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Historical review (1996-2002) and assessment of the 2003 snow crab (*Chionoecetes opilio*) fishery off eastern Nova Scotia (Areas 20 to 24)

Revue historique (1996-2002) et évaluation de la pêche du crabe des neiges (*Chionoecetes opilio*) en 2003 au large de la côte est de la Nouvelle-Écosse (zones 20 à 24)

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Abstract

The assessment of the snow crab stock status for eastern Nova Scotia (ENS) in 2003 is presented based on the 1996 – 2003 fisheries data (logbook and sea sampling of the commercial catches) and 1997 – 2003 trawl surveys. Two additional indicators of stock status were introduced in this assessment: spatial analysis of the landings and degree of aggregation. In addition, minor changes were made to the computation steps used to develop mapping and abundance estimations that have rescaled the previous survey series relative to those of 2003.

Landings in ENS have remained at record levels (>10,000 t) since 2000, but signs of the adult population decline are now becoming apparent. Fishery, at-sea observer and trawl survey indicators all point to a declining commercial biomass. Considering that the estimated abundance of recruits is at low levels for the past 2-3 years and the abundance of crab expected to recruit in 2-3 years will also stay at low levels, it is likely that the abundance of the resource will continue to decline for a few more years. However, the presence of small crab (15-50 mm) suggests that recruitment may improve after the anticipated period of lower abundance.

Résumé

L'évaluation de l'état du stock de crabe des neiges de l'est de la Nouvelle-Écosse (ENÉ) est présentée pour 2003 basé sur les données de la pêcherie de 1996 – 2003 (carnets de bord et échantillonnages en mer des prises commerciales) et les relevés au chalut de 1997 – 2003. Deux indicateurs additionnels de l'état du stock ont été introduit dans cette évaluation : l'analyse spatiale des débarquements et le degré d'agrégation. De plus, des changements mineurs au processus de calcul utilisé pour établir la cartographie et les estimations d'abondance ont rapportés les séries provenant des relevés antérieurs à l'échelle de celles de 2003.

Les débarquements de l'ENÉ sont demeurés à des niveaux records (>10,000 t) depuis 2000, mais des signes de déclin de la population adulte deviennent maintenant apparent. Les indicateurs de la pêcherie, de l'échantillonnage en mer et du relevé au chalut tous indiquent une biomasse commerciale déclinante. Considérant que l'estimation de l'abondance des recrues est à un bas niveau depuis 2-3 ans et que cette abondance devrait rester faible pour les 2-3 prochaines années, il est vraisemblable que la ressource va continuer à décliner pour quelques années à venir. Cependant, la présence de petits crabes (15-50 mm) suggère que le recrutement pourrait s'améliorer après la période anticipée de faible abondance.

1.0. INTRODUCTION

Harvesting of snow crab (*Chionoecetes opilio*) off the coast of eastern Nova Scotia (ENS) began in the late 1970s (Fig. 1). Snow crab stocks in ENS experienced large declines in the early 1980's (Tremblay et al., 1994). The increase in landings in the years following the fisheries crash of 1985 were attributed to an increase of abundance and biomass, an expanded fishing area, and an increase of total effort (Tremblay and Eagles 1995). In response to the industry's request to limit excessive exploitation to avoid a repeat of 1985, new management measures were introduced between 1994 and 1999 to protect the long-term stability of these fisheries (Anonymous, 1999). However, the lack of an extensive fishery-independent survey to give reliable abundance and biomass information limited the development of these fisheries during that period. It was speculated in the stock assessment of 1995 that unless there has been a fundamental shift in the productive capacity of ENS snow crab grounds, the high levels of landings were unlikely to continue (Tremblay and Eagles, 1996). As a precaution, it was even recommended in the assessment of 1996 that total effort and landings did not increase at least until a better method to assess this resource could be found (Biron et al., 1997). The introduction of the bottom trawl survey in 1997 and the first estimation of the exploitable biomass in 1999 gave the information needed, and resulted in a 6 folds increase in TAC without endangering the snow crab stock. Landings in ENS have been at record levels (>10,000 t) since 2000, but signs of the adult population decline are now becoming apparent.

Snow crab fishery management areas in ENS have changed considerably since harvesting began (Fig. 2). In 2003, there was five Crab Fishing Areas (CFAs) in ENS (CFAs 20, 21, 22, 23 and 24) that have been further divided into 15 independently managed sub-units: 20 inside, 20 outside, 22 northern, 22 Glace Bay Hole (GBH), 23A, 23B, 23C, 23D, 23 slope, 24A, 24B, 24C, 24D, 24E and 24 slope (Fig. 3). However, CFAs in ENS do not reflect the biological distribution of the resource, and presenting the survey results based on these CFAs compromised the reliability of the biomass estimates (Biron et al., 2001). Therefore since 1999, snow crab stock assessment in ENS is based on the two larger 'units' of the resource: one in north-eastern Nova Scotia (N-ENS) that comprises CFAs 20, 21 and 22; and the other in south-eastern Nova Scotia (S-ENS) that comprises CFAs 23 and 24 (Biron et al., 2000).

2.0. THE FISHERY

2.1. Description of the fishery

2.1.1. History – During the early years of these fisheries, landings increases with increase in effort and peak at 1,634 t in 1979, but landings and CPUE then collapsed within four fishing season (Tremblay et al., 1994). By 1985, these fisheries were believed to be near commercial total collapse beyond recovery with only 89 t of crab landed that year (Elner and Robichaud, 1985). However, a pulse of pre-recruits entered the commercial catches of snow crab in 1986 in all CFAs (Elner and Robichaud, 1987), and from 1986 to 1993, landings again rose rapidly in phase with effort to reach 2,016 t in 1993 (Tremblay and Eagles, 1996). From 1982 to 1993, the management of these competitive fisheries was based strictly on effort controls (seasons, licences and trap limits). The number of licenses remained stable except for CFA 24 where 7 new licenses were added between 1989 and 1991.

Substantial changes in management measures were introduced from 1994 to 1999 such as individual boat quota (IBQ), total allowable catch (TAC), 100% dockside monitoring, mandatory logbook, at-sea monitoring by certified observers and the introduction of sub-areas to ensure the distribution of fishing effort. Additional management measures included mandatory biodegradable panel to prevent ghost fishing and to avoid landing of 10% or more soft shelled crab in the catch. Voluntary measures requested by fishermen were also introduced during that period such as a shortened season (CFA 21), reduced number of trap from 30 to 25 (CFA 21), and no fishing on Sunday (CFA 22). From 1994 to 1997, landings of snow crab in ENS remained stable at around 1,500 t per year, while the trend in CPUE has steadily increased and the one in fishing effort steadily decreased. In fact, landings between 1994 and 1999 were mostly limited by TACs, IBQs or fleet caps that were developed based on ‘recent landings history’ rather than being based on the scientific survey (Biron et al., 1997). The increases in landings observed in 1998 (2,331 t) and 1999 (3,600 t) resulted mainly from the introduction of new temporary allocations that had to be fished outside ‘traditional fishing grounds’ in CFAs 20, 23 and 24 (Biron et al., 1998b, 2000). Again, the new temporary allocations were arbitrarily developed rather than being survey based. The number of permanent licenses in N-ENS remained unchanged from 1994 to 1999 at 5 licenses in CFA 20, 32 in CFA 21, and 37 in CFA 22. During this period, no temporary allocations were allowed in CFA 21 and 22, while 4 temporary permits were issued in CFA 20 in 1999. The number of permanent licenses in S-ENS increased by two licenses in each of its two areas in 1997, and remained unchanged in 1998 and 1999 at 24 licenses in CFA 23 and 23 in CFA 24. The number of temporary permits allocated each year in S-ENS varied between 1994 and 1999, but the overall trend has been an increase from 5 permits in 1996 to 13 in 1999 in CFA 23 and from 6 to 22 permits in CFA 24.

In 1999, the assessment of the stock status for the first time in ENS was based on a trawl survey (Biron et al., 2000). Estimated biomass index and density maps revealed that the geographical distribution of the resource was greater than the area being exploited at the time, especially in S-ENS. Consequently, TAC in N-ENS increased from 900 t in 1999 to 1,015 t in 2000, and from 2,700 t to 8,800 t in S-ENS. IBQs of regular licenses and existing temporary allocation increased as a result. There were no changes in the number of permanent licenses in all CFAs but the number of temporary permit holders increased from 4 to 5 in CFA 20, from 13 to 53 in CFA 23, and from 22 to 56 in CFA 24.

2.1.2. Current status – Abundance indices and distributions obtained from trawl surveys showed a substantial decrease in adolescent males from 1997 to 2002 in N-ENS and S-ENS, while adult males ≥95 mm of carapace width (CW) had remained stable. Trends in average CPUE increased during this period to reach unprecedented levels in all CFAs. From 2000 to 2003, TAC remained near 8,800 t in S-ENS while it increased by 50% in 2002 to reach 1,500 t in N-ENS.

New temporary allocations (total of 200 t) were given to 4 exploratory permits in 2001 and 2002 to conduct a trap survey along the slope of the Scotian Shelf. A similar survey was repeated in 2003 but with an allocation of 300 t and 5 exploratory permits. From 2000 to 2003, the number of permanent licenses in N-ENS remained unchanged at 5 licenses in CFA 20, 32 in CFA 21 and 37 in CFA 22, while the number of temporary permits in CFA 20 increased to 6 in 2002 and 2003. In S-ENS, a change of 'temporary' into 'permanent' status for First Nations in 2002 created 13 new permanent licenses in CFA 23 and 8 in CFA 24. There was an additional 250 t allocated to a native band in CFA 24. A decrease of the existing temporary fishermen allocations resulted in a decrease of the number of temporary licence holders. In 2002 and 2003, there were 37 permanent licenses and 37 temporary permits in CFA 23, and 34 permanents and 40 temporaries in CFA 24 (excluding exploratory permits introduced on the Scotian Shelf slopes).

There were very little changes in other fishery management measures from 2000 to 2003. In 2001, some modifications were made on the shape of the outside sub-areas of S-ENS, and the number of traps allowed was increased from 30 to 45 in CFA 23. Requirements for vessel monitoring system (VMS) now cover all temporary permits, and in CFA 23, permanent license holders that choose to start fishing in June. The Management Plan in 2003 was a roll-over from the one in place in 2002 (Table 1).

2.2. Materials and methods (logbooks and at-sea observer data)

2.2.1. Logbooks – Raw data on catches and fishing effort were obtained from the mandatory logbooks. Copies of the original completed logs and the compiled electronic database were obtained from the Maritimes Region Statistics Division of the Department of Fisheries and Oceans Canada (DFO). Thereafter, total seasonal landings for each CFA were obtained from a revised preliminary report produced by the Statistics Division in January 2004. The average CPUE of the fleet at year (i) corresponds to the ratio of the total catch from the fishermen's logbooks (y) and the corresponding number of trap hauled (th) reported only in properly completed logs: $CPUE_i = \sum y_i / \sum th_i$. In 2003, properly completed logbook represented 94.3% of the total landings in ENS. Total effort (i.e. total number of traps hauls: TH) was estimated from total seasonal landings in the revised preliminary report produced by the Statistics Division (Y_i) divided by average CPUE: $TH_i = Y_i / CPUE_i$.

The increase in TAC allowed after 1997 has been associated with dynamic changes in fishing and landing behaviour caused by new allocations for 'non-traditional' grounds located further offshore and which resulted in changing fishing patterns and increasing soak time (Biron et al., 2000). A first attempt at standardizing CPUE and fishing effort for soak time had little impact on the overall calculated CPUEs. Other factors were also influencing the results but could not be quantified, such as the introduction of new gear, the extended fishing season in S-ENS starting earlier and finishing later, new fishing grounds being exploited, inexperience of new fishermen, limitation on daily landings by buyer some years, introduction of sub-areas (Biron et al., 2001). As a result, unstandardized CPUE and fishing effort were used considering this fast changing fishery make these values as reliable as 'improperly' standardized values.

2.2.2. Spatial analysis of seasonal landings (areal index) - At the Regional Advisory Process (RAP) in February 2003, it was recommended to assess the fishery-related data based on a detailed description of how the fishery changed over time. One method suggested was a spatial analysis of the reported landings. This gives a simple areal index of the size of the commercial fishing grounds (i.e. number of 10' X 10' grids necessary to account for 95% of the catch in a given fishing season). This approach has been used in the past for northern shrimp and cod assessments in Newfoundland, Canada (David Orr, pers. comm., DFO, St. John's, NL). In general, within the Newfoundland region, CPUE was inversely correlated to the areal index for the snow crab stock (David Orr, pers. comm., DFO, St. John's, NL). Fishermen tended to concentrate on pockets of snow crab, but when the catch rates dropped, the areal index increased as the fishermen started to search for areas with higher concentrations of crabs. Logbooks with erronous locations (i.e. location on land, outside the Scotian Shelf, or outside of designated fishing area) were ignored and represented 0% to 15% of the logbooks between 1996 and 2003. The spatial analysis was completed as follows:

1) create a 10' X 10' grid pattern over the fishing area,
2) add up the amount of catch within each grid,
3) order the grids by decreasing catch (i.e. from highest to lowest),
4) count the number of grids necessary to account for 95% of the catch,
5) repeat this process for each year throughout the history of the fishery.

2.2.3. Commercial snow crab availability (abundance index) – Average seasonal landings per grid of commercial fishing grounds (i.e. 95% of landings divided by the areal index value of that given season) seems to provide an adequate index to compare the variation in abundance of the commercial-sized snow crab over the size of the commercial fishing grounds of any given season. This approach follows previous analyses where total landings were divided by km^2 of fishing grounds for any given year (Tremblay et al., 1994), however in this report, the size of the fishing grounds is expressed as 10' by 10' grids (i.e. not converted into km^2) and only grounds with commercial concentration are being considered (i.e. grids necessary to account for 95% of the catch). Therefore, by considering the seasonal variation in the size of the commercial fishing grounds to describe the availability of the commercial-sized crab, a relative abundance index can now be compared between fishing seasons.

2.2.4. At-sea observer sampling - Two types of commercial sampling were conducted: at-sea sampling and port sampling. At-sea sampling was carried out onboard commercial vessels to provide an assessment of the percentage of soft shell crabs in the catches and the size structures of crabs caught. Measurements were done solely by certified observers. The total number of male crabs, the position and depth of the trap were recorded for each randomly sampled trap, and a sub-sample of 20 to 40 crabs was taken randomly for the following measurements: CW and chelae height (CH) using modified vernier calipers (Watson and Wells, 1970), carapace hardness of the right claw using a hardness gauge (Foyle et al., 1989), and carapace condition (CC) (Appendix 1; Moriyasu et al., 1998). It should be noted that because this is a summer fishery, a minimum of 20 crabs are sampled on warm sunny days to reduce handling-induced mortality, while on cool overcast days a maximum of 40 crabs can be sampled. For the port sampling, a sub-sample of 20 crabs was collected at random after a fisherman had sorted the catch. The same measurements as conducted during at-sea sampling were taken.

Catch composition (% of different crab categories) was estimated based on carapace hardness (hard or soft), size (legal and sub-legal) and morphometric maturity. New-soft (CC-1) and clean crab (CC-2) with durometer readings <68 were considered as postmolt soft shell crabs (Moriyasu et al., 1998). The terminology of male maturity phase follows Sainte-Marie et al. (1995). Adult (terminal molt) and adolescent (non-terminal molt) males were identified based on the following discriminant function assigning individuals to the correct groups in 99% of cases (for adult males: $Y > 0$), calculated for ENS male snow crab (Biron et al., 1999):

$$Y = 19.775707 \ln(CH) - 25.324040 \ln(CW) + 56.649941$$

2.3. North-eastern Nova Scotia fishery-related data and results

2.3.1. Fishing distribution and landings – In 2003, as in previous years, fishermen from CFAs 20, 21 and 22 northern exploited the grounds located within the near shore trough that is commonly shared by all three CFAs (Fig. 4). Little fishing effort was reported around St. Paul Island and along the snow crab boundary of CFAs 19/20. In CFA 22 GBH, fishing activity was limited to the Glace Bay Hole fishing grounds with little exploration along the Laurentian Channel slope (Fig. 4). Fishermen from CFAs 20 and 22 GBH have reported a shallower distribution of the commercial concentration in 2003 than in previous years. It appears that fishing in these areas was better at shallower depth (i.e. 40-60 fathoms) than the usual fishing grounds exploited in recent years (i.e. 60+ fathoms). Also, some commercial catches in 2003 were reported in areas normally considered hard bottom such as on the bank of Aspy Bay. These hard bottoms were not considered snow crab ground previously.

Of the 177 t of snow crab allocated to fishermen in CFA 20, 172 t was landed from the inside grounds and 6 t from the outside grounds over a 9 weeks period in 2003. Temporary fishermen landed 69 t of their 75 t allocation in the inside grounds, but only after permanent fishermen had captured their allocation of 102 t. In CFA 21, the total landings of 547 t (TAC of 545 t) occurred over a five weeks period, although 95% of the catch was landed during the first two weeks. CFA 22 northern fishermen landed 480 t within three weeks (TAC of 477 t), while those from CFA 22 GBH took two weeks to land 296 t (TAC of 294 t).

2.3.2. CPUE and effort – In 2003, the average CPUE of 76.8 kg/th in N-ENS represented a 24% decrease compared to 2002 (Table 2). By management areas, average CPUEs in 2003 decreased by 38% in CFA 20, 18% in CFA 21 and 30% in CFA 22 northern, while remaining similar in CFA 22 GBH area (Table 3; Fig. 5). Total effort in N-ENS increased by 32% in 2003 compared to 2002 (Table 2). Excepted for CFA 20 outside, increases in fishing effort were reported for all CFAs in 2003 compared to 2002 (Fig. 5).

2.3.3. At-sea sampling by observers – In 2003, a total of 115 traps was sampled at sea, corresponding to 0.6% of the total number of trap hauls (Fig. 6). From these traps, 4,214 males were measured. The average seasonal percentage of soft-shelled and adolescent increased in 2003 compared to 2002, but generally continued on the downward trend that began in 1997 (Fig. 7). The seasonal average percentage of skip molters was 8%, of which 6% were of legal size (Fig. 7). The mean CW of commercial-sized adult crabs caught at-sea in 2003 decreased in CFA 20 compared to 2002, increased in CFAs 21 and 22 GBH, and remained similar in CFA 22 northern (Fig. 8). The catch composition from the sea sampling in N-ENS had a similar distribution in size, but the proportion of CC 3 (42%) decreased while 3M (38%) and 4 (16%) increased compared to 2002 (81%, 14 % and 2%, respectively) (Fig. 9).

2.3.4. Spatial analysis – The changes that occurred to the fisheries were illustrated by the spatial analysis of the reported landings for the period of 1997-2003 (Fig. 10). The areal index varied from 14 to 18 grids from 1997 to 2002, and increased to 19 grids in 2003 (Fig. 11). The abundance index increased from 12.3 kg/grid in 1997 to 82.7 kg/grid in 2002, but dropped by 10% to 75.1 kg/grid in 2003 (Fig. 11). Little variation in the number of grid fished was anticipated since these areas have limited fishing grounds available, a fact observed by the little change in fishing positions over the years (Fig. 4).

2.4. South-eastern Nova Scotia fishery-related data and results

2.4.1. Fishing distribution and landings – In 2003, as in recent years, fishing effort and distribution in S-ENS was influenced by sub-area boundaries and an imposed arrangement with shrimp fishermen concerning the mutual use of fishing grounds (Fig. 12). Accordingly, some areas in S-ENS were closed to the crab fishery for a part of the year.

In CFA 23, permanent licence holders captured 2,702 t and temporary licence holders landed 1,912 t (excluding 'exploratory' landings from the slope of the Scotian Shelf) for a total landing of 4,614 t (TAC of 4,765 t). In CFA 24, permanent licence holders captured 2,387 t, while temporary ones landed 1,566 t (excluding the landings from the slope area) for total landings of 3,952 t in 2003 (TAC of 4,048 t). The reported commercial landings on the Scotian Shelf slopes were 133 t in CFA 23 (TAC of 120 t) and 180 t in CFA 24 (TAC of 180 t). The discrepancy between the reported landings and TAC on the slope of CFA 23 was partly the result of reported fishing activities and landings by 2 permanent licence holders.

2.4.2. CPUE and effort – The average CPUE in 2003 decreased by 13% in S-ENS compared to 2002 (Table 4). This translated into a 16% decrease in CPUE in CFA 23 and 9% in CFA 24 (Table 3). The average CPUE trends in all sub-areas were negative except for 23C and

24D (Table 4; Figs. 13 and 14). In 2003, CPUEs derived from the limited commercial fishery that occurred on the slope of the Scotian Shelf during the trap survey decreased by 19% in CFA 23 and increased by 62% in CFA 24. Total effort in S-ENS increased by 13% in 2003 compared to 2002, representing a 17% increase in CFA 23 and 8% in CFA 24 (Table 4).

2.4.3. At-sea sampling by observers – In 2003, a total of 1,033 traps were sampled at sea, corresponding to 1.2% of the total number of trap hauls and 39,709 males were measured (Fig. 6). The average seasonal percentage of soft-shelled slightly decreased in 2003 fishing season compared to 2002, continuing on the downward trend that began in 2000 (Fig. 7). The mean CW of commercial-sized adult crabs caught at-sea in 2003 was similar to the 2002 value in CFA 24, while it increased slightly in CFA 23 (Fig. 8). The seasonal average percentage of skip molters was 14.3%, of which 11.3% were of legal size (Fig. 7). The catch composition in S-ENS had a similar distribution in size, but the proportion of CC 3 (51.8%) decreased while 3M (26.2%) and 4 (14.3%) increased compared to 2002 (65.2%, 18.7 % and 8.4%, respectively) (Fig. 9).

2.4.4. Spatial analysis – The evolution of the fisheries were clearly illustrated by the spatial analysis of the reported landings for the period of 1997-2003 (Fig. 10). The areal index increased from 43 grids in 1997 to a peak of 98 in 2000, decreased in 2001 and 2002, and increased to a new record level of 101 grids in 2003 (Fig. 11). The abundance index increased slowly from 12.3 kg/grid in 1997 to 31.3 kg/grid in 1999, and then rapidly between 2000 and 2002 to 76.2 kg/grid and 93 kg/grid, but dropped by 11% to 83.2 kg/grid in 2003 (Fig. 11). The rapid increase in areal and abundance indices corresponded with the 5-fold increase in allocation in 2000 that saw new allocation and fishing effort distributed towards 'new' areas.

2.5. Discussion – Fishery-related data

2.5.1. The fishery - Overall, fishery indicators in all CFAs such as CPUE, areal and abundance indices showed negative trends in 2003 compared to 2002. This is the first time since the mid 1990's that negative trends are observed. There is uncertainty in using CPUE as an index of abundance because catch rates in ENS are affected by changes in fishing gear, season, soak time, fisherman experience, fishing pattern, closures and seasonal movement (Biron et al. 2002). However, except for sub-areas 23C and 24D, different levels of CPUE decrease were observed in all fishing areas. The slight decrease in CPUE combined with increased landings and/or high seasonal CPUE values of 120 kg/th or more in CFAs 22 GBH, 23B and 24B can easily be argued as being comparable to the record levels CPUE observed in 2002 in these same areas. The areal and abundance indices suggested that the increase in allocations in N-ENS between 1997 and 2002 had been mostly possible because of an increase in abundance of commercial crabs, while there was no expansion of the fishing grounds. In S-ENS however, the indices suggested that the increase observed between 1997 and 2000 had been possible because of both an increase in abundance of commercial crabs and the expanded fishing grounds. The decrease in areal index combined with the increase in the abundance index from 2000 to 2002, a period with similar TAC, suggested an increase in commercial crab abundance that peaked in 2002. The increase in the areal index combined to the decrease in the abundance index observed in 2003 suggested an overall decline in the commercial crab population in N-ENS and S-ENS compared to 2002.

Based on the logbook data, the areas most affected by the decline were the fishing grounds located near-shore (i.e. CFAs 20 inside, 21, 22 northern, 23A and 24A) that have seen the highest increase in fishing pressure in terms of fishing effort and landing catches since 1999. In S-ENS, fishermen seemed to adapt to these changes by catching less crab in CFAs 23A and 24A in 2003 compared to 2002, the difference having been caught in 23B and 24B instead. However, the fishing effort (TH) increased in both sub-areas A and B in 2003. Wherever possible, actions should be taken to reduce fishing pressure in these near shore areas to curtail the decline in catches.

2.5.2. At-sea Observer sampling - Size distributions of the catch in 2003 were similar to 2002, but overall the catch was composed of slightly older animals based on the CC. The proportion in the catch of soft shell crab and adolescent increased in 2003 compared to 2002, but generally remained low compared to the long-term trend. Sea sampling covered only a small portion of the fishery with an average of 0.6% of the total seasonal trap hauls being sampled annually since 1997 in N-ENS (i.e. 40 to 137 traps per year), and an annual average of 0.9% in S-ENS (i.e. 233 to 1,170 trap per year). The relatively small at-sea sample size for 1998-99 or for specific fishing grounds is considered bias in representing the fishery. Overall trends suggested that low levels of pre-recruits (R-4, R-3, R-2) and recruitment (R-1) currently entering these fisheries have been declining since 1997-98. The majority of crabs in the catch (85% to 92%) were adult males of CC 3 and 3M.

3.0. THE ANNUAL TRAWL SURVEY

3.1. Annual trawl survey

Before 1999, the snow crab biomass in ENS was estimated indirectly using catch and effort methods such as Leslie analysis. This analysis cannot be used to calculate biomass estimates for the following year(s) and its applicability is very limited by violation of underlying basic assumptions (Miller, 1975; Conan and Maynard, 1987; Mohn and Elner, 1987). The trawl survey has been conducted since 1997 in CFAs 22, 23 and 24 and since 1998 in CFAs 20 and 21. The use of standard statistical techniques such as the arithmetic mean is not accurate to estimate snow crab abundance due to a highly aggregated distribution pattern of this species (Miller, 1975; Conan and Maynard, 1987). Therefore, the survey data were analysed by geostatistical techniques (kriging). Kriging improves the accuracy of snow crab abundance estimation and distribution by dealing with spatial auto-correlation between sampling units (Conan and Maynard, 1987; Hébert et al., 2003).

A preliminary trawl survey was conducted in CFA 23 prior to the fishery in June 1996. A total of 23 stations were sampled (Fig. 16). The geographic distribution of commercially harvestable crab coincided with the distribution of catches based on fishermen's logs (Biron et al., 1997). This experimental trawl survey showed the usefulness of trawl gear to measure snow crab abundance in ENS and provided the first fishery-independent information on population structure, abundance and distribution for part of CFA 23.

The first comprehensive annual trawl survey was conducted in 1997 (Fig. 16). The initial data collected were good but fishery parameters estimated from this survey were not considered reliable at that time because of numerous uncertainties (Biron et al., 1998). One of the greatest source of uncertainties believed to affect the survey-based abundance and biomass was that concentrations of crab were found in the gullies between banks. The Scotian Shelf off the coast of ENS is extremely rugged, quite different from the relatively smooth bottom of the southern Gulf of St. Lawrence (sGSL) where this type of survey had been developed for snow crab. Therefore, a simple areal expansion of the survey estimates was not felt to be appropriate. In addition, size-weight relationship and discriminant function equations used to convert numbers into weight and identify maturity of male crab were not yet developed for ENS. Despite these shortcomings, the trawl survey was considered to be a useful tool for describing the potential distribution of the resource. In particular, the survey indicated two large concentrations of mature crab that were located outside of where the bulk of the fishery occurred in 1997 in CFAs 23 and 24.

In 1998, the survey covered CFAs 20 and 21, as well as parts of the non-traditional fishing grounds of CFA 23 and 24 (Fig. 16). Size distributions from the trawl survey indicated an increase in recruitment in S-ENS and CFA 22 northern (Biron et al., 1999). This new recruitment was to occur over the following three years, but the absence of immature crab (< 56 mm) also indicated a decline in recruitment in the long-term (DFO, 1999). In 1998, new size-weight relationship and discriminant function equations were established specifically for ENS snow crab population (Biron et al., 1999). The potential to increase the TAC was recognized in 1998 but there was still no scientific basis for providing any magnitude to these increases.

The surveyed surface in 1999 expanded to cover the St. Paul Island area, the Misaine, Artimon and most of Banquereau Banks areas, as well as the Gully area (Fig. 16). The projected habitat area (PHA) was introduced to compensate for the overestimation of commercial size snow crab resulting from the irregular bathymetry and subsequent bottom temperatures profiles of ENS (Biron et al., 2000). The PHA was incorporated into our assessment process by means of "masks" which imposed restrictions or boundaries on the interpolation process (Biron et al., 2002). The "mask" included a series of zero values that were positioned onto areas of highly probable zero densities (Fig. 17). Different "masks of zero" were used for commercial and non-commercial snow crab categories, but for commercial-sized adult crabs it was assumed that all grounds shallower than 70 m depth had no crab population. In addition to this restriction, snow crab density projections were only made over areas between 90 m and 300 m depths. This area was deemed to represent the region covered by fishing grounds and a boundary (called "cookie-cutter") was established to limit projections only to those areas (Biron et al., 2000). Data from all stations sampled were used without any mask or cookie cutter to plot the size distributions.

Between 2000 and 2002, the number of stations, and the shape of the surveyed area changed with the knowledge gained during the previous surveys and at the request of the industry to have all known fishing grounds surveyed (Fig. 16). Areas added to the survey in a given year, and found to be negligible habitat, were withdrawn the following year (e.g., Laurentian Channel, Western Banks, Emerald Basin). Changes were made to the computations used to develop survey biomass index estimates that would correspond more closely to the biomass supporting the fishery such as improving the method calculating the start and end points of each trawl station. New technology were introduced such as the Net Mind net monitoring system to replace the SCANMAR system, steel doors replacing wooden doors to improve the behaviour of the trawl in deep water (i.e. >300 m), and adding a Minilog depth sensor to the net to better pinpoint touch down and lift off. The PHA was found to be too restrictive and a new "mask of zero" was developed (Fig. 17). The new restrictions were that all grounds shallower than 20 m depth along the shore of mainland Nova Scotia and Cape Breton had zero snow crab density. All grounds shallower than 70 m on the Scotian Shelf (i.e. major banks) or deeper than 380 m along the Laurentian Channel were considered to be of zero density (Biron et al., 2002). The area located outside the surveyed region in Emerald Basin was also considered to be of zero density because of relatively warm bottom temperatures (Biron et al., 2001). In addition, the mask in the Misaine Bank area was modified to better reflect the bottom irregularity of that region (Biron et al., 2002). The "cookie-cutter" was modified to limit projections from covering areas shallower than 70 m on major banks, and areas around the surveyed perimeters that were further than the equivalent of one - 10' latitude by 10' longitude grid from the last trawl station surveyed (Biron et al., 2002). The 2002 annual trawl survey was conducted in late summer / early fall in consideration to seasonal movement that had been affecting the spring surveys in past (DFO, 2003). Seasonal trawl surveys in N-ENS in 2001 and 2002 confirmed the presence of colder bottom temperatures in the shallower hard bottom area in the spring compared to summer and fall (Biron et al., 2003).

Since its beginning in 1997, the annual trawl survey has been highly inconsistent from year to year (Table 5). The number of trawl stations and surface surveyed changed every year, four different vessels used in seven years and the timing of the trawl survey has changed from spring to fall, i.e. from a pre-season survey between 1997 and 2001 to a post-season survey in 2002 and 2003. The effects of these changes were not assessed. Furthermore, it quickly became apparent that CFAs did not reflect the biological distribution of the resource in ENS, and presenting the survey results based on these CFAs compromised the reliability of the biomass estimates (Biron et al., 2001). Trawl survey results were presented based on the two larger 'units' of the resource: N-ENS and S-ENS (Biron et al., 2000).

The number of trawl stations sampled during the annual survey has increased from 150 in 1997 to 322 in 2000, but steadily decreased to 258 by 2003. Consequently, variations in total surveyed area rendered comparison difficult between years. In order to allow for comparison among years, the overall trends of pre-recruits and commercial-sized adult males have been reported based on the original surface that was surveyed in 1997 for S-ENS and 1998 for N-ENS (Fig. 15). However in 2003, 35 of the 234 trawl stations planned for the annual survey in S-ENS had to be abandoned due to poor weather conditions. Because some of these stations were located in the originally surveyed area, calculations of the overall trends of pre-recruits and commercial-sized adult males for the 1997-2003 time-series were rescaled based on the surface covered in 2003.

3.2. Materials and Methods (trawl survey)

3.2.1. Trawl sampling – A Bigouden *Nephrops* trawl was used (20 m head line, 27.3 m foot rope mounted with a 3.2 m long, 8 mm galvanised chain, and mesh size of 80 mm in the wings, 60 mm in the belly and 40 mm in the cod-end; Conan et al., 1994). A systematic random sampling design was used to determine the location of trawl stations. One location was randomly chosen within each 10 minute latitude / longitude grid. In some areas of N-ENS, two stations were selected per grid in an attempt to improve our understanding of the stock distribution in that region. Once selected, original stations from the first survey were used every year. The duration of each tow varied between 4 to 6 minutes at an average speed of two knots depending on depth, current speed and sediment. The length of a tow was determined in 1987 (Moriyasu et al., 1998). The *Nephrops* trawl was constructed to digs into the bottom sediment, and tows longer than 5-8 minutes resulted in a full load of sediment, reduced catchability, and significant net damage. The onboard starting point for each tow was based on the locking of the winch drums after a predetermined amount of warp is released (3 times the distances of the depth). The tow ends as soon as the winches are started in order to bring the trawl back onboard. In cases of abnormal net behaviour or damage, a new tow was done.

