SEASONAL MONITORING SURVEYS OF SCALLOP (*PLACOPECTEN MAGELLANICUS)* IN SCALLOP PRODUCTION AREAS 1 AND 4 FROM 2000-2005

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TABLE OF CONTENTS

ABSTRACT

Nasmith, L., and Smith, S.J. 2017. Seasonal monitoring surveys of scallop (*Placopecten magellanicus*) in Scallop Production Areas 1 and 4 from 2000-2005. Can. Tech. Rep. Fish. Aquat. Sci. 3216; v + 38 p.

Surveys of scallop populations in the Bay of Fundy have been conducted by Fisheries and Oceans Canada annually since 1981. During the June 2000 survey, large numbers of small scallops (less than 55 mm shell height) were caught in Scallop Production Areas (SPAs) 1A and 4. The abundance of these small scallops were the largest in the survey in almost a decade. The fishing industry expressed concern that this year class could suffer from a mass mortality event like that which occurred in 1989/1990. A seasonal monitoring survey was initiated in October 2000 to increase sampling frequency and monitor for signs of increased mortality. The monitoring surveys continued until 2005. No mortality events were observed in SPA 1A or SPA 4 during the monitoring program. This monitoring program had the benefit of allowing for the collection and examination of data at a higher resolution than is capable in the annual surveys.

RÉSUMÉ

Nasmith, L., et Smith, S.J. 2017. Relevés de surveillance saisonnière des pétoncles (*Placopecten magellanicus*) dans les zones de production de pétoncles 1 et 4, de 2000 à 2005**.** Rapp. tech. can. sci. halieut. aquat. 3216 v + 38 p.

Les relevés sur les populations de pétoncles de la baie de Fundy sont menés par Pêches et Océans Canada (MPO) chaque année depuis 1981. Au cours du relevé de juin 2000, un grand nombre de pétoncles de petite taille (hauteur de coquille inférieure à 55 mm) ont été capturés dans les zones de production de pétoncles (ZPP) 1A et 4. L'abondance de ces petits pétoncles était la plus importante depuis près de dix ans. L'industrie de la pêche s'est dite préoccupée par le fait que cette classe d'âge puisse souffrir d'un épisode de mortalité massive comme celle qui a eu lieu en 1989-1990. Un relevé de surveillance saisonnière a été effectué en octobre 2000 pour accroître la fréquence des prélèvements et surveiller les signes de mortalité accrue. Les relevés de surveillance ont continué à être effectués jusqu'en 2005. Aucun épisode de mortalité n'a été observé dans les ZPP 1A ou 4 dans le cadre du programme de surveillance. Ce programme de surveillance a permis la collecte et l'examen de données à une plus grande échelle que ne le permettent les relevés annuels.

INTRODUCTION

Surveys of Atlantic Sea Scallop (*Placopecten magellanicus*) populations in the Bay of Fundy have been conducted by Fisheries and Oceans Canada (DFO) annually since 1981. These research surveys collect information on scallop abundance, biomass, and growth. Annual surveys are beneficial in that they allow for careful monitoring of the stock status and health. While annual surveys can characterize the stock at the time of sampling, seasonal changes between surveys within a scallop population are not observed. During the June 2000 scallop survey large numbers of small scallops (less than 55 mm shell height) were caught in Scallop Production Areas (SPAs) 1A and 4 (Figure 1). The abundance of these small scallops was far greater than in the previous year (Figure 2) and the largest in almost a decade (Smith and Lundy 2000). These small scallops, identified as the 1998 year class, were widespread over the survey area, but were more abundant in shallower depths (<90 m).

The scallop fishing industry expressed concern that this year class could suffer from a mass mortality event. A mass mortality event had occurred in 1989/1990 that affected the large 1984 and 1985 year classes (Smith and Lundy 2002). In that instance, large numbers of scallops caught in the June 1989 survey were observed to have gelatinous meats, and clappers (dead, paired empty shells) were abundant in both years. A mass mortality event was also recorded for calico scallops (*Argopecten gibbus*) exhibiting similar symptoms off the coast of Florida in late 1988. That mortality event was caused by an invasive species of protozoan (Moyer et al. 1993). However, scallop samples from the Bay of Fundy taken in 1989 were not sufficiently preserved for histological analysis to identify if the cause was the same.

To address the concerns of industry, a seasonal survey was initiated in October 2000 to increase sampling frequency and monitor for any signs of increased mortality in the scallop population. In this case, mortality could be monitored through dead, paired shells in the catch. In addition, the survey provided the opportunity to work with industry to collect growth and yield data throughout the year. The F/V Julie Ann Joan was used by DFO Science to collect data on this large recruitment pulse. This project was fully funded by DFO Science until January 2003 when funding was no longer available. At that time the Full Bay Scallop Association agreed to a Joint Project Agreement with DFO Science to fund this project until March 2005.

The data collected was examined at the time of collection but had not been analyzed or published since the sampling program ended in 2005. The purpose of this report is to compile and summarize all of the data from this project.

METHODS

DATA COLLECTION

The collection of data occurred roughly every two months between October 2000 and August 2005. The June and August data was collected during the annual scallop research vessel surveys aboard the J.L. Hart from 2000 to 2004. Starting in 2000, the monitoring occurred only in SPA 4 (Figure 3). In the fall of 2002, after discussions with the Inshore Scallop Advisory Committee, the sampling program was extended to include stations in SPA 1A (Figure 3). Two other areas were included at different times, Annapolis Basin (SPA 5, December 2000 and 2003) and the Brier Island/Lurcher Shoal area (SPA 3, March 2001; Table 1). These sampling events were opportunistic and are not included in these analyses.

In all, 28 trips were made over five years. There were slight modifications to the survey and sampling protocols over time. Generally, 10–15 tows were conducted in an SPA during each sampling event. Tows were randomly distributed within strata used by the annual inshore scallop survey. The number and length of tows (10–20 minutes) varied through time due to weather and quantities of scallops caught. There were shorter tows in the first 18 months of monitoring, due to high abundances of scallop. Sampling was done from one drag lined with a 38 mm mesh. All live scallops and clappers (dead, paired empty shells) were counted and the shell height was measured in 5 mm size bins. A subsample of three animals per 5 mm shell height bin was collected from each tow for further detailed sampling. The detailed sampling included weighting the meat (adductor muscle) and an exact shell height measurement. The total age of the shells were determined based on growth rings, and the number of shock marks on the shells were recorded. Age was used to model growth and also to determine cohorts. Shock marks are marks created on a shell from non-lethal interaction with fishing gear. Gonad and viscera weights along with sex of the individual animals were collected beginning in October 2002 to allow for the creation of a spawning index. Tow information, such as start and end location, depth, course of tow, tidal cycle, and bottom type were recorded throughout the project.

QUALITY CONTROL

All data collected during the program were entered into flat files, but not uploaded to the ORACLE database designed for the annual scallop surveys (SCALLSUR database). When survey data are entered into the database there are checks in place that may identify keystroke and other data-entry errors. The sampling data from this project had not gone through that process. Before analyses began, the data entered in the flat files were checked against the original field data sheets when possible. Data entry was validated for all data types collected.

RESULTS

The scallop population in the Bay of Fundy is surveyed annually and the assessment results are presented by SPA (*e.g.*, Nasmith et al. 2016). The results of this monitoring program are presented by SPA as well. Comparisons of these data to the annual scallop survey results over the same time period should be done cautiously, especially with respect to abundance metrics. The monitoring data comes from a single drag whereas survey data is taken from the whole drag. The monitoring data was also collected using different gear and vessels than those used for the annual survey. The monitoring data has not been standardised to a common tow length or prorated for area swept due to lack of tow distance data. While an estimate of tow distance could potentially be derived from start and end locations for each tow to improve the estimates from the monitoring program, that work has not been done. While the monitoring data may not be directly comparable to survey data, it has benefits as a large multi-year data set independent from the annual survey. The higher sampling resolution allows for the examination of patterns that cannot be observed in an annual survey such as the rapid growth of the 1998 cohort. In some cases, the monitoring survey can be used as a validation of assumptions made from survey data (e.g., inter- vs intra-annual changes in condition factor).

DATA AVAILABLE

The longest continuous monitoring took place in SPA 4, with 28 sampling events in which meat weight/shell height information was collected between June 2000 and June 2005, and 14 cruises from October 2002 to August 2005 during which viscera and gonad weight data were collected (Table 2). In SPA 4, each calendar month was sampled at least once, but some months were only sampled once in the five years, as in the case of April and September. For months that were sampled multiple years, sampling years were not always consecutive. In SPA 4, detailed height, weight and age data was collected from 11 550 scallops, and gonad and viscera weight from 2 239 scallops.

For SPA 1A, there were 12 sampling events between January 2003 and June 2005 (Table 3). Meat weight/shell height information was recorded for all sampling events, and viscera and gonad weight data for 11 of those sampling events. There were no samples in any year for July, October, or December in SPA 1A. In SPA 1A, detailed height, weight and age data was collected from 3 874 scallops, and gonad and viscera weight from 1 689 scallops.

SHOCK MARKS

Shock marks are created on a shell from non-lethal interaction with fishing gear. Aged shells were checked for shock marks. In SPA 1A, 11.8% of aged shells had at least one shock mark. The number of observed shock marks in SPA 1A ranged from zero to four. The proportion of shells with shock marks was greater in SPA 4 at 22.4%. The number of observed shock marks in SPA 4 ranged from zero to five. There was no demonstrable relationship between age, or commercial fishing effort and number of shock marks.

MORTALITY

No mortality events were observed in SPA 1A or SPA 4 during the monitoring program (Figures 4 and 5). Over the course of the monitoring, commercial sized (≥ 80 mm) clappers averaged 3 per tow in SPA 4, and 4 per tow in SPA 1A, with the largest number of clappers observed in 2003. Recruit size (65–79 mm) clappers were rare, averaging less than one per tow in both monitored areas. Pre-recruit (≤ 65 mm) clappers averaged 1.2 per tow in SPA 4 and 1.6 in SPA 1A. The highest numbers occurred early in the program, in 2000 and 2001 in SPA 4 and in 2003 in SPA 1A. The proportion of clappers in the total catch averaged from 3.1 to 4.4 % for SPA 4 and SPA 1A respectively (Figures 6 and 7).

Shell height frequencies for clappers in SPA 1A over the monitoring program (Figure 8) showed a broad size range of clappers, and a relatively consistent abundance in the samples. Shell height frequencies for SPA 4 showed relatively more pre-recruits very early in the program (although scallops under 40 mm are not reliably caught in the gear; Figure 9). After that, shell height frequencies show a broad size range of clappers, with pre-recruits and recruits dominating until November 2001, when commercial size clappers became more common (Figure 10). The large 1998 year class would have been recruiting to the fishery at that time and likely made up the bulk of the clappers observed.

LIVE SCALLOP ABUNDANCE

Abundance of commercial scallops in the tows was greatest throughout 2003 in SPA 1A (Figure 11), with an average of 72 scallops per non-standardized tow over the sampling time. Sampling began in SPA 1A after the 1998 year class reached commercial size, and elevated numbers of recruit sizes were observed in the spring of 2003 (Figure 12), but no recruitment events were evident over the rest of the monitoring time. Pre-recruits and recruits in SPA 1A averaged 1.6 and 7.9 scallops per tow over the monitoring program respectively.

Abundance of commercial scallop in tows in SPA 4 increased steeply in 2001 (Figure 13). The average number per tow of commercial size scallops in June 2001 was 98.9 scallops, this increased to 260 per tow in August and to the time series maximum of 633 per tow in November. This increase in scallops is evident in the 1998 year class recruiting in the shell height frequency for that year (Figure 14). This recruitment kept commercial numbers elevated until the end of 2003 (Figure 15). Numbers in 2004 were similar to pre-recruitment event values in 2000.

The strong year-class was clearly captured in the high numbers of recruits and pre-recruits (Figure 14). Over the time series, the average number of pre-recruits and recruits per tow was 24.1 and 70.8 respectively, but median values were much less at 2 and 5 per tow, respectively. After that year class recruited in 2001, no other large recruitment events were observed during the monitoring program.

1998 YEAR CLASS

The 1998 year class was two years old when monitoring began in SPA 4. In May 2000, two-year old scallop ranged in size from 35–59 mm and by December of that year, they ranged from 40–69 mm (Figure 16). They were first observed at commercial sizes in May 2001, when 17% of age three scallops were of commercial size. They continued to recruit throughout 2001 and in November, 82% of age three scallop caught (and aged) were of commercial size. At the start of 2002, all the age four scallops caught and aged were commercial size.

MEAT WEIGHT

The weight data collected from the detailed sampling is useful because each weight can be linked to a shell height and an age, and therefore a cohort. The weight data were not used to convert the numbers per tow to biomass, as has been done for the annual scallop assessments, because the tows were not standardised and the program sampling was not intended to be used to estimate biomass.

Since each weight is associated with an aged shell, this allows for an examination of weight of cohorts in the samples. In SPA 1A (Figure 17), the older (top panel) cohorts had fewer representatives in the samples, so meaningful patterns are obscured by observations from one individual (e.g., the 1994 cohort in 2005). There were more data from relatively younger cohorts (Figure 17, bottom panel). Most cohorts in SPA 1A had summer decreases in weight in 2003, and gradually increasing weights throughout 2004 into early 2005. Decreases in weight were observed from winter to spring 2005.

In SPA 4, there was an increase in weight in the older cohorts over time, but less gain in the oldest cohorts, which is expected as growth slows with age (Figure 18, top panel). In the younger cohorts, annual increases and fluctuations are more pronounced (Figure 18, bottom panel). In 2001-2003, there were decreases in weight from winter into spring and summer, then increases again in the falls and winters. This pattern was not evident in 2004, in which weights increased throughout the winter/spring from the previous year.

CONDITION FACTOR

Condition is expressed as the average meat weight of a 100 mm shell in grams. This metric is used in the inshore scallop assessments and the information for it comes from the detailed shell height/meat weight sampling. The meat weight/shell height relationship was modelled and condition estimated per the methods in Nasmith et al. 2016.

Condition was estimated by tow, and then an average of each sampling event was calculated. In SPA 1A, average condition decreased through the start of 2003, and increased in November (Figure 19, bottom panel). The few sampling events in 2004 make it difficult to discern any seasonal treads. From the end of 2004 until the summer of 2005 there was a steady decrease in condition. The minimum average observed condition over the time period was 8.6 grams/decimeter^3 (g/dm^3) in August 2005, and the maximum was 12.3 g/dm^3, observed in both June and September 2004. The mean of all sampling events was 10.9 g/dm^3.

Condition in SPA 4 had long-term fluctuations and interannual variability (Figure 19, top panel). Within a year, condition is generally thought to decrease from winter to summer, then increase again in the fall. However, as in 2001 to 2002, the increase in the fall is not necessarily to levels observed the previous winter. Average condition in late fall of 2001 was less than in the summer of that year. As well, in 2004, average December condition was less than in the previous June. The minimum condition observed in the time period was 9.7 g/dm^3 in August 2005, the maximum was 13.9 g/dm^3 in December 2000. The mean from the sampling period was 12.3 g/dm^3.

To look for patterns between winter and summer condition, the mean June condition for each year was compared to the previous December or January (Table 4). In most years of sampling, the average condition factor in June was less than the previous December. The decrease was not consistent, ranging from 1 to 31%, with an average decrease of

9.5% over the 5 years. The change in condition from December to June 2004 was different in that condition was 12% greater in the summer than the previous winter.

The annual scallop survey in the Bay of Fundy generally takes place between June and August every year, so condition samples taken at that time represent summer condition. The monitoring samples described in this report were taken throughout the year. When annual survey estimates of condition were compared to the annual averages from the monitoring program (all months used), the trend in condition was the same (Figure 20). The values from the monitoring program were higher than the survey values. The biggest differences in SPA 4, 7.8 and 8.2% were in 2000 and 2005, although there was not a full year of data from monitoring sampling in those years. The other years were different by 4% or less, except for 2003, which was 7.3% greater than the survey. This suggests that the summer condition samples obtained in the annual survey are likely a good indicator of annual condition patterns and track the trend in average annual condition.

