Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

C S A S

Canadian Science Advisory Secretariat

Research Document 2003/018

S C C S

Secrétariat canadien de consultation scientifique

Document de recherche 2003/018

Areas 18 and 19 snow crab, *Chionoecetes opilio*, stock assessment in the southeastern Gulf of St. Lawrence in 2002.

Évaluation de stock du crabe des neiges, *Chionoecetes opilio*, des zones 18 et 19 dans le sud-est du golfe du Saint-Laurent en 2002.

M. Hébert, E. Wade, D. Giard and/et M. Moriyasu

Oceans and Science Branch / Direction des Océans et des sciences
Gulf Region / Région du Golfe
Department of Fisheries and Oceans / Ministère des Pêches et Océans
Gulf Fisheries Centre /Centre des Pêches du Golfe
P.O. Box 5030 / C.P. 5030
Moncton, NB E1C 9B6

ISSN 1499-3848 (Printed)

Canada

ABSTRACT

The 2002 assessment of the southeastern Gulf of St. Lawrence snow crab, *Chionoecetes opilio*, stock (Areas 18 and 19) was done based on data from the commercial fishery (fishermen's logbooks, at-sea observer's measurements, purchase slips from processing plants and quota monitoring reports) and trawl survey.

In **Area 18**, the 2002 quota was increased from 476 t in 2001 to 680 t, but landings only reached 72% of the quota. The fishing effort in 2002 was estimated at 26,414 trap hauls, an increase of 60% compared to 2001 (16,446 trap hauls). As usual, the majority of the fishing effort and landings was located in one or two small areas at the northern bundary of the Area. The average catch rates (CPUE) in 2002 was estimated at 18.6 kg per trap haul (kg/th), an increase of 22% compared to 2001 (15.3 kg/th). The annual percentage of soft-shelled crabs was 5.0%, a decrease compared to 2001 (8.6%). The mean size of commercial-sized crabs in sea samples has been decreasing since 1995 from 118.6 to 106.7 mm of carapace width (CW).

The 2002 trawl survey indicated an increase in the commercial biomass (B) index in Area 18 to 3,438 t ± 36%, which represents a 323% increase compared to the 2001 estimate (1,065 t ± 115%) and the highest record since the beginning of the survey. The index of recruitment to the fishery (3,283 t ± 36%) represents 96% of the biomass index. The high abundance of prerecruits (R-3 and R-2) observed in the 2002 trawl survey could increase the level of recruitment to the fishery for the next two or three years. Although the survey biomass index of commercial-sized crabs was estimated at its highest observed level, the exploitation strategy for next year should be set to allow an accumulation of residual biomass. It is also important to consider the factors of uncertainty (seasonal movement of crabs, possible overestimation of survey biomass index) and some negative signs of the stock condition (low CPUE, decrease in the mean size of commercial-sized crabs and high dependency on the new recruitment). A close in-season monitoring is necessary to protect the future recruitment to the fishery.

In **Area 19**, the 2002 landings decreased by 16% (3,279 t) compared to 2001 (3,910 t). The fishing effort in 2002 was estimated at 46,828 trap hauls, which is comparable to the 2001 level (46,251 trap hauls). The fishing effort was widely spread all over the Area in 2002. The average CPUE decreased by 22.4% from 88.5 kg/th in 2001 to 72.3 kg/th in 2002. The annual percentage of soft-shelled crabs was 3.5%, the lowest level since 1990. The mean size of commercial-sized crabs in sea samples has been decreasing since 1995 from 120.5 to 110.0 mm CW.

