Fisheries and Oceans Canada
Science

Pêches et Océans Canada
Sciences

C S A S

Canadian Science Advisory Secretariat

S C C S

Secrétariat canadien de consultation scientifique

Research Document 2002/015

Document de recherche 2002/015

Not to be cited without
permission of the authors *

Ne pas citer sans
autorisation des auteurs *

Assessment of the scallop stock in Scallop Production Area 1 in the Bay of Fundy for 2001

Évaluation du stock de pétoncle de la zone de production du pétoncle 1 (baie de Fundy) en 2001

Dale Roddick

Invertebrate Fisheries Division
Science Branch
Department of Fisheries and Oceans
P.O. Box 1006
Dartmouth, Nova Scotia

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883

Canada

Abstract

Starting on 1 January 1997, the Bay of Fundy scallop fishery was divided into Scallop Production Areas (SPA's) for management considerations. This move was made in response to declining catches and concerns over the long term viability of the scallop fishery. SPA 1 is the largest SPA in the Bay of Fundy, and is accessible, at least in part, to all Bay of Fundy scallop license holders. This assessment examines survey data, logbook data, and port sampling data.

Survey biomass estimates and commercial catch rates declined from the historic peak in 1988/89, to the lowest levels in either time series in 1997. Since that time they have improved, and there is a large recruitment pulse in the Digby area entering the fishery. This pulse is not evident in the Cape Spencer or Upper Bay areas of SPA 1. In the Cape Spencer area the population has started to decline as the moderate year class that recruited to the fishery in 2000 is fished down. In the Upper Bay area the strong year class that recruited to the fishery in 2001 will be followed by two weaker year classes. The large recruitment pulse in the 8-16 mile area off Digby is not available to all fleet sectors, complicating setting a single quota for SPA 1. Preliminary work with a biomass dynamic model indicates that the 8-16 mile area off Digby can sustain a sizable increase to the TAC. Under an assumption that natural mortality in 2002 will be similar to that of 2001, an increase to the 500-600 t range would still not exceed $F_{0.1}$

Résumé

Depuis le 1er janvier 1997, on gère la pêche du pétoncle de la baie de Fundy au moyen de zones de production du pétoncle (ZPP). Cette mesure a été prise en réaction à la baisse des captures et aux inquiétudes concernant la viabilité à long terme de cette pêche. La ZPP 1 est la plus grande de la baie de Fundy et est accessible, du moins en partie, à tous les détenteurs de permis de pêche du pétoncle de la baie de Fundy. La présente évaluation porte sur les données des relevés, des registres de bord et des échantillonnages aux ports.

Les biomasses estimées par relevés et les taux de capture de la pêche commerciale ont diminué, passant de leur maximum historique en 1988-1989 à la plus faible valeur de leur série chronologique respective en 1997. Depuis, ces chiffres se sont améliorés, et la région de Digby connaît une forte vague de recrutement de pétoncles, qui ne semble pas s'étendre aux secteurs de Cape Spencer et du fond de la baie, dans la ZPP 1. La population du secteur de Cape Spencer diminue à mesure que l'on pêche la classe d'âge d'importance moyenne recrutée en 2000. Dans le secteur du fond de la baie, la forte classe d'âge recrutée en 2000 sera suivie par deux classes d'âge plus faibles. Les pétoncles de la forte vague de recrutement observée dans le secteur situé de 8 à 16 milles au large de Digby ne sont pas accessibles à tous les secteurs de la flottille, ce qui complique l'établissement d'un quota unique pour la ZPP 1. Les résultats préliminaires obtenus au moyen d'un modèle dynamique de la biomasse indiquent que ce secteur situé au large de Digby peut soutenir une hausse marquée du TAC. Si l'on suppose que la mortalité naturelle en 2002 sera semblable à celle de 2001, une augmentation du TAC à 500-600 tonnes ne dépasserait pas la valeur $F_{0,1}$.

Introduction

Commercial scallop fishing in the Bay of Fundy was first reported by W.F. Ganong in 1889 (Ganong 1889), who reported that about 200 bushels originating from Maces Bay and L'Etang Harbour were sold annually in Saint John. In the 1920's, a commercial fishery started in Annapolis Basin N.S., where Lescarbot had first reported scallops in 1609 (Lescarbot, 1609). This fishery quickly moved out into the productive grounds off Digby, Nova Scotia, and now occurs throughout the Bay of Fundy and the inshore and offshore waters around Nova Scotia.

Scallop fishing regulations were first initiated in 1918 with licenses, a minimum size and closed seasons. These types of regulations are still in use for this fishery. Special regulations for specific areas within the Bay of Fundy date back to 1939 when a restriction on gear width was introduced specifically for Grand Manan waters. On the Nova Scotia side, a special zone was created off Digby in 1952, with a closed season from May 1 to September 30 to provide an area close to port for the winter fishery. This area has evolved into what is currently managed as Scallop Production Area 4. The Bay of Fundy scallop fishery became a limited entry fishery in 1972. Over time the scallop fleet still grew as more Bay of Fundy scallop licences were issued, and new licence categories for the inshore New Brunswick and Upper Bay areas were created. In 1986 an accord was reached between the scallop fleets, separating the offshore and Bay of Fundy fleets and creating the Mid Bay line for inshore New Brunswick based vessels. In 1987 an effort to cancel "inactive" inshore licences had limited success.

On January 1, 1997, in response to declining catches and concerns over the long term viability of the fishery, the Bay of Fundy was divided into Scallop Production Areas (SPA's) for better management (Figure 1). Total Allowable Catches (TAC's) were introduced at this time, with sharing formulas to divide the TAC between the scallop fleets for areas where more than one fleet fished.

Scallop Production Area 1 in the Bay of Fundy is a large area encompassing several different fishing grounds, and is accessible by three different scallop license categories (Table 1). Full Bay scallop licenses are able to fish scallops anywhere in the Bay of Fundy and are usually held by larger vessels (>25.5 Gross Tons). Mid Bay license holders can fish for scallops on the northern side of the Mid Bay line (Figure 1), and Upper Bay license holders east of the Upper Bay line. These last two categories of licenses are typically held by smaller multi-purpose vessels that fish local waters.

Scallop fishing regulations in 2001 consisted of:

Limited entry.
Restrictions on gear type - no offshore or green sweep drags.
Maximum width of gear - 5.5 m
Minimum ring size - 82 mm.
Meat count (minimum average meat weight) - 45/500g.
Minimum shell size - 95 mm.
Total Allowable Catches, either as individual vessel quotas in the Full Bay Fleet or an overall allowable catch for the Mid and Upper Bay fleets.
Hail out upon leaving port and Hail in 2 hours before landing.
Dockside monitoring of catches.
Required to keep a Logbook (Scallop Monitoring Document) reporting location catch and effort.
Special seasons, i.e. for a 2-mile conservation zone along the New Brunswick coast, 1-mile closure along the Digby Neck. In 2001 there was also a closure of SPA 1 from the SPA 4 line out to 12 miles from shore to protect an area with a high density of juveniles until October 15.

Landings in SPA 1 have increased from the low of 130 t in 1997, and for 2001 were 387 t in total (285 t for the Full Bay vessels, 59 t for the Mid Bay vessels and 43 t for the Upper Bay vessels). This was an 11 % increase in landings over 2000, and almost three times that of 1997. A portion of SPA 1 outside SPA 4, which contained large numbers of juvenile scallops, was closed until October 15.

The main concentration of scallops in SPA 1 is an area that runs between Centerville and Hampton on the Nova Scotia side, over towards Cape Spencer on the New Brunswick side. This area is divided into SPA's 1 and 4, and by the Mid Bay line (Figure 1). The largest portion is on the Nova Scotia side of the Mid Bay line, and is accessible only to the Full Bay fleet, while that on the New Brunswick side is accessible to both the Mid and Full Bay fleets. There are several smaller grounds further up the Bay, including those fished by the Upper Bay fleet.

There is no survey covering the entire SPA 1, but there are productive portions that have had multiple surveys. The SPA boundaries cut through an area that has a long time series of annual surveys (Figure 2). Although the survey areas are not an exact match to the new SPA boundaries, it was felt that the match was close enough that it would be better to retain the consistency of the surveys than to alter their format.

Surveys used in this assessment are: 1) the annual surveys in the "2-16 mile" section from Sandy Cove to Hampton, excluding Area 4; 2) several older surveys, and recent annual ones covering the section from 16 miles going towards Cape Spencer, New Brunswick; and 3) recent surveys that were carried out in the Upper Bay.

Data Availability:

Research surveys

There have been annual surveys of the Digby portion of SPA 1 since 1981 (Kenchington et al. 1995). The Cape Spencer grounds were first surveyed in 1987, (Chandler et al., 1989) during a survey of the Northern side and Upper Bay area. Robinson and Chandler (1990) and Robinson et al. (1992) conducted surveys covering the Cape Spencer area in 1989, 1990 and 1991. Annual surveys of the Cape Spencer area were initiated with grid surveys in 1996 and 1997, in conjunction with the stratified random surveys of the 2-16 mile Digby area. The design was changed to a random survey in 1998. The Upper Bay area was surveyed in 1986-87 (Chandler et al., 1989), and in conjunction with studies on the effects of opening the Peticodiac River causeway in 1998 (Kenchington et al., 1998) and twice in 1999. It was surveyed with Industry cooperation in 2000, and as part of the regular Bay of Fundy surveys in 2001.

Logbooks

Logbooks were required for vessels >25 gross tonnes (G.T.) starting in 1973. In 1979 the requirement was changed to vessels > 25.5 G.T. or > 14 m Length Over All (LOA). These requirements covered most of the Full Bay license holders but few of the Mid Bay or Upper Bay licenses, although some of these vessels submitted logbooks. In the Full Bay Fleet, the percentage of active licenses that submitted logs has varied from 11 to 100%. The Mid Bay and Upper Bay license holders agreed to complete logbooks on a voluntary basis in 1996 and logbooks became mandatory for these fleets in 1997.

The logbook database has been moved to an Oracle system and there was additional editing done during this transition. In addition, the assignment of historical landings to the current SPA boundaries was redone (Smith and Lundy, 2002).

In 2001 the quota season for the Full Bay fleet was changed from the calendar year to one starting October 1, and running to September 30 the following year. This was done to bring it in line with their traditional fishing season in SPA 4. The quota season for the Mid and Upper Bay fleet remains on a calendar year. For this analysis of SPA 1 all data is analyzed on a calendar year basis

Port sampling

Port samples have been collected from the Full Bay Fleet landing in Nova Scotia since 1983, first on a voluntary basis, and since 2000 as part of the dockside monitoring program, but there had been no port sampling program covering the Mid Bay or Upper Bay Fleets in SPA 1.

There are occasional Mid Bay port samples from an industry program targeted at SPA 6, and in October of 1999, a port sampling program was initiated in conjunction with an extension of the allowable catch limit for the Mid and Upper Bay fleets. Most of the samples from this program came from the Upper Bay area, while most of the available Full Bay samples come from the 2-16 mile Digby Area.

Methods

Survey Methods

The survey analysis was divided into separate areas. The first was the area 2-16 miles off the Nova Scotia shore from Sandy Cove to Hampton, excluding SPA 4, for which a time series of surveys exists. Annual surveys of this area have been conducted since 1981, but the station allocation scheme and area covered has changed during this period. For a full description of these changes see Kenchington et al. (1995). For this reason, the 1991 to 2001 surveys, which are of a consistent area and with the most consistent design, will be the main ones used for this analysis, with the older surveys used to look at longer-term trends. The survey area is now split between SPA 1, and SPA 4, which extends out to 8 miles from Sandy Cove to Parkers Cove (Figure 1). The SPA 1 survey in this area was therefore broken down into two sections, the 8-16 mile area from Sandy Cove to Hampton, and a 2-8 mile area above SPA 4 (Figure 2).

Tows of approximately 8 minutes duration were carried out at each randomly assigned station with a set of 4 Digby buckets (0.762 meters wide, 76 mm rings with rubber washers), 2 lined and 2 unlined. The catch of scallops in the lined (38 mm diagonal mesh liner) was used to estimate the catch of scallops <80 mm shell height, and the catch in the unlined buckets was used for scallops $\geq$ 80 mm shell height. Catches were standardized to an 800 m tow with a 7 bucket drag (800 m * 5.334 m = 4,267.2 m^2). Trends are examined in stratified mean numbers of scallops per standard tow. The strata used in the stratification of the 8-16 mile zone can be seen in Figure 2, with the number of stations assigned on the basis of strata area and variance.

A separate analysis was conducted for the Cape Spencer area, for which there is an irregular series of surveys covering different areas, and with differences in the way they have been conducted. Surveys tows were again standardized to an 800 m tow with 7 buckets. Catches from older surveys that had been recorded in round weight were converted to meat weights by dividing by the conversion factor of 8.33, which is the conversion factor used by Statistics Branch. Station assignments were on a grid in 1987, 1996 and 1997, and randomly assigned in 1989, 1990, and 1991 and since 1998.

In the Upper Bay area the 1986-1987 survey was described in Chandler et al. (1989). Data were only available in summary form from this survey, and so the closest match to the later survey areas were the numbers per standard tow for unlined drags. This will contain some scallops less than 80 mm shell height but there were no data available for height frequencies on a tow by tow basis. The data are included here for comparison with the latter surveys with the caution that the numbers are not directly comparable but the distribution should be. The 1998 and 1999 surveys were conducted by commercial vessels using 8, 2 foot wide, toothed, "Miracle drags", the 2000 survey used 9, 2 foot wide "Northshore drags". Drags 1 and 5 were lined with 38 mm diagonal mesh, and all were made with 78 mm rings and rubber washers. In 2001 the survey took place as part of the regular Bay of Fundy surveys using the survey gear. The same protocols as used in the other surveys were followed for the Upper Bay surveys. Mean numbers per standard tow and shell height frequencies were used to compare surveys and the survey results were used to produce contour maps of numbers per standard tow with the ACON package (Black, 2002).

CPUE's for SPA 1 were calculated from the Full Bay logs for the 1976 to 2001 period, the Mid Bay logs for 1992-2001and the Upper Bay logs for 1997-2001.

Port sampling data was broken down into areas corresponding to the survey analysis: outside SPA 4 8-16 miles offshore from Sandy Cove to Hampton, the Cape Spencer area, and the Upper Bay. To examine changes in the size distribution of the catch with time, the meat weight frequencies by month were plotted for 1996 to 2001.

Population Model

For the 8-16 mile area off Digby for which we have the best data series within SPA 1, we used the same biomass dynamic model that was used for the SPA 4 assessment. (Smith and Lundy 2001). This approach uses changes in population and catch biomass instead of using changes in numbers as in most VPA type models. The general form of the model is :

$$(\text{Adult Biomass})_{t+1} = (\text{Surviving Adult Biomass})_{t} + (\text{Recruitment Biomass})_{t+1} \qquad (1)$$

where,

$$(\text{Surviving Adult Biomass})_{t} = (\text{Adult Biomass})_{t} + (\text{Biomass increase due to growth})_{t}$$
$$- (\text{Losses due to Natural Mortality})_{t} - \text{Catch}_{t} \qquad (2)$$

In this case the adult biomass is assumed to be the biomass of fully recruited scallops. It is assumed that growth in biomass can be modeled as:

$$w_a = \square + \square w_{a-1}, \text{ where } w_a = \text{weight at age } a. \qquad (3)$$

It is also assumed that selection is “knife edged”, that the rate of natural mortality is the same for all recruited scallops, and that natural mortality can be modeled using the survey clapper ratio as:

$$Z_t = (S/2)M_t\,[SL_{t-1} + (2 - S)\,L_t]\square_t \qquad (4)$$

where S = the dissolution rate or separation time as a fraction of a year

M_t is the natural mortality rate in year t, and Z_t and L_t are the clapper and live populations in year t.

Survey numbers and biomass estimates are stratified estimates, and catch is the portion of the SPA 1 catch that comes from this area as estimated from the logbook data.

The main parameters the model estimates are: K - a scaling factor or proportionality constant by which the state equations in the model are scaled to increase the convergence rate (actual scaling is by K^3), S - the dissolution rate of paired empty shells as a portion of the year, and parameters qI and qR, which are constants that relate the survey biomass (I_t) and recruitment (R'_t) to the population biomass and recruitment as:

$I_t = q_I B_t \square_t$ and $R'_t = q_R R_t \square_t$, where $\square_t$ and $\square_t$ are the respective error terms.

The parameters are estimated using a Bayesian approach with the public domain package BUGS (WinBUGS). A complete description of the model is given in Smith and Lundy (2002).

The output from this model was examined to predict the effects of various catch levels on the population for the next two years.

Results

Traditional Area surveys

Based on the mean number of scallops <80 mm per standard tow for the 10 strata in the 8-16 mile survey (Table 2), there is a large recruitment pulse entering the fishery. The highest densities are centered on the Digby gut area where extremely high densities are seen, with much smaller increases seen at either end of the 8-16 mile survey area. This pulse is already showing up in the >80 mm size class, as the faster growing individuals have reached this size (Table 3). When all sizes, and stratified totals are examined (Tables 4 and 5, Figure 3), the size of this pulse becomes more evident.

The area occupied by this recruitment pulse does not extend into the 2-8 mile section of the survey area (Table 6, Figure 4), which shows a gradual increase from the low of 1997 but no dramatic recruitment pulse.

The older surveys dating back to 1981 can be used to look at the longer term history, before the last large recruitment pulse of the late 1980's. These surveys are of different designs and sometimes slightly different areas, but serve to show the large scale trends in the fishery (Figure 5). The recent survey catch rates are not as high overall as those of the 1980's pulse, due to the more restricted area occupied.

The survey shell height frequencies for the 8-16 mile area are shown in Figure 6 for the 1981 to 2001 surveys. This figure shows the two recruitment pulses that have occurred in this area in the last two decades, and between them the decline in abundance to the low of 1997. There is a noticeable difference in the position of the modes in the survey shell height frequencies between the two events. In the first case, the size mode was first noticed in the survey at 25 mm in 1986, and had grown to 60 mm by the1987 survey. In the recent surveys the size mode first showed up at 40 mm in the 2000 survey data, and had reached 75 mm by the 2001 survey. This large pulse (1998) year-class appears to be growing faster than usual. It is already entering the fishery and will be fully recruited this coming year, almost a full year sooner than normal.