GROWTH

Annual average height at age for all cohorts was similar (Figure 21). The most variability was in younger ages, but the annual average size of age three scallops was within the bounds used in the inshore surveys to define recruit scallops (65-80 mm), and the mean for age four scallops was above the size used to define commercial size (≥ 80 mm). However, when all the data is considered (not just the mean), some age threes are not recruit size, and not all age fours are commercial size (Figure 22). Additionally, it was not uncommon in the samples for large age two scallops to be recruit size. In SPA 4, the 1998 cohort at age three surpassed commercial size between August (mean: 79.0 mm) and November (mean: 84.6 mm) of 2001. Looking at mean height-at-age on a monthly basis for each cohort throughout the sampling time, this is the only such case where the mean of the sample was large (or small) enough at age three to have it not be classified as a recruit. In many cases there were observations outside the range for pre-recruit and recruit for ages two and three, but the means generally conformed to these ranges.

Von Bertalanffy growth parameters were determined for SPA 1A and SPA 4 (Table 5). L_∞ was consistently lower in SPA 1A than SPA 4 by about 5 mm. K was similar between both areas, while t_o was greater in SPA 1A than in SPA 4. When separated by depth, there was little difference among the parameters in SPA 1A. In SPA 4, the greatest L_∞ was at depths of 50 to 75 m, but the sample size at that depth is low. The majority of the tows for sampling were in recorded depths greater than 75 m.

SPAWNING

A gonadosomatic index (GSI) value was calculated as the gonad weight divided by the sum of the meat, gonad, and viscera weights, and then multiplied by 100 to be expressed as a percent value. Decreases in GSI can be indicative of spawning, but also resorption. The collection of gonad weights was more sporadic than the other variables being monitored (Tables 2 and 3). The timing in the samples is not frequent enough to fully document an annual cycle within any of the years sampled. It was assumed that there is a set seasonal trend to GSI values and that there would be little variability within months among years. The values were averaged by month across years to try to represent an average annual cycle.

Typically, GSI values increase as scallops are preparing to spawn and decrease rapidly after a spawning event. Pre-recruit scallops in both areas had low GSI values (Figures 23 and 24, upper panels). In SPA 1A, there was a decrease in pre-recruit GSI in the spring, and also in the fall (Figure 23). Spring samples were not collected from SPA 4, and there was no change in pre-recruit GSI in the fall. In SPA 1A, recruit GSI decreased from April to May, but there was only one individual sampled in April, so nothing should be inferred from that data point (Figure 23, middle panel). There was a fall decrease in recruit GSI in SPA 1A. In SPA 4, recruit size scallops had a clear, large decrease in GSI between August and October, indicative of a fall spawn. There was also a slight decrease in GSI from April to May, which could be indicative of a spring spawn, but the variation in the measurements from the spring is high (Figure 24, middle panel). Both areas show large decreases in commercial size GSI between August to September and/or October (Figures 23 and 24, lower panels). There was no indication of a spring spawn in commercial size scallop.

Using large size categories (*i.e.*, recruit, commercial) may mask size-specific differences that occur on a smaller scale. GSI was examined at 5 mm shell height bins. This allows for more variation in spawn magnitude (i.e., GSI decrease) by size, and also by season. Tthe average per cent decrease in GSI by 5 mm shell height bin for both the spring and fall is plotted in Figures 25 and 26. In SPA 1A (Figure 25), the smallest size scallops (35-50 mm) had very small spring decreases in GSI. Some small scallop had both fall and spring GSI decreases that were either both very small and similar (55–60 mm and 65-69 mm), or were greater in the fall (70–75 mm). There was no evidence of spring decreases in GSI in scallop greater than 75 mm shell height. In SPA 1A, the greatest change in GSI was in the fall decrease of 15% in scallops 140–145 mm.

A similar general pattern was observed in SPA 4 (Figure 26). There were very small (< 5%) decreases in GSI in the spring for the smallest scallops (≤ 49 mm), but no fall changes in GSI. There were decreases in GSI in both the spring and fall for scallops 50–59 mm, with the decreases in both seasons being small (< 5%). Scallops from 65–74 mm had both spring and fall decreases in GSI, with the spring decreases being very small (< 5%), and the fall being almost 10%. There was no evidence of spring decreases in GSI in scallops > 75 mm. The greatest change in GSI was a fall decrease of 20%, in scallops 120–125 mm.

The sizes of scallops showing spring decreases in GSI (< 75 mm), are well above the size of reproductive maturity (two years, ~ 50 mm) and almost at the size at which it is thought sea scallops begin to produce significant reproductive output (four years, ~ 80 mm; MacDonald and Thompson 1988). It is possible that spring spawns occur in this population, but only among young, small scallops. To answer this question fully, higher resolution sampling, especially in the spring and fall would be needed.

TIME SERIES ANALYSIS

Formal time series analysis was considered, given the cycles that seem to be present in the data. Since the sampling did not follow strict timing, the actual frequency in the data was determined. The natural periodicity in sampling in SPA 4 was quarterly from May 2000 to August 2005. The quarters are based on a calendar year, with the first quarter from January to March, then April to June, etc. This is not necessarily a useful periodicity for the types of patterns of interest in scallop biology. Even at this level of grouping, the third quarter from 2003 is “missing” so the data needed to be coerced into a time series data set for analysis. These preliminary explorations (decomposition of the data) of the condition, GSI, and wet meat weight data were computed only or SPA 4 data since it is the longer data series. The wet meat weight (all size classes) had a strong trend signal that dominated the data with seasonal signal being a much smaller component of the data (Figure 27 show results for commercial size scallops). For condition factor, the trend signal was greater than the seasonal signal as well (Figure 28). The GSI data had a strong seasonal component (Figure 29).

DISCUSSION

The objective of this program to monitor the large 1998 year class for mortality, growth, and yield was achieved. There were no mortality events and the large year class was easily tracked as it recruited to the fishery. Although only one drag was counted from the tows for the monitoring program, this was enough for the purposes of tracking relative abundances of live and dead scallops. The high detailed sampling rate (over 15 000 individuals) provided enough data that it could be separated by cohort and still be meaningful. This program also allowed for the collection and examination of gonad and viscera weight, which is not collected in the annual scallop survey. This program had the added benefit of allowing examination of data at a higher resolution than is capable in the annual surveys.

While the monitoring program succeeded in its main goal, secondary benefits of attempting to track monthly or seasonal changes in scallop biology were not fully realized. Once analyses were attempted outside the scope of the original program, issues with the methodology and sampling timing became apparent. Some data were difficult to compare to the annual survey due to the subsampling used and lack of tow distance information. However, even with that information, caution would be required due to differences in sampling coverage between the survey and the monitoring program. The timing of the samples became an issue with the time series analysis, and when looking at the GSI data for evidence of spawning.

Problems encountered in this data highlight the differences between monitoring and research. This sampling was not intended for time series analysis, or to describe spawning patterns. The program captured the data it was meant to, and generated a large, comprehensive dataset in the process. However, as this was not a research program with specific questions meant to be answered, analysis of the data using certain techniques may not be possible. Should opportunity arise again for a high resolution sampling program, attempts should be made to balance monitoring needs with any research questions that may be of interest. The type of data collected, as well as how and when should be considered with respect to both monitoring and research goals. Efforts should be made, especially for multi-year programs, to maintain consistency in sampling methods.

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Mark Lundy designed and implemented this project as an opportunity to involve the fishing industry in monitoring their fishery. This project was a success because of his leadership and vision, and he lead the way to using fishing boats and crews to conduct the annual surveys in Scallop Fishing Area 29 starting in 2001 and the Bay of Fundy starting in 2005. We thank Captain Kevin Ross (deceased) and the crews of F/V Julie Ann Joan and F/V Royal Fundy for their dedication to the collection of the data for this project, as well as the Full Bay Scallop Association for financial support for this project. Thank you to David Keith for reviewing an early draft and to Anna Serdynska and Lindsay Beazley for reviewing the document.

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TABLES

Table 1. Summary of timing, number of tows, and the number of scallops sampled for each sampling event in Scallop Production Areas (SPAs) 3 and 5 during the monitoring program. Data from these tows were not analyzed in this report.

Year	Month	Total tows	SPA	Meat weight & aged shells	Gonad & tissue weights
2000	December	5	5	345	0
2001	March	30	3	972	0
2003	December	4	5	168	0

Table 2. Summary of monitoring program in Scallop Production Area 4 by survey strata (see Figure 1) and the number of scallops sampled for each sampling event.

Year	Month	Total tows	Tows by Strata					Meat weight & aged shells	Gonad & tissue weights
			2	3	4	9	10		
2000	May	4	0	0	3	0	1	218	0
2000	June	6	4	0	0	1	1	353	0
2000	October	9	3	0	3	1	2	183	0
2000	December	11	3	2	2	1	3	585	0
2001	February	11	2	1	4	2	2	427	0
2001	May	13	3	4	5	0	1	421	0
2001	June	13	3	4	3	1	2	581	0
2001	August	6	0	3	1	1	1	277	0
2001	November	12	4	2	3	0	3	381	0
2002	January	12	3	3	3	0	3	433	0
2002	March	15	2	5	3	2	3	499	0
2002	May	14	3	5	2	1	3	470	0
2002	June	14	5	3	3	2	1	592	0
2002	July	15	2	4	5	3	1	429	0
2002	October	15	3	4	5	2	1	500	206
2003	January	15	3	3	4	2	3	410	0
2003	March	15	4	3	4	1	3	575	138
2003	May	15	4	5	3	2	1	392	188
2003	June	15	4	3	3	3	2	463	267
2003	August	15	4	3	4	2	2	434	183
2003	November	15	5	4	3	1	2	355	173
2003	December	14	3	4	3	2	2	301	153
2004	February	15	4	4	2	2	3	320	148
2004	June	15	4	5	2	2	2	366	178
2004	September	15	3	5	3	2	2	456	179
2004	December	15	4	3	4	2	2	263	129
2005	February	15	3	5	3	2	2	246	122
2005	April	9	3	3	0	2	1	185	83
2005	June	15	2	5	3	1	4	192	92
	Totals	380	90	95	86	43	59	11307	2240

Table 3: Summary of monitoring program in Scallop Production Area 1A by survey strata (see Figure 1) and the number of scallops sampled for each sampling event.

Year	Month	Total tows	Tows by Strata						Meat weight & aged shells	Gonad & tissue weights
			12	13	14	18	19	20		
2003	January	13	0	8	0	0	2	3	380	0
2003	March	14	2	7	0	0	2	3	366	232
2003	May	14	2	7	0	0	2	3	334	167
2003	June	14	4	4	1	0	5	1	482	206
2003	August	10	3	3	1	0	1	2	324	156
2003	November	14	2	6	1	0	2	3	352	181
2004	February	8	1	5	0	0	1	1	336	183
2004	June	15	2	7	0	0	2	4	328	166
2004	September	15	1	4	3	1	4	2	182	178
2005	February	15	1	9	0	0	3	2	227	63
2005	April	11	0	9	0	0	1	1	185	95
2005	June	15	2	7	0	0	1	5	210	130
	Totals	165	20	76	6	1	26	30	3706	1763

Table 4. Differences in mean condition factor (g/dm^3) between winter and the following summer months in Scallop Production Area 4.

Winter	Summer	Winter CF	Summer CF	Change (g)	%
Dec 2000	June 2001	18.38	12.64	- 5.74	-31.2
Jan 2002	June 2002	10.83	10.71	-0.12	-1.1
Jan 2003	June 2003	11.48	11.35	-0.13	-1.1
Dec 2003	June 2004	11.45	12.84	+1.39	+12.1
Dec 2004	June 2005	12.8	11.07	-1.73	-1.8

Table 5. von Bertalanffy growth parameters and number of shells (n) in the analysis for Scallop Production Areas 1 A and 4.

Area	Linf	K	to	n
SPA 1A (all)	135.56	0.253	0.252	3874
75-100 m	136.49	0.265	0.215	1157
>100 m	135.18	0.27	0.269	2690
SPA 4 (all)	140.60	0.253	-0.007	11550
<50 m	140.03	0.267	0.184	262
50-75 m	148.79	0.234	0.073	321
75-100 m	140.18	0.256	-0.011	9371
>100 m	140.12	0.279	0.055	1596

FIGURES

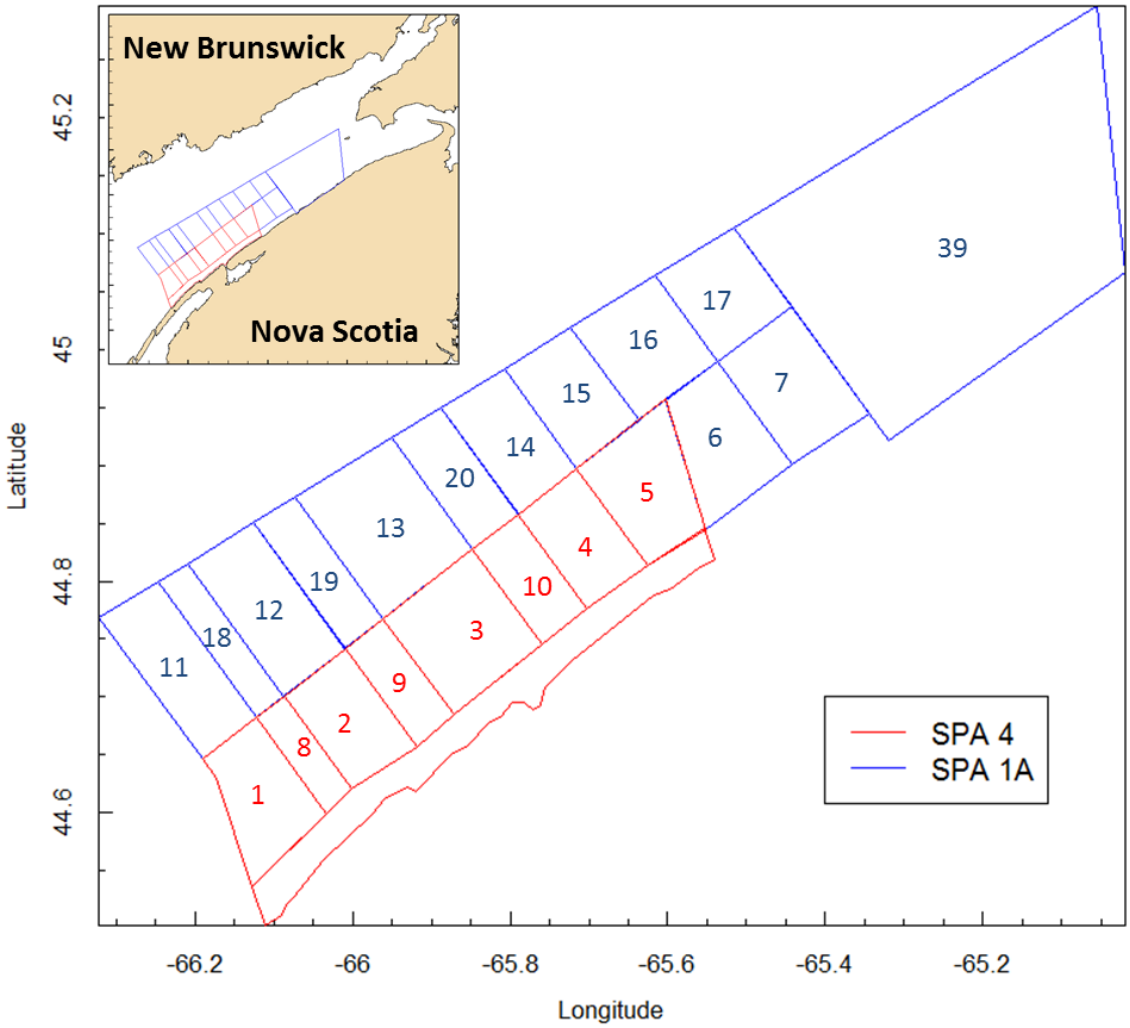

Figure 1. Scallop Production Areas 4 (red lines) and 1A (blue lines) in the Bay of Fundy and the survey strata designations used in scallop surveys.