The 2002 survey biomass index of commercial-sized crabs (4,930 t ± 30 %) has decreased by 5 and 20% compared to 2001 and 2000 respectively, but still above

the 1993-1998 levels. The index of recruitment to the fishery was estimated at 2,947 t ± 47%, which was comparable to the level of 2001 (2,927 t ± 47%). The 2002 recruitment to the fishery index represents 60% of the total commercial biomass index. The abundance of prerecruits R-2 is at the highest level observed since the beginning of the trawl surveys. In addition, the abundance of prerecruits R-3 has just slightly decreased from 2001. These pulses of prerecruits may maintain recruitment to the fishery for the next 2 or 3 years. Although the survey biomass index of commercial-sized crabs remained relatively high at a level above the 1993-1998 average, the exploitation strategy for next year should be set to allow an accumulation of residual biomass. It is also important to consider the factors of uncertainty (seasonal movement of crabs, possible overestimation of survey biomass index) and some negative signs of the stock condition (decrease in CPUE and the mean size of commercial-sized crabs). A close in-season monitoring is necessary to protect the future recruitment to the fishery.

RÉSUMÉ

Le stock du crabe des neiges, *Chionoecetes opilio*, dans le sud-est du golfe du Saint-Laurent (zones 18 et 19) a été évalué en 2002 à partir des données de pêche commerciale (carnets de bord des pêcheurs, des observateurs en mer, des bordereaux d'achat des usines de transformation et des rapports de contingents) et des relevés au chalut.

Dans la **zone 18**, le contingent est passé de 461 t en 2001 à 680 t en 2002, mais les débarquements ont seulement atteint 72% du contingent. L'effort de pêche en 2002 a été estimé à 26 414 casiers levés, une augmentation de 60% comparativement à 2001 (16 446 casiers levés). Comme d'habitude, la majorité de l'effort de pêche et des débarquements était localisée dans une ou deux petites régions à la bordure nord de la zone. La moyenne des prises par unité d'effort (PUE) en 2002 a été estimée à 18,6 kg par casier levé (kg/cl), une augmentation de 22% comparativement à 2001 (15,3 kg/cl). Le pourcentage annuel des crabes à carapace molle a été de 5,0%, une diminution comparativement à 2001 (8,6%). La taille moyenne des crabes de taille commerciale dans les échantillons en mer a diminué depuis 1995 de 118,6 à 106,7 mm de largeur de carapace (LC).

Le relevé au chalut de 2002 a indiqué une augmentation de l'indice de la biomasse commerciale (B) pour la zone 18 à 3 438 t ± 36%, ce qui représente une augmentation de 323% comparativement à 2001 (1 065 t ± 115%), soit le niveau le plus élevé enregistré depuis le début du relevé. L'indice du recrutement à la pêcherie (3 283 t ± 36%) représente 96% de l'indice de la biomasse commerciale. L'abondance élevée des prérecrues (R-3 et R-2) observée lors du relevé au chalut de 2002 pourrait augmenter le niveau du recrutement à la pêcherie pour les deux ou trois prochaines années. Malgré que l'indice du relevé de la biomasse des crabes de taille commerciale soit le plus élevé à ce jour, la stratégie d'exploitation pour l'an prochain devrait permettre une accumulation de la biomasse résiduelle. Il est aussi important de considérer les facteurs d'incertitudes (déplacement saisonnier des crabes, possible surestimation de l'indice de la biomasse du relevé) et certains signes négatifs de la condition du stock (faible PUE, diminution de la taille moyenne des crabes de taille commerciale et grande dépendance sur le nouveau recrutement). Un suivi serré de la saison de pêche est nécessaire pour protéger le futur recrutement à la pêcherie.

Dans la **zone 19**, les débarquements de 2002 ont diminué de 16% (3 279 t) comparativement à 2001 (3 910 t). L'effort de pêche en 2002 a été estimé à 46 828 casiers levés, ce qui est comparable à celui de 2001 (46 251 casiers levés). L'effort de pêche a été dispersé dans toute la zone en 2002. La PUE moyenne a diminué de 22,4% de 88,5 kg/cl en 2001 à 72,3 kg/cl en 2002. Le pourcentage annuel des crabes à carapace molle a été de 3,5%, soit le plus bas niveau depuis

1990. La taille moyenne des crabes de taille commerciale dans les échantillons en mer a diminué depuis 1995 de 120,5 à 110,0 mm LC.