Cape Spencer surveys

The Survey Mean numbers per tow for the Cape Spencer area (Figure 7) show a decline in the numbers of scallops larger than 80 mm from the 2000 survey, and little sign of smaller scallops. The survey height frequencies (Figure 8) show a moderately strong year class entered the fishery in 2000 and has been fished down the last two years. There are no strong year classes following this one, and so catch rates will decline as the strong year class is fished down.

Upper Bay surveys

The Upper Bay area had a strong year class recruit to the fishery in 2001 (Figures 9 and 10). This year class is stronger in the Upper Bay than in Cape Spencer and catch rates are presently high. As in the Cape Spencer area, there are no strong year classes evident for the next few years and catch rates can be expected to decline for the next 2 to 3 years as the recruited population is fished down.

Overall the current situation for SPA 1 can be seen in Figure 11, with a strong year class localized to the Digby area and low recruitment in the rest of the SPA. The recruited population that is currently sustaining the fishery will be fished down in most of SPA 1, while an exceptionally strong year class is entering the fishery off Digby.

Logbook data

The catch and effort distribution from the 2001 logbooks is shown in Figure 12. The Upper Bay was fished harder this year than in the past as it was providing high catch rates compared to the Cape Spencer Area, and the 8-12 mile area off SPA 4 was closed until October 15. The catch and effort in SPA 1 for the 1976 to 2001 period from Full Bay logbooks (Table 7), shows the large recruitment pulse that entered the fishery in 1988 and 1989. This pulse can be seen with the highest CPUE in the time series recorded in 1989. Since then, CPUE declined to the lowest levels in the time series in 1997. CPUE has increased since then, and dramatically increased the last two years.

The catch rates from the Mid Bay logbooks (Table 8) show the same trend, with the lowest CPUE in 1997, and an increase since than with a large increase the last two years. The Upper Bay series (Table 9) only starts in 1997 and decreased until 1999. CPUE also has increased the last two years with a large jump this year.

The CPUE's for all three fleets follow each other fairly closely for the time periods they overlap. This is attributed to the pattern of a decline in catch rates as the large year classes that were wide spread throughout the Bay of Fundy were fished down and more controls were put on the fishery in 1997 to allow the stock to rebuild. The Full Bay fleet, for which we have the longest time series, is now at the median level for the 1976 to 2001 time period. With the large recruitment pulse off Digby it is expected that the Full Bay fleet CPUE will diverge from the rest in 2002.

Port Sampling

The 1999-2001 data from the port samples in SPA 1 was broken down into three areas to match the breakdown of the surveys: 8-16 miles off the Sandy Cove to Hampton area; the Cape Spencer area; and the Upper Bay.

In the 8 to 16 mile area the meat weight distributions for the last three years indicated that the fishery was relying on fairly large scallops up until the last part of 2001 (Figure 14). The September samples indicate that the fishery had started to fish the abundant incoming year class.

In the Cape Spencer samples (Figure 15) the fishery relied on larger scallops in 2001 as there was no abundant incoming year class in this area.

In the Upper Bay area there was targeting of the recruiting year class (Figure 17) in 2001, with some port samples not making the legal meat count.

Model

The input data used for the biomass dynamic model is presented in Table 10. These data come from the annual surveys of the area. During the first runs of the model for the 8-16 mile area, it was found that the slow growth rates in the deeper water of the Centerville strata had a large effect on the survey data. Since the fishery tended to avoid this area, it was decided to exclude it in subsequent runs of the model. The parameter and variance estimates from the model are given in Table 11, while the output is in Table 12.

The estimated recruitment for 2002 (Table 12) is the largest in the time series, although the 2001 biomass is not as large as that through most of the 1981-1991 time period. The high recruitment indicates a large number of scallops just under 80 mm in the population estimates. The estimated fishing mortality is slightly higher than the last few years, but still well below that seen in 1987-1989. The model residuals (Figure 18) indicate a good fit to the data, with the model still having some problems in fitting the clapper and recruit estimates during the die off in 1987-89. The estimates for the number of clappers peak in the 1990 survey. With the faster growth rate of the currently recruiting year class there is also a larger residual for the 2001 recruits. The process error term has the highest residuals. While the other error terms account for measurement error, this term captures the errors due to such things as environmental fluctuations as the model attempts to use the data to move from the current state to the next one in time. The retrospective analysis (Figure 19) looks at the stability of the estimates as new data are added each year. If estimates for a specific year change as new data are added it indicates that the model has problems and that the current estimates may not be good for predicting the future. The retrospective plots shown in Figure 19 do not exhibit any serious retrospective problems. The largest changes are seen in the biomass estimates, and these appear to be an under-estimate in the current year, which would make for conservative predictions. Regressions of the estimated Biomass to the Full Bay CPUE, and Fishing Mortality to Effort were done as a check against survey independent estimates. The regression of estimated Biomass versus commercial CPUE (Figure 20) is good with an r^2 of 0.84. Total Allowable Catches (TAC's) were introduced for this area in 1997, and subsequent years are all below the regression line. The plot of Fishing mortality versus Effort (Figure 21) shows a conspicuous 1990 outlier. The calculated total effort for this year was based on logbooks that only covered 14% of the catch. If this point is removed the r^2 is 0.89.

Discussion

The most obvious event in SPA 1 is the large year class recruiting to the fishery in the 8-16 mile area off Digby. This large pulse is not seen in the other areas of SPA 1, and so will complicate management for the next few years. Traditionally there has been a single quota for SPA 1, shared by fleets that have access to different portions of the SPA and fish under either a competitive quota (Mid and Upper Bay) or Enterprise Allocations (Full Bay). The recruitment pulse off Digby is only accessible to the Full Bay fleet, and so raising the quota for all fleets would put undue pressure on the stock in other areas. There will have to be a change in either the single quota for all of SPA 1, or a sharing formula that reflects differences in population status and fleet access throughout SPA 1 will have to be devised.

The Cape Spencer area will be largely dependent on the year class that has just recruited to the fishery for the next few years. It is already being fished down and although the survey shows moderate levels of recruits for the next few years, there is no large year class that will enter the fishery.

The fishery in the Upper Bay area is currently fishing the same 1997 year class as seen in the Cape Spencer area. The survey estimates are higher in the Upper Bay, and the stock is providing good catch rates, but once again the following year classes are not large and the fishery will be largely dependent on this recruited year class for the next few years. The Upper Bay was fished harder in 2001 than it has been for the last several years, and this increased effort in a small area will result in this year class being fished down sooner.

The model for the 8-16 mile area appears to fit the data well and holds promise as a means to set objective targets and monitor progress towards them. The parameter S resulting from the model (the dissolution rate of paired empty shells as a portion of the year) has a median value of 0.6114, which translates to 223 days. This compares to the estimate of 33 weeks (231 days) from Merrill and Posgay (1964), and those reported by Dickie and Medcof (1963) which ranged from 1.5 months to 2 years.

It will take a few years of applying the model and seeing how well the model estimates hold up, and there will no doubt be some further refinements of the model and the input data.

The population estimates from the model were projected forward to 2002 using two different assumptions about the natural mortality. In the first case it was assumed that the natural mortality in 2002 will be the same as was seen in 2001. In the second case the natural mortality was set at three times that of 2001. Under these scenarios the estimates for the biomass in 2002 are:

Assumption	Mean Biomass (t)	Std. Dev.	0.025	Median	0.975
$M_{2002} = M_{2001}$	11,100	10,270	2,672	8,022	41,360
$M_{2002} = 3^* M_{2001}$	8,392	7,881	1,901	6,077	31,070

The predicted fishing mortality resulting from a range of catch levels with these predictions is shown in Table 13. This table also gives the probability that $F_{0.1}$ (estimated as 0.21) will be exceeded at that catch level. As can be seen from the table, the assumptions about natural mortality are just as important to the resulting F as the catch level that is taken out. At the present time the mortality rate in SPA 4 is being monitored for any sign of a die off like that seen in 1987-1989. The scallops are still at a size that letting them grow will increase the overall yield, but the fears of another die off increase pressure to raise the quota. The logic of this is to catch the scallops before they die, and also to thin them out to make them less susceptible to density dependent stresses such as starvation and disease. With only one other documented die off, and no determination on the cause of it, the probability of it re-occurring is impossible to determine.

The predicted risk of exceeding $F_{0.1}$ increases as the 2002 quota for the 8-16 mile area goes beyond 500 t.

Although the scallop stock in SPA 1 outside the Digby area has rebuilt from the low level seen in 1997, the fishery is still very dependent on incoming recruitment. With recruitment tending to be highly variable it is hoped that as the population size is allowed to increase, the drops in catch rates between recruitment events will be reduced.

Conclusion

The catch rates in SPA 1 have improved as the population has been allowed to increase. For the next few years the large year class recruiting in the 8-16 mile area off Digby will occupy the Full Bay Fleet while the Mid and Upper Bay fleets will be dependent on recently recruited year classes with low levels of incoming recruits.

Since the large recruitment off Digby is not available to all fleet sectors, an increase in a single quota shared by all fleet sectors as in the past few years is not recommended. Either a separate quota for the 8-16 mile zone or a sharing formula that reflects different levels of access to recruiting year classes is called for. The quota in the 8-16 mile zone can be in the 500 t range, while for the rest of SPA 1 the catch levels should remain at their present levels.

References

Black, G.A.P. 2002. ACON Data Visualization Software User Manual - Version 9.15 - March 7, 2002. <http://www.mar.dfo-mpo.gc.ca/science/acon/>

Chandler, R.A., G.J. Parsons and M.J. Dadswell. 1989. Upper and northern Bay of Fundy scallop surveys, 1986-87. Can. Tech. Rep. Fish. Aquat. Sci. 1665:37pp.

Dickie, L.M. and J.C. Medcof. 1963. Causes of mortalities of scallop (*Placopecten magellanicus*) in the southwestern Gulf of St, Lawrence. J. Fish. Res. Bd. Canada. 20:451-857.

Ganong, W.F. 1889. The economic mollusca of Acadia. Bull. Nat. Soc. New Brunswick 8:116pp.

Kenchington, E., D.L. Roddick and M.J. Lundy. 1995. Bay of Fundy Scallop analytical stock assessment and data review 1981-1994: Digby Grounds. DFO Atlantic Fisheries Research Document 95/10, 70pp.

Kenchington, E., I. Dempsey and M.J. Lundy. 1998. Peticodiac River Causeway Monitoring Programme: Scallops. Dept. of Fisheries and Oceans internal document. 13 pp.

Lescarbot, M. 1609. Histoire de la Nouvelle France. Paris.

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.

Robinson, S.M.C. and R.A. Chandler. 1990. The Grand Manan scallop stock assessment 1988-1989. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 90/81. 26pp.

Robinson, S.M.C., J.D. Martin and R.A. Chandler. 1992. Grand Manan and Cape Spencer scallop stock update: 1990-1991. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 92/79. 23pp.

Smith, S. J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. Canadian Journal of Fisheries and Aquatic Science. 54:616-630.

Smith, S.J. and M. Lundy. 2001. Scallop Production Area 4 in the Bay of Fundy: Stock status and forecast. DFO Canadian Science Advisory Secretariat Research Document. 2002/018. 89pp.

Thompson, S. K. 1992. Sampling, John Wiley & Sons, New York, N.Y.

Table 1. Number of licenses issued and number of active vessels for each license type having access to Area 1.

	Mid-Bay*		Full Bay		Upper Bay	
Year	Licenses	Active	Licenses	Active	Licenses	Active
1978	n/a	n/a	88	n/a	n/a	n/a
1979	n/a	n/a	83	n/a	n/a	n/a
1980	135	n/a	90	n/a	n/a	n/a
1981	290	n/a	102	68	n/a	n/a
1982	278	n/a	104	66	n/a	n/a
1983	253	n/a	111	77	14	n/a
1984	262	n/a	104	82	14	n/a
1985	269	133	106	70	15	7
1986	238	127	98	67	13	10
1987	214	146	95	80	16	13
1988	211	130	99	91	16	15
1989	211	129	99	96	16	16
1990	210	145	99	94	16	16
1991	210	144	99	93	16	12
1992	206	143	98	90	16	12
1993	208	171	96	99	16	13
1994	209	178	96	92	16	10
1995	209	147	99	94	16	8
1996	208	149	99	96	16	1
1997	207	153	99	78	16	6
1998	207	130	99	75	16	9
1999	203	135	99	69	16	14
2000	203	123	99	63	16	12
2001	203**	133**	99**	57**	16**	15**

*Prior to 1987 these licenses were New Brunswick inshore licenses.
**Preliminary, data to November 2001.

Table 2. Mean number of scallops <80 mm per standard tow by stratum and year for stratified random survey.

	Centreville	CV to GH	Gulliver's Head	GH to DG	Digby Gut	DG to DC	Delaps Cove	Parker's Cove	Young Cove	Hampton
1991	30.67	9.60	16.33	2.50	13.00	15.25	6.24	0.00	11.65	12.60
1992	9.15	17.17	10.92	6.53	32.29	70.87	15.97	44.30	14.10	16.63
1993	11.26	n/a	14.40	16.87	9.30	2.78	4.76	4.50	10.27	2.40
1994	19.00	14.00	30.06	17.40	111.73	31.13	16.73	4.20	8.22	4.32
1995	13.73	16.90	18.23	71.27	106.67	87.90	14.20	8.12	5.75	3.04
1996	15.05	33.30	24.45	22.83	26.62	29.38	14.25	7.50	8.03	13.17
1997	24.99	28.63	37.08	58.89	40.15	16.18	5.73	3.90	21.90	15.01
1998	26.89	40.00	50.91	41.41	23.26	14.16	21.79	4.20	11.44	5.24
1999	27.07	29.50	42.38	75.82	62.36	18.52	74.96	9.46	10.63	0.00
2000	40.90	52.34	90.53	232.75	1,128.58	970.79	556.09	10.44	32.06	16.10
2001	33.03	92.27	74.34	459.14	1,774.79	1,446.82	388.63	54.94	77.59	24.36

Table 3. Mean number of scallops □ 80 mm per standard tow by stratum and year for stratified random survey.

	Centreville	CV to GH	Gulliver's Head	GH to DG	Digby Gut	DG to DC	Delaps Cove	Parker's Cove	Young Cove	Hampton
1991	348.0	259.2	267.4	203.1	229.7	147.3	157.8	4.0	216.0	157.9
1992	272.9	326.1	229.6	188.6	133.8	140.1	136.7	118.1	128.0	200.8
1993	205.80	n/a	226.14	168.13	181.85	107.45	68.20	78.30	77.38	92.50
1994	140.50	87.60	169.34	162.40	129.79	101.20	76.30	63.98	52.65	58.80
1995	165.17	213.30	172.02	67.87	121.12	115.65	60.35	60.22	41.93	41.33
1996	82.23	166.50	168.20	143.30	87.11	82.47	29.92	53.75	57.72	47.33
1997	99.70	138.58	172.73	149.04	179.30	64.43	37.27	44.94	39.20	38.86
1998	52.33	175.63	109.29	180.76	99.11	100.74	57.40	32.82	56.57	58.29
1999	56.70	87.60	170.12	142.46	128.87	99.37	55.30	52.37	45.76	17.03
2000	51.54	95.46	120.74	146.82	132.77	152.07	104.74	90.04	90.48	65.08
2001	60.07	74.37	117.73	220.83	375.88	331.70	273.86	66.64	71.64	68.69

Table 4. Mean number of scallops of all sizes per standard tow by stratum and year for stratified random survey.

	Centreville	CV to GH	Gulliver's Head	GH to DG	Digby Gut	DG to DC	Delaps Cove	Parker's Cove	Young Cove	Hampton
1991	378.7	268.8	283.7	205.6	242.7	162.6	164.0	4.0	227.7	170.5
1992	282.0	343.2	240.5	195.1	166.1	211.0	152.6	162.4	142.1	217.5
1993	217.06	n/a	240.54	185.00	191.15	110.22	72.96	82.80	87.65	94.90
1994	159.50	101.60	199.40	179.80	241.51	132.33	93.02	68.18	60.87	63.12
1995	178.90	230.20	190.25	139.13	227.79	203.55	74.55	68.34	47.68	44.37
1996	97.28	199.80	192.65	166.13	113.73	111.85	44.18	61.25	65.76	60.50
1997	124.69	167.20	209.82	207.93	219.45	80.62	43.00	48.84	61.10	53.87
1998	79.22	215.63	160.20	222.17	122.35	114.90	79.19	37.03	68.01	63.53
1999	83.77	117.10	212.50	218.28	191.23	117.88	130.26	61.82	56.39	17.03
2000	92.44	147.80	211.26	379.57	1,261.35	1,122.86	660.83	100.48	122.54	81.18
2001	93.10	166.63	192.07	679.97	2,150.68	1,778.51	662.49	121.58	149.23	93.04

Table 5. Stratified mean number of scallops per standard tow over all strata for stratified random survey.

	<80	SE	Lower	Upper	□ 80	SE	Lower	Upper	Total	SE	Lower	Upper
1991	12.12	2.08	7.8	16.2	198.74	15.39	161.1	224.8	210.86	16.31	171.9	236.3
1992	23.80	6.15	12.5	35.5	178.55	17.75	146.5	211.8	202.36	22.52	159.2	243.0
1993	8.47	1.44	6.0	11.1	136.42	12.27	113.4	161.2	144.89	12.54	119.0	170.0
1994	30.90	7.09	16.2	43.4	105.03	8.12	69.4	108.9	135.92	11.38	92.3	143.0
1995	36.94	6.66	25.3	50.4	101.79	9.91	82.0	122.0	138.73	13.13	114.2	164.9
1996	18.76	2.52	13.0	22.9	86.57	9.49	64.3	102.7	105.33	10.01	80.5	121.3
1997	25.20	2.48	20.7	30.0	98.01	7.26	84.1	112.1	123.21	8.21	107.0	139.3
1998	22.85	2.23	18.4	27.1	85.72	7.24	71.2	100.0	108.56	8.57	92.4	125.2
1999	36.2	4.46	27.5	45.3	85.9	6.94	73.73	99.97	122.03	8.32	105.8	137.3
2000	354.5	86.78	204.0	535.8	104.6	7.02	90.88	118.17	459.1	88.02	304.8	651.1
2001	504.28	142.01	263.1	812.9	176.21	23.45	133.4	255.8	680.49	159.06	413.9	1007.0

Stratified mean numbers with associated standard errors (Thompson, 1992). Bootstrap confidence limits for 95% CI's (1000 reps, BWR method, Smith 1997

Table 6. Stratified mean number of scallops per standard tow over all strata for <8 mile part of Eastern Bay of Fundy.