Net behaviour was monitored by NetMind® sensors. A Minilog® temperature / depth sensor complemented other electronic sensors. Information for each tow on duration, position at start, mid and end, horizontal opening of the trawl using NetMind®, and water depth was recorded. Water depths ranged from 50 m to 450 m. The horizontal opening of the trawl was measured every 4 seconds with the distance NetMind® sensors. The swept distance by the trawl was estimated from the position (latitude \ longitude) measured every second with a

DGPS system. The swept surface for each tow was then calculated using an instantaneous surface algorithm (Surette, pers. comm., DFO Moncton).

The catch composition of each tow was photographed, and all male crabs were measured for CW, CH, carapace hardness and CC. Size-frequency histograms were adjusted to the surface area swept by the trawl. All female crabs were measured for CW and the width of the fifth abdominal segment. The presence and the colour of the eggs were also recorded.

3.2.2. Mapping and abundance estimation by kriging – Kriging (Matheron, 1970; Clark, 1979) was used to estimate biomass and map density of different crab categories (Conan, 1985; Conan et al., 1988; Conan et al., 1994). Kriging consisted of two procedures: (1) analyzing and modelling the covariance between sampling units as a function of distance using a variogram; and (2) then interpolating the densities of crab in non-sampled areas by using the covariance function to assign weights to neighbouring samples. The irregular bathymetry and subsequent bottom temperature profiles that may render a portion of the area non-habitable for commercial-sized adult males was accounted for by using the PHA modified in 2001 (Biron et al., 2002). Maps of density and variance contour were generated by using point kriging and a fitted variogram. Block kriging was also used to estimate an average density and variance over the whole area and thereby estimating the total number of crab present in a given area. A kriging program (MPGEOS) developed for the snow crab stock in sGSL was used.

Numbers of crab were converted to biomass using the size frequency histograms and a CW-weight relationship, $W = 1.543 \times 10^{-4} CW^{3.206}$ (Biron et al., 1999). Mortality between the survey and the fishing season (5-8 month period) was considered as null except for category-5 crabs (very old crab). Biomass index was projected for (1) total biomass (B) for the following fishing season without considering the mortality for category-5 crabs, (2) annual recruitment to the fishery (R-1), and (3) biomass of category-5 crabs (OB). The abundance indices of adult males ≥95 mm CW and future recruitment to the fishery (R-4, R-3, R-2) at the time of the survey were also estimated. The terms R-4, R-3 and R-2 represent the adolescent males with a CW ranging between 56-68 mm, 69-83 mm and >84 mm, respectively (Hébert et al., 2003). A portion of these crabs could be available to the fishery in 4, 3 and 2 years respectively. In addition, the abundance indices of immature and mature females were estimated. The abundance and biomass indices of the different categories of crabs should not be considered as absolute values since we do not take into account natural mortality (or any other loses than reported landings and category-5 crab), emigration or immigration, and catchability of the trawl in our calculations.

3.2.3. Degree of aggregation – Indicators used for monitoring the status of a resource and degree of exploitation that could be relevant to snow crab management were suggested by J.F. Caddy (pers. comm.,), and one variation of these indicators has been included in the traffic light analysis presented in this document. The indicator is represented as the percentage of the area surveyed that contains ≥1000 adult male crabs ≥95 mm CW / km^2 at the time of the survey. The criterion of ≥1000 crabs / km^2 was set arbitrarily. However, it should be noted that in the sGSL the relationship CPUE – density indicated that CPUE decreased when density fell under 1000 crabs / km^2, but remained constant above that level (Elmer Wade, pers. comm.).

3.2.4. Temperatures – It has been common practice to attach a temperature probe (VEMCO Ltd.) to the trawl for each tow. Each year, temperature data are sent to Hydrologic Services, DFO-Halifax for recording / analysis. However, for comparison purposes and to better illustrate differences, bottom temperature data collected during the trawl surveys were projected into geographic distribution maps. These do not account for difference and variation in sampling time (hour/day), date, tide, current and topography.

<u>3.3. Annual trawl survey data and results</u>

3.3.1. North-eastern Nova Scotia - In 2003, 59 stations were sampled during the post-season trawl survey that was conducted between October 13 - 26 on board the chartered vessel Marco Michel (Fig. 16). There were 1,045 males and 581 females collected and measured in N-ENS in 2003. The total biomass index (B) from the 2003 trawl survey data was estimated at 2,201 t [1,327-3,502 t]* (*95% confidence intervals), and was comprised of 460 t [187-954 t] of soft shell (R-1) and 1,741 t [1,140- 2,548 t] of hard shell crab (RB) (Fig. 18). The abundance of recruit increased slightly in 2003 compared to 2002, but was still at lower recruitment level compared to the 1998-99 period (Fig. 19). The abundance of commercial size adult males has decreased in 2003 compared to 2002 (Fig. 19). The abundance of adolescent decreased slightly in 2003 compared to 2002, a trend that started since the survey began in 1998 (Fig. 19). The adult female abundance in 2003 was similar to 2002 (i.e. generally low and almost exclusively comprised of multiparous females), while a noticeable increase in immature female was observed in 2003 compared to 2002 (Fig. 20). Size distributions of adolescent and adult male crabs caught by the annual post-fishery trawl survey in 2003 were similar to 2002, but it also showed a large pulse of immature crab <56 mm CW in 2003 (Fig. 21). The average CW estimated from the trawl survey in N-ENS was 112.1 mm, a similar value to 2002 (Fig. 22). The mean weight of commercial-sized crab caught during the 2003 survey was 614 g, an increase compared to 2002 and the long-term trend since 1998 (Fig. 23).

Maps of contour density distribution clearly illustrated the low level of pre-recruits and recruitment found during the trawl survey in 2003 in comparison to earlier years (Figs 24, 25 and 26). The density distribution of hard-shelled adult crab increased from 1997 to 1998, remained similar from 1998 to 2002, and decreased in 2003 (Fig. 27). From 2000 to 2003, the main concentrations of females disappeared compared to the 1997 - 1999 levels (Figs 28 and 29).

3.3.2. South-eastern Nova Scotia - In 2002, 199 stations were sampled during the post-season trawl survey that was conducted between November 3 and December 21 on board the chartered vessel Marco Michel (Fig. 16). There were 4,598 males and 1,810 females collected and measured in S-ENS in 2003. Size frequency distribution of crabs caught by the annual post-fishery trawl survey in 2003 showed a decrease in density of adolescents and adults > 50 mm CW compared to 2002 (Fig. 30). Total biomass (i.e. based on total surveyed area) of commercial-sized adult males was estimated at 27,385 t [22,172 – 31,549 t] in 2003, and was comprised of 2,939 [2,130- 4,021 t] of soft-shelled crabs and 24,446 t [20,042- 29,528 t] of hard-shelled crab. The average CW from the trawl survey in S-ENS was 112 mm, which was comparable to those observed since 1999 (Fig. 22). The mean weight of commercial-sized crab caught during the 2003 survey was 608.7 g, a small increase over the estimated 2002 value (Fig. 23). Maps of density distribution clearly illustrated the low level of pre-recruits and recruitment found during the trawl survey in 2003 compared to earlier years (Figs 31, 32 and 33). The remaining commercial crabs were more predominant in and around sub-areas 23B and 24B, although smaller concentrations were found in all sub-areas (Fig. 34). Main concentrations of adult females have disappeared since 2000 compared to the 1997 - 1999 levels (Fig. 35). The density concentration of immature female has increased in 2003 compared to 2002, with the highest concentrations found in sub-areas 23A and 24A (Fig. 36).

The biomass index of commercial-sized adult males for the original surveyed area used for comparison since 1997 has been rescaled to the surface surveyed in 2003 (i.e. 20,607 km^2). The biomass index for the original surveyed area was estimated at 20,567 t [16,449 – 25,422 t] in 2003, and was comprised of 2,368 t [1,718- 3,184 t] of soft-shelled crabs and 18,200 t [14,731- 22,238 t] of hard-shelled crab (Fig. 37). Based on the original surveyed area (23AB and 24AB), the abundance of commercial size adult males has been slowly decreasing since its high abundance period of 1998-2000 (Fig. 38). In 2003, the relative abundance of soft and hard-shelled adult males ≥ 95 mm CW decreased compared to 2002. The abundance of adolescent decreased compared to 2002 with lower recruitment in comparison to earlier years (Fig. 38). In 2003, the adult female abundance was similar to 2002 (i.e. generally low and almost exclusively comprised of multiparous females), while a small increase in immature female was observed (Fig. 20).

3.3.3. Temperature distribution from the trawl surveys - Bottom temperatures from the trawl survey in 2003 were generally colder compared to 2002 (Fig. 39). This is true for S-ENS that was surveyed between November 3 and December 21 in 2003 compared to August 13 to September 24 in 2002, but also for N-ENS which were surveyed during the same period in 2002 and 2003. In N-ENS, banks had warmer bottom temperatures and gullies colder water compared to 2002. Most of the slope water in CFA 23 was in the 0°C to 2°C range while it was mostly between 2°C to 4°C on the slope of CFA 24 (Fig. 39).

3.4. Discussion - Biomass and abundance estimates

3.4.1. Variation in biomass index amongst sub-areas **–** The current management areas and sub-areas do not necessarily correspond to the biological distribution of the resource, and to use CFAs as a reference point to present the trawl survey results compromise the reliability of the biomass estimates (Biron et al., 2001). High concentration of commercial crab observed with the trawl survey has been changing location every year since the survey started. The highest concentration of hard-shelled adult males were found in CFAs 20, 21 and 22 northern in 1998, in CFAs 21 and 22 GBH in 1999, in CFA 22 GBH in 2000, in CFAs 20 and 21 in 2001, in CFA 22 northern in 2002, and in CFAs 21 and 22 in 2003 (Fig. 27). In addition, the method used to estimate abundance in ENS is designed to give a global view of the population, and small areas such as those in N-ENS are considered micromanagement. The method should be reconsidered if micro-assessment is the goal. Furthermore, it is currently impossible to estimate an accurate biomass index in S-ENS sub-areas such as 23C (long narrow surface), 23D (two small unrelated fishing grounds) and 24D (very narrow fishing grounds), even if they are covered by the trawl survey and their biomass included in the total biomass index.

3.4.2. North-eastern Nova Scotia -The 2003 trawl survey in N-ENS indicated a total biomass index of 2,201 t (1,327 – 3,502 t), representing a 22% decrease in total biomass index compared to the 2002 estimate. The estimate in 2003 was the forth-consecutive year with low level of recruitment following the large wave of recruitment to the fishery (based on abundance of R-3, R-2, R-1) prior to 2000. However, the presence of small crab (15-50 mm) in the trawl survey in 2003 suggested that recruitment might improve after the anticipated period of lower abundance. The Glace Bay Hole experiment indicated that limited concentration of snow crab might be unaccounted for and located in the untrawlable perimeter of the surveyed area producing an overly conservative biomass index. The proportion of unaccounted crab might vary from survey to survey depending on environmental factors and timing of the survey.

3.4.3. South-eastern Nova Scotia - In S-ENS, the commercial biomass index was estimated at 27,385 t [22,172 – 31,549 t], a 10% decrease in total biomass index overall compared to 2002. The abundance index of hard-shelled adult male ≥95 mm CW decreased over the long-term trend for the second consecutive year. The highest decrease in biomass index occurred in the original surveyed area (23AB and 24AB), areas that have seen a consistent increase in fishing pressure since 1996 (in term of reported landings and total fishing effort). Areas located at the peripheral (i.e. 23C, 24B, 24C and 24D) saw increases. Based on the current knowledge, it would be simplistic to believe that the decrease inside the original surveyed area can be explained by the gain in the peripheral areas. It is more likely that the original surveyed area is actually gaining crab from the peripheral areas. The Sable Is. Bank area is currently at the peak of a wave of recruitment, more likely to overflow than attract crab. The south slope of Banquereau (23C) reported a 32% increase in seasonal CPUE to a record 142 kg/th in 2003, and the Misaine-Banquereau area was seemingly at the peak of a wave of recruitment in 2000. Again, more likely to export than attract crab.

The trawl survey on the Scotian Shelf slopes in 2003 proved that it would be a mistake to assume that a uniform and synchronised snow crab population inhabit such a large region as S-ENS. There were indication of peaks in recruitment in N-ENS, Chedabucto Bay area and CFA 4X in 1998, Misaine-Banquereau area in 2000, and now Sable Is. area in 2003.

4.0. GLACE BAY HOLE EXPERIMENT

An experiment was conducted in N-ENS to establish the distribution, biomass and other biological parameters of the snow crab population over a large area of soft and hard bottom by simultaneously conducting a trawl, video camera and trap survey. Overall, the total surface of this sub-area is composed of 23% of hard shallow bottom, 34% of muddy bottom located between 90 m and 200 m depth range, and 43% of the deeper Laurentian slope and channel area which is excluded from the annual trawl survey. The selected region, the Glace Bay Hole (GBH), is a relatively small area of muddy bottom that is bounded to the north, east and south by the shallow hard bottom of Smokey and St. Ann's Banks, and to the west by the deeper and warmer waters of the Laurentian Channel (Fig. 38). The annual survey in 2001 did not find any amount of snow crab on the Laurentian slope of N-ENS (Biron et al., 2002). There is also the seemingly inaccuracy of the trawl survey method to estimate biological parameters of the snow crab in that area. In addition, the timing for the fishery seems to be of great importance in GBH where anecdotal evidences showed the lack of large commercial crab concentration immediately prior to the fishery (Biron et al., 2001).

4.1. Materials and Methods (GBH experiment)

4.1.1. Trawl survey – Twenty trawl stations that are normally covered by the annual trawl survey in the area of interest were sampled on June 25 and 26 with the chartered 65 feet vessel Marco Michel (Fig. 40). The trawl sampling methodology and the mapping and abundance estimation by kriging were identical to those applied during the annual trawl survey described above (page 10, section 2.5.2.).

4.1.2. Video camera survey – Thirty video camera stations were sampled between June 17 and July 3 with the 65' research vessel CCGC Opilio (Fig. 40). Twenty-five stations were filmed using an underwater video camera towed by a sled. Each station consisted of two tows crossing each other to form an 'X'. The duration of each tow varied between 15 to 20 minutes at an average speed of 1.5 knots. Two laser pointers indicated a 15 cm wide marking on the grounds at all time ('reference point'), and the average width seen at the reference point level was 1.2 m. A GPS system was integrated on the monitor screen, and start and end point were taken at the moment of touch down and lift off. Positions were adjusted to the predetermined amount of warp released for each tow. Videos were converted into hard data. For every section of 20 seconds of video, the position was taken and all species observed at the reference point level were recorded. Snow crab observed were separated into 3 categories: commercial-sized adult male, undersize crab (adults, adolescents, males and females) and immature (twonies size and smaller). Kriging was used to estimate population and map density of each snow crab category.

In addition, five stations were filmed with the use of a pendulum. These stations located in GBH were too deep for the sled system which can only reach a depth of 100 m. The pendulum was able to reach depths of 225 m and consisted of a conical trap mounted with a back fin to stabilise any possible rotation movement. A camera, connected to a pen and tilt, and light sources were mounted inside the trap. The pendulum was lowered on the side of the vessel straight to the bottom. As the vessel drifted, the pendulum advanced by hopping around. Although the methodology for these stations failed to produce usable data for kriging, the video still provided visual information.

4.1.3. Trap survey - A trap survey was conducted after the trawl and video camera surveys were completed in order to qualify (i.e. categorise) crabs observed during the video camera survey. Conical modified traps (i.e. smaller mesh size) were set on the same positions than video camera stations, while unmodified shrimp traps were set in between stations (Fig. 40). Shrimp traps have proved efficient for catching immature males and all categories of female in past experiences (unpublished data). The total number of male crabs, the position and depth were recorded for each trap, and a sub-sample of 40 crabs was taken randomly for the following measurements: all male crabs were measured for CW, CH, carapace hardness and CC; all female crabs were measured for CW and the width of the fifth abdominal segment. The presence and the colour of the eggs were also recorded. Catch composition (% of different crab categories) was estimated based on carapace hardness (hard or soft), size (legal and sub-legal) and morphometric maturity following the same method as described in the at-sea observer sampling (page 8, section 2.2.).

4.2. GBH experiment data and results

4.2.1. Trawl survey – There were 276 males and 144 females collected and measured during the pre-season trawl survey in GBH in June 2003. The kriging surface was 2,148 km^2. The total biomass index (B) from the GBH trawl survey data was estimated at 1,297 t [605 – 1,989 t], and was comprised of 118 t [11- 225 t] of soft-shelled crab (R-1) and 1,179 t [594 – 1,764 t] of hard-shelled crab (RB). The abundance (density) of adolescent ≥56 mm CW was estimated at 328 crabs / km^2 and at 317 crabs / km^2 for adolescent ≥76 mm CW. The same kriging surface and calculations were applied to the post-season trawl survey in GBH in October 2003, and the total biomass index (B) was estimated at 1,019 t [427 – 1,672 t]. It was comprised of 165 t [0 - 391 t] of soft-shelled crab (R-1) and 854 t [427 – 1,281 t] of hard-shelled crab (RB). The abundance (density) of adolescent ≥56 mm CW was estimated at 132 crabs / km^2, and at 132 crabs / km^2 for adolescent ≥76 mm CW. The abundance (density) of adult ≥95 mm CW was 1,044 crabs / km^2 in July and 842 in October.

Maps of density contour distribution illustrated that at the time of the trawl survey in July, commercial-sized crab were mostly distributed in GBH (Fig. 41). The high-density concentration observed in the southern part of the surveyed area was actually due to only 1 trawl station with a very high density, while the immediate surrounding stations had very little commercial crab.

4.2.2. Video camera survey – The ‘quality’ of the observation varied depending on the type of bottom being surveyed with the video camera. For example, immature and undersized crabs could easily be identified and counted on soft muddy bottom, even when half buried, because of the steadiness of the camera being towed on this uniform bottom. The camera was also relatively steady on gravel and rocky bottom, but immature and ‘smaller’ undersized (i.e. < 60 mm) snow crabs were much harder to see because of the presence of similar sized peddles. The distinction between the two was only possible when these small snow crabs moved around. Unfortunately, their mobility was not enough in some instance to ensure their identification and some unidentified crabs were missed and not counted. Overall, there were 37 immature and 15 undersized crabs that could not be identified between toad, rock or snow crab, although most of them were found on grounds where only toad crabs had been identified. On shallower grounds, sections of some transects had algae that could have hidden crabs from the camera's view. However, all commercial sized snow crabs were easily identified on muddy, gravel and rocky bottom. Only in the rare case of extremely rugged bottom that commercial sized snow crab might have been missed, being hidden by boulders or missed when the sled swung into a different position after hitting an obstacle.

Converting video images into hard data proved to be extremely time consuming. Video had to be viewed at 1/4 and 3/4 of the normal speed in order to see all, including movement, and sometime repeatedly to properly identify crabs, and stopping for measurements. Overall, the ratio was 10 hours of work to convert 1 hour of video into hard data, excluding data entry and analysis.

In 2003, there were 25 stations sampled during the pre-season video camera survey on Smokey and St Ann's bank that were used for assessing the abundance and distribution of snow crab on these mostly hard grounds. The kriging surface was 1,700 km^2. Five of these stations are normally sampled during the annual trawl survey. There were 485 snow crabs identified during the video camera survey, 331 immature, 59 undersized, and 95 male crabs ≥95 mm CW. By using the mean weight of 578.8 g estimated from the trawl survey for adult ≥95 mm CW, the total biomass index (B) from the video camera survey was estimated at 1,297 t [605 – 1,989 t]. The abundance (density) of adult ≥95 mm CW was estimated at 2,247 crabs / km^2 for the video camera surveyed area. The projected snow crab population was comprised of 65% immature, 12% undersized and 22% of commercial sized crab (Fig. 42). The majority of the immature crabs observed during the survey was concentrated in and around the muddy bottom of GBH (Fig. 41). The highest densities of undersized crabs were mostly distributed along the hard slope on both side of Smokey Bank (Fig. 41), and the highest densities of commercial crab were found on the muddy bottom of the gully and GBH (Fig. 41). However, the concentration of commercial sized crabs found in GBH did extend well onto the bank in a westward manner.

4.2.3. Trap survey - In 2003, a total of 20 conical traps were sampled during the trap survey following the at-sea observer protocol and 475 males were measured (Fig. 43). No soft-shelled adults were captured in the process, while the average seasonal percentage of adolescents and skip molters were 6.5% and 6.3% of the catch, respectively. A large proportion of the sampled crabs (27%) were undersized adult males.

4.3. Discussion - GBH experiment

The GBH experiment indicated that at the time of the surveys in late June – early July 2003, the highest abundance (density) of adult ≥95 mm CW was located on the hard bottom immediately surrounding the GBH area. Although some of these grounds are covered by the trawl survey, it also indicated that parts of Smokey Bank judged untrawlable because of rocky bottom were harbouring, sometime high, densities of commercial crab (i.e. 1000-4000 crabs/km^2). It is unclear however if this distribution is typical for late June - early July of every year, or an oddity for 2003. Fishermen from 22 GBH reported fishing in shallower water in 2003 compared to recent years. This experiment supported the rational for moving the annual trawl survey in 2002 from spring to fall to avoid the seasonal movement in winter and early spring towards the shallower and colder bottom of the banks to moult and mate (Biron et al., 2003).

The GBH experiment was not designed to compare the video camera survey with the trawl survey, but only to investigate the distribution of crab over soft and hard grounds before the fishery. All stations should have been surveyed by both methods if a valid comparison was warranted. There are also uncertainties associated with comparing abundance and biomass indices resulting from two different sampling methods. One can not simply add the biomass index from the two surveys and claim it to be representative of CFA 22 GBH. Some of the surveyed areas were located in CFA 22 northern, and some grounds were commonly surveyed by both surveys. However, general conclusions can still be drawn from the GBH experiment: 1) Overall trend calculated for N-ENS are apparently representative of the stock since the survey covers the highest densities grounds; 2) excluding the surface of the banks from kriging has produced an overly conservative biomass index; 3) the seemingly resilience of N-ENS to the current historical harvesting level might have been caused by a limited concentration of snow crab unaccounted for and located in the untrawlable perimeter of the surveyed area; and 4) inter-annual fluctuation in bottom temperature at the time of the survey may affect to a certain degree the magnitude of any perceived fluctuation in the population by affecting the distribution of snow crab between trawlable and untrawlable grounds.

5.0. SCOTIAN SHELF SLOPES

Some fishing activities were first reported in the Scotian Shelf slopes in 2000. After a limited voluntary trap survey by industry in 2000, a formal two-year trap survey with four experimental licences and an annual allocations of 50 t each was conducted in 2001 and 2002 (Biron et al., 2003). This trap survey was repeated in 2003, but with five experimental licences with allocations of 60 t each. The objectives of this project were to determine the distribution, density (mean number of crab / trap) and movement pattern (by tagging) of snow crab in these offshore areas.

Since fishery activities were reported on the slope of the CFAs 23 and 24 in 2000, there have been requests by managers and industry to evaluate the snow crab population on the Atlantic side slope of Banquereau and Sable Is. Bank (Fig. 38). The trap surveys and restricted commercial fisheries between 2000 and 2002 could only show the presence of adolescent and adult snow crab along the two slopes, and that some areas had relatively high abundance of commercial crab concentrations (Biron et al., 2003). Larger average CW and a higher proportion of older crab were attributed to an ‘accumulation’ of the stock (Biron et al., 2000). The increase in adolescent and soft-shelled adults during the trap surveys and commercial fishery in 2001 and 2002, especially in CFA 24, were puzzling and could either indicate a decrease of the commercial portion of the stock, or that a pulse of recruitment was occurring (Biron et al., 2003). However, there was no sound scientific basis to provide any direction concerning the potential, if any, of these areas. Therefore, a trawl survey was conducted in 2003 in an attempt for determining the available commercial biomass on both slopes.

5.1. Materials and Methods (Scotian Shelf Slopes)

5.1.1. Exploratory trap surveys – The surveys occurred within the slope of Banquereau and Sable Island Banks. No effort was permitted within the proposed Sable Gully marine protected area. From this protected area, the survey extended northward to 45°00’ latitude in CFA 23 and westward to the 61°00’ longitude in CFA 24. The areas were divided into 16 km (10 mile) sections, within which two transects were set with 1 trap placed at depths of 70 m, 100 m, 200 m and 300 m in 2003. This was to be done a minimum of two times between May and November, with at least one month apart between fishing. In the fall of 2003, gear conflict had arisen between the swordfish fishery and the trap survey, and the depths of 200 and 300 m were abandoned and replaced by a new depth range: 60 m, 70 m, 80 m and 100 m. Selected fishermen were requested to follow the same management measures as for the commercial fisheries (i.e. mandatory logbook, hail requirements, 100% dockside monitoring, 25% at-sea observer coverage, etc.). For each trap, the total number of male crabs, the position and depth of the trap were recorded, and a sub-sample of 40 crabs was taken randomly for the following measurements: CW, CH, CC and hardness of the right claw. Additional reporting requirements included a description of by-catch species (e.g. lobster, Jonah crab, others). Temperature probes (VEMCO Ltd.) were attached to twelve traps of one participant. Tagging projects were conducted on the slopes in 2001, 2002 and 2003.

5.1.2. Trawl survey - The coverage of the areas of interest by the trawl survey was adapted to the particularities of sampling and estimating snow crab population in relatively long but narrow surfaces in two ways: 1) by limiting the sampling of the slope only to areas comprised between 50 and 300 m depth; and 2) by increasing the number of stations sampled to 1 station per 5' x 5' grid instead of 1 per 10' x 10' grid. A systematic random sampling design was used to determine the location of trawl stations within these two parameters.

A total of 78 trawl stations were sampled on the slope of the Scotian Shelf between June 27 and 30, 2003 with the chartered 65 feet vessel Marco Michel. The trawl sampling methodology and the mapping and abundance estimation by kriging were exactly the same as the ones applied during the annual trawl survey described above (page 10, sections 2.5.1. and 2.5.2.).

5.2. Scotian Shelf Slopes data and results

5.2.1. Exploratory trap surveys - Some of the fishing locations for the trap surveys along the slope of the Scotian Shelf in 2003 are shown in Fig. 44. The 2003 trap survey data for two of the five participants was received too late (i.e. Feb. 24, 2004) to be included in this report. In 2003, the mean number of crab by depth range was the highest between 60 m and 100 m, and decreased rapidly with depth (Fig. 45). An exception was noted during the fall portion of the trap survey in CFA 24 where high number of crab was also caught at 200 m. Overall, there were 6,433 males measured during the trap survey in 2003. The average CW from the trap survey was 114.7 mm in CFA 23 and 113.3 mm in CFA 24. In CFA 23, the proportion of adolescents in the catch increased from 4% in summer to 13% in the fall for a seasonal value of 10% (Fig. 46). Much higher proportions were reported in CFA 24 at 53% adolescents in the catch in summer and 34% in fall 2002 for a seasonal value of 39% (Fig. 46). Distribution of the abundance of crab caught per trap during 2001-2003 surveys seemed to indicate a decrease in abundance from spring/summer to fall on the slope of CFA 23, but an increase in abundance on the slope of CFA 24 (Fig. 47). The temperature profile was colder on the slope of Banquereau than Sable Is. banks during the trap survey in 2003 (Fig. 48).

5.2.2. Trawl survey - There were 38 trawl stations surveyed on the slope of CFA 23 and 40 for CFA 24 between July 1 and 5, 2003 (Fig. 49). There were a total of 1,920 males and 156 females collected and measured during the Scotian Shelf slopes trawl survey in 2003. The total area covered by kriging was 2,958 km^2 for the slope of CFA 23 and 3,018 km^2 for the slope of CFA 24. In CFA 23, the total biomass index (B) was estimated at 4,336 t [2,698 - 8110 t], and was comprised of 497 t of soft-shelled adults [15 – 2,781 t] and 3,839 t of hard-shelled adults [2,683 – 5,329 t]. Total biomass index (B) for the slope of CFA 24 was estimated at 8,708 t [6,142 – 11,992 t], and was comprised of 5,039 t of soft-shelled adults [3,524 – 2,618 t] and 3,669 t of hard-shelled adults (2,618 – 5,002 t). Both areas were comparable in the abundance of hard-shelled adult males, but recruitment represented only 10% of the commercial biomass on the slope of CFA 23 compared to 58% in CFA 24. Maps of contour of density distribution clearly illustrated that higher concentration of pre-recruit and recruitment were found on the slope of CFA 24 during the survey than CFA 23 (Fig. 50).

5.3. Discussion - Scotian Shelf Slopes

Results of the trawl and trap surveys in 2003 indicate that there is a potential to increase allocations on the Scotian Shelf slopes, but there is still no sound scientific basis to provide any magnitude to these increases. It is important to realise that abundance and biomass index of the different categories of crabs found during the trawl survey should not be considered as absolute values. This may be especially true for this first comprehensive trawl survey because the method had to be modified and adapted to the particularities of sampling two long but relatively narrow surfaces. The minimum time series acceptable by the Science group to produce biomass index estimates and forecasts with confidence was and will remain 3 years (Biron et al., 1998).

The exploratory trap survey in 2001 and 2002 showed the presence of adolescent and adult male snow crabs along the slope of the Scotian Shelf, but mostly at depth of 60 m to 200 m (Biron et al., 2003). It was confirmed during the 2003 trap survey. From the 2001-2003 time series, the distribution of the abundance of crab caught per trap during the surveys indicated a decrease in abundance on the slope of CFA 23 but an increase in abundance on the slope of CFA 24 (Fig. 47). This seemingly difference in the life cycle phase of each slope is being supported by the trawl survey that identified a comparable abundance of hard-shelled adult males between the two areas, but recruitment represented 10% of the commercial biomass on the slope of CFA 23 compared to 58% in CFA 24. Furthermore, there was a much higher concentration of pre-recruits found on the slope of CFA 24 compared to the slope of CFA 23 (Fig. 50). Based on one trawl survey and the 2001-2003 traps surveys, it seems as if the population on the slope of CFA 23 is currently at the end of a recruitment wave, while the population on the slope of CFA 24 is currently at its peak. However, it may be premature to make any conclusion since different temperature profiles have been observed on the slopes of CFAs 23 and 24 that may justify a different distribution of the snow crab population on the bank and slope of Banquereau compared to the own observed on the bank and slope of Sable Is. Bank (Figs 39 and 48).

Spatial plots (Fig. 47) of snow crab counts per trap showed the apparent seasonal movement of the crab stock which seems more acute in CFA 24 (Sable Island Bank). Over the three year study, the number of crab observed in the spring and summer in CFA 24 is less than the one observed in the fall, while the opposite seemed to be occurring in CFA 23 (Banquereau Bank). This variation may be due to the seasonal migration from other areas. In addition, the importance of the relation between the slope areas and the nearest fishing grounds (i.e. area 23D, 23C and 24D), if any, remains unknown but 4 of the 26 tags returned from the slopes tagging experiments were captured in these areas.

6.0. SNOW CRAB MOVEMENT

It is generally believed that in eastern Canada snow crab only travel short distance, usually less than 20 km on average (Brêthes and Coulombe 1989, Lefebvre and Brêthes 1991, Watson 1970, Watson and Wells 1971, Taylor 1992). Snow crab has been described as a kind of sedentary species that show movement essentially on a local scale (Watson 1970; Harden-Jones 1984; Taylor 1992). However, recent observations seem to contradict these conclusions that may not be general for every geographical area (Brêthes and Coulombe 1989; Taylor 1992). The purpose of tagging by the Snow Crab Section of DFO-Moncton since 1996 is to investigate the benthic movement of adult male snow crab tagged in different locations in ENS.

6.1. Material and Methods (Snow Crab Movement)

6.1.1. Tagging - Only vigorous adult males of CC-2, 3 and 4 captured with commercial snow crab traps were tagged using a modified spaghetti tag mounted with a numbered plastic disc and a metal sleeve. The tag was placed between the second and third legs, and secured by squeezing the metal sleeve. This particular placement of the tag still allows the male crab to open his abdomen, which is required during mating. Tagging was done onboard industry and/or research vessels. Crabs were measured for CW, CH and CC, tagged and released at the surface of the water in pre-determined positions.

6.1.2. Tag-return – Fishermen who catch a tagged crab are asked to remove the tag, mark down the location, depth and date of capture, and send this information with the tag to DFO. In exchange, information on the tag sent in and a reward (e.g. caps, clipboard, pen, etc…) is sent back to the participating fishermen.

6.2. Tagging data and results

In 2003, 153 adult male crabs were tagged on Smokey Bank, 318 in the Misaine Bank area, 242 on the slope of CFA 23, and 250 on the slope of CFA 24 (Fig. 51). Two of the 11 tag-returns received for the 2001 CFA 24 slope project (N=198 tagged crab) were caught in CFA 24D, and the remaining on the slope of CFA 24 (Fig. 52). One of the 10 tag-returns received for the 2001 CFA 23 slope project (N=297 tagged crab) was caught in CFA 23D, Artimon Bank area, and the remaining on the slope of CFA 23 (Fig. 52). One of the 5 tag-returns received for the 2002 CFA 23 slope project (N=248 tagged crab) was caught in CFA 23C, Artimon Bank area, and the remaining on the slope of CFA 23 (Fig. 52).