L'indice du relevé de 2002 de la biomasse commerciale (4 930 t ± 30%) a diminué de 5 et 20% comparativement à 2001 et 2000 respectivement, mais demeure au-dessus des niveaux de 1993-1998. L'indice du recrutement à la pêcherie a été estimé à 2 947 t ± 47%, ce qui est comparable au niveau observé en 2001 (2 927 t ± 47%). L'indice du recrutement à la pêcherie de 2002 représente 60% de l'indice total de la biomasse commerciale. L'abondance des prérecrues R-2 est la plus haute observée depuis le début des relevés au chalut. De plus, l'abondance des prérecrues R-3 n'a que légèrement diminué par rapport à 2001. Ces vagues de prérecrues pourraient maintenir le recrutement à la pêcherie pour les 2 ou 3 prochaines années. Malgré que l'indice du relevé de la biomasse des crabes de taille commerciale soit demeuré relativement élevé, à un niveau au-dessus de la moyenne de 1993-1998, la stratégie d'exploitation pour l'an prochain devrait permettre une accumulation de la biomasse résiduelle. Il est aussi important de considérer les facteurs d'incertitudes (déplacement saisonnier des crabes, possible surestimation de l'indice de la biomasse du relevé) et certains signes négatifs de la condition du stock (diminution de la PUE et de la taille moyenne des crabes de taille commerciale). Un suivi serré de la saison de pêche est nécessaire pour protéger le futur recrutement à la pêcherie.

Introduction

Historic of Area 18 fishery:

Harvesting of snow crab in Area 18 (Fig. 1) began in 1979 by 14 inshore vessels with exploratory licenses, using a maximum of 30 traps per license. These licenses were converted into permanent ones the following year and 9 additional licenses were issued to explore grounds further offshore. Midshore vessels fished these same fishing grounds until 1983. In 1984, Area 18 was exclusively set aside for inshore fishermen. An overall quota initially established at 835 t in 1981 was reduced to 626 t in 1986 and increased to 674 t from 1988 to 1990. In the spring of 1991, a 200 t quota was allocated to promote a spring fishery in this area. A 674 t quota was then set for the fall of 1991 and spring of 1992. This quota was raised to 749 t for 1992-93 and had remained the same until 1995. Since 1992, there have been 30 participants in this fishery. In 1995, 30 temporary (one year) license holders using a total of 26 inshore vessels fished 109 t of the total quota (709 t). The spring fishery was not being actively pursued by participants (the 1995 spring landing was 10 t) and was then abolished to simplify the management of the fishery. In 1996, the total quota was set at 340 t and was fished by the 30 traditional license holders. The fishery was prematurely closed (landings of 306 t) because of a high incidence of soft-shelled crabs and a low CPUE. No temporary licenses were issued due to the predicted declining stock condition. In 1997, the total quota was set at 580 t, but the fishery was prematurely closed for a second consecutive year for the same reasons as in 1996, with landings at 406 t (70% of the total quota). In 1998, landings were 289 t, which corresponds to 70% of the total quota set at 411 t. The fishery was closed three times during the fishing season because of the high percentages of soft-shelled crabs in the catches and the low commercial quality of landed crabs. In 1999, the quota of 408 t was reached for the first time since 1995. For the 2000 fishery, a quota of 408 t was allotted at the beginning of the fishing season and an additional 68 t was added during the season. The quota was reached (landings of 472 t). In 2001, the quota was set at 478 t but landings reached only 53% of the total quota. The 2002 quota was set at 680 t and 487 t (71.6% of the total quota) were landed.