	<80	SE	□ 80	SE	Total	SE
1991	7.300	3.105	72.100	13.181	75.900	13.956
1992	5.375	3.062	132.100	27.330	137.475	25.949
1993	2.350	0.981	84.950	25.337	87.300	25.140
1994	7.271	2.293	58.542	17.434	65.812	19.081
1995	3.800	1.456	72.100	13.181	75.900	13.956
1996	4.500	3.414	49.200	14.002	53.700	14.579
1997	6.094	2.442	29.897	6.670	35.991	7.332
1998	7.678	2.398	34.788	9.518	42.465	11.573
1999	1.604	1.604	38.868	5.668	40.473	6.537
2000	9.371	3.283	59.311	18.807	68.682	21.068
2001	7.339	2.359	47.607	10.460	54.946	11.655

Table 7. Historic trends in SPA 1 from Full Bay logbooks. Class 1 data is logbook records for which all catch effort and location information is complete. Total effort is in 1000 h, and is estimated from total catch and Class 1 CPUE. The number of Class 1 log records used to estimate the CPUE is “n”.

Year	# Vessels	Total * Catch(t)	Logged Catch(t)	% Logged	Class 1 Catch(t)	Class 1 Effort	Total Effort	Average CPUE(kg/h)	n	Standard Deviation
1976		9	12	7	57	5	353	821	14.5	44 7.1
1977	23	33	59	177	59	1470	780	43.0	238	20.5
1978	33	140	134	96	133	4445	3885	35.9	682	27.4
1979	35	123	103	83	101	4136	4735	26.1	612	11.4
1980	34	114	100	88	99	3181	3351	34.0	522	15.1
1981	41	90	81	90	79	2468	2638	34.0	386	18.4
1982	43	107	98	91	91	2892	3279	32.8	487	18.2
1983	60	257	226	88	195	10220	12431	20.7	1488	10.5
1984	65	269	259	96	240	15867	15636	17.2	2139	11.2
1985	56	294	255	87	233	18089	21093	13.9	2049	6.8
1986	35	133	69	52	64	5463	10683	12.5	673	5.7
1987	19	292	46	16	46	2680	11958	24.4	350	29.9
1988	15	855	96	11	79	2542	23606	36.2	354	23.7
1989	23	1903	242	13	189	4191	38931	48.9	577	29.3
1990	17	1996	273	14	220	8230	68360	29.2	877	16.1
1991	24	594	161	27	103	5468	30286	19.6	559	14.8
1992	40	721	315	44	231	13529	40150	18.0	1261	6.9
1993	56	576	297	52	176	13248	41341	13.9	1161	5.7
1994	62	210	164	78	72	6532	18409	11.4	625	4.4
1995	63	351	238	68	142	16522	40033	8.8	1409	3.0
1996	62	237	119	50	71	9273	30473	7.8	907	3.4
1997	82	106	124	117	111	17276	16009	6.6	2012	3.1
1998	66	188	185	99	165	23926	26114	7.2	2486	2.9
1999	66	212	218	103	206	25481	25177	8.4	2768	3.1
2000	61	261	273	105	260	23227	22324	11.7	2582	5.2
2001	54	285	286	100	261	15591	15729	18.1	1886	9.7

* 1976-1996 estimated by prorating total Full Bay landings by logbook data, accuracy varies with the number of vessels submitting logbooks. 1997 is the first year for which landings were recorded by the new SPA’s by Statistics Branch.

Table 8. Historic trends in SPA 1 from Mid Bay logbooks. Class 1 data is logbook records for which all catch effort and location information is complete. Total effort is in 1000 h, and is estimated from total catch and Class 1 CPUE. The number of Class 1 log records used to estimate the CPUE is “n”.

Year	# Vessels	Total * Catch(t)	Logged Catch(t)	% Logged	Class 1 Catch(t)	Class 1 Effort	Total Effort	Average CPUE(kg/h)	n	Standard Deviation
1992	3		22		22	1809		13.2	228	5.1
1993	6		27		26	2650		9.8	241	4.7
1994	15		51		41	4358		9.4	440	4.0
1995	18		24		15	1815		8.1	138	4.7
1996	28		24		14	2008		6.8	244	3.8
1997	42	13	14	108	12	3099	3032	4.2	455	2.0
1998	35	33	33	97	30	5019	5701	5.9	663	2.0
1999	41	51	47	93	45	6289	7044	7.2	834	3.8
2000	42	63	63	99	58	5823	6272	10.1	819	4.5
2001	47	59	59	101	54	4030	4174	14.1	608	7.6

*1997 is the first year for which landings were recorded by the new SPA’s by Statistics Branch.

Table 9. Historic trends in SPA 1 from Upper Bay logbooks. Class 1 data is logbook records for which all catch effort and location information is complete. Effort is in 1000 h, and total effort is estimated from total catch and Class 1 CPUE. The number of Class 1 log records used to estimate the CPUE is “n”.

Year	# Vessels	Total Catch(t)	Logged Catch(t)	% Logged	Class 1 Catch(t)	Class 1 Effort	Total Effort	Average CPUE(kg/h)	n	Standard Deviation
1997	6	11	11	106	11	1830	1638	6.5	209	6.3
1998	10	12	12	97	11	1852	1950	6.2	229	2.5
1999	14	19	19	100	18	2910	3159	6.1	365	2.6
2000	12	25	26	101	22	2113	2610	9.7	290	4.3
2001	15	43	43	100	39	2625	2861	15.0	424	8.2

Table 10. Input data for Model

vb

Year	Survey 80+ Biomass (t)	Recruits Biomass t	Clappers *1000	Survey 80+ numbers*1000	Average meat weight g	Catch (t)
1981	538.86	12.63	4,366	39,808	13.5	66
1982	525.85	14.25	2,926	37,239	14.1	186
1983	670.22	9.15	3,113	49,226	13.6	137
1984	333.67	7.94	1,966	26,477	12.6	159
1985	406.39	6.95	1,186	31,477	12.9	77
1986	328.68	9.51	1,178	27,705	11.9	166
1987	297.98	82.21	2,033	25,569	11.7	587
1988	790.78	137.72	1,198	106,604	7.4	1,013
1989	551.43	57.15	4,050	64,879	8.5	399
1990	464.99	13.68	17,590	48,692	9.6	267
1991	374.76	4.04	7,721	30,366	12.3	278
1992	348.28	10.38	4,456	28,066	12.4	279
1993	275.16	4.01	1,761	21,770	12.6	118
1994	224.96	6.34	2,178	16,903	13.3	147
1995	191.34	11.48	2,474	15,810	12.1	138
1996	163.98	7.10	1,255	14,528	11.3	37
1997	152.51	9.24	1,571	16,392	9.3	123
1998	144.54	9.39	2,539	15,024	9.6	87
1999	179.47	14.06	2,116	14,967	12.0	95
2000	214.50	25.23	1,767	18,577	11.6	110
2001	343.11	412.11	1,879	31,824	10.8	200

Table 11. Parameter and variance estimates (9000 reps) from model.

Node	Mean	SD	0.025	Median	0.975
Parameters					
K	4219	4191	993	2594	17580
S	0.6231	0.1525	0.3608	0.6114	0.9389
qI	0.2026	0.1349	0.0226	0.1818	0.5091
qR	0.0480	0.0279	0.0070	0.0453	0.1085
Variances					
Process	0.0869	0.0328	0.0427	0.0804	0.1671
Biomass	0.0548	0.0178	0.0297	0.0518	0.0982
Clappers	0.2606	0.1345	0.1024	0.2292	0.6059
Recruits	0.2945	0.1561	0.1106	0.2569	0.6923

Table 12. Estimates from model run for 8 to 16 mile area of SPA 1

Year	Estimated Biomass (80+)	Estimated Recruitment Biomass (t+1)	Natural Mortality	Fishing Mortality	Predicted Survey 80+
1981	2,887	309	0.18	0.02	522.7
1982	2,979	356	0.13	0.06	538.2
1983	3,226	212	0.11	0.04	578.6
1984	2,092	205	0.12	0.08	377.2
1985	2,141	173	0.07	0.04	387.0
1986	1,888	233	0.08	0.09	342.1
1987	1,766	2,007	0.13	0.40	316.2
1988	3,787	1,783	0.03	0.31	689.8
1989	3,347	1,084	0.10	0.13	602.3
1990	2,609	332	0.50	0.11	473.2
1991	2,143	117	0.32	0.14	388.4
1992	1,837	247	0.23	0.16	330.7
1993	1,536	111	0.13	0.08	277.1
1994	1,262	164	0.19	0.12	227.9
1995	1,032	257	0.24	0.14	186.1
1996	918	174	0.15	0.04	166.3
1997	870	227	0.17	0.15	157.7
1998	830	251	0.25	0.11	150.0
1999	984	348	0.21	0.10	178.2
2000	1,210	606	0.16	0.10	217.3
2001	1,839	6,375	0.11	0.12	331.0

Table 13. Predictions for fishing mortality in 2002 (F_{2002}) and the probability that $F_{0.1}$will be exceeded for various catch levels and two assumptions for natural mortality.

	$M_{2002} = M_{2001}$		$M_{2002} = 3 * M_{2001}$	
Catch in 2002	F_{2002}	Probability F_{2002} Exceeds $F_{0.1}$	F_{2002}	Probability F_{2002} Exceeds $F_{0.1}$
200	0.030	0.002	0.040	0.011
300	0.044	0.013	0.061	0.049
400	0.060	0.043	0.083	0.129
500	0.076	0.100	0.106	0.231
600	0.092	0.173	0.131	0.329
700	0.109	0.255	0.156	0.421

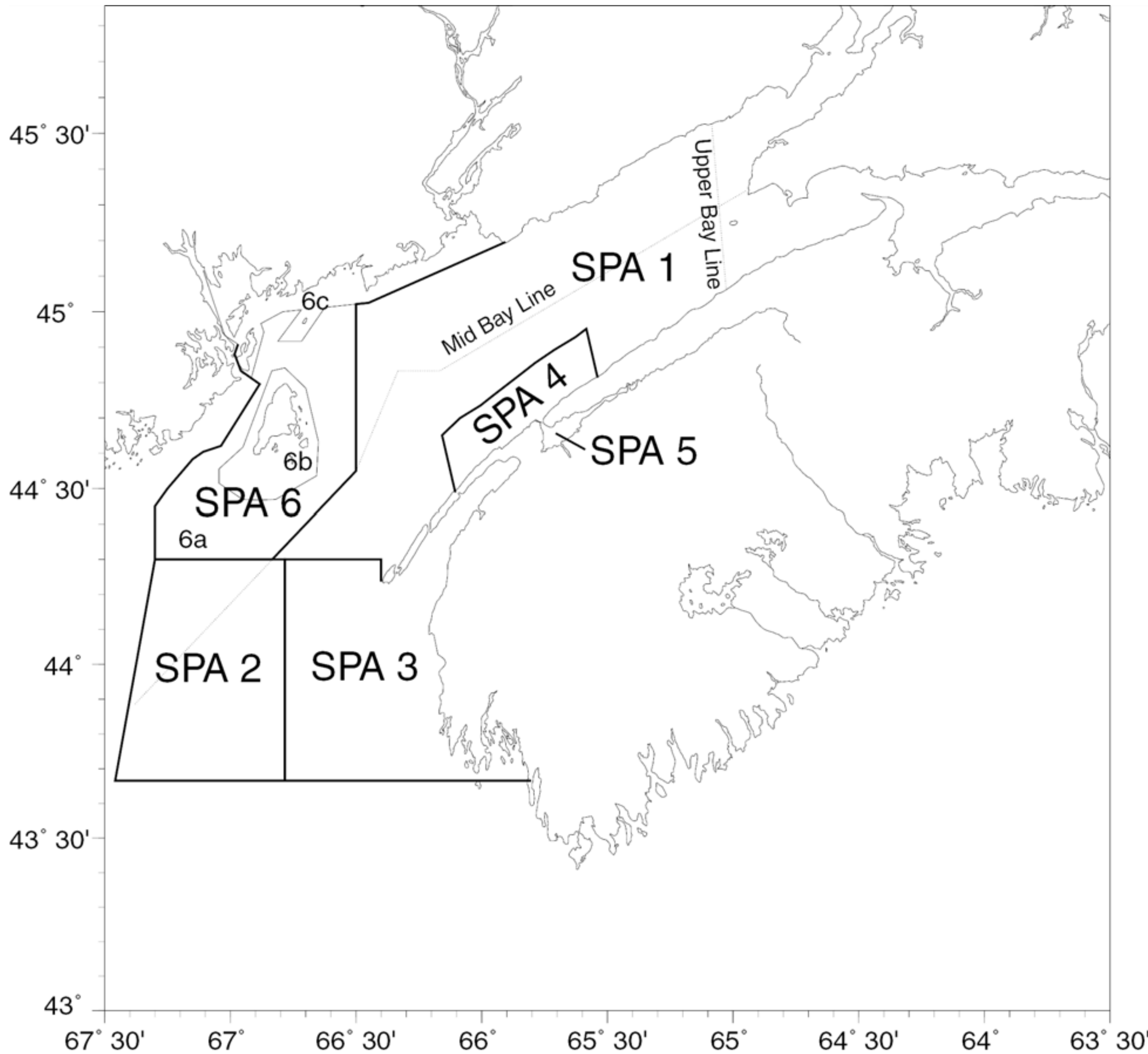


Figure 1. Scallop Production Areas (SPA's) and regulated lines in the Bay of Fundy.

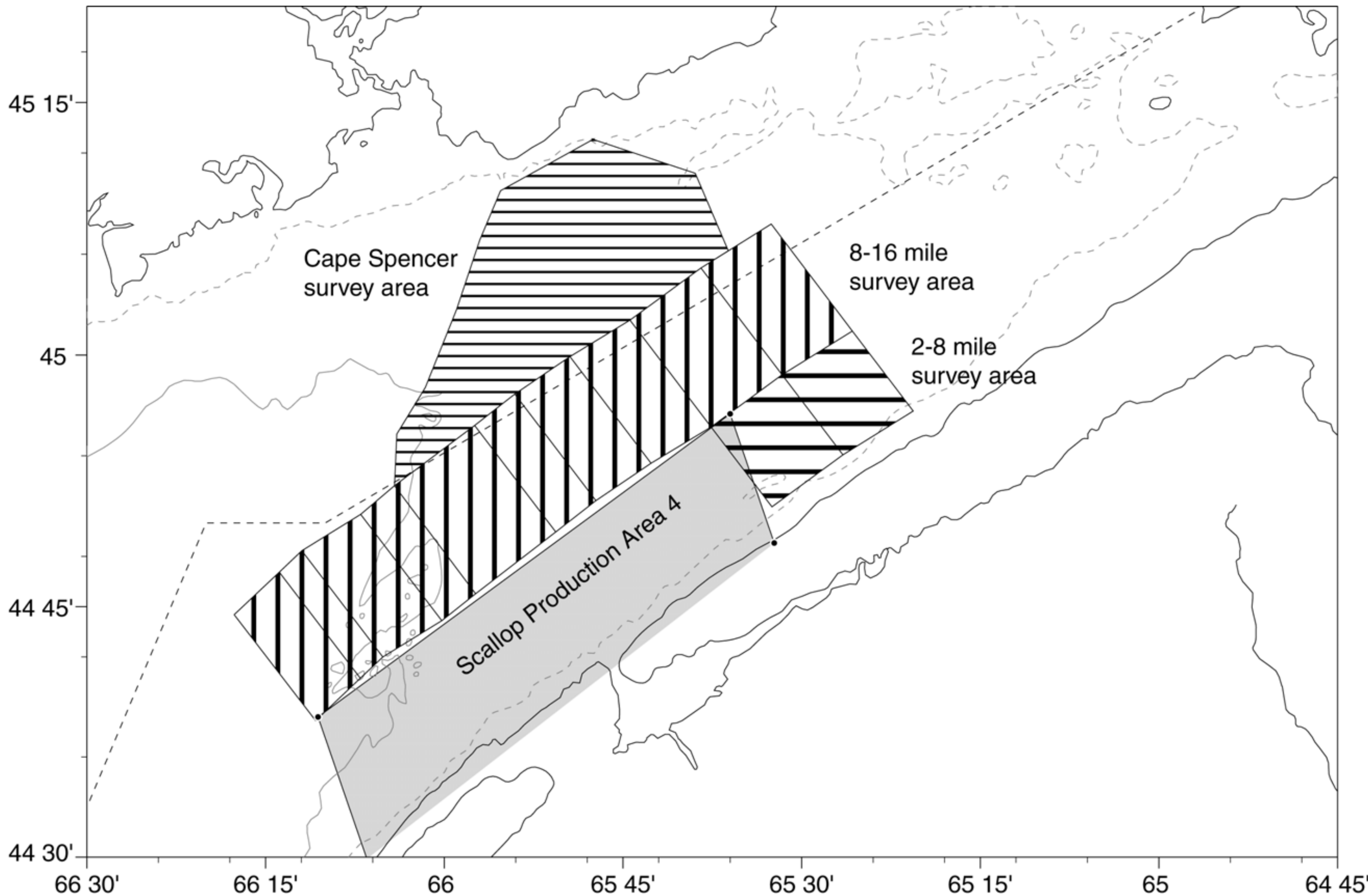


Figure 2. The 8-16 mile and 2-8 mile sections of SPA 1 that have a consistent series of annual surveys, and the Cape Spencer survey area.