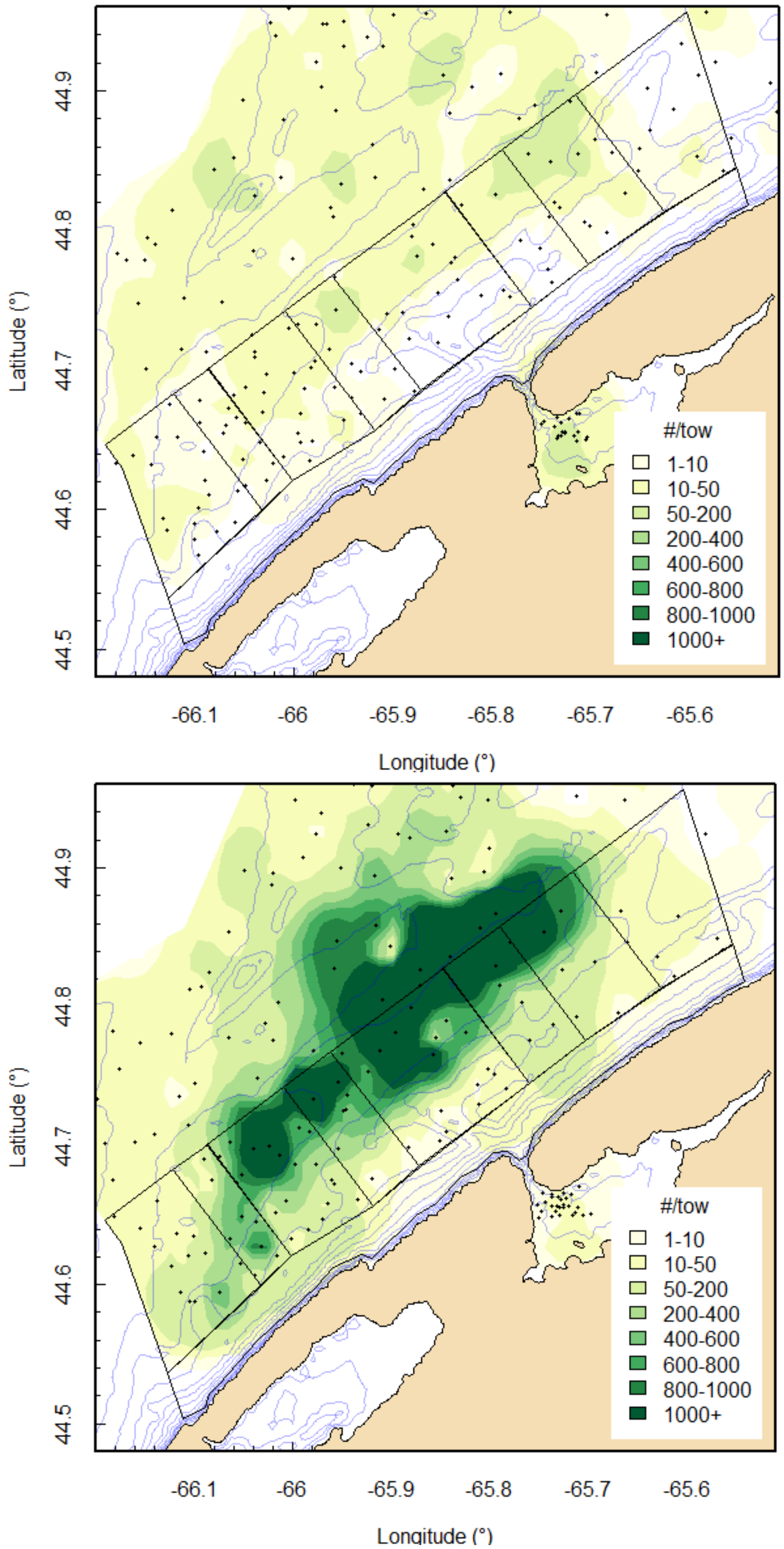

Figure 2. Density (number per tow) of pre-recruits (<65 mm shell height) in the annual Bay of Fundy survey in 1999 (top panel) and 2000 (bottom panel).

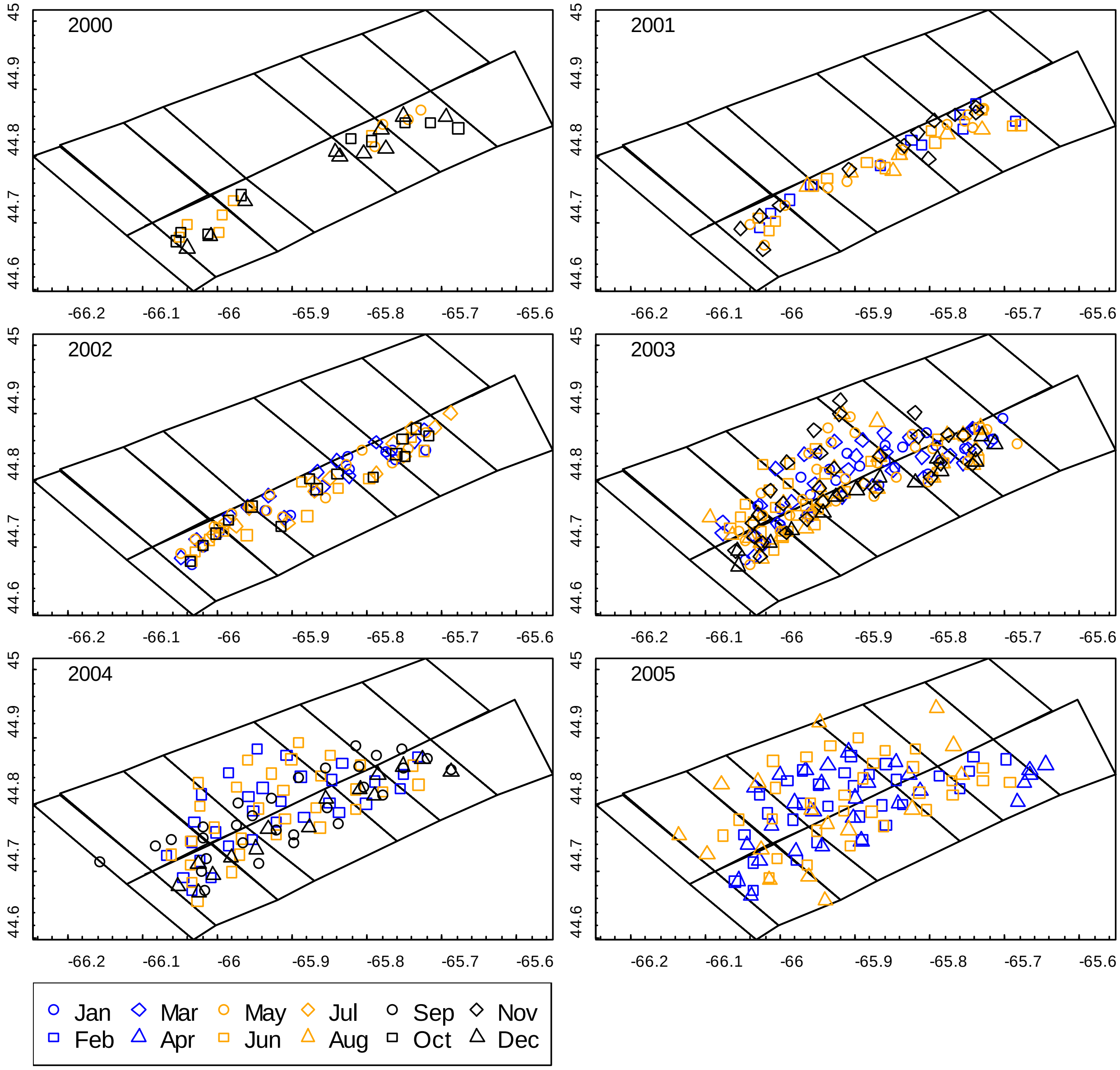

Figure 3. Location of sampling tows by month in Scallop Production Area 1A and 4 from 2000 to 2005.

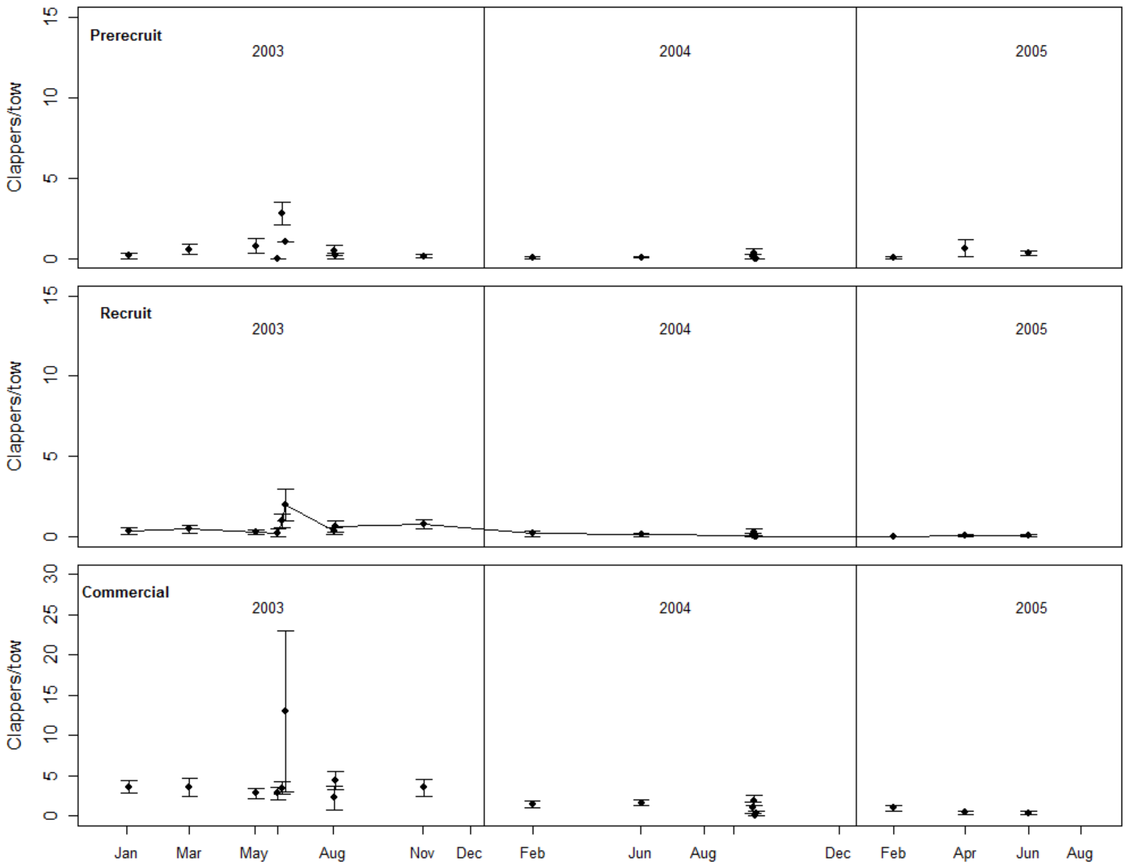

Figure 4. Relative clapper abundance (mean ± 1SE) by day from sampling events in Scallop Production Area 1A for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Note different axes.

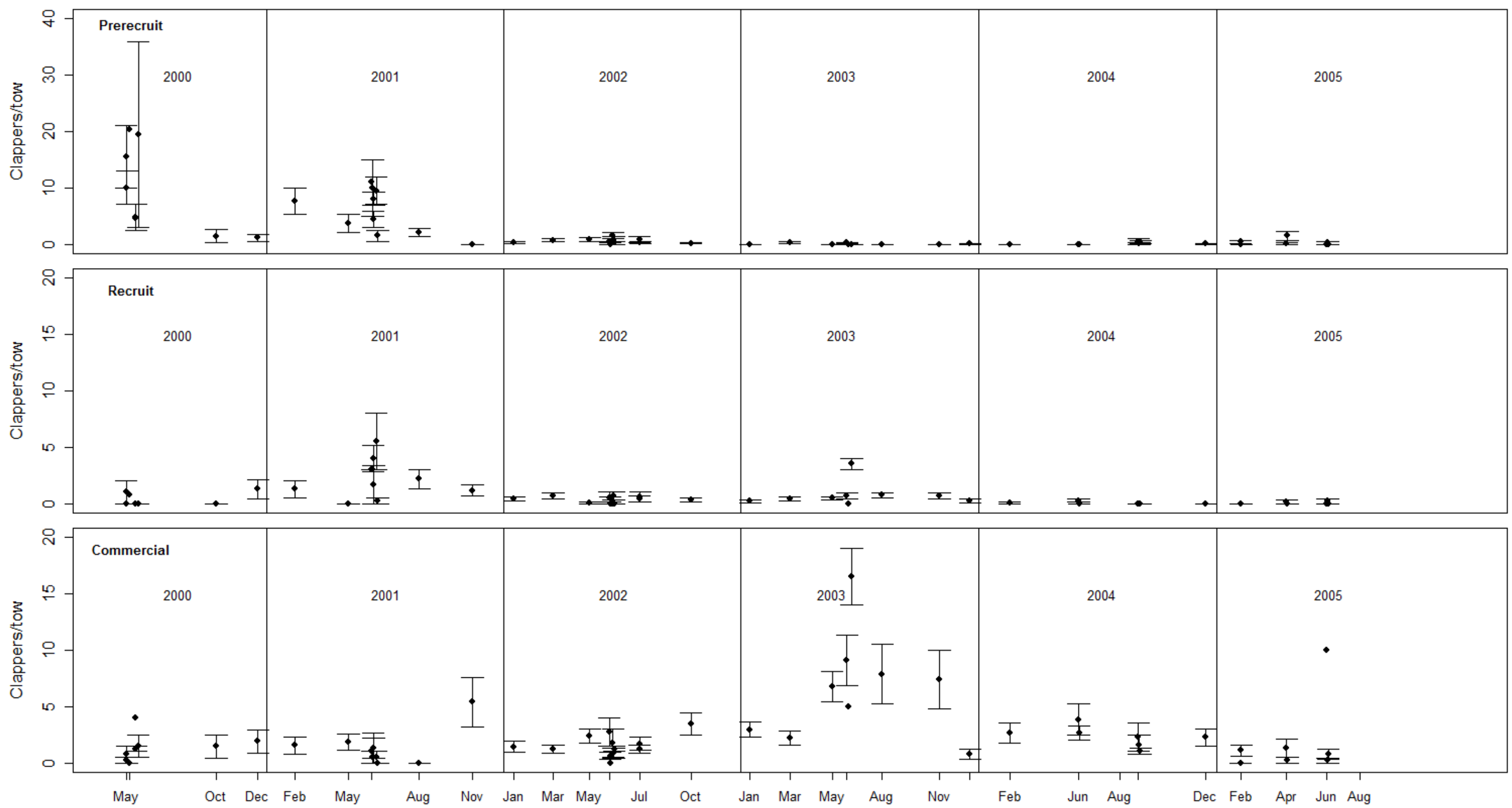

Figure 5. Relative clapper abundance (mean ± 1 SE) by day from sampling events in Scallop Production Area 4 for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Note different axes.

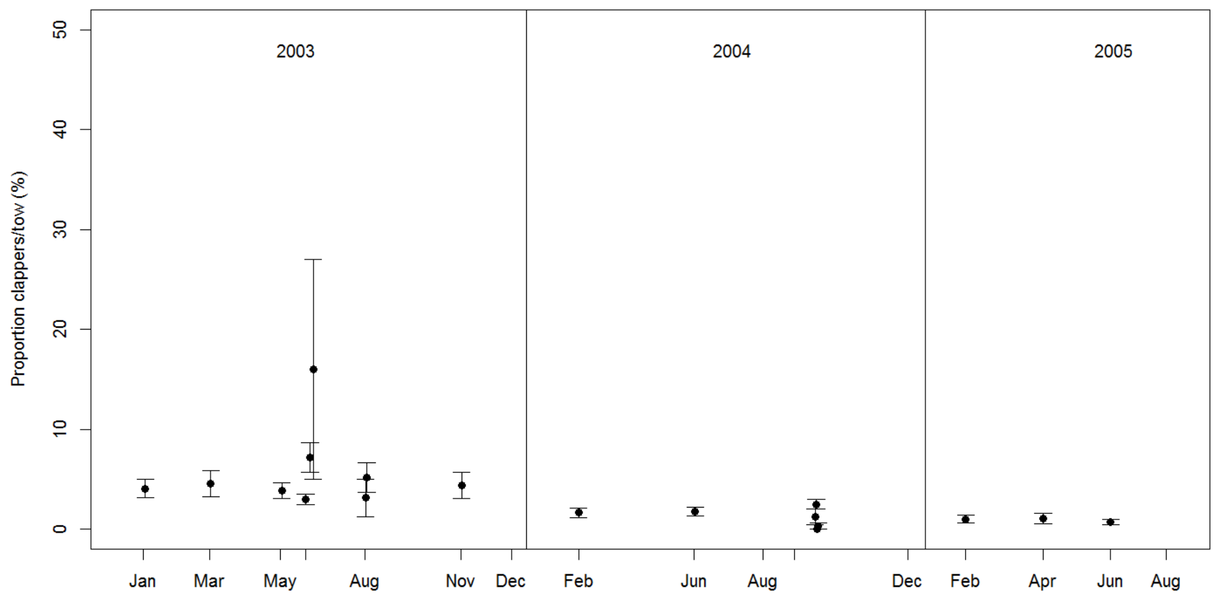

Figure 6. Percent of commercial (≥ 80 mm) size clappers in catch by day (mean ± 1SE) during sampling events in Scallop Production Area 1A.