Historic of Area 19 fishery:

In 1978, Area 19 (Fig. 1) was established for the exclusive use of inshore fishermen using vessels less than 13.7 m (45 feet) in length. The number of permanent license holders increased throughout the years from 14 in 1978 to 74 in 1995. Landings, controlled by quota, ranged from 900 to 1,390 t between 1979 and 1991. The quotas, set at 1,686 t from 1992 to 1994, were reached. In 1995, 37 temporary (one year) license holders using 25 inshore vessels fished 134 t of the total quota (1,577 t). In 1996, the 37 temporary license holders were converted into permanent licenses and the 111 permanent license holders fished a quota of 1,343 t. In the same year, a 5-year partnership was signed between the Department of Fisheries and Oceans (DFO) and Area 19 snow crab fishermen's

association (Anonymous, 1996). In 1997, the total quota was set at 1,386 t and was increased to 1,991 t in 1998 (the 1998 landings reached 1,988 t). In 1999, the quota was set at 1,986 t, which represented 63% of the exploitable biomass index. For the 2000 season, a quota of 3,370 t was set and shared between traditional and temporary fishermen according to the co-management agreement (2,702 t to traditionals and 668 t to temporaries). The fishing season was closed before the temporary fishermen had time to finish their quotas because of a high incidence of white crab (hard-shelled crab with low meat yield) in landings and also to permit DFO Science Branch to conduct the trawl survey. In 2001, a new co-management agreement for a period of 9 years was signed between DFO and Area 19 snow crab fishermen. The 2001 quota in Area 19 increased to 3,910 t and was shared between traditional (3,617 t) and temporary (293 t) fishermen according to the co-management agreement. The 2002 quota of 3,285 t, shared between traditional (2,705 t) and temporary (580 t) fishermen, was caught (landings of 3,279 t).

Historic of assessment methods:
Prior to 1990, the biomass of snow crab for the western Cape Breton fisheries (Areas 18 and 19) has been estimated indirectly from catch and effort data using Leslie analysis (Leslie & Davis, 1939; Ricker, 1975). In 1990, a trawl survey with a geostatistical data analysis (kriging) was introduced (Conan & Maynard, 1987) to enhance the precision of snow crab abundance estimation and establish sound stock management strategies. New management measures were introduced in 1991. One of the strategies used was to determine the total allowable catch (TAC) or quota based on the biomass of adult male crabs $\geq$95 mm CW. A second management strategy was to avoid soft-shelled crabs in the catches because they are of poor commercial quality, unable to participate in mating and represent recruits for the following fishing seasons. Soft-shelled crabs are discarded at sea by fishermen. They are fragile and should be carefully handled to avoid mortality before being returned to the sea. Monitoring of soft-shelled crabs in the catches during the fishery can be achieved by using a durometer gauge (Foyle et al., 1989). Since 1997, a protocol for the daily monitoring of the soft-shelled crabs was put in place for the western Cape Breton fisheries. These fisheries could be partially or completely closed when the average of soft-shelled crabs (in number) exceeds 20% over two consecutive periods of two days. In 2002, the protocol for Area 19 was modified as a remedy for enhancing the protection of newly molted crabs for the summer fishery. A new criterion of carapace hardness at 78 units was introduced instead of 68 units for soft-shelled crabs, which is currently used for the spring fishery in the southern Gulf of St. Lawrence. The reason for this change is that newly molted crabs (soft-shelled crabs) exceed the limit of carapace hardness at 68 units in the summer. In Area 18, an individual boat quota was established from 1991 to 1997 based on the trawl survey results. In 1998 and 1999, the quota was established using only the information on the fishery performances, i.e., catch per unit of effort (CPUE)

and percentage of soft-shelled crabs. In Area 19, an individual boat quota has been established since 1991 in collaboration with the industry based on the trawl survey results.

Materials & Methods

Fishery monitoring:
Raw data on catches and fishing effort were obtained from the fishermen's logbooks and the sales slips of processing plants. The data were compiled by the Informatics and Statistics Branch of Gulf Regions of the Department of Fisheries and Oceans and re-verified by the Science Branch. Not all logbooks were usable. The mean CPUE of the fleet at year (i) corresponds to the ratio of total catches from sales slips (where available) or the fishermen's logbooks (y_i) and the corresponding number of trap hauls (th_i) reported in the logbooks: $CPUE_i = \sum y_i / \sum th_i$. The total effort (total number of trap hauls: (TH_i) was then estimated by total landings (Y_i) from the quota report divided by average $CPUE_i$: $TH_i = Y_i/CPUE_i$. The geographic distribution of fishing effort was presented as the sum of the total number of trap hauls within each grid of 5 minutes latitude by 5 minutes longitude. The fishing positions were taken from logbooks. In Area 19, the fishing performance between the traditional and temporary fishermen is different (DeGrâce et al., 2001) and in order to better compare the annual CPUE, from 1998 to 2002, only data from traditional fishermen were used.