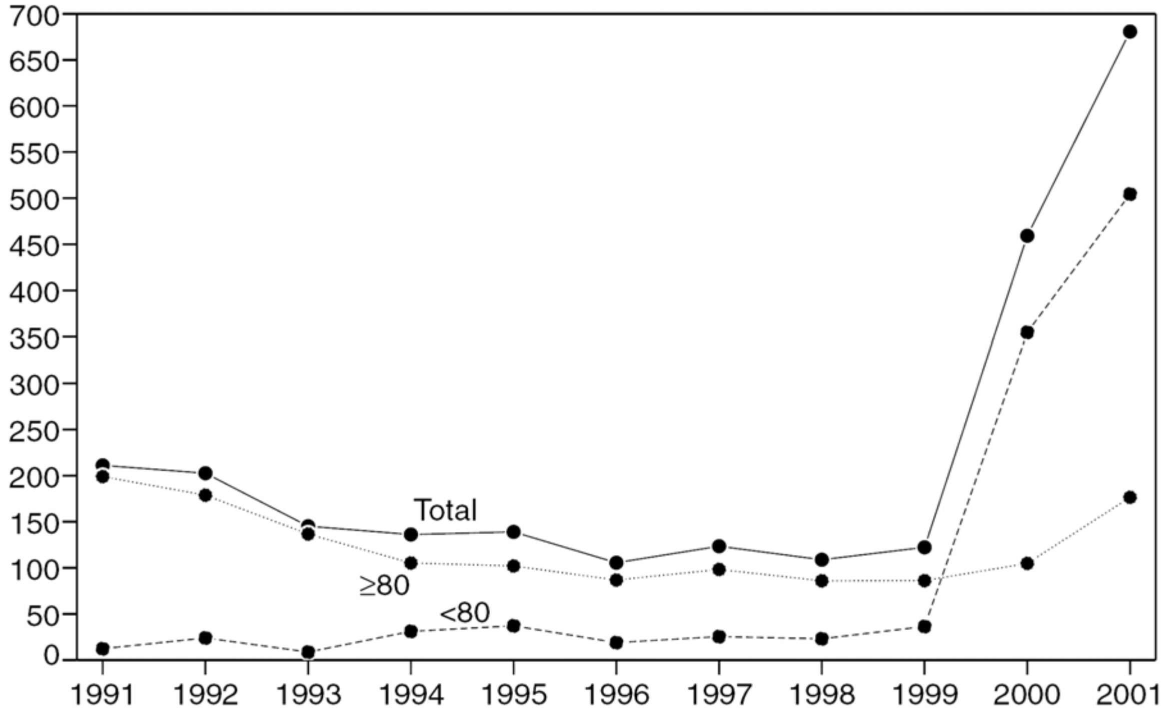


Figure 3. Stratified mean numbers per standard tow in the 8-16 mile area of SPA 1.

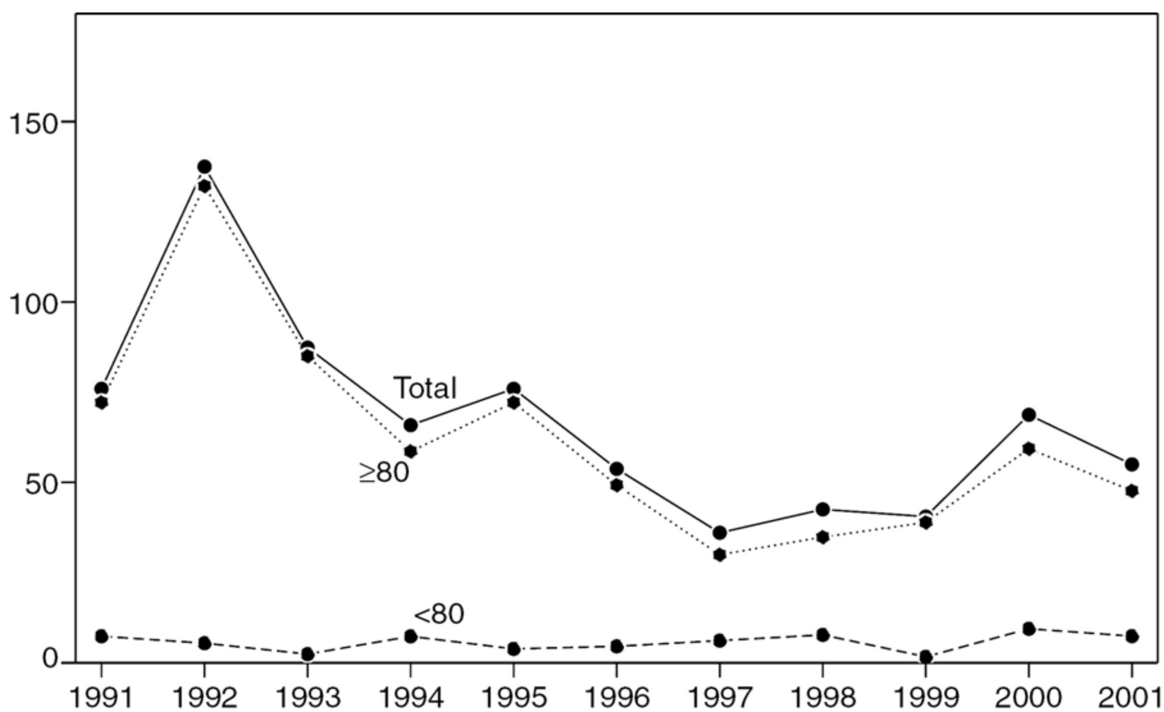


Figure 4. Trends in stratified mean numbers of scallops per standard tow in the 2-8 mile area of SPA 1.

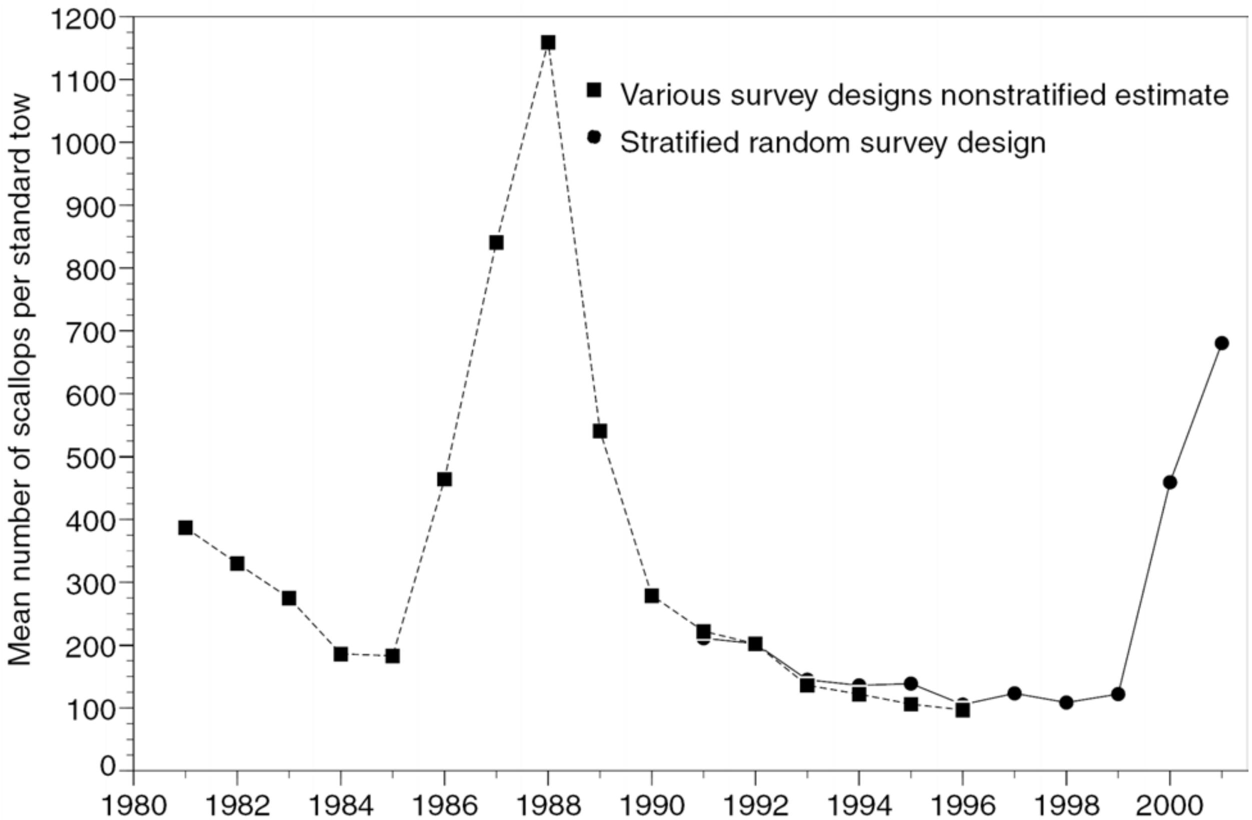


Figure 5. Long term trend in mean number of scallops per standard tow for the 8-16 mile area of SPA 1.

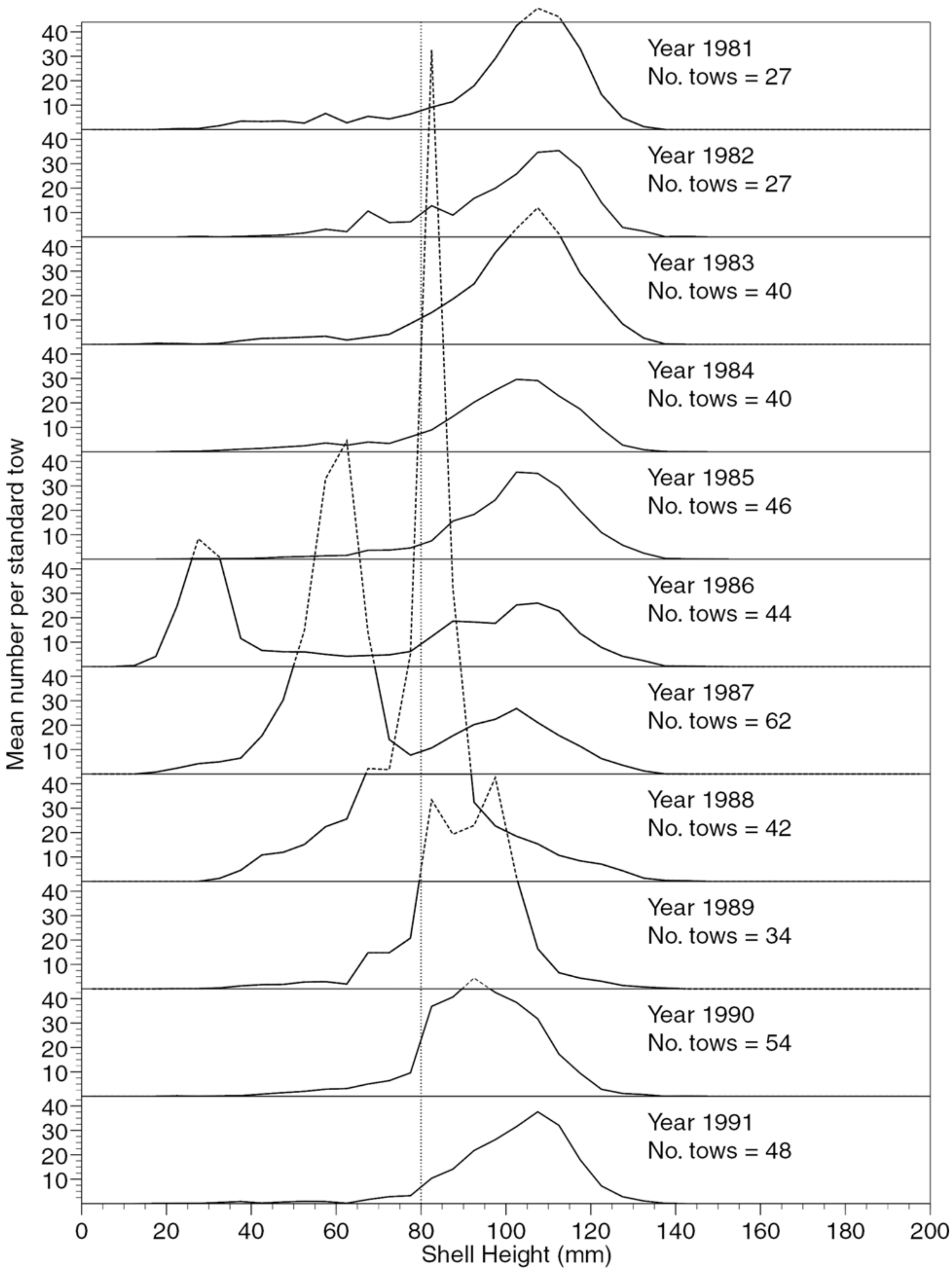


Figure 6a. Survey shell height frequencies for the 8-16 mile area off Sandy Cove to Hampton.

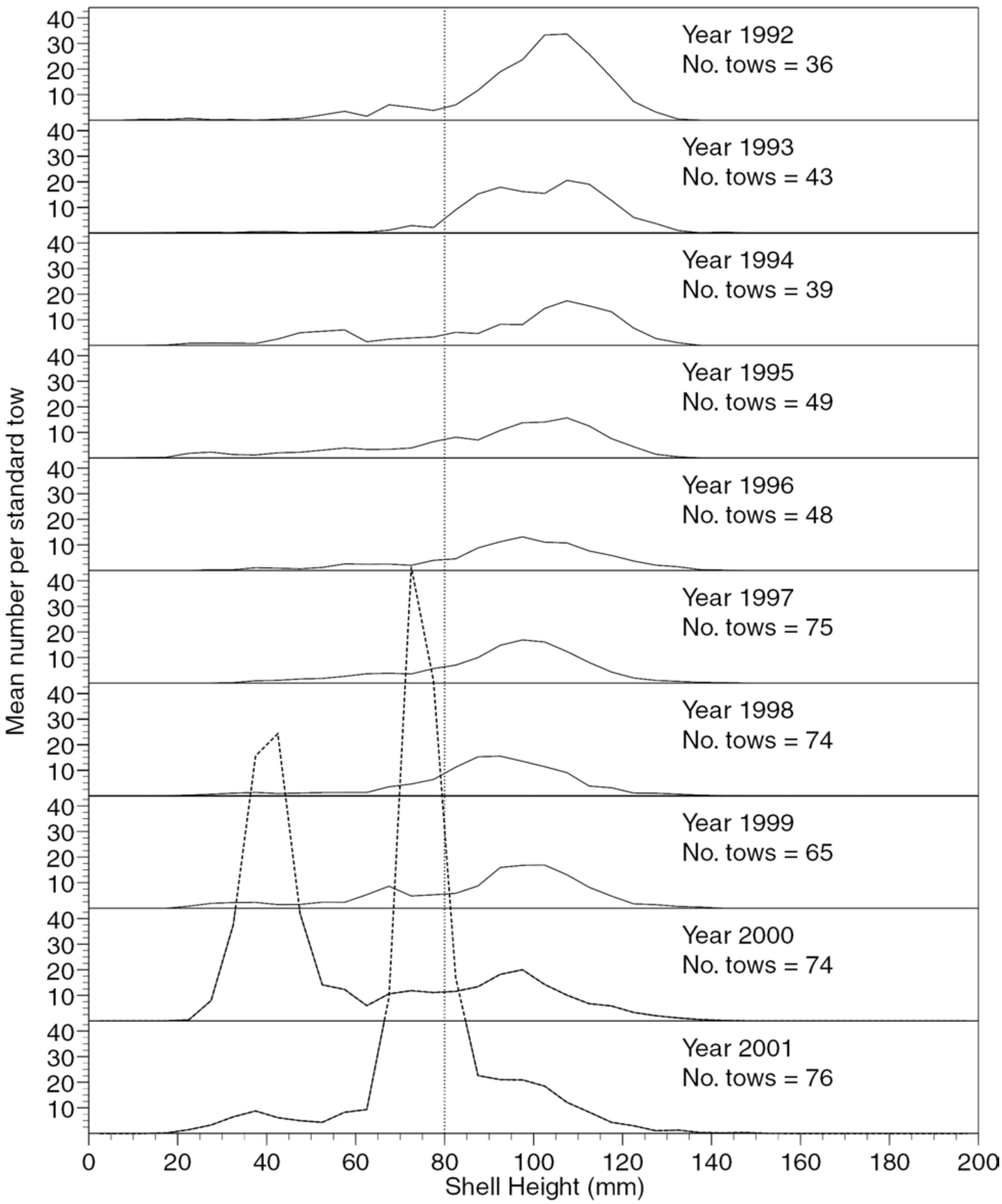


Figure 6b. Survey shell height frequencies for the 8-16 mile area off Sandy Cove to Hampton.

