonly left on each valve. The percent of the meat discarded has not been calculated for Digby shuckers, and is expected to vary with shell shape in the different parts of the Bay, and with catch abundance. Due to this Area being closed for a large portion of the year (see above) samples could only be expected from June through to November. The meat count was met on both grounds in Area 3 throughout our sampling periods.

The distributions of the meat weights are shown below, with the voluntary 10 g minimum meat weight indicated. In 1995 there where no samples taken from the Brier Island beds. In 1996 a large number of smaller animals were taken in May, while the later samples included animals which were generally above the minimum target size. On Lurcher Shoal, the meat weight frequency in 1996 was similar to that observed in 1995. Many scallops landed were smaller than the voluntary minimum size (dashed line), although this target was not in effect at the time of fishing.

Area 3 (Brier Island/Lurcher Shoal) Meat Weight Statistics for the Full Bay Licence Holders by Month and Year Calculated from Port Samples of the Commercial Catch

Year	Month	Meat weight (g)				Sample size	Meat count
		Mean	Min	Max	s.d.	(n meats)	per 500 g
Brier Island Fishing Grounds							
1983	May	10.62	3.66	17.95	3.20	85	47.1
	June	9.00	3.96	27.17	4.19	106	55.6
1991	May	13.55	6.59	38.84	5.70	74	36.9
	June	20.23	4.45	37.55	6.93	50	24.7
1992	June	12.91	5.60	26.20	4.03	77	38.7
	July	13.36	2.80	59.20	8.86	434	37.4
	Sept.	8.64	3.80	17.00	2.12	583	57.9
1993	April	12.50	3.30	25.60	4.74	318	40.0
	May	10.59	3.40	29.60	5.99	280	47.2
	June	9.98	3.90	26.70	3.58	200	50.1
	Sept.	11.31	3.60	42.90	6.51	379	44.2
	Nov.	14.00	7.30	23.70	3.37	71	35.7
1994	March	20.91	9.30	37.00	6.75	53	23.9
	April	19.00	4.90	42.00	7.64	419	26.3
	May	13.64	5.50	22.00	3.20	292	36.7
	June	16.18	4.60	51.50	7.26	1055	30.9
	July	22.00	11.00	37.50	6.30	111	22.7
1996	May	10.80	2.90	25.90	4.33	155	46.3
	July	19.80	15.80	23.90	2.17	35	25.3
	August	15.48	11.10	24.10	3.19	37	32.3
Lurcher Shoal Fishing Grounds							
1991	June	6.67	2.19	27.58	1.95	1210	75.0
	July	9.17	3.08	33.67	5.15	437	54.5
	August	7.73	3.70	25.51	3.09	134	64.7
1992	June	9.84	3.30	29.00	3.86	312	50.8
	July	10.88	2.50	38.40	4.59	907	46.0
	August	15.20	9.40	27.00	2.75	66	32.9
	Sept.	9.17	4.60	15.70	2.14	446	54.5
1993	April	8.89	3.00	23.80	3.79	225	56.2
	May	7.00	3.00	25.30	2.44	711	71.4
	June	8.21	3.10	17.00	2.02	122	60.9
	Sept.	10.04	3.50	27.80	3.96	597	49.8
	Nov.	14.06	6.10	30.40	4.77	142	35.6
1994	April	15.72	5.60	43.50	7.10	380	31.8
	May	14.40	3.60	32.30	3.80	851	34.7
	July	12.31	4.80	34.30	4.05	971	40.6
1995	June	16.64	5.50	26.70	4.69	59	30.0
	July	14.33	5.70	29.30	4.61	344	34.9
	August	14.16	5.80	24.80	4.37	78	35.3
1996	June	11.83	4.30	29.20	4.01	350	42.3
	July	13.30	4.00	37.10	5.89	279	37.6
	August	17.58	10.40	25.30	3.34	75	28.4
	Nov.	12.40	5.10	28.00	4.30	243	40.3


%
Brier Island Commercial Port Sample Weight Frequency Distribution
Year 96, Month 5
N = 155
Year 96, Month 7
N = 35
Year 96, Month 8
N = 37
40
20
0
10
20
30
40
50
60


Lurcher Shoal Commercial Port Sample Weight Frequency Distribution
Year 95, Month 6
N = 59
Year 95, Month 7
N = 344
Year 95, Month 8
N = 78
Year 96, Month 6
N = 350
Year 96, Month 7
N = 279
Year 96, Month 8
N = 75
Year 96, Month 11
N = 243
40
20
0
10
20
30
40
50
60
Meat Weight (g)

Area 4: Digby Grounds

Description of the Area

All 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 (Fig. 11) as opposed to the 6 miles in 1996 (cf. Kenchington et al. 1995c). This Area dissects a scallop bed which extends at least to the 16 mile line with overflow to the rest of Area 1 (Fig. 1). However, the growth rates are much higher in this area than in the rest of Area 1 and so there is some biological basis for supporting a distinct area for these scallops as was requested by industry.

1997 Interim Management Plan

To be set pending March 1997 scallop stock assessment meeting.

History of the Area

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. In 1987 the Inside Fishing Zone was extended to 8 nautical miles from shore (to protect small scallops), the equivalent of the present Area 4. In 1992, the Inside Zone returned to the 6 mile distance from shore. Since 1992, much of the effort has been concentrated on the Brier Island and Lurcher Shoal stocks, with 63% of the 1995 catch coming from those beds. 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 pre-recruit scallops. In addition, a 1 mile closure in SFA28A from April 19th to December 31 was effected to avoid conflict with the lobster fishery. This closure area was subsumed by the extended closure of the Inside Zone.

The scallop beds off Digby, N.S. have been variable over the last decade. Two strong recruitment pulses, first observed in 1986 and 1987 as 2 year old animals, 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 and off Cape Spencer, N.B. In the spring of 1989, the incidence of "clappers" (empty paired shells) off Digby rose from an average of 3% over the previous four years to approximately 23%. By the fall, this value further increased to 51%, with over 90% dead in some areas. An overview (1981-1994) of fishing activity and stock assessments on the Digby beds has been documented recently (Kenchington et al. 1995a, 1995b, 1995c, Kenchington et al. 1996).

Research Vessel Stock Surveys

A stock survey of the Digby grounds was conducted in June 1996 using the research vessel "J.L. Hart" with 4 gang gear (see Area 2 above for description of gear). The 1996 survey predated the establishment of Area 4 and so covered the traditional survey area from Centreville to Hampton to 16 miles from shore. The survey was of a stratified random design by area, with the number of stations allocated to each area dependent upon the geographical area of the stratum. The assignment of stations was a two step process: 1) 100 survey stations were randomly assigned according to one of three zones: Core Area, Below Core Area and Above Core Area (Robert et al. 1985b), which were originally defined according to commercial catch levels. The number of stations per zone reflect the relative geographic area of each zone (Kenchington et al. 1995a). Accordingly 53, 16 and 31 stations were assigned to the Core Area, Below Core Area and Above Core Area zones respectively. 2) Survey station positions were then randomly assigned according to one of ten area strata within the zones: Centreville, Centreville-Gulliver's Head, Gulliver's Head, Gulliver's Head - Digby, Digby, Digby - Delaps Cove, Delaps Cove, Parkers Cove, Young Cove, Hampton. Approximately 0.02% of Area 4 was surveyed.

These area strata were defined by 4 mile wide bands extending from 2 to 16 miles from shore landmarks (e.g., Gulliver's Head) except for the Digby Gut band which was 6 miles wide. Each band was then subdivided into one mile interval areas (e.g., two miles off Delaps Cove). Total area (square miles) was calculated for each designated area (e.g., Digby Gut) and for each area between the designated bands (e.g., between Digby Gut and Delaps Cove) and the percentage of the total area was calculated. This percentage was then used to calculate the number of stations per designated area. Further to this, in each area stratum the number of stations less than, and greater than 6 miles was calculated based on the area of each stratum. Finally, the number of stations and the station location within a one mile band for each stratum were selected randomly. The total number of tows by area are shown below:

Allocation of Survey Stations by Area Stratum

DESIGNATED AREA	LENGTH x WIDTH	SQ. MI.	%TOTAL	# STN	<6	>6 miles
CORE						
G HEAD	15MI X 4MI	60	10.5	11	4	7
BETWEEN G HEAD & GUT	15MI X 3MI	45	7.9	8	3	5
DIGBY GUT	15MI X 6MI	90	15.8	16	5	11
BETWEEN GUT & DELAPS	15MI X 3MI	45	7.9	8	3	5
DELAPS COVE	15MI X 4MI	60	10.5	10	4	6
BELOW						
BETWEEN CV AND GH	15MI X 2MI	30	5.3	5	2	3
CENTREVILLE	15MI X 4MI	60	10.5	11	4	7
ABOVE						
PARKERS COVE	15MI X 4MI	60	10.5	11	4	7
YOUNG COVE	15MI X 4MI	60	10.5	10	4	6
HAMPTON	15MI X 4MI	60	10.5	10	4	6
TOTAL		570	100.0	100	37	63

The location of the 1996 tows are shown in figure 16. At each station the shell height and meat weight of each animal was recorded. The shells were returned to the laboratory where they were later aged. Bottom temperature was recorded for each tow using a VEMCO digital sub-surface temperature recorder (Vemco Ltd., Shad Bay, N.S.). This data was given to the Marine Environmental Data Service (MEDS through Dr. K. Drinkwater, DFO) and is not presented here. Note that the portion of Area 4 form 0 to 2 miles is not surveyed although commercial activity does take place there.

The total number of scallops caught in the stock assessment surveys from 1989 to 1996 are shown in figure 12. The changes in the range of the Y-axis from 10,000 in 1989 to 500 in 1996 tell the story of this stock. The lack of significant recruitment until 1994 is seen in this figure. The 1993 year-class (age 2 in 1995) can be tracked easily to the age 3 scallops in the 1996 survey. The same figure shows the shell height distribution over time for the Outside Zone (6 to 16 miles) which is partially in Area 4 (6-8 miles) and partially in Area 1 (8-16 miles). The Area 4 CPUE of the research vessel survey was 8.07 kg/h based on the weight of animals > 80 mm from unlined drags and prorated to 7 gang gear and 8 minute tows.

The average number of scallops-at-age caught in the 1986-1996 stock surveys are given in Table 1. The 1996 catch-at-age was determined by two methods: 1) using three depth defined age curves, and 2) directly from the raw data, as all scallops in the survey were aged. In the first analysis, the three depth related growth curves used in previous assessments were used to estimate the age of the animal from the shell height of animals whose age was not determined (Robert et al. 1990). The way that these growth curves were used in the past has not been clearly documented. The computer program (developed by Dr. G. Jamieson, DFO, 1978) subtracts 1.0 from the value of $t_{(0)}$ given below, effectively shifting the growth curve over 1 year to the left (i.e., a 3 year old becomes a 2 year old). The value of the height-at-age produced from this shifted growth curve then becomes the maximum height for that age. The animals within a 5 mm shell height bin are proportioned above and below this age group cut off according to where it lies within the 5 mm bin (e.g., a bin of 45-49 mm shell height with an age 2 cut off of 46 mm would proportion 1/5 of the animals in that bin to age 2 and 4/5 to age 3). Although we don't know the reasoning for this protocol, one rationale for this method would be that the old growth curves were based on ring sizes which were laid down in the spring. Assuming very little shell growth takes place between January and when the ring is laid down, the ring size is a maximum for the previous age's height. Data produced from the growth curves is compared with earlier data produced with the same curves:

Von Bertalanffy Growth Curves Used to Estimate Numbers-at-Age (Robert et al. 1990)

Depth	L_{inf}	k	$t_{(0)}$
< 85 m	143.210	0.2221	1.3800
86-105 m	133.763	0.2414	1.4011
> 105 m	125.989	0.2610	1.4469

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 1996. The average number of scallops per standard tow in the Inside Zone has remained quite constant since 1992 with a slightly increasing trend showing from 1994 to 1996. The average numbers in

Area 4 are slightly higher (Table 1 and below) however the same age groups, 3 and 4, are numerically dominant in both areas. On the Outside beds which form a part of Area 1 and are not directly dealt with in this document, there is little change from 1995 with a slight downward trend in the average number per standard tow and there are few pre-recruit scallops. The total average numbers are quite similar in both Zones.

The use of the growth curves in estimating the mean numbers-at-age was contrasted with the mean numbers-at-age determined from the actual ages of the shells (Table 2) for the Inside Zone, the Outside Zone and for Area 4. In figure 13 the calculated numbers-at-age are plotted with the observed numbers-at-age. In all areas the numbers of 2 and 3 year old scallops are underestimated by the growth curve method. In the Inside Zone and Area 4 the scallops over the age of 4 are slightly overestimated by the growth curve method, with the exception of the 5 year old scallops which are underestimated. In both cases the age 9 and older animals are closely represented by the growth curve method. In the Outside Zone, the age 4 to 8 scallops are overestimated by the growth curves while the age 9 and over are underestimated. This discrepancy between the calculations appears to relate to the representativeness of the growth curves used, but will be compounded by the slicing method described above.

The spatial distribution of scallops, determined from the biomass surveys, was contoured using the ACON software package with data derived from Delaunay triangles and inverse distance weighted interpolation (see Area 2: Southwest Bank above for details). The distribution of animals is shown in figure 14. The greatest concentration of scallops in Area 4 is in the area of Centreville and Gulliver's Head (Fig. 14). This is the area where the pre-recruits are concentrated, although there were concentrations of 100 Age 1 to 4 animals per standard tow and greater off Digby Gut as well. The distribution of recruited scallops is mapped into two age groups, 5 to 7 year olds and 8+. There are fewer scallops per tow in the Ages 5 to 7 group compared with the pre-recruits (Fig. 15), with the largest concentrations being 50 to 100 animals per standard tow off Centreville and Delaps Cove. Figure 14, age 8+ scallops, represents the remnants of the 1985 and 1986 year-classes (which accounted for the high landings in the early 1990s). In 1995, the greatest abundance of these older scallops was seen in the area off Hampton, in the Inside Zone. That area still had high concentrations of the old scallops in the 1996 survey, however, the greatest concentrations were in the Outside Zone off Centreville. In the new Area 4, the oldest animals (8+) are found in the Centreville Stratum and off Delaps-Parkers Cove (Fig. 15).

In 1995 the dominant age group was Age 2. These scallops were located in the portion of Area 4 which was closed to fishing. This pre-recruit year-class was predominant in the Inside Zone off Gulliver's Head and Centreville, but extended upstream to Delaps Cove (Kenchington et al. 1996). These scallops were still present in the 1996 survey, with the Age 3 animals being the largest age group (Table 2, Fig. 16). There were some Age 2 scallops in the 1996 survey but these were concentrated off Centreville in the Closed Area (Fig. 16). As in 1995, there is little recruitment above Delaps Cove.

Figure 17 shows the number of live scallops caught, versus the number of clappers (dead paired shells), by area stratum for the Inside and Outside fishing zones. The large numbers of small scallops seen in the inside area off Centreville, Gulliver's Head, and Digby during the 1995 survey are still evident. The large numbers of clappers amongst the pre-recruit sizes in the 1995 survey have disappeared with the greatest concentration of clappers at the 100 mm shell height and greater size off Centreville in both Zones. There is a small new year class evident in the Centreville Inside Zone stratum, and in the Digby and Delaps Outside Zone strata.

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 and calculated as for Area 3 above:

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
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
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

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.

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. Three contrasting results are given below for further understanding of the method.

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

Age 1	Str. Total	Str. Mean	s.e. (mean)	Allocation	Strata	Total	Max. Efficiency
	163,740	0.85	0.54	15.80	1.40	17.19	76.95%

Mean Number of Age 1 Scallops per Stratum

Stratum Name	Number of Tows	Proportion of Total Area in Stratum	Mean	Std. Dev.
Centreville	7	0.13333	4.44	10.48
Centreville- Gulliver's	3	0.06667	0.00	0.00
Gulliver's Head	6	0.13333	0.00	0.00
Gulliver's - Digby	5	0.10000	0.60	1.34
Digby Gut	6	0.20000	0.16	0.39
Digby - Delaps Cove	4	0.10000	0.00	0.00
Delaps Cove	7	0.13333	1.22	2.21
Parkers Cove	6	0.13333	0.00	0.00

Analysis of the Age 1 scallops is presented above. The allocation effect for Age 1 scallops is large because this age group largely appeared in strata that had large sample sizes, with the Centreville stratum having the largest standard deviation and sample size (7). The stratum with the second largest standard deviation also received seven sets. In this case, the strata effect contributed little to the gain in precision and all gains were do to the sample to stratum allocation. To gain the theoretical maximum efficiency for this age group of 76.95 percent all the sampling would be restricted to just four strata with most of the samples in the Centreville and Delaps Cove strata. Such a reallocation would increase the efficiency by 60 percent over present levels (Maximum Efficiency - Total).

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

Age 6	Str. Total	Str. Mean	s.e. (mean)	Allocation	Strata	Total	Max. Efficiency
	1,903,209	9.84	1.19	4.06	27.35	31.40	38.35

Mean Number of Age 6 Scallops per Stratum

Stratum Name	Number of Tows	Proportion of Total Area in Stratum	Mean	Std. Dev.
Centreville	7	0.13333	23.25	14.46
Centreville- Gulliver's	3	0.06667	14.93	7.96
Gulliver's Head	6	0.13333	11.36	6.85
Gulliver's - Digby	5	0.10000	7.41	7.46
Digby Gut	6	0.20000	6.57	5.03
Digby - Delaps Cove	4	0.10000	7.12	8.47
Delaps Cove	7	0.13333	6.81	7.77
Parkers Cove	6	0.13333	4.18	3.51

The Age 6 scallops above show a "mediocre" result for the allocation effect, mainly due to the small sample sizes associated with the second and third largest standard deviations in the Digby-Delaps Cove and Centreville-Gulliver's Head strata, respectively. The maximum efficiency expected here is 38.35 percent which is close to that observed. Reallocating samples to strata would only improve the situation by 7 percent. The strata component is high indicating that there is information contained in the strata boundaries about the distribution of Age 6 scallops.

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

Age 9	Str. Total	Str. Mean	s.e. (mean)	Allocation	Strata	Total	Max. Efficiency
	916,680	4.74	0.61	-10.73	17.43	6.69	28.91

Mean Number of Age 9 Scallops per Stratum

Stratum Name	Number of Tows	Proportion of Total Area in Stratum	Mean	Std. Dev.
Centreville	7	0.13333	6.58	3.19
Centreville- Gulliver's	3	0.06667	12.31	6.68
Gulliver's Head	6	0.13333	4.85	1.90
Gulliver's - Digby	5	0.10000	2.54	2.36
Digby Gut	6	0.20000	4.07	5.20
Digby - Delaps Cove	4	0.10000	2.26	2.81
Delaps Cove	7	0.13333	4.25	4.01
Parkers Cove	6	0.13333	4.01	2.32

The negative allocation effect for this Age 9 group was mainly due to the large standard deviation in the Centreville-Gulliver's stratum which received the smallest sample sizes. More sampling is required in these strata for this age group. The theoretical maximum efficiency is 28.91 percent. That is an increase of about 21 percent over present levels all due to the optimum allocation of sets to strata. Note that the relatively large strata effect was reduced by the poor allocation scheme.

All the theoretical maximum efficiency calculations are based on "all things being equal" considerations. That is, assuming that you were only interested in improving the efficiency of your Age 4 estimate (at the possible expense of the precision of the other ages) and assuming that the observed standard deviations were reasonable estimates of the population standard deviations, then we could come up with a new allocation scheme that would improve the precision. However, as with all field surveys, we are interested in more than one age group and/or species and compromises on allocation schemes must be made.

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. In fact for these age groupings the current allocation of samples to strata is detrimental to obtaining precise estimates of the mean or total abundance. In the combined ages analysis, the strata effect was always positive and in the case of age groupings 5–7 and older, there appears to be information in the strata boundaries associated with the spatial distribution of the scallops that contributed to increasing the precision.

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

Ages	Str. Total	Str. Mean	SE (Mean)	Efficiency Allocation	Efficiency Strata	Efficiency 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

To investigate for stability over time we used the observed variances to estimate the percentage of the total sets that would be assigned to each stratum in an optimal allocation for the years 1993 to 1996. The first two years of the series were dropped because some strata were missed or only received one observation. These calculations were made for ages 1 to 4, ages 5+ and all ages (Fig. 18).

The main pattern for ages 1 to 4 was that the Delaps and Parkers Cove strata were consistently low variability strata and could be assigned small samples sizes based on historical patterns. However, the other strata all exhibited highly variable percentages of samples assigned making it difficult to use historical patterns to assign stations in the future. For the most part the patterns for ages 5+ were more stable than for ages 1 to 4, with the possible exceptions of the Centreville-Gulliver's Head and Digby-Delaps Cove strata. It appears that equal sample sizes for the Centreville, Gulliver's Head, Digby, Delaps and Parkers Cove strata (Fig. 16) may be an appropriate allocation with smaller sample sizes being assigned to the remaining strata. The pattern for all ages is a combination of those of the above two age groups and mainly inherits the variability noted for the younger age group. This variability makes it difficult to come up with a compromise allocation for all age groups.

The second way of allocating samples in proportion to the variance is to adaptively allocate during the survey based on the observed variances. These methods are discussed in Thompson and Seber (1996) and may bear some further investigation in a survey situation.

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 "Str. Total" column above and in the table below. All ages were derived from the new stratum specific growth curves (see below) applied to length frequencies prorated to the set level.

Number of Scallops by Age (1991-1996) Estimated from the Research Vessel Surveys

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

Confidence intervals at the 95% level (bootstrap, percentile limits using 2000 reps, Smith 1997) were calculated for the total abundance and the fishable abundance (Ages 5+). The total numbers of scallops in Area 4 was estimated as 26,266,805 with the lower and upper bounds at 18,335,749 and 32,551,758. Of the approximately 26 million scallops in this area, only 11,568,832 are age 5 and older (lower limit 9,510,265; upper limit 13,807,968).

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. While total population estimates have increased since 1994, the largest portion of the numbers in 1996 consists of ages 2 to 4. The 1993 year-class is the largest seen at age 3 to date in this short survey series and this year-class has been very large since it first appeared at Age 1 in 1994. The estimated numbers at age 5+ in 1996 remains below the levels observed for this age group in 1991 to 1994 and older age groups are at the lowest observed since 1991.

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 Year-Class

Age	Centre.	Centre.-Gull.	Gull.	Gull.-Digby	Digby	Digby-Delaps	Delaps	Parkers
1	114,457	0	0	11,605	6185	0	31,493	0
2	467,670	404,697	346,349	37,739	39,339	15,386	240,404	12,894
3	768,174	**1,176,828**	**4,261,043**	325,757	**1,863,489**	**1,109,639**	380,679	12,894
4	430,773	222,840	586,848	325,936	861,847	356,763	236,815	49,428
5	592,357	352,281	513,458	205,974	558,595	522,732	495,749	114,024
6	599,480	192,457	292,955	143,217	254,040	137,670	175,710	107,681
7	410,697	231,756	285,164	17,068	174,025	133,089	144,399	49,016
8	338,260	219,873	202,928	32,340	113,100	56,160	138,140	62,437
9	169,655	158,751	125,159	49,033	157,482	43,718	109,475	103,406
10	514,669	208,236	301,779	214,912	649,333	78,804	338,652	478,937

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. The meat weights-at-age are presented below and the differences between the more productive grounds off of Digby and the less productive grounds south of Digby are evident.

Estimated Meat Weight-at-Age for each of the Strata in the Area 4 1996 June Survey

Age	Centre.	Centre-Gull.	Gull.	Gull.-Digby	Digby	Digby-Delaps	Delaps	Parkers
1	0.02	0.01	0.06	0.15	0.26	0.03	0.00	0.04
2	0.85	0.55	1.12	1.31	1.73	1.25	0.71	1.04
3	2.69	2.19	3.49	3.67	4.37	4.26	3.98	3.54
4	4.84	4.52	6.61	6.85	7.69	8.23	8.43	6.98
5	6.85	6.99	9.92	10.43	11.20	12.36	12.70	10.73
6	8.52	9.28	13.05	14.05	14.57	16.16	16.23	14.34
7	9.82	11.23	15.82	17.48	17.63	19.44	18.91	17.59
8	10.79	12.81	18.17	20.60	20.29	22.14	20.85	20.37
9	11.51	14.05	20.09	23.35	22.54	24.30	22.22	22.68
10 +	12.02	15.00	21.64	25.71	24.41	25.99	23.17	24.55

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

The biomass of Ages 5+ was estimated as 172 mt with the lower and upper bounds estimated by the bootstrap method as (95%): 142 and 208 kg. The total biomass estimates for the population with bootstrap confidence intervals was 230 mt with lower and upper bounds of 189 and 278 mt, respectively.

Population Abundance and Biomass Estimates

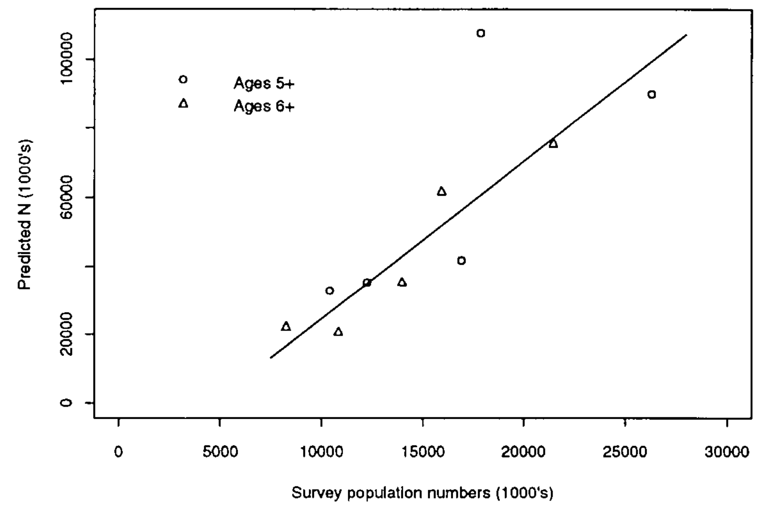
The total mortality estimates described above were used along with setting M=0.1 to estimate the total number of animals in the population based on the commercial catch-at-age, $\hat{N}$, as per the method described for Area 3 (Brier Island/Lurcher Shoal). Catches-at-age from the commercial catch are presented below.

Numbers-at-Age Estimated for the Commercial Catch. Numbers are in 1000's

Ages	1991	1992	1993	1994	1995
1	0	0	0	0	0
2	0	0	1	0	0
3	65	133	174	178	59
4	1134	1243	1180	1432	278
5	**2943**	2577	2196	2253	703
6	3312	**2384**	2060	1586	727
7	3196	1587	**1553**	1060	503
8	3256	1006	1073	**1107**	278
9	2692	787	701	656	**246**
10+	2814	5907	4128	2001	1585
Total	29412	15624	13066	10273	4379
4+	29347	15491	12891	10095	4320
5+	28213	14248	11711	8663	4042
6+	25270	11671	9515	6410	3339

The resultant estimates of $\hat{N}$ are compared with survey catches-at-age for ages 5+ and 6+ in the figure below. These estimates are quite stable and suggest a linear relationship between population and survey numbers for these age groups in the limited range that has been observed.

Regression of Survey Numbers Against Predicted Numbers



The regression of the estimated population size using the catch equation and total mortality estimates from the surveys with survey population numbers from the Area 4 survey is illustrated above. The solid line is for the regression equation for the 6+ age group. The linear regression of $\hat{N}$ on survey numbers results in an equation with a non-zero intercept. Therefore we chose to use averages of the ratio of $\hat{N}$ to survey numbers to estimate the scaling factor for converting survey to population (i.e., $1/q$). The individual ratios and their means are presented in the table below:

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

The estimates of average $1/q$ were then used to convert total meat weight from the survey to population estimates. Meat weights from the survey were estimated using the stratum specific growth curves to estimate average weight-at-age as above. While growth curves are derived from observations during the 1996 survey they were used to estimate weight-at-age for all years. The resultant population meat weights-at-age 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

These estimates of q were evaluated by comparing the exploitation rates derived from the total mortality estimates from the survey and using the ratio of meat weight landed to estimated meat weight in the population using the $1/q$ estimates. The results are shown in the table below:

Year	Ages 5+		Ages 6+	
	Using Z estimates	Using $1/q$ estimates	Using Z estimates	Using $1/q$ estimates
1991	31.5	43.0	33.4	56.0
1992	13.3	30.0	18.8	36.0
1993	28.2	25.0	26.8	30.0
1994	24.7	23.0	30.8	25.0
1995	12.4	15.0	14.9	19.0

The results are similar to one another with the $1/q$ exploitation rates being higher than the Z calculated exploitation rates in 1996 and in all years except 1994. These results give some confidence to our estimates of q and therefore the population estimates were used to generate TAC advice under different exploitation scenarios (see below).