Since 1990, DFO has been conducting a sampling program (observer program) on board commercial vessels (Fig. 2) to provide a weekly assessment of the percentage of soft-shelled crabs in the catches. For each trap sampled, the position, depth and total number of male crab were recorded. A sub-sample of 40 crabs was chosen randomly and the following measurements were taken: carapace width (CW), chela height (ChH), carapace condition (CC: Hébert et al., 1997) and hardness of the carapace (CH) measured at the base of the right propodus with a durometer (Foyle et al., 1989).

The catch composition (% of different categories of crab) was estimated based on the carapace hardness (hard or soft), size (legal and sub-legal), and morphometric maturity (adolescent and adult). The terminology described by Sainte-Marie et al. (1995) is used in this paper; ‘‘adolescent‘‘ formerly called morphometrically immature and ‘‘adult‘‘ formerly called morphometrically mature (Conan & Comeau, 1986). Individuals with carapace conditions 1 and 2 and claw hardness less than 68 on the durometer were considered as soft-shelled crabs (Hébert et al., 1992). The annual and weekly mean percentages of soft-shelled crabs were calculated based on the size distributions obtained at-sea and at-port samplings, then weighted by the landing for each sampled vessel (Hébert et al., 1992).

Trawl survey:
A trawl survey has been conducted since 1990 in the southeastern Gulf of St. Lawrence except for 1997 and 1998 (no survey has been conducted in Area 18) to evaluate the commercial biomass and population dynamics. From 1990 to 1992, the trawl survey in Areas 18 and 19 was conducted before the fishing season but since 1993, the trawl surveys were conducted after the fishing season. From 1990 to 1998, the "Emy-Serge", (65 feet side-trawl wooden boat with 375 HP), was used to conduct the trawl survey. Since 1999, the "Den C. Martin", (65 feet stern-trawl steel boat with 402 HP), has been utilized to conduct the survey. The "Emy-Serge" was sold, which rendered us unable to perform a comparative study between the two boats. Without a comparative study between the two survey vessels, the biomass estimates from both time series could not be compared. It was also decided at the last RAP meeting (Anonymous, 2001) that the 2000 biomass estimate from the 1999 trawl survey was not considered to be reliable due to the malfunction of the Netmind® sensors and the difficulty to calculate the swept area by the trawl. This problem was resolved for the 2000 trawl survey by calibrating the distance sensors and adding a Netmind® depth sensor and a Minilog® depth-temperature probe to the trawl to better monitor the touchdown of the trawl net.

A systematic random sampling design was used to determine the location of trawl stations (Fig. 3). One to two locations were randomly chosen among nine sub-grids (station in the middle of the grid) within each grid of 10 minutes latitude by 10 minutes longitude. The center of each sub-grid chosen was used as the position of each trawl station. The starting and ending positions and time of each tow, depth and bottom water temperature were recorded. Once the locations of each tow were determined, they remained fix every year. A Bigouden *Nephrops* trawl net originally developed for Norway lobster (*Nephrops norvegicus*) fisheries in France was used (20 m opening with a 27.3 m foot rope on which is mounted a 3.2 m long, 8 mm galvanized chain; Conan et al., 1994). All stations were trawled during daylight time. For each tow, the predetermined amount of warp was let out (3 times the distance of the depth) and winch drums were locked. The start time of a standard tow was determined when the trawl touched the bottom monitored by the Netmind® depth sensor (signal received at every 7 seconds) and the Minilog® temperature-depth probe (signal received at every 3 seconds) attached to the trawl. The duration of each tow varied between 4 to 6 minutes at an average speed of approximately 2 knots depending on the depth, current speed and sediment type. The catch of each tow was photographed after the catch had been released to the deck and downloaded on a computer. The horizontal opening of the trawl was measured every 4 seconds with the Netmind® distance 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, unpublished). The following information was recorded for all captured individuals: CW, ChH, CH and CC for males; CW, width of the 5th abdominal segment (AW)

and CC for females. The color of the eggs of mature females and the color of the gonads of immature females were noted.