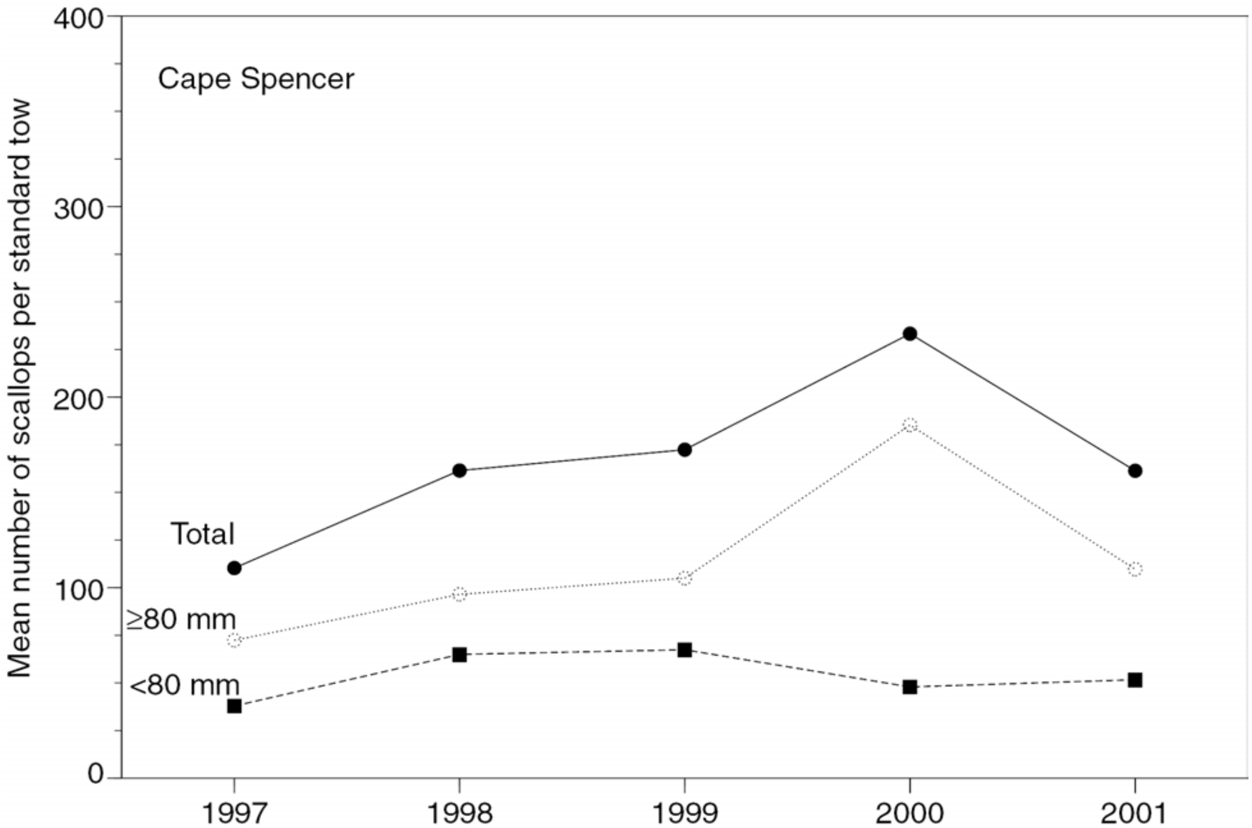


Figure 7. Survey mean numbers per standard tow for the Cape Spencer area of SPA 1.

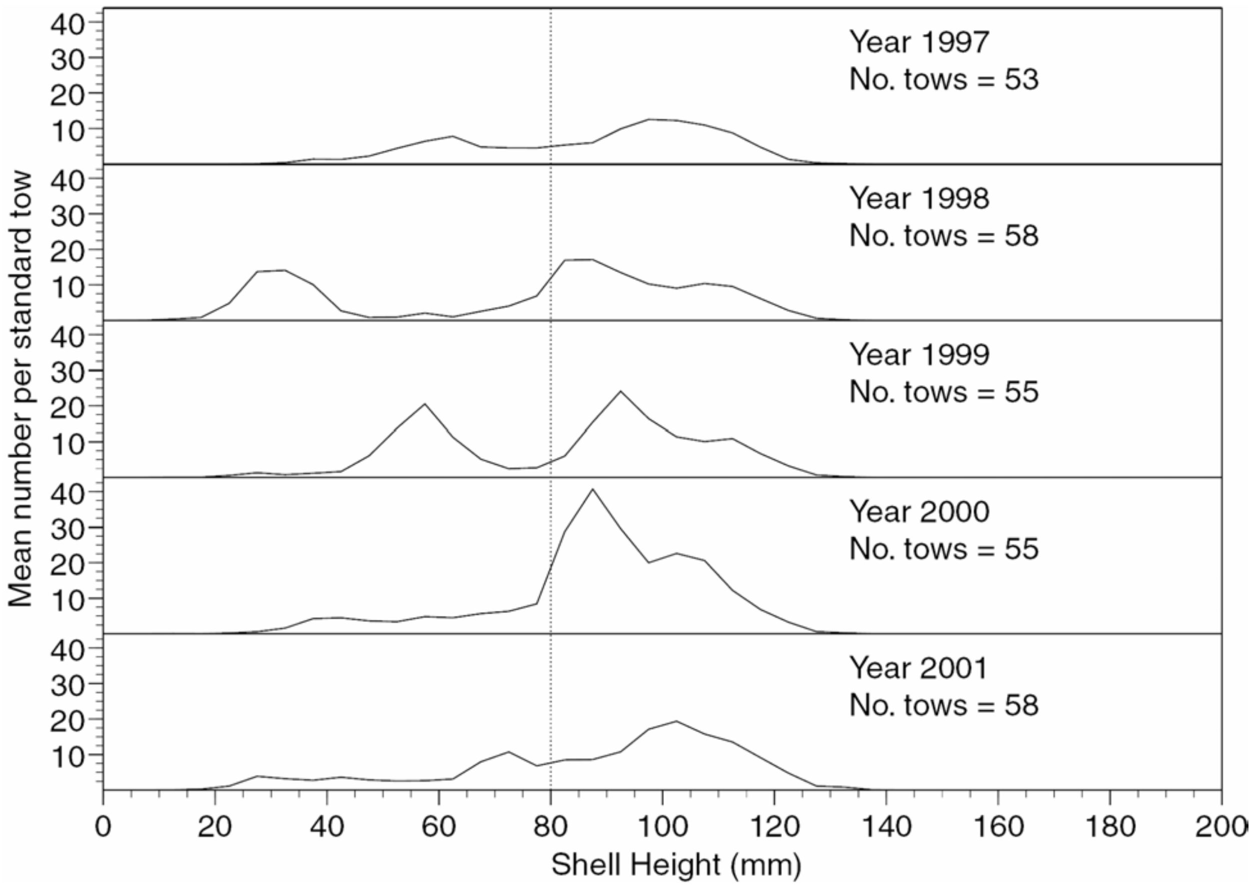


Figure 8. Survey shell height frequencies for the Cape Spencer area of SPA 1.

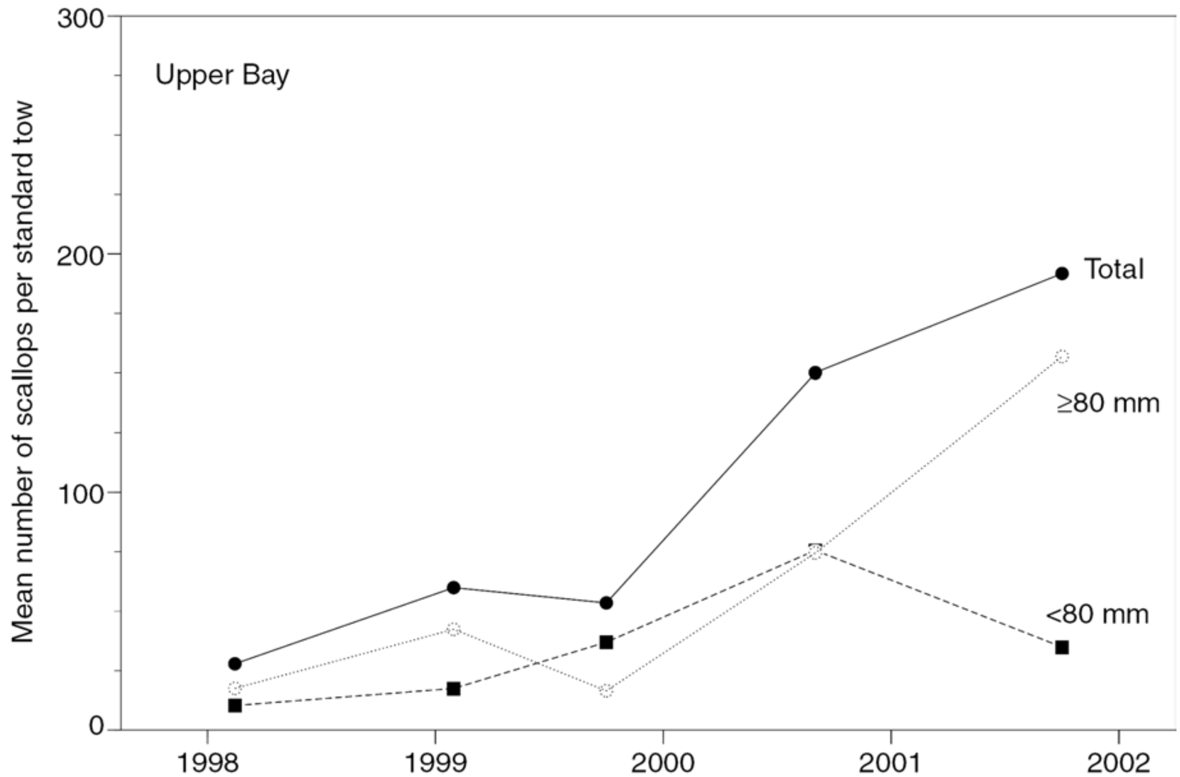


Figure 9. Survey mean numbers per standard tow for the Upper Bay area of SPA 1.

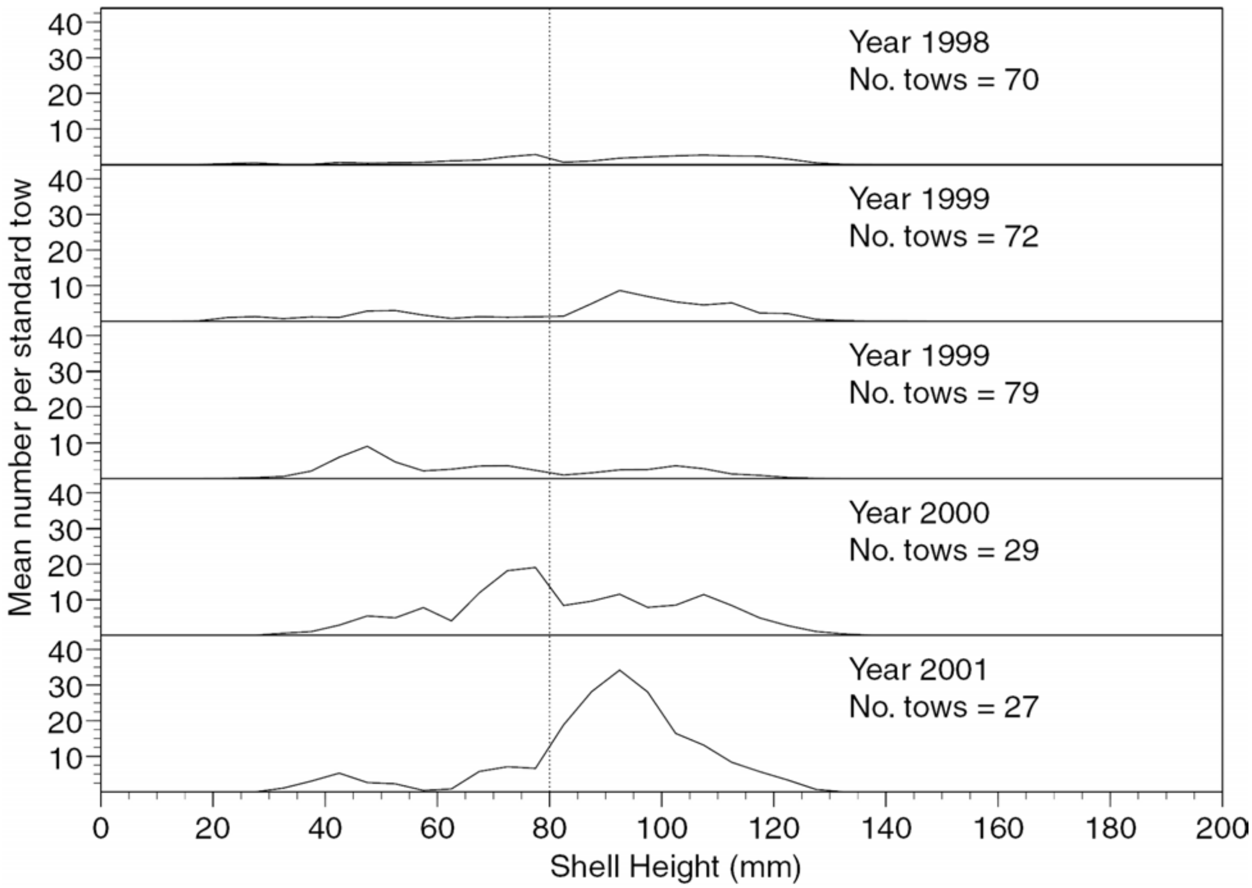


Figure 10. Survey shell height frequencies for the Upper Bay area of SPA 1.

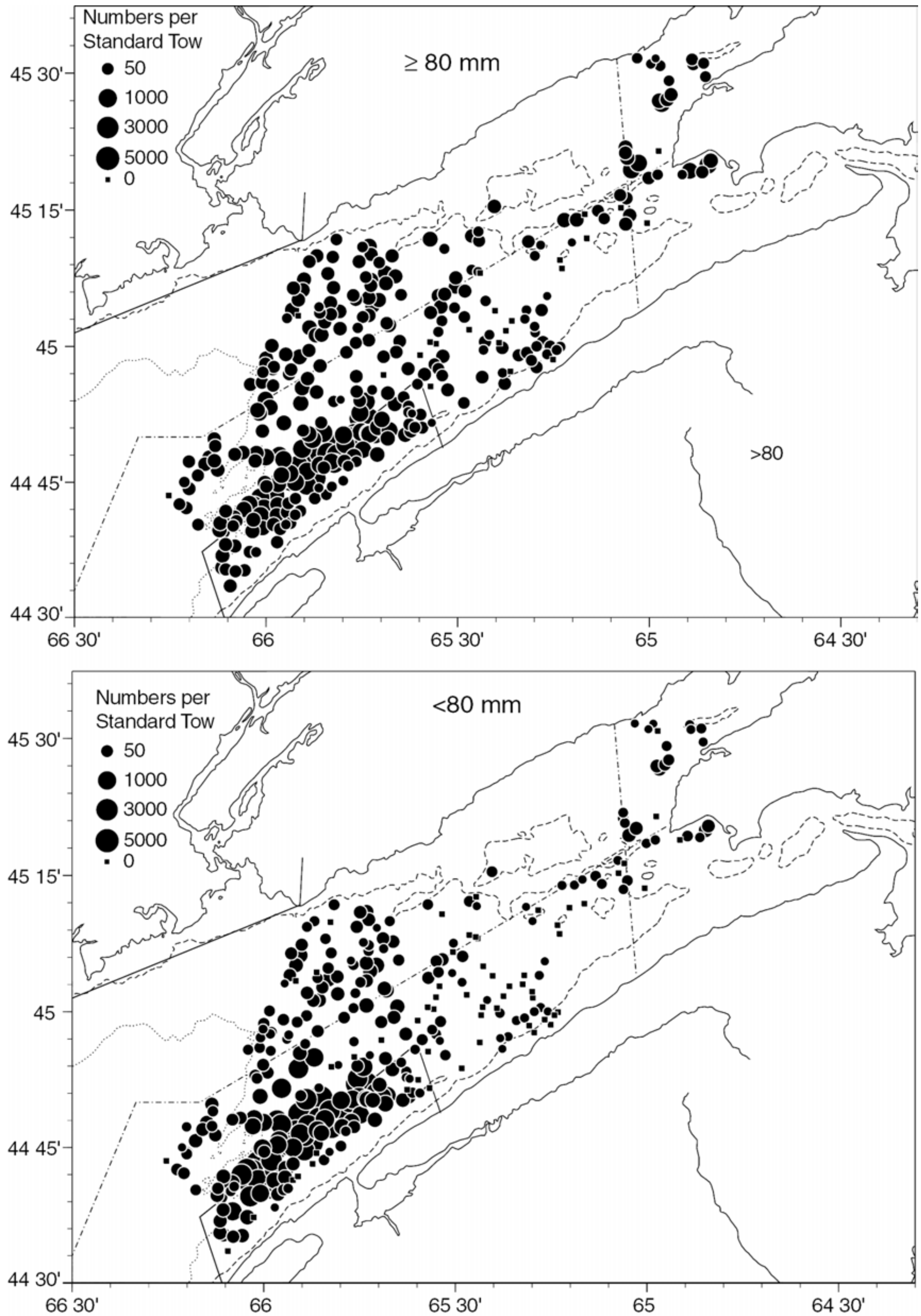
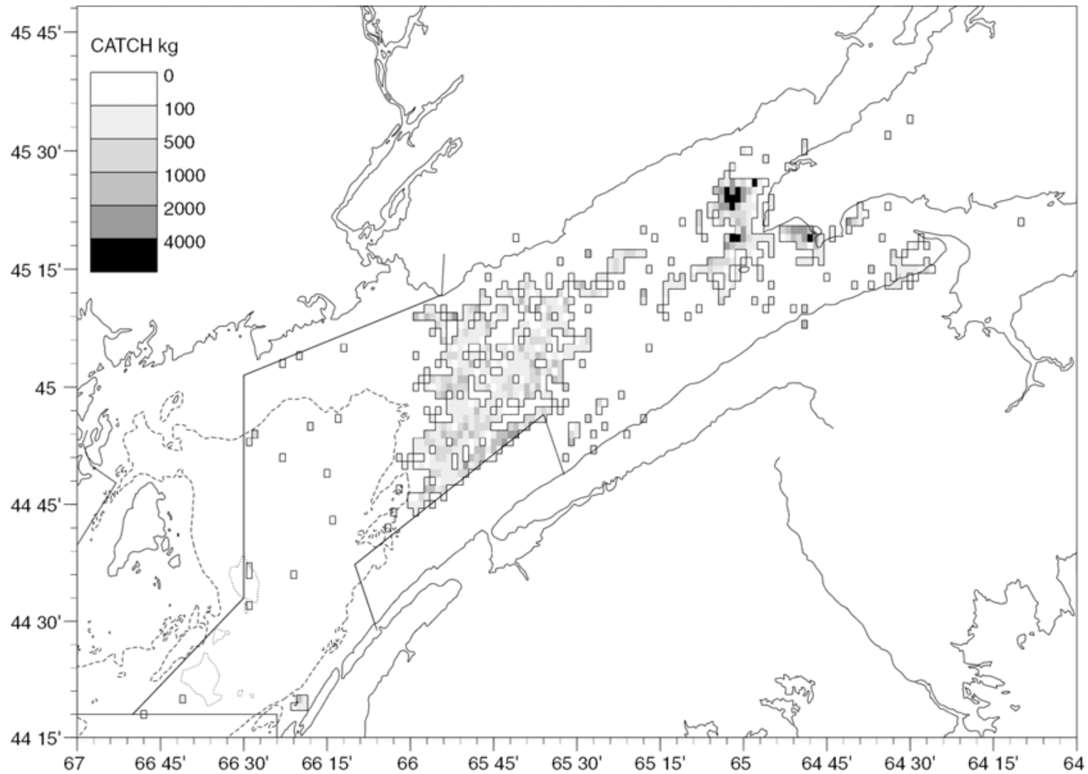


Figure 11. Numbers of recruited (>= 80 mm) and pre recruit (< 80 mm) scallops per standard tow from 2001 survey stations in SPA 1 and 4 in 2001.