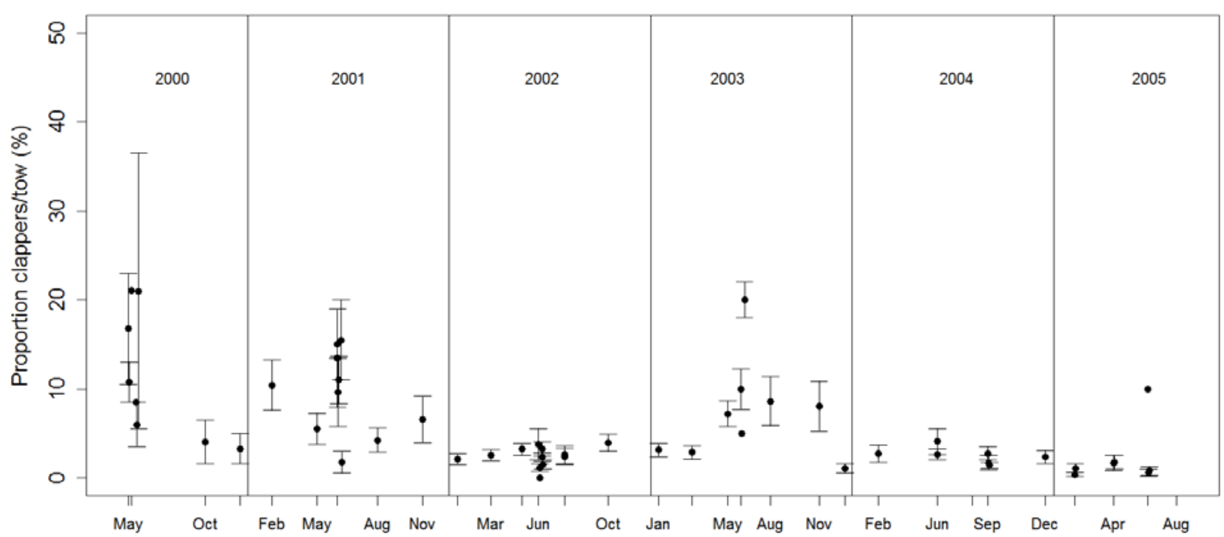

Figure 7. Percent of clappers in catch by day (mean ± 1SE) during sampling events in Scallop Production Area 4.

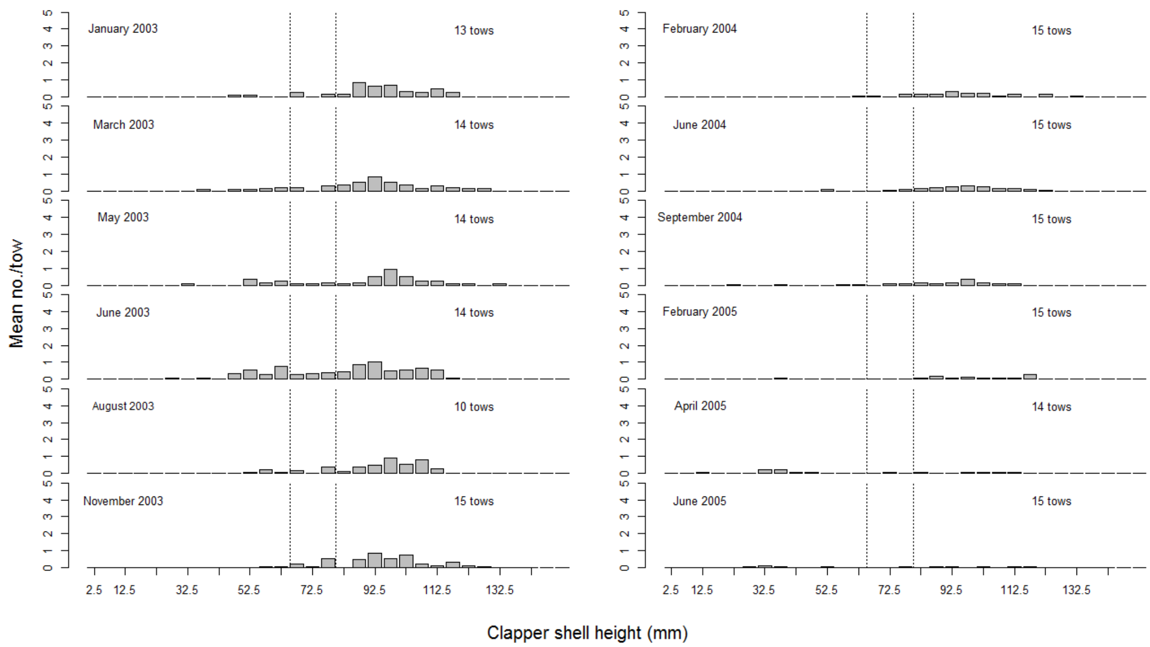

Figure 8: Shell height frequency of scallop clappers caught in Scallop Production Area 1A for sampling events in 2003 to 2005. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

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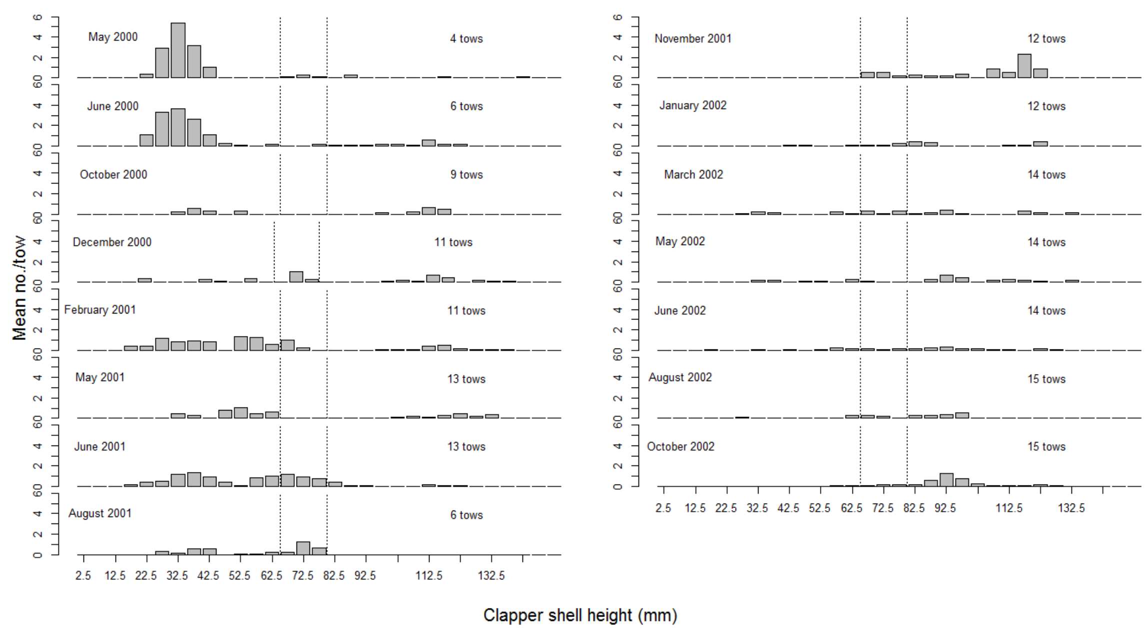

Figure 9: Shell height frequency of scallop clappers caught in Scallop Production Area 4 for sampling events in 2000 to 2002. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

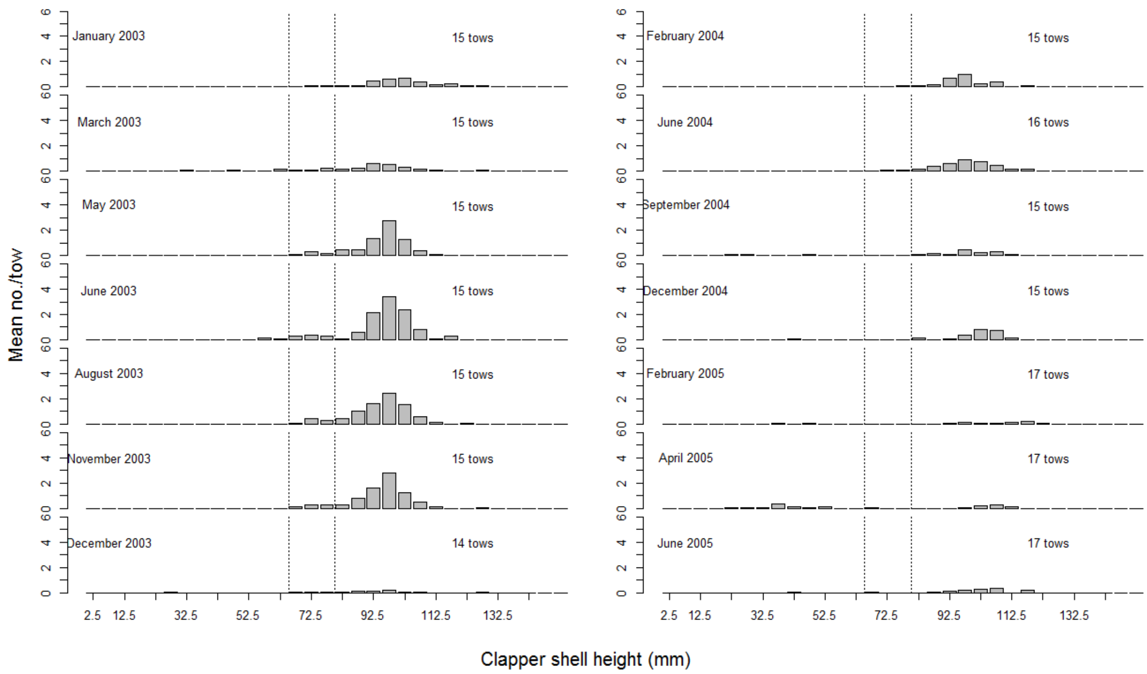

Figure 10: Shell height frequency of scallop clappers caught in Scallop Production Area 4 for sampling events in 2003 to 2005. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

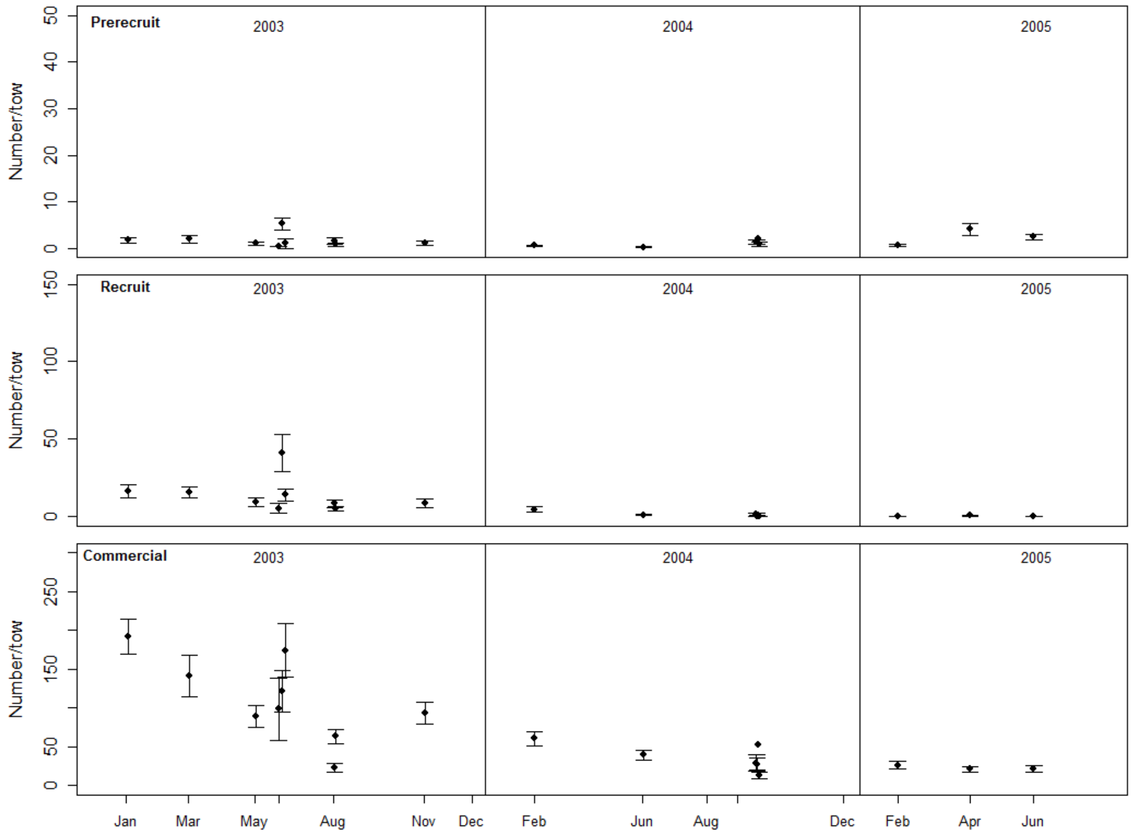

Figure 11. Relative scallop abundance (mean ± 1SE) during sampling events in Scallop Production Area 1A for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Note different axes.

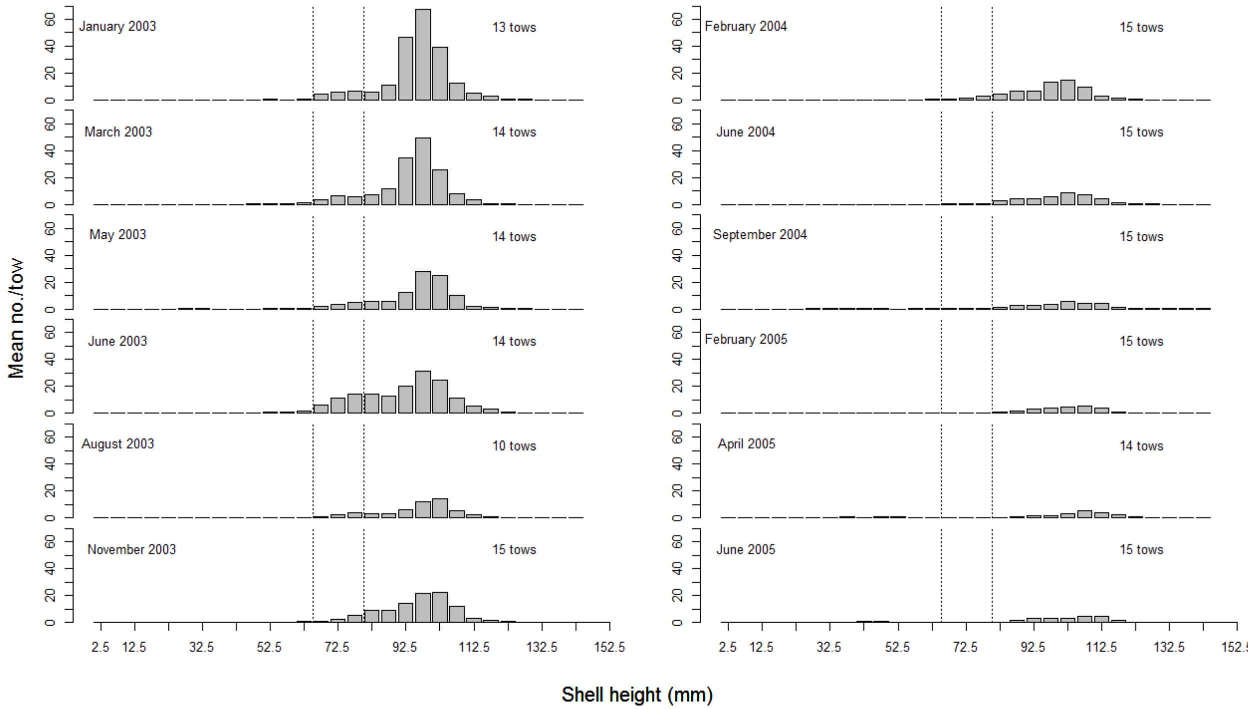

Figure 12. Shell height frequency of scallops caught in Scallop Production Area 1A for sampling events in 2003 to 2005. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