A kriging (MPGEOS) program (Wade et al., unpublished) for snow crab stock assessment in the southern Gulf of St. Lawrence was used to estimate annual abundance and density contours for both males and females based on their size and maturity status. Using point kriging and a fitted variogram, we generated maps of density and variance contour. We further used block kriging for estimating an average density and variance to estimate the total number of crab present in a given area. The abundance of snow crab estimated by kriging was converted into biomass (called biomass index hereafter) using a size-weight relationship. To convert size to weight, a size-weight relationship was calculated for adult hard-shelled males: $W = (2.665 \times 10^{-4}) CW^{3.098}$ (Hébert et al., 1992). Mortality between the survey and the fishing season (8-9 month period) was considered as null except for category-5 crabs (very old carapace). 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), and (3) biomass of category-5 crabs (OB). The abundance indices of future recruitment to the fishery (R-3 and R-2) were also estimated. The R-3 group represents the adolescent crabs with a CW between 69 and 83 mm caught at the time of the survey, which a portion could be available for harvesting in 3 years. The R-2 group represents the adolescent crabs with a CW larger than 83 mm caught at the time of the survey, which a portion could be available for harvesting in 2 years.

Seasonal movement of commercial-sized males:
In the previous RAP sessions, a hypothesis of seasonal movement from the Cape Breton corridor toward Cape Breton gully was proposed (Moriyasu, unpublished). If there is an incoming commercial biomass into the Cape Breton gully (Area 19) after the fall trawl survey, it may suggests that the traditional calculation of exploitation index was overestimated. In order to examine this hypothesis, an additional trawl survey (54 stations, Fig. 3) has been conducted after the regular fall trawl survey in 2001 and prior to the following fishing season in July 2002. The biomass and its distribution of all commercial-sized adult males in the fall 2002 and commercial-sized hard-shelled adult males in the summer 2002 were compared. Finally, based on these results, the level of exploitation was re-estimated.

Abundance of adult males, pubescent and spawning females and Sex ratio in the southeastern Gulf of St. Lawrence:

The hypothesis on the crab movement from the northwest towards the southeastern area of the southern Gulf of St. Lawrence throughout their life cycle was discussed at the 2001 RAP session as one of the causes for the differential stock fluctuation pattern between southwestern Gulf (Areas 12 & 12E) and southeastern Gulf (Cape Breton corridor portion of Areas 12, 18, 19 & 12F). Subsequent analyses on geographic distribution of different instars revealed that the snow crab population was distributed without interruption between the two units (Moriyasu et al., 2001). However, it is thought that this approach is still valid especially when assessing global trends in the southeastern Gulf because of possible active seasonal migration of crab within this unit. The boundary between the two units was set at 62˚10 ‘ (Fig. 1) based on the historical fishing effort and fishable biomass distributions.

Within the southeastern unit, the abundance indices of pubescent and spawning (primiparous and multiparous) females were estimated to verify the sex ratio. The term pubescent defines females with a narrow abdomen and orange gonads during the period of trawl survey (July – September) that would molt to maturity the following winter (February) as nulliparous females, mate, extrude fertilized eggs and become primiparous (first brood). The term multiparous defines females, which are in their second brood or older.