2001 Logged catch by one minute squares.

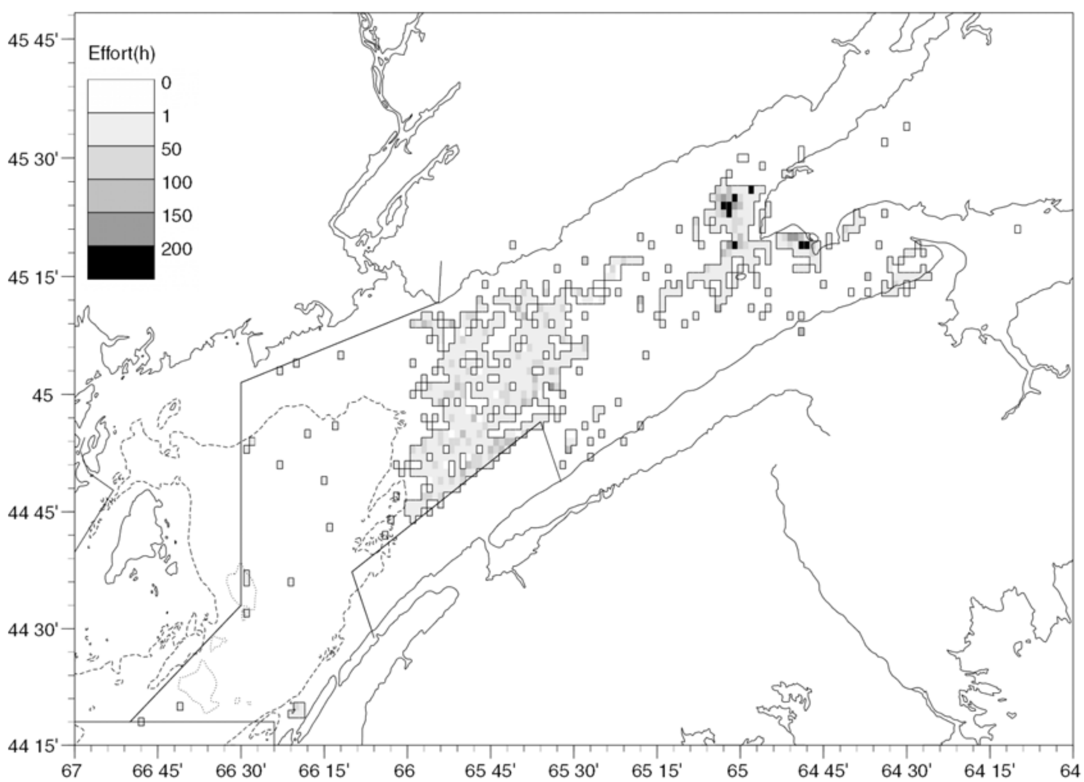


Figure 12. Logged catch and effort (h) aggregated by one minute squares for 2001 in SPA 1.

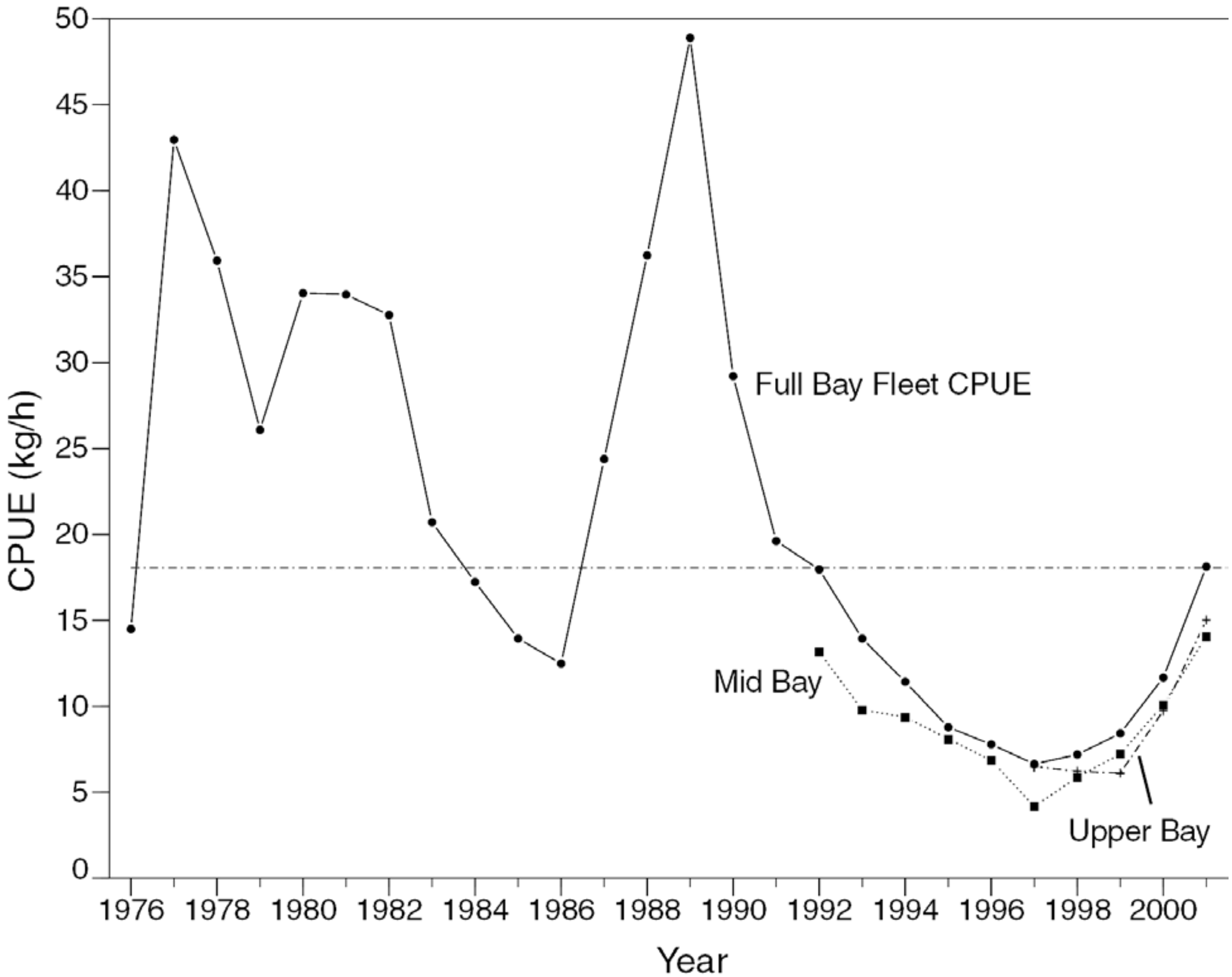


Figure 13. Mean CPUE for all three fleets in SPA 1 from logbook data. Horizontal line is the median CPUE for the Full Bay fleet for 1976-2001.

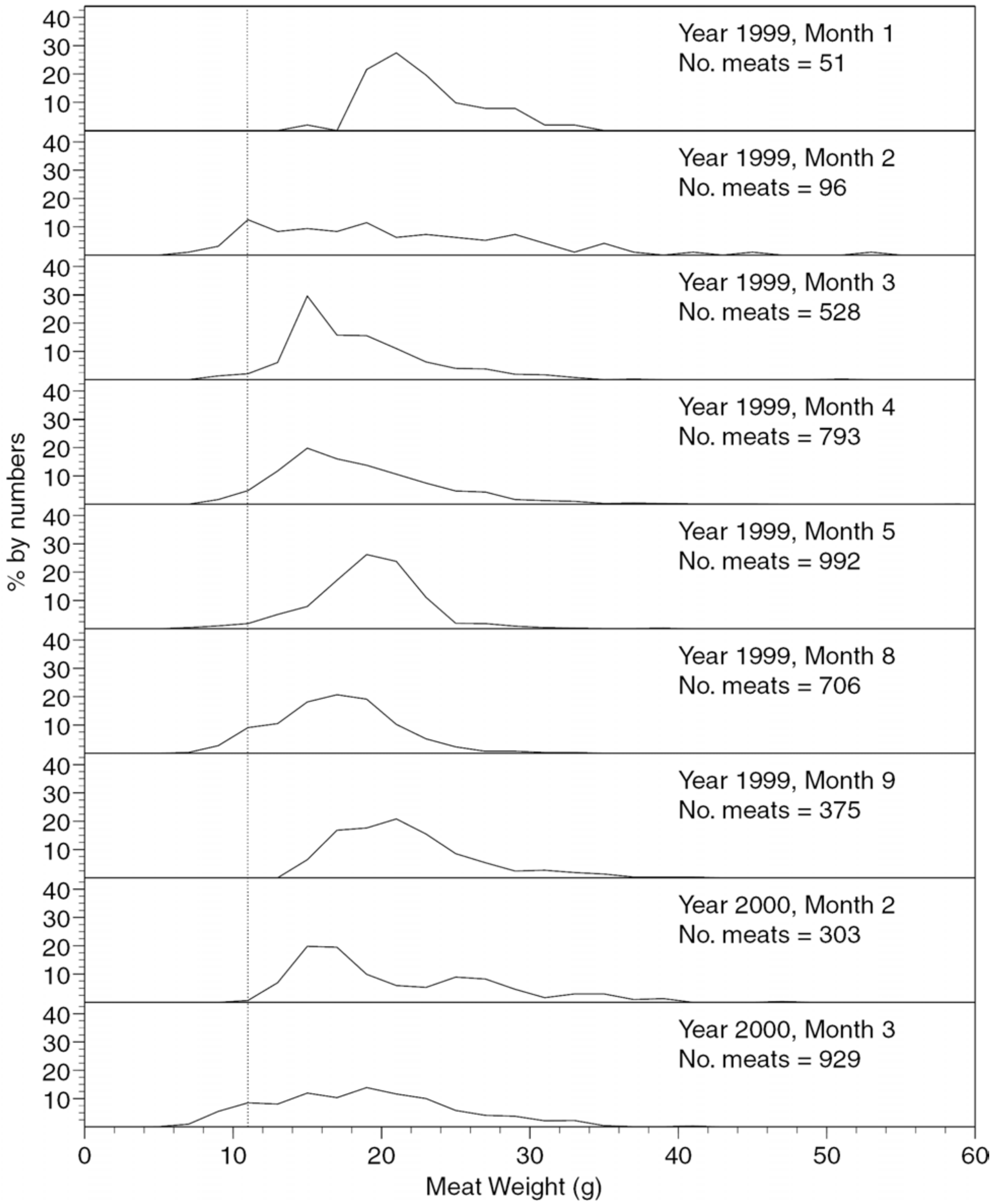


Figure 14a. Meat weight distribution for port samples for vessels fishing in the Digby 8-16 mile area of SPA 1 from Sandy Cove to Hampton for 1999-2001. Line at 11 g is equivalent to a 45/500g scallop meat.

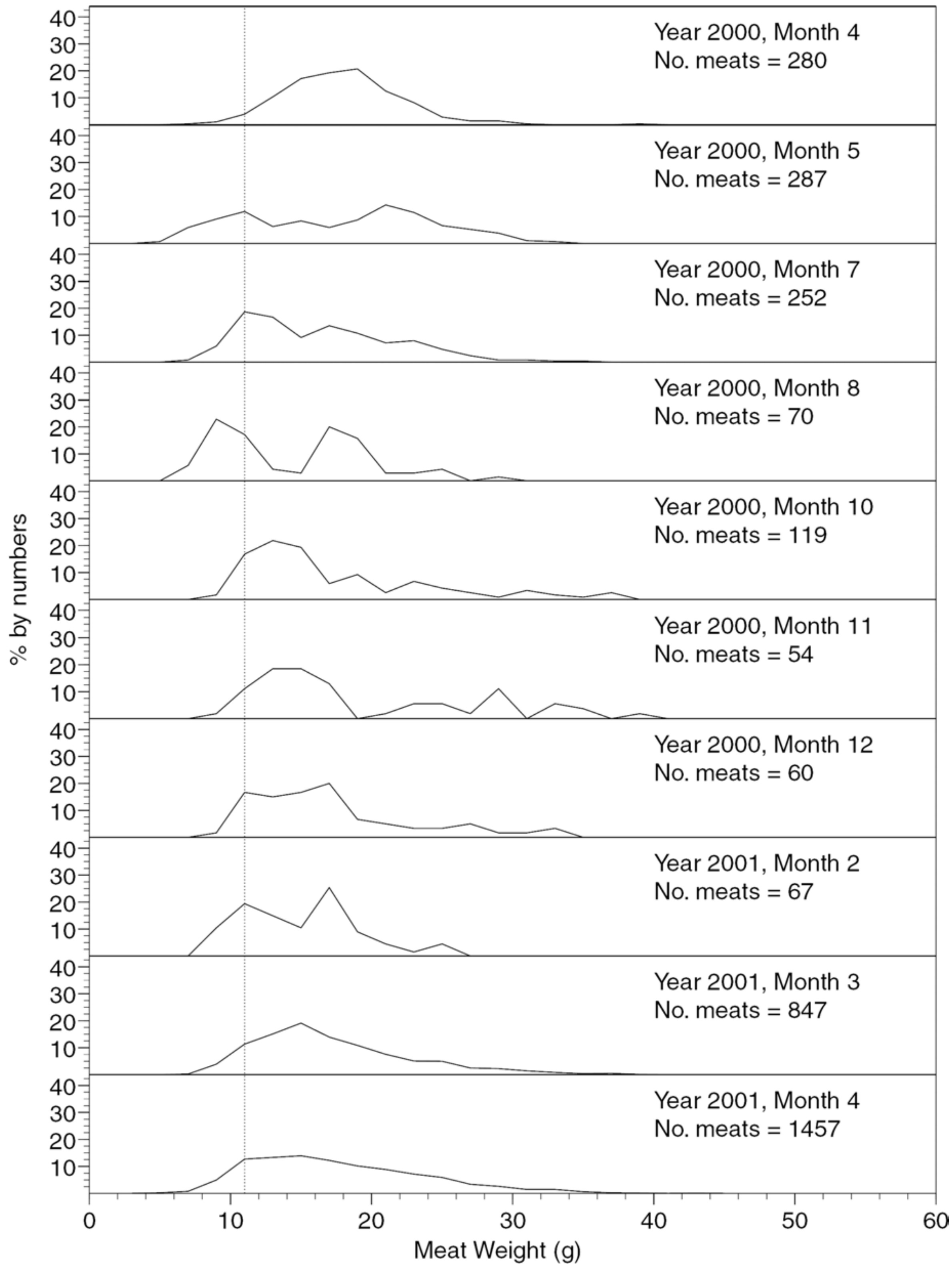


Figure 14b. Meat weight distribution for port samples for vessels fishing in the Digby 8-16 mile area of SPA 1 from Sandy Cove to Hampton for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

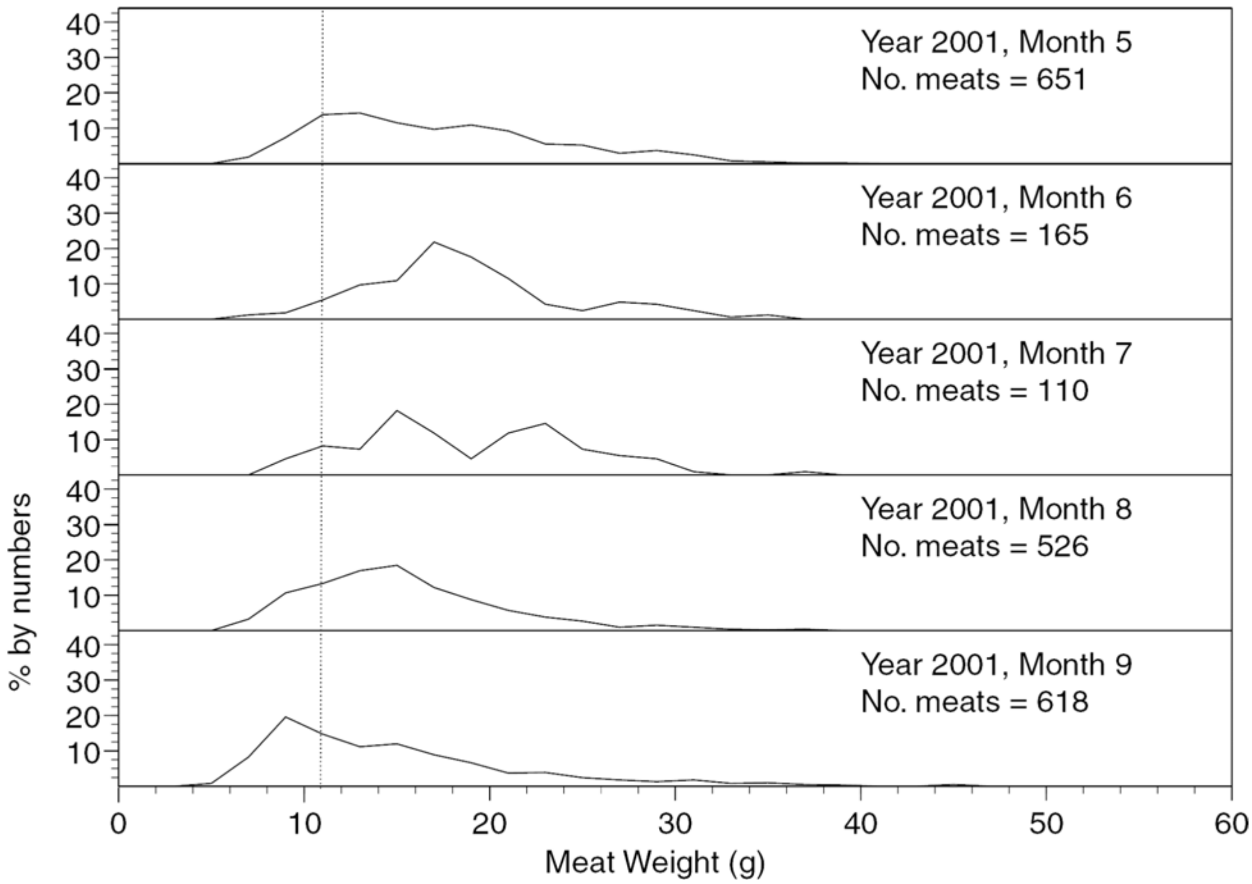


Figure 14c. Meat weight distribution for port samples for vessels fishing in the Digby 8-16 mile area of SPA 1 from Sandy Cove to Hampton for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