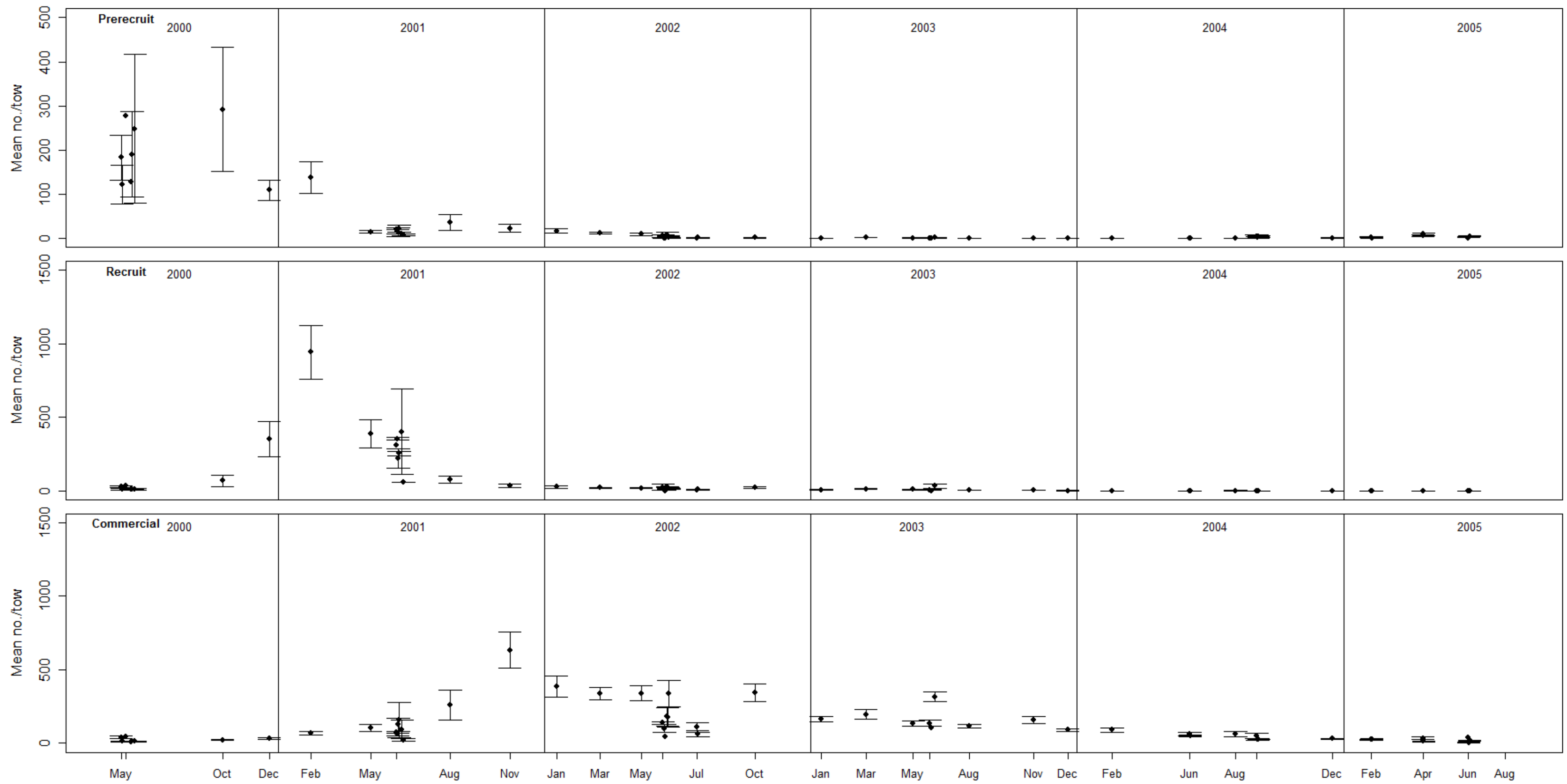

Figure 13. Relative scallop abundance (mean ± SE) during sampling events in Scallop Production Area 4 for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Note different axes.

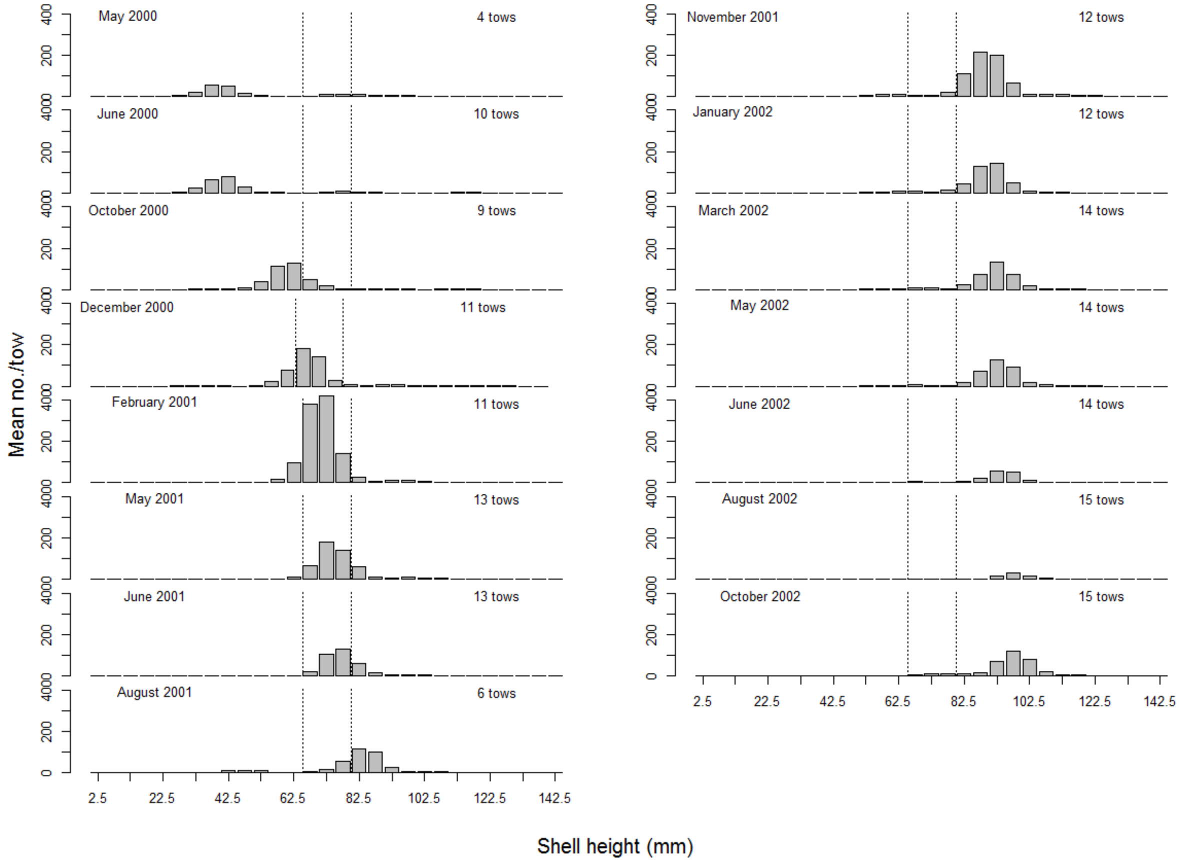

Figure 14. Shell height frequency of scallops caught in Scallop Production Area 4 for sampling events in 2000 to 2002. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

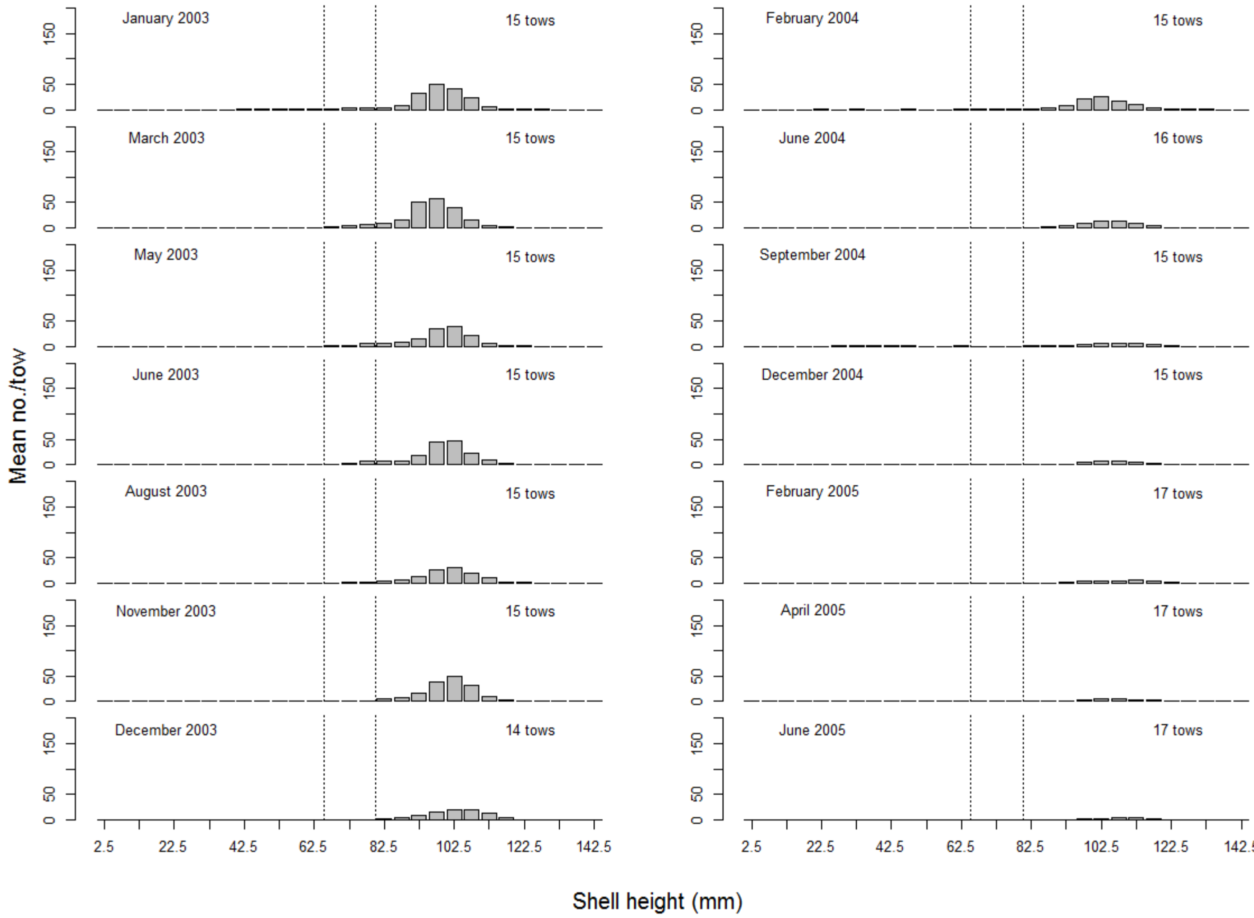

Figure 15. Shell height frequency of scallops caught in Scallop Production Area 4 for sampling events in 2003 to 2005. Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

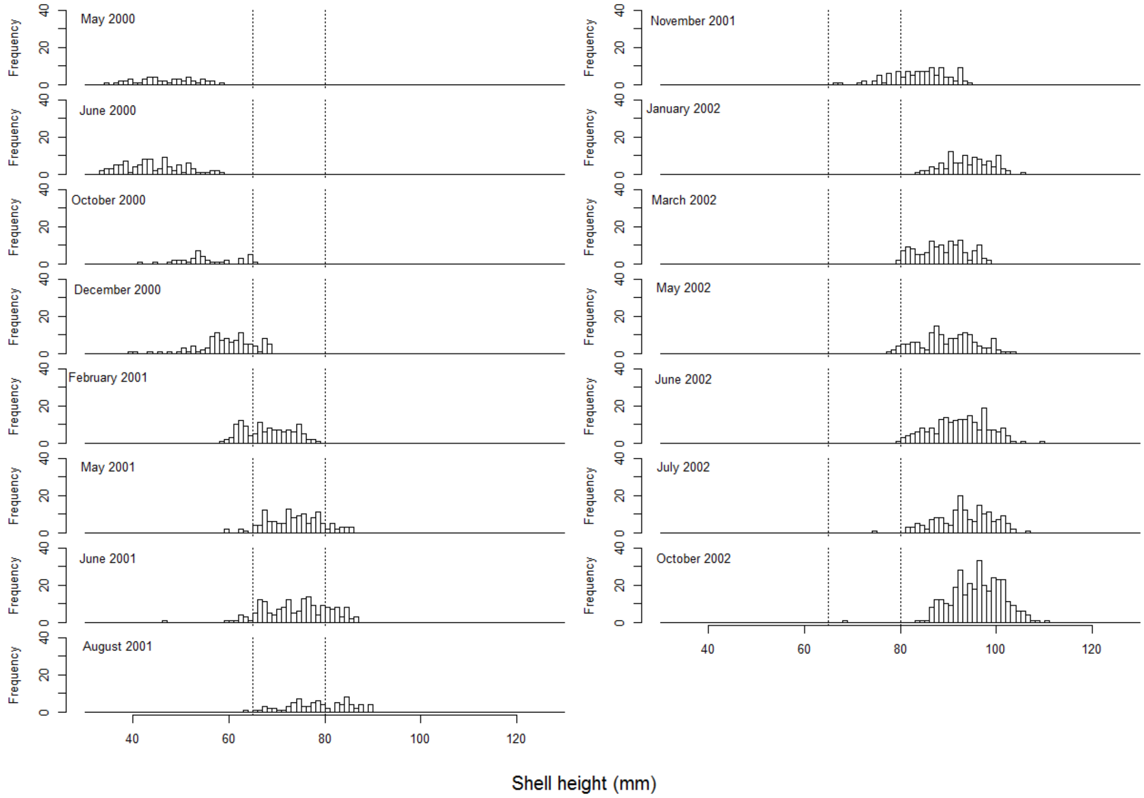

Figure 16. Shell height frequency of the 1998 year class in Scallop Production Area 4 for sampling events in 2000 (age 2) to 2002 (age 4). Dotted lines at 65 and 80 mm encompass the recruit size class, scallops over 80 mm are commercial size.