Ageing Data

Scallops were collected for ageing during the June 1996 research vessel survey. All animals landed were ultimately aged. In these analyses only the age of the animal and the shell height were recorded, as for Area 3. As the scallops were collected in June, the majority of that year's shell growth will have been laid down (> 80%), therefore these curves are not representative of the chronological age of the animals, but are more applicable to converting June survey shell height frequencies into numbers-at-age. A total of 3290 animals were aged. These growth curves reflect the height distribution of the population at the time of sampling.

Twelve von Bertalanffy functions were used to describe the growth of the scallops in Area 4, calculated as in Area 2.

An analysis of the residual sums of squares was used to determine if fitting multiple growth curves to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Many combinations of curves were evaluated based on divisions of the data set into two depth intervals and eight area strata as defined above. The depth range of the survey stations in Area 4 was 66 to 111 m, and so two depth strata were constructed, < 88 m and > 88 m. There were no data for the Parkers Cove and Digby-Delaps Cove strata for the > 88 m stratum, nor were there data for the Centreville and Centreville-Gulliver's Head strata for the < 88m stratum. In all area strata where two depth stratum were present, the use of two curves was a significant improvement over the use of a single area stratum curve. The use of multiple curves was a significant improvement over using a single depth stratum curve or a combined data curve for the entire area. Comparisons of area strata pairs were not evaluated for possible reduction in the number of curves. The resultant parameters of the von Bertalanffy models are listed below:

Area 4 Subareas	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
Centreville	716	116.241 (0.653)	0.36438 (0.00967)	0.7013 (0.0511)	0.89
Centreville-Gulliver's	326	121.259 (0.016)	0.31999 (0.01609)	0.7531 (0.0837)	0.93
Gulliver's Head < 88m	89	133.751 (1.582)	0.27494 (0.01629)	0.5176 (0.1362)	0.97
Gulliver's Head > 88m	658	124.478 (1.482)	0.31347 (0.01319)	0.7532 (0.0641)	0.92
Gulliver's-Digby < 88m	96	145.801 (2.188)	0.22222 (0.01367)	0.2477 (0.1584)	0.96
Gulliver's-Digby > 88m	88	159.132 (17.943)	0.15725 (0.03818)	-0.1795 (0.3449)	0.92
Digby Gut < 88m	225	137.596 (1.9793)	0.24765 (0.01693)	0.1238 (0.1740)	0.93
Digby Gut > 88m	232	131.478 (2.481)	0.25506 (0.01726)	0.3905 (0.1287)	0.93
Digby-Delaps Cove	231	138.142 (2.558)	0.29450 (0.02003)	0.7049 (0.1267)	0.90
Delaps Cove < 88m	196	127.764 (1.042)	0.40038 (0.01849)	1.1757 (0.0910)	0.93
Delaps Cove > 88m	78	131.070 (2.004)	0.32337 (0.00622)	0.2328 (0.0509)	0.88
Parkers Cove	91	139.192 (1.998)	0.26903 (0.02467)	0.6192 (0.2595)	0.92

For some purposes a general growth curve is of more use than a group of specific growth curves (e.g., in calculating a yield per recruit model for the whole of Area 4). The growth curve coefficients for Area 4 are given below:

Von Bertalanffy Growth Coefficients for Area 4

Area 4	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
	3291	127.2317 (0.4533)	0.3104 (0.0049)	0.7214 (0.0302)	0.91

Meat Weight-Shell Height Regressions

Samples were collected (see Ageing Data above) for calculating the relationship between shell height and meat weight. The wet weight of the adductor was recorded to 0.01 g. Data were used to calculate linear regressions, by area, of the ln (meat weight) on ln (shell height).

The function is expressed as ln (meat weight)=b*ln (shell height) +c, where, b is the slope of the line, and c is the intercept. Functions were fit using program REGRESSION of the SPSS Release 4.0 software package (SPSS Inc. 1990) as for Area 2 above. The regression model was not forced to pass through the origin. Each regression model was significant, that is, the slope was significantly different from 0. An analysis of the residual sums of squares was used to determine if fitting multiple regressions to the same set of data was a significant improvement over using a single curve (Chen et al. 1992). Combinations of functions were evaluated to determine whether one growth curve per subarea or per depth could be used or whether different subarea/depth functions were required. The use of 12 functions was a significant improvement over the use of a single function. The resultant parameters of the regression models are listed below:

Area	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
Centreville	716	2.812 (0.033)	-10.790 (0.147)	0.92	8.7g
Centreville-Gulliver's	326	3.130 (0.039)	-12.143 (0.172)	0.95	9.7g
Gulliver's Head < 88m	89	2.909 (0.062)	-10.945 (0.289)	0.96	11.6g
Gulliver's Head > 88m	658	2.972 (0.028)	-11.357 (0.122)	0.94	10.2g
Gulliver's-Digby < 88m	96	2.950 (0.042)	-11.092 (0.192)	0.98	12.1g
Gulliver's-Digby > 88m	88	3.176 (0.079)	-12.193 (0.341)	0.95	11.4g
Digby Gut < 88m	225	2.946 (0.042)	-11.045 (0.191)	0.96	12.5g
Digby Gut > 88m	232	3.179 (0.043)	-12.165 (0.185)	0.96	11.9g
Digby-Delaps Cove	231	3.164 (0.043)	-12.010 (0.195)	0.96	12.9g
Delaps Cove < 88m	196	2.808 (0.070)	-10.393 (0.325)	0.89	12.7g
Delaps Cove > 88m	78	3.181 (0.046)	-12.092 (0.207)	0.98	12.8g
Parkers Cove	91	2.913 (0.083)	-10.934 (0.395)	0.93	12.0g

The meat weight per 100 mm shell height value for each area/depth stratum shows an increase from Centreville to Digby-Delaps with a slight decrease toward Parkers Cove. This is consistent with observations of meat yield in these strata. Within area strata, the animals in the greater than or equal to 88 m strata are larger than those in the deeper strata.

The meat weight-shell height regression parameters for the whole of Area 4 are given below:

Area 4	N	b (s.e.)	intercept (s.e.)	Adjusted r^2	Meat Weight 100 mm Shell
	3291	3.046 (0.014)	-11.654 (0.064)	0.93	10.7g

Statistics for Meat Weight, Shell Height and Age by Area/Depth Stratum

Variable	Mean	Std Dev	Minimum	Maximum	N	Meat Ct(Mean)
Centreville						
WEIGHT	8.14	4.32	.10	22.20	717	62.5
HEIGHT	93.18	21.07	18	129	717	
AGE	6.49	3.12	1	17	717	
Centreville-Gulliver's						
WEIGHT	7.32	5.95	.20	30.50	326	71.4
HEIGHT	83.40	25.35	31	131	326	
AGE	5.46	3.01	2	15	326	
Gulliver's Head < 88m						
WEIGHT	14.93	8.05	.80	36.60	89	33.5
HEIGHT	103.99	24.04	39	140	89	
AGE	7.40	3.52	2	15	89	
Gulliver's Head > 88m						
WEIGHT	5.40	4.54	.20	24.30	658	92.6
HEIGHT	75.17	19.44	29	126	658	
AGE	4.11	1.92	2	13	658	
Gulliver's-Digby < 88m						
WEIGHT	15.76	10.15	.10	44.40	96	31.6
HEIGHT	103.61	25.79	22	145	96	
AGE	6.97	3.58	1	15	96	

Statistics for Meat Weight, Shell Height and Age by Area/Depth Stratum (cont'd)

Gulliver's-Digby > 88m						
WEIGHT	5.86	4.58	1.10	25.60	88	85.3
HEIGHT	77.03	16.10	48	124	88	
AGE	4.16	1.36	2	10	88	
Digby Gut < 88m						
WEIGHT	13.74	8.80	1.70	38.50	225	36.5
HEIGHT	98.39	22.64	59	147	225	
AGE	6.18	3.25	3	15	225	
Digby Gut > 88m						
WEIGHT	6.66	6.00	.30	28.20	232	75.8
HEIGHT	77.95	18.81	30	129	232	
AGE	4.33	2.16	2	14	232	
Digby-Delaps Cove						
WEIGHT	11.28	7.82	2.10	39.60	231	44.3
HEIGHT	90.91	20.06	56	144	231	
AGE	4.81	2.11	2	14	231	
Delaps Cove < 88m						
WEIGHT	15.56	7.29	.10	33.50	196	32.0
HEIGHT	103.77	21.03	24	160	196	
AGE	6.65	2.97	2	14	196	
Delaps Cove > 88m						
WEIGHT	13.04	9.16	.40	35.80	78	38.5
HEIGHT	93.69	24.52	32	141	78	
AGE	5.73	2.98	2	14	78	
Parkers Cove						
WEIGHT	20.95	9.84	.70	39.40	91	23.9
HEIGHT	116.82	22.47	31	149	91	
AGE	9.21	3.78	2	15	91	

The mean, standard deviation and minimum and maximum values for meat weight, shell height and age are given above for each area depth stratum in Area 4. Each strata has a wide range of age groups, generally 2 to 14, with meat weights ranging from 0.1 to 44.6 g. There is a contrast between the average age of the animals in Parkers Cove and the rest. This area has scallops with an average age of 9 years.

The meat count associated with the average weight of the meat in the catch is also shown below for each area/depth stratum. The meat count ranged from 23.9 meats per 500 g off Parkers Cove to 92.6 meats per 500 g in the closed area off Gulliver's Head in water greater than 88 m. The count is higher where the small scallops are found.

1996-1997 Fishing Activity

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 from Digby Gut to Port Lorne landed 153936 lb (69824.9 kg or 69.8 metric tons). The log data shows catch per unit effort (CPUE) was 8.87±3.24 kg/hour with a minimum of 2.56 kg/h and a maximum of 18.8 kg/h. The log records show that 945 "days" were fished (final figure). Of this, 89% was landed in Area 4 (see Fig. 19 for fishing locations), i.e., 137003 lb, 62144.2 kg or 62.1 metric tons. The log data shows catch per unit effort (CPUE) was 8.89±3.25 kg/hour with a minimum of 2.56 kg/h and a maximum of 18.8 kg/h. The log records show that 910 "days" were fished in Area 4 (final figure). In addition, 1996 landings from the 6 to 8 mile portion of the Area are estimated at 9.1 mt.

Therefore, total removals from Area 4 are approximately 71.2 mt. This is down from the 94.8 mt harvested in 1995:

Landings Area 4 (metric tons meats)

Year	1991	1992	1993	1994	1995	1996
Area 4	678.7	318.4	244.2	162.7	94.8	71.2*

* including preliminary landings from 6-8 miles of 9.1 mt

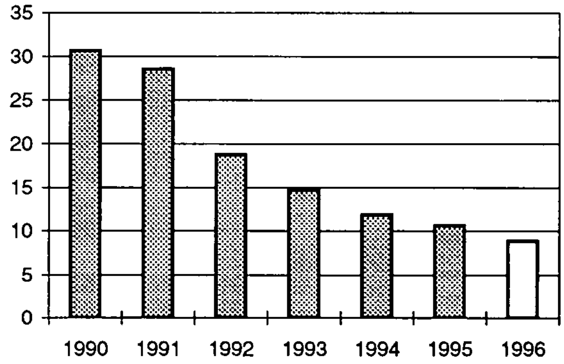
Catch per unit effort was the lowest on record for this Area in 1996. The summary statistics for CPUE from 1990 to 1996 are shown below:

CPUE kg/h for the Inside Zone 1990-1996

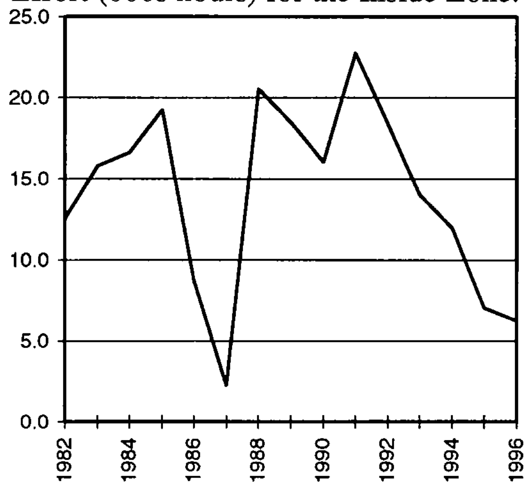
Year		Mean	Std. Dev.	Min.	Max.	N
Inside Zone						
	1990	30.66	11.40	5.62	71.27	266
	1991	28.55	14.85	6.66	125.62	515
	1992	18.75	7.59	5.61	69.44	625
	1993	14.73	5.47	3.53	42.15	361
	1994	11.84	4.54	4.46	64.23	394
	1995	10.60	4.62	4.35	24.91	205
Area 4	1996	8.89	3.25	2.56	18.80	910

The maximum CPUE values have fallen from 1994 to 1996, bringing the standard deviation down as well. These changes in the CPUE summary statistics reflect the low biomass of scallops on the Digby beds, as supported by research vessel survey information (see above). The mean CPUE for Area 4 from the research vessel survey is 8.07 kg/h (see above) which is comparable to the commercial mean CPUE for this area (8.89 kg/h). Historical data on CPUE for the Inside Zone and for the new Area 4 is illustrated below. The new Area 4 data is not directly comparable to the Inside Zone area and so back calculations will be required to convert the old data into CPUE for Area 4. Effort fell only slightly in 1996 despite closure of a large portion of Area 4 for most of the year.

CPUE kg/hour (Open box Area 4, dockside monitoring data; Shaded boxes Inside Zone, log data)



Effort (000s hours) for the Inside Zone.



From January 1, 1997 to March 15, 1997 a further 0.687 mt have been removed illegally from Area 4 according to the dockside monitoring statistics.

Port Sampling of Commercial Catch

Port sampling of the commercial catch was carried out as for Area 3. A total of 2962 animals were processed and the locations of the port samples are shown in figure 14. The port sampling data for the Inside and Outside Fishing Zones from 1991 to 1995 are given in Kenchington et al. (1996). The port sampling data for the new Area 4 for the years 1995 to 1996 are given below:

Area 4 (Digby) Meat Weight Statistics for the Full Bay Licence Holders by Month and Year Calculated from Port Samples of the Commercial Catch

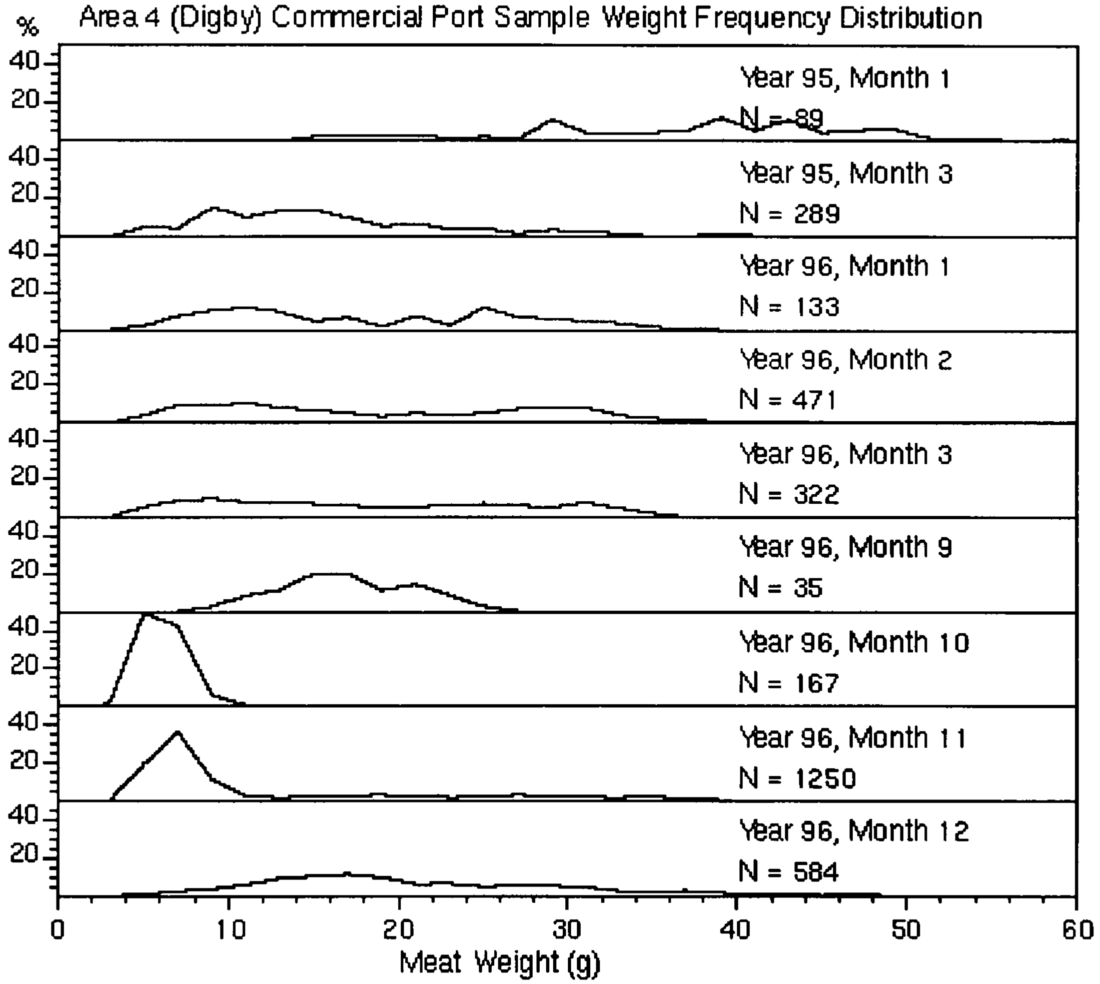
Year	Month	Meat weight (g)				Sample size	Meat count
		Mean	Min	Max	s.d.	(n meats)	per 500 g
1995	January	36.73	15.10	63.50	10.37	89	13.6
1995	March	15.81	5.00	41.40	7.23	289	31.6
1996	January	18.37	4.60	37.00	8.53	133	27.2
1996	February	19.01	4.40	43.80	9.42	471	26.3
1996	March	18.35	4.30	38.70	8.81	322	27.2
1996	Sept.	16.95	8.00	25.40	3.86	35	29.5
1996	October	6.10	3.70	12.30	1.28	167	82.0
1996	Nov.	12.41	4.00	49.70	9.57	1250	40.3
1996	Dec.	21.06	5.50	46.80	8.73	584	23.7

The meat count was meet in all but one of the samples (see October 1996), where large numbers of small scallops were landed. This sample was from a single vessel and showed a meat count of 82/500 g. In general, most of the meat counts were below 30/500 g and a wide distribution of scallop sizes were landed. The two examples of the high number of small scallops landed occurred when a portion of the former Inside Zone was open to fishing in the fall (see above). This type of fishing would also have occurred if the rest of the Inside Zone were open that year, as the major settlement of small scallops was in the area which was not opened to fishing in 1996.

Estimates of the weight of the commercial catch-by-age were calculated using the port sampling data. Meat weights were not available for the 1996 fishery.

Meat Weight (mt) Landed by Commercial Fishery for Area 4 (< 8 miles) by Age Group

Ages	1991	1992	1993	1994	1995	1996
All	649	315	249	172	89	69
5+:	640	305	240	160	87	
6+:	607	276	215	135	79	


Area 4 (Digby) Commercial Port Sample Weight Frequency Distribution
%
Year 95, Month 1
N = 89
Year 95, Month 3
N = 289
Year 96, Month 1
N = 133
Year 96, Month 2
N = 471
Year 96, Month 3
N = 322
Year 96, Month 9
N = 35
Year 96, Month 10
N = 167
Year 96, Month 11
N = 1250
Year 96, Month 12
N = 584
Meat Weight (g)

Area 5: Annapolis Basin

Description of the Area

All area known as Annapolis Basin south of a line joining the following points: 4442 N 6545.2 W to 4441.5 N 6546.8 W (Fig. 1). The Annapolis Basin scallops are a separate stock from the scallops in Area 4, as evidenced by differing recruitment patterns and tagging data.

1997 Interim Management Plan

TAC: 25 mt
Meat Count: 30/500 g (subsequently changed to 40/500 g)
Minimum Meat Weight: 15 g (voluntary)
Shell Height Minimum: 104 mm
Season: Closed February 1, 1997 to December 31, 1997

Fishing History of the Area

Scallops were harvested from the Annapolis Basin as early as 1600 and in the 1800's the existence of extensive beds of scallops were known (see review by Kenchington and Lundy 1994). The commercial fishery, as we know it today, began in 1920. The importance of this fishery lies in the timing of the harvesting rather than the total landed catch. As of June 11, 1975, scallop harvesting could only occur in the Annapolis Basin from December 1 to April 30, and due to a conflict with the lobster fishery a restraining order further closed the Basin to scallop fishing during December when lobster traps are in place. While the total landed catch from this Area has not been large when compared to the total catch from all Areas, during January and February landings from the Basin may represent 40% of the total scallop landings for those months.

Research Vessel Stock Surveys

A depth stratified stock survey of the Annapolis Basin was conducted in 1993 (Kenchington and Lundy 1994). This survey showed that most of the scallops were found in the 13.6-38.6 m (60-125 ft) depth stratum. The shell height frequency distribution showed a multimodal distribution indicating that several year-classes were present. There were also a healthy number of smaller, pre-recruit scallops 25-40 mm in shell height, and of older animals. The oldest recorded scallops in the survey were 11 years and these were found in the shallowest depth stratum. The frequency distribution of the population suggested that the population is self-sustaining and that regular recruitment has occurred at least over the past decade.

Most of the scallops are concentrated south and southeast of Victoria Beach in the areas reported by the fishermen to be the most lucrative grounds (Kenchington and Lundy 1994). The same general spatial distribution is shared by the three age groupings, that is, there does not appear to be a separate area favouring juvenile scallops. Some tows did not catch any scallops, particularly those toward the more easterly reaches of the Basin. The bottom type in the area favoured by the scallops is predominantly rock and gravel. There was very little sand bottom in the survey area. The mud bottom dominates the shallower water.

The bottom temperature profile identified a warm water temperature strata in the deeper water surrounding the major scallop concentrations. Examination of the raw data shows that temperature did not vary by more than 1°C with tidal phase in any one stratum. In 1996, the temperature regime was recorded hourly at four locations within the Basin on the Hillsburn Basin Aquaculture lease site using Vemco temperature probes. This site is in shallow water away from the commercial beds with a low tide depth of 7-8 m and high tide depth at 15-16 m. The probes showed a maximum temperature of 14.9°C (September 26, 1996) and a minimum of -1°C (January 6, 1996). These data were given to the Marine Environmental Data Service (MEDS through Dr. K. Drinkwater, DFO) and are not presented here.

A number of small lobster (< 60 mm carapace length), and flounder (< 90 mm) were observed in the by-catch in areas deeper than 13.5 m. Other invertebrates noted were crabs, sea cucumbers, sea urchins, whelks, starfish, shrimp, clams and mussels.

In the summer of 1996 a number of tows were made to collect small scallops for experiments with the Hillsburn Basin Scallop Group. These identified a large number of pre-recruit scallops (2 years old) on the beds.

Ageing Data

Scallops were aged from the 1993 stock survey (Kenchington and Lundy 1994). The parameters of the von Bertalannfy equation are:

Von Bertalanffy Growth Coefficients for Area 5

Area 5	N	L_{inf}	k	$t_{(0)}$
Annapolis Basin	149	188.35	0.176	0.937

The curve is unreliable in the size-at-age for larger animals as there were no scallops greater than 140 mm amongst the random sample of 149 shells included in the data set. The curve is well-defined for animals less than 7 years old. This growth curve indicates very good growth and represents one of the highest growth scallop stocks in Atlantic Canada.

Meat Weight-Shell Height Regressions

The meat yield of the scallops in the Annapolis Basin is very high and represents the best yield per animal in the Bay of Fundy. The results of the regression model presented in Kenchington and Lundy (1994) are presented below:

Area 5	N	b	intercept	Adjusted r^2	Meat Weight 100 mm Shell
Annapolis Basin	149	2.85	-10.334	0.73	16.3g

1997 Fishing Activity

In 1997 this area was fished under a dockside monitoring protocol. A total of 4.918 mt were removed.

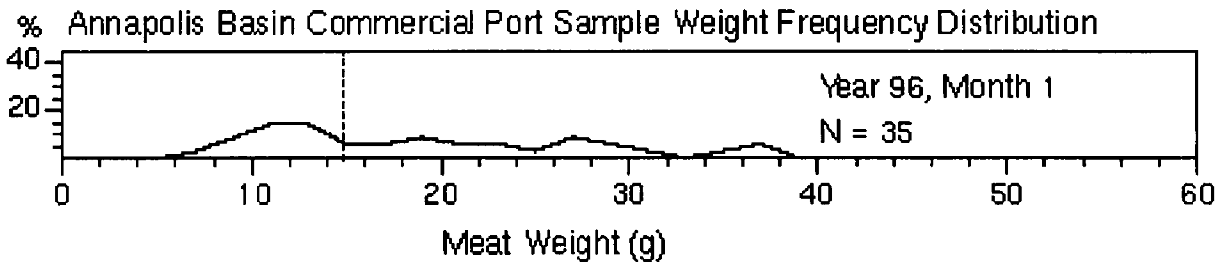
Preliminary analysis of the Class 1 log data from the dockside monitoring program shows catch per unit effort (CPUE) was 6.37±2.5 kg/hour with a minimum of 2.5 kg/h and a maximum of 14.0 kg/h. The Class 1 log records totaled 100 "days" fished. The Class 1 log catch was 7694 lb or 3490 kg. The total number of days fished was 125.

Port Sampling of Commercial Catch

Port sampling of the commercial catch was carried out as for Area 3; only one sample was collected in January of 1996:

Area 5 (Annapolis Basin) Meat Weight Statistics for the Full Bay Licence Holders by Month Calculated from Port Samples of the Commercial Catch

Year	Month	Meat weight (g) Mean	Min	Max	s.d.	Sample size (n meats)	Meat count per 500 g
1996	January	19.03	7.0	37.8	8.71	35	26.3



The meat count of the sample was 26, well below the legal count of 40/500 g and even below the recommended count of 30/500 g. The distribution of the meat weights shows that large meats were harvested, as well as small meats below the voluntary minimum meat weight (dashed line). The presence of a strong pre-recruit year class in the same bed as the older animals meant that small scallops were landed with the larger ones. Many fishers left the bed before the quota was taken to allow the smaller scallops to grow.

Area 7: St. Mary's Bay

Description of the Area

All area known as St. Mary's Bay following the coastline inside a line joining the following points: 4414.2 N 6624 W to 4415.2 N 6612.5 W (Fig. 1). The St. Mary's Bay scallop stocks are closely associated with Area 3 and most likely dependent on Area 3 for recruitment.

1997 Interim Management Plan

TAC: 100 mt
Meat Count: 30/500 g
Minimum Meat Weight: 15 g (voluntary)
Shell Height Minimum: 104 mm
Season: Open June 1, 1997 to July 15, 1997

Research Vessel Stock Surveys

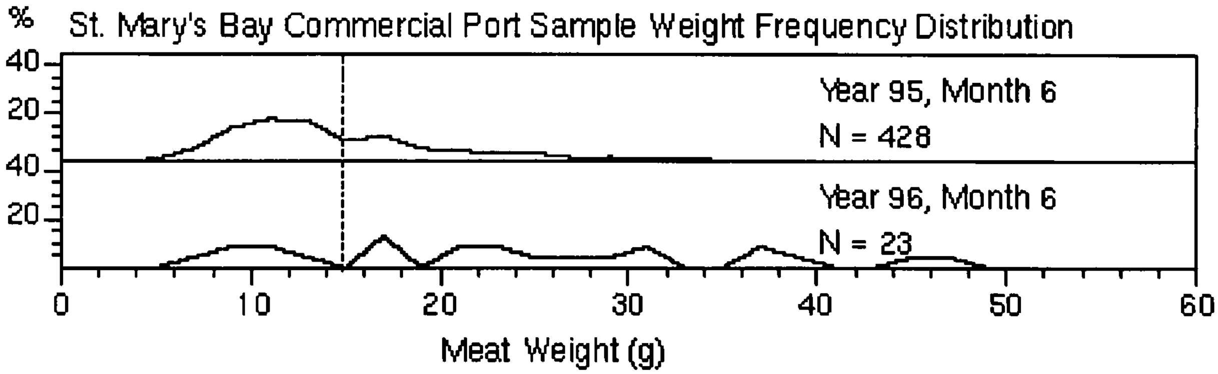
There has been no stock survey of St. Mary's Bay, although 4 stations were sampled there in 1994 as part of the Brier Island/Lurcher Shoal (Area 3) survey (Kenchington and Lundy 1996). These stations did not extend very far into the Bay and so are not necessarily representative of the scallop population there.