The sex ratio (SR) was calculated as the quotient of functionally mature females and males (ready to mate) (Emlen & Oring, 1977). For snow crab, the ratio was calculated as a half of the abundance of mature females (F_m) on the abundance of adult males with a CW larger than 95 mm (M_L). The females that are ready to mate in the subsequent mating season have to carry developed eggs during the survey period (July-September). However, it is difficult to distinguish between clear orange eggs 3-7 month earlier from dark orange eggs 15-17 months earlier during the summer trawl survey onboard the survey vessel. Therefore, half of the abundance of mature females was used as an approximation for the abundance of spawning females carrying well developed embryo based on the assumption of a 2-yr embryonic development cycle (Moriyasu & Lanteigne, 1998). This ratio (SR_{mL}) represents the sex ratio for the re-mating sequence (SR: males vs. multiparous females) in the following spring. For the first mating sequence (males vs. pubescent females), the sex ratio (sr) was calculated as a quotient of the abundance of pubescent females (F_p) on the abundance of either total adult males (M_T) or those with a CW $\geq$ 95 mm (M_L). Lovrich et al. (1995) observed that large adult males tend not to move to shallower waters to mate with pubescent females and the mating occurs mainly between pubescent females and smaller adult males. This behavior may not be so static as described by these authors and rather vary depending on the inter- and intra-sexual density and size dependent

factors (Sainte-Marie et al., 1999; Rondeau & Sainte-Marie, 2001; Sainte-Marie et al., 2002; Sainte-Marie, pers. comm.).

Results and Discussion

Area 18:

Fishery information: In 2002, the fishery in Area 18 was opened on April 15 and closed on August 10. The fishery was inactive between June 1st and July 3rd. The 2002 quota was increased from 476 t in 2001 to 680 t, but landings only reached 72% of the quota (Table 1, Fig. 4). The fishing effort in 2002 was estimated at 26,414 trap hauls, an increase of 60% compared to 2001 (16,446 trap hauls) (Table 1). As usual, the majority of the fishing effort and landings was located in one or two grids at the northern boundary of the Area (Figs. 5 & 6). The average CPUE in 2002 was estimated at 18.6 kg/th, slightly higher than 2001 (15.3 kg/th) (Table 1, Figs. 7 & 8).

Sea sampling provided a good coverage of the main fishing grounds in the western Cape Breton (Areas 18 and 19) fisheries in 2002 (Fig. 2). In Area 18, a total of 78 traps were sampled (3.5% trips covered) and 3,063 males were measured during the 2002 fishing season. The percentage of trips covered was similar to the 2001 season but the numbers of trap sampled and crabs measured were higher than the 2001 season (56 traps, and 2,179 crabs, respectively). The annual mean percentage of soft-shelled crabs decreased to 5.0% in the 2002 fishing season compared to 8.4% and 8.6% in 2000 and 2001, respectively (Table 1, Fig. 9). The weekly percentage of soft-shelled crabs varied between 0.5 and 13.9% (Fig. 10). A higher percentage of white crab appeared in the fishing grounds near the northern boundary, but no closure of the fishery occurred in 2002 (Fig. 11). The catch composition (Table 2) changed in 2002 compared to 2001. A continuous increase in percentage of “pigmy” crab (adult males of sub-legal size) has been observed since 2000 (19.5% in 2000, 42.1% in 2001 and 47.1% in 2002). The percentage of skip molters increased from 5.3% in 2001 to 8.6% in 2002, whereas the percentage of soft-shelled crabs has been stable since 2000 (around 5.7%). The commercial catch composition by carapace condition (Table 3) showed an increase in the percentage of commercial-sized adult males of carapace conditions 1+2 (soft/white) and crabs in carapace condition 3 became the main component of the fishery in 2002. A continuous decrease in the percentage of commercial-sized adult males of carapace condition 3 in the catches since 1999 (Table 3) followed by a sudden increase in 2002 suggests the change in population phase, i.e. ageing of the former generation replaced by a new recruitment wave. Size frequency distributions of male crabs caught at-sea (Fig. 12) also showed a sudden change in size structure in 2002. The high fishing pressure on the commercial biomass resulted in a gradual decrease of the larger-sized animals. Size distributions of male crabs by carapace condition from the at-sea sampling (Fig. 13) showed that new males (carapace conditions 1 and 2) were extremely scarce in the commercial

catches in 2002. In addition, the percentage of older crab increased towards smaller size classes (Fig. 13). This may be the result of size-preferential fishing activity or size-dependent catchability difference. However, the mean size has still been continuously decreasing since 1995 from 118.6 mm CW to 106.7 mm in 2002 (Fig. 14). The mean size may continue to decrease until a new wave of recruitment to the fishery arrives.