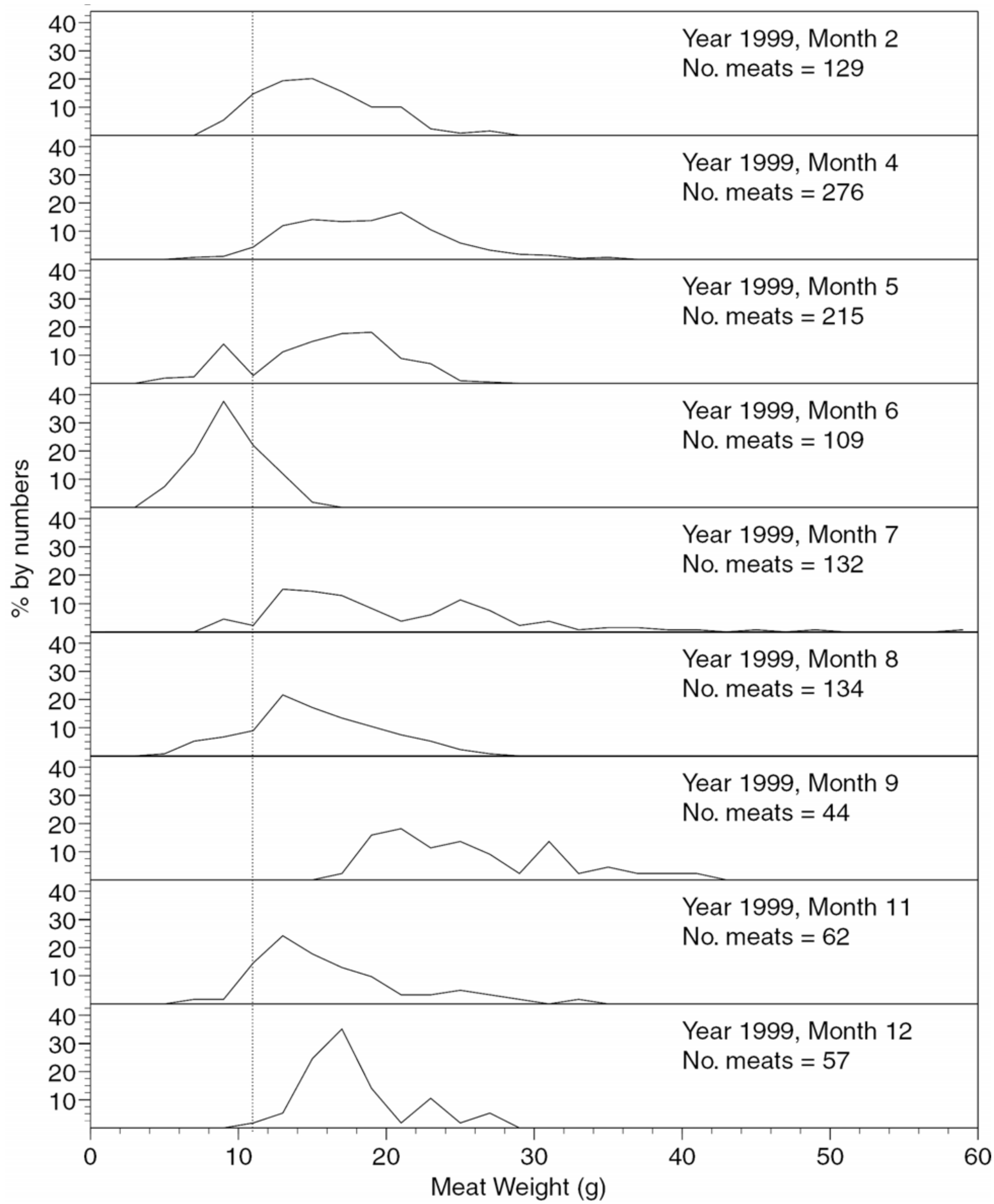


Figure 15a. Meat weight distribution for port samples for vessels fishing in the Cape Spencer area of SPA 1 for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

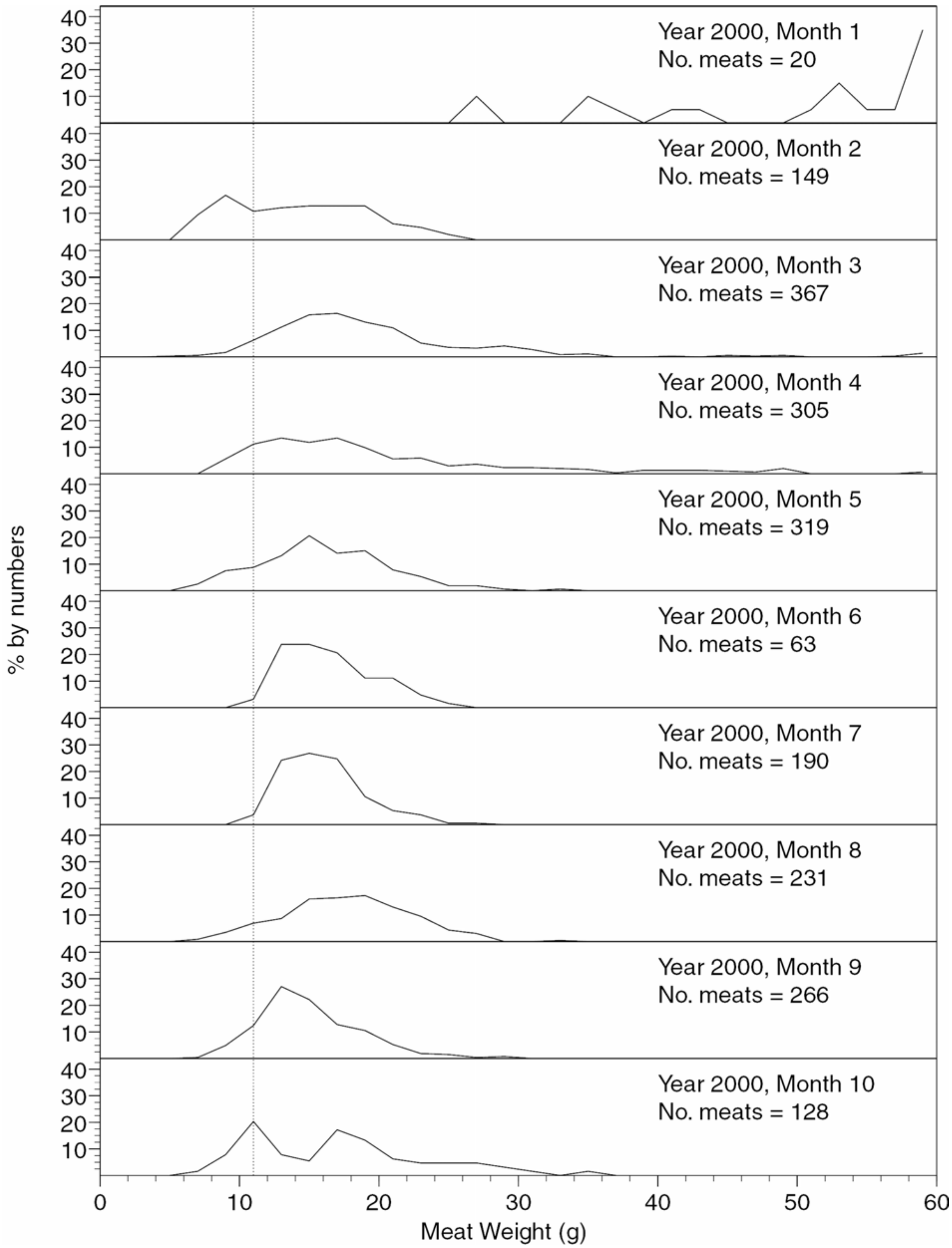


Figure 15b. Meat weight distribution for port samples for vessels fishing in the Cape Spencer area of SPA 1 for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

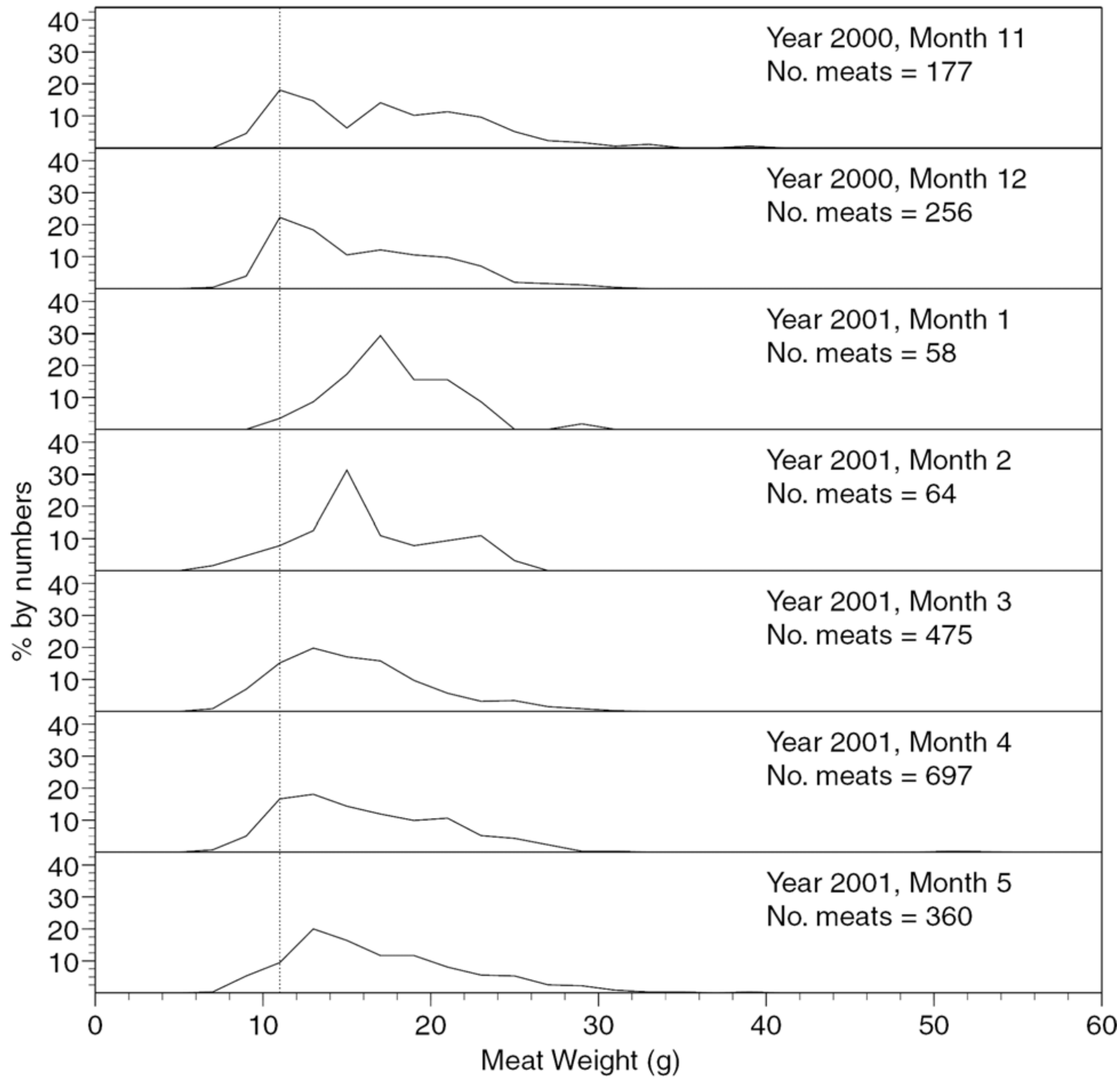


Figure 15c. Meat weight distribution for port samples for vessels fishing in the Cape Spencer area of SPA 1 for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

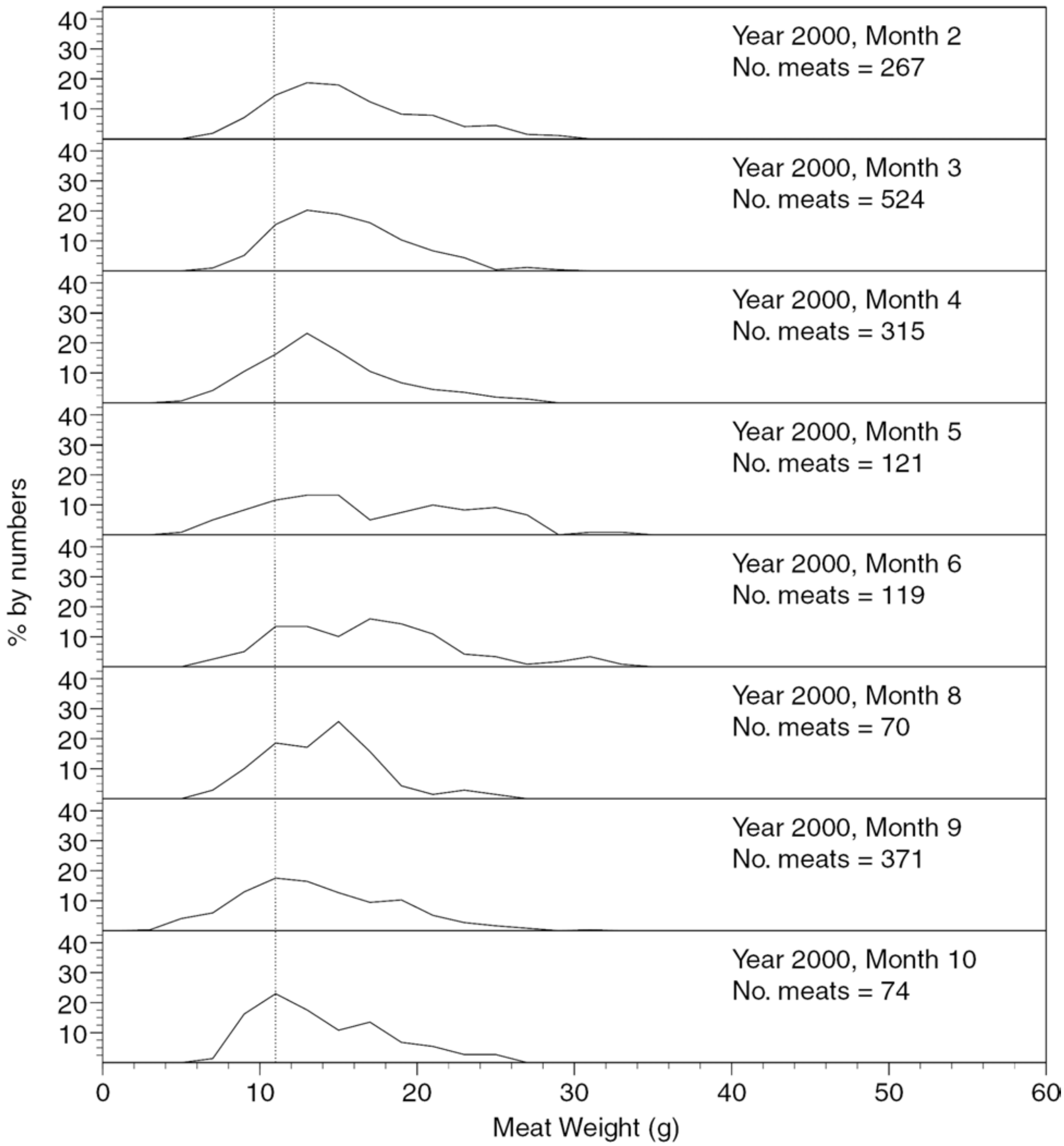


Figure 17a. Meat weight distribution for port samples for the Upper Bay area of SPA for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