Port Sampling of Commercial Catch

Port sampling of the commercial catch was carried out as for Area 3. Very few samples are available from St. Mary's Bay because of the duration of the fishery and proximity of port samplers.

Area 7 (St. Mary's Bay) Meat Weight Statistics for the Full Bay Licence Holders by Month and Year Calculated from Port Samples of the Commercial Catch

Year	Month	Meat weight (g)				Sample size	Meat count
		Mean	Min	Max	s.d.	(n meats)	per 500 g
1990	June	17.65	8.05	34.78	4.97	57	28.3
1992	June	34.10	7.10	71.60	13.78	132	14.7
1993	January	29.47	7.90	60.40	15.92	39	17.0
	May	18.80	7.90	68.70	11.09	105	26.6
	June	42.84	7.80	70.70	13.13	109	11.7
1994	June	17.09	3.70	67.30	11.42	465	29.3
	July	28.89	7.60	64.60	12.31	33	17.3
1995	June	15.77	3.90	72.10	8.52	428	31.7
1996	June	23.65	7.30	46.40	11.64	23	21.1



In 1996 the range of scallops caught was broad, as in previous years, however, in the one sample we had, the maximum meat weight was lower. Despite the landings of very large meats, scallops under the voluntary minimum meat weight of 15 g were landed (dashed line), although this weight target was not in effect at the time of fishing.

Determination of Minimum Meat Weights/Counts

In the past, meat counts in the inshore scallop fisheries have not been based on biological concerns. The presence of several cohorts of animals on most beds means that the opportunities for mixing large meats with small meats are great, and consequently small scallops can be fished down within a legal meat count (e.g., Kenchington et al. 1995b). It is necessary to have a minimum meat weight and/or effective shell height regulation to prevent the blended count from destroying the incoming year-classes. The overfishing of small scallops not only results in loss of meat yield, but also results in loss of reproductive output. Although scallops mature sexually at very small sizes, the gonad production increases annually as the scallops grow. The increase in the gonad closely follows the increase in the meat weight (Roddick et al. 1994), and so models which optimize the meat yield per individual will also optimize the gonad production. Lowering the blended meat count and instigating a minimum meat size would allow higher long-term yields by allowing the scallops to grow larger before they are caught while increasing the reproductive potential of the bed.

As a first step in determining the minimum sizes that would allow optimal growth before capture, a set of yield isopleth diagrams were prepared for various scallop beds using the standard Beverton and Holt (1957) model. In all cases, these diagrams were calculated with a natural mortality rate of 0.1, an assumed maximum age of 20 years, the von Bertalanffy parameters, k and t_0, from growth-in-length curves for the bed in question (see Ageing data below), an arbitrary value for the asymptotic meat weight, Fishing Mortality rate values from zero to one, and ages at (knife-edge) first capture (recruitment to the gear) of zero to ten years. The calculations and the plotting of the diagrams were performed with Maple V software.

Like any other yield isopleth diagrams, these show the relative catch that would be achieved from any given year-class, summed through its life, for any chosen age-at-first-capture and any chosen Fishing Mortality rate. The actual catch from a year-class would be strongly influenced by the number of young scallops initially in that year-class (the number of recruits to the bed, as distinct from recruits to the gear- the difference being a function of natural mortality in the period between these events). It would also be influenced by the asymptotic meat weight. These factors can, however, be ignored when comparing the relative yields from a particular year-class on a particular bed that could be achieved by different ages-at-first-capture and different Fishing Mortality rates.

Area	N	L_{inf} (s.e.)	k (s.e.)	$t_{(0)}$ (s.e.)	r^2
Area 2 Southwest Bank	100	134.543 (3.953)	0.1510 (0.0198)	-1.835 (0.558)	0.94
Area 3 Brier/Lurcher	5474	127.199 (0.351)	0.2786 (0.0032)	0.196 (0.027)	0.90
Area 4 Digby	3291	127.232 (0.453)	0.3104 (0.0049)	0.721 (0.030)	0.91
Area 5 Annapolis Basin	149	188.35	0.176	0.937	–

Alterations to the Fishing Mortality rate during the years that a year-class was being actively fished would cause deviations from the values represented in the yield isopleth diagrams.

These diagrams only give a first indication of long-term optima and do not address the consequences of the dynamic approach to such optima.

If recruitment to the scallops beds was similar each year, these diagrams would show not only the relative yields that would be achieved from one year-class summed through its exploited life but also the relative yields that would be achieved in any one year from all of the year-classes then subject to exploitation. In reality, recruitment to the beds is, of course, highly variable and it is known that this variability distorts yield isopleth diagrams (Sinclair et al. 1983). Nevertheless, these diagrams can be taken as a first indication of the relative annual yields that could be achieved under various combinations of the age-at-first-capture and the Fishing Mortality rate – assuming that each of those was held stable over an extended time period.

Specific to scallops, the Beverton and Holt (1957) model does not take account of the mass mortalities that are known to occur in this species and which would reduce the benefit from leaving scallops in the sea longer. It also makes no allowance for differences in the growth rate within each ground, which as is seen above, can be considerable. From a commercial perspective, it takes no account of differences in the value per unit weight of different sizes of meats. Most importantly, it assumes "knife-edge" age-at-first-capture. This "knife-edge" assumption may seriously distort the yield isopleth diagrams. They are, however, offered as first approximations, pending the results of on-going model development. The Thompson-Bell Yield per Recruit model incorporates age specific mortality and selectivity, as well as an age-weight key. However we have very little data to construct accurate keys for either of these parameters and so the advantages of this model over the Beverton and Holt model are dubious. The Beverton and Holt model utilizes calculus to derive a more complete solution than the difference equations of the Thompson-Bell method.

The selectivity of the gear was evaluated by Worms and Lanteigne (1986) in the Gulf of St. Lawrence on various bottom types. The generalized model produced was :

1\(1+exp (-(-9.1975+0.1247 x Shell Height)))

When this model is applied to the height-at-age data for each Area it produces the following selectivities:

Age	Area 2 SW bank	Area 3 Brier/Lurcher	Area 4 Digby	Area 5 Annapolis
1	0.00	0.00	0.00	0.00
2	0.01	0.05	0.02	0.00
3	0.04	**0.35**	**0.24**	**0.11**
4	**0.17**	**0.76**	**0.72**	**0.64**
5	**0.42**	0.92	0.92	0.94
6	**0.69**	0.97	0.97	0.99
7	**0.85**	0.99	0.99	1.00
8	0.93	1.00	1.00	1.00

In Areas 3, 4 and 5, the number of years to go from less than 10% to over 90% retention is 3, with only one large increment generally going from age 3 to 4. In Area 2 where growth is slow, there is a more gradual selectivity vector, thus the yield per recruit model may be less accurate for this Area. Thus, the Beverton and Holt assumption of "knife-edge" recruitment approximates the measured selectivities with the information available at present.

Each of the yield isopleth diagrams for Areas 2 to 5 (Fig. 20) has the classic shape of such diagrams produced by the Beverton and Holt (1957) model. Each shows that the maximum theoretical yield would be achieved by leaving the scallops to grow for several years (6 to 10, depending on the bed in question) and then fishing intensively. Roddick et al. (1994) reported an optimum age-at-first-capture of 8 years at F >0.5 for Digby scallops assuming a dome-shaped selectivity, and 6 years at F> 0.3 using the gear selectivity of Worms and Lanteigne (1986) with the Thompson and Bell model. The Beverton and Holt model for a similar area and using updated growth curves (Fig. 20) indicates that the maximum theoretical yield is achieved at Age 8 with F> 0.5.

The yield isopleths (Fig. 20) also show that the same ages-at-first-capture, coupled with much lower fishing intensities, would produce almost the same yields with much lower fishing costs (Fig. 20). At lower ages-at-first-capture, high Fishing Mortality rates would cause yields to be depressed since most scallops would be caught before they had sufficient time to grow. At very low Fishing Mortality rates, yields would also be depressed because the resource would be under-exploited and too many scallops would die of natural causes before they could be caught.

Superimposed on the yield isopleth diagram for Area 5 (Annapolis Basin) are lines drawn at the ages at which the average scallop reaches a meat weight corresponding to 30, 35, 40 and 45 meats per 500 g (i.e. meat weights of 16.67, 14.29, 12.5 and 11.11 g respectively, Fig. 21). The meat counts for surrounding age groups are also calculated based on the yield and age models described above (see Area 5 Annapolis Basin). It can be seen that even fishing at 30-45/500 g could result in growth over-fishing of the resource if the Fishing Mortality is high. Also, at Age 5 the scallop meat growth is very fast such that the animal is moving through several meat count increments within a single year. While fishing at a 30 count would offer some yield advantages over fishing at a 45 count, the percent increase would probably not be detectable. Such benefits would not be achieved immediately. Cutting (real) effort would obviously involve an immediate and proportionate cut in catches. The reduced pressure on the resource would then lead to higher biomass and, over a few years, increased yields.

The yield isopleth diagrams were used to assess the minimum meat weights listed in the 1997 Bay of Fundy Interim Management Plan:

Area 3 (Brier Island, Lurcher Shoal)

The blended meat count outlined in the Plan is 45/500 g, and the voluntary minimum meat weight is 10 g. From figure 20 it can be seen that the optimum age-at-first-capture for this area as a whole is age 7. The weight at this age from the regression models corresponds to the 10 g minimum meat weight with a shell height of 108 mm (about 4.25"). The corresponding meat count is 45/500g, but this is a straight count and not a blended count. The 95 mm minimum shell height corresponds approximately to a 5 year old animal which is two years less than the minimum meat weight equivalent. The range of scallops sizes in both areas by depth is seen on pg. 16. As the minimum meat count for optimum yield corresponds with a straight 45 count, lower counts (e.g., 40) may be required to accommodate blending practices. Shifting the minimum meat weight to 8.6 g would not produce large yield losses and would give the straight count of 58/500 g (Fig. 20) if Fishing Mortality is above 0.5, as it was estimated for the Lurcher beds in 1995. Reducing the minimum size to 6.8 g (age 5 and the minimum shell height in the Plan) would result in about a 6% loss in yield over F>0.3.

This analysis is based on generalized models for the whole area, as only one set of regulations can apply within the Area. The scallops in the deep water area off Lurcher will become an important broodstock component as they will be left in the water for a longer period of time before reaching the count. Kenchington et al. (1996) confirmed that these deep living scallops develop mature gonads and contribute to the spawning pool. Therefore, the present requirements for this Area are good from the point of yield and reproductive conservation, however the two minimum size restrictions (height and weight) should be brought into concert.

Area 4 (Digby)

The 1997 Interim management plan does not outline meat count and minimum size restrictions. From figure 20 it can be seen that the optimum age-at-first-capture for this area as a whole is age 8. The weight at this age from the regression models corresponds to a 16 g minimum meat weight with a shell height of 113 mm (about 4.5"). The corresponding straight meat count is 31/500g. At a minimum meat weight of 10 g, the scallop age is approximately 5.5 years. This is still near the optimum yield isopleth (Fig. 20) and there are no large losses associated with the lower cut off. The minimum shell height of 95 mm (3.75") corresponds with the minimum meat weight of 10 g. A blended meat count of 45/500 g to go with these later size restrictions would then be lower than the straight count (50/500 g) for the minimum size, which is appropriate.

The use of a generalized model in Area 4 will favour the harvesting of scallops north of Centreville and leave the Centreville animals in the water for a longer period of time. As this area stratum is upstream of the main bed, it is the most likely source of seed supply to the Area (see Kenchington and Lundy (1996b).

Area 5 (Annapolis Basin)

The blended meat count outlined in the Plan was 30/500 g, and the voluntary minimum meat weight is 15 g. The shell height minimum is 104 mm (about 4"). The blended meat count was later changed to 40/500 g in recognition of the low yield losses incurred as discussed above and in figure 21. From figure 19 and 20 it can be seen that the optimum age-at-first-capture for this area is age 8 to 10+. To fish at the optimum yield target would mean fishing at below a 15 count. Fishing at the present targets result in a 30 to 40% loss of potential yield, however, the animals are old enough (age 5) to have spawned several times and so recruitment overfishing at these targets should not be a problem under normal conditions. Both of the minimum size targets (weight and height) correspond to the blended meat count requirement. Therefore blending practice will force the actual meat count to be lower. The growth rate for this Area offers the opportunity to increase yields over a relatively short time (1 to 2 years) and could provide an experimental fishery for testing some of the theory proposed above.

<u>Area 2 (Southwest Bank)</u>

The blended meat count outlined in the Plan for this Area is 45/500 g, and the voluntary minimum meat weight is 10 g. The shell height minimum is 95 mm (about 3.75"). According to figure 9 the requirements for this Area will largely eliminate fishing on Southwest Bank, the only place in the Area for which we have data. The optimum maximum age-at-first-capture is about 8-10 years, however the straight meat count at that age is approximately 95/500 g. The minimum meat weight rarely reaches 10 g in this area. Fishing at 116 count (Age 5) would result in a 9% loss over fishing at a 100-95 count at F>0.3. A more realistic minimum meat size would be 5 g (Age 6) with a corresponding shell height of 80 mm and a meat count of less than 100. Moving to a 4 g meat, a shell height of 60 mm and a meat count of 120/500 g would also result in a 9% loss at F 0.3-F 0.4 to a 20% loss in yield fishing at F>0.8.

Application of Yield Determination to TAC Advice

A biologically based TAC was requested for Area 3 (Brier Island) and Area 4 (Digby), the only Areas where we have adequate survey information. The yield options above were translated into TAC options for each Area using the biomass estimates presented above for each Area.

Area 3 (Brier Island/Lurcher Shoal)

We are unable to calculate TAC advice for Area 3 due to our inability to determine catchability of the survey. However, we can provide a context for the TAC of 237 proposed in the 1997 Interim Management Plan for this area. This analysis assumes that growth balances losses due to natural mortality and that recruitment has been minimal since 1995.

Landings in 1995 were equal to 920 mt. The estimate of total mortality detailed above implies a fishing mortality of 0.48 and hence an exploitation rate of 36% over the whole area. Survey abundance in 1996 (5+) has declined from 1995 by about 30%. Landings from Area 3 in 1996 are estimated at 252 mt from logbook records (28% of the total catch).

Given that the 1995 landings were 920 mt with an exploitation rate of 36%, the population biomass in that year is estimated at around 2556 mt. The 1996 population biomass is approximately 1636 mt (2556 mt - 920 mt) from which landings of 252 mt were taken for an exploitation rate of 15%, leaving 1384 mt for 1997. Therefore, the planned 1997 catch of 237 mt could correspond to an exploitation rate of around 17% with an implied fishing mortality of 0.08 with M=0.1. This is a decrease over 1995 fishing levels.

Area 4 (Digby)

The recommended restrictions on size allow for the harvesting of animals aged 5+. The biomass of Ages 5+ for Area 4 from 2 to 8 miles from shore was estimated as 614 mt with the lower and upper bounds estimated by the bootstrap method as (95%): 506 and 743 mt. Since the survey, the 1996 fishery removed 56.7 mt from the TAC area (Area 4 from 2 to 8 miles). An additional 14.5 mt were removed from Area 4 in the 0 to 2 mile portion. These removals leave approximately 449 to 686 mt Age 5 and above.

Total Allowable Catch (TAC) recommendations were calculated for the whole of Area 4 from 2 to 8 miles for four levels of exploitation based on the population meat yield estimates described above:

Exploitation Rate (%)	Fishing Mortality (F)	TAC (mt)
15	0.27	92
20	0.34	123
25	0.40	154
30	0.48	184

Estimated exploitation rate for 1996 is equal to 56.7/614 = 9.2% (confidence intervals: 11.2%, 7.6%) implying a fishing mortality of 0.10 assuming M=0.1.

If we confine the catch of 56.7 mt in 1996 to the estimated weight in the fished zone only we need to obtain the survey biomass estimate for the area fished. Overlapping the fishing effort map for the 1996 season given in figure 19 with the strata map shows the fishing confined to the northern half of the Digby stratum and includes the area between Digby and Delaps, Delaps Cove, between Delaps and Digby, and the Parker Cove strata. The survey estimates of total meat weight for this area are 69 and 53 mt for ages 5+ and 6+, respectively. Multiplying by the $1/q$ factors suggests population meat weights of $3.57\times69 = 246$ mt and $2.92\times53 = 155$ mt. Assuming that the reported catch of 56.7 mt is mainly composed of 5+ animals then the resultant exploitation rate of 23% implies a fishing mortality of 0.28 (again assuming M=0.1) in the fished area.

Application of a Thompson-Bell yield per recruit model using the selectivity published in Kenchington et. (1995a) described above resulted in an F0.1 of 0.18 and an Fmax of 0.43. Therefore, fishing in 1996 was in excess of F0.1 but below Fmax. Fishing in excess of F0.1 can not be maintained without strong recruiting year-classes and the survey indicates that although the 1993 year-class may be the strongest observed in six years, most of it is confined to the area between Centreville and Gulliver's Head. Typically, scallops in these areas exhibit slower growth than in the more northern areas of Area 4 and hence have a lower productivity. Therefore consideration of exploitation rates above 25% are strongly discouraged. New TAC estimates will be made immediately following the June 1997 survey.

1996 Fishery Performance: Landing Statistics and Dollar Value

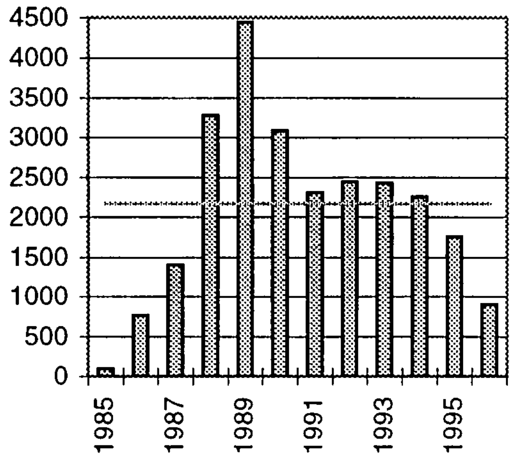
Landings from the whole of the Bay of Fundy by all fleet sectors are listed in the table and illustrated below. In 1996, landings include the 76.7 mt from SFA29 which is outside of the regulation fishing area. Landings in the Bay fell by 49% in 1996 over 1995. The landed value of the 1996 catch was approximately $13.9 million.

Landings (mt)

Ave 85-90	1991	1992	1993	1994	1995	1996*
2319	2304	2443	2429	2254	1754	900

*preliminary

Bay of Fundy Scallop Landings (mt)
(dash line: average over time series)



Full Bay Fleet Characteristics

The number of Full Bay licences are given in Table 3. The total number of licences remain the same in 1996 with 91 licences active. The number of groundfish licences held by Full Bay scallop licence holders has increased in 1996 to 61 (Table 4) while the other types of licences have remained about the same. The buyers of these licences tend to be multi-licence holders as is seen with the increase in the number of licences with 3 additional licences (Table 5). In 1996 the Full Bay fleet landed 76.67 mt from SFA 29 which is outside of the regulation fishing area.

1996 Landings By Statistical District ,Vessel Size Class and Month

The 1996 landings in the Upper Bay are provided by month in Table 6. Total landings were approximately 7.7 mt, with 85% of this being landed by small vessels (under 25.5 G.T.). In 1996 landings were reported for all months except January to March and November and

December. Landings are generally harvested from resident stocks.

In 1996, landings for the southwest New Brunswick area, including Grand Manan (District 50) were approximately 154 mt (Table 7). A large area south of Grand Manan is closed from April 1 to the second Tuesday in January by variation order. The effect of this closure is seen in the landings from the smaller vessels which largely fish these beds. Landings by the larger vessels in District 50 continue throughout the year but are highest in the first half.

The landings for Statistical Districts 48 and 49 (Saint John and surrounds, Table 8) were approximately 45 mt. Most of these landings were in District 49, and by vessels under 25.5 G.T. Combined landings of Districts 48 to 53 were approximately 200 mt.

Landings in Statistical Districts on the Nova Scotia side of the Bay of Fundy are shown in Tables 9 and 10, and detailed in this document and in Kenchington and Lundy (1996). In contrast to other Statistical Districts, landings in these areas are almost exclusively by vessels over 25.5 G.T.

The Total Landings for the Bay of Fundy were approximately 900 mt (Table 11).

Annual Trends in Landings By Statistical District and Vessel Size Class (1986-1996)

Landings in all Statistical Districts declined in 1996 except for the landings by vessels over 25.5 GT in District 51 (Campobello). Annual landings in the Upper Bay Districts (Districts 40, 44, 79, 24) are illustrated in figure 22. Most of the landings in these Districts since 1986 are reported by small vessels under 25.5 G.T., however, in 1989, landings from the larger vessels begin to appear. Landings by the over 25.5 G.T. vessels in the Upper Bay declined again by 1994 and were negligible in 1996 (Fig. 22).

Annual landings in the Grand Manan area and surrounds are shown in figure 23. In contrast to the Upper Bay, landing pattern by vessel size has shifted during the period of 1986-1996. In Grand Manan itself (District 50), small vessels contributed most to the catch from 1986 to 1988. Since 1988, most of the landings have been by over 25.5 G.T. vessels until 1996 when the landings by the smaller vessels were greater than those of the larger ones by a slight margin. This pattern is also seen in District 53, beginning in 1991, but 1995 saw a shift back to small boats landing the majority of the catch which was maintained in 1996. In District 51 large vessels dominated the catch from 1988 to 1991, however from 1992 to 1995 small vessels have landed more in this area. In 1996 landings by both vessel size classes were equal. In District 52, small vessels have consistently dominated the catch since 1986, however the total amount landed in this District is small relative to Districts 50, 51 and 53.

The annual landings by vessel size class from 1986 to 1995 for the Saint John area (Districts 48, 49) are shown in figure 24. Smaller vessels contribute most to the landings. Landings in District 48 peaked in 1989 and 1990 as the result of an exceptionally strong year class reaching the legal size limit in this area. These landings have since declined to 1986 and 1987 levels. In District 49 landings peaked in 1993. Landings for the combined area peaked in 1989 and 1990 at 735 mt, but are currently at a low level (below that reported by Robert and Lundy (1987) from 1981 to 1985).

Annual landings for the Digby area, including Digby Neck, (District 37, 38, 39) are shown in figure 25. Large vessels have consistently dominated the catch in this time series. Some landings by small vessels were reported in 1989 from the Parker's Cove area (District 39). Landings in District 38 (Digby) have declined steadily since the peak in 1989, while landings in Districts 34 and 36 (Meteghan, Yarmouth, Fig. 25) have increased sharply from 1991 to 1993 and 1994 respectively. Both of these areas have seen a decline in 1995 and again in 1996. These peak landings in Districts 34 and 36 reflect the heavy exploitation by the Digby fleet, of the grounds in the Brier Island and Lurcher Shoal areas beginning in 1990 (Kenchington et al. 1995a). The decline in landings in both figures 25 and 26 reflects the general low abundance throughout the Bay of Fundy in 1996.

Relationship Between Landings and Value By Fleet Sector (1986-1996)

Although the District landings show trends by geographical area and vessel size class, the performance of each fleet sector can only be estimated from these data. Landing figures for the Full Bay and Mid Bay fleets are not available at the time of writing. Figure 27 illustrates the landings and revenue by each fleet sector. Recently, market price for Bay of Fundy scallops has been determined by size, with larger meats demanding the highest price. Thus the relationship between landings and revenue is not strictly one of amount caught versus dollar paid, as size of the product is factored into the value.

Landings and revenue for the Full Bay fleet peaked in 1989 and then fell in 1990 and 1991. Prior to 1992 revenue followed the landing pattern, however in 1992 market prices began to increase and in 1994 revenue was at its second highest value. In 1995 revenue fell sharply as a result of lower landings, although the price has remained high. The volume decrease was largely noted in the fall. Landings and revenue were also linked in the Mid Bay fleet statistics until 1992, however revenue peaked in 1993. Revenue earned by this fleet also fell sharply in 1995 and again in 1996. A similar pattern is seen in the Upper Bay fleet with the decline in revenue beginning in 1994 and continuing to 1996. Overall, revenues and landings in 1995 have dropped dramatically (Table 11). A full account of the economic performance of the fleet from 1986 to 1993 can be found in Digou (1994).

References

Beverton, R.J.H. and S.J. Holt, 1957. On the Dynamics of Exploited Fish Populations. *Fishery Investigations Series II*, Volume XIX.

Black, G.A.P., 1988. ACON- A shaded contour program for plotting irregularly spaced data. Unpublished manuscript, Department of Fisheries and Oceans, Scotia-Fundy Region. Version 4.18, 50pp.

Chen, Y., Jackson, D.A. and H.H. Harvey, 1992. A comparison of von Bertalanffy and polynomial functions in modelling fish growth data. *C.J.F.A.S.*49: 1228-1235.

Digou, D., 1994. Scotia-Fundy region harvesting sector overview, 1986-1993. *Econ. Com. Anal. Rep.* 144: 39pp.

Jamieson, G.S. and M.J. Lundy, 1979. Bay of Fundy Scallop Stock Assessment - 1978. *Fish. Mar. Serv. Tech. Rep.* 915: 14 pp.

Kenchington, E. and M.J. Lundy, 1991. 1990 Bay of Fundy Scallop Stock Assessment. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 91/26: 28 pp.

Kenchington, E. and M.J. Lundy, 1993. Sea Scallop (*Placopecten magellanicus*) Fishing Areas in the Bay of Fundy. *DFO Atl. Fish. Res. Doc.* 93/17, 8pp.

Kenchington, E. and M.J. Lundy, 1994. The Annapolis Basin Scallop Fishery: A Historical Perspective and 1993 Stock Assessment. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 2230, 24pp.

Kenchington, E.L., Lundy, M.J. and D.L. Roddick, 1995 a. Bay of Fundy scallop analytical stock assessment and data review 1981-1994: Digby grounds. *DFO Atl. Fish. Res. Doc.* 95/10, 70 pp.

Kenchington, E.L., Lundy, M.J. and D.L. Roddick, 1995 b. 1991-1994 Bay of Fundy scallop stock surveys and fishery statistics: Brier Island and Lurcher Shoal and an evaluation of the effectiveness of the meat count regulation for these stocks. *DFO Atl. Fish. Res. Doc.* 95/9, 24 pp.

Kenchington, E.L., Lundy, M.J. and D.L. Roddick, 1995 c. An overview of the scallop fishery in the Bay of Fundy 1986 to 1994 with a report on fishing activity trends amongst the dual licence holders in the Full Bay fleet. *DFO Atl. Fish. Res. Doc.* 95/126, 24 pp.

Kenchington, E. and M.J. Lundy, 1996. 1995 Bay of Fundy Scallop Stock Assessments: Brier Island and Lurcher Shoa l. *DFO Atl. Fish. Res. Doc.* 96/15: 31 pp.

Kenchington, E. and M.J. Lundy, 1996b. An assessment of areas for scallop broodstock protection in the approaches to the Bay of Fundy. *DFO Atl. Fish. Res. Doc.* 96/13: 21 pp.

Kenchington, E., Roddick, D.L. and M.J. Lundy, 1996. 1995 Bay of Fundy Scallop Stock Assessements: Digby, and 1995 Landings by Statistical District for the Bay of Fundy. *DFO Atl. Fish. Res. Doc.* 96/14: 70pp.

Lundy, M.J. and E. Kenchington, 1992. Brier Island Revisited: A 1991 scallop stock status report. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 92/42: 15 pp.

Merrill, A.S. and J.A. Posgay, 1964. Estimating the natural mortality rate of the sea scallop (Placopecten magellanicus). *ICNAF Research Bulletin* 1: 88-106.

Robert, G. and M.J. Lundy, 1987. The Grand Manan area scallop stock assessment - 1987. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 88/21: 31pp.

Robert, G. and M.J. Lundy, 1989. Gear performance in the Bay of Fundy scallop fishery.II.- Selectivity studies. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 89/17, 32 pp.

Robert, G., Lundy, M.J. and M. A. E. Butler-Connolly, 1985a. Scallop Fishing Grounds on the Scotian Shelf. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 85/28: 45 pp.

Robert, G., Lundy, M.J. and M. A. E. Butler-Connolly, 1985b. Bay of Fundy scallop stock assessment-1984. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 85/27, 29pp.

Robert, G., Lundy, M.J. and M. A. E. Butler-Connolly, 1986. Scallop Fishing Grounds on the Scotian Shelf - 1985. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 86/41: 43 pp.