6.3. Discussion – Snow crab movement

It has been suggested by Brêthes and Coulombe (1989) that some of the snow crab movement may correspond to a density regulation mechanism driving animals towards low density places. According to them, it is possible that some exchanges between fishing areas compensate the effect of differential fishing mortalities among fishing grounds. Although this is probably true, to a certain extend, other factors must be at play to explain the seemingly higher dynamics of a few sites where crab can be recaptured up to five CFAs away from the release sites. Nevertheless, the pattern in snow crab movement indicates the possible existence of contact between local fishing grounds and/or management areas and sub-areas in all regions studied. Therefore, crab movement between areas is assumed to be active but was not explicitly considered in this assessment.

Three types of movement affect the trawl survey and the assessment of the stock in ENS: seasonal, migration and oscillatory movement. It is to avoid seasonal crab movement that had been affecting the spring surveys that the annual trawl survey is now conducted in late summer and early fall (Biron et al., 2002). Previous research had demonstrated seasonal movement towards shallower and colder water in winter and early spring for breeding (Hooper, 1986; Brêthes and Coulombe, 1989; Comeau et al., 1998) and molting (Sainte-Marie and Hazel, 1992; Lovrich et al., 1995; Comeau et al., 1998). In ENS, shallower often means hard untrawlable bottom (Biron et al., 2000). However, if cold water remains longer on the bank, it may change the distribution of crab before the start of the fishery, or affect early summer research such as the GBH experiment in 2003. Crabs in some areas such as GBH seemed to be more active in terms of seasonal movement (Biron et al., 2003).

Greater travelled distance has been observed over the more dynamic habitat found in most of ENS than any other Atlantic regions (Biron et al., 2003). Average distance travelled by male crab within 12 months was in the range of 15 km to 160 km. These results were similar to those being observed in Alaska where average distance ranged from 10 km to 170 km within one year (McBride, 1982). Immigration may be beneficial to supplement the crab fisheries of N-ENS, but no one can yet assess its contribution, nor the emigration rate outside N-ENS.

The term oscillatory movement is used to describe the possible shift that can occur when a concentration is located on management or demarcation lines of a surveyed surface. For example, this has been affecting CFAs 20, 21 and 22 northern since the trawl survey began in 1998. But this may also affect the abundance indices of the original surveyed area that has consistently seen its perimeter demarcation line splitting concentrations of crabs every year. It may actually be worthwhile to eliminate, or at least reconsider the usefulness of this area used for annual comparison in the assessment now that the survey has stabilised to a similar surface since 2000.

7.0. SOURCES OF UNCERTAINTIES

Ever since the first trawl survey was conducted in 1997 and snow crab abundances estimated in 1999, it has been custom to enumerate all uncertainties that are believed to affect the scope of the stock assessment for ENS. Some of the uncertainties listed below are carried from previous research documents.

7.1. Mortality – The natural mortality (e.g. predation, diseases, etc.) of commercial crab between the time of survey and the fishing season has not been taken into account. According to Wade et al. (2003), the natural mortality for commercial-sized crabs in SGSL was estimated from 26 to 40% between the time of the survey and the following fishing season. This mortality was attributable in large part to the newly molted adult males (R-1). ENS being in a low recruitment phase, it is expected that mortality rates would tend to be toward lower mortality rates.

7.2. Movement – Movement of crab amongst CFAs is expected but was not explicitly considered in this assessment. It has been suggested by Brêthes and Coulombe (1989) that some exchanges between fishing areas compensate the effect of differential fishing mortalities among fishing grounds. Although this is probably true, to a certain extend, other factors must be at play to explain the seemingly higher dynamics of a few sites (e.g. GBH).

7.3. Sex-ratio – For the Scotian Shelf stock assessment, no monitoring of reproductive output has been done and the reaction of the snow crab population against the current exploitation level is unknown. We, at least, found that the abundance of adult females decreased significantly through the last 3-4 years and currently their abundance has reached the lowest level ever since the trawl survey has begun. If the Scotian Shelf is self-reproducing system, this decline of female spawning stock may result in a serious stock decline in the future. Furthermore, the appearance of immature female in 2003 that may indicate the beginning of a new wave of females in the snow crab population at a time when the adult male population is declining and the fishery is getting more aggressive. An understanding of relationships between females abundance (or total egg production), sex-ratio requirement and future recruitment to the population is needed to infer the viability of fishing strategies (Hébert et al., 2003).

7.4. Habitat changes – Bottom temperatures in the north-eastern Scotian Shelf were typically warmer-than-average during the late-1970s and early 1980s. In the mid-1980s they declined reaching a minimum in the early 1990s (Drinkwater et al. 2003). Temperatures then rose gradually until 1999 when they reached above average values for the first time since the mid-1980s. Temperatures continued to rise through to 2000 but dropped below average in 2001 and rose again above the mean in 2002. During 2003, temperatures were significantly colder than the long-term average (1971-2000), having cooled relative to observations in 2002. On the north-eastern Scotian Shelf, the snow crab habitat index, defined by the area of the bottom with temperatures of -1° to 3°C, increased to above average and represents the highest value of the time-series. The average temperature within the habitat is at its lowest point (1.1 °C). Although not as extreme, similar conditions were present in the Sydney Bight area. This is consistent with the observed colder temperatures in 2003. Given that colder conditions in these regions are considered to be advantageous for snow crab, the higher snow crab habitat index and the below-average bottom temperatures indicate that bottom conditions were significantly more favourable for the adult snow crab in 2003 compared to conditions observed during 2002 (Chassé et al. 2004).

7.5. Snow crab distribution versus the trawl survey – Introduced in 1999 to compensate for the overestimation of adult males snow crab ≥ 95 mm CW that was created by the particularly rough bottom encountered in CFAs 23 and 24, the projected habitat criteria were naturally applied to the smaller CFAs 20, 21 and 22 fisheries as well because they are part of ENS (Biron et al., 2001). Although depth was used to calculate the kriging surface, it is more of a coincidental parameter that seems to best describe the commercial size snow crab habitat (but not a limiting factor). The boundaries of distribution are mainly determined by the temperature factor, while the formation of large populations in a particular area are determined by a set of factors such as the direction of the currents that transport the larvae, the type of bottom substrates, sufficient space and a supply of food for foraging adults (Slizkin 1982). Furthermore, bottom temperature at the time of the survey may affect to a certain degree the distribution of snow crab between trawlable and untrawlable grounds.

In addition, the geographic distribution of females, juveniles, adolescents and undersized adult males is different from that of commercial-sized adult. Further studies are required to improve our knowledge on the distribution of all size-classes of male and female snow crab.

7.6. Catchability and bottom type - The estimation of the "biomass index" is based on the assumption that the catchability of commercial-sized male crab in front of the trawl net foot rope was 100%. However, the GBH experiment in 2003 seems to suggest the trawl might not have been 100% effective on hard bottom such as gravel. Catchability may also be a function of time of year the survey is conducted, the type of gear (wooden doors versus steel doors, etc…) and how the gear performed as monitored by NetMind or Scanmar.

7.7. Inconsistency with the trawl survey – The survey series has suffered from changes in vessels, areas covered, gear used and timing. Again in 2003, the post-season trawl survey in S-ENS began 3 months later and comprised 35 less trawl stations than in 2002, making comparison with 2002 and previous pre-season estimates more uncertain because the effect of these changes could not be assessed. Changes in survey design and vessel are sometime necessary; however, for inter-annual comparisons it would be preferable that the area be fixed, that it be restricted to a limited time period each fall and that a protocol be developed to ensure consistency of data between years.

The consequences of some of the changes are becoming more apparent but the reason for the difference are not necessarily understood such as having different mean weight and CW between spring and fall trawl surveys. For example, the mean weight during the spring survey in N-ENS in 2001 was 540 g and 604 g in the fall for an average of 581 g for both surveys. This would easily explain the increase in biomass index in 2002 although the commercial crab abundance had decreased compared to 2001.

8.0. TRAFFIC LIGHT ANALYSIS

The traffic light analysis has been adopted by the Northwest Atlantic Fisheries Organization (NAFO) as a precautionary approach to assessment and management of stock, and it is becoming the norm to see some form of 'traffic light analyses' as a conclusion of a stock assessment (Koeller et al. 2000; Caddy, in preparation). Some chosen parameters that are indicatives of the stock status are compared with the previous year, and a green, yellow or red 'light' is determined for the current year. First introduced in the ENS stock assessment in 2000, the challenge remains in finding valid parameters that are indicatives of the current health of the snow crab stock in ENS (Biron et al. 2001).

8.1. Materials and Methods (Traffic light Analysis)

Selected indicators referred to underlying factors that could affect fishing success, stock abundance and/or resource productivity. Indicators used were: CPUE, areal and abundance indices for the fishery data; percentages of soft-shelled, immature, skip molter and average CW for the observer data; biomass index, pre-recruits and recruitment abundance, and degree of aggregation for the annual trawl survey data; and temperature to describe the habitat. These factors were assessed from the standpoint of impact on resource status, on future abundance and stock productivity using three categories of evaluation: 1) positive outlook – green, 2) uncertainty of the impact – yellow and 3) concerns about the current and/or future condition of the stock – red (Koeller et al., 2000). Specific criteria for each indicator are presented in Appendix 2.

8.2. Traffic light data and results

The stock status was assessed by viewing all indicators in combination that are presented as performance reports for N-ENS and for S-ENS in Table 6.

8.3. Discussion - Traffic light approach

According to Caddy (2003), the traffic light approach offers a way of using multiple indicators and their critical reference points for managing populations of invertebrates for which age structure information and stock recruit relationship-based reference points are unavailable. Traffic light is a visual tool that indicates the status of the stock, but also the interdependence of indicators over time (Koeller et al., 2000). Although fishery managers and industry may appreciate this exercise, it has not been completed and needs a weighting system to be applied to each indicator to adequately represent their uncertainty or importance of their impact on the snow crab stock. Currently, all indicators are used without considering their precision or implication for the stock status. For example, the index of abundance (total landings divided by the number of grids necessary to account for 95% of the catch) could be confounded by changes in management plan and fishing patterns. It is possible that snow crab population could be increasing within each CFA, but if at the same time the number of sub-areas was increased (i.e. forcing fishermen to fish an area that might not have been fished otherwise) then the index of abundance could potentially give the impression that the abundance is decreasing. Another concern is that using simple year-to-year changes for

CPUE (or areal index, abundance index, temperature) makes the traffic light analysis very sensitive to annual variation. Better understanding of the dynamic of each indicator will come with longer time-series.

The current traffic light approach use three sources of data directly related to the snow crab stock status: 1) fishery, 2) at-sea observer and 3) trawl survey data. Another data source, temperature, was used to describe the snow crab habitat. The indicators may directly describe the status of the stock such as the abundance (fishery) and biomass (survey) indices, or indirectly such as the abundance of skip molters (observer) that follows total commercial biomass due to a possible 'density dependent' mechanism by inhibiting adolescent to molt when the commercial biomass is high (Comeau et al., 1998; Hébert et al., 2004). New indicators such as the degree of aggregation (survey), abundance (fishery) and areal (fishery) indices were introduced (Figs 11 and 53). This list of stock assessment indicators could easily have been further expanded to include indices from other proven sources of data such as the groundfish trawl survey (Tremblay, 1997), or the status of other species (predator, prey, etc.) such as it is the case in the Scotian Shelf shrimp stock assessment (Koeller, 2003).

The current traffic light approach seems to well summarize the status of the snow crab stock in ENS despite of the inconsistency of information and lack of a weighting system. The trend for N-ENS and S-ENS shows some warning signs between 1996 and 1999, a period that corresponded to high recruitment and increasing abundance of commercial snow crab; mostly positive signs between 1999 and 2001, a period of high abundance and decreasing recruitment; and the beginning of warning signs in 2002 and 2003, a period of decreasing abundance and low recruitment.

9.0. CONCLUSION AND RECOMMENDATIONS

9.1. Management considerations

9.1.1. Management areas and sub-areas – Since the beginning of the snow crab fishery in ENS, CFA and sub-areas have been created and modified to ensure the distribution of effort in ENS (Fig. 1). In that respect, the current management CFA and sub-areas succeeded in spreading some of the effort over the entire fishing grounds for snow crab in ENS. However, management lines should be flexible to adapt to a dynamic fishery observed in ENS since 1997. If the snow crab industry is interested in biomass estimate indices by management areas, then management areas should reflect the distribution of the stock and the limitations of the methods currently used by Science. Hopes to obtain accurate biomass estimate for long and narrow areas (e.g. 23C), large but with multiple distanced small fishing grounds (e.g. 23D) or very narrow strip of fishing grounds cut from a larger unit (24D) is unrealistic.

In N-ENS, current management lines may become a problem in the future if allocation continue to be based on the single snow crab population that is distributed in that region simply by restricting the mobility of the fishermen. If management lines can not simply be removed, the industry will have to come up with new and creative management measures adapted to their concerns (e.g. permeable borders under certain circumstances), or be prepared to react quickly to protect the resource at the first sign of a problem during the course of a fishing season.

9.1.2. Scotian Shelf slope surveys - The survey indicates a pulse of pre-recruit and recruitment is occurring on the slope of Sable Is. bank. This is confirmed by the increasingly high proportion of adolescent that were found in the trap survey in 2001, 2002 and 2003. Therefore, measures should be taken to limit the high incidence of soft shelled-crab and adolescent that will be affecting this fishery. This recruitment pulse has not been observed on the slope of CFA 23 during the same trawl survey.

There is discrepancy between the rate of old crab reported during the trap surveys and commercial fisheries on the slopes between 2001 and 2003, and the rate observed during the trawl survey in 2003. It seems reasonable to believe that dirty 'older' crabs covered with epibiont were mistaken for old carapace condition 5 crabs. Work reported at the RAP in 2003 (L. Savoie, pers. comm. DFO Moncton) combined with recent observations from the first slope trawl survey on the slopes indicated that epibiont such as barnacle may settle on crab shortly after molting to adulthood, and be completely covered by the time the crab reach carapace condition 3M or 4. Estimations of old CC 5 crab from the trawl survey were <2% of the total estimated commercial biomass index in CFA 23 and <1% in CFA 24.

9.1.3. Fishing season in S-ENS - Since 2000, landings after September 15 are due to personal choices, delays in getting started, vessels fishing multiple licenses (i.e. possession of more than 2 licenses), mechanical or health problems, and not because of a lack of commercial crab. In terms of biology, the 2003 fishing season in S-ENS ran too late increasing the likelihood of problems with white crab and mortality (Biron et al., 2002). In S-ENS, one way to reduce the manipulation of these crabs would be to shorten the fishing season by closing it earlier, and if the trawl survey is to remain after the fishery, which it should, then the fishing season should end before September.

9.1.4. Soft and White crab protection – Rigidly monitored and enforced protocols to control the capture of soft and white crab are required to minimise the mortality of these crabs and to protect future recruitment to the fishery. This is especially important if an aggressive fishing effort is to be maintained. Although the crab population is aging, there is a possibility of increased incidence of soft-shelled crab, particularly if the commercial biomass reaches low levels. For example, recruitment in 2003 accounted for 21% of the total biomass index estimated from the trawl survey in N-ENS compared to 7% in 2002, but this seemingly large increase in recruitment is mostly due to the decrease in hard-shelled crab (-880 t) rather than the small increase in recruitment (+260 t) over 2002 (Fig. 18). It may be especially important to protect soft and white crab, or any adolescent during low recruitment periods. Furthermore, considering that new pre-recruits will start to enter R-3/R-2 categories in the near future, this is the time to tighten the protocol(s).

9.2. Outlook for 2004 and beyond

The biomass estimate indices of hard-shelled adults in S-ENS apparently peaked in 1998-2000 and decreased at a 10-20% rate in 2002 and 2003. Excepted for the Sable Is. Region, the survey indicated that S-ENS was at the end of a wave of pre-recruits (R-4, R-3, R-2) and recruitment (R-1). In N-ENS, the end of the recruitment wave apparently came in 2000-2001, and has remained low since 2001. The hard-shelled adult abundance in N-ENS peaked in 2001-2002, and decreased by 22% in 2003. With the estimated abundance of recruits at low levels for the past 2-3 years and the indication that the abundance of crab expected to recruit in 2-3 years will also stay at low levels. It is likely that the abundance of the resource will continue to decline for a few more years. However, the presence of small crab (15-50 mm) suggests that recruitment may improve after the anticipated period of lower abundance.

9.3. Exploitation strategies and harvesting strategies

Overall, logbooks, at-sea observer and trawl survey indices indicated signs of a decline of the adult male snow crab population, a trend forecasted for the next few years considering the low level of recruitment entering the fishery (Table 6). At this point in the snow crab ‘life cycle’, two possible exploitation strategies are still available: 1) spread catches over a period of years to offset the low level of recruitment or 2) maximize catches in the short-term.

9.3.1 Spread catches over a period of years – By opting for smaller catches in 2004, it may be possible to somewhat offset the rate of decline of the population of commercial-sized males with a range of appearances and survival potentials. The idea being to ‘cushion’ the anticipated several years of lower recruitment. However, snow crab quality may deteriorate, natural mortality would likely increase and there would be wasted yield of crab that would otherwise die. If this strategy is adopted, it would be critical that the industry does not only target high quality crab. If dirty crab (CC 4 and 5) were to be discarded, the exploitation rate on new recruits would be proportionally higher. Furthermore, high grading would result in excessive fishing mortality on a stock already declining.

9.3.2. Maximize catches over the short term – This approach would make it possible to take advantage, in the short term, of the snow crab biomass that is currently available and that is declining in quantity and quality in the near future due to aging of the population. The higher the quota and the lower the remaining biomass, the faster the available commercial biomass will decline.

9.3.3. Harvesting scenarios – There is three possible harvesting scenarios available to any fisheries: increase allocation, status quo, or decrease allocation. Increasing the allocation over all of the fishing grounds that have been surveyed since 2000 is ill advised because all indicators (fishery, observer and trawl survey) points to a declining commercial biomass. Unless the industry is prepared to take drastic cut over short periods of time in the near future.

Status quo is not recommended under the current management measures. Status quo, for a third year in a row and during the declining phase of commercial crab is the equivalent to increasing the exploitation. With a more aggressive fishery must come maturity. If the only line of defence this fishery has against any potential problems is Science assessment of the stock 6 months after the fishery, then there is a serious problem! The fishery could potentially become too aggressive. In other aggressive crab fishery, maturity meant more cost for the daily monitoring of the fishery to protect against 'bad surprises' such as high incidence of soft and white-shelled crab, highgradings, or localised depletion. Clear, simple and applicable protocols must be in place to guide the closures of problem areas, and they must be rigidly applied. Maturity meant more cost to ensure that the proper protection of the resource is deployed against illegal landings, highgrading, or any other abuses. And it must be rigidly applied. There is no room for abuses of the resource in an aggressive fishery. Monitoring has to be in place and running on the first day of any fishery.

Decreasing the allocation over all of the fishing grounds that have been surveyed since 2000 could slowdown the decline in adult males, but will never stop it nor will it make it possible to 'stabilise' the catches over the next few years. In addition, the decreased harvest scenario would be the best chance of ensuring that there are enough large males to mate with females in the near future. This would be the most conservative approach, but also the harvesting strategy that has the potential to produce the highest wasted yield of crab in the short to mid-term.

9.4. Scientific recommendation

Due to the uncertainty described in this document together with some negative signs of reproductive potential of the Scotian Shelf snow crab population, it is recommended to decrease harvesting levels in 2004 so that the long-term sustainability of the snow crab fishery can be protected.

10.0. ACKNOWLEDGEMENT

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Table 1. Summary of the Management Plan measures for the 2003 snow crab fisheries in eastern Nova Scotia.

Area	Season	Permanent licenses	Traps allowed	Total quota permanent licenses (kg)	Temporary licenses	Traps allowed	Total quota temporary licenses (kg)
20	July 20- Sept. 15	5	30	102,000	6	30	75,000
21	July 20- Sept. 15	32	25	545,000	-	-	-
22	*Inside group:*[1] July 20- Sept. 15	21	30	477,000	-	-	-
	Outside group:[1] July 20- Sept. 15	16	30	294,000	-	-	-
23	*All sub-areas:* *Sub-area 23D* May 27 – Oct. 31 *All other sub-areas* June 1st – Oct. 31	37	45	2,738,150	37	45	2,027,094
	Exploratory slope: June 1 – Nov. 30	-	-	-	2	45	120,000
24	*All sub-areas:* *Sub-area 24D* June 1st – Oct. 31 *All other sub-areas* July 1st – Oct. 31	34	45	2,482,100	40	45	1,565,650
	Exploratory slope: June 1 – Nov. 30	-	-	-	3	45	180,000

[1] Both groups have agreed not to land on Sundays.

Table 2. Total allowable catch (TAC), active licenses, landings, catch rate (CPUE) and effort statistics for snow crab in north-eastern Nova Scotia (Crab Fishing Areas 20, 21 and 22), 1997-2003.

Year	Active licenses/permits	TAC (t)	Landing Statistics (t)	Total mean CPUE (kg/trap haul)	Total Effort (1000's of trap hauls)
1997	74	540	534	23.3	22.9
1998	74	660	657	41.6	15.8
1999	78	900	899	54.8	16.4
2000	79	1,015	1,017	68.3	14.9
2001	80	1,065	1,066	94.1	11.3
2002	80	1,493	1,492	100.9	14.8
2003	80	1,493	1,501	76.8	19.5
Average (99-03)		1,193	895	79.0	15.4

Table 3. Average CPUE by Crab Fishing Areas and sub-areas in eastern Nova Scotia.

CFA	*2000*	*2001*	*2002*	*2003*	*trend*
N-ENS	68.3	94.1	100.9	76.8	-
20 inside	56.7	92.1	102.2	48.3	-
20 outside	36.3	46.3	38.9	12.9	-
20 all	46.9	66.1	67.8	44.0	-
21	65.4	95.0	96.8	77.7	-
22 northern	68.4	89.9	116.4	81.0	-
22 Glace Bay Hole	104.0	137.0	127.1	120.6	-
22 all	78.4	106.8	120.0	92.6	-
S-ENS	85.0	88.5	110.1	95.9	-
23 sub-area A	102.6	113.1	141.9	94.5	-
23 sub-area B	99.9	97.8	134.0	120.1	-
23 sub-area C	65.6	136.3	108.2	134.8	+
23 sub-area D	62.4	47.3	76.6	71.8	-
23 all	83.4	82.1	117.2	98.7	-
24 sub-area A	81.8	108.8	132.1	78.9	-
24 sub-area B	99.6	126.1	138.1	133.7	-
24 sub-area C	90.3	97.5	92.9	85.5	-
24 sub-area D	83.3	88.6	89.4	126.1	+
24 sub-area E	50.8	65.6	55.1	46.0	-
24 all	86.7	99.3	103.0	92.2	-

Table 4. Total allowable catch (TAC), active licenses, landings, catch rate (CPUE) and effort statistics for snow crab in south-eastern Nova Scotia (Crab Fishing Areas 23 and 24), 1997-2003.

Year	Active licenses/permits	TAC (t)	Landing Statistics (t)	Total mean CPUE (kg/trap haul)	Total Effort (1000's of trap hauls)
1997	59	1,163	1,157	50.9	22.7
1998	67	1,671	1,558	68.9	22.6
1999	-	2,700	2,700	71.1	38.0
2000	158	8,799	8,701	85.0	102.4
2001	163	8,823	8,912	88.5	102.9
2002	149	8,822	8,767	110.1	79.6
2003	145	8,813	8,817	95.9	89.6
Average (99-03)		7,591	7,579	90.1	82.5

Table 5. Annual trawl surveys history from 1997 to 2003.

		North-eastern Nova Scotia			*South-eastern Nova Scotia*		
Year	Vessel	# of stations	Area (km^2)	Survey period	# of Stations	Area (km^2)	Survey period
1997	Glace Bay Lady	26	2,600	May 15-20	124	18,500	May 20 - June 11
1998	Marco Brittany	56	4,250	May 20-25 June 12-17	158	18,500	June 2-12 Sept. 25 - Nov. 14
1999	Marco Brittany	60	4,400	June 8 July 6-9 July 18-19	214	23,200	May 3-22 June 16-25 July 12-15
2000	Marco Brittany	64	4,800	May6-16	253	27,500	May 16 - June 29
2001	Marco Brittany[1] Marco Michel[2] Den-C Martin[3]	69	5,000	April 26- May 10[1]	234	28,900	May 8-25[1] June 23- July 5[2] July 12-20[3]
2002	Marco Michel	59	5,000	Oct. 10-16	241	32,500	Aug. 13 - Sept. 24
2003	Marco Michel	59	5,000	Oct. 18-26	199	27,200	Nov. 3 – Dec. 21

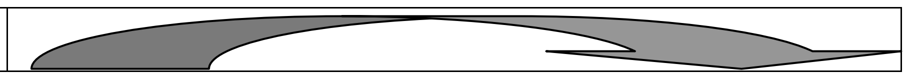
Table 6. Retrospective Traffic Light Analysis (1996-2002) and current assessment (2003).

Northern ENS	1996	1997	1998	1999	2000	2001	2002	2003
Fishery data								
CPUE (kg)	Green	Green	Green	Green	Green	Green	Green	Yellow
Areal index			Green	Yellow	Green	Green	Green	Yellow
Abundance index			Green	Green	Green	Green	Green	Yellow
Observer Data								
% soft-shelled	Red	Red	Yellow	Green	Green	Green	Green	Green
% immature	Green	Green	Yellow	Yellow	Yellow	Yellow	Red	Red
Size (CW)					Green	Yellow	Yellow	Green
% skip molter	Green	Yellow	Yellow	Green	Green	Green	Yellow	Yellow
Survey Data								
Biomass index		Green	Green	Green	Green	Green	Yellow	Yellow
Pre-recruits (R3, R2)		Green	Yellow	Yellow	Yellow	Red	Red	Red
Recruitment (R1)		Green	Green	Green	Yellow	Yellow	Red	Red
Surface								
Other Data								
Temperature					Green	Green	Yellow	Green

Commercial crab trend

Southern ENS	1996	1997	1998	1999	2000	2001	2002	2003
Fishery Data								
CPUE (kg)	Green	Green	Green	Green	Green	Green	Green	Yellow
Areal index			Green	Yellow	Yellow	Green	Green	Yellow
Abundance index			Green	Green	Green	Green	Green	Yellow
Observer Data								
% soft-shelled	Red	Red	Red	Yellow	Green	Green	Green	Green
% immature	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Size (CW)					Green	Yellow	Yellow	Green
% skip molter	Green	Yellow	Yellow	Green	Green	Green	Yellow	Yellow
Survey Data								
Biomass index		Green	Green	Green	Green	Green	Yellow	Yellow
Pre-Recruits (R-3, R-2)		Green	Green	Green	Green	Yellow	Yellow	Red
Recruitment (R-1)		Green	Green	Green	Yellow	Yellow	Red	Red
Surface			Green	Yellow	Green	Yellow	Yellow	Yellow
Other Data								
Temperature	Green	Green	Green	Green	Green	Green	Yellow	Green

Commercial crab trend



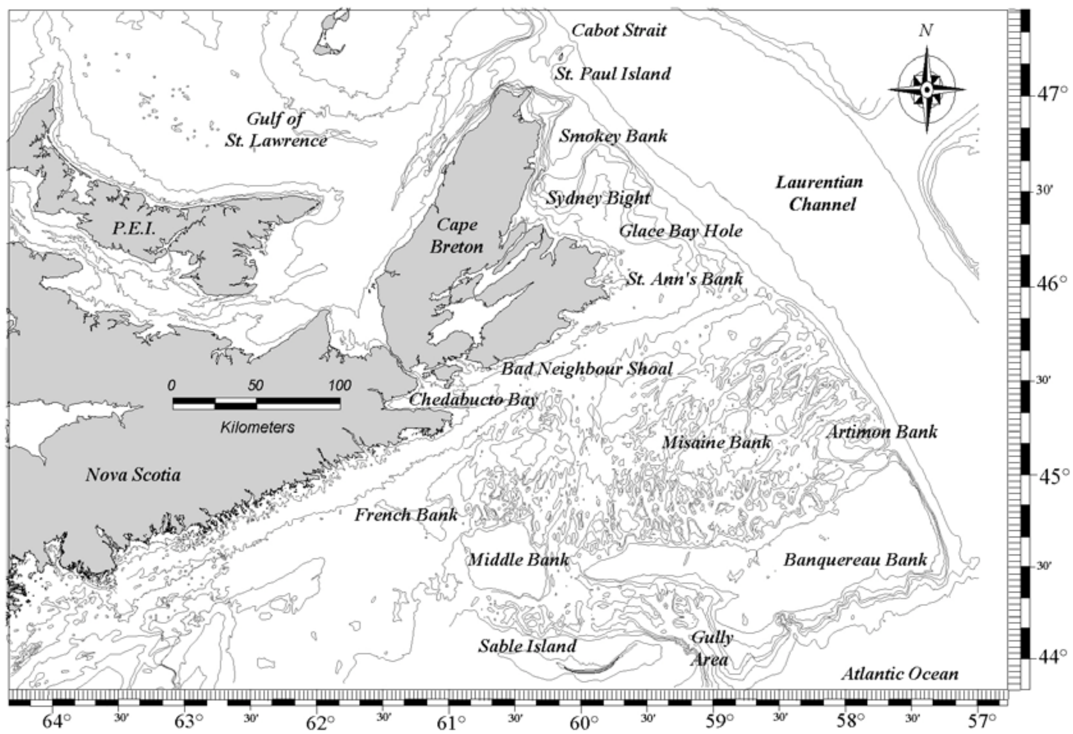


Figure 1. Areas and locations of eastern Nova Scotia referred to in this document.

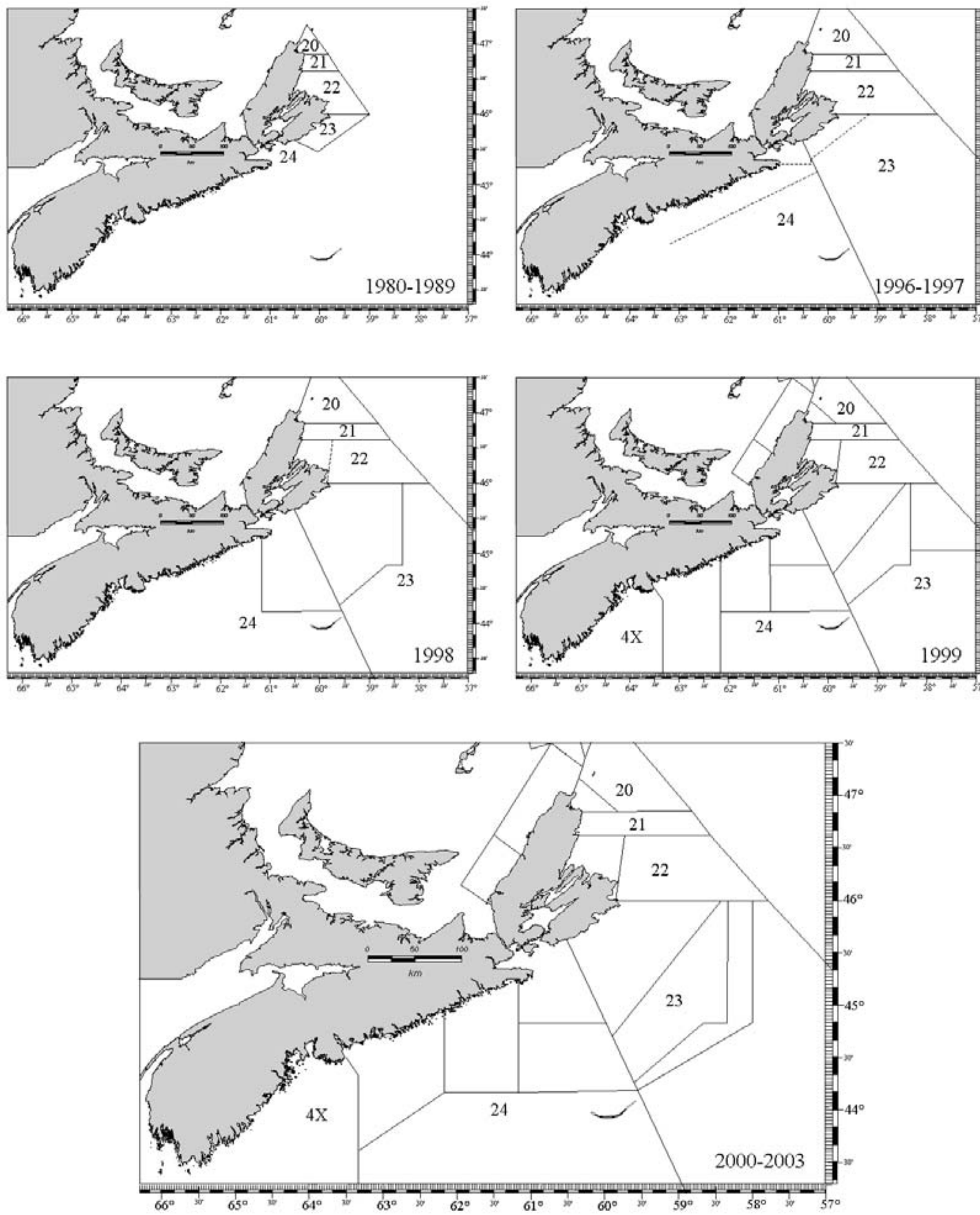


Figure 2. Snow crab management area and sub-areas in eastern Nova Scotia since the 1980's.