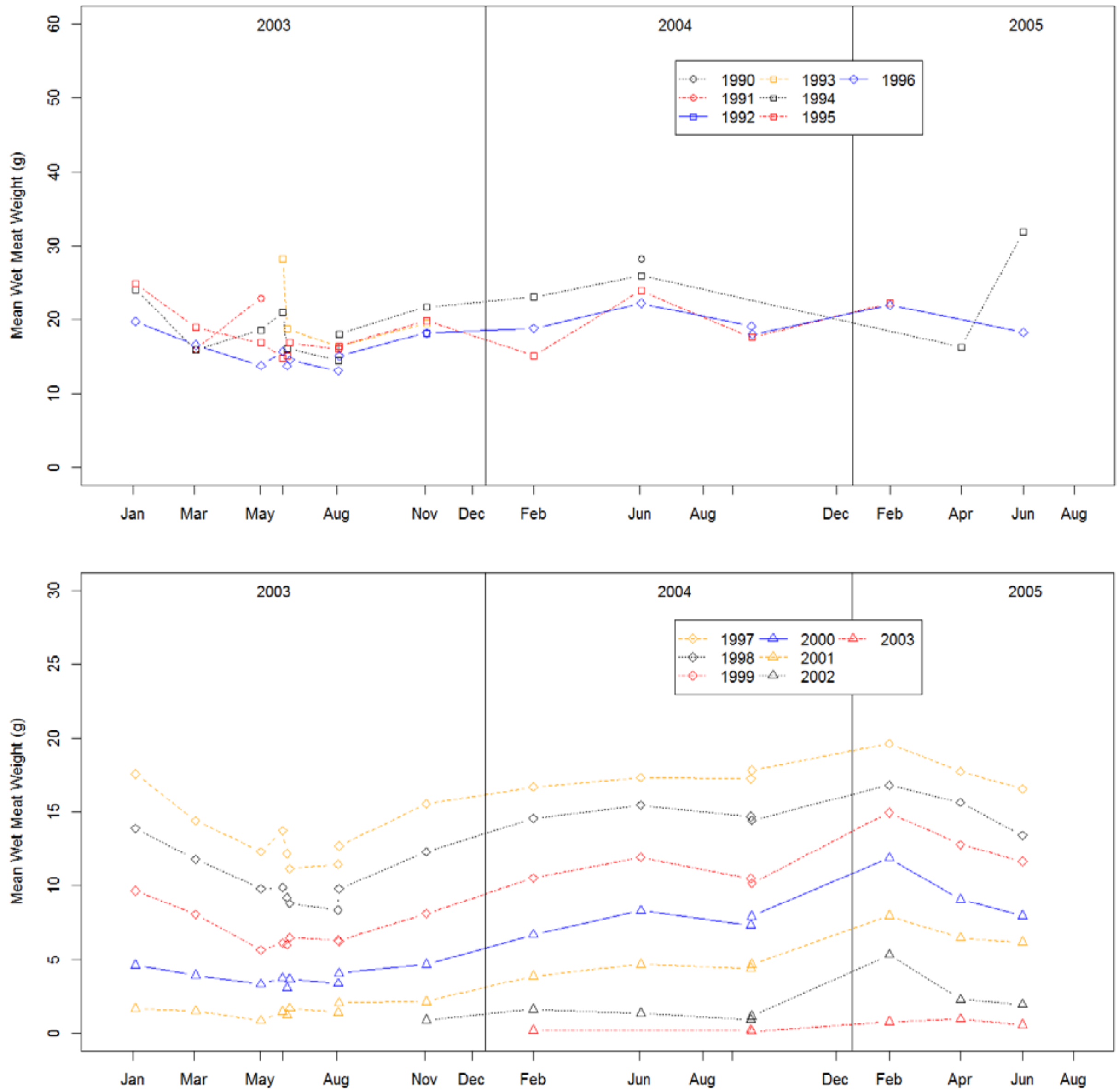

Figure 17. Mean wet meat weight (g) in Scallop Production Area 1A by cohort.

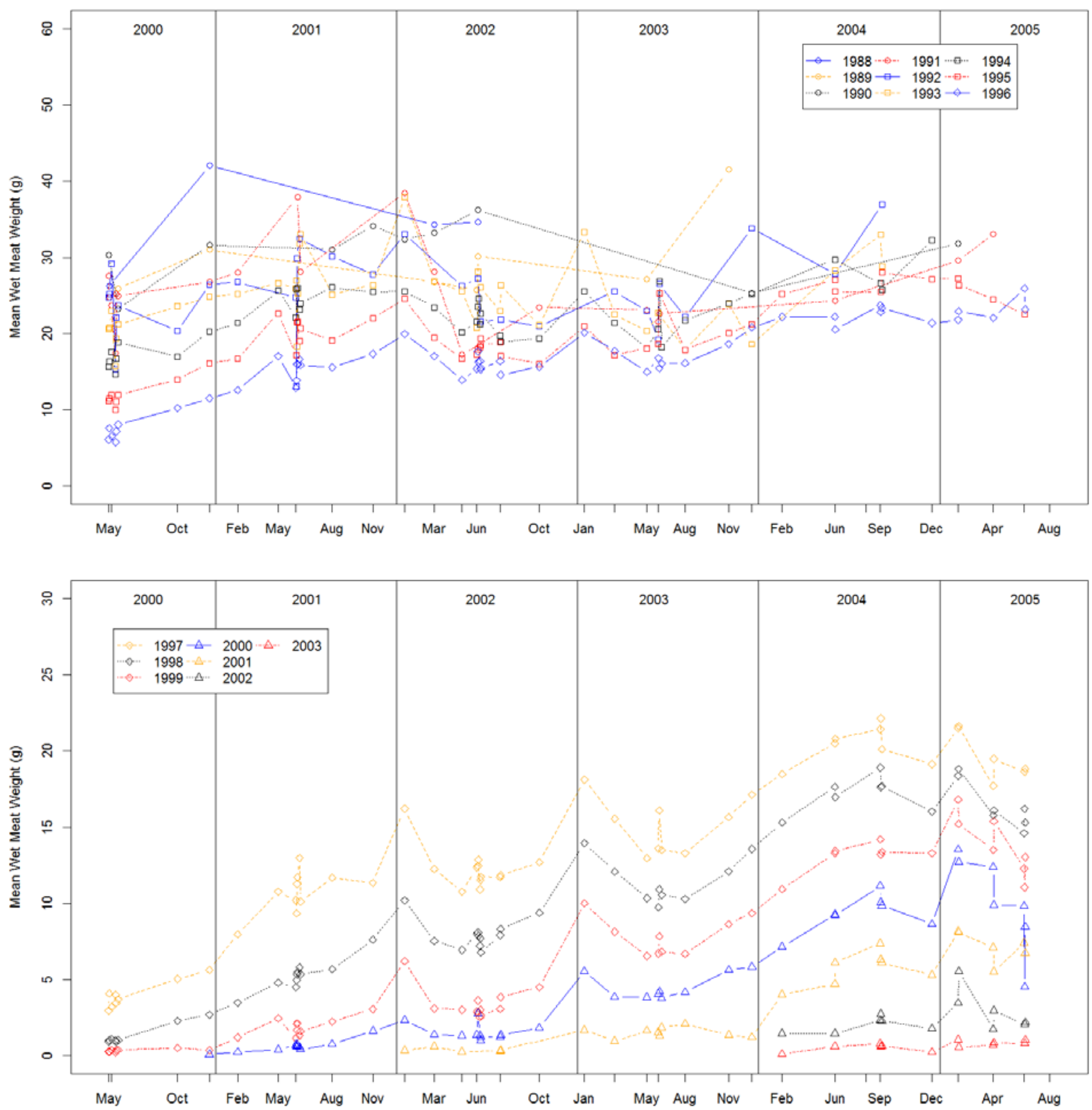

Figure 18. Mean wet meat weight (g) in Scallop Production Area 4 by cohort.

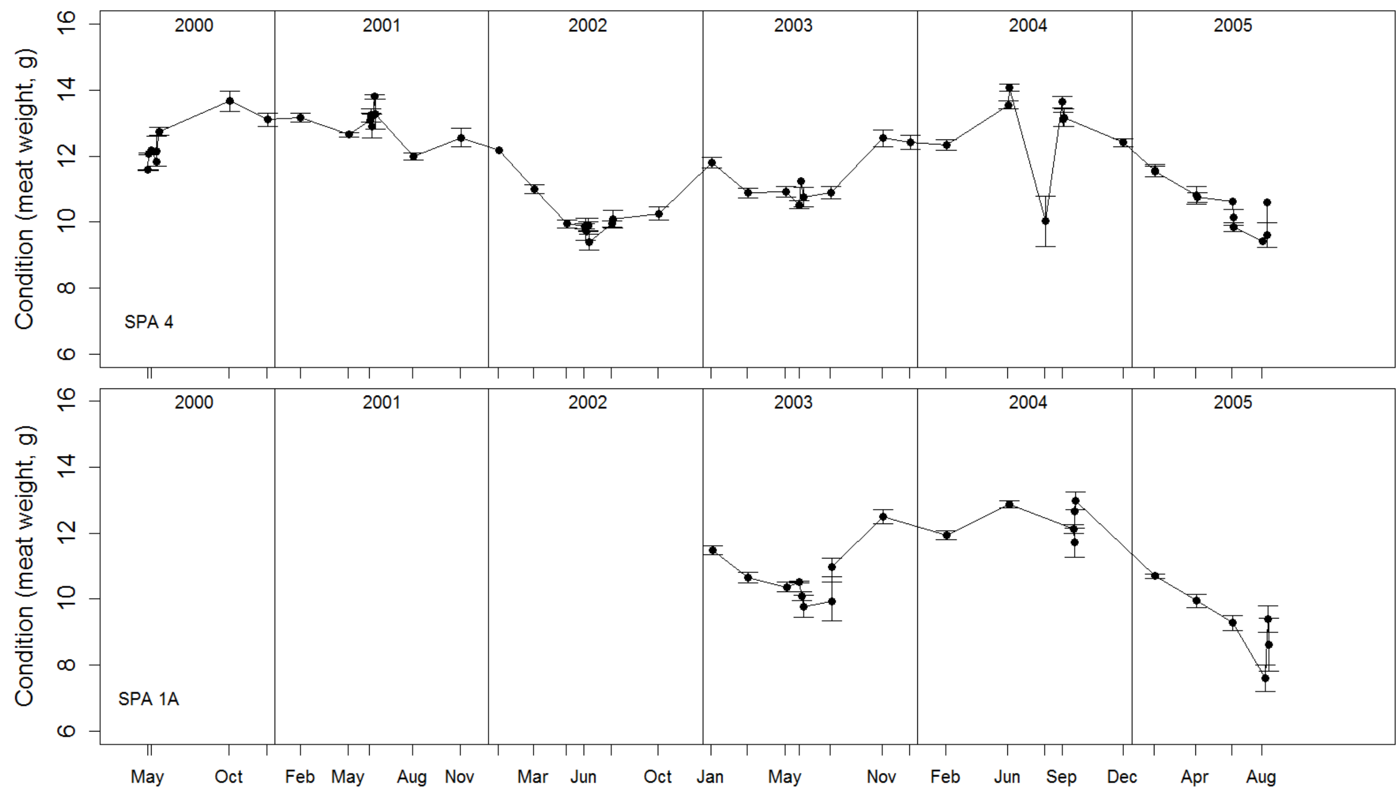

Figure 19. Mean (± SE) condition (meat weight of a 100 mm shell in grams (g/dm^3)) in Scallop Production Areas 4 (top) and 1A (bottom).

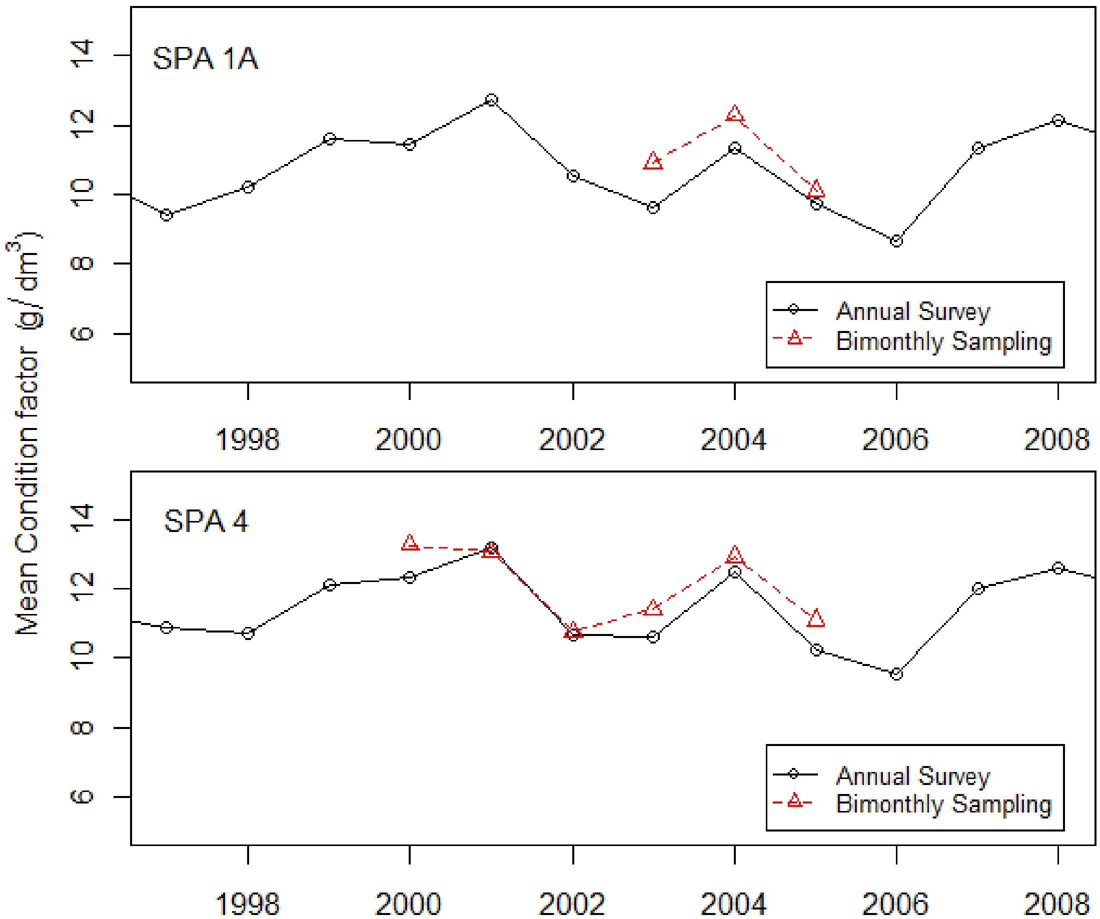

Figure 20. Comparison of condition (average meat weight of a 100 mm shell in grams *(g/dm^3)) from the annual Bay of Fundy Survey and the average annual value from monitoring sampling.*

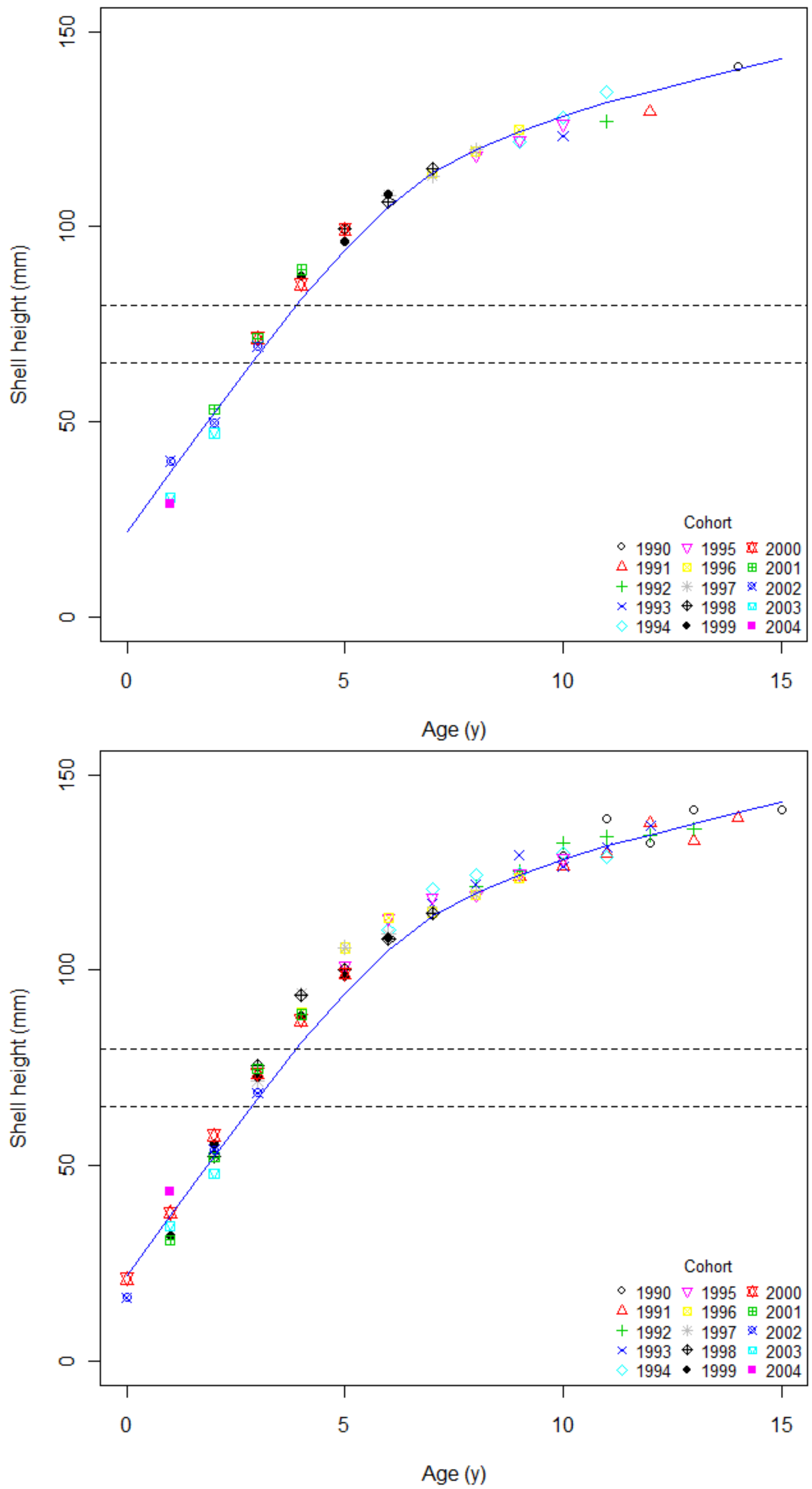

Figure 21. Annual mean height at age for different cohorts in Scallop Production Area 1A (top panel) and Scallop Production Area 4 (bottom panel). Dotted horizontal lines indicate the size range for recruit scallops (65-80mm). Blue line is lowess curve.