Robert, G., Butler-Connolly, M.A.E and M.J. Lundy, 1990. Bay of Fundy scallop stock assessment-1989. *Can. Atl. Fish. Sci. Adv. Comm. Res. Doc.* 90/31, 35pp.

Roddick, D., Lundy, M.J. and E.L.R. Kenchington, 1994. Yield per recruit analysis and minimum meat weight recommendations for the Bay of Fundy scallop fishery *DFO Atl. Fish. Res. Doc.* 94/58: 15 pp.

Sinclair, M., O'Boyle, R. and T.D. Iles, 1983. Consideration of the stable age distribution assumption in analytical yield models. *CJFAS* 40: 95-101.

Smith, S. J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. *Can. J. Fish. Aquat. Sci.* 54: (in press).

Smith, S.J.and S. Gavaris, 1993. Improving the precision of fish abundance estimates of Eastern Scotian Shelf cod from bottom trawl surveys. *N. Am. J. Fish. Manage.* 13: 35--47.

SPSS Inc. 1990. SPSS® Reference Guide. Chicago, USA., pp. 485-486.

Thompson, S. and G. A. F. Seber, 1996. Adaptive Sampling. John Wiley & Sons.

Watson, D.F. and G.P. Phillip, 1985. A refinement of inverse distance weighted interpolation. *Geo-Processing* 2: 315-327.

Worms, J. and M. Lanteigne, 1986. The selectivity of a sea scallop (Placopecten magellanicus) Digby dredge. ICES CM/k:23, 25 pp.

Table 1. 1986-96 Digby Stock Survey (Centreville to Hampton). Average Number of Scallops-at-Age Caught in a Seven-gang Digby Drag Projected from the Average of an End and a Middle, Unlined Bucket for Recruits (age >4 years) and from the Average of an End and a Middle, Lined Bucket for Prerecruits (age ≤4 years)

	Age (years)											
	2	3	4	5	6	7	8	9	10+	Total	No. of Stations	% Clappers
Inside 6 mile												
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	
Outside 6 mile												
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

Table 2. 1996 Digby Stock Survey. Comparison of Mean Numbers-at-Age Determined from Three Depth-Defined Growth Curves Applied to Shell Height Data with the Actual Mean Ages of Those Shells

	Age (years)										
	2	3	4	5	6	7	8	9	10+	Total	No. of Stations
Inside 6 mile											
1996 growth curves	3	25	19	12	17	10	8	7	16	117	37
1996 aged shells	6	37	14	18	8	5	4	5	15	113	37
Area 4											
1996 growth curves	3	29	32	12	17	12	9	7	15	136	44
1996 aged shells	7	50	20	17	7	6	5	6	15	132	44
Outside 6 mile											
1996 growth curves	2	10	17	11	16	14	11	7	9	97	63
1996 aged shells	3	19	14	11	7	8	8	9	18	96	63

Table 3. Number of (1) Bay of Fundy licensed vessels (Source: Licensing Unit, Fisheries and Oceans, Halifax) , (2) active scallop fishing licenses for vessels over 25.5 G.T. supposed to follow log procedures, and (3) vessels complying with log procedures.

Year	(1)	(2)	(3)
1981	99	68	65
1982	107	66	63
1983	115	77	74
1984	106	82	76
1985	96	70	67
1986	96	67	57
1987	95	80	44
1988	98	91	16
1989	98	96	14
1990	99	94	13
1991	99	91	26
1992	99	90	44
1993	99	99	63
1994	99	92	80
1995	99	94	72
1996*	99	91	53

*preliminary

Table 4. Number of Full Bay of Fundy scallop licenses and additional licenses carried from 1981-96. Source: Licensing Unit, Resource Allocation and Licensing Branch, DFO, Halifax.

Year	Scallop	Groundfish	Squid	Herring	Lobster	Shrimp	Swordfish	Crab	Mackerel	Salmon
1981	99	81	12	36	23	3	5	-	4	1
1982	107	86	12	32	20	2	6	1	1	1
1983	115	91	15	30	20	3	7	-	1	1
1984	106	79	13	30	16	1	7	-	3	-
1985	96	73	12	25	12	2	7	-	2	-
1986	96	74	12	26	10	3	30	-	1	-
1987	95	73	12	17	9	3	45	-	1	-
1988	98	68	12	17	8	3	50	-	1	-
1989	98	61	13	13	4	2	47	-	-	-
1990	99	61	12	9	7	2	42	-	-	-
1991	99	64	13	9	6	2	32	-	-	-
1992	99	61	12	9	4	2	27	-	-	-
1993	99	59	11	9	4	2	25	-	-	-
1994	99	58	11	9	4	2	24	-	-	-
1995	99	54	12	11	4	1	27	-	1	-
1996	99	61	12	13	3	2	30	-	3	-

Table 5. Number of Bay of Fundy scallop licenses with 'n' additional licenses from 1981-96. Source: Licensing Unit, Resource Allocation and Licensing Branch, DFO, Halifax.

	Number of Additional Licenses						
Year	0	1	2	3	4	5	# Scallop Lic.
1981	12	35	31	17	4	-	99
1982	16	38	40	10	3	-	107
1983	20	41	39	12	3	-	115
1984	21	41	28	12	4	-	106
1985	19	37	28	8	4	-	96
1986	10	38	31	13	3	1	96
1987	8	34	39	10	2	2	95
1988	12	33	38	11	3	1	98
1989	16	38	33	9	1	1	98
1990	19	42	27	9	1	1	99
1991	25	36	28	8	1	1	99
1992	29	38	22	8	1	1	99
1993	31	39	19	8	1	1	99
1994	31	40	18	8	1	1	99
1995	28	44	16	8	2	1	99
1996	29	41	13	12	4	-	99

Table 6. 1996 landings in metric tonnes of scallop meats by Statistical District for the Upper Bay. King's Co.: 40; Cumberland Co.: 24, 44; Albert Co.: 79. (1 indicates landings from vessels < 25.5 G.T., and 2 indicates landings from vessels > 25.5 G.T.). Source: Commercial Data Division, Program Coordination and Economics Branch, DFO, Halifax

	40		24		44		79	
Month	1	2	1	2	1	2	1	2
January	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-
March	-	-	-	-	-	-	-	-
April	-	-	0.12	-	-	0.72	0.72	-
May	-	-	-	-	-	-	0.24	-
June	-	-	-	-	-	-	1.30	-
July	-	-	-	-	-	-	0.84	-
August	-	-	-	-	-	-	2.70	0.24
September	-	-	-	-	-	-	0.36	0.24
October	-	-	-	-	-	-	0.24	-
November	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-
Total	-	-	0.12	-	-	0.72	6.40	0.48

Table 7. 1996 landings in metric tonnes of scallop meats by Statistical District for Grand Manan and surrounds. Grand Manan: 50; Campobello: 51; Charlotte Co.: 52, 53. (1 indicates landings from vessels < 25.5 G.T., and 2 indicates landings from vessels > 25.5 G.T.). Source: Commercial Data Division, Program Coordination and Economics Branch, DFO, Halifax

	50		51		52		53	
Month	1	2	1	2	1	2	1	2
January	22.80	12.90	5.20	1.90	1.00	-	1.40	-
February	12.90	9.80	4.00	1.10	1.70	-	0.60	-
March	10.00	5.90	3.30	0.12	1.40	-	0.60	-
April	2.50	2.40	0.84	0.36	0.24	-	0.12	-
May	0.60	0.60	0.84	4.00	-	-	0.24	-
June	0.36	2.70	1.30	4.50	-	-	0.24	-
July	1.10	3.00	0.96	2.70	-	-	-	-
August	2.30	4.80	0.48	2.50	-	-	0.12	-
September	5.30	6.10	-	-	-	-	-	-
October	2.20	3.00	-	-	-	-	-	-
November	0.24	0.24	-	-	-	-	-	-
December	-	0.60	-	-	-	-	-	-
Total	60.30	52.04	16.92	17.18	4.34	-	3.32	-

Table 8. 1996 landings in metric tonnes of scallop meats by Statistical District for Saint John and surrounds. Saint John: 48, 49. (1 indicates landings from vessels < 25.5 G.T., and 2 indicates landings from vessels > 25.5 G.T.). Source: Commercial Data Division, Program Coordination and Economics Branch, DFO, Halifax

	48		49	
Month	1	2	1	2
January	-	-	6.70	3.10
February	0.20	-	5.20	2.70
March	-	0.24	7.10	2.90
April	0.36	-	1.90	0.60
May	-	-	0.72	0.84
June	-	-	0.36	0.24
July	0.24	0.48	0.72	0.24
August	1.70	1.70	1.10	0.84
September	0.60	0.84	0.48	0.48
October	0.12	1.10	0.24	0.60
November	-	0.24	0.24	-
December	-	-	-	-
Total	3.22	4.60	24.76	12.54

Table 9. 1996 landings in metric tonnes of scallop meats by Statistical District for Digby and surrounds. Digby: 37, 38, 39. (1 indicates landings from vessels < 25.5 G.T., and 2 indicates landings from vessels > 25.5 G.T.). Source: Commercial Data Division, Program Coordination and Economics Branch, DFO, Halifax

	37		38		39	
Month	1	2	1	2	1	2
January	-	0.72	0.12	15.10	-	-
February	-	-	0.12	1.80	-	-
March	-	0.84	0.84	36.30	-	0.12
April	-	-	0.24	40.10	-	0.12
May	-	1.60	1.40	61.80	0.12	1.30
June	-	3.40	1.10	51.70	-	0.24
July	-	0.72	0.72	36.40	0.60	0.84
August	-	-	0.96	54.20	-	0.48
September	-	0.72	-	22.30	-	0.12
October	-	1.80	-	15.70	-	-
November	-	0.60	0.60	46.70	-	0.36
December	-	-	0.12	32.30	-	1.10
Total	-	10.40	6.22	414.40	0.72	4.68

Table 10. 1996 landings in metric tonnes of scallop meats by Statistical District for Yarmouth (34) and Meteghan (36). (1 indicates landings from vessels < 25.5 G.T., and 2 indicates landings from vessels ≥ 25.5 G.T.). Source: Commercial Data Division, Program Coordination and Economics Branch, DFO, Halifax

	34		36	
Month	1	2	1	2
January	-	12.90	-	-
February	-	2.50	-	0.12
March	-	5.80	0.12	0.60
April	-	6.40	-	0.60
May	0.60	17.30	-	2.20
June	0.72	25.50	-	23.30
July	-	32.30	-	7.60
August	0.36	32.50	-	5.90
September	-	23.00	-	7.10
October	-	42.20	-	12.80
November	-	4.50	-	2.30
December	-	1.60	-	0.24
Total	1.68	206.50	0.12	62.76

Table 11. Landed Value ($000) by Fleet Sector

Year	Full Bay Licenses	Mid Bay Licenses	Upper Bay Licenses	Total (mt)
1985	9332.0	2979.4	114.9	938.4
1986	6948.5	3164.8	148.0	762.4
1987	13371.8	2411.5	371.4	1400.5
1988	28183.8	2295.3	560.5	3278.6
1989	33604.8	4163.5	726.4	4446.9
1990	21691.3	5604.4	820.1	3086.6
1991	17412.0	4210.8	725.8	2304.2
1992	22093.0	5493.8	546.8	2442.5
1993	28426.5	7240.0	740.9	2429.2
1994	30035.5	7065.2	339.4	2253.9
1995	22859.2	5758.4	162.5	1754.1
1996	10416.1	3469.0	12.2	899.8

† Data for 1996 is preliminary.

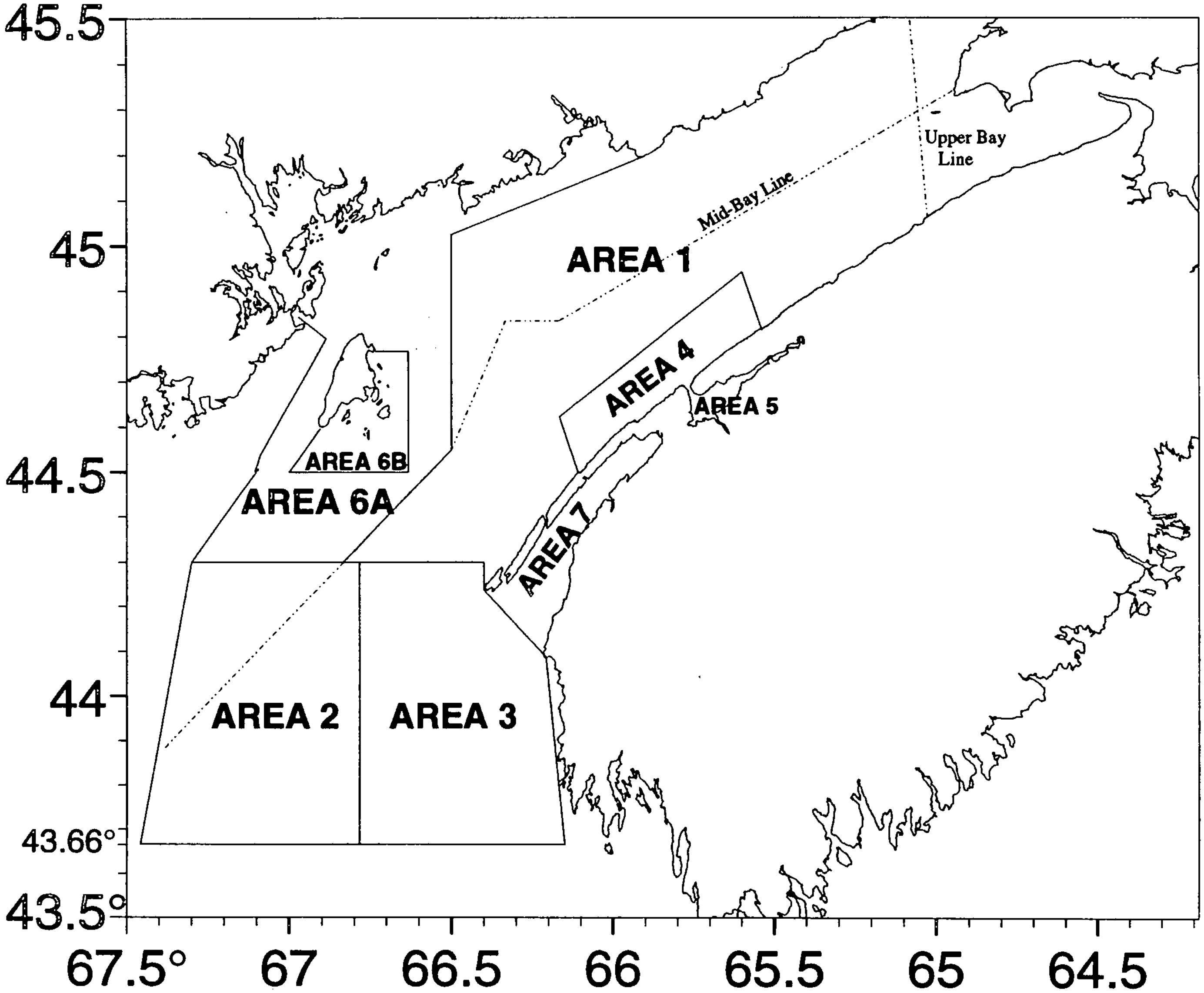


Figure 1. Scallop fishing areas in the Bay of Fundy.

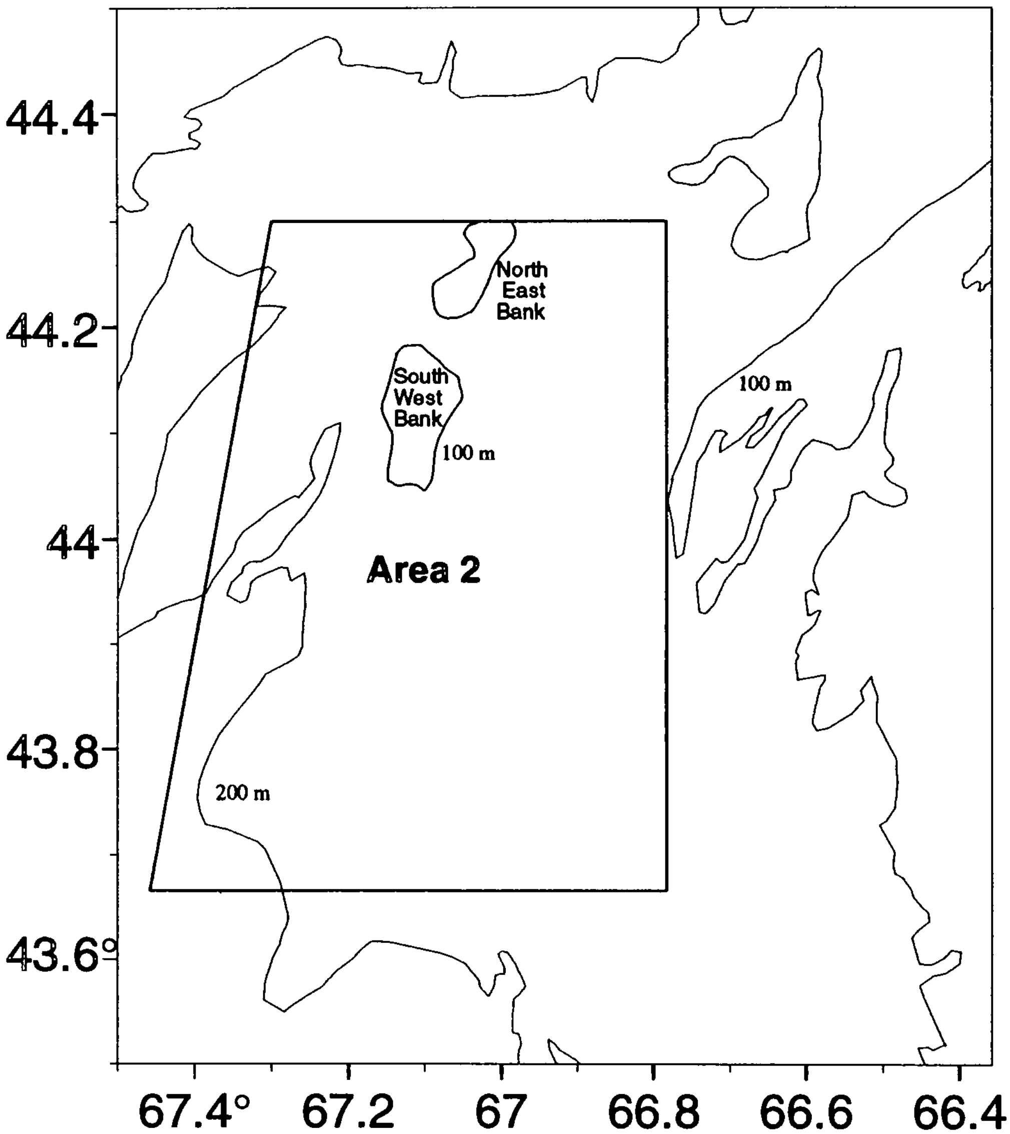


Figure 2. Location of main scallop beds in Area 2.

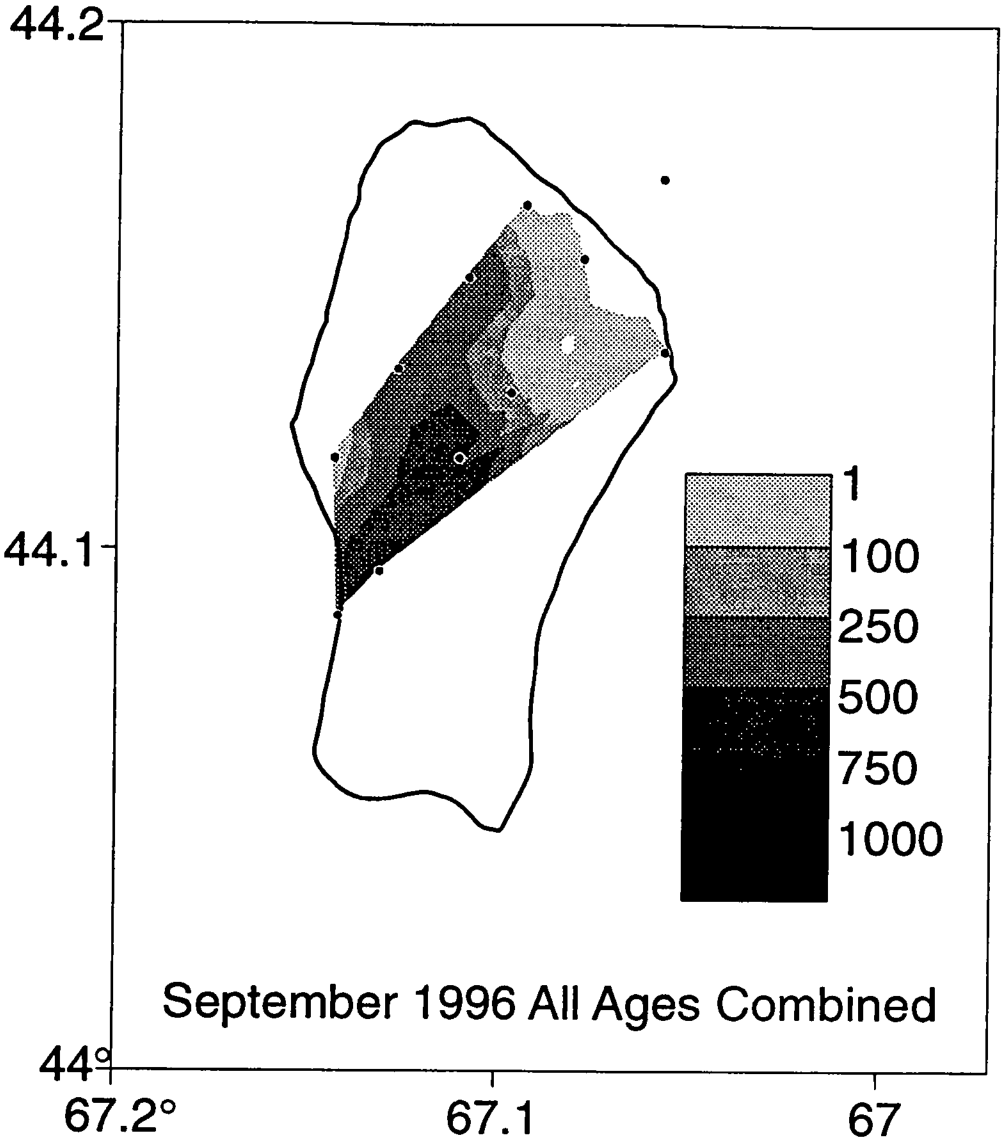


Figure 3. Location of tows on Southwest Bank and scallop abundance (number of scallops per standard tow) as determined from the 1996 research vessel survey.

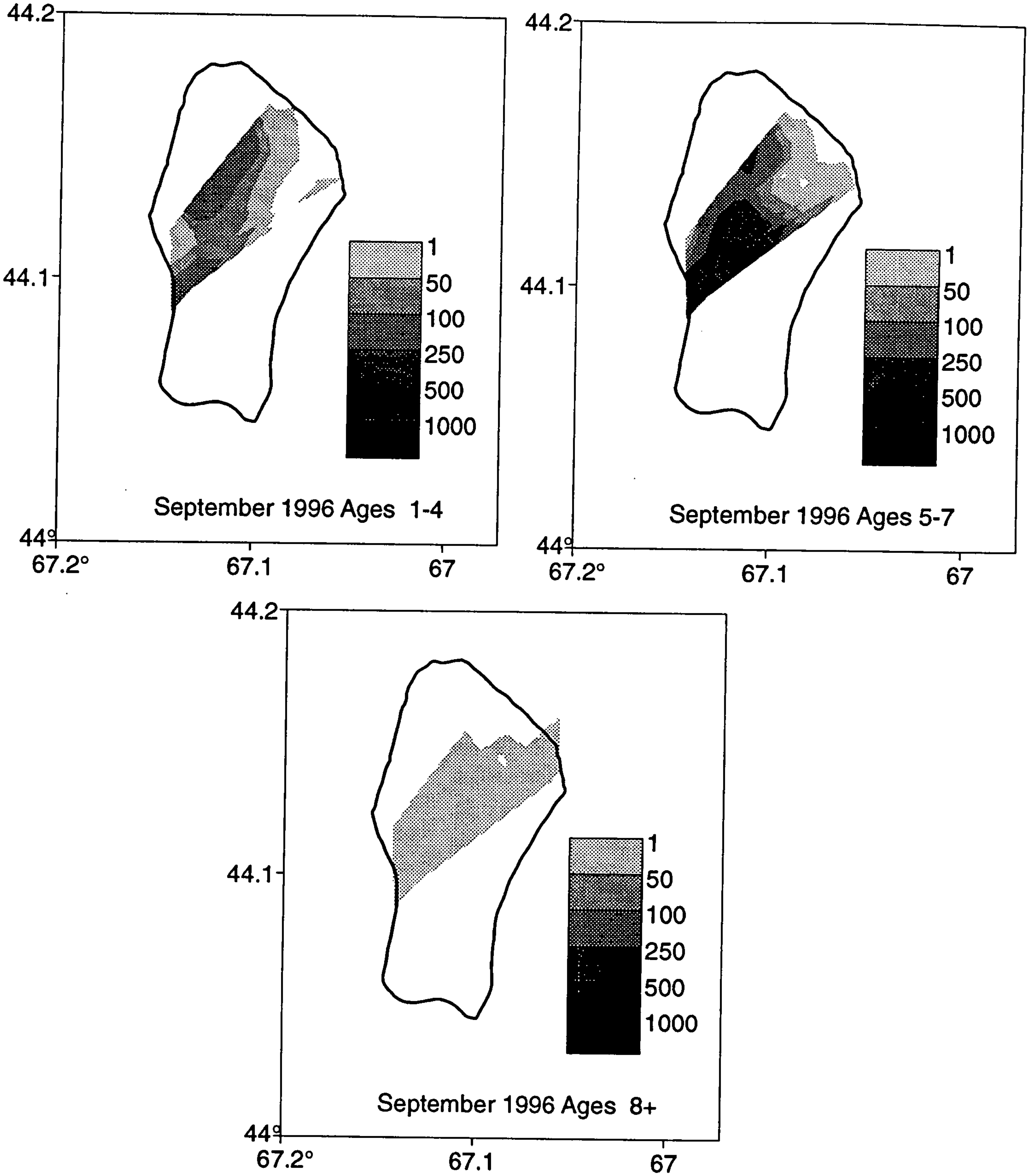


Figure 4. Spatial distribution of scallops on Southwest Bank by age group from abundance isopleths of 1996 survey data. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in lower corner of map).

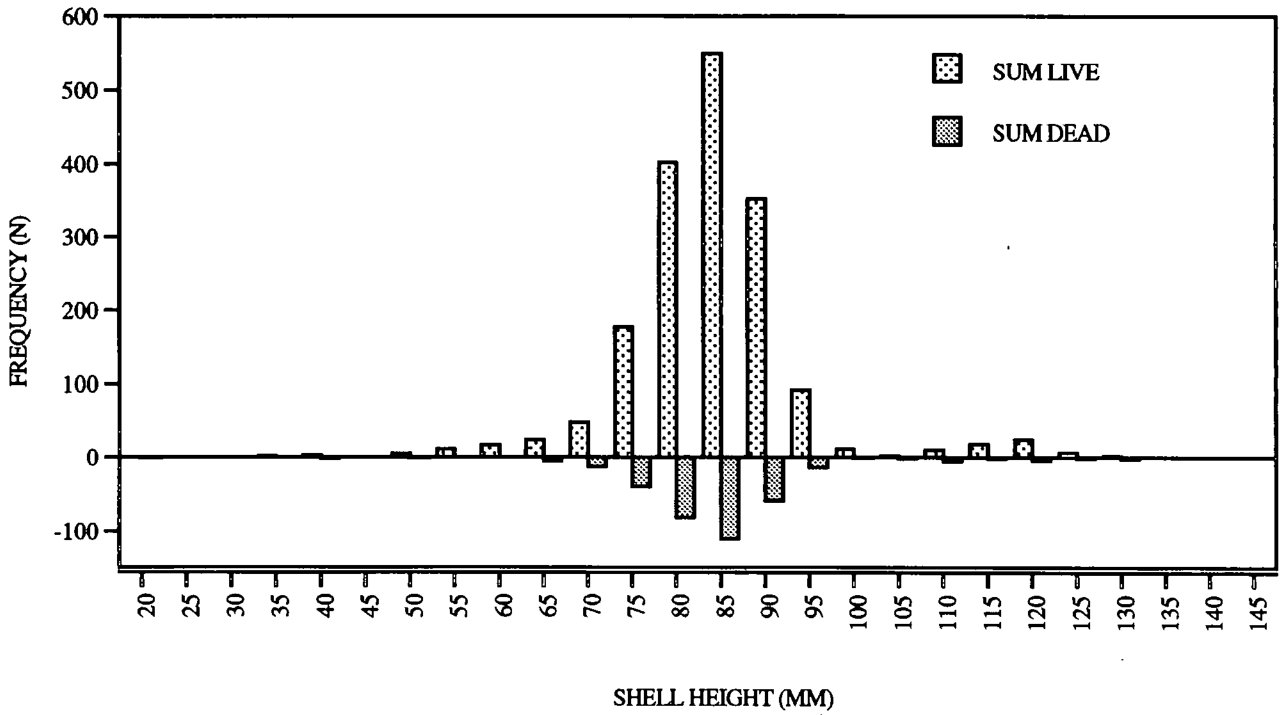


Figure 5. Shell height frequency distribution of scallops in the Southwest Bank survey area. The numbers of live animals appear above the line while the number of clappers (dead paired shells) appear below the line.