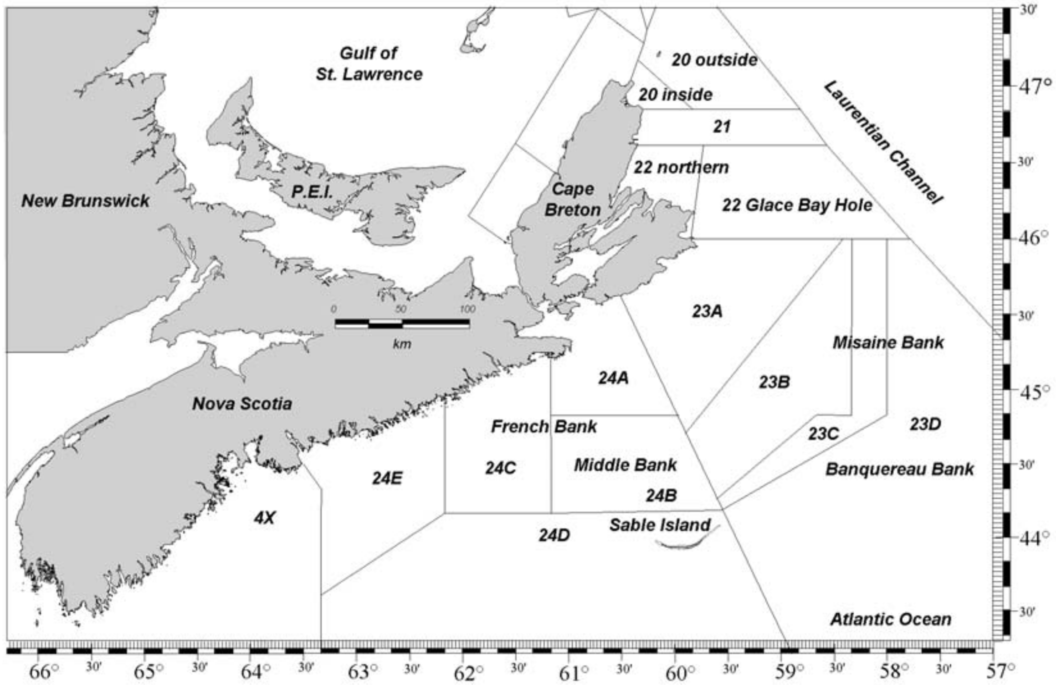


Figure 3. Snow crab management areas and sub-areas off eastern Nova Scotia.

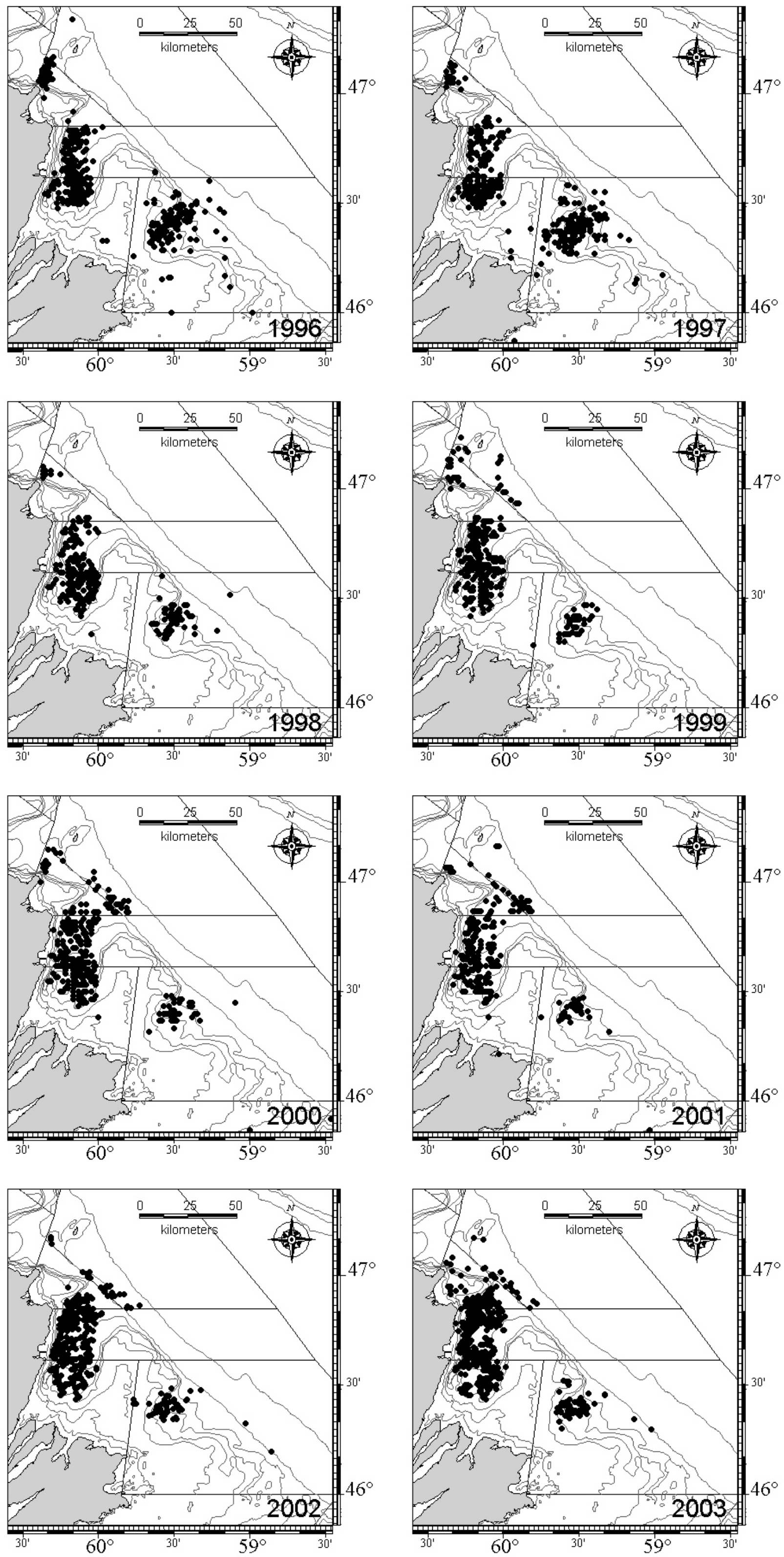


Figure 4. Reported logbook positions in north-eastern Nova Scotia from 1996 to 2003.

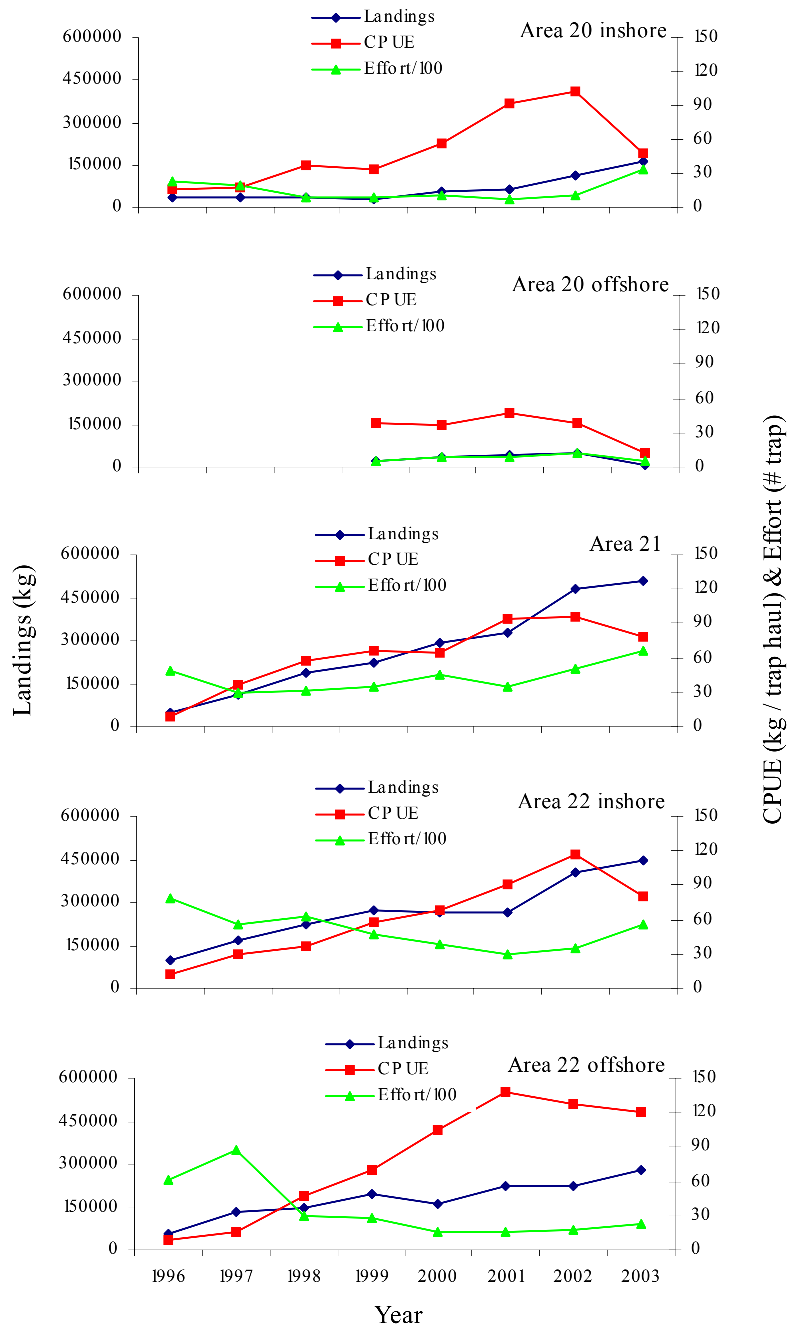


Figure 5. Snow crab landings, catch per unit of effort (CPUE) and fishing effort for north-eastern Nova Scotia from 1996 to 2003.

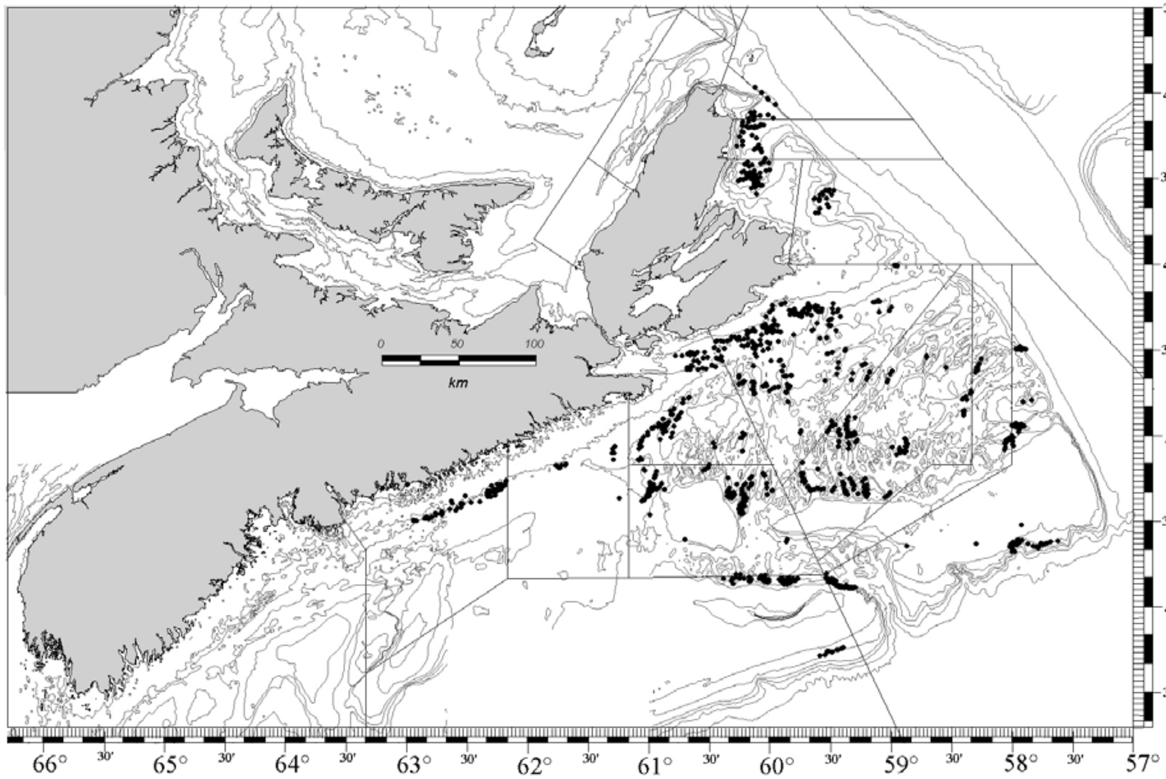
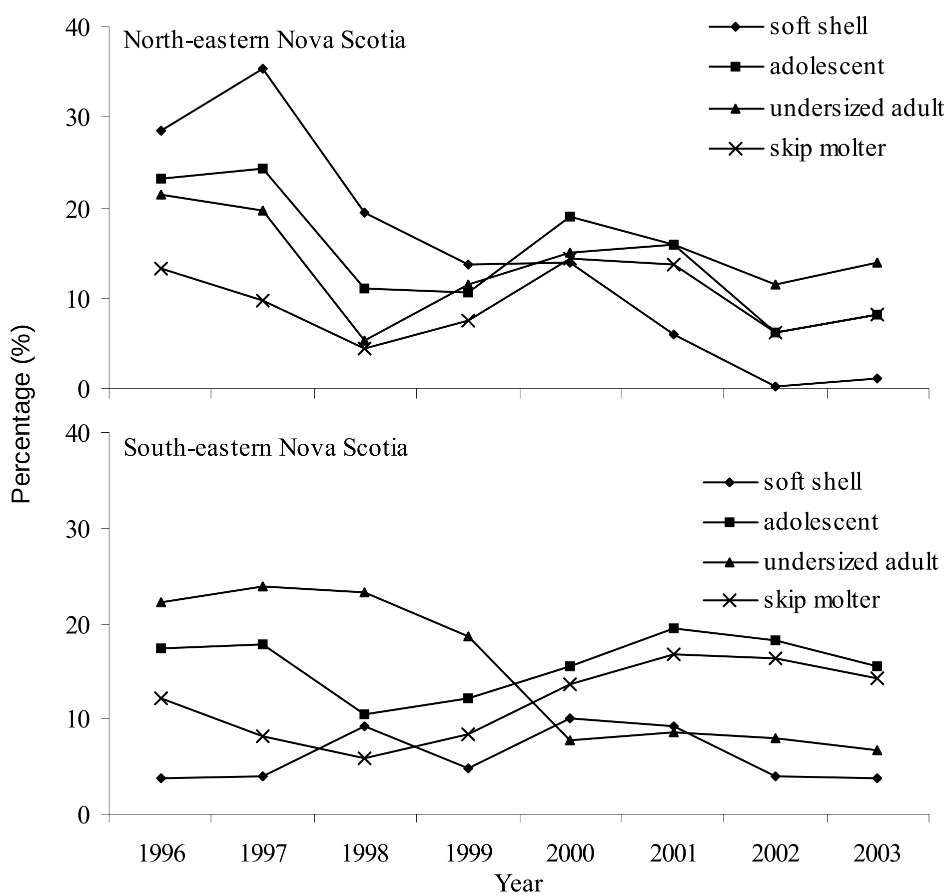


Figure 6. Reported observer positions in eastern Nova Scotia in 2003.



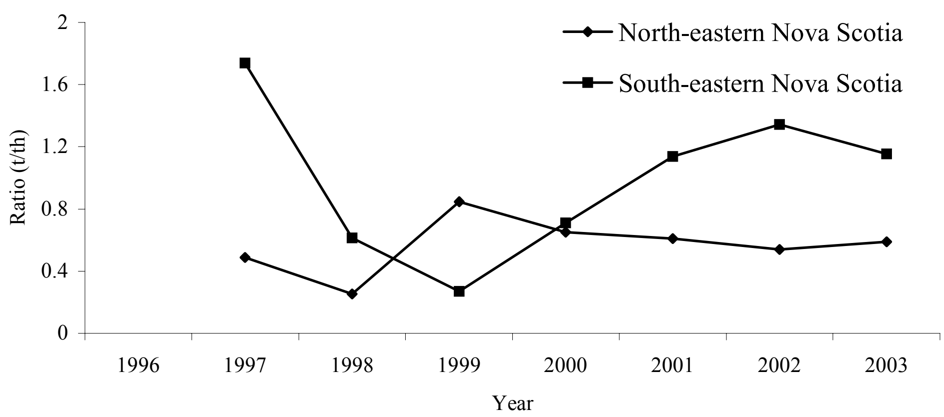


Figure 7. Seasonal percentage of different categories of snow crab and the ratio between traps sampled at-sea and total trap hauls of the fishery in north-eastern and south-eastern Nova Scotia.

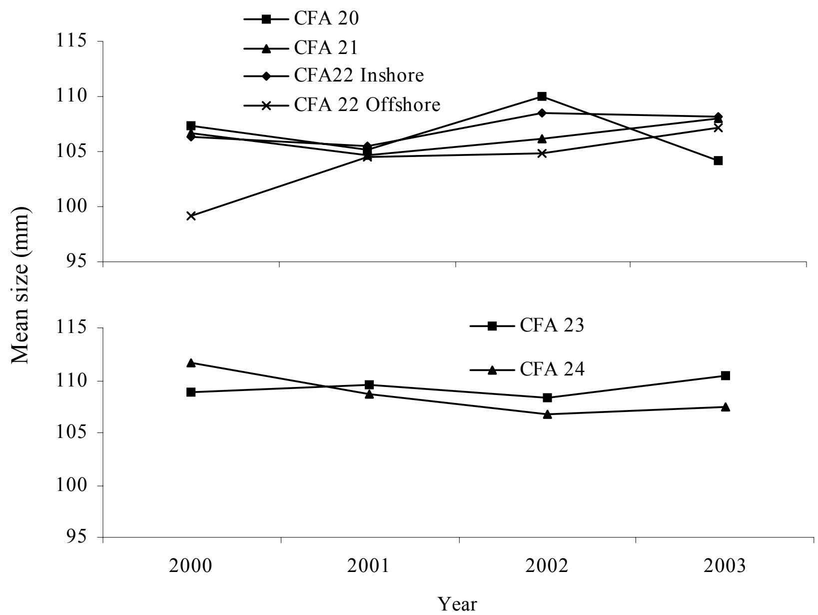


Figure 8. Mean size of commercial size snow crabs from sea sampling for north-eastern and south-eastern Nova Scotia.

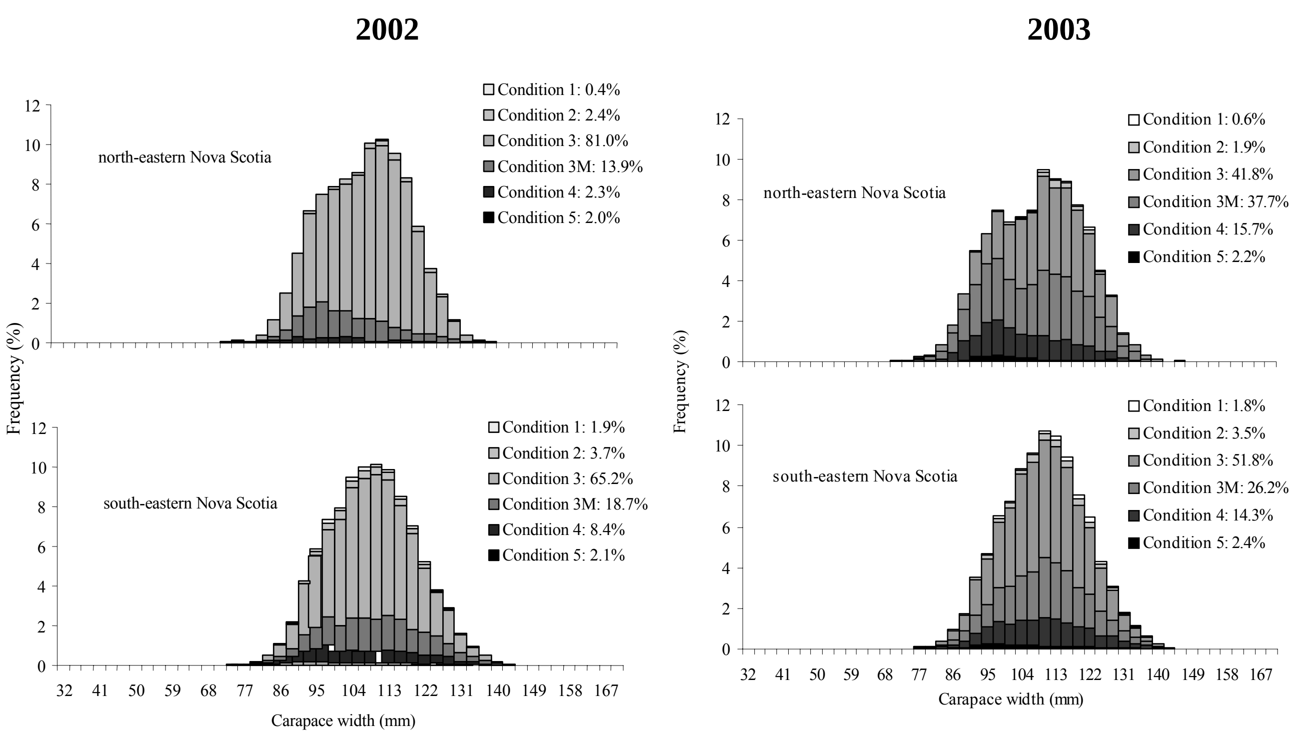


Figure 9. The 2002 and 2003 catch composition from sea sampling, in north-eastern and south-eastern Nova Scotia.

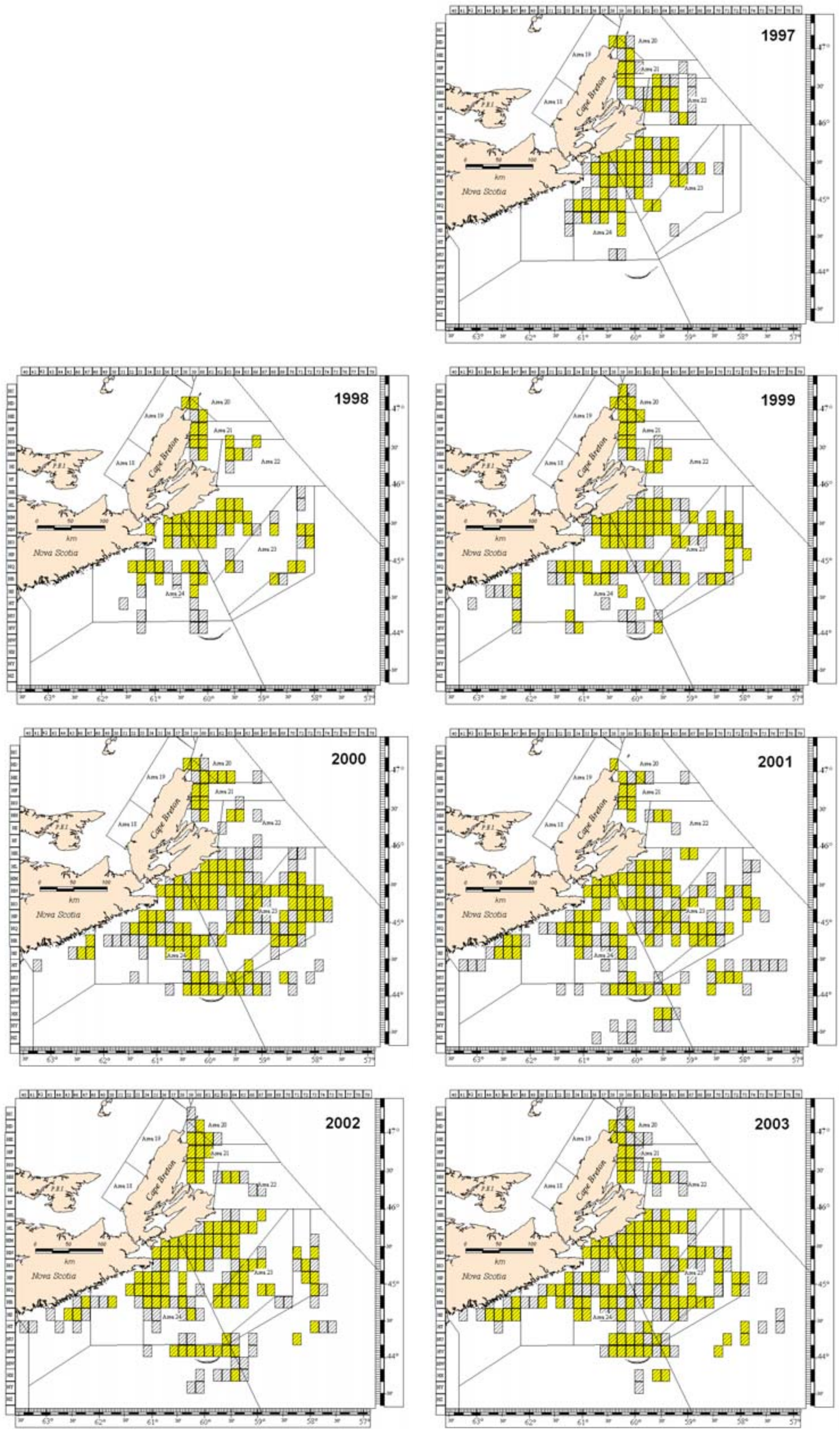


Figure 10. Spatial analysis of the reported landings for the period of 1997 to 2003 (yellow squares indicate grids from which 95% of the catch was taken).

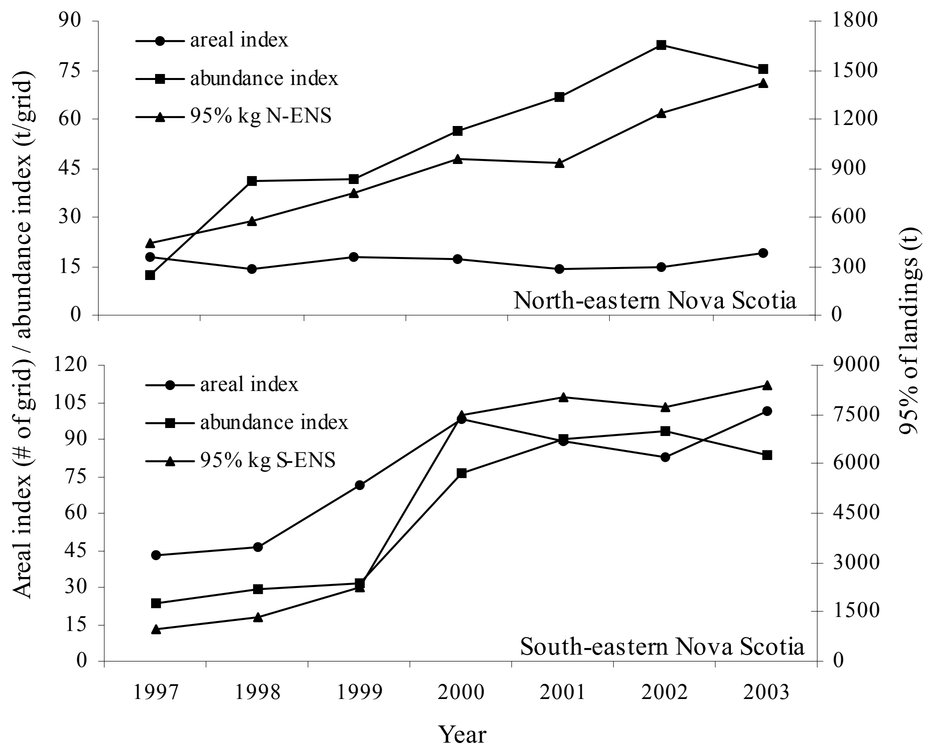


Figure 11. The areal and abundance index from the spatial analysis.

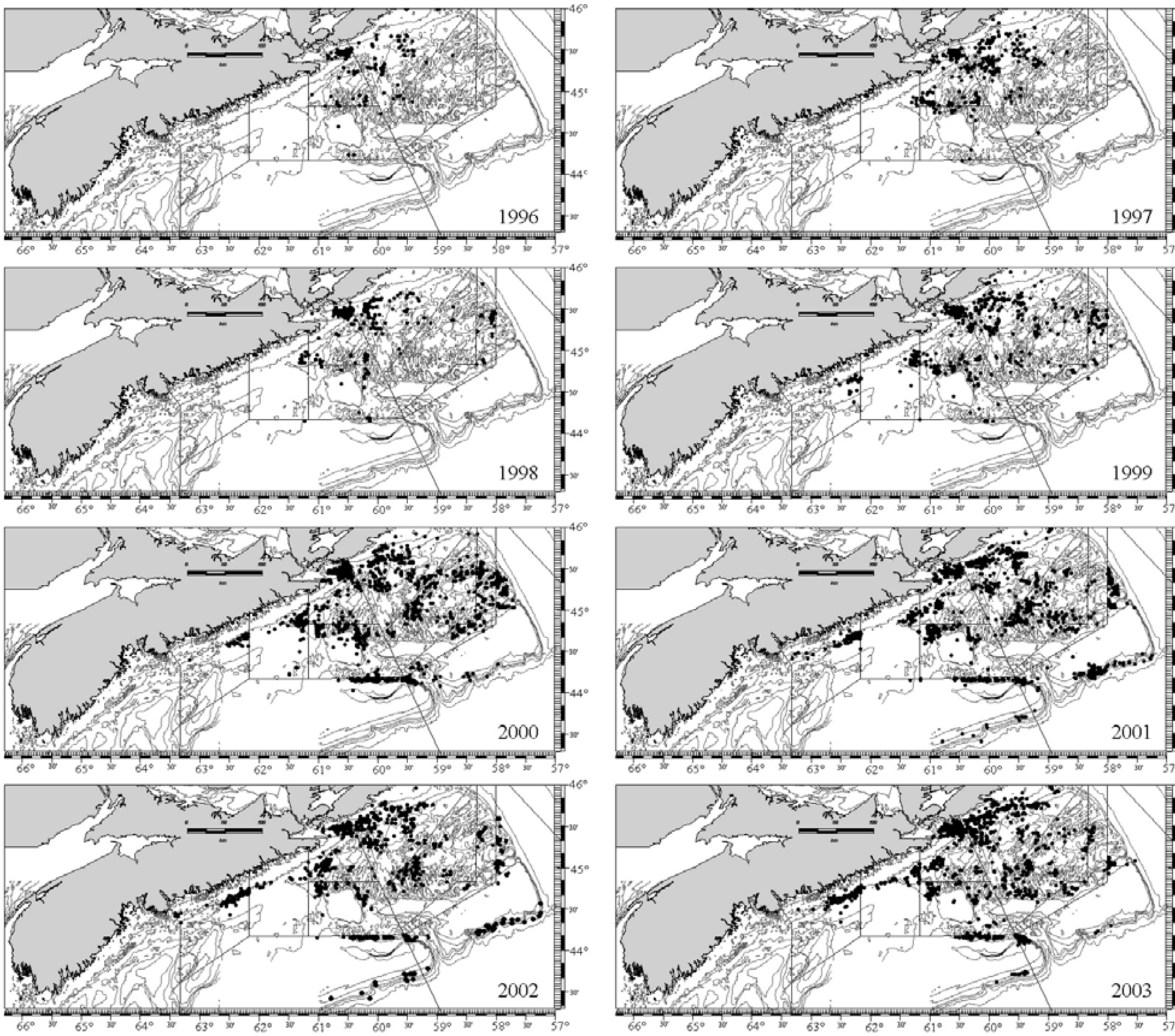


Figure 12. Reported logbook positions in south-eastern Nova Scotia from 1996 to 2003.

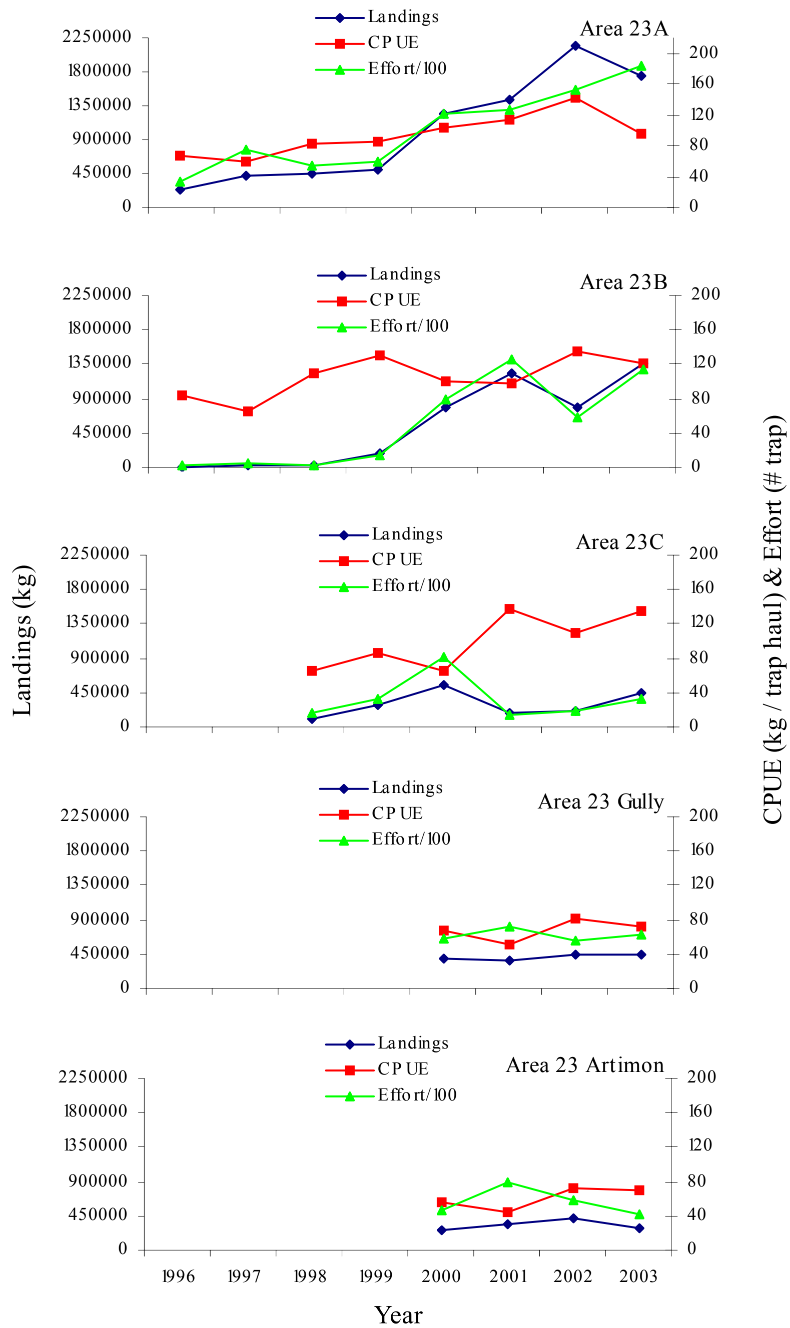


Figure 13. Snow crab landings, catch per unit of effort (CPUE) and fishing effort for the Crab Fishing Area (CFA) 23 from 1996 to 2003.