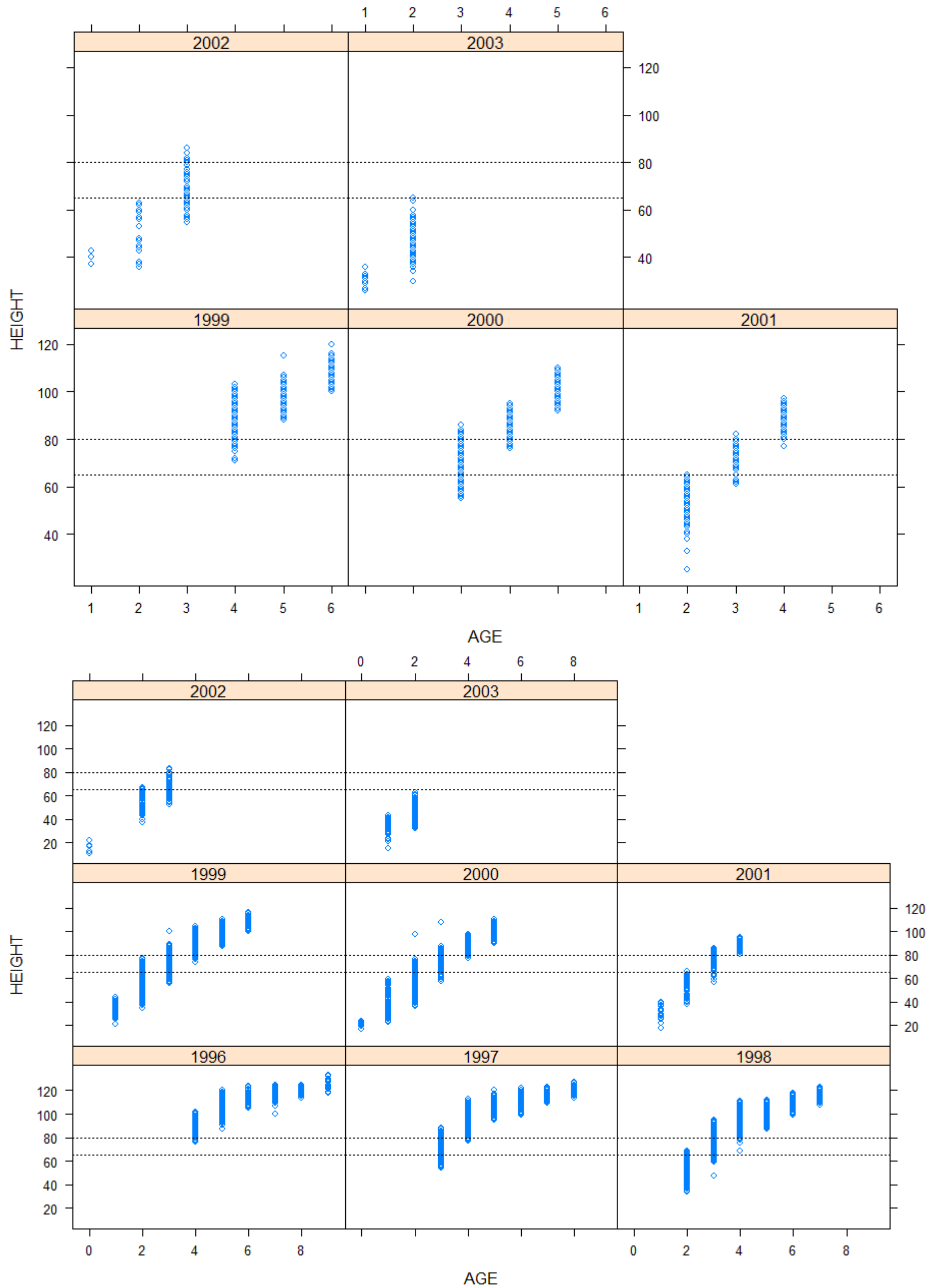

Figure 22. Height by age for each cohort for Scallop Production Area 1A (top panel) and 4 (bottom panel). Lines indicate size range of recruit scallop.

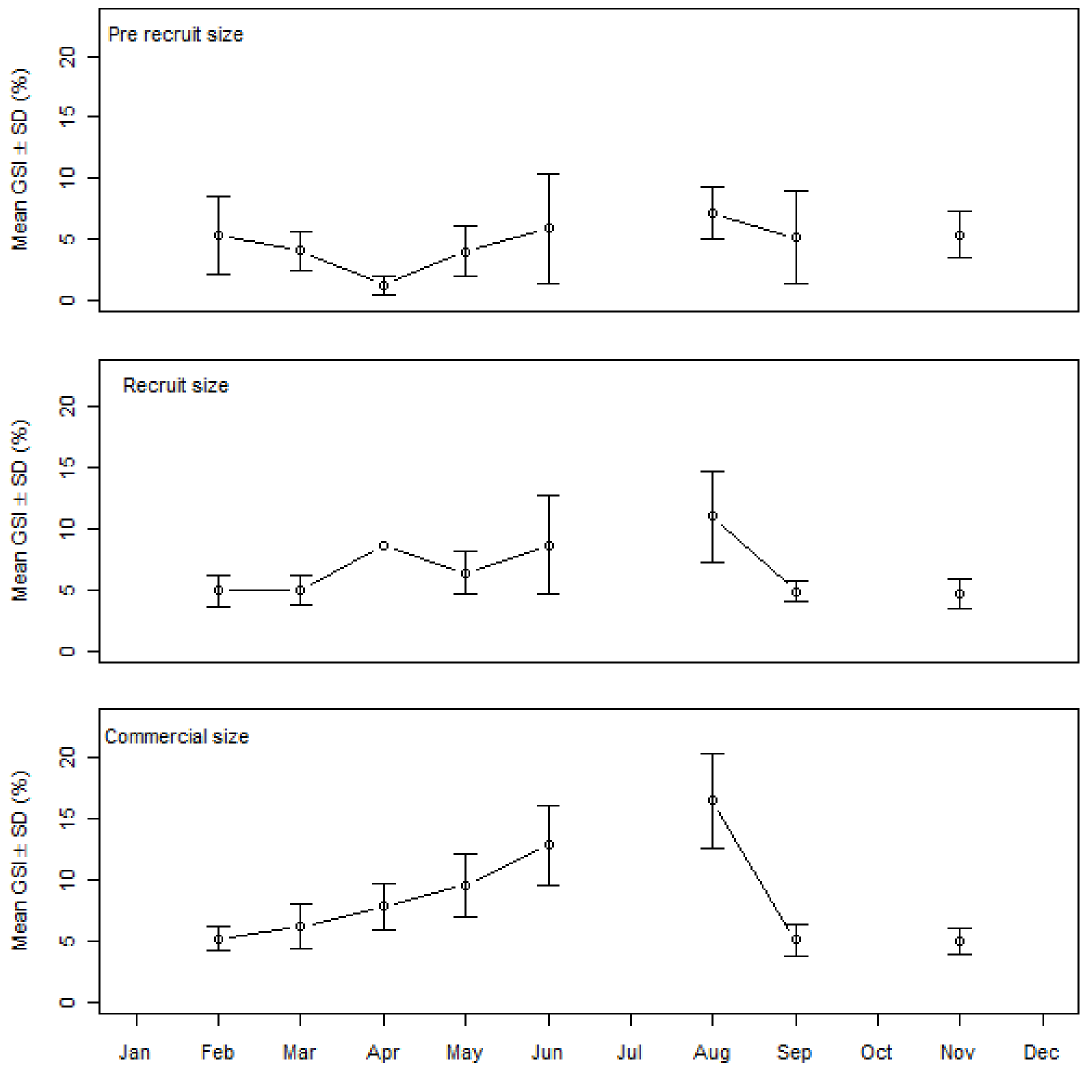

Figure 23. Average (± 1 SD) monthly GSI (%) in Scallop Production Area 1A for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Each month is averaged across years from 2003-2005. See Table 3 for information on which months were sampled in which years.

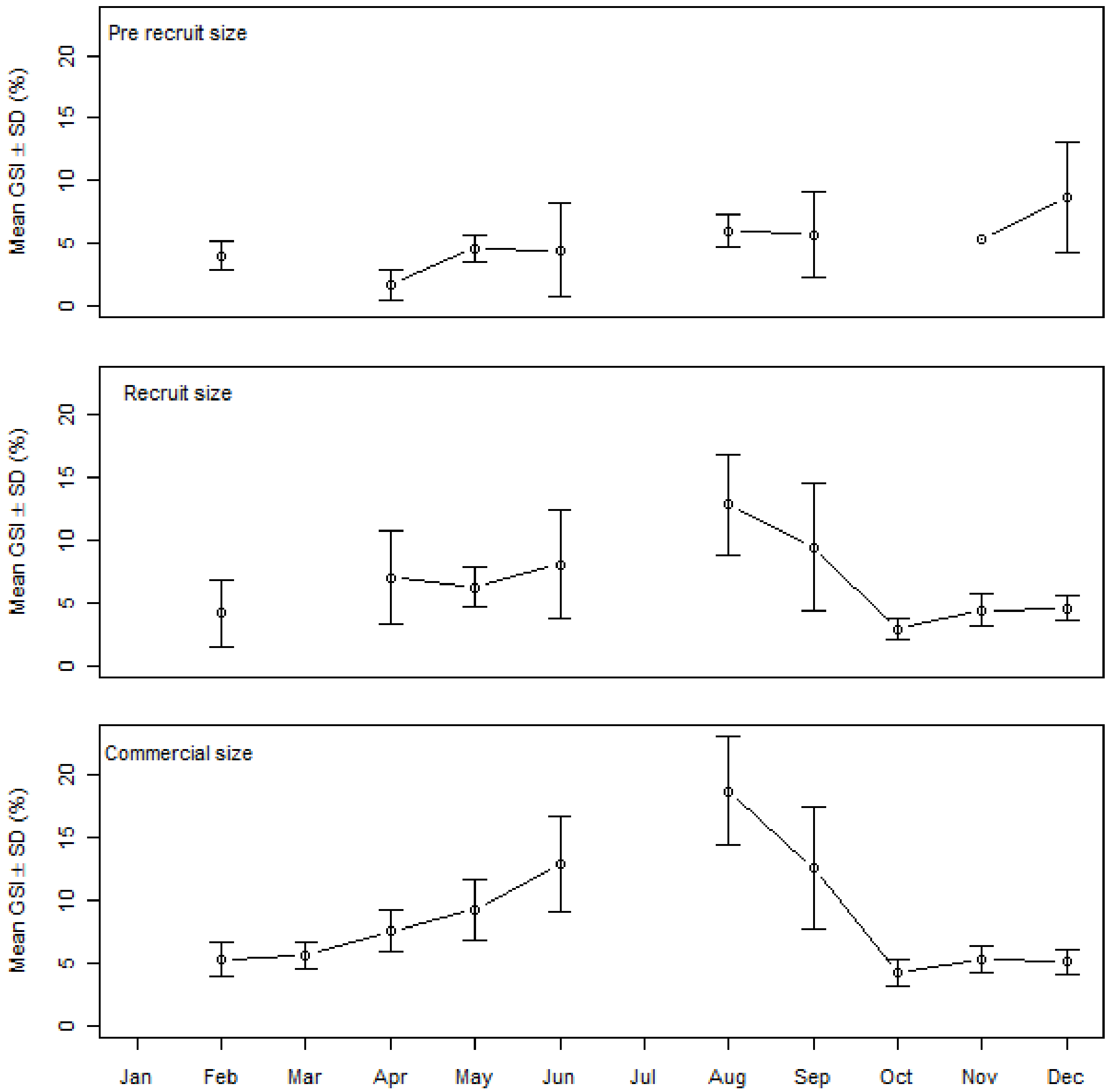

Figure 24. Average (± 1 SD) monthly GSI (%) in Scallop Production Area 4 for pre-recruit (< 65 mm), recruit (65-79 mm), and commercial (≥ 80 mm) sized scallops. Each month is averaged across years from 2002-2005. See Table 2 for information on which months were sampled in which years.

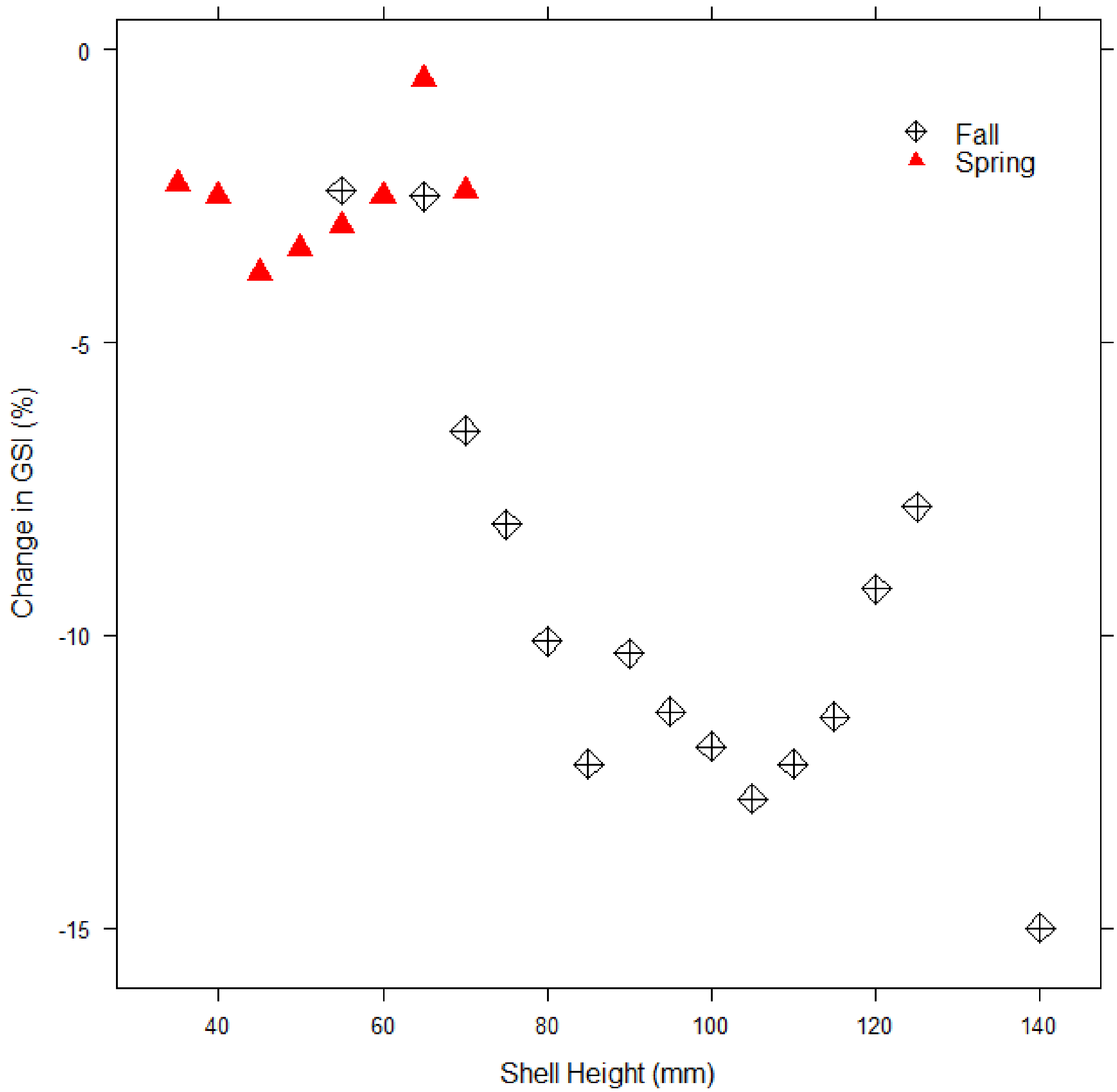

Figure 25. Magnitude of observed decreases in GSI (%) in Scallop Production Area 1A in the spring and fall. Data is grouped by shell height (mm) and averaged across the monitoring years.