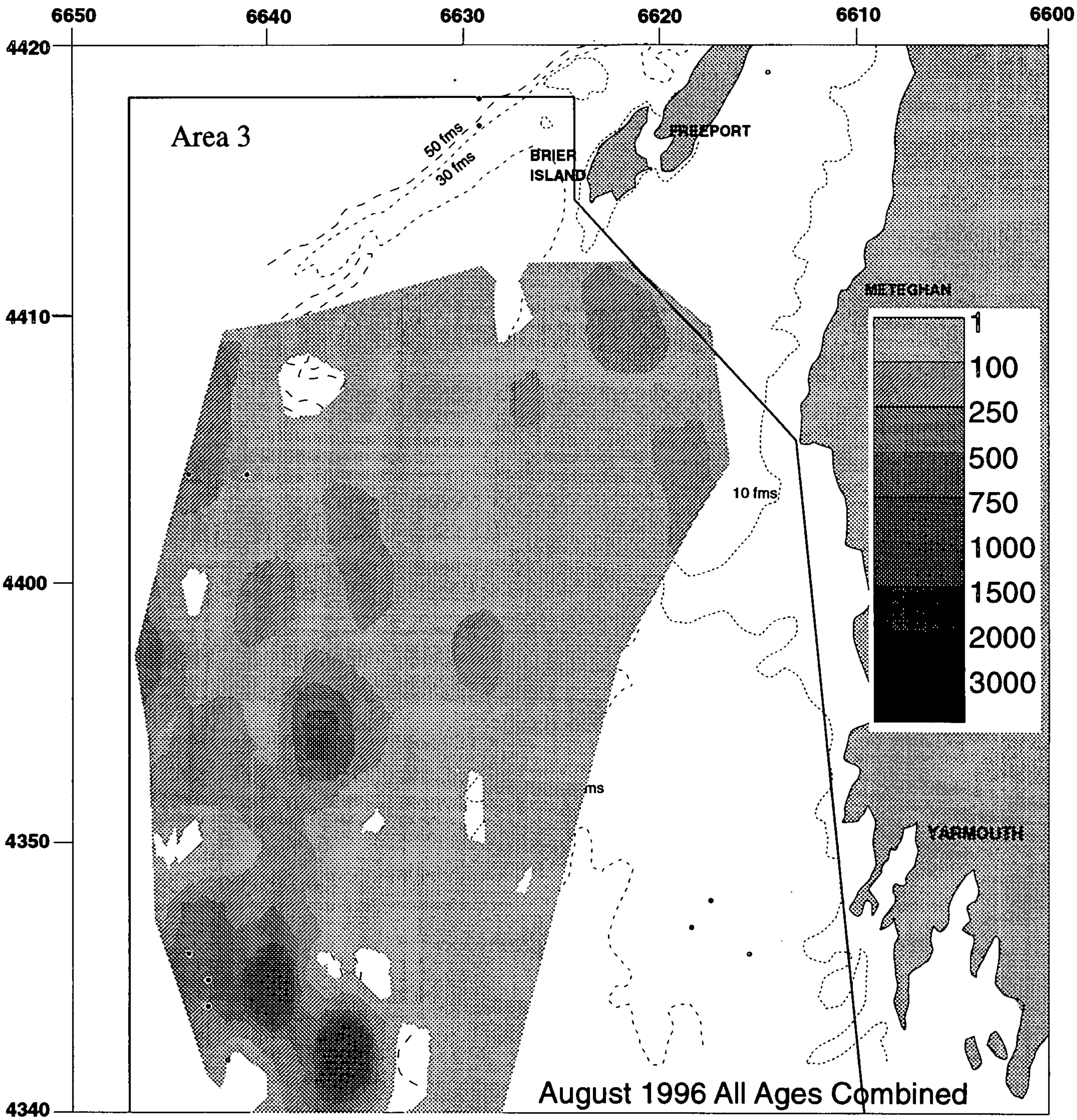


Figure 6. Spatial distribution of all ages combined in Area 3 from abundance isopleths of 1996 survey data. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in lower corner of plot). Dots refer to locations of port samples.

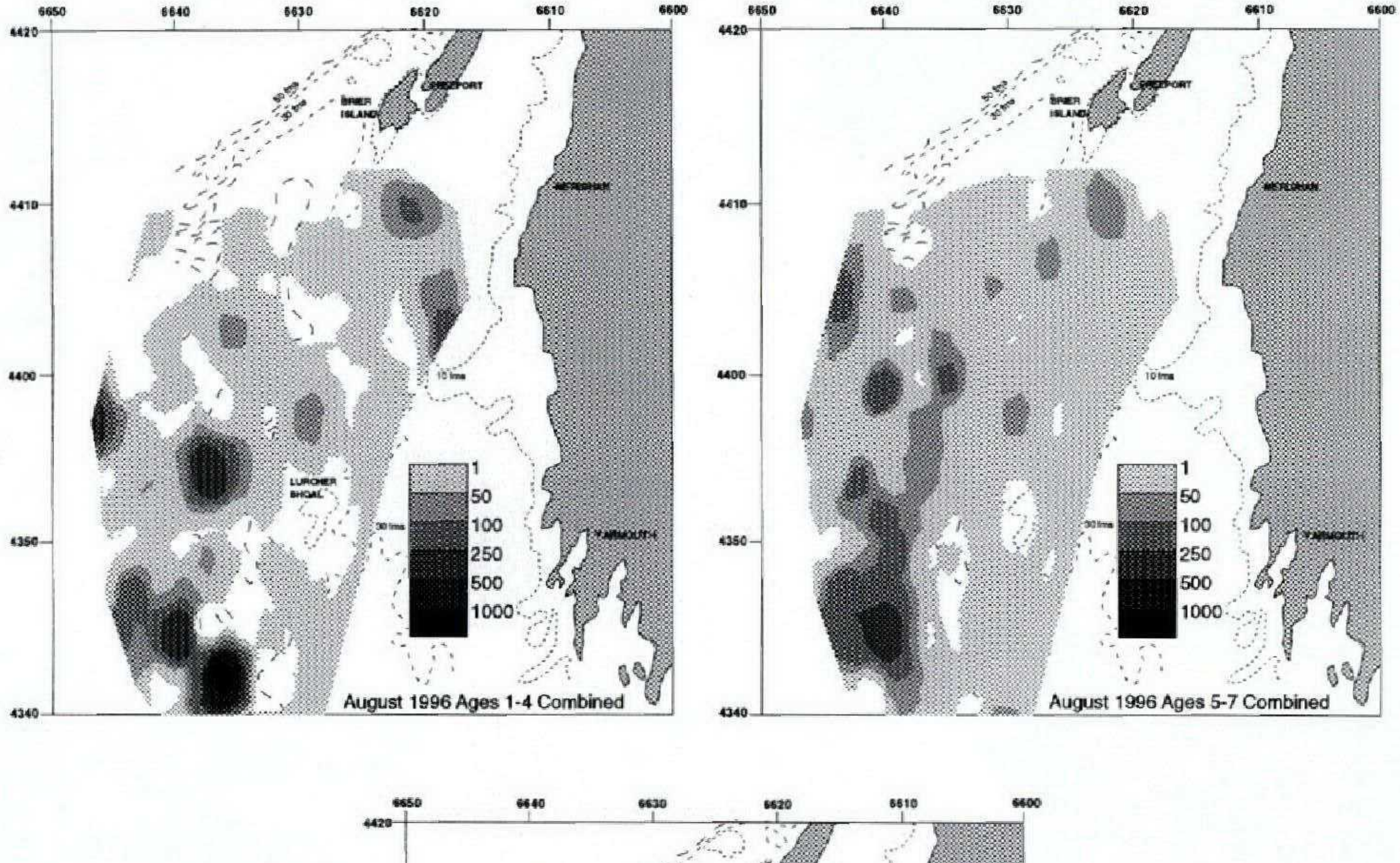


Figure 7. Spatial distribution of scallop age groups (1-4, 5-7, 8+) from abundance isopleths of 1996 survey data. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in lower corner of map).

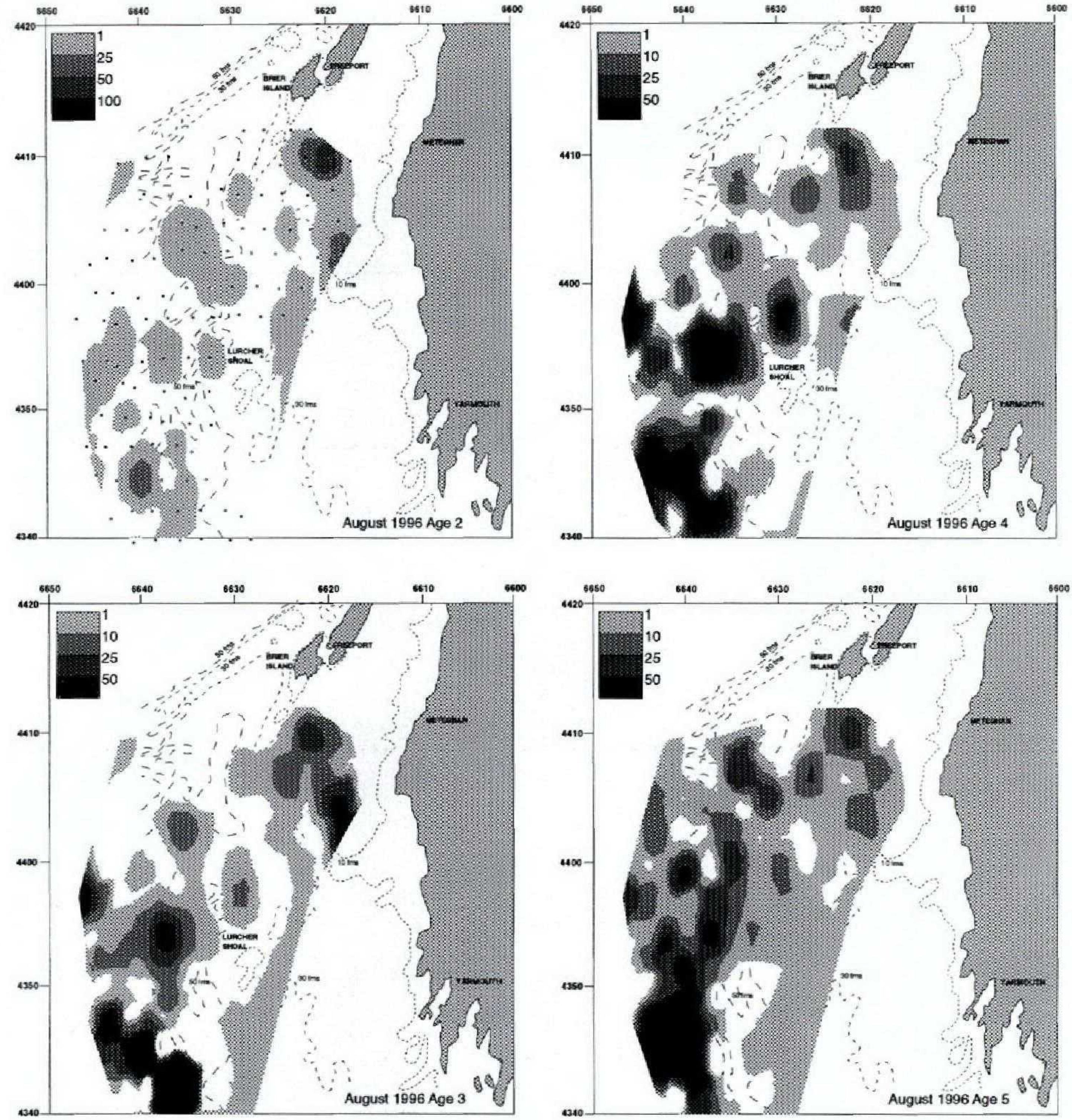


Figure 8. Spatial distribution of scallops by age in Area 3 determined from abundance isopleths of the 1996 research vessel survey. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in lower corner of plot). Tow locations depicted as dots on the age 2 plot.

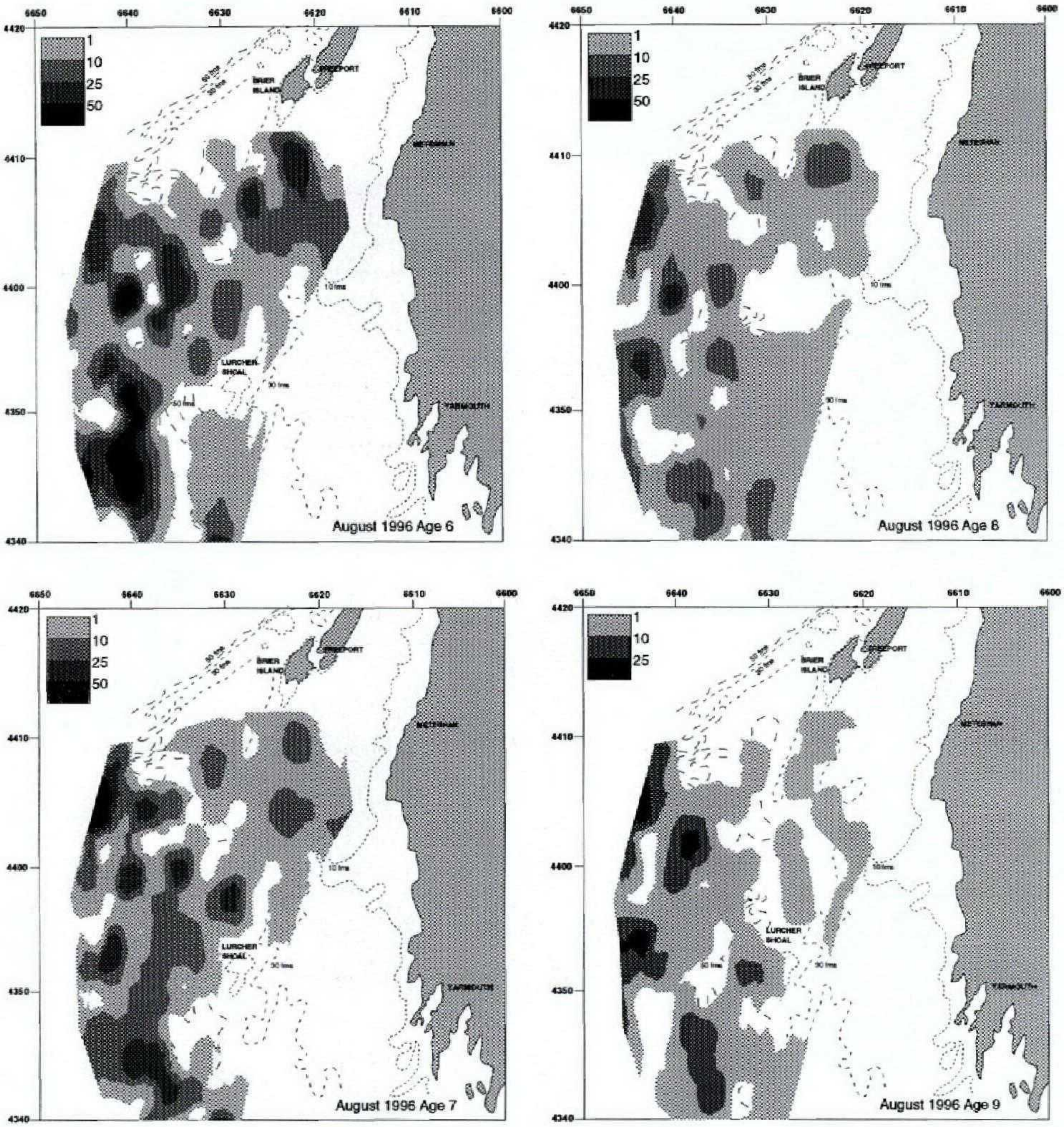
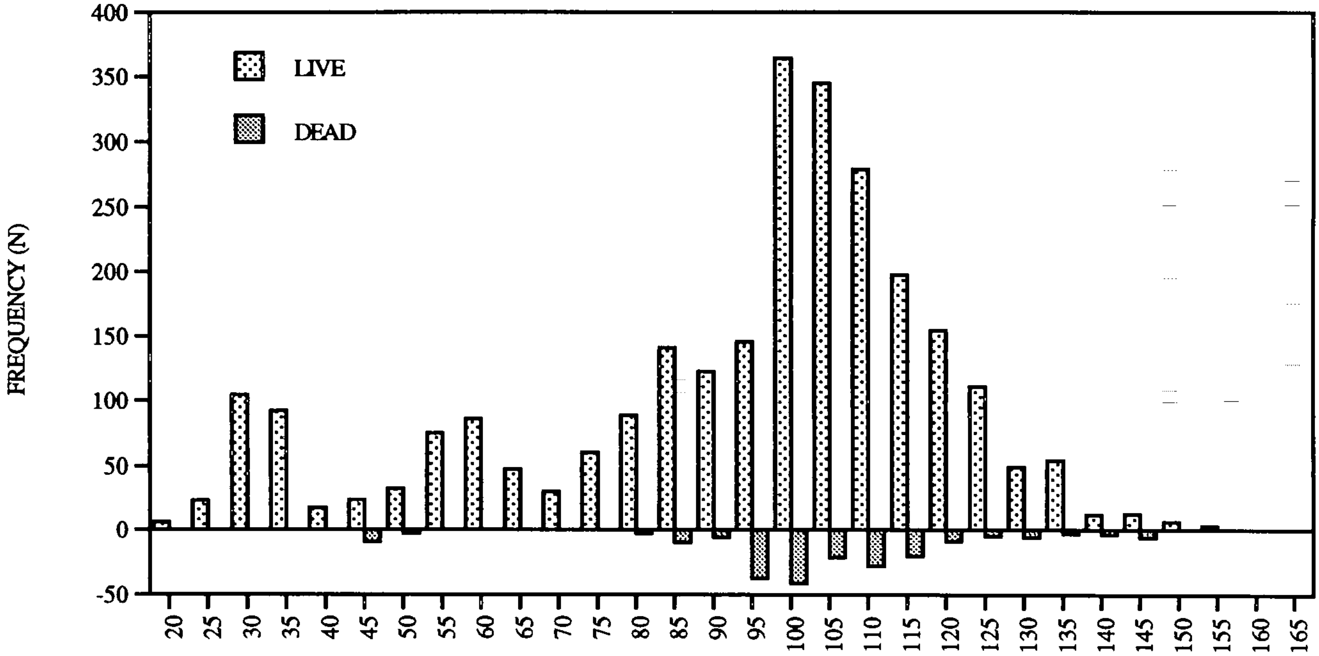


Figure 8 Cont'd. Spatial distribution of scallops by age.

FREQUENCY BRIER ISLAND



FREQUENCY LURCHER

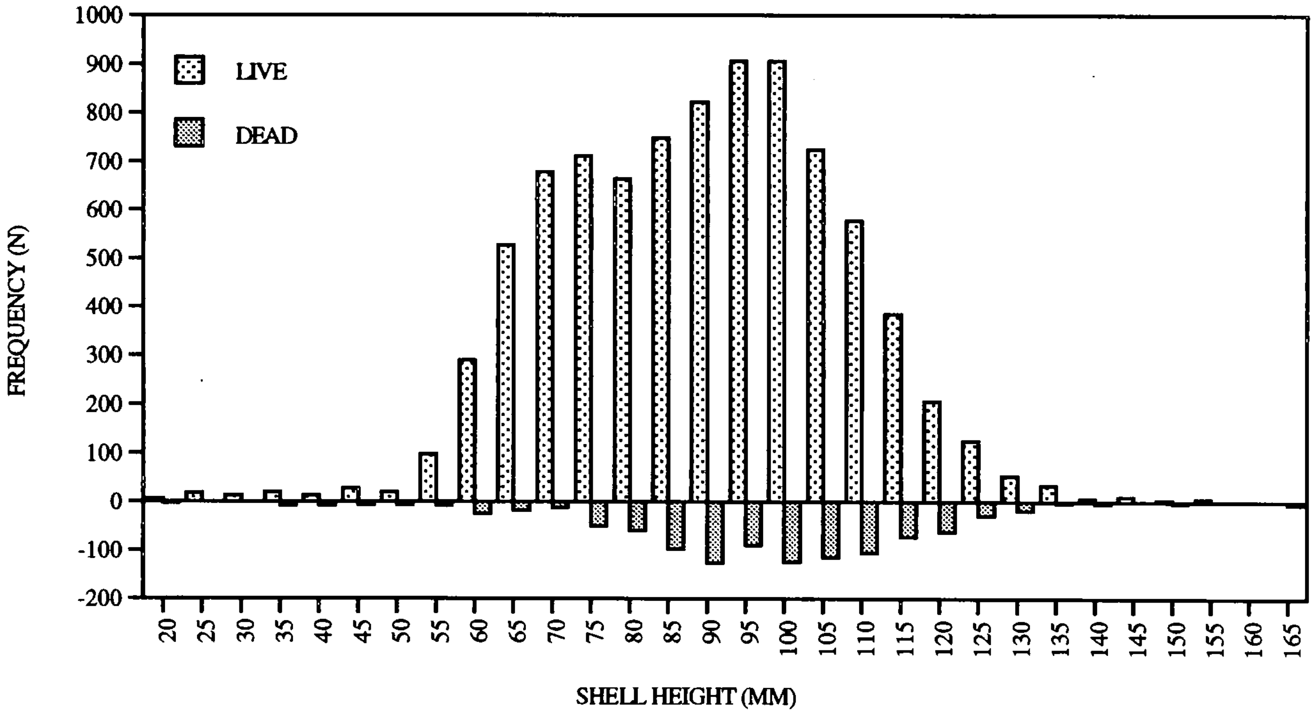


Figure 9. Shell height frequency distribution of the total number of live and dead (clappers) scallops caught during the August 1996 stock survey.

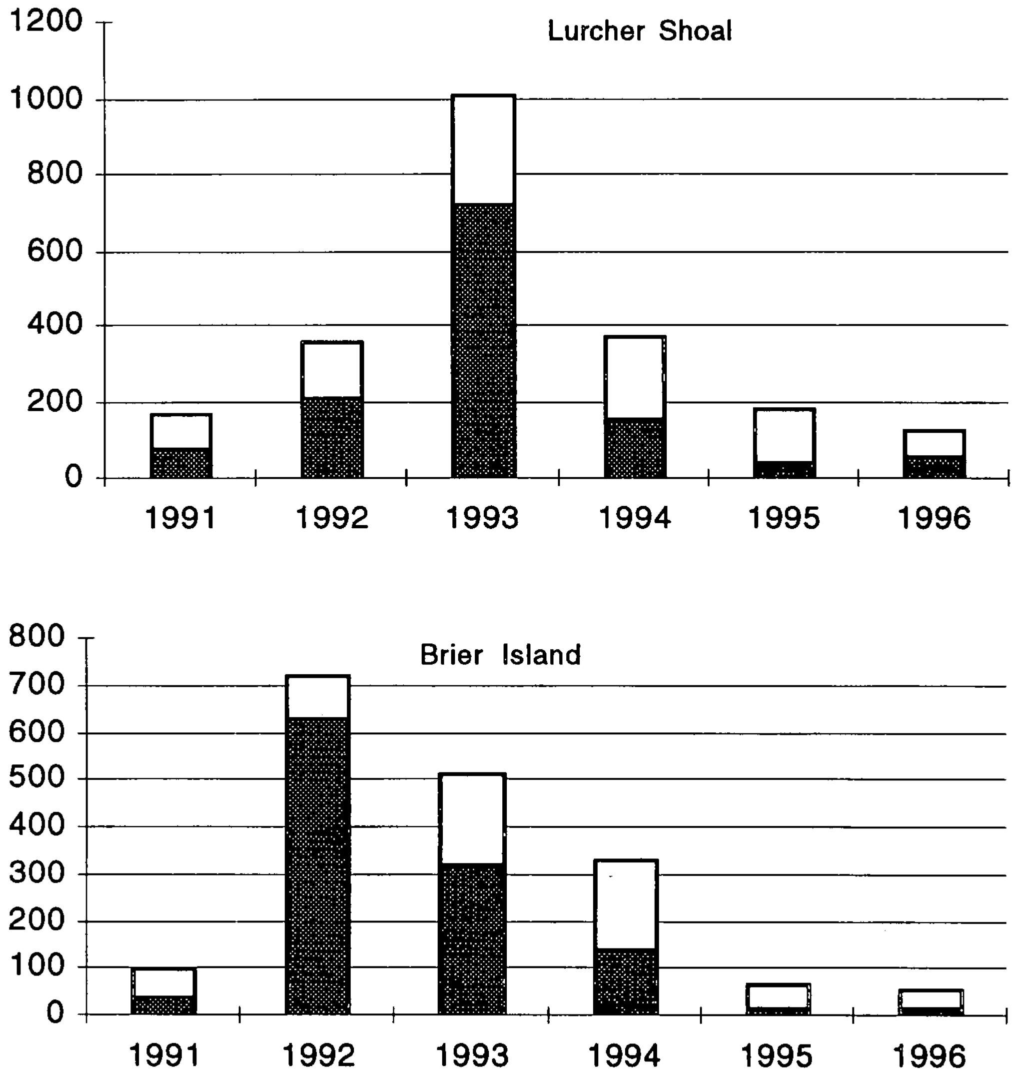


Figure 10. The relative number of prerecruit (dark box) and recruited scallops (ages 5+, open box) in Area 4, as determined from the average number of scallops per standard tow from the research vessel survey data. Data is broken down into Brier Island and Lurcher Shoal subareas.

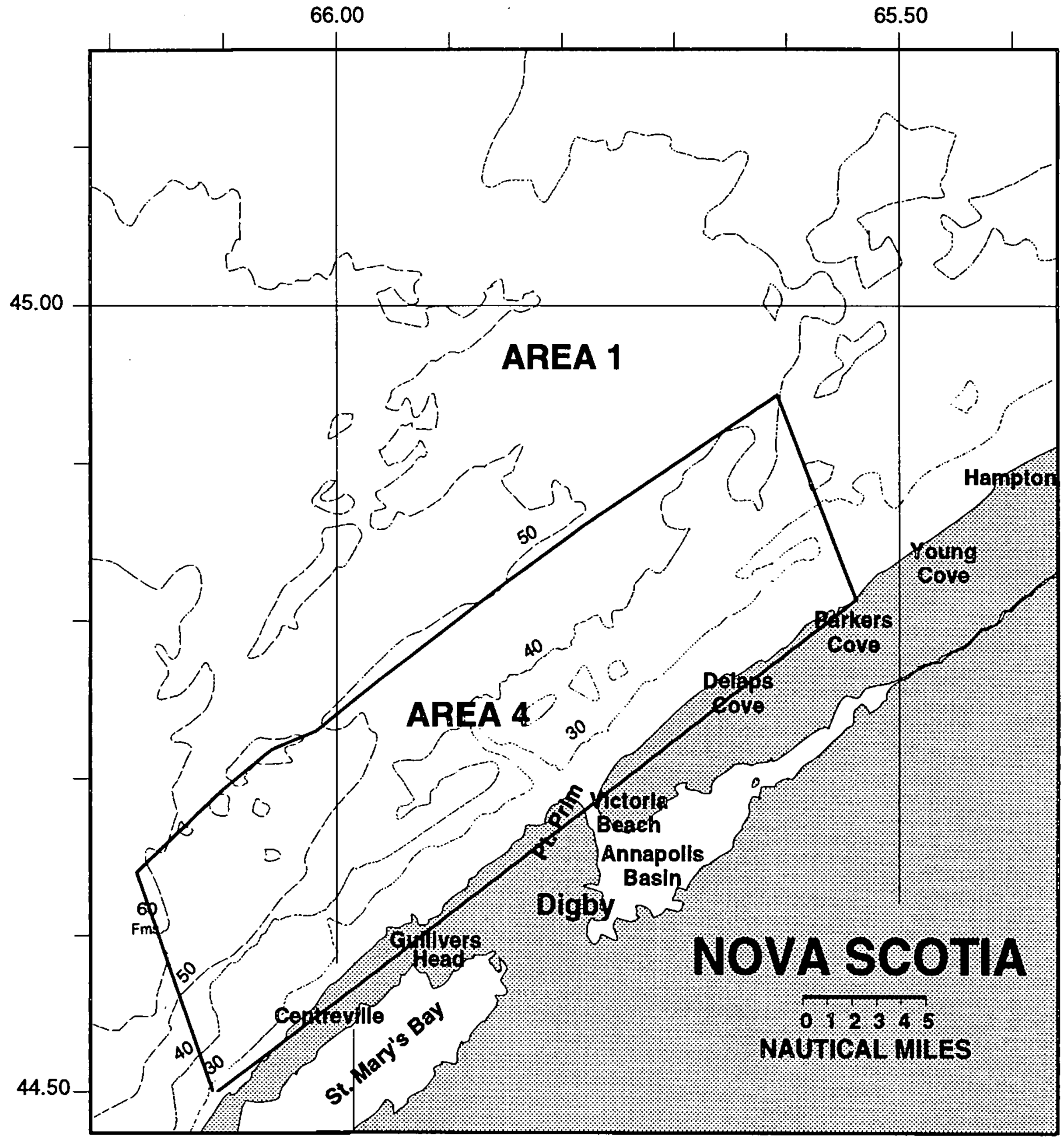


Figure 11. Location of the Area 4 boundaries with respect to landmarks on the Nova Scotia shoreline.