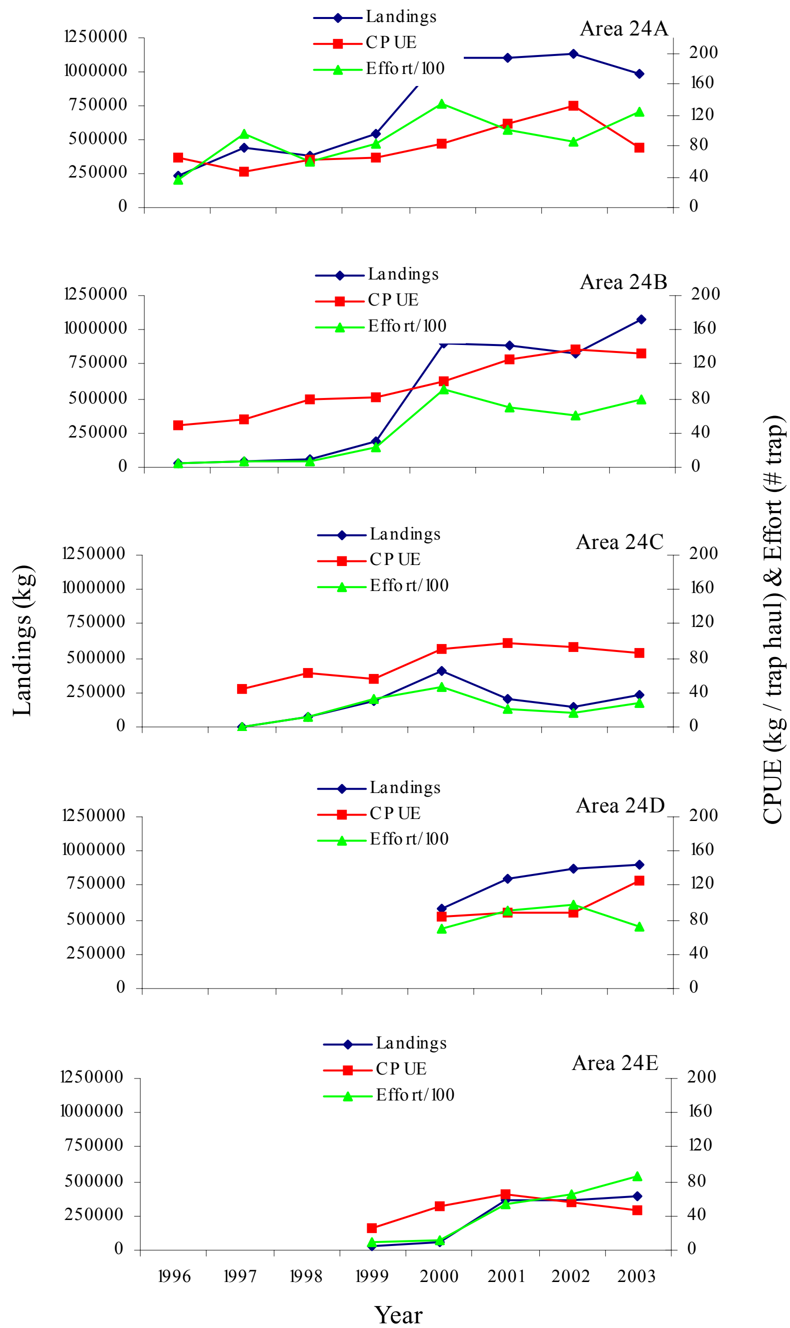


Figure 14. Snow crab landings, catch per unit of effort (CPUE) and fishing effort for the Crab Fishing Area (CFA) 24 from 1996 to 2003.

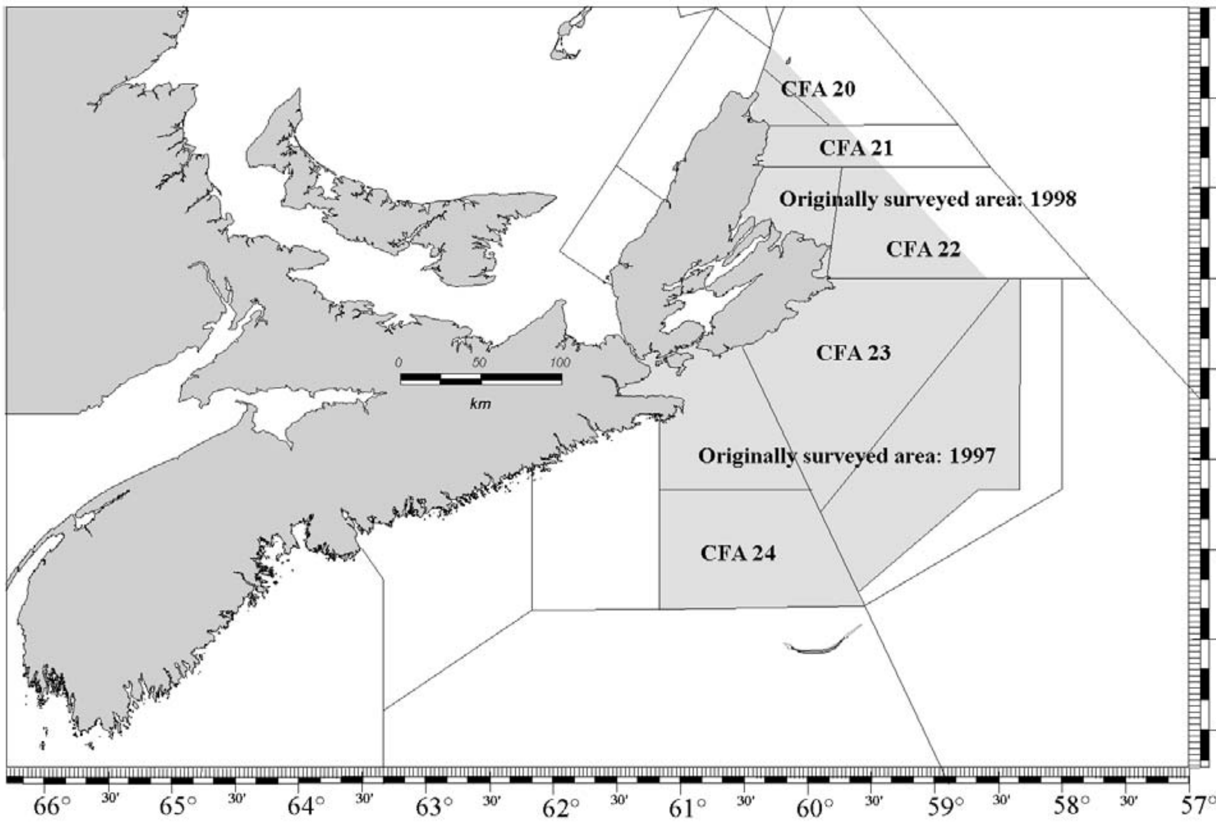


Figure 15. Originally surveyed areas of Crab Fishing Areas 20 to 24.

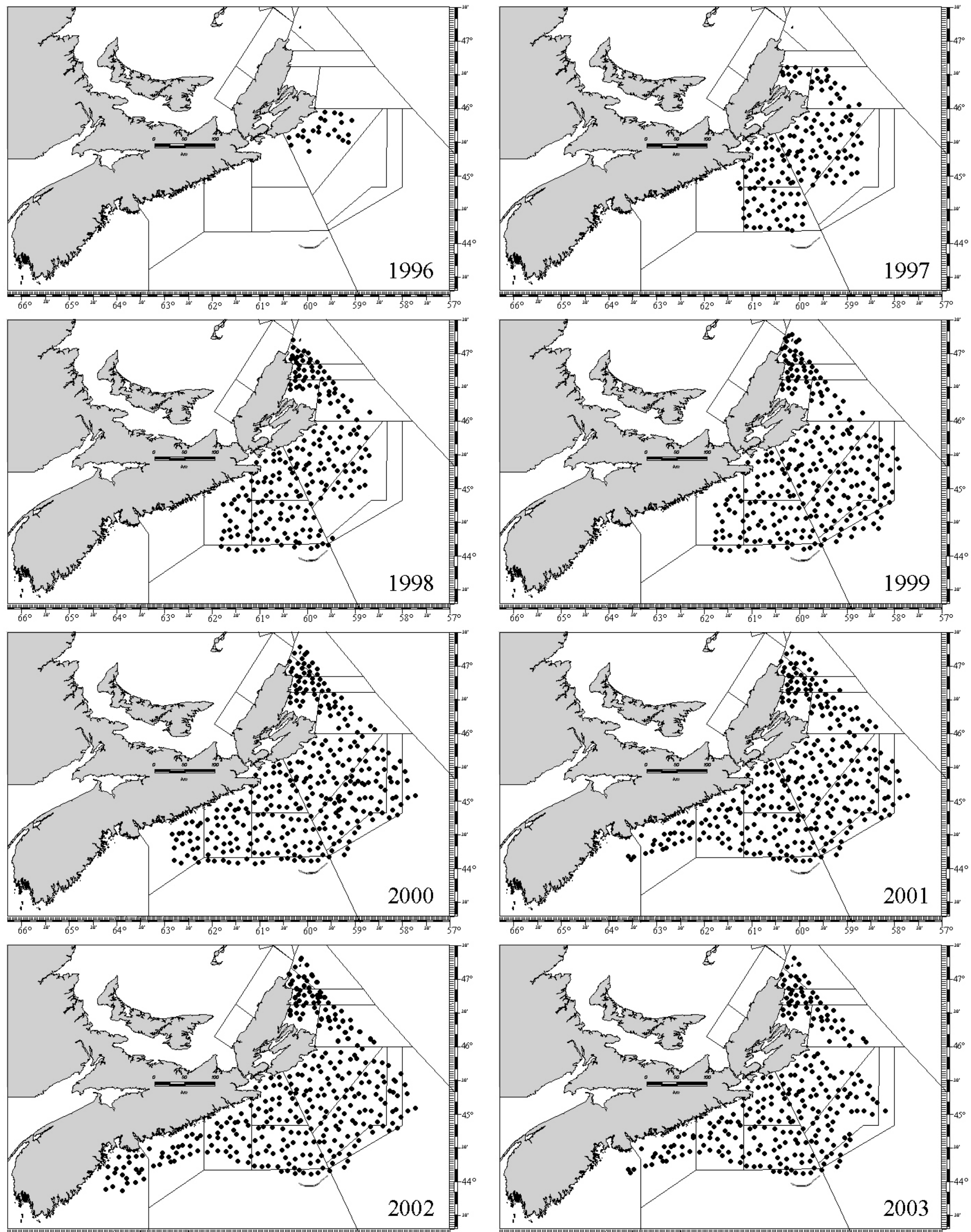


Figure 16. Location of snow crab trawl survey stations from 1996 to 2003.

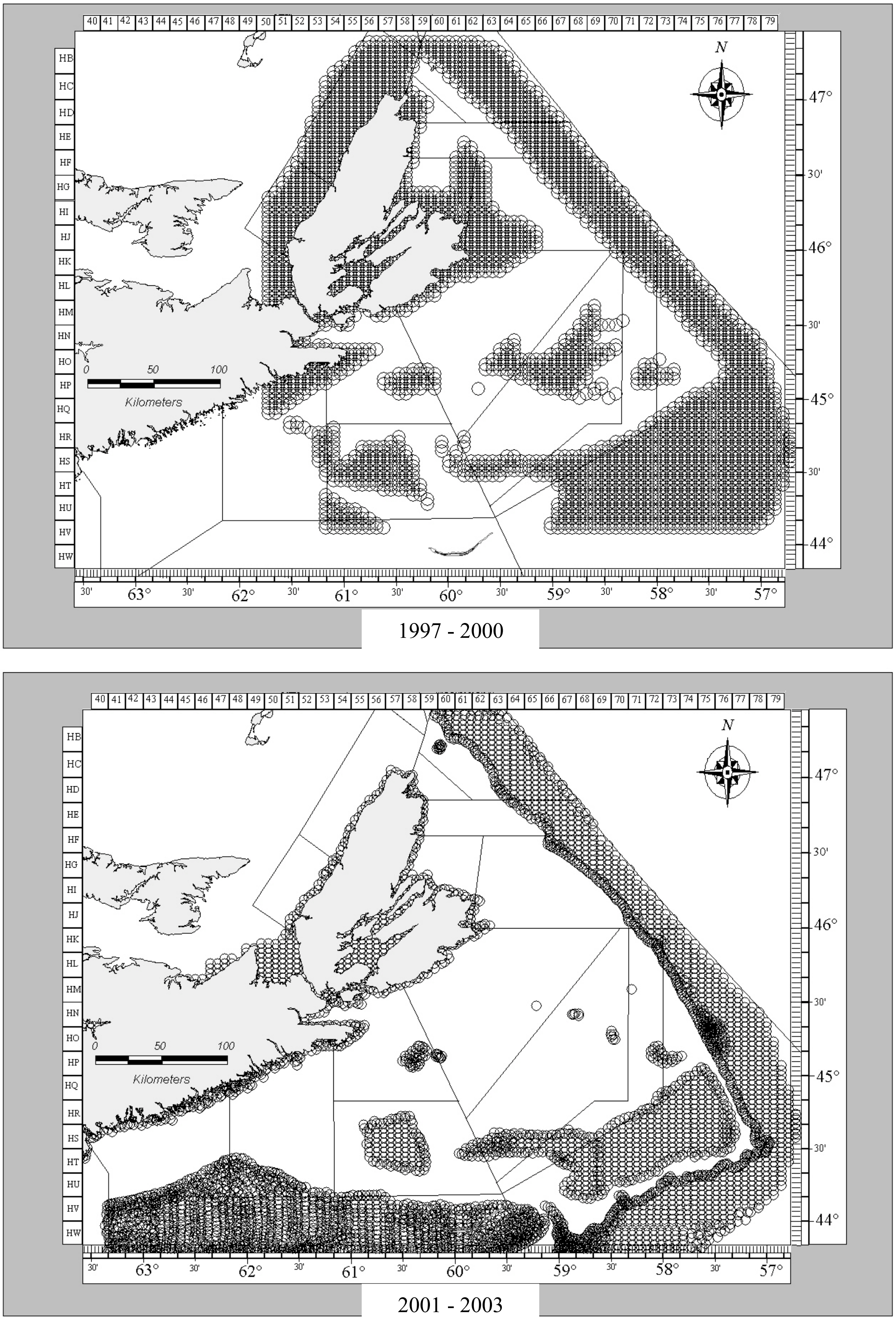


Figure 17. Masks with the pseudo-zeros used for kriging.

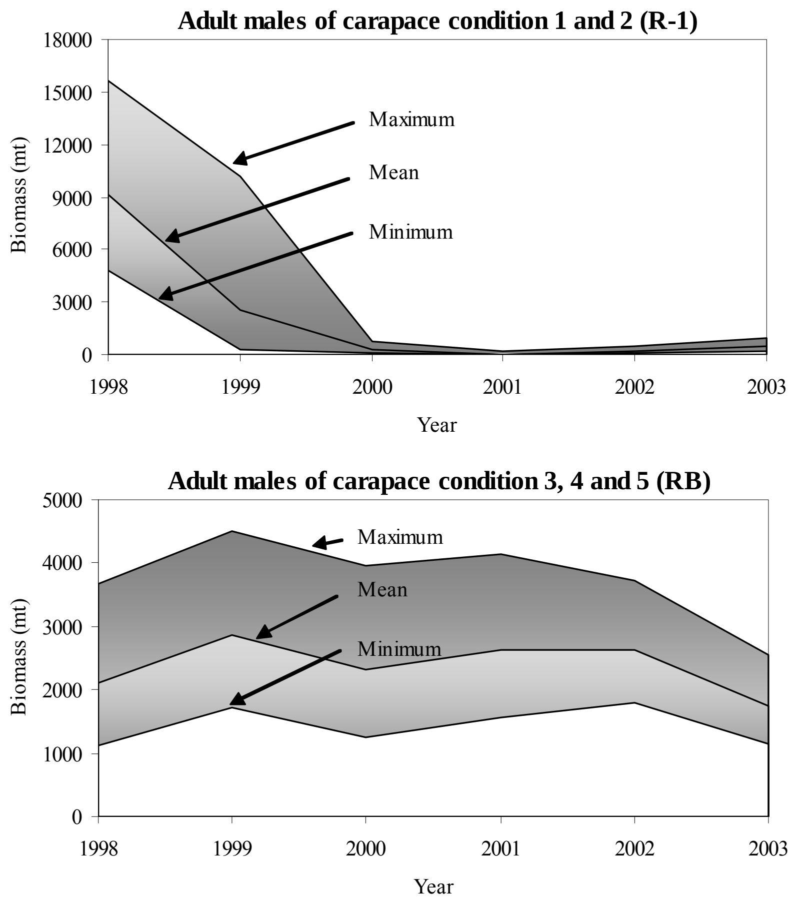


Figure 18. Biomass index for north-eastern Nova Scotia.

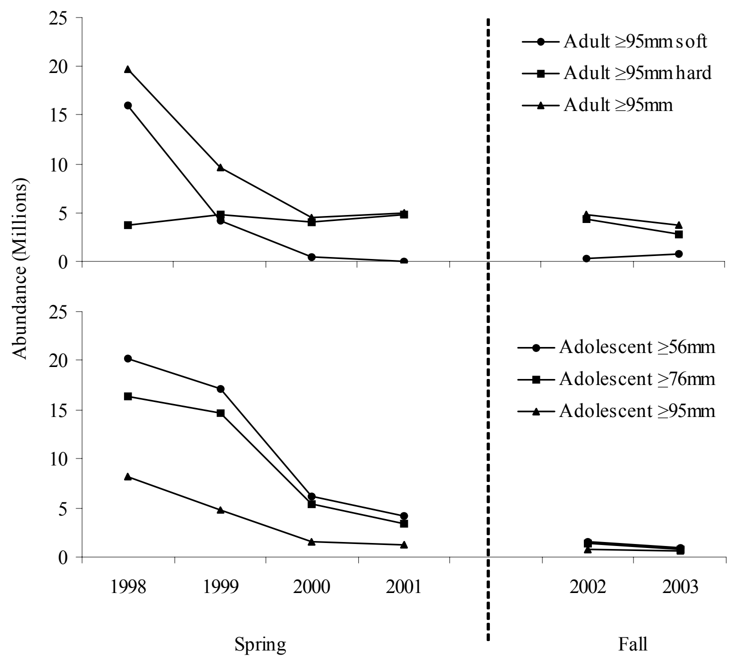


Figure 19. Relative abundance of commercial-sized adult and pre-recruits males observed during the trawl surveys in north-eastern Nova Scotia.

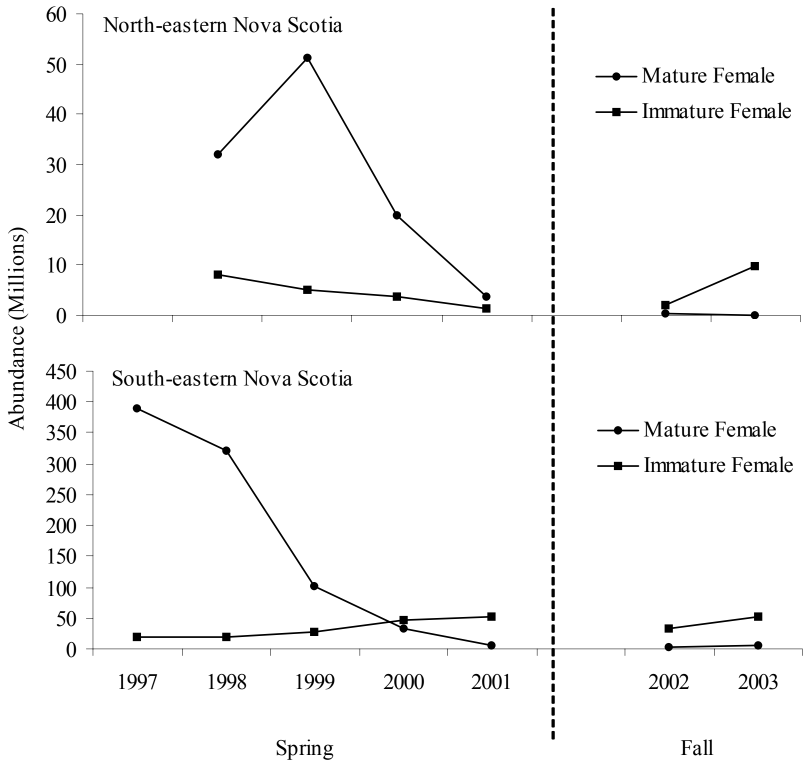


Figure 20. Relative abundance of mature and immature females observed during the trawl surveys in eastern Nova Scotia.

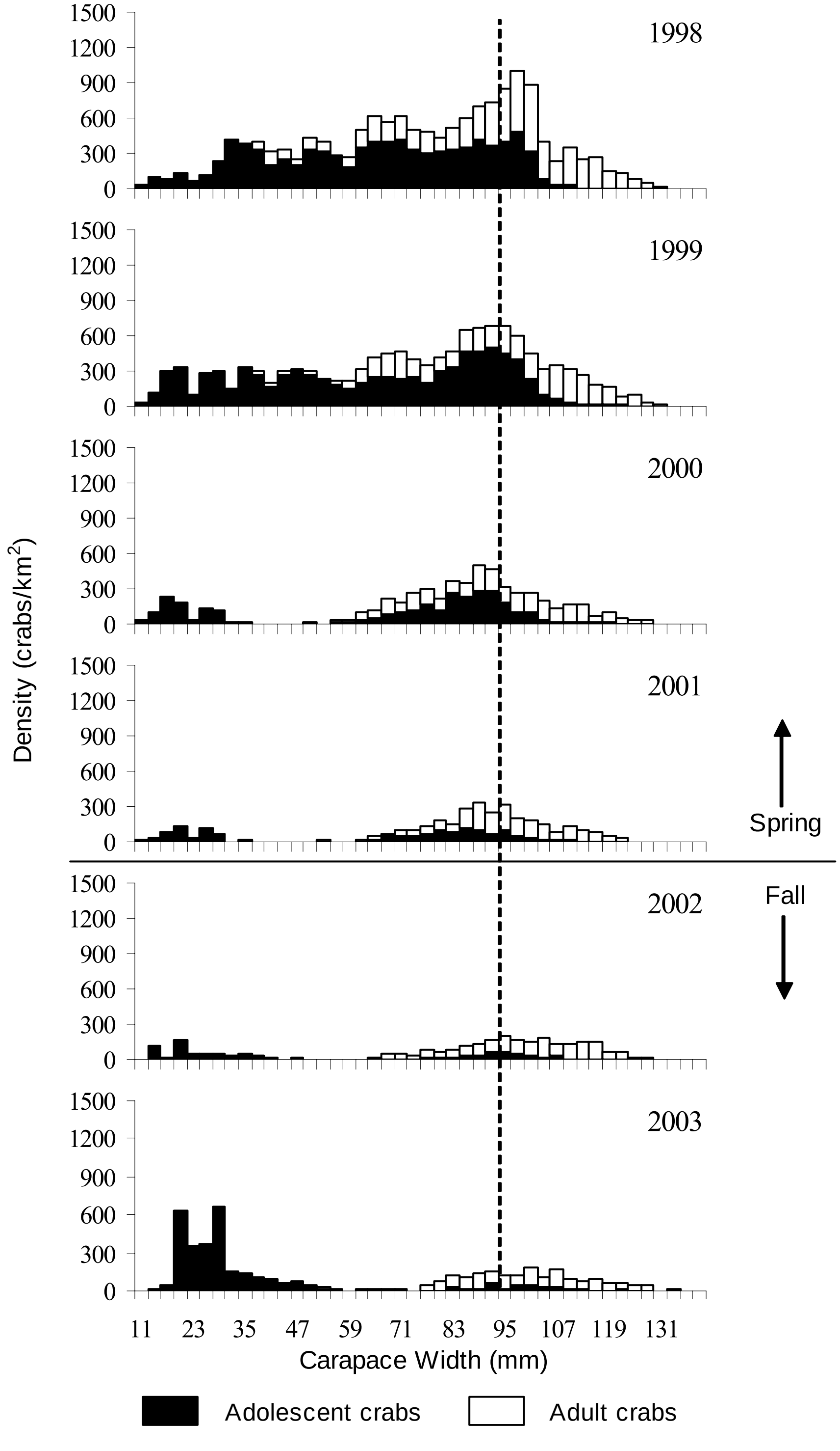


Figure 21. Survey size frequency of male snow crab in north-eastern Nova Scotia from 1998 to 2003.

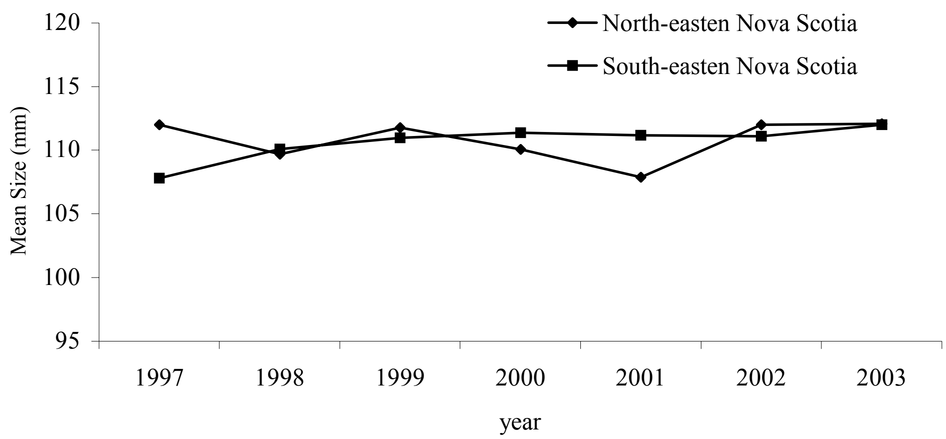


Figure 22. Mean size of commercial size snow crabs from the trawl surveys for north- and south-eastern Nova Scotia (Crab Fishing Areas 20 to 24).

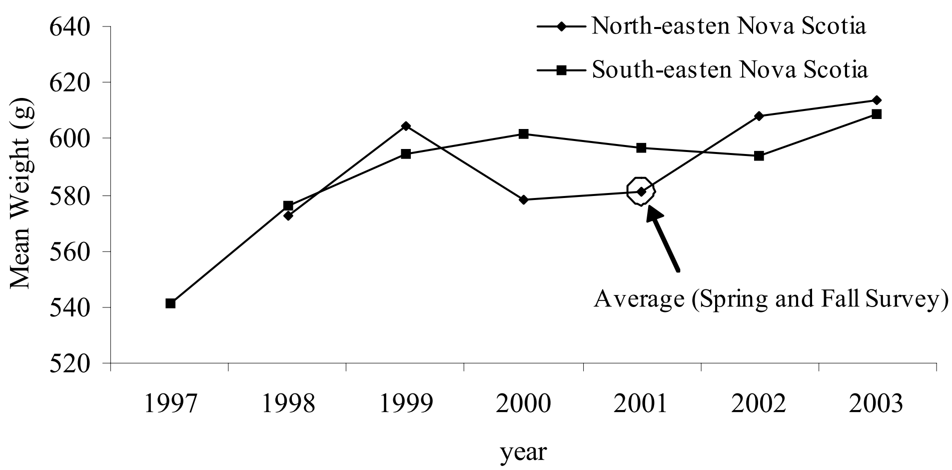


Figure 23. Mean weight of commercial size snow crabs from the trawl surveys for north- and south-eastern Nova Scotia (Crab Fishing Areas 20 to 24).

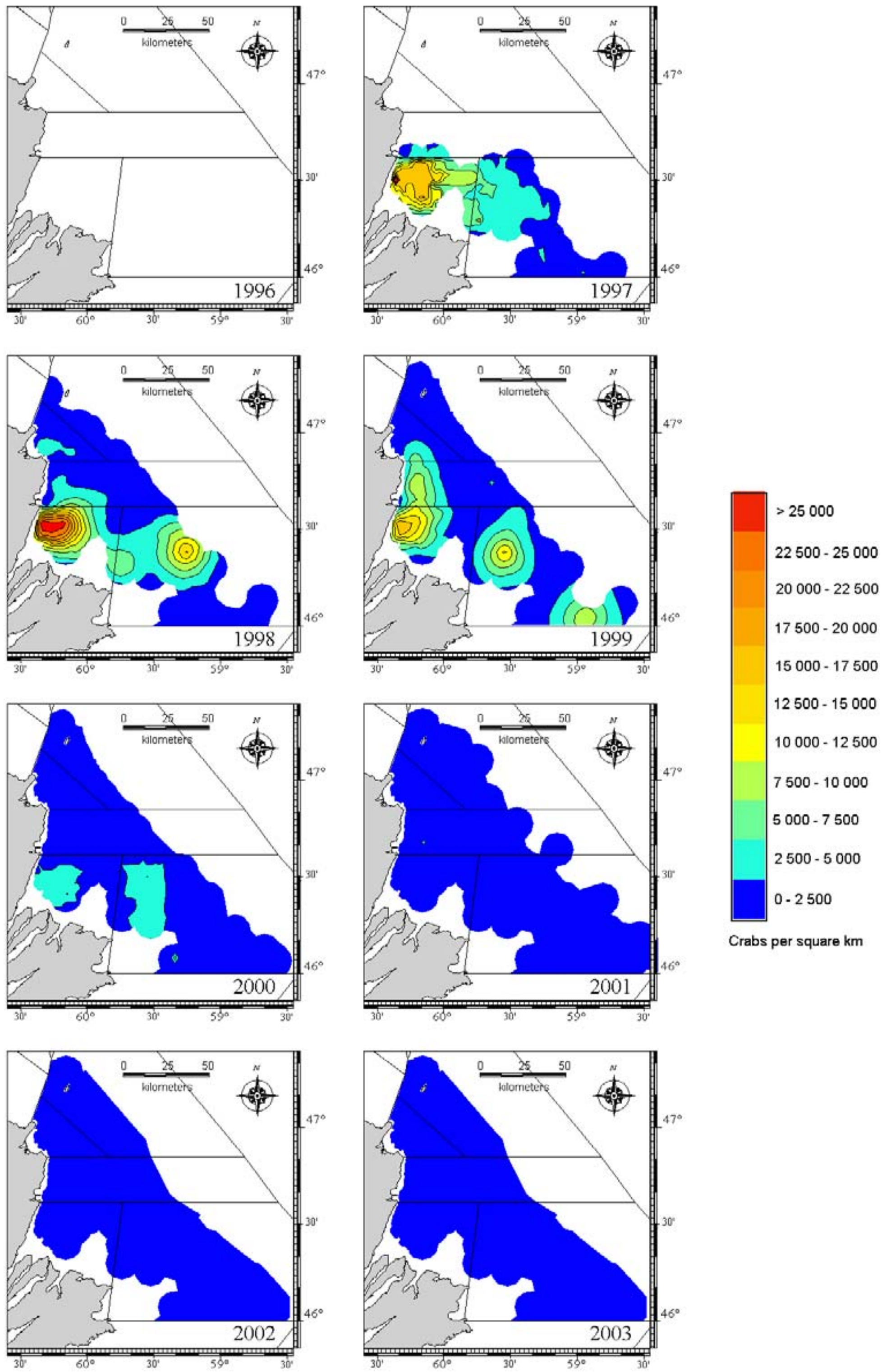


Figure 24. Snow crab density distribution of adolescent males (≥56mm carapace width) in north-eastern Nova Scotia from 1997 to 2003.