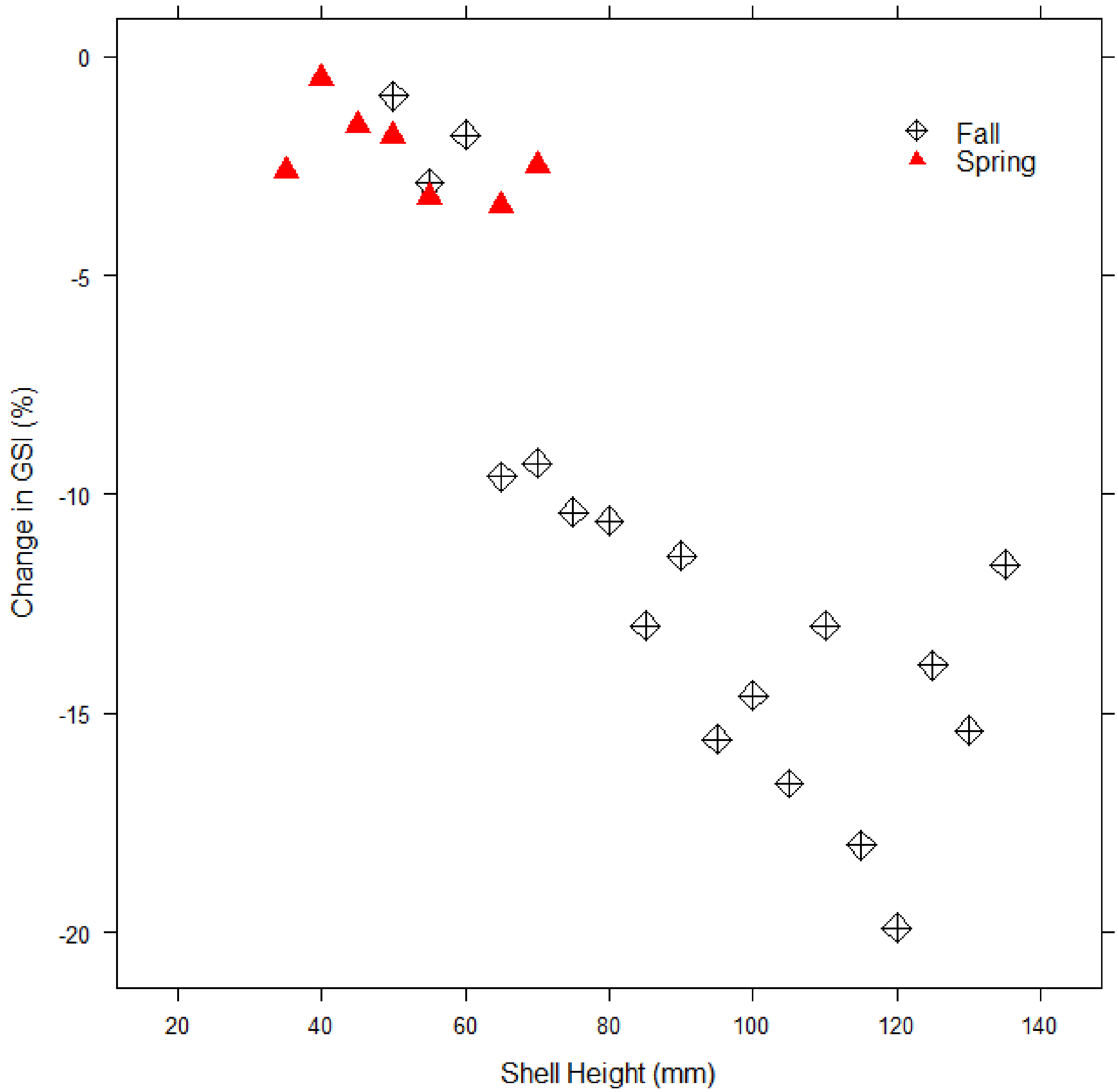

Figure 26. Magnitude of observed decreases in GSI (%) in Scallop Production Area 4 in the spring and fall. Data is grouped by shell height (mm) and averaged across the monitoring years.

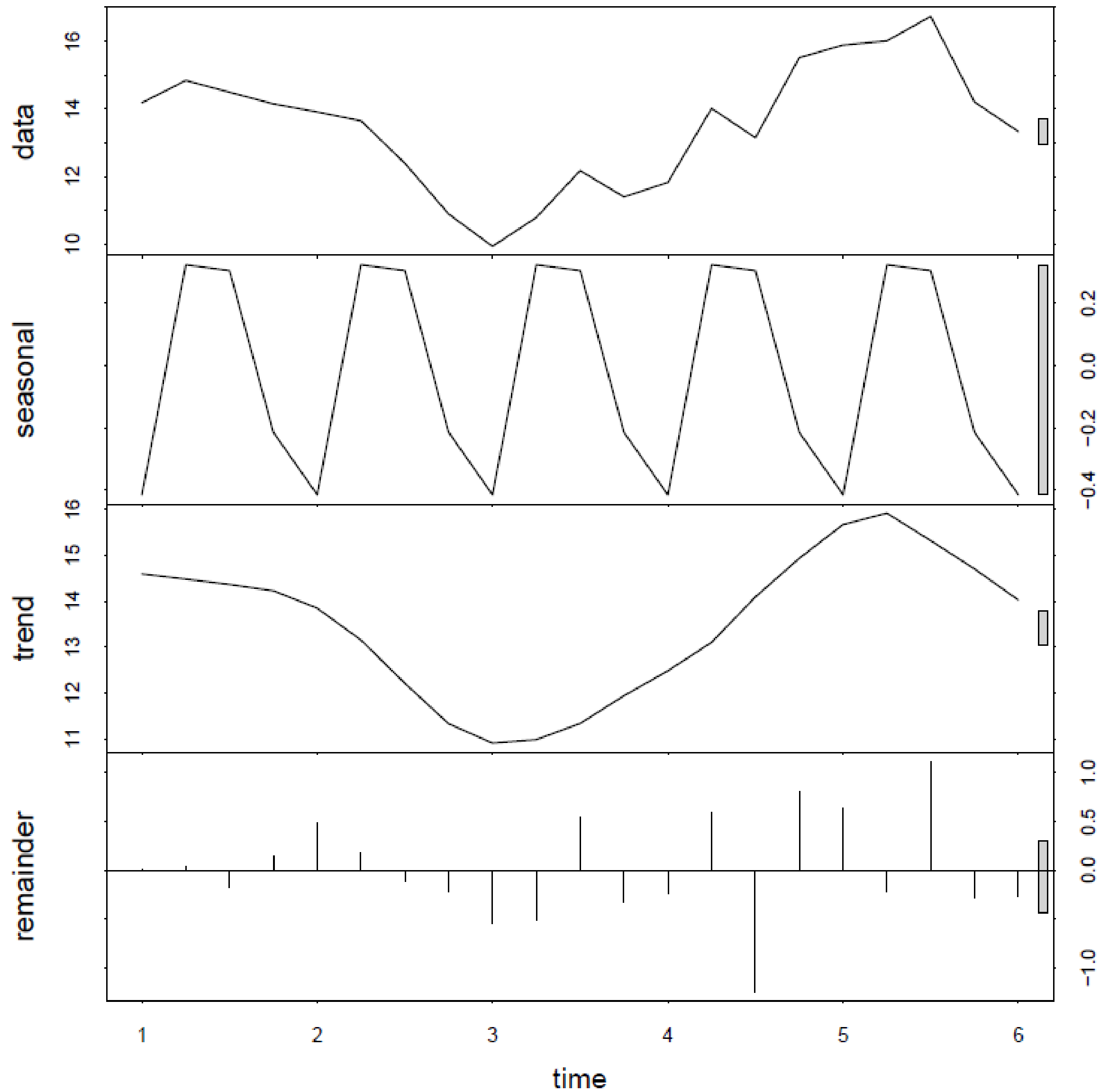

Figure 27. Quarterly decomposition of the meat weight data in Scallop Production Area 4 from May 2000 to August 2005. Plots from top: original data, seasonal signal, data trend, and stochastic component of the data (remainder).

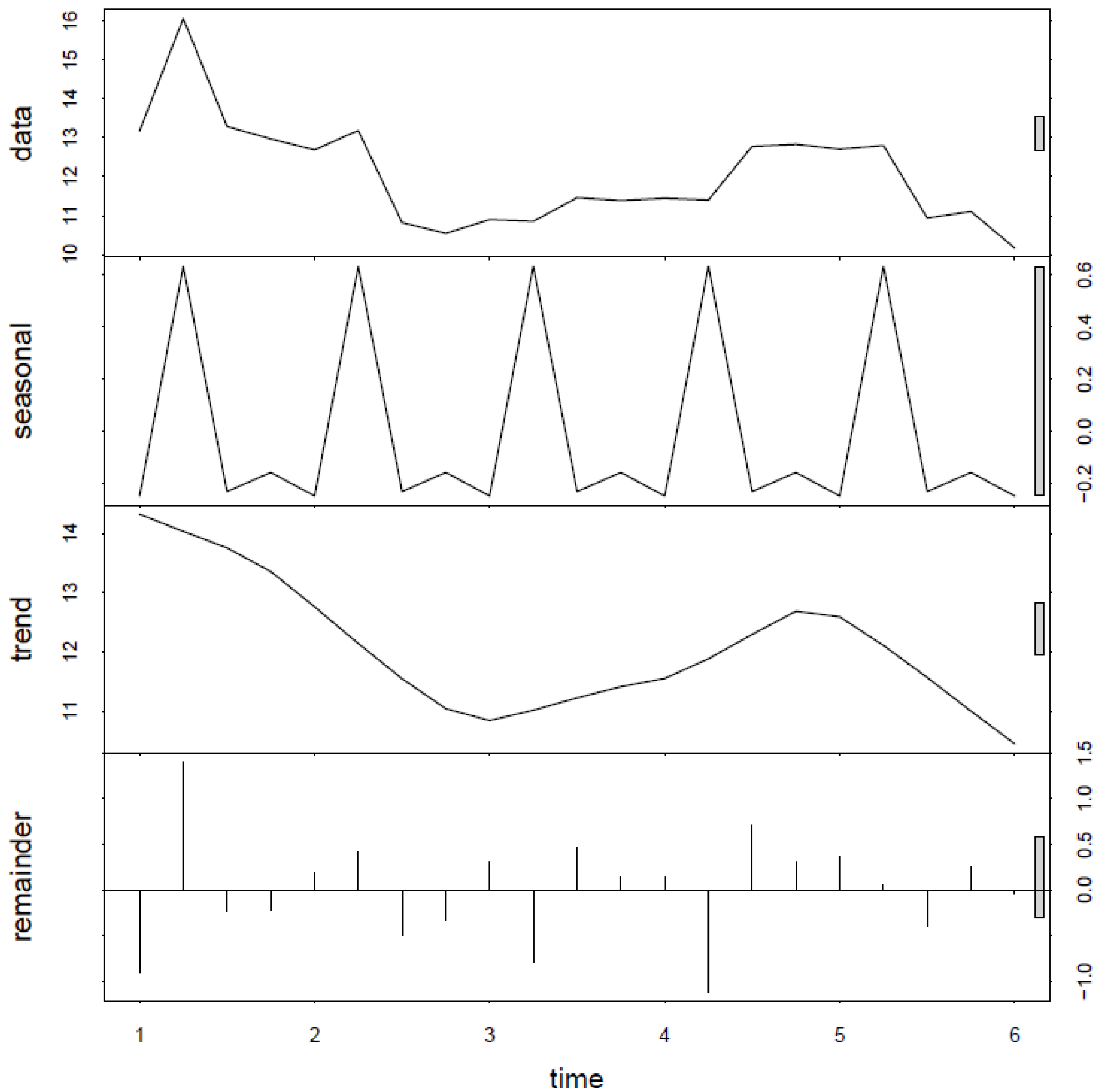

Figure 28. Quarterly decomposition of the meat condition data in Scallop Production Area 4 from May 2000 to August 2005. Plots from top: original data, seasonal signal, data trend, and stochastic component of the data (remainder).

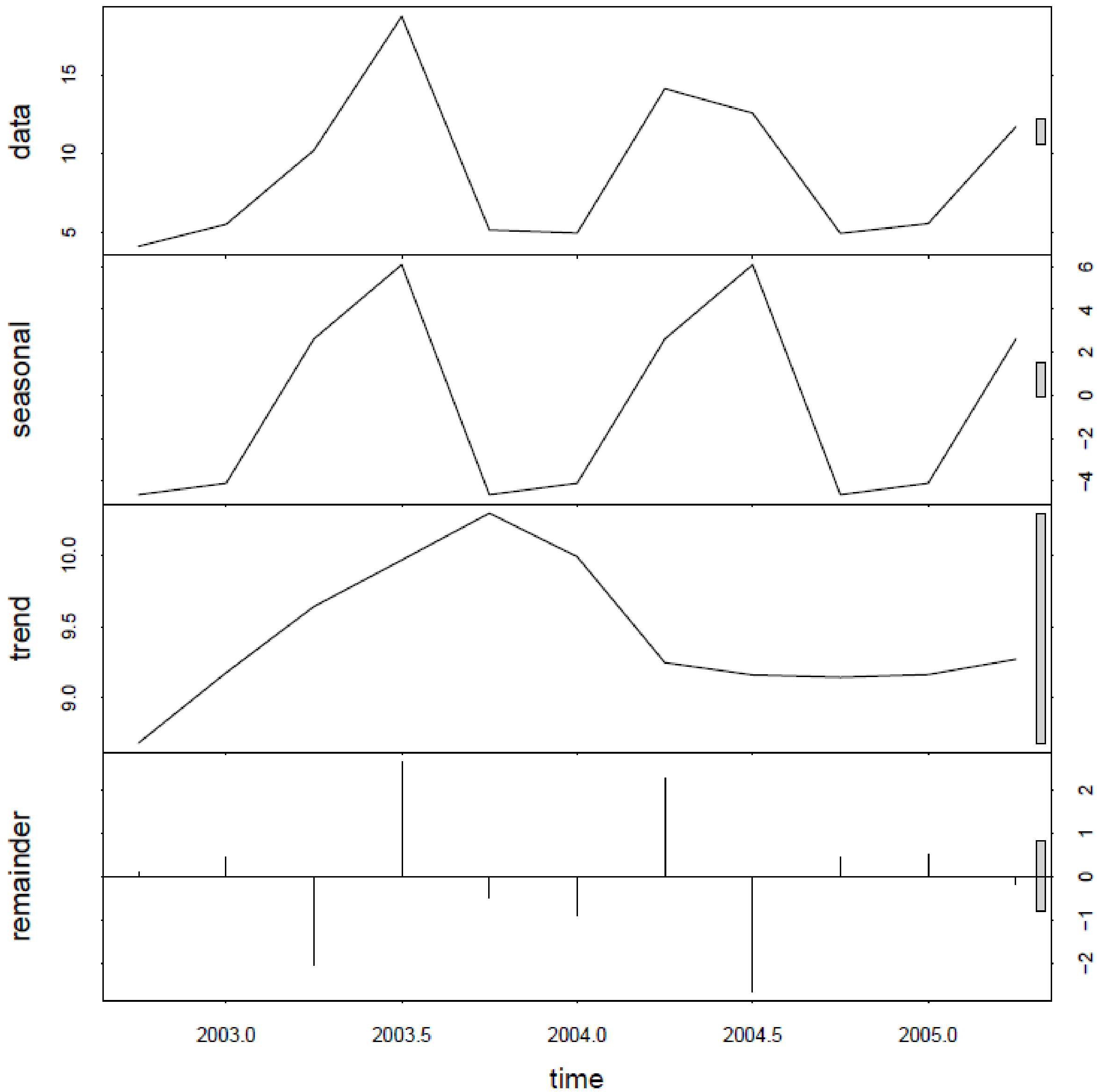

Figure 29. Quarterly decomposition of the gonadosomatic index data in Scallop Production Area 4 from 2003 to August 2005. Plots from top: original data, seasonal signal, data trend, and stochastic component of the data (remainder).