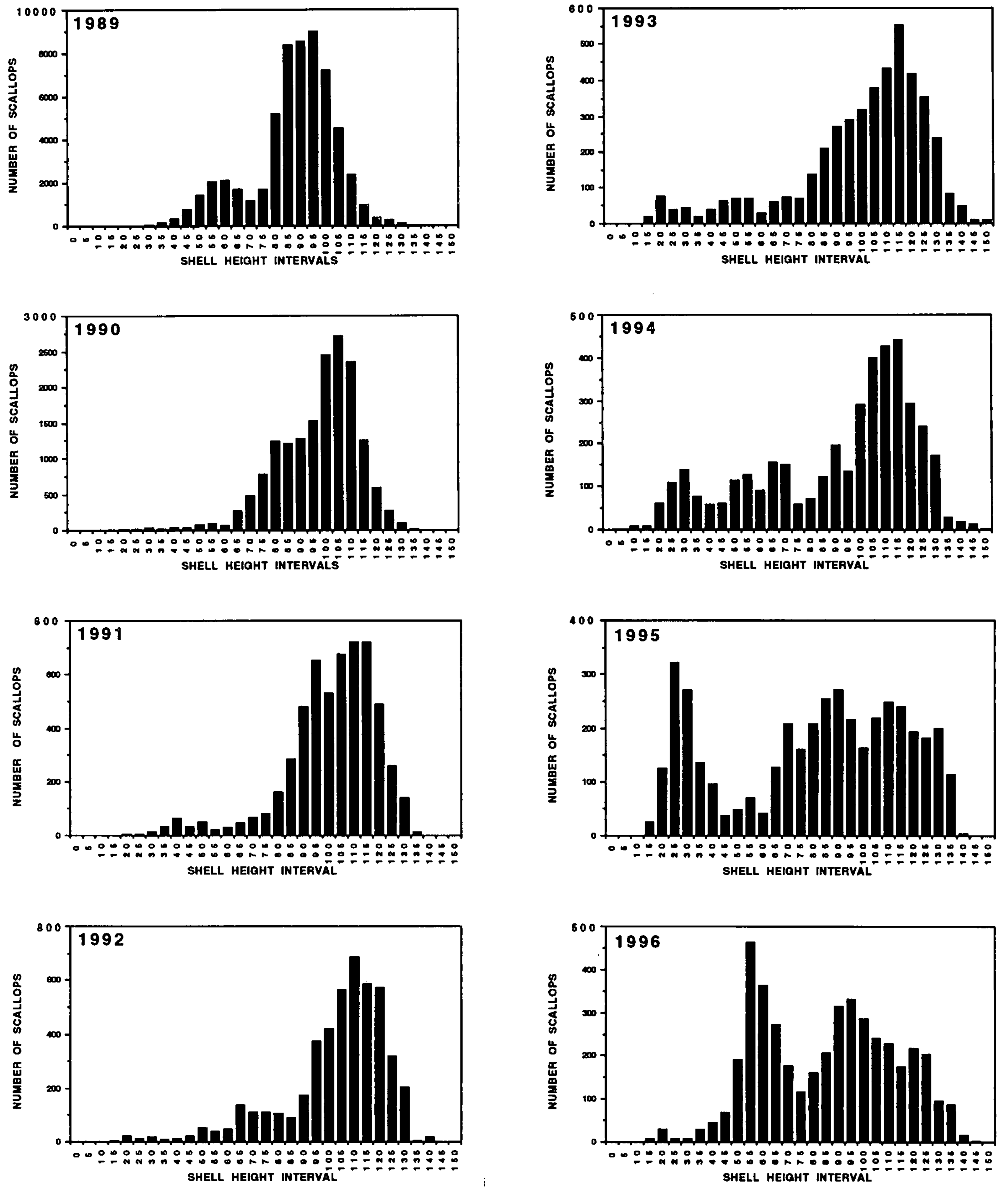


Figure 12. Shell height frequency distribution determined from the 1989-1996 Digby stock assessment survey of the Inside Fishing Zone (< 6 miles). Note the different scales.

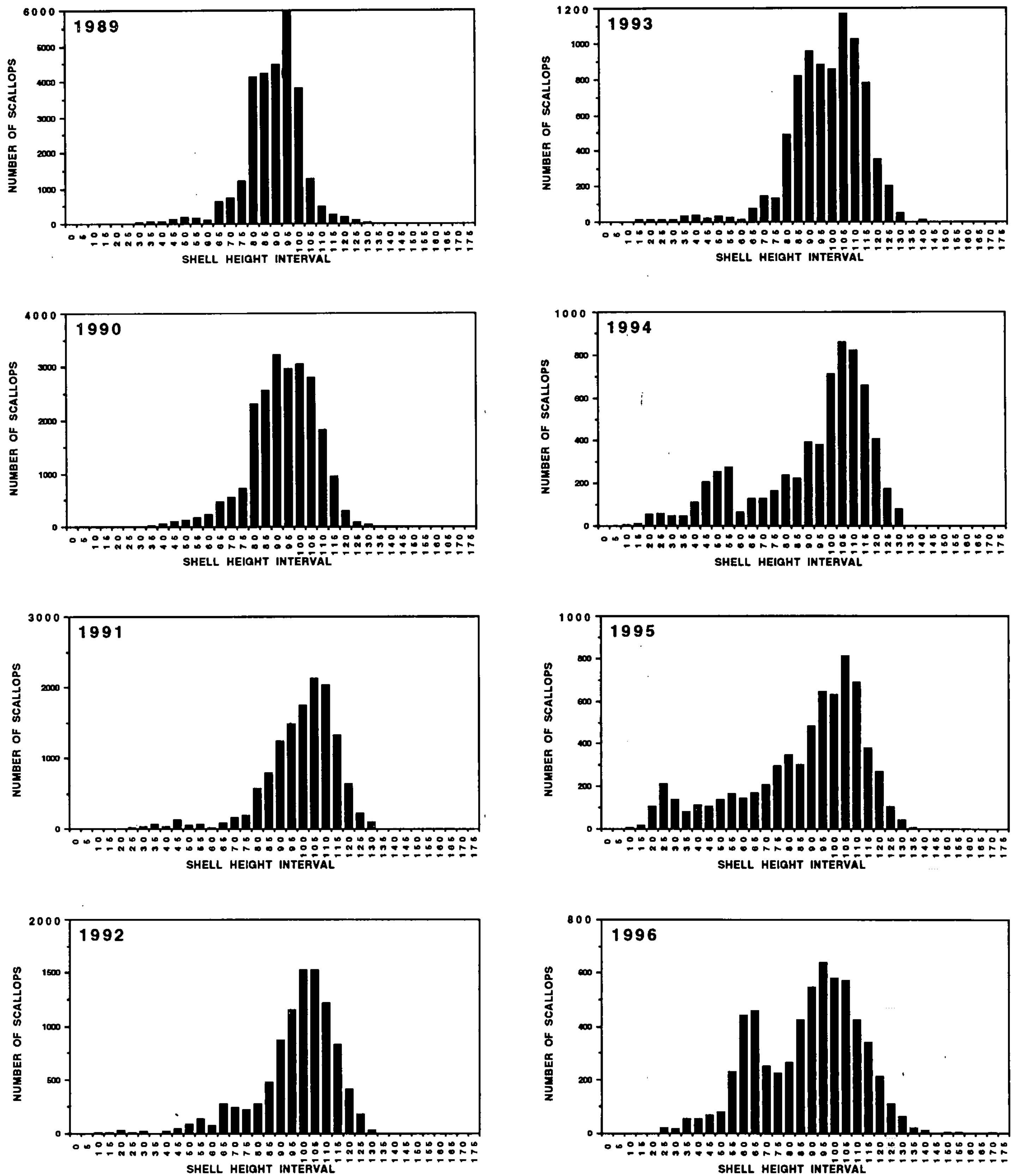
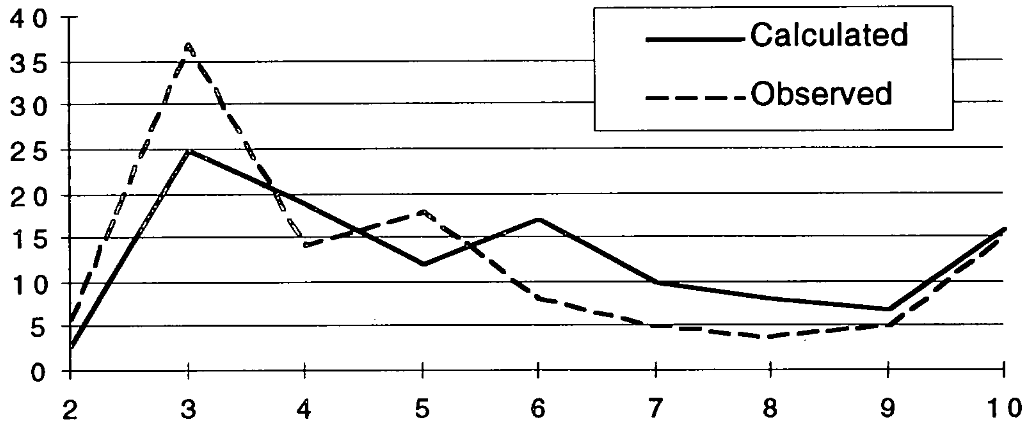
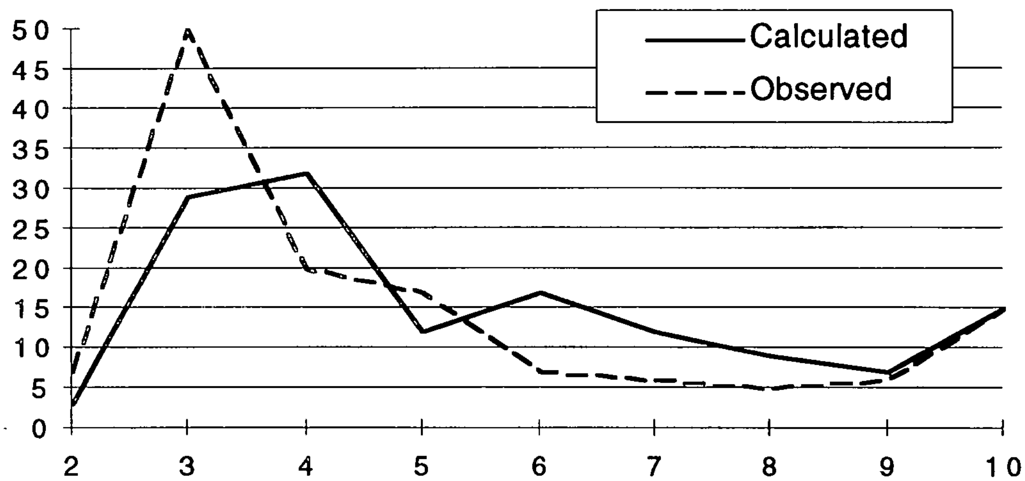


Figure 12. cont'd. Shell height frequency distribution determined from the 1989-1996 Digby stock assessment survey of the Outside Fishing Zone (> 6 miles). Note the different scales.

INSIDE ZONE



AREA 4



OUTSIDE ZONE

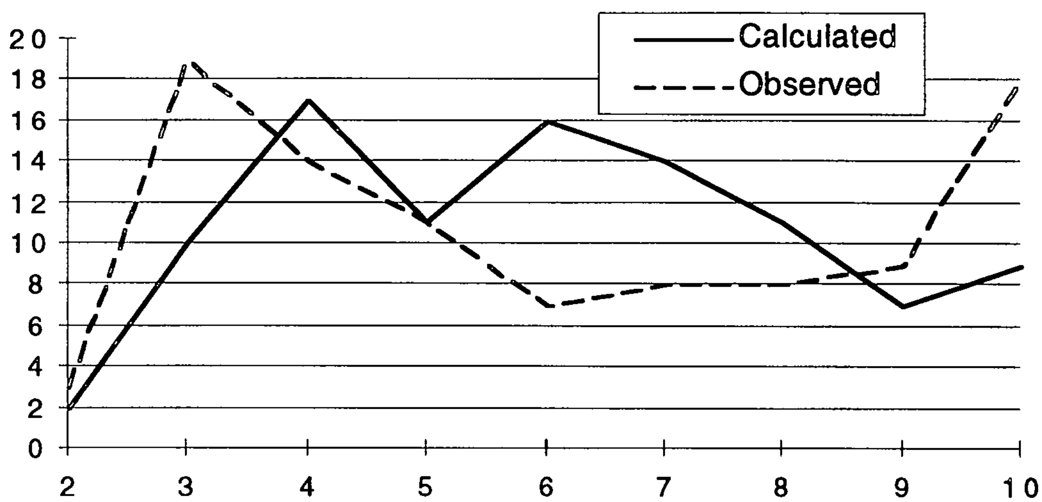


Figure 13. Comparison of observed age group means with those determined using depth defined growth curves for each of the Inside Zone, Area 4 and the Outside Zone based on 1996 survey data.

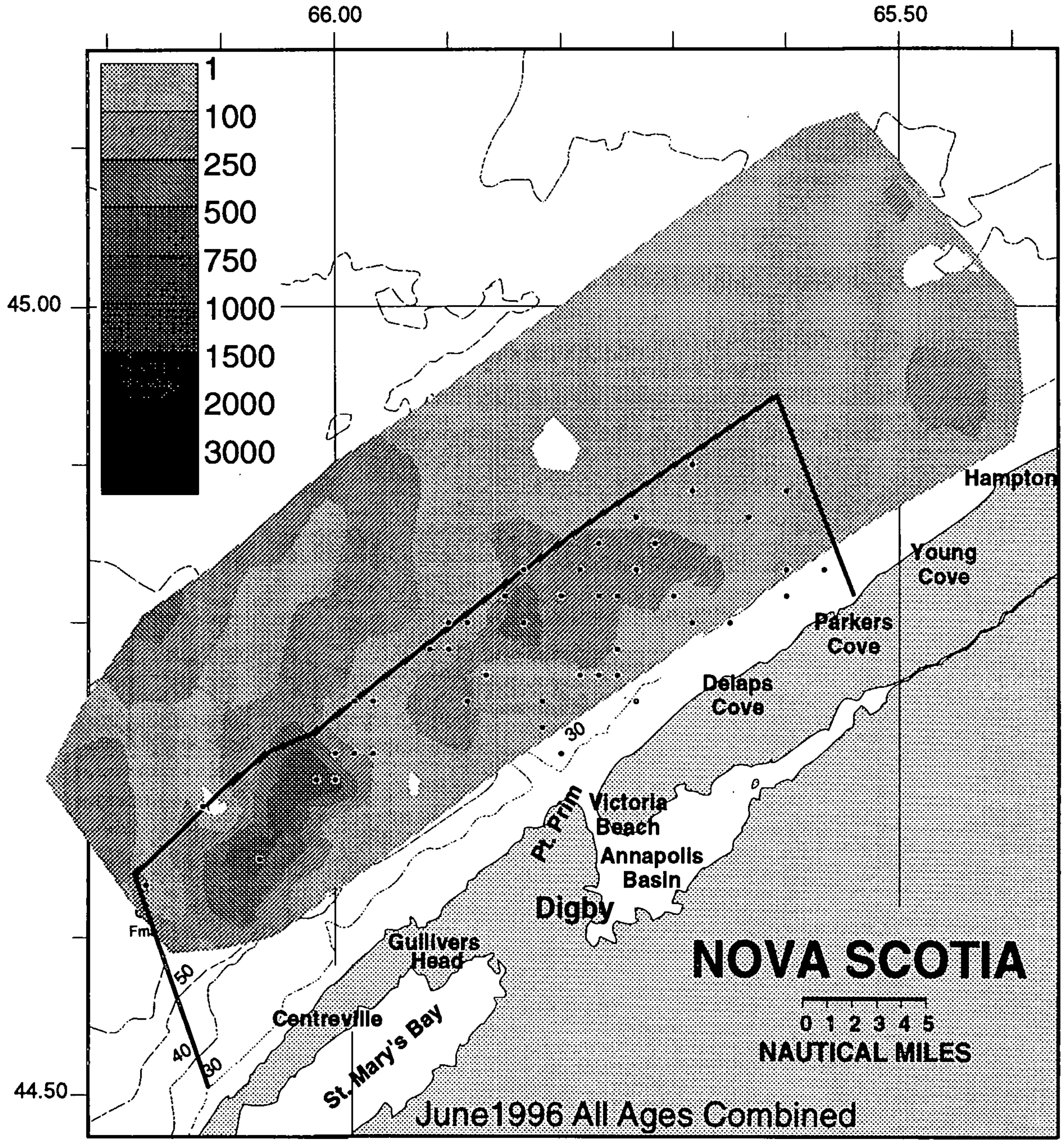


Figure 14. Spatial distribution of all ages combined in Area 4 (bold line) from abundance isopleths of 1996 survey data. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in upper corner of map). Dots refer to locations of port samples.

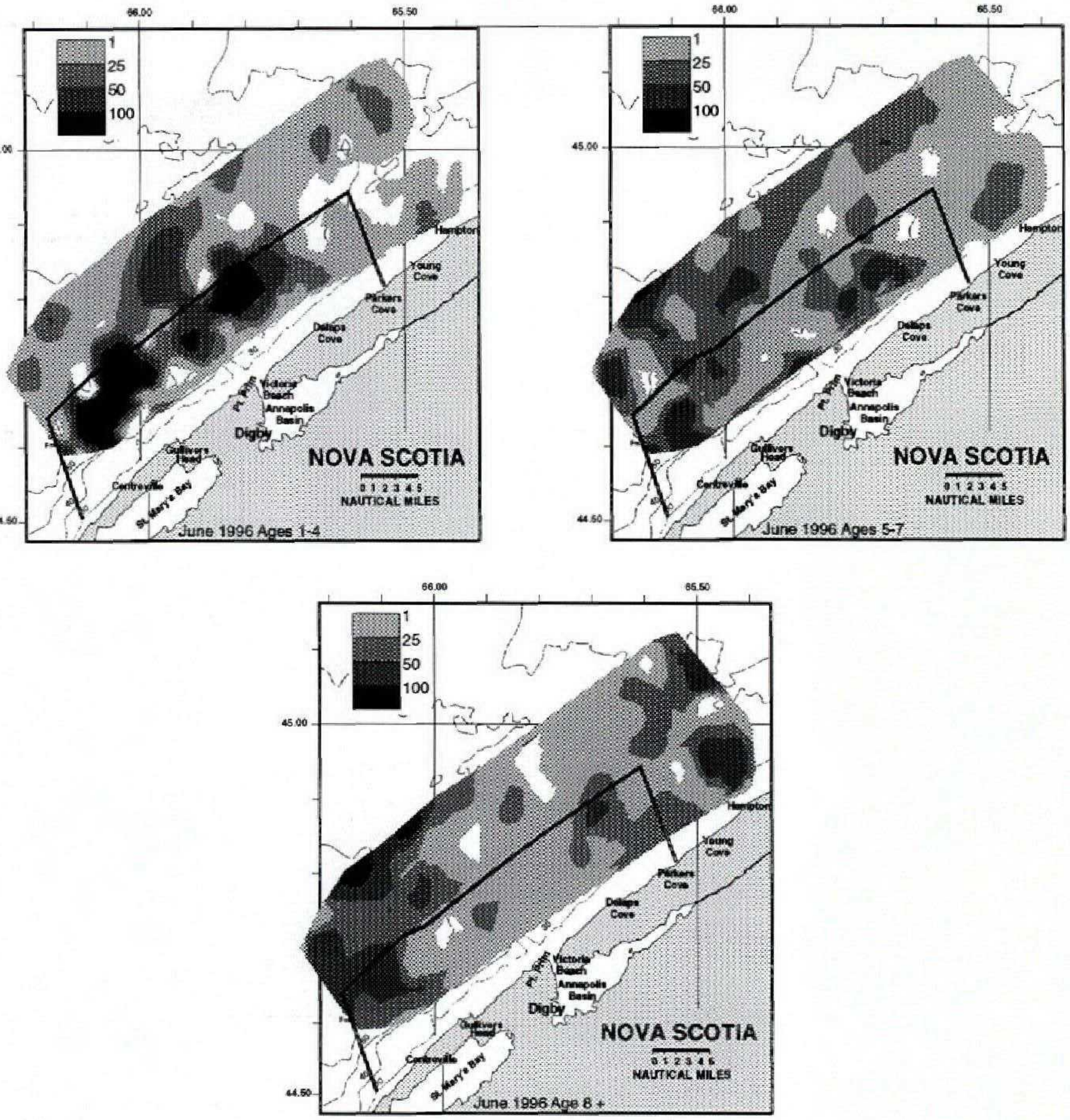


Figure 15. Spatial distribution of scallop age groups (1-4, 5-7, 8+) from abundance isopleths of 1996 survey data. Darakening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in upper corner of plot).

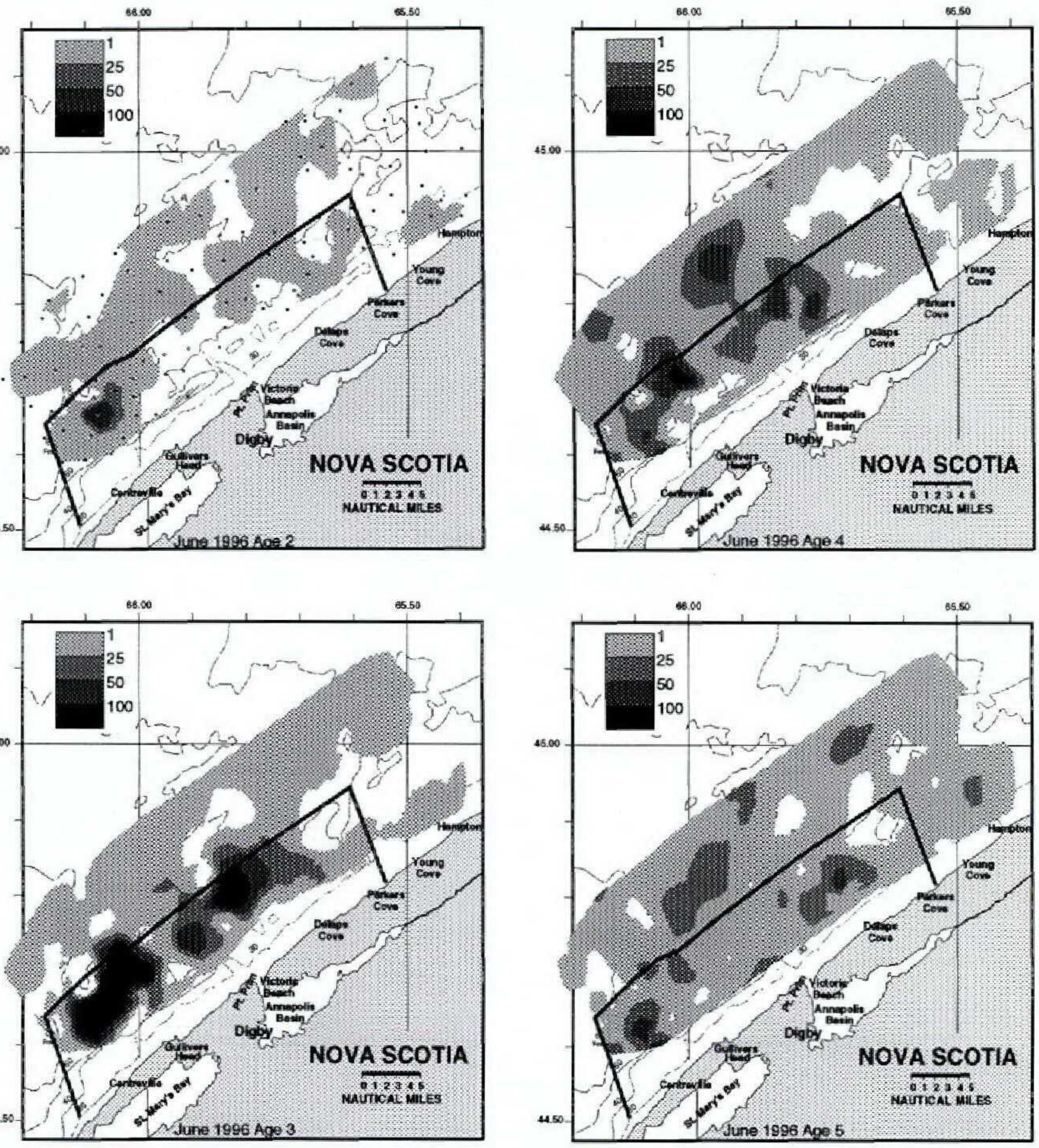


Figure 16. Spatial distribution of scallops by age in Area 4 determined from abundance isopleths of the 1996 research vessel survey. Darkening shades of grey within isopleths refer to increasing number of scallops per standard tow (grey scale in lower corner of plot). Tow locations depicted as dots on the age 2 plot. Note the different scales.