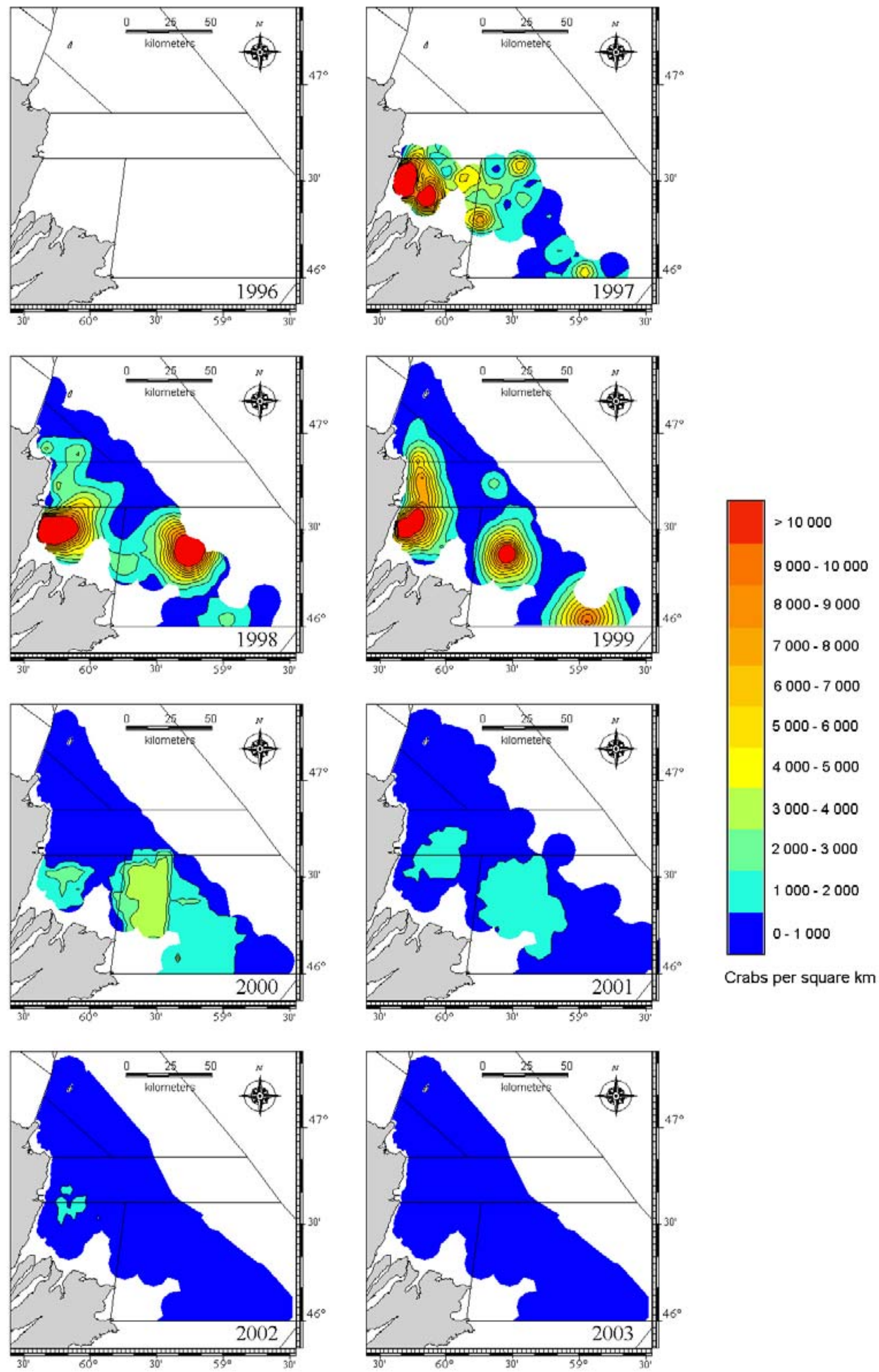


Figure 25. Snow crab density distribution of adolescent males (≥76mm carapace width) in north-eastern Nova Scotia from 1997 to 2003.

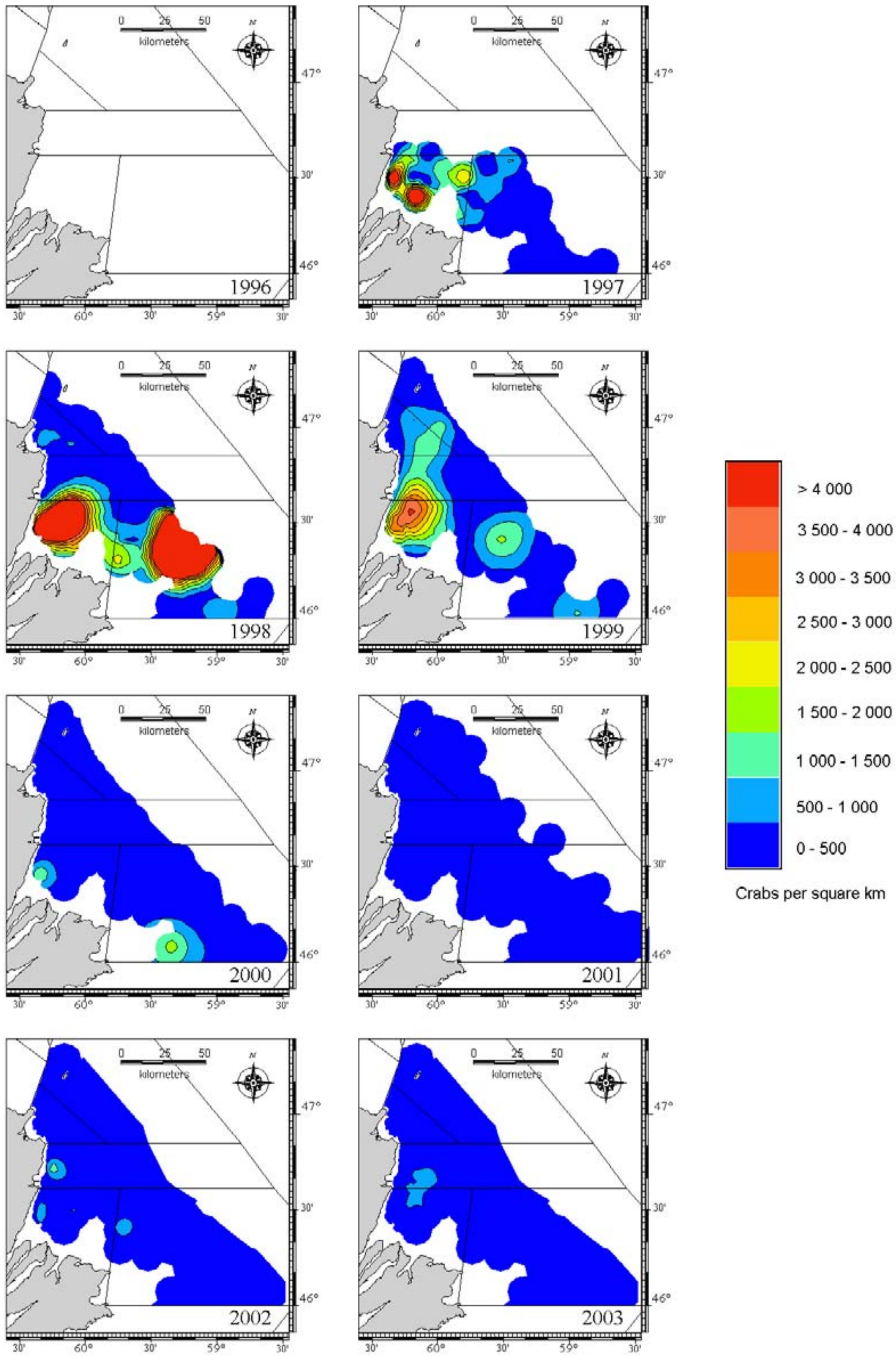


Figure 26. Snow crab density distribution of adult males (≥95mm carapace width) of carapace conditions 1 and 2 in north-eastern Nova Scotia from 1997 to 2003.

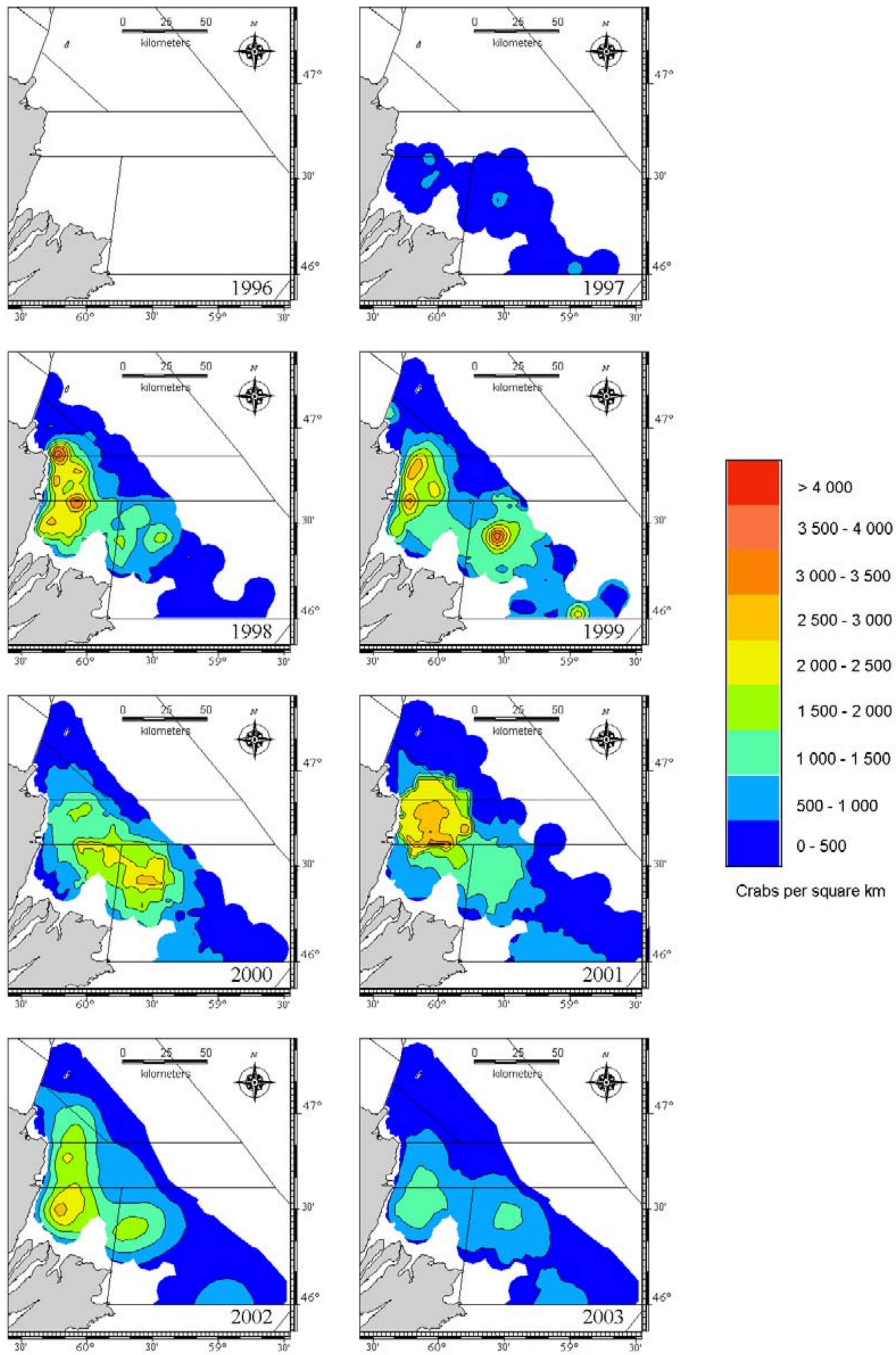


Figure 27. Snow crab density distribution of adult males (≥95mm carapace width) of carapace conditions 3, 4 and 5 in north-eastern Nova Scotia from 1997 to 2003.

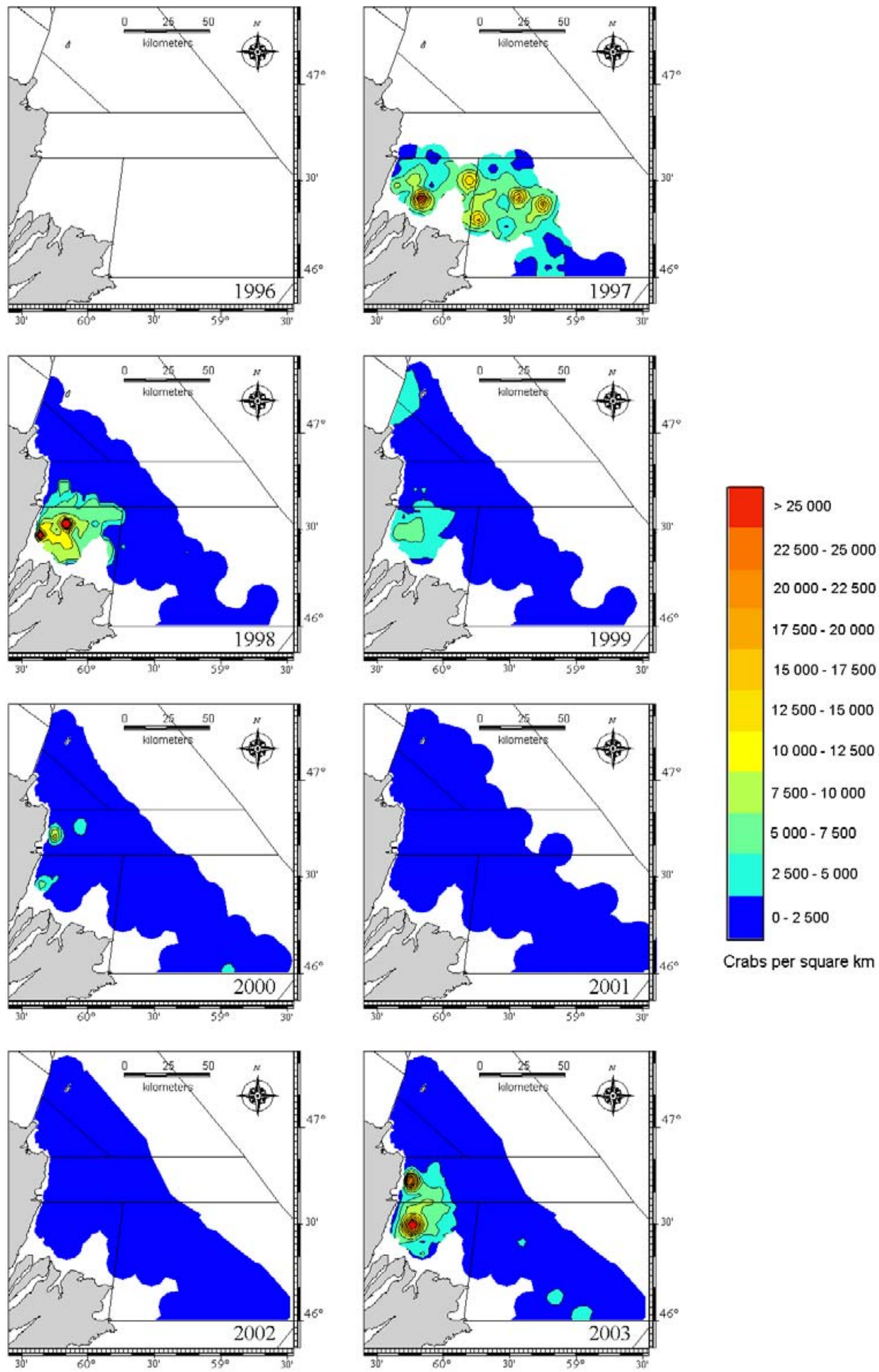


Figure 28. Snow crab density distribution of immature female in north-eastern Nova Scotia from 1997 to 2003.

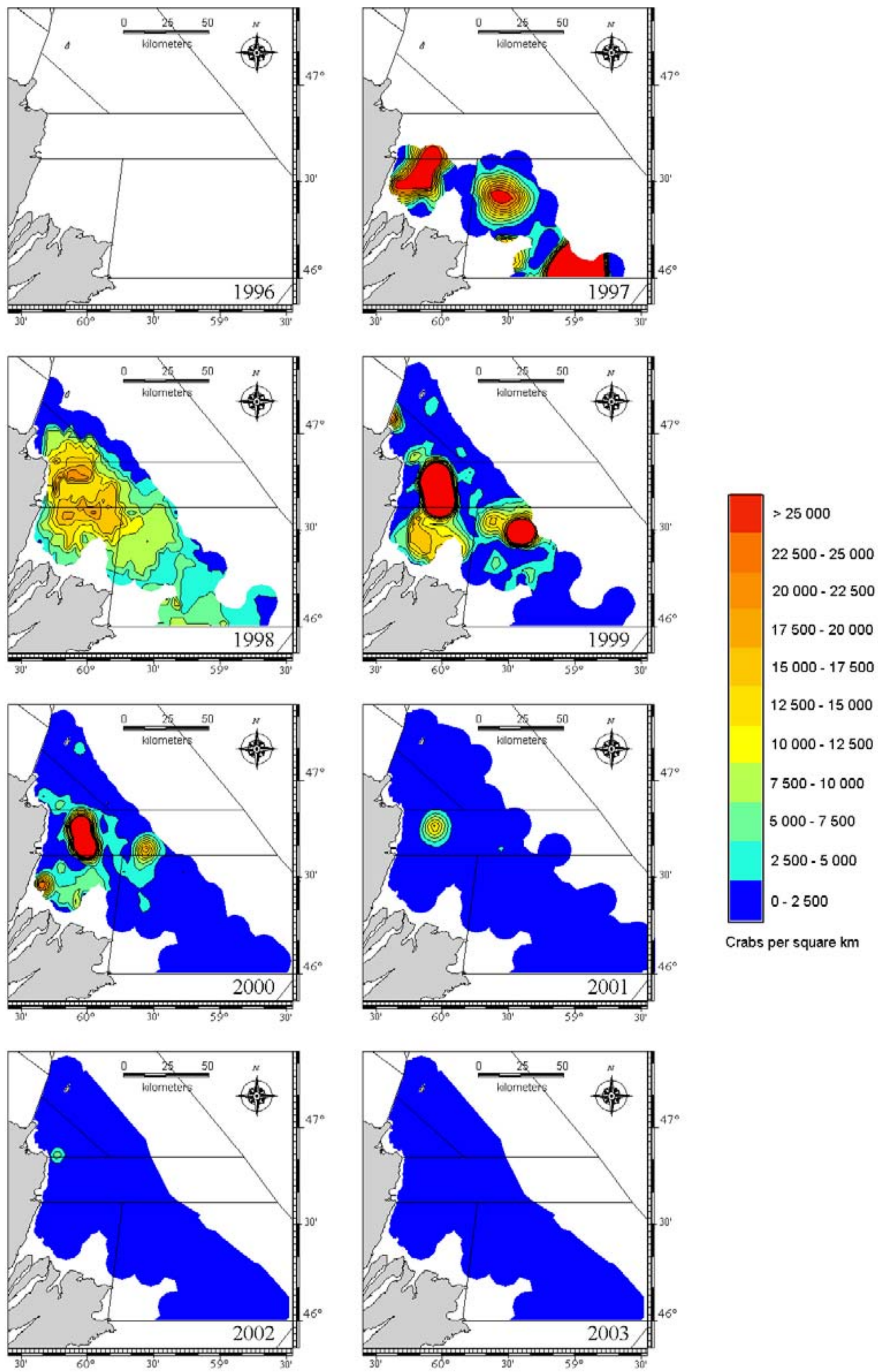


Figure 29. Snow crab density distribution of mature female in north-eastern Nova Scotia from 1997 to 2003.

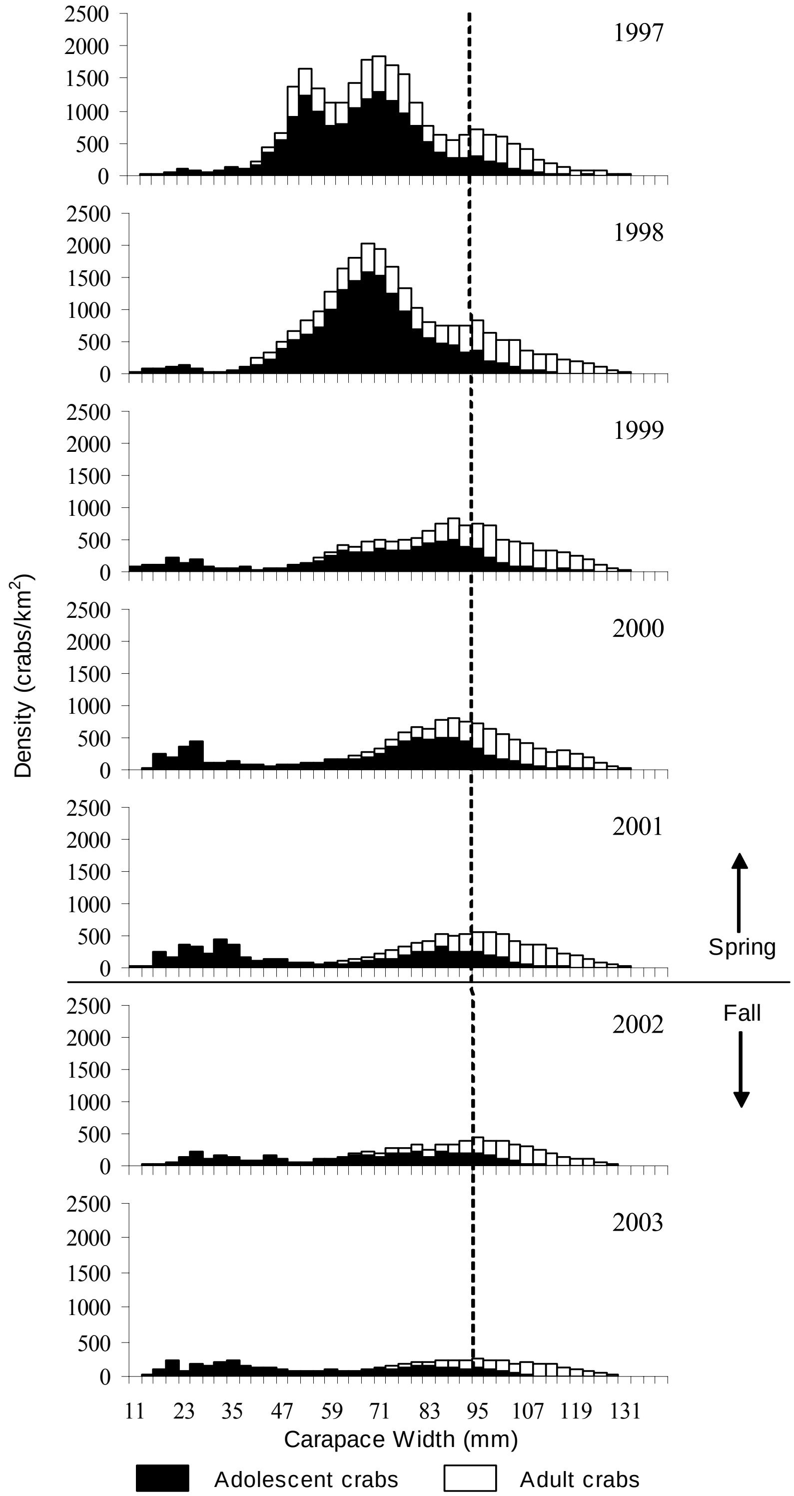


Figure 30. Survey size frequency of male snow crab in south-eastern Nova Scotia from 1997 to 2003.

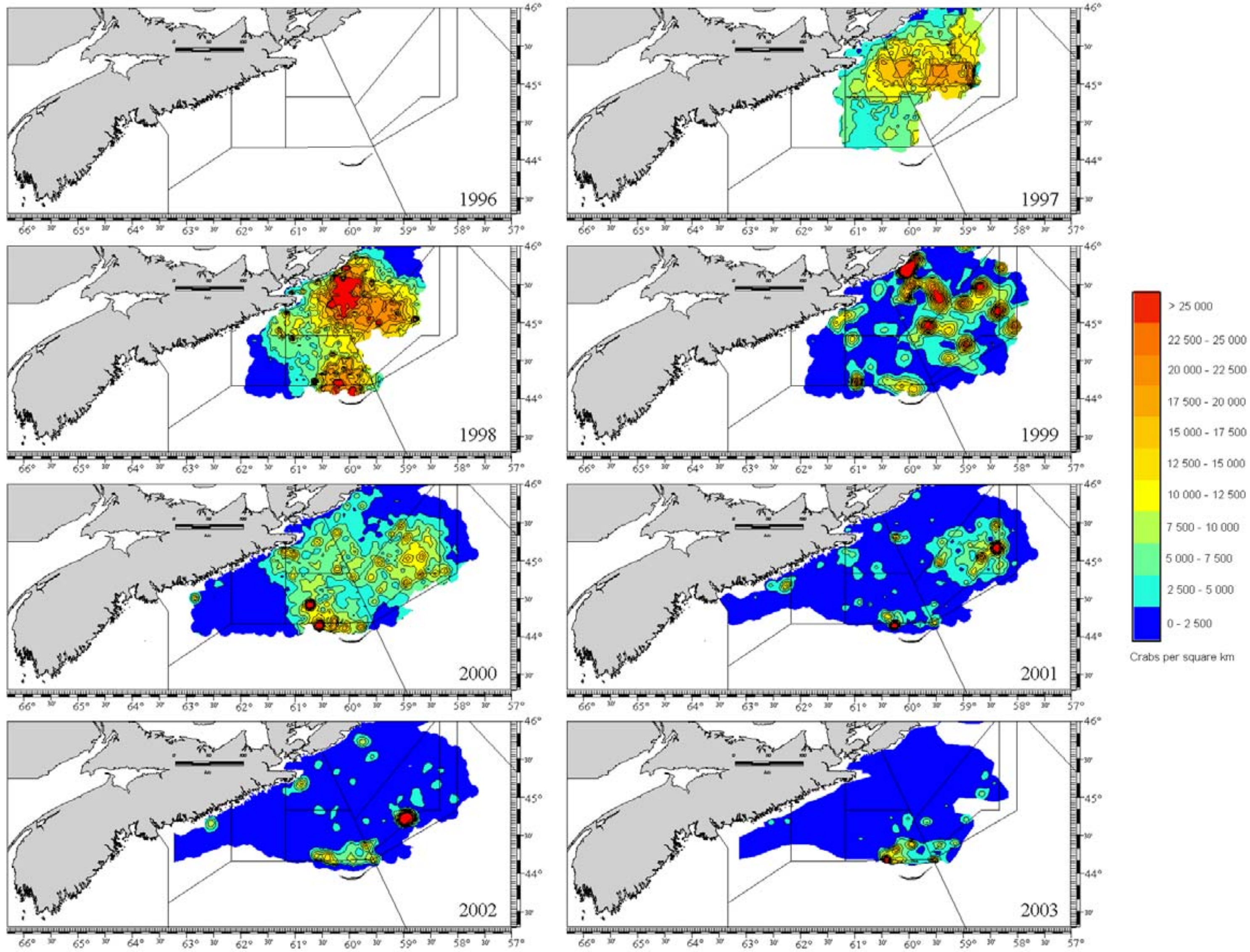


Figure 31. Snow crab density distribution of adolescent males (≥56mm carapace width) in north-eastern Nova Scotia from 1997 to 2003.

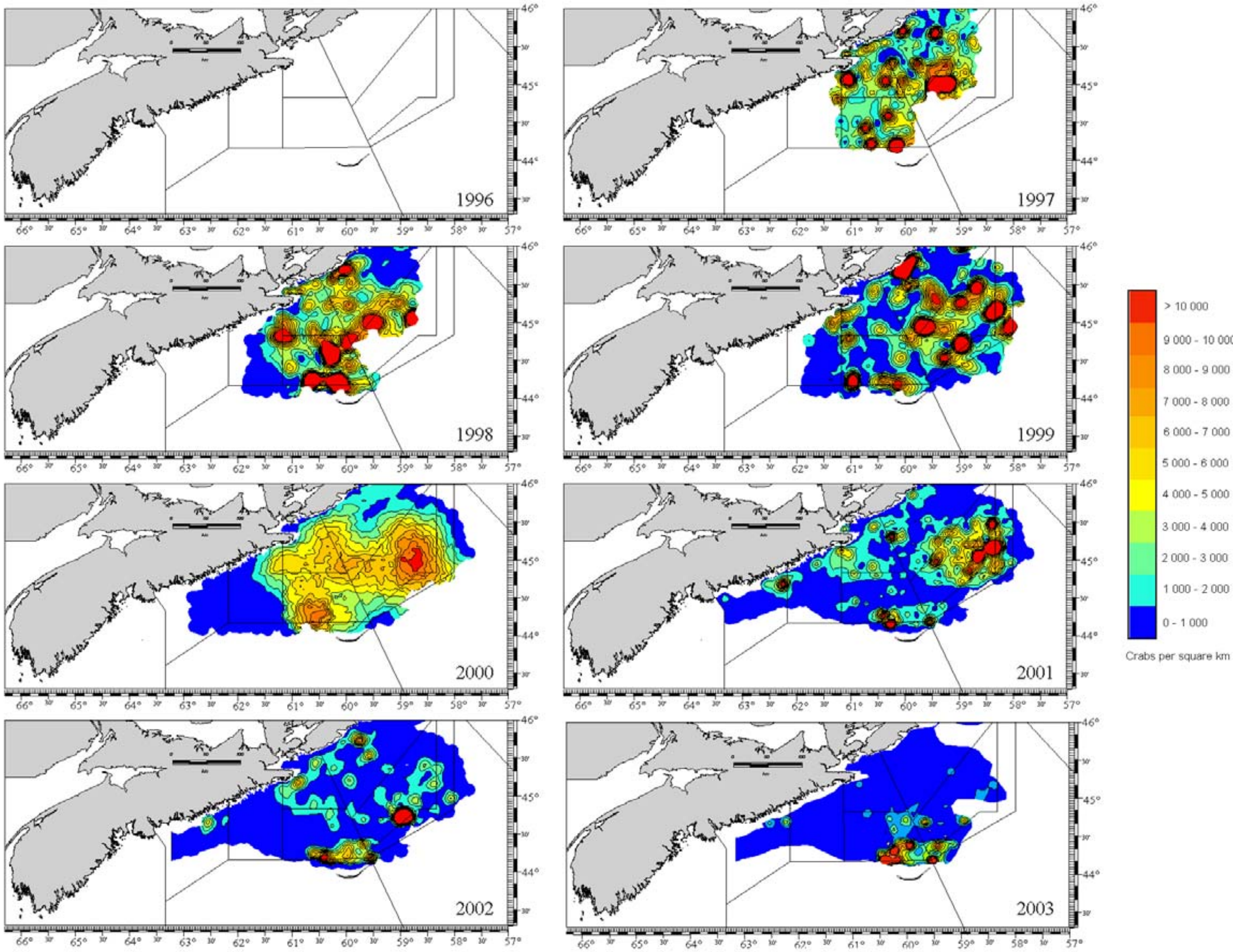


Figure 32. Snow crab density distribution of adolescent males (≥76mm carapace width) in north-eastern Nova Scotia from 1997 to 2003.

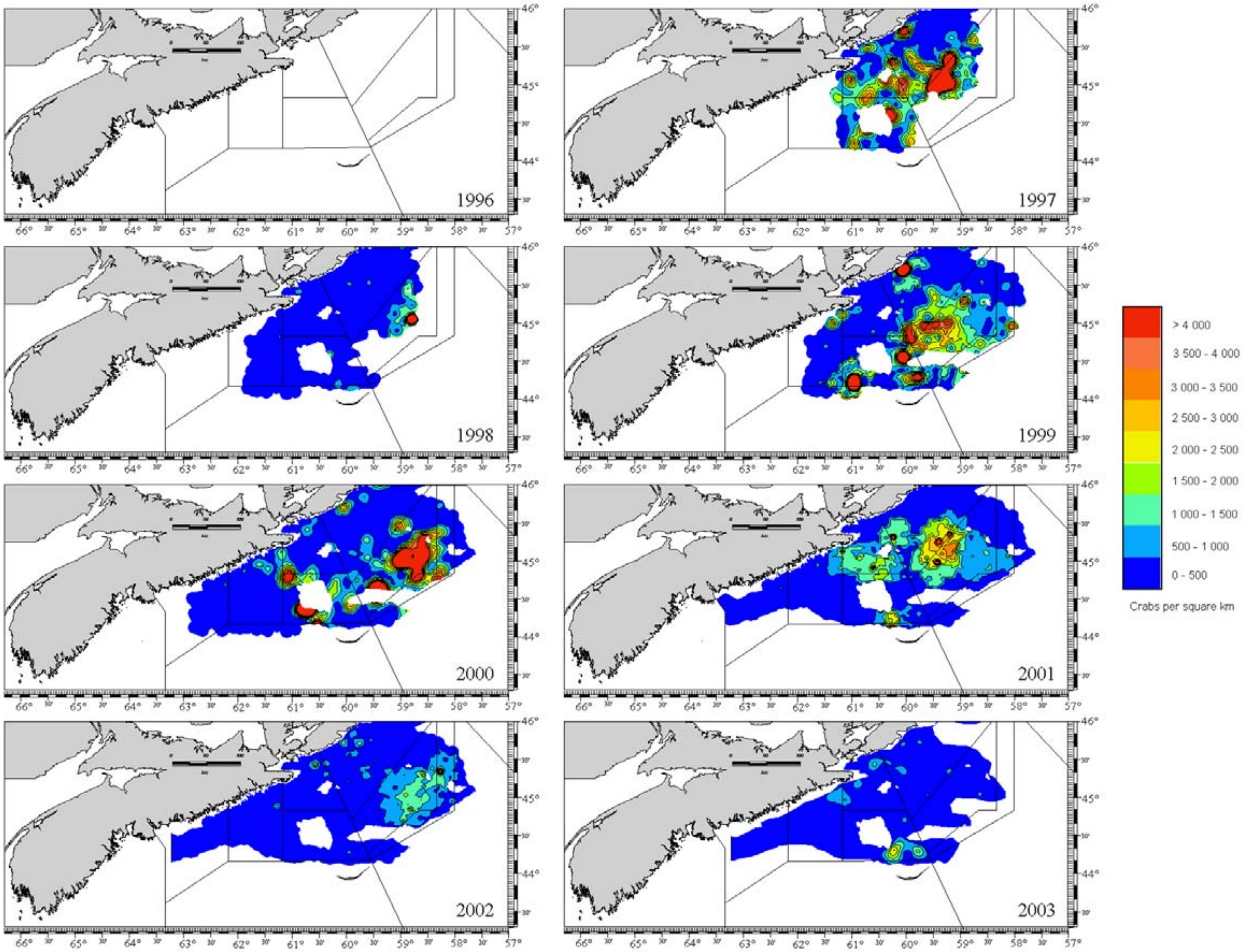


Figure 33. Snow crab density distribution of adult males (≥95mm carapace width) of carapace conditions 1 and 2 in north-eastern Nova Scotia from 1997 to 2003.