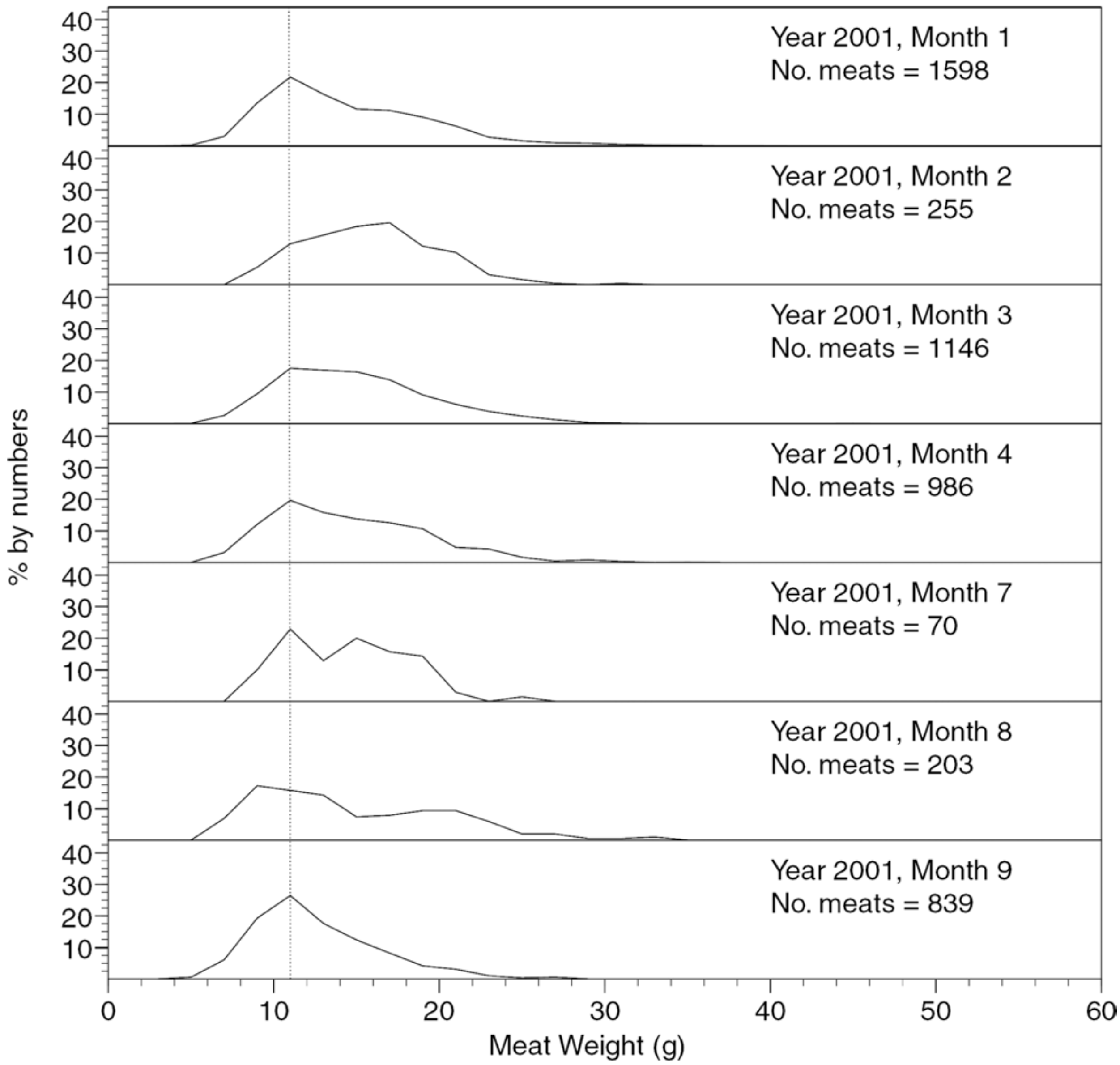


Figure 17b. Meat weight distribution for port samples for the Upper Bay area of SPA for 1999 to 2001. Line at 11 g is equivalent to a 45/500g scallop meat.

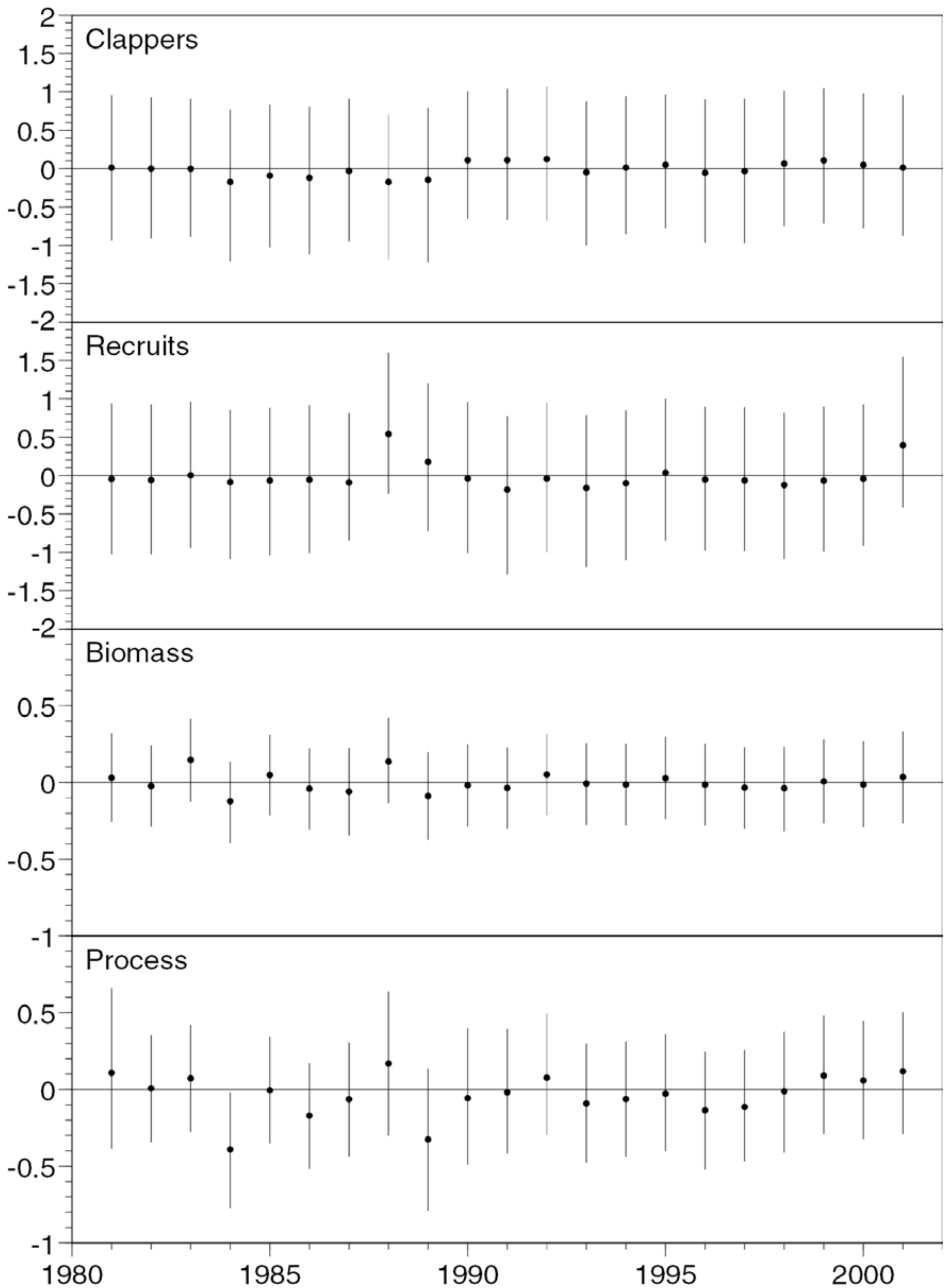


Figure 18. Residuals for the four main error terms in the liklihood for the model run on the 8-16 mile Digby area excluding Centerville.

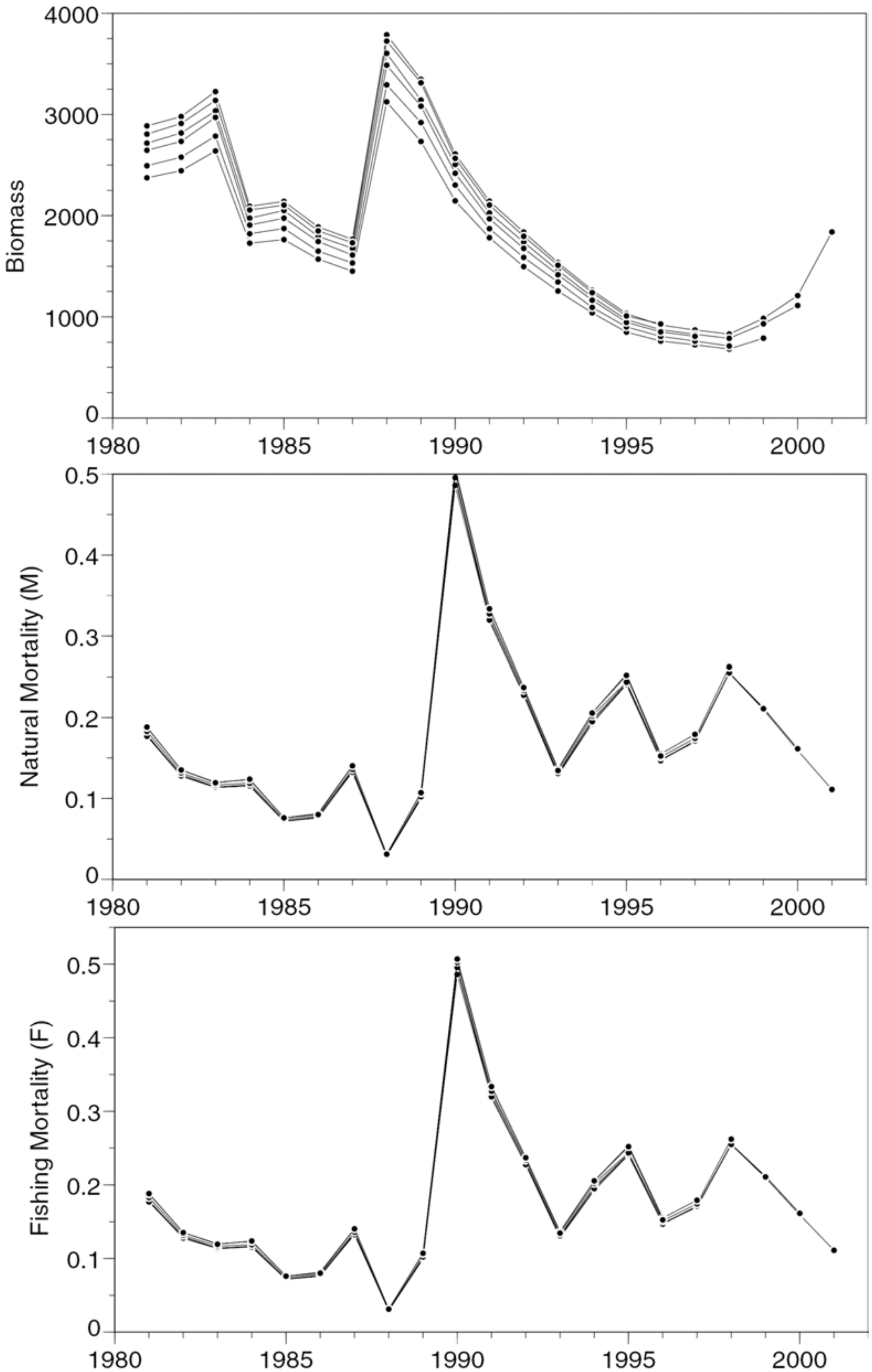


Figure 19. Retrospective analysis of the Biomass Dynamic model for the 8-16 mile Digby area excluding Centerville.

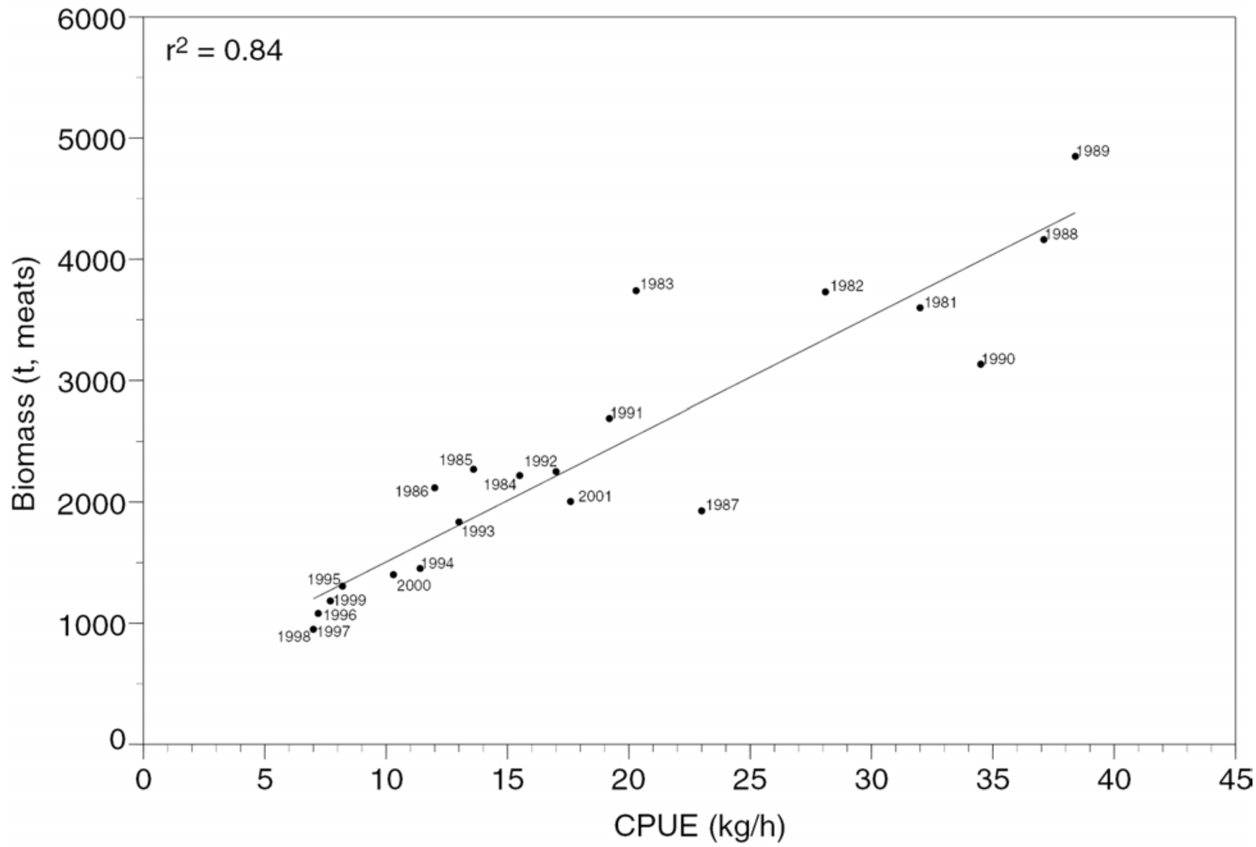


Figure 20. Plot of model Biomass estimates versus commercial CPUE for the 8-16 mile Digby Area.

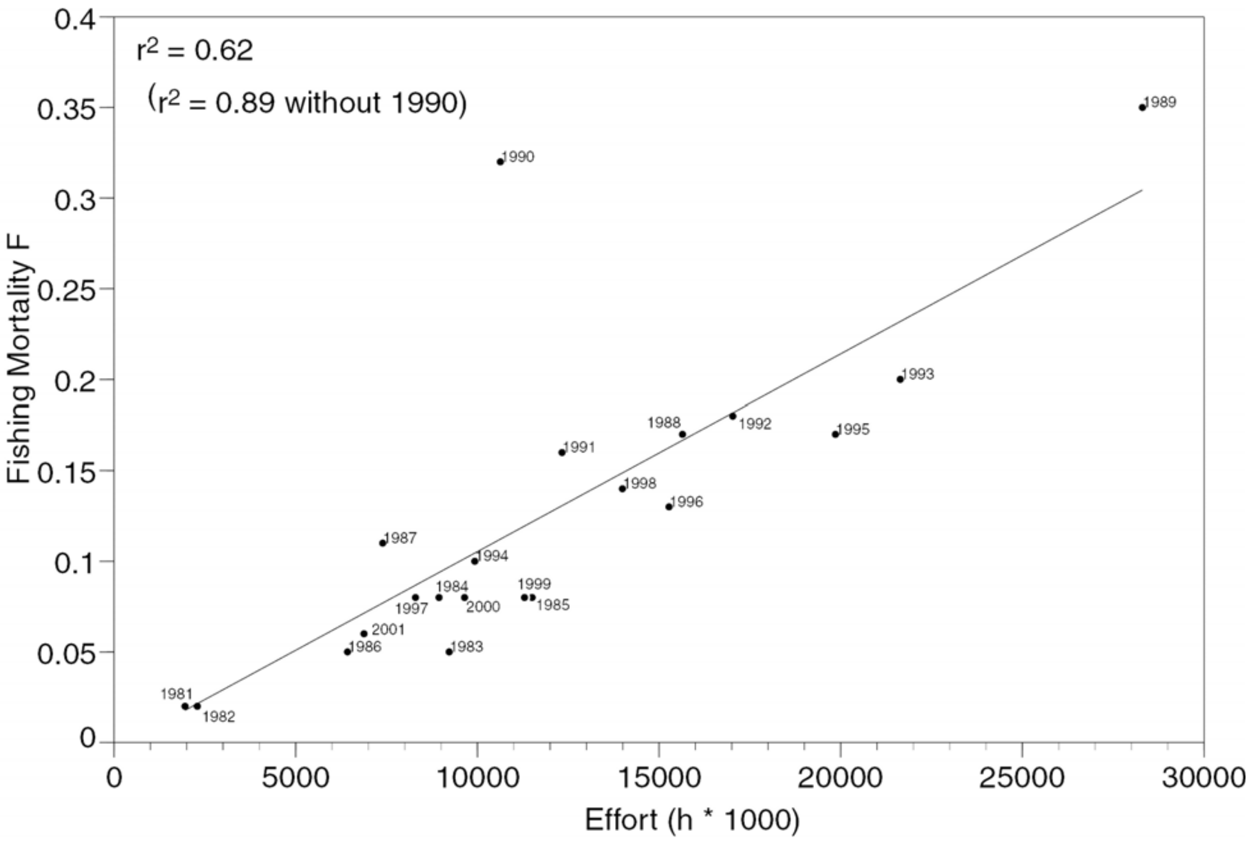


Figure 21. Plot of model estimate of F versus commercial effort for the 8-16 mile Digby area.