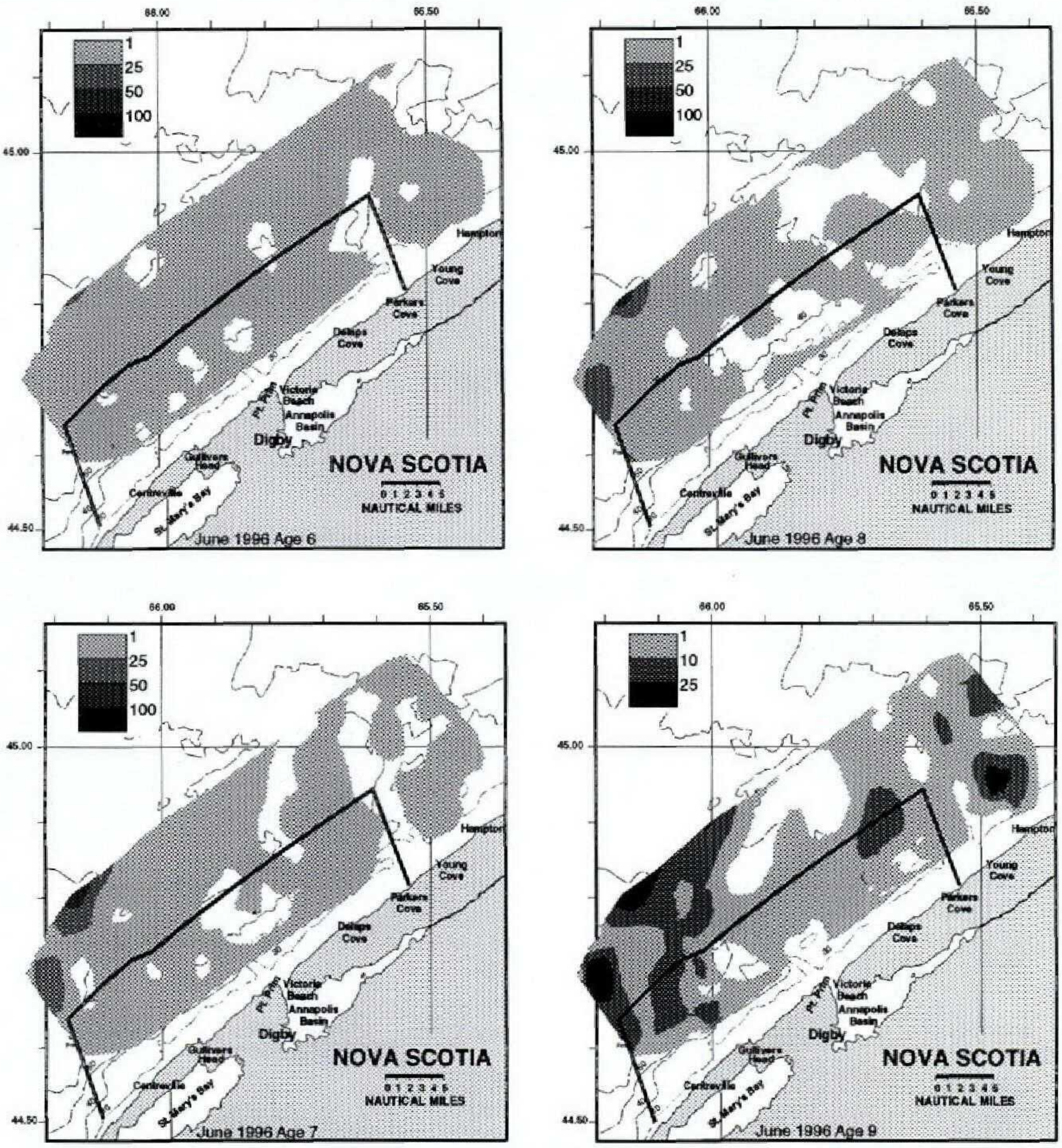
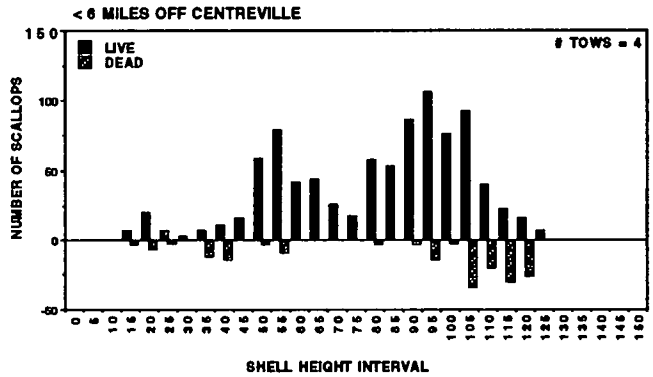
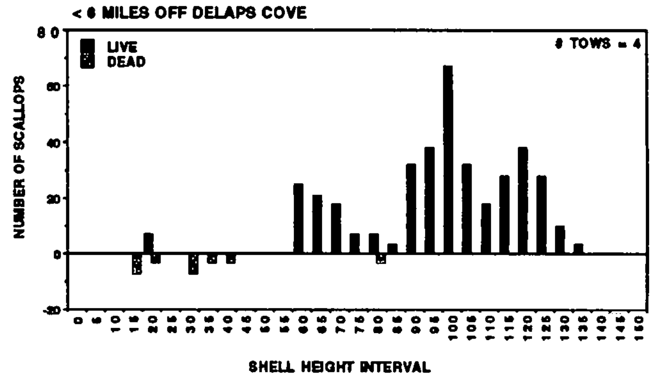
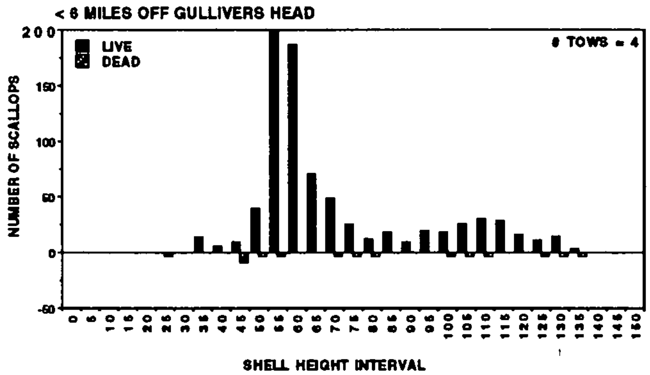
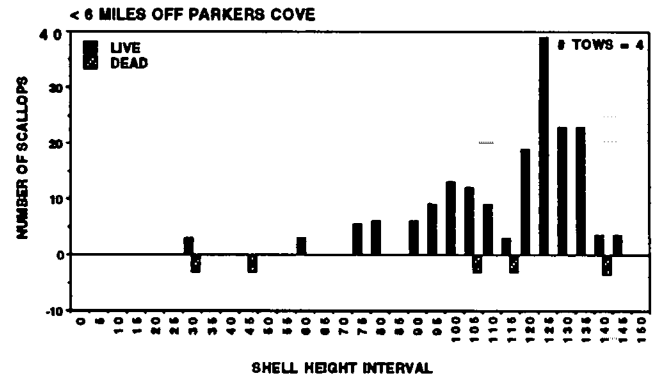


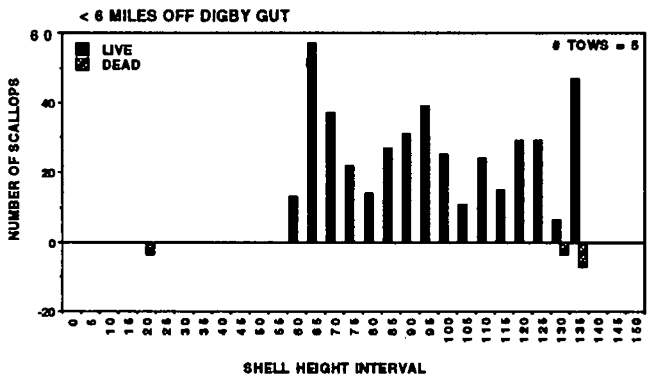
Figure 16 Cont'd. Spatial distribution of scallops by age.

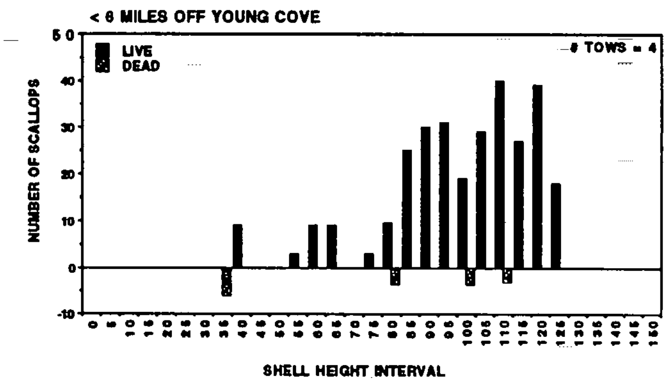












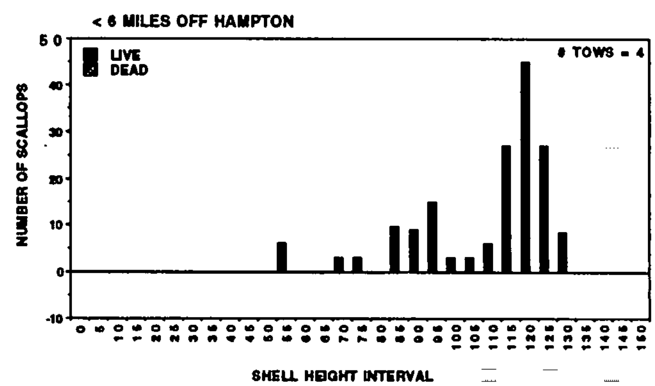
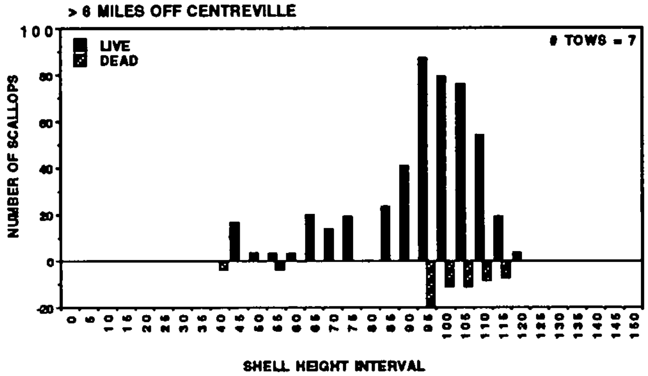
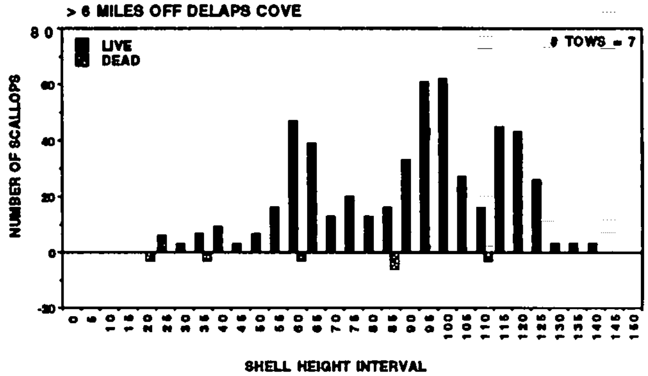
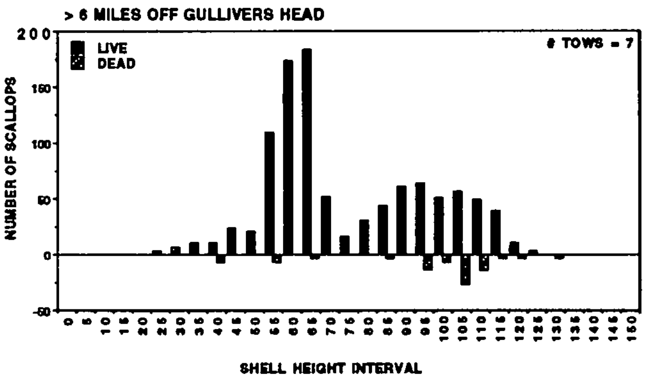
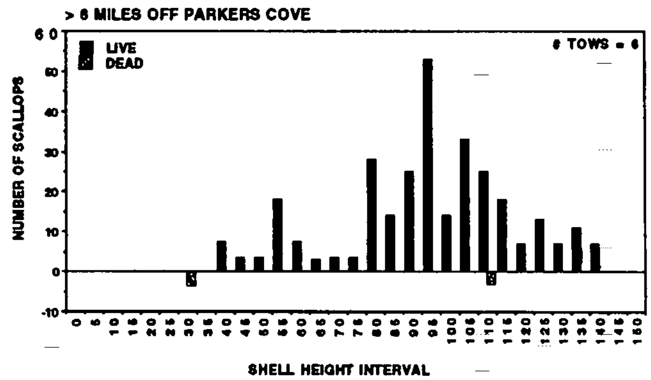


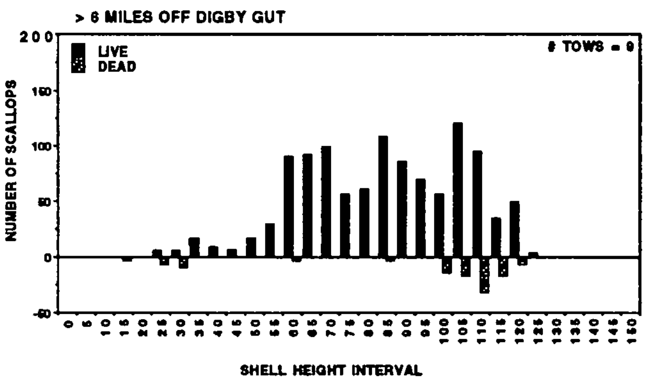
Figure 17. The shell height frequency distribution of live scallops (above line) and dead scallops (below line) for the Inside and Outside Zones off Digby. Note the different scales..











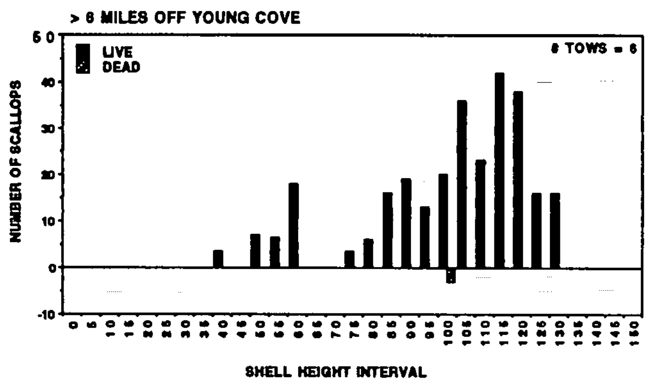
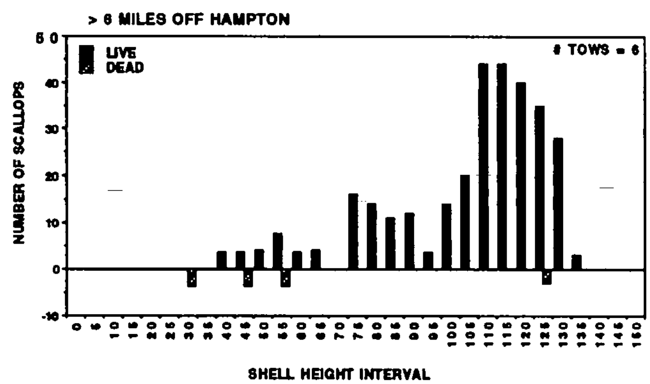
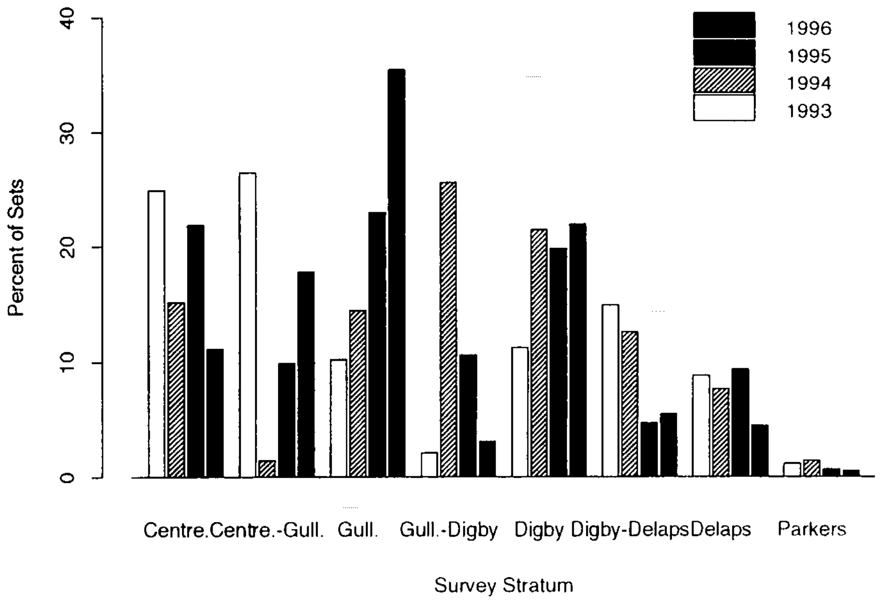


Figure 17 cont'd. The shell height frequency distribution of live scallops (above line) and dead scallops (below line) for the Inside and Outside Zones off Digby. Note the different scales.



AGES 1-4



AGE 5+

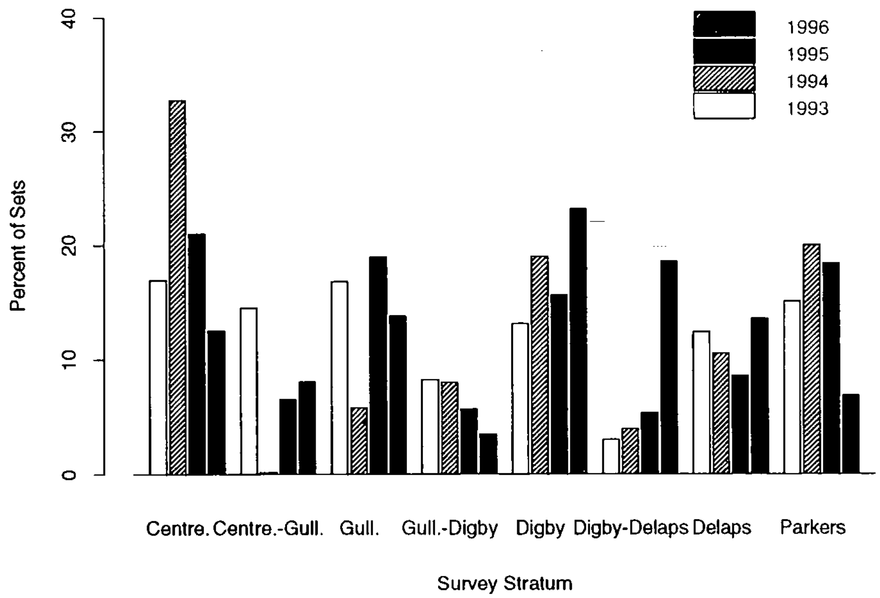


Figure 18. The percentage of the total sets that would be assigned to each stratum in an optimal allocation for the years 1993 to 1996.

ALL AGES COMBINED

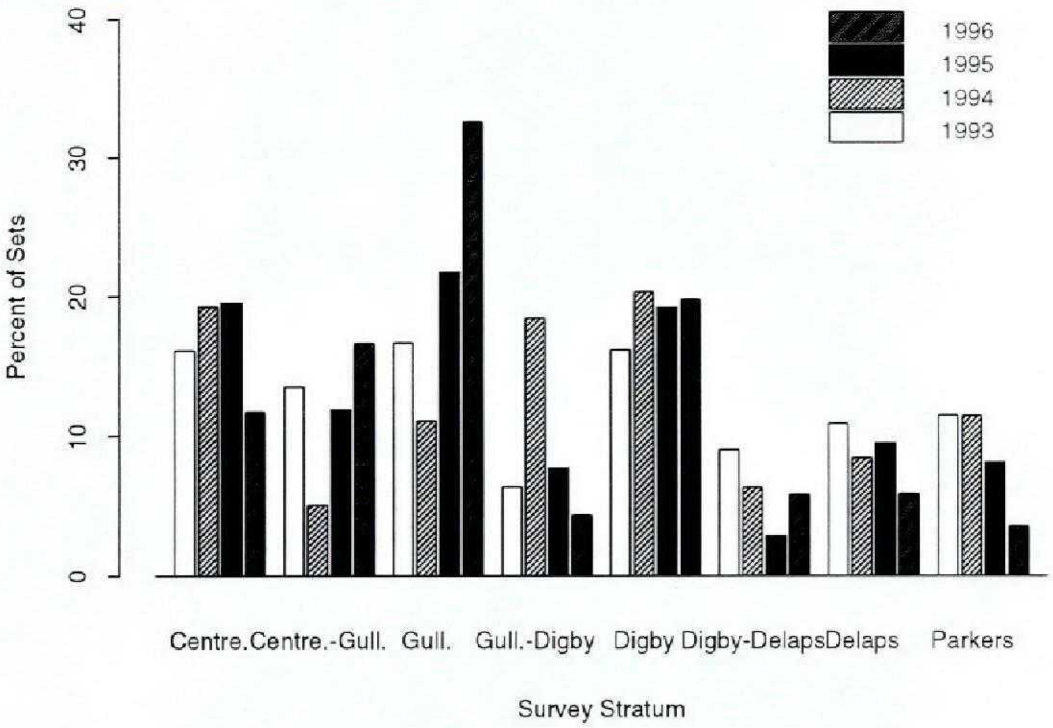


Figure 18. cont'd. The percentage of the total sets that would be assigned to each stratum in an optimal allocation for the years 1993 to 1996.

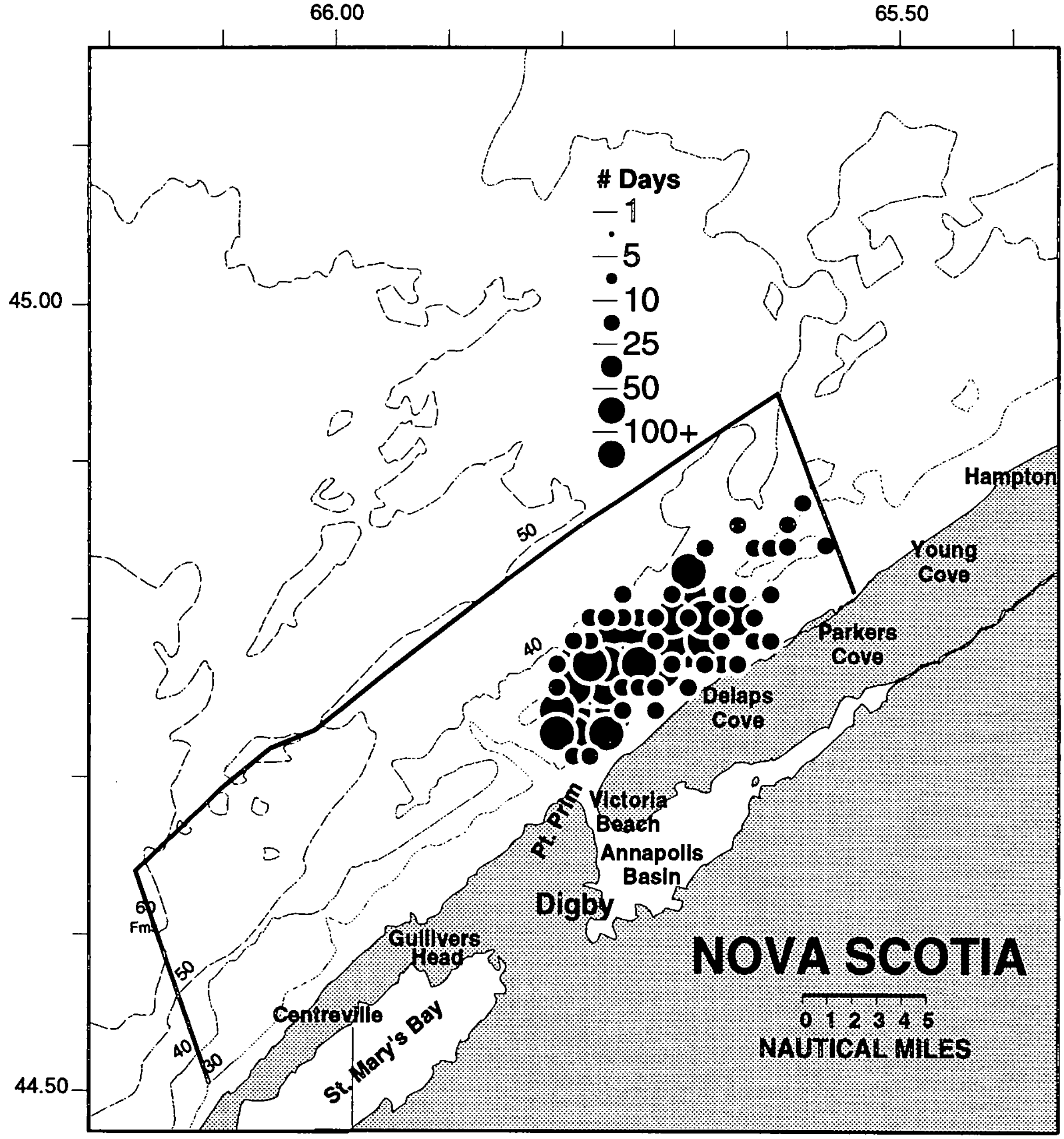
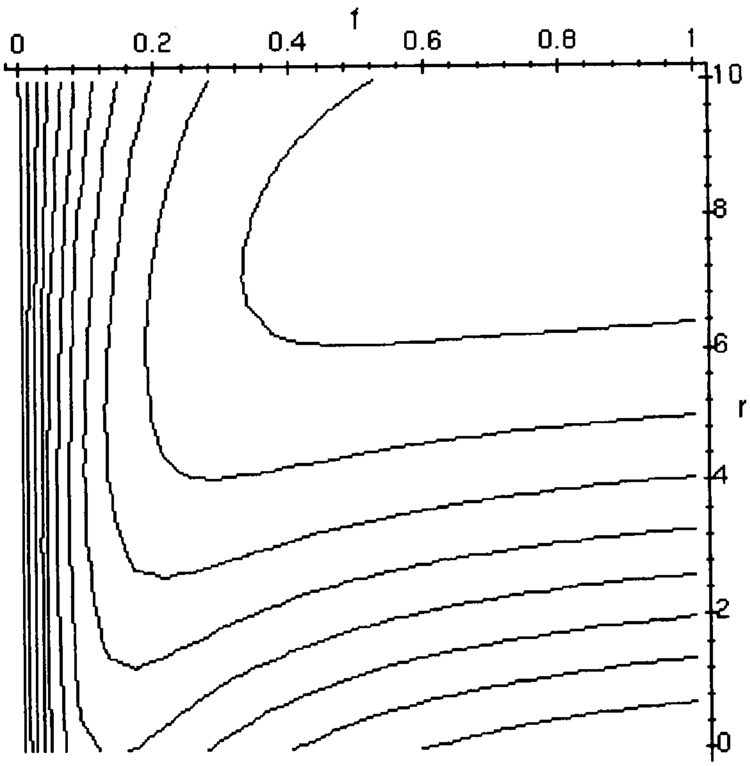
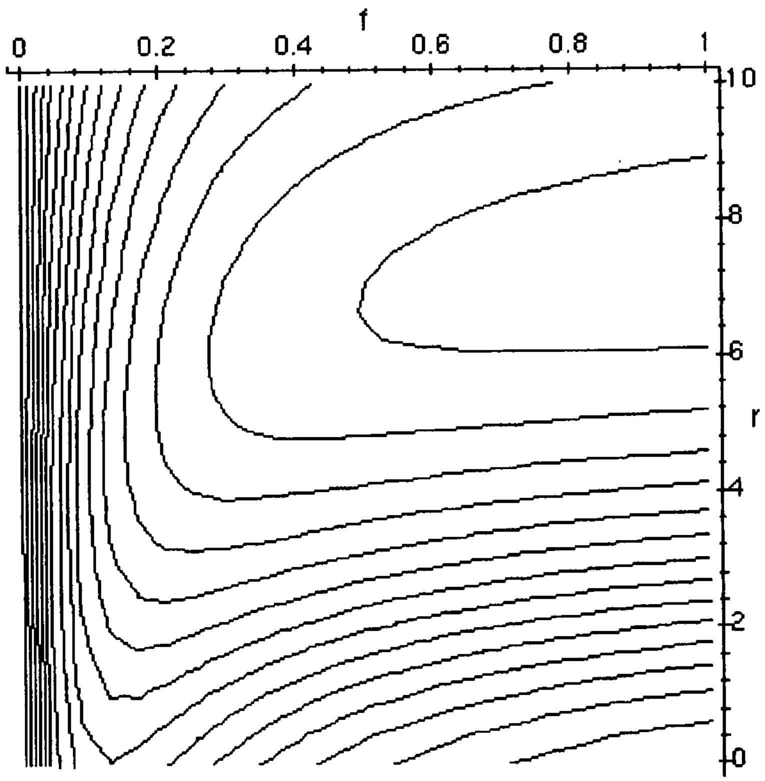


Figure 19. Location of fishing effort (days) during the 1996 fishery in Area 4.