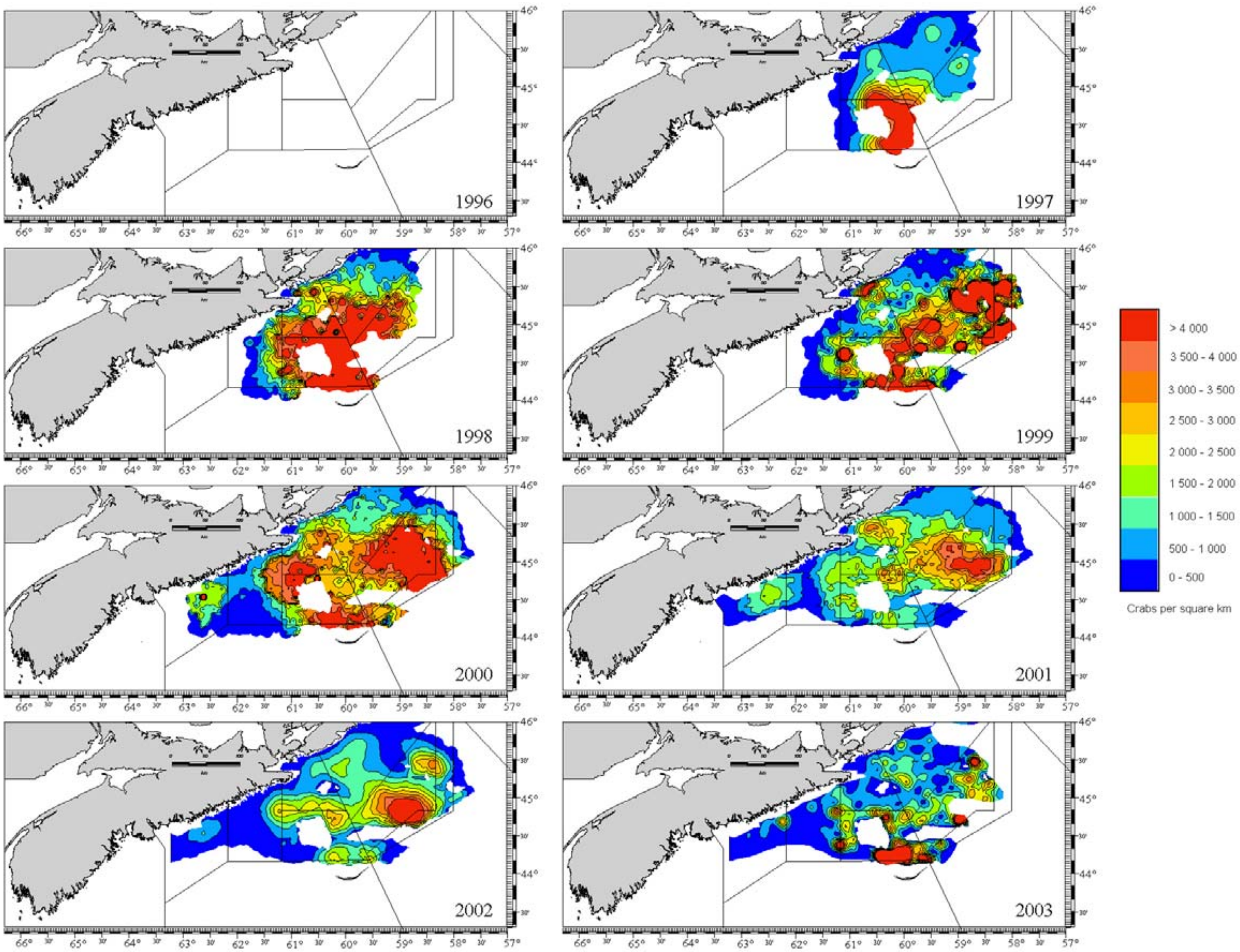


Figure 34. Snow crab density distribution of adult males (≥95mm carapace width) of carapace conditions 3, 4 and 5 in north-eastern Nova Scotia from 1997 to 2003.

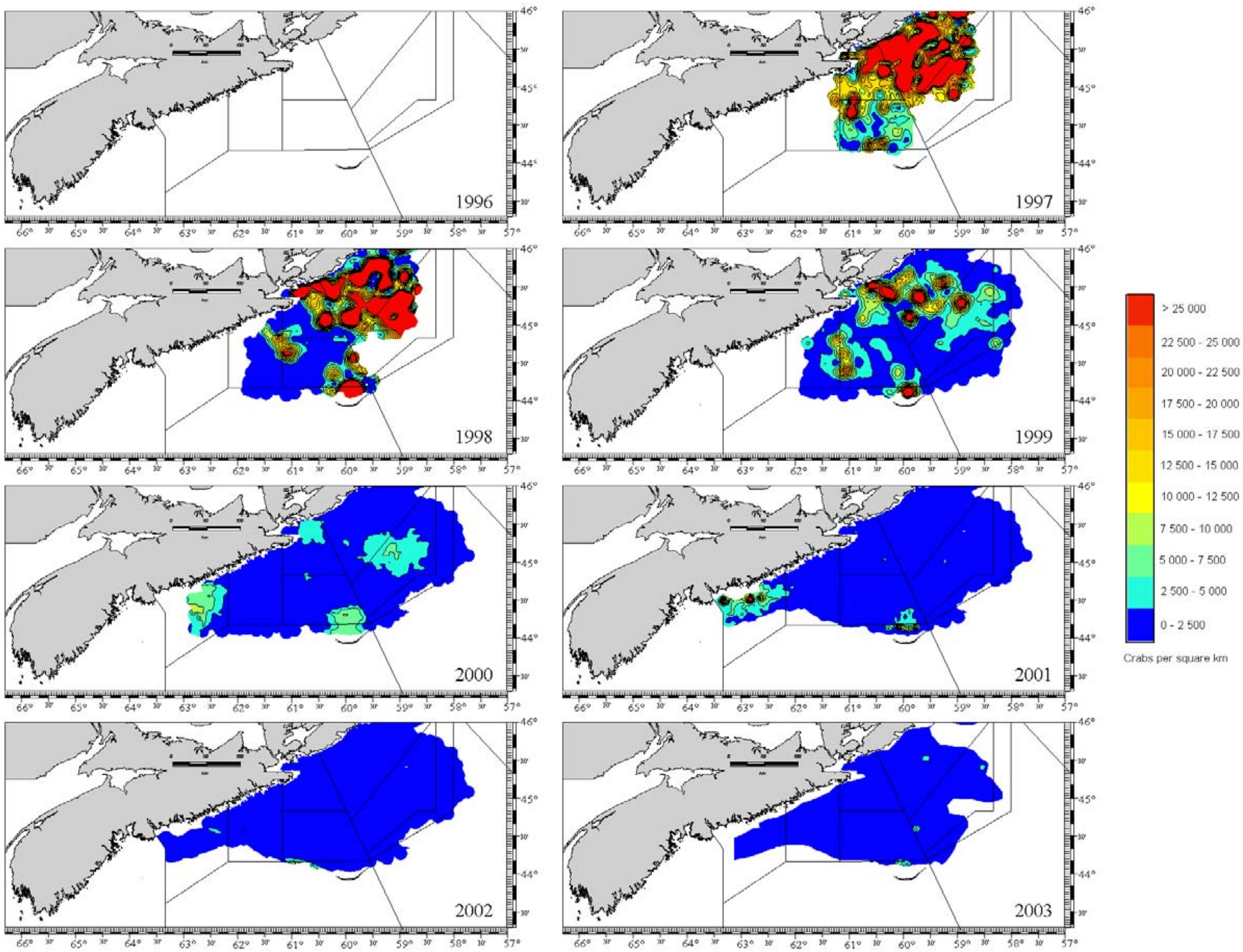


Figure 35. Snow crab density distribution of mature female in north-eastern Nova Scotia from 1997 to 2003.

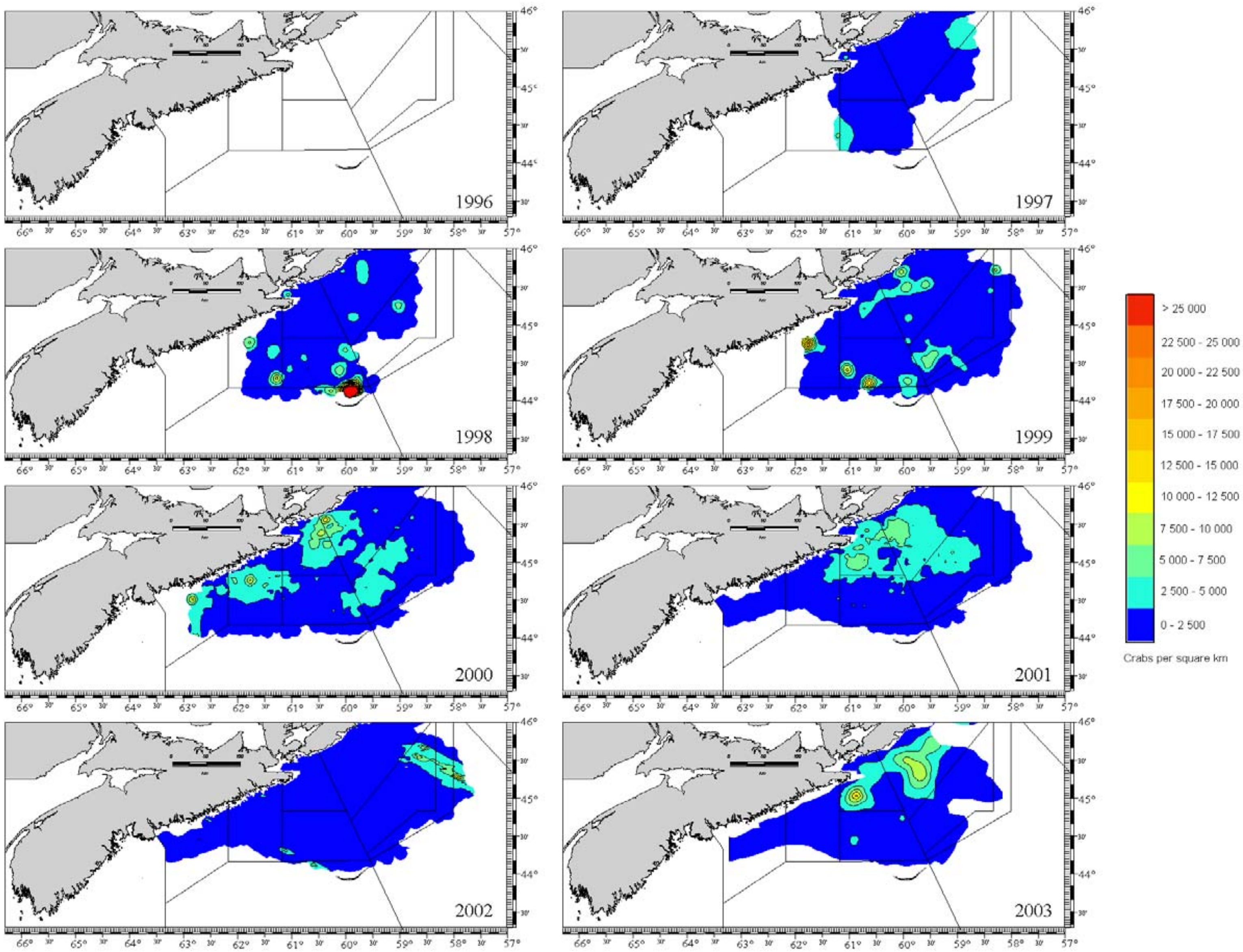


Figure 36. Snow crab density distribution of immature female in north-eastern Nova Scotia from 1997 to 2003.

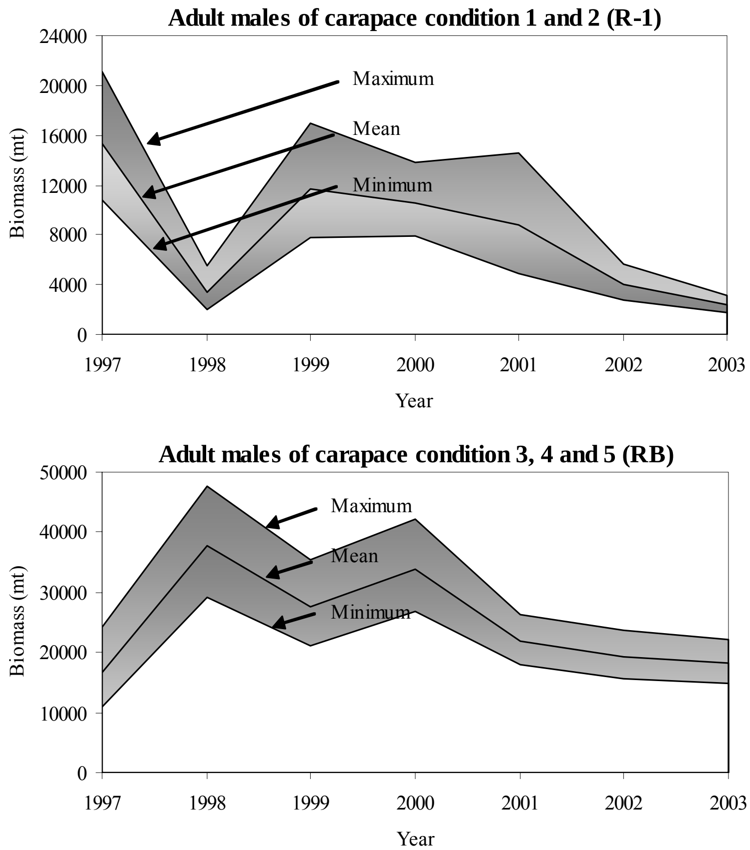


Figure 37. Biomass index for south-eastern Nova Scotia.

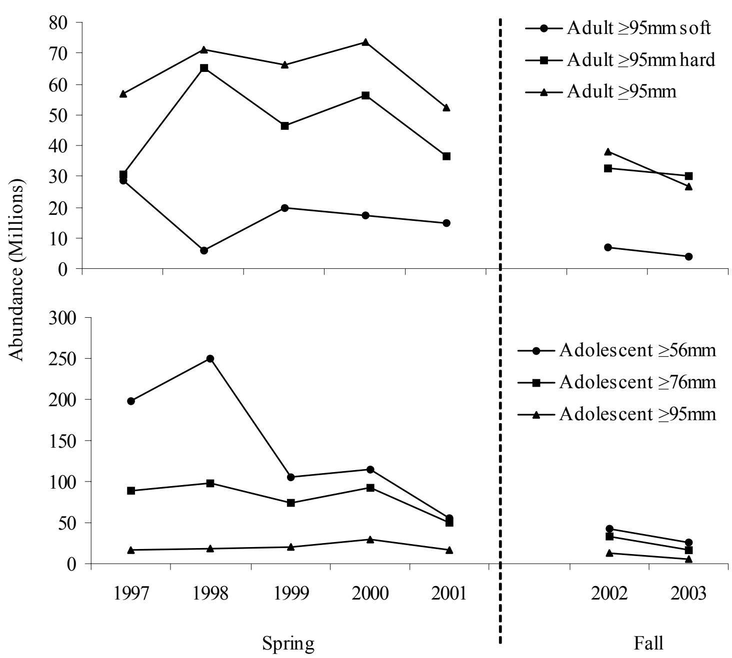


Figure 38. Relative abundance of commercial-sized adult and pre-recruits males observed during the trawl surveys in south-eastern Nova Scotia.

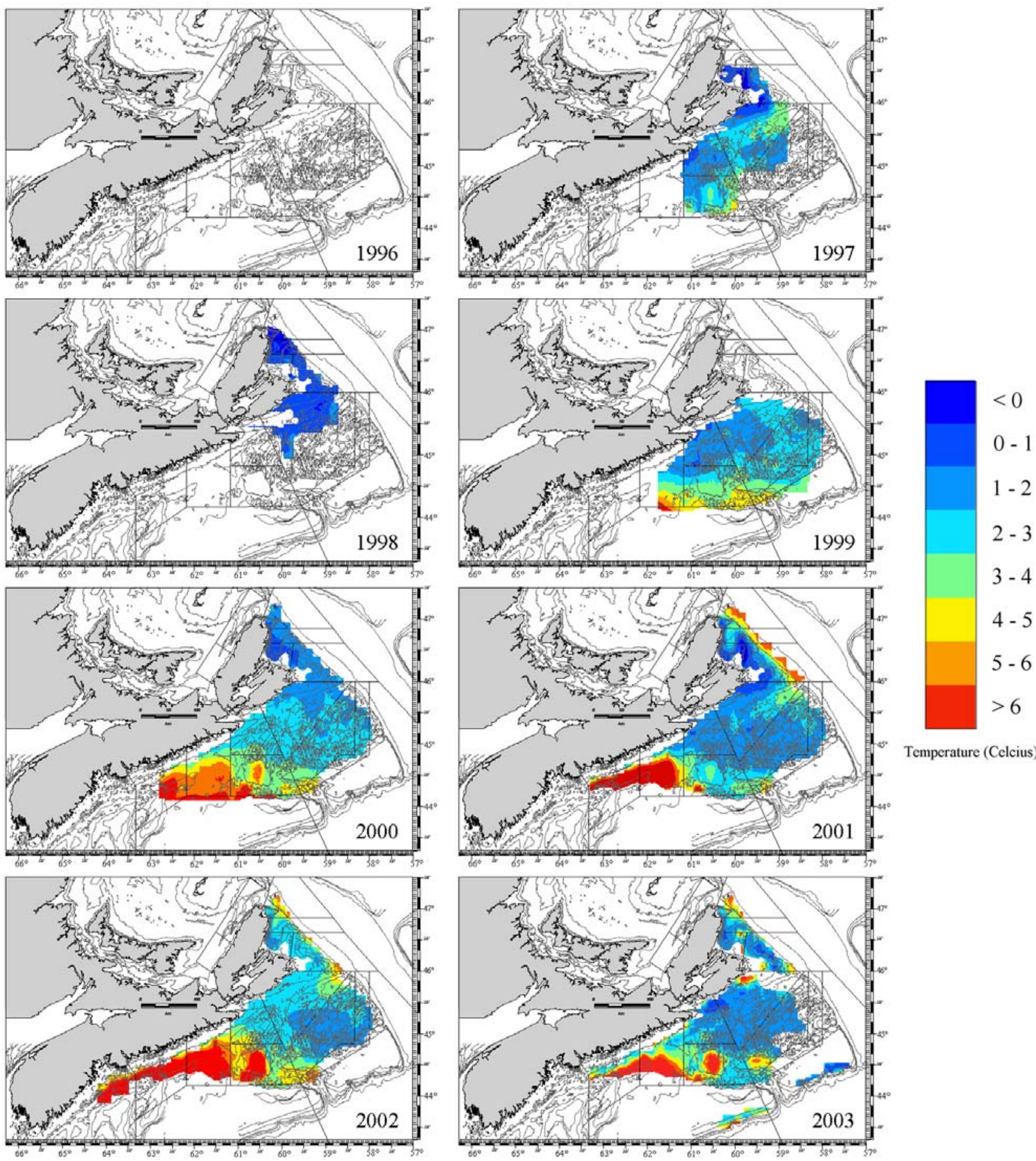


Figure 39. Snow crab trawl survey temperature observed for the years 1996 to 2003 for eastern Nova Scotia.

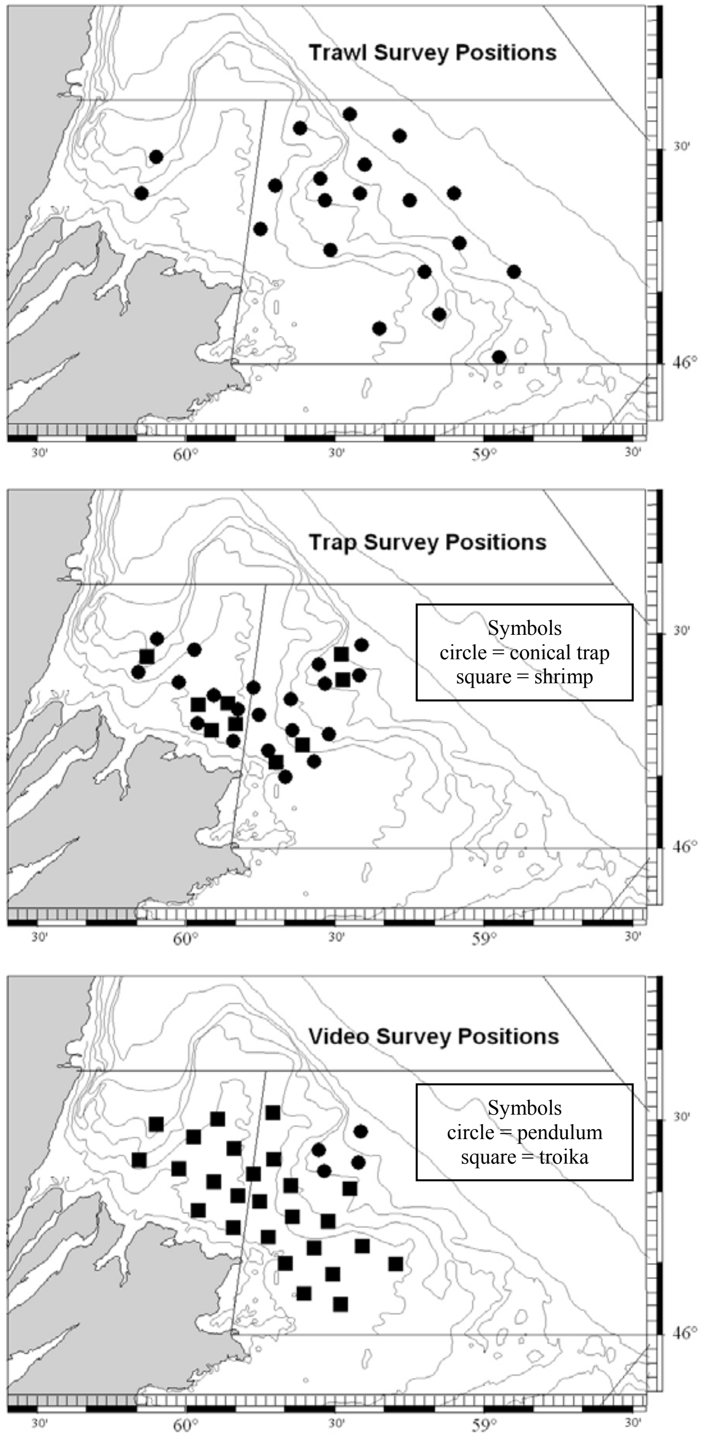


Figure 40. Location of snow crab trawl, trap and video survey stations for the Glace Bay Hole experiment in 2003.

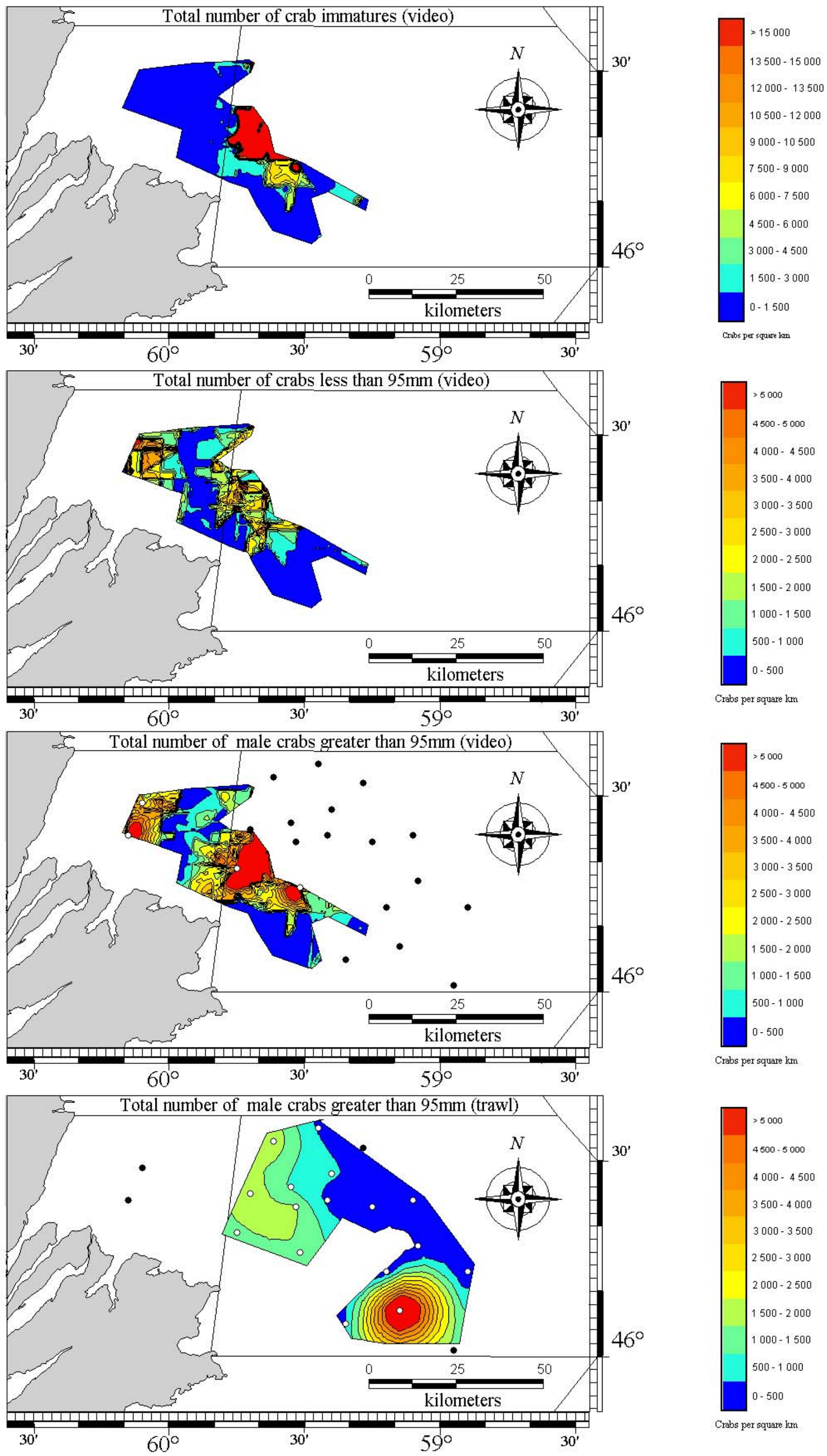


Figure 41. Snow crab density distribution from the video survey and trawl survey (summer) in Crab Fishing Area (CFA) 22 (Dots are the trawl station positions).

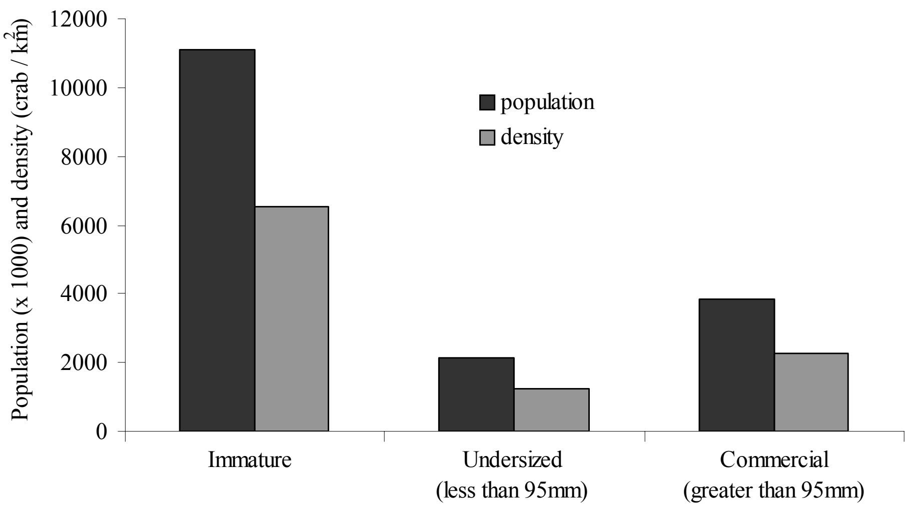


Figure 42. Snow crab density and abundance from the video survey in Crab Fishing Area (CFA) 22.

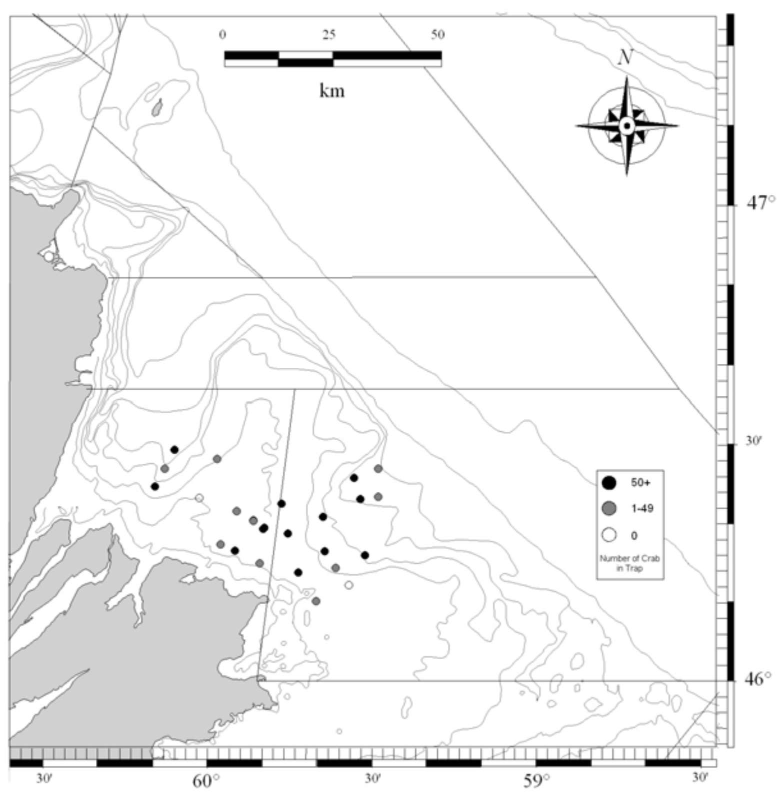


Figure 43. Distribution of fishing set positions with and without snow crab from the trap survey in Glace Bay Hole (CFA 22) in 2003.