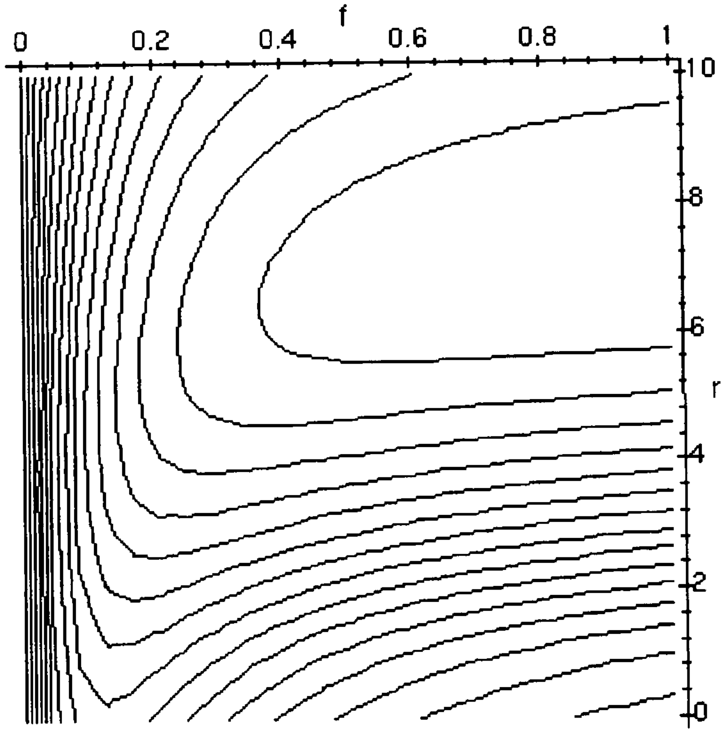


Area 2 Southwest Bank

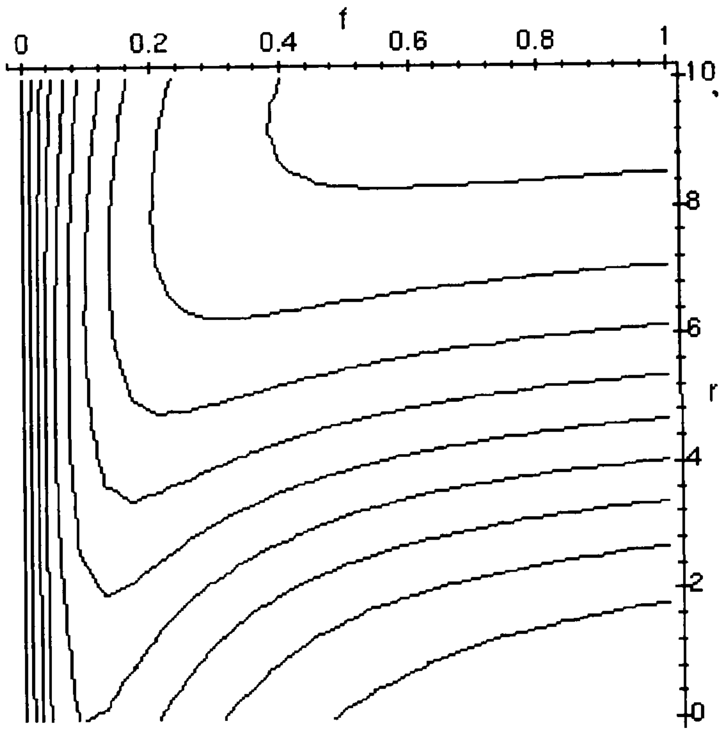


Area 3 Brier Island/Lurcher Shoal

Figure 20. Yield isopleth diagrams for Areas 2, 3, 4, and 5 produced using the Beverton and Holt model. The axes are Fishing Mortality (f) and Age-at-first-Capture (r).



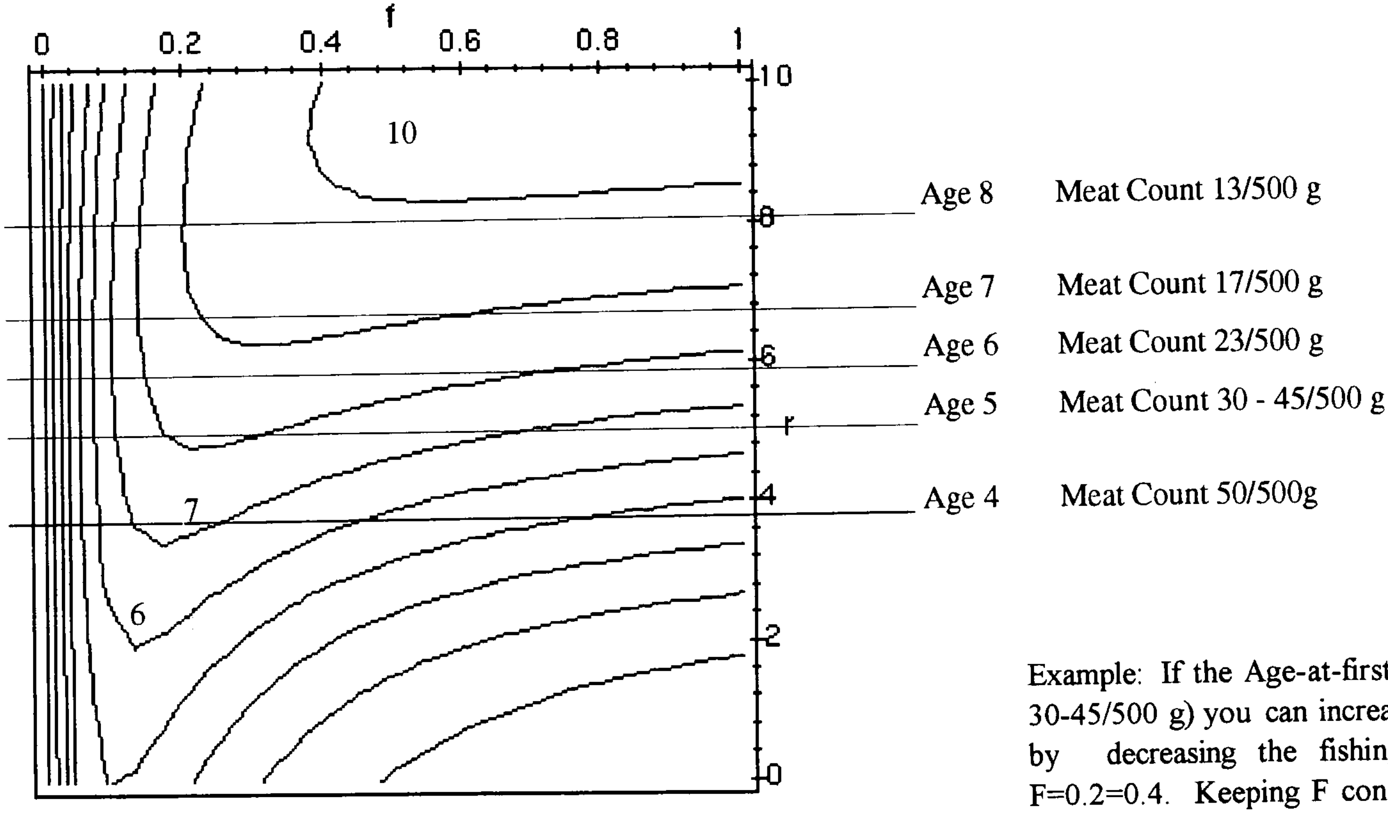
Area 4 Digby



Area 5 Annapolis Basin

Figure 20 cont'd. Yield isopleth diagrams for Areas 2, 3, 4, and 5 produced using the Beverton and Holt model. The axes are Fishing Mortality (f) and Age-at-first-Capture (r).

Area 5 Annapolis Basin Yield Isopleth Diagram



Example: If the Age-at-first-Capture is 5 (meat count 30-45/500 g) you can increase the yield by 1/7 (14%) by decreasing the fishing effort from F=0.8 to F=0.2=0.4. Keeping F constant at F=0.8 you would have to leave the animals in the water one year longer (Age-at-first-Capture) to achieve the same effect through changing the meat count to 23/500 g.

Figure 21. Use of the yield isopleth diagram to discern the potential effect of meat count changes on yield under different fishing effort scenarios.

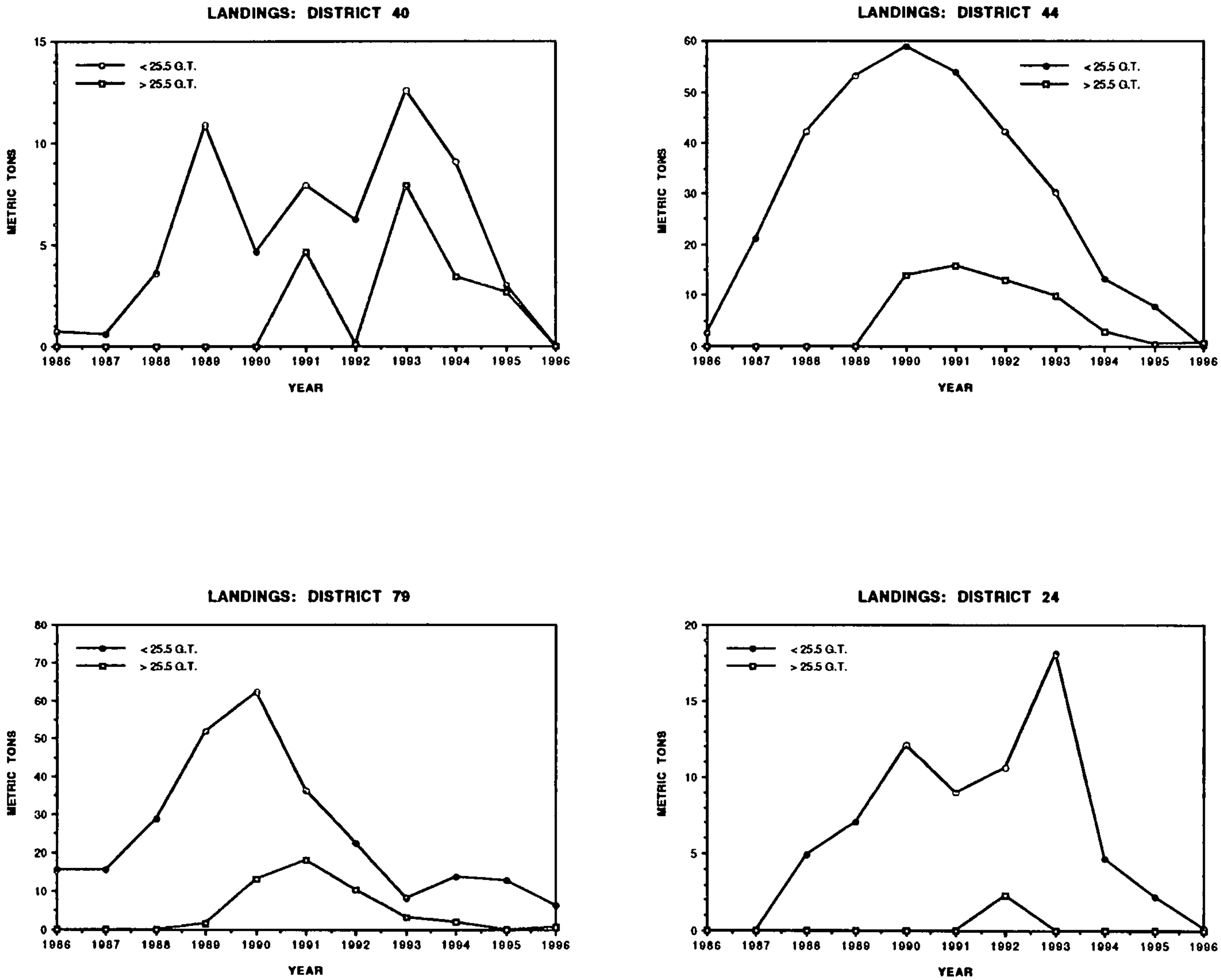


Figure 22. Annual landings (1986-1996) for the Upper Bay Districts by vessel size class.

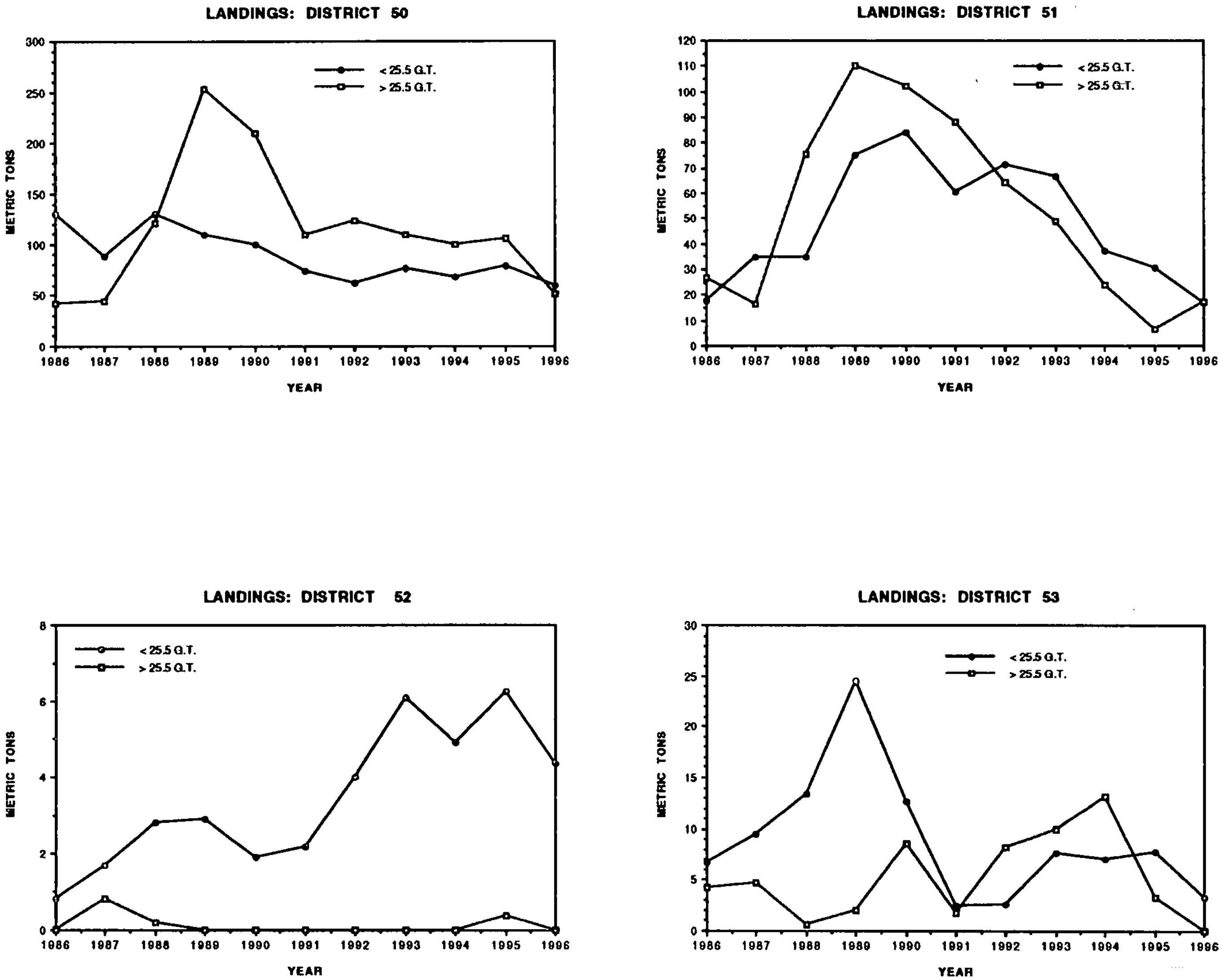
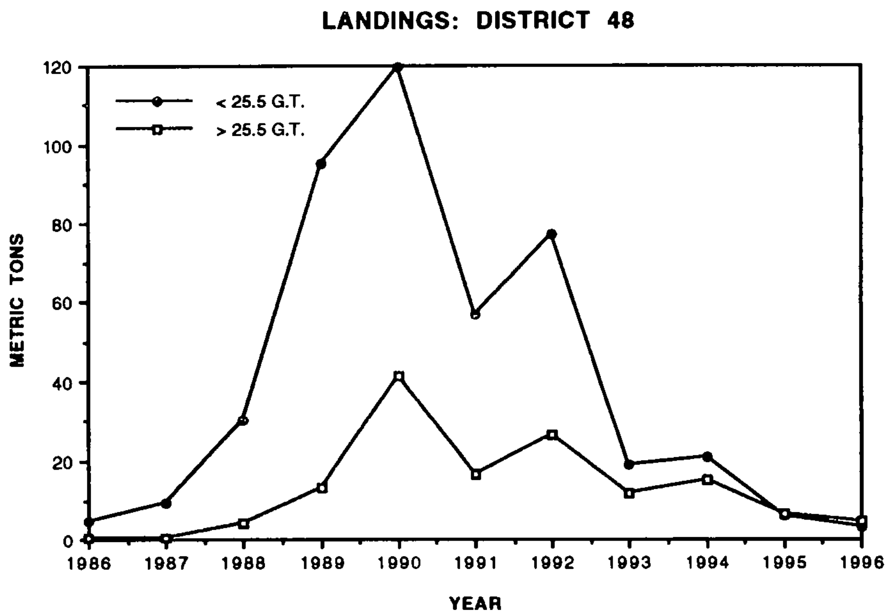


Figure 23. Annual landings (1986-1996) for the Districts in the Grand Manan area and surrounds by vessel size class.



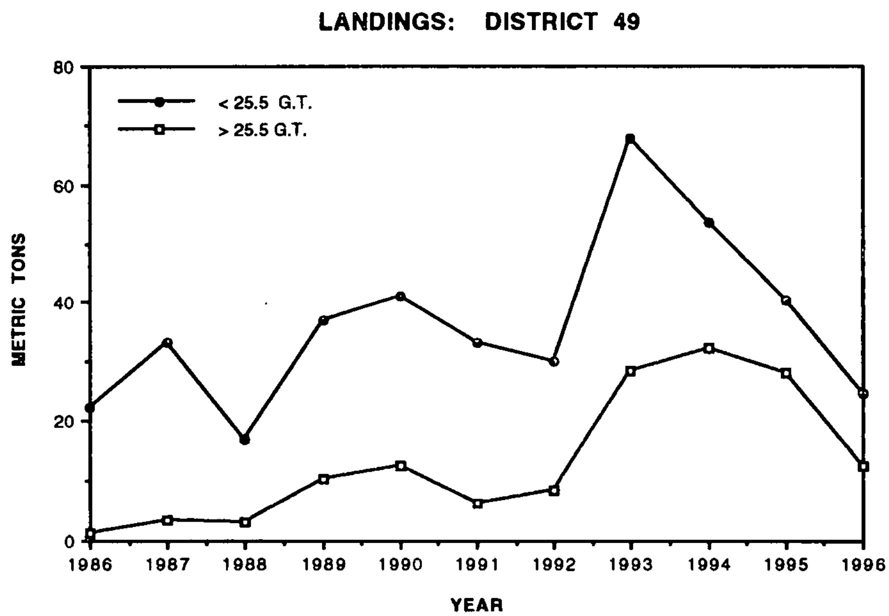


Figure 24. Annual landings (1986-1996) for the District in the Saint John, N.B. area by vessel size class.

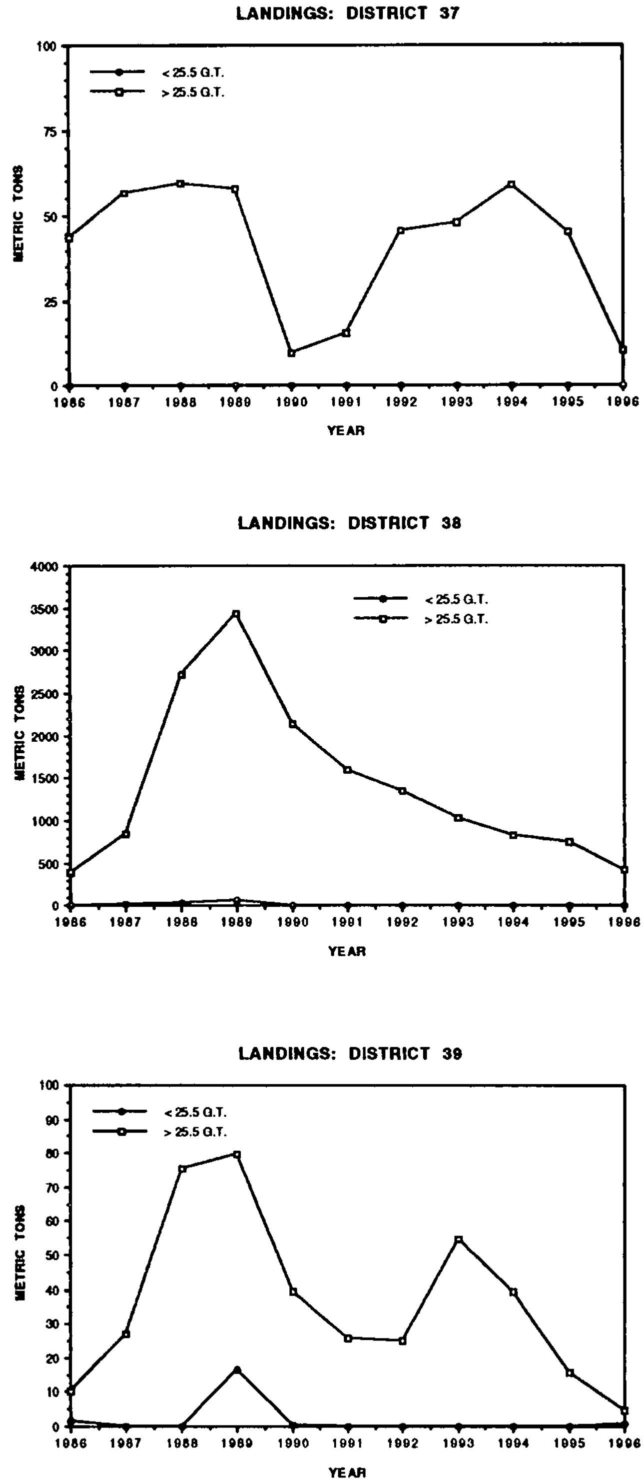
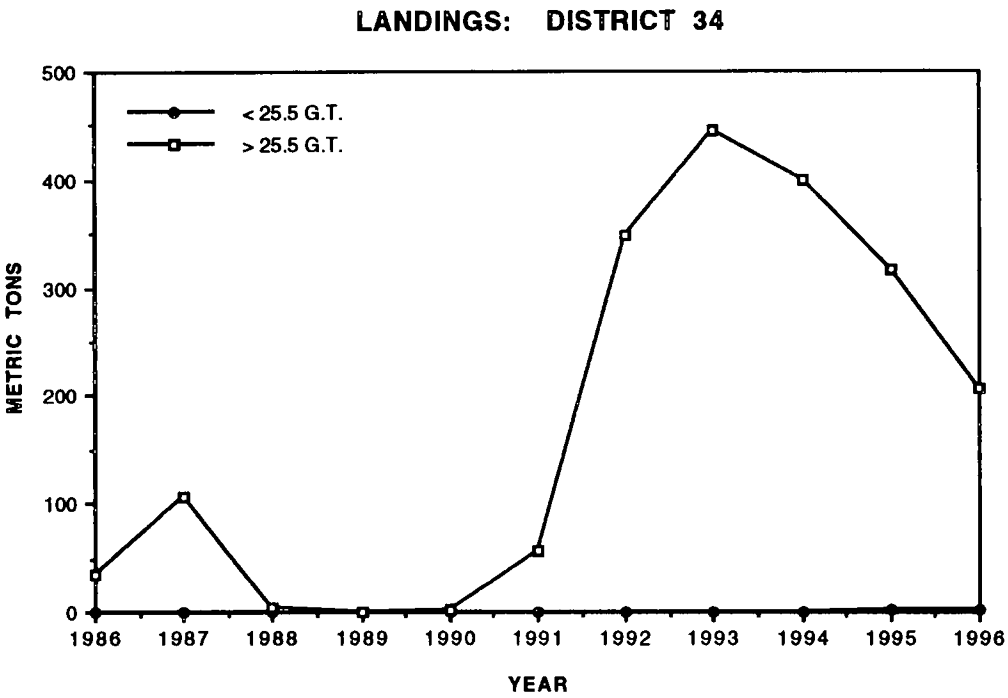


Figure 25. Annual landings (1986-1996) for the District in the Digby area by vessel size class.



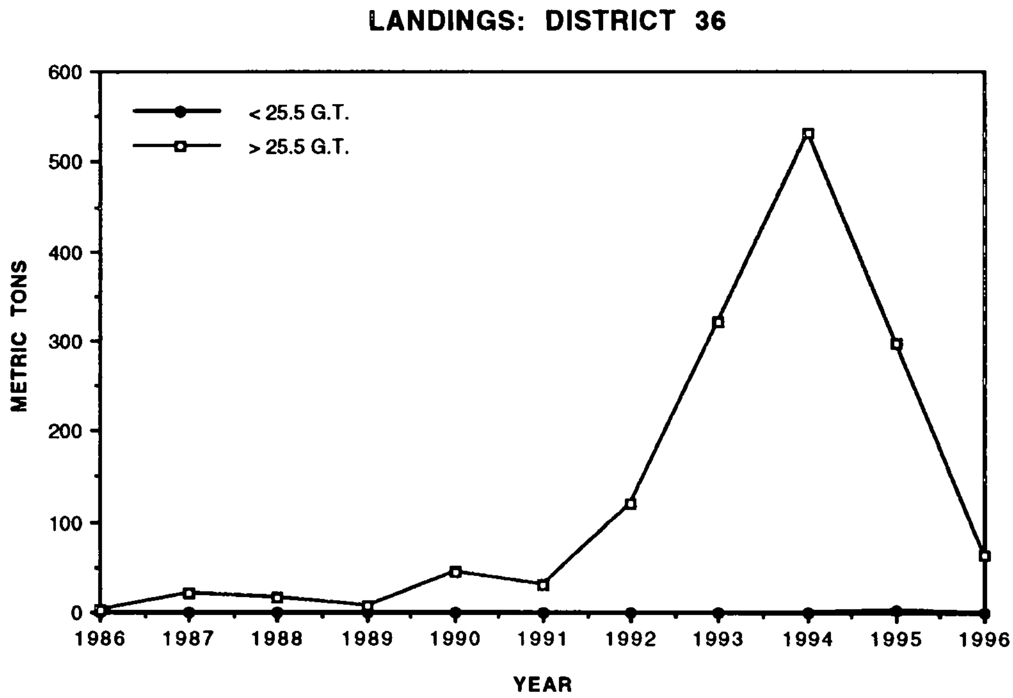


Figure 26. Annual landings (1986-1996) for the Yarmouth (34) and Meteghan (36) Districts by vessel size class.

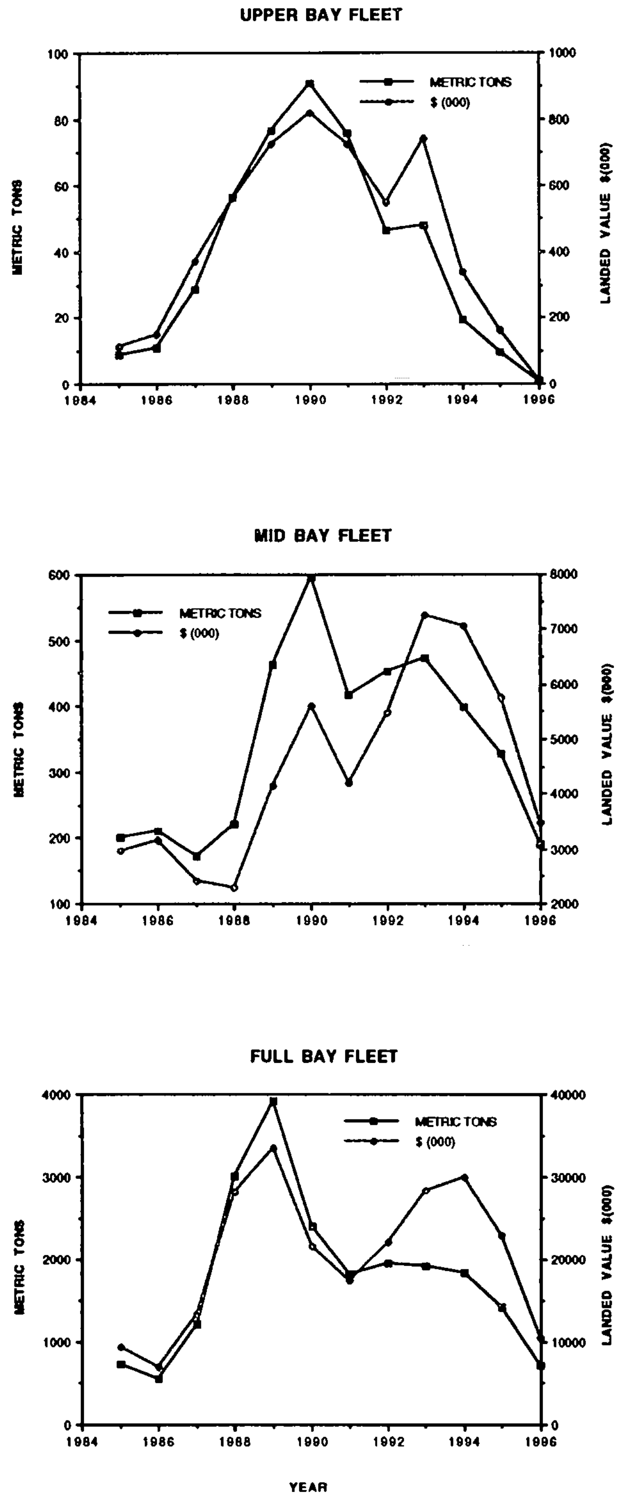


Figure 27. Annual landings and revenue (1985-1996) by fleet sector in the Bay of Fundy.