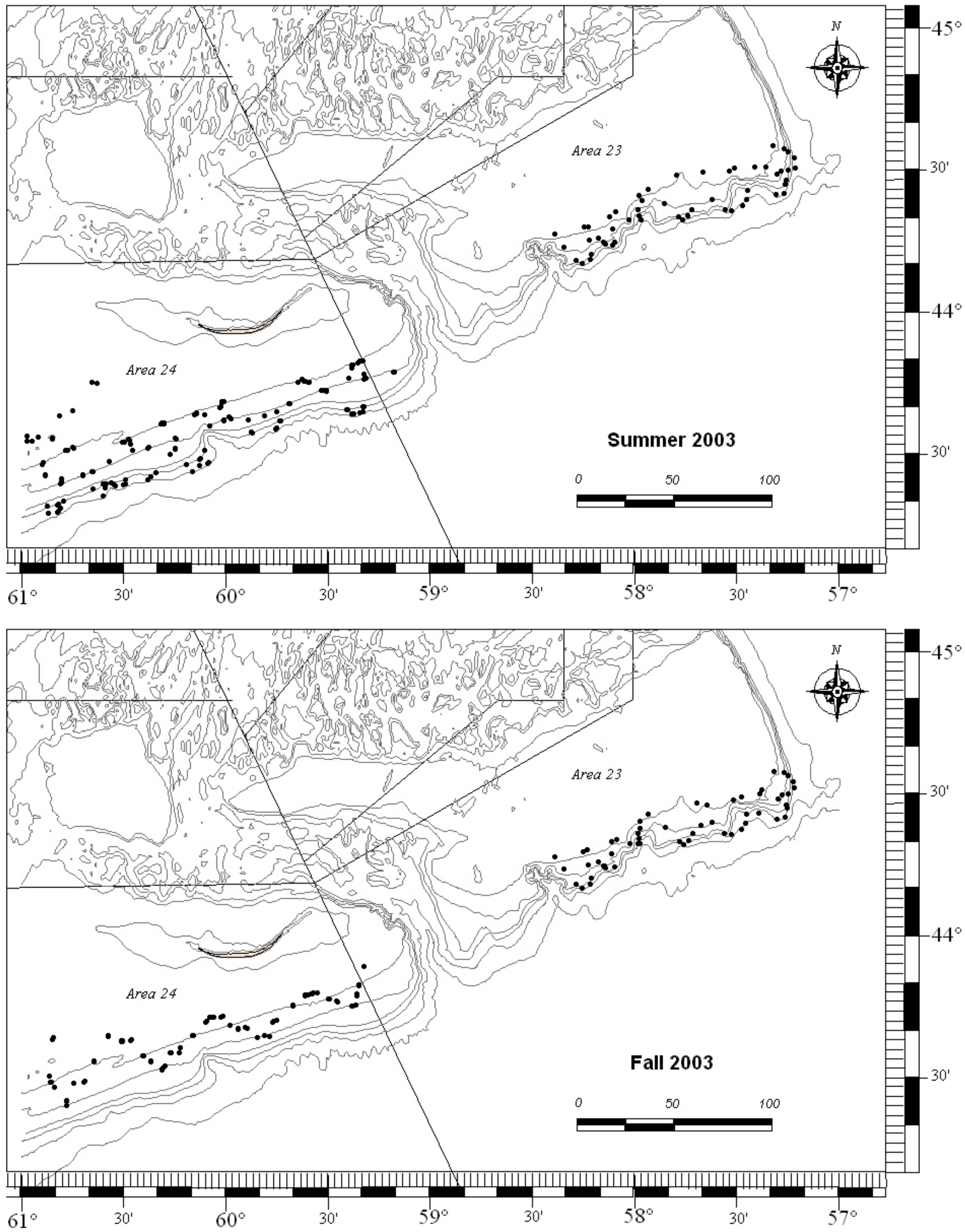


Figure 44. Reported trap positions of snow crab slope survey in 2003.

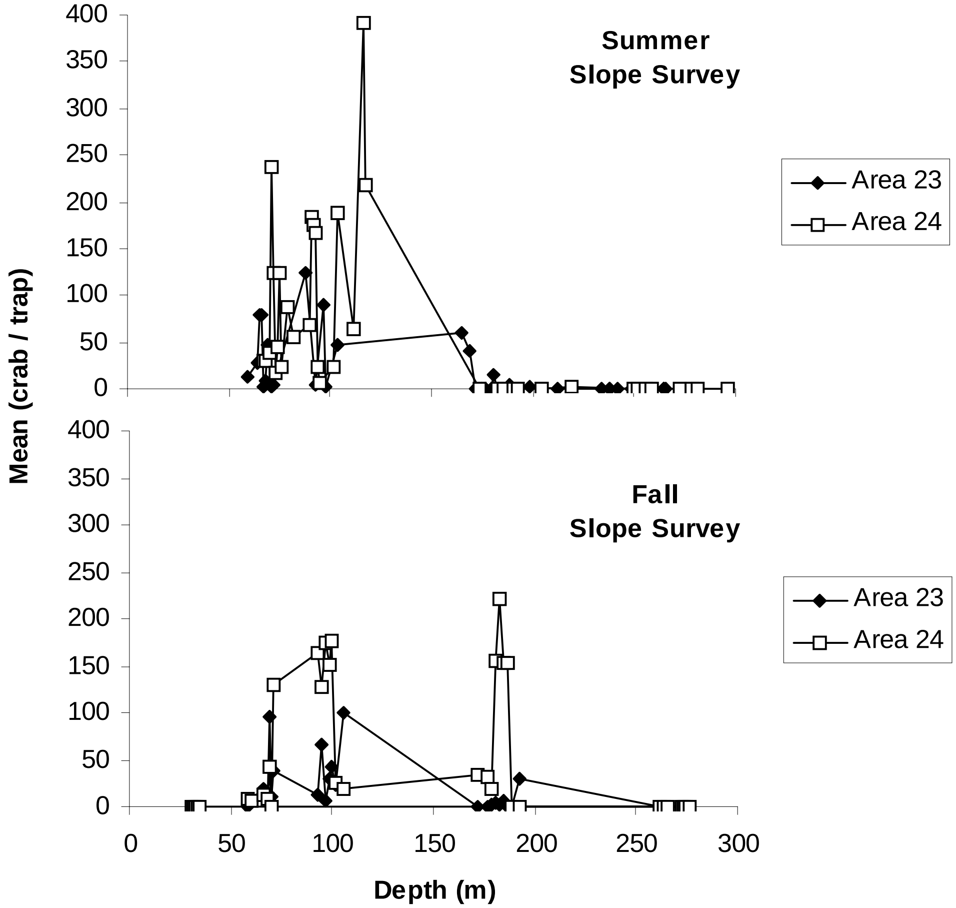


Figure 45. Mean number of crabs per trap by depth (m) for the snow crab slope survey in Crab Fishing Areas (CFAs) 23 and 24 in 2003.

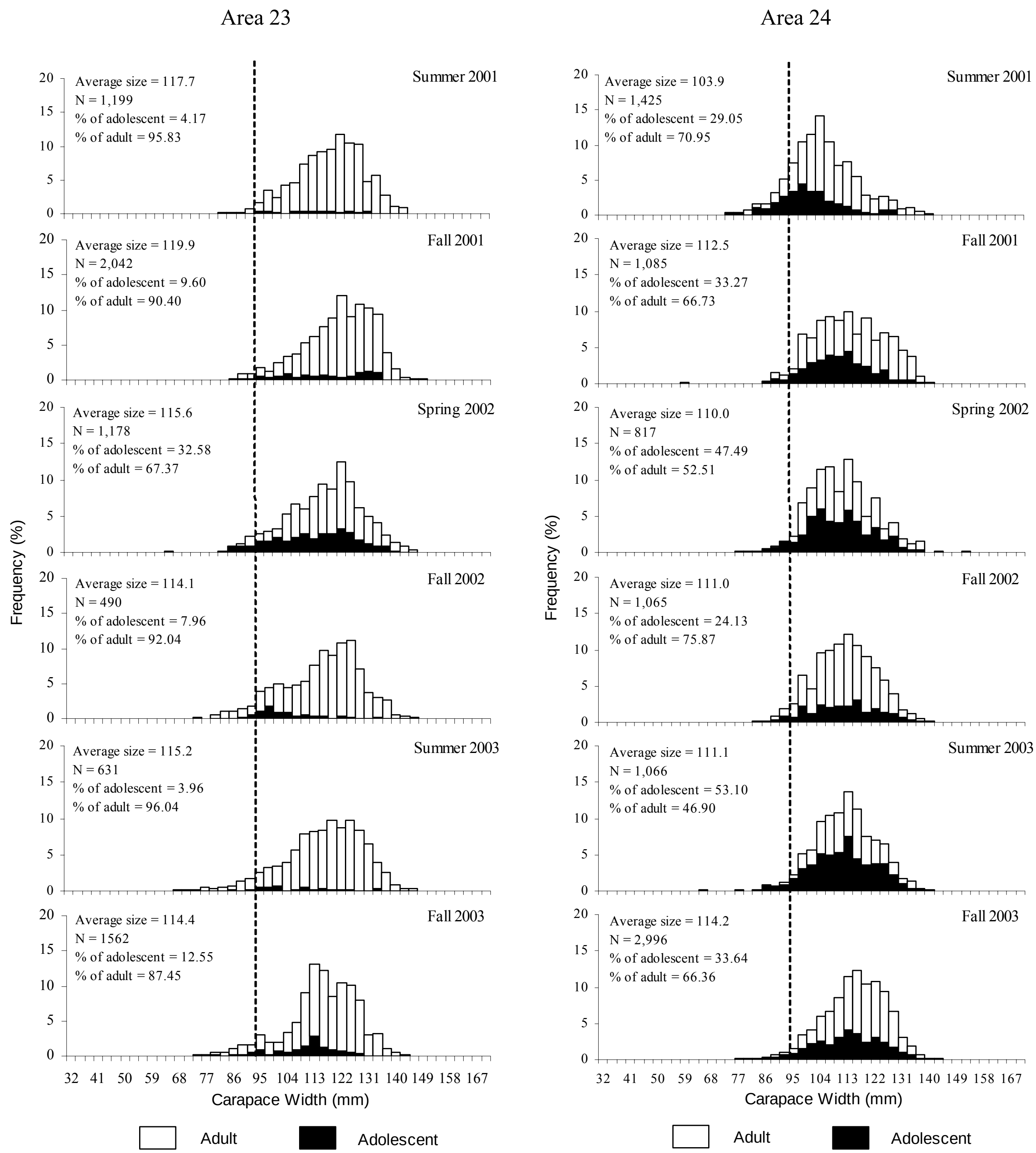


Figure 46. Size frequency distribution from the exploratory trap survey on the slope of Crab Fishing Areas (CFAs) 23 and 24.

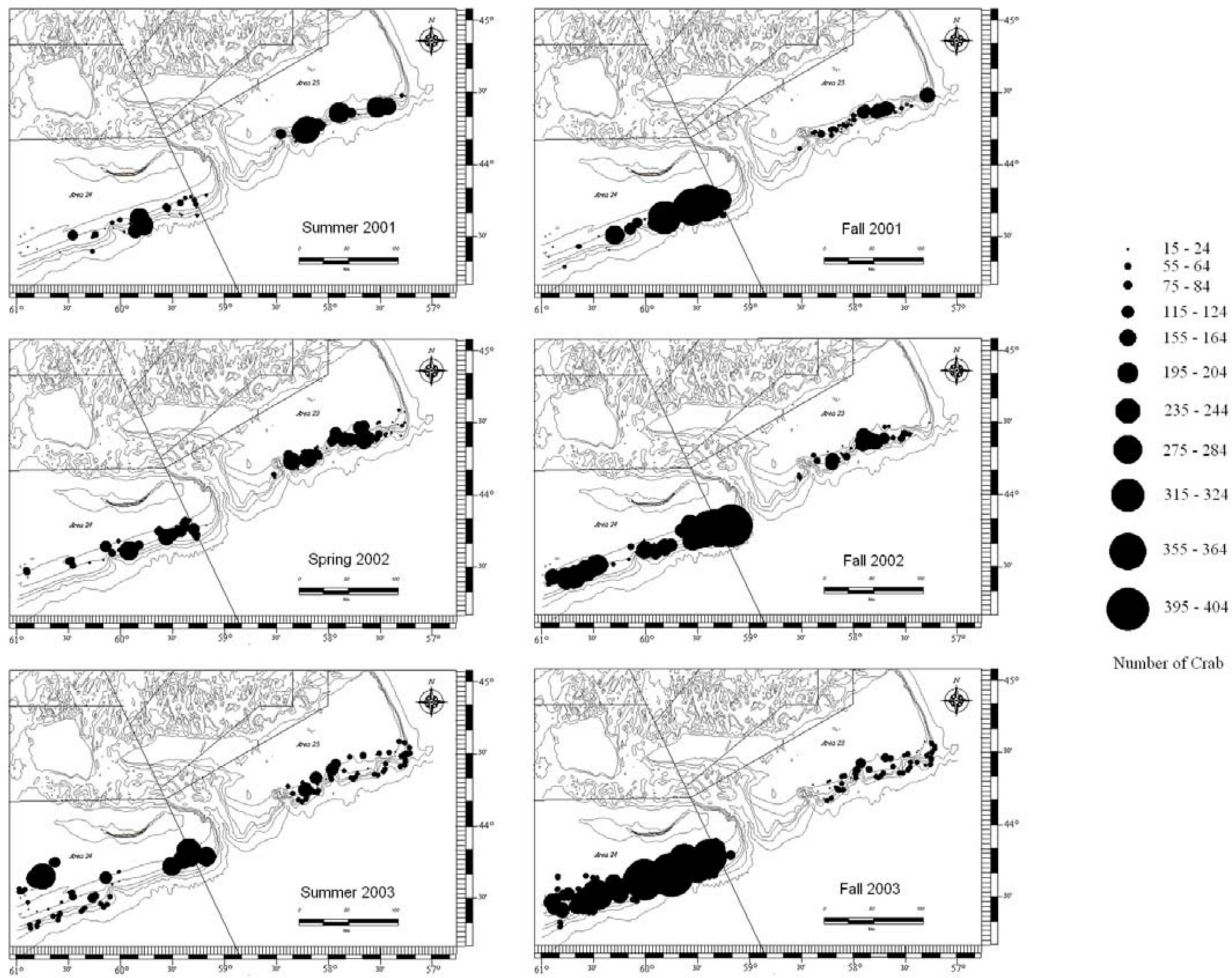


Figure 47. Snow crab counts per trap observed during the snow crab slope survey from 2001 to 2003.

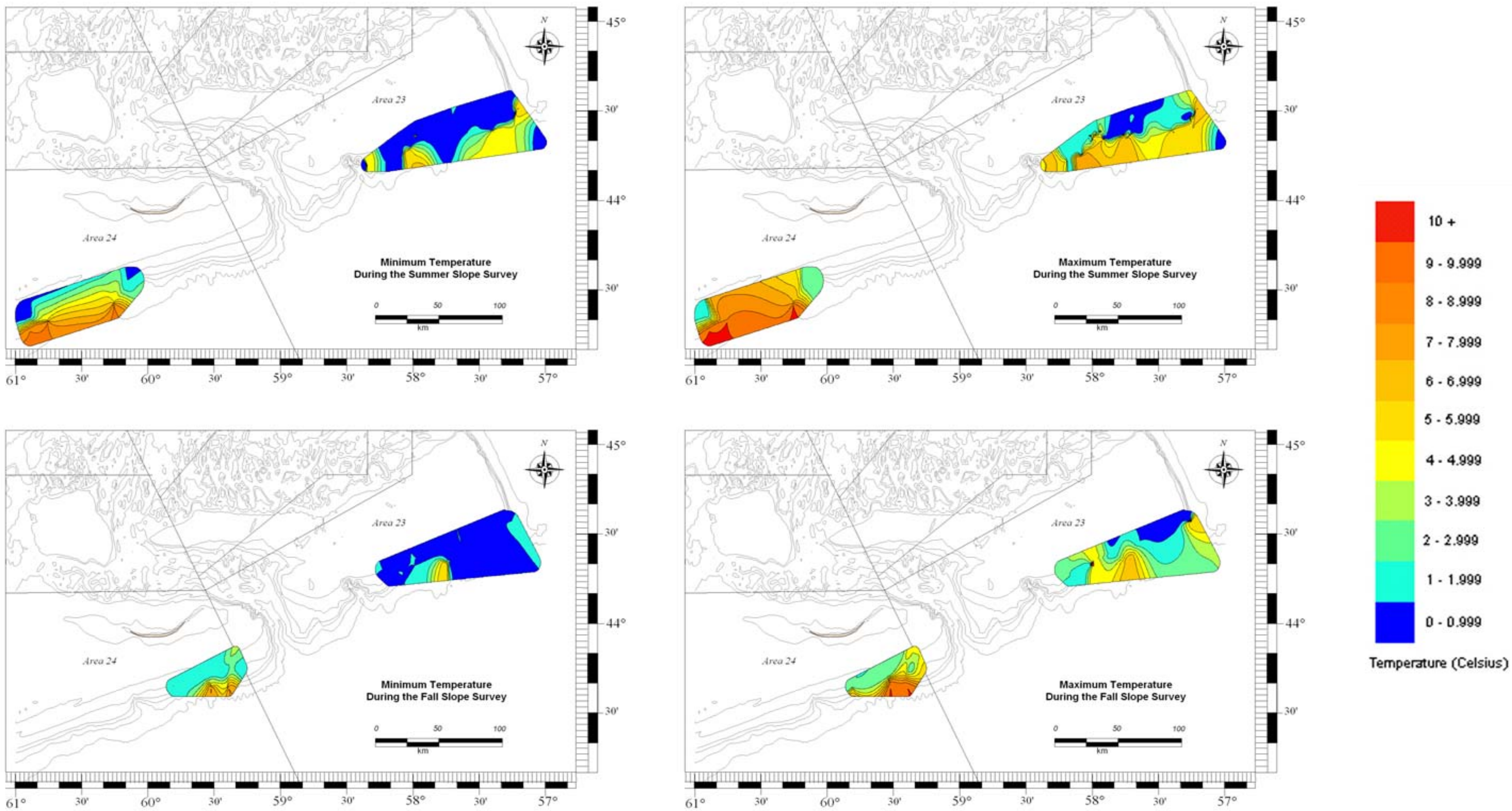


Figure 48. Temperature data observed during the snow crab slope survey in 2003.

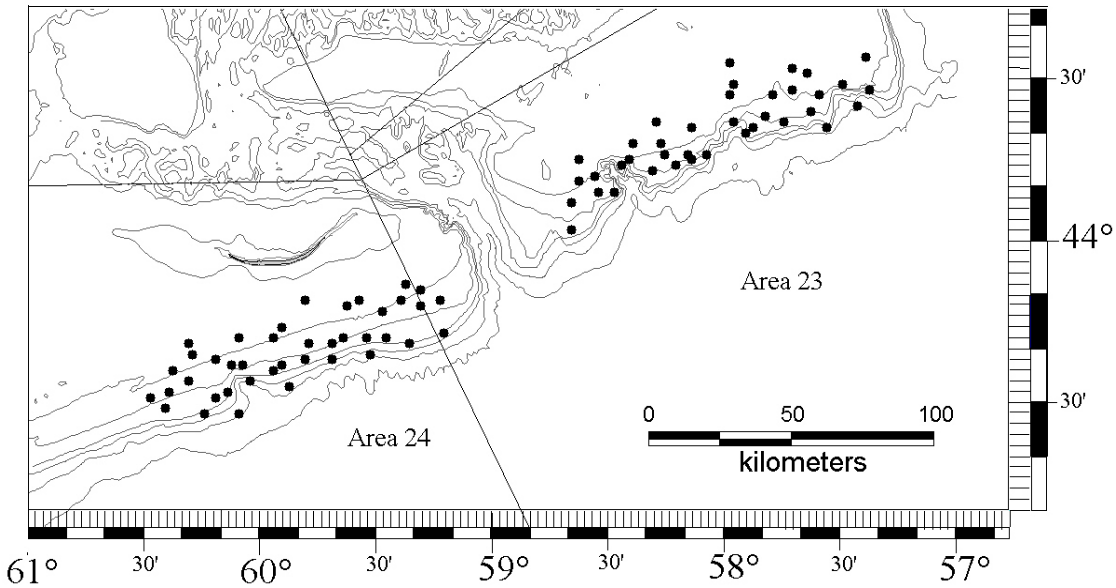


Figure 49. Location of snow crab trawl survey stations on the slope in 2003.

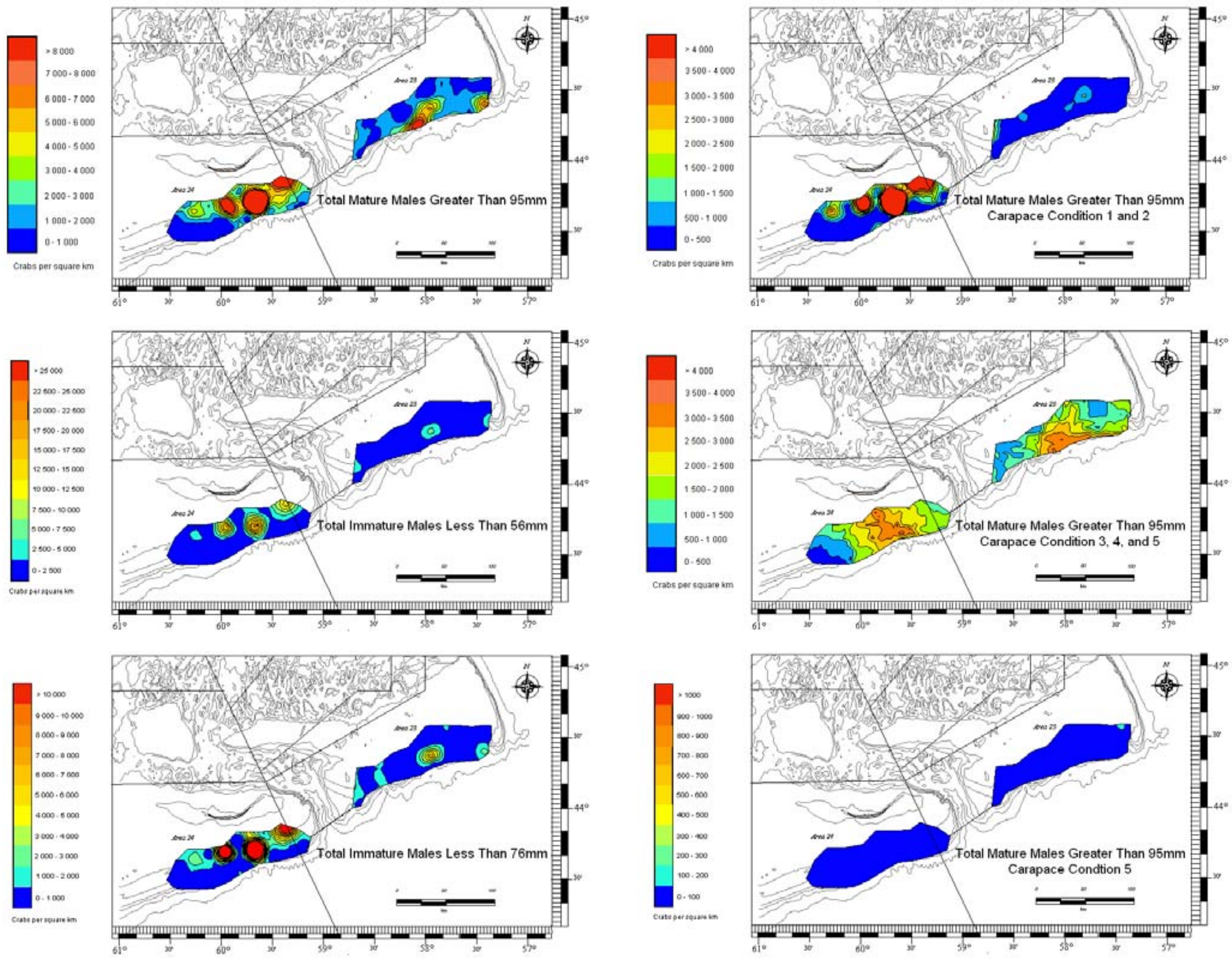


Figure 50. Snow crab density distributions from the snow crab trawl survey in Crab Fishing Areas (CFAs)) 23 and 24 on the slope in 2003.

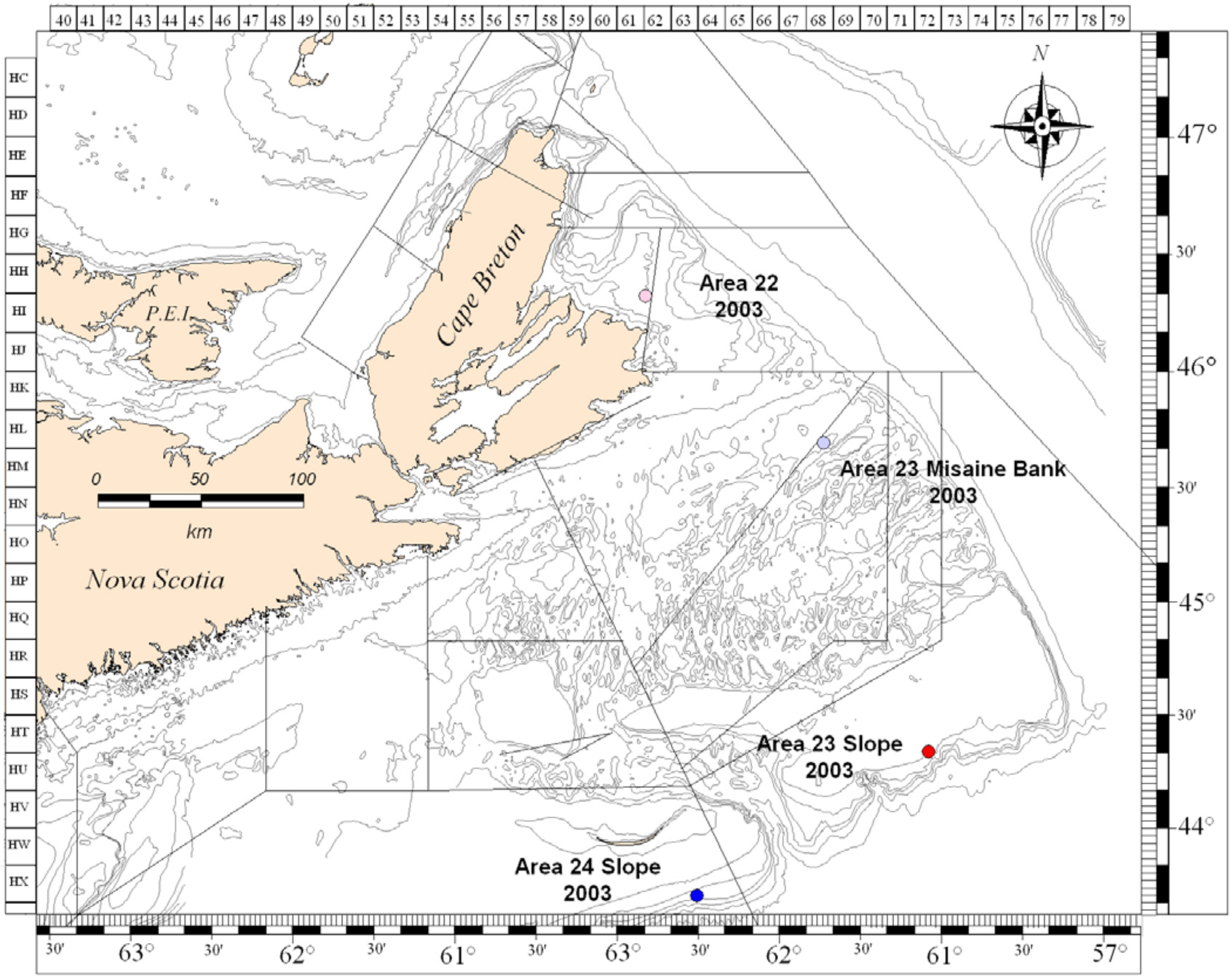


Figure 51. Eastern Nova Scotia tagging sites in 2003.

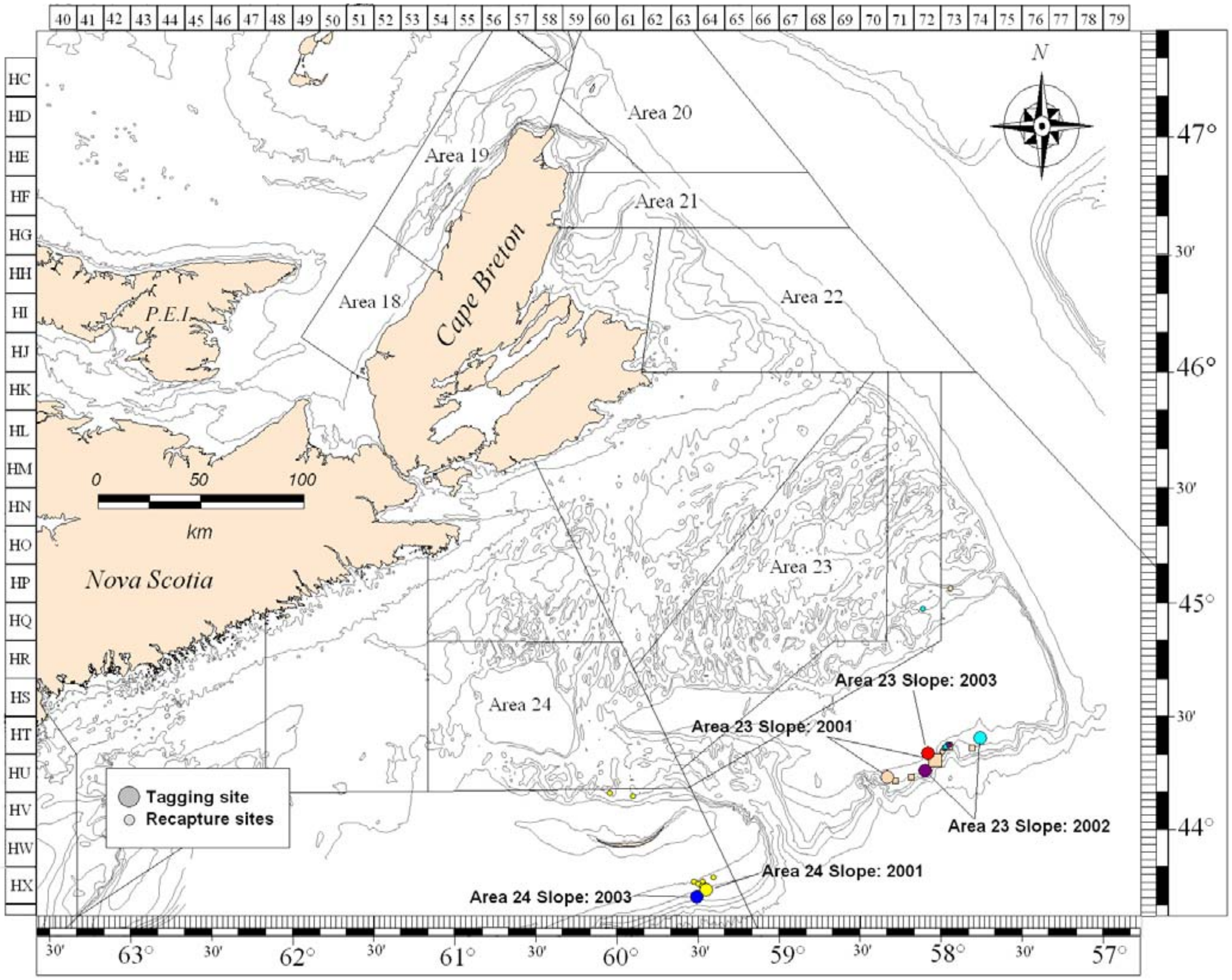


Figure 52. Tag returns from the Scotian Shelf (slope) in 2001, 2002 and 2003.

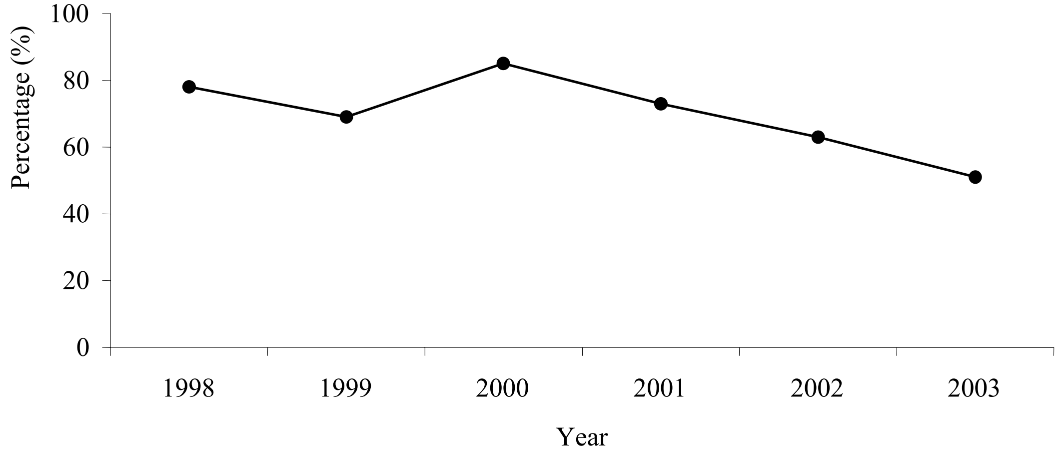


Figure 53. Degree of aggregation (% area above 1000 adult male crab ≥ 95 mm CW / km2) for south-eastern Nova Scotia.

Appendix 1

Classification of carapace stages developed for the Southern Gulf of St. Lawrence stock based on carapace condition, durometer reading and corresponding approximate age after terminal molt.

Category	Stage	Durometer reading	Carapace condition	Approximate age after terminal molt
New soft	1	< 68	brightly colored, iridescent, soft, no epibionts, chelae easily bent.	0-5 months
Clean	2	variable	brightly colored, some iridescence, may have epibionts, chelae not easily bent	5 months- 1 year
Inter-mediate	3	> 68	dull brown dorsally and yellow-brown ventrally, no irridescence, shell abrasion evident, epibionts.	8 months -3 years
Old	4	> 68	carapace very dirty but hard, decay may be present at leg joints, epibionts removable at processing plant.	2 - 5 years
Very old	5	variable	carapace very dirty and may be soft (durometer reading < 68), progression of decay may be evident, epibionts not removable at processing plant.	4-6 years

Appendix 2

Traffic Light Analysis criteria.

Fishery Data			
CPUE (kg)	increase	decrease	below ???
Areal index	increase	decrease	below ???
Abundance index	increase	decrease	below ???
Observer Data			
% soft-shelled	0 to 14.9	15 to 19.9	20 and up
% immature	0 to 9.9	10 to 19.9	20 and up
Size (CW)	increase	decrease	below ???
% skip molter	increase or high	decrease or low	below ???
Survey Data			
Biomass index	increase or high	decrease or low	below ???
Pre-recruits (R3, R2)	increase	decrease	below ???
Recruitment (R1)	increase	decrease	below ???
% Surface	75 and up	50 to 74.9	below 50
Other Data			
Temperature	decrease or low	increase	???