Trawl survey: The commercial biomass index (B) at the time of survey (without considering the natural mortality) was estimated at 3,438 t (±36%), which represents a sudden increase of 323% compared to the 2001 projection (Table 4, Fig. 15). This biomass index was concentrated in the mid-western border between Area 12 and 18 with another patch of lesser abundance in the northwestern corner of Area 18 (Fig. 16). The index of recruitment to the fishery (R) was estimated at 3,283 t (± 36%) constituting 96% of the commercial biomass index. Although the commercial biomass indices cannot be compared during the two periods of 1991-92 and 1993-2002 due to the difference of timing of the survey (in 1991 and 1992, the survey was conducted between spring and fall seasons, while, since 1993, the survey has been conducted after the fishing season), we can assume that we have had two peaks (1992 and 2002) of the commercial biomass index since 1991.

The abundance of prerecruits R-3 (Fig. 17) has remained at a high level since 2000, varying between 6.1 and 7.2 million of individuals. A high abundance of R-3 was also observed in 1995 (7.3 million). The abundance of prerecruits R-2 has been continuously increasing since 2000 from 3.9 to 4.9 million in 2002, reaching almost the same level as 1995 (5.0 million), which was the highest abundance of R-2 in the past decade. However, the high abundances of prerecruits (R-2 and R-3) did not necessarily result in a subsequent high abundance of fishable biomass index. The projected geographic distribution of adolescent crabs ≥ 56 mm CW in the 2000 survey (Fig. 18) coincided well with the geographic distribution of commercial-sized males in the 2002 survey. The projected geographic distribution pattern of adolescent males ≥ 56 mm CW in 2001 has changed from that seen in 2000, i.e. two highly concentrated patches found within Areas 18 and 19 in 2000 were more diffused over the southeastern Gulf in 2001. This pattern was maintained in 2002. This may result in a higher incidence of soft/white crabs during the 2003 season over the fishing grounds in the southeastern Gulf if the fishing pressure is too high. The biomass index of category 5 (very old crab) was low (76 t ±191%).

Size distributions of crabs caught in the trawl survey (Fig. 19) showed a continuous growth of younger instars found in 1999 towards larger size categories. The comparison of histograms since 1990 suggests that a high abundance of prerecruits has occurred three times in the past (1990, 1995 and 2001). Hébert et al. (2002) stated that although the size distributions in 2001 suggested a potential for a significant increase in fishable biomass in the near future within this fishing area, the abundance of prerecruits may not necessarily contribute to the future

biomass as it is uncertain whether this potential recruitment to the fishery will stay within the area after molting to adult phase. It seemed that these prerecruits stayed after molting to adult phase and will become the main component of fishable biomass for the 2003 season, contrary to what happened with abundant prerecruits observed within the Area in 1995-1996. The mechanism of retention of prerecruits and fishable biomass in this Area is still unknown.

Area 19:

Fishery information: The 2002 fishing season started July 8 and closed September 11 with a total quota of 3,280 t. During June (1-21), four vessels fished approximately 87 t in order to collect funds for the DFO/Area19 agreement. For Area 19, the landings have increased since 1996 and reached the highest level ever recorded for this Area in 2001 (3,910 t) (Table 5, Fig. 20). In 2002, the landings decreased by 16% (3,279 t). The traditional and temporary fishermen caught their quota (total of 3,285 t) by the 9th fishing week. Seventy-three temporary fishermen started fishing on July 25th (first landings occurred on July 26th) with an individual quota of 7.95 t (17,495 lbs). The 2002 landings mainly came from the southern part of Area 19. There was a reduction in fishing effort in the northwestern fishing grounds compared to 2001, while a greater coverage of the entire surface of Area 19 was observed in 2002 (Fig. 6). The average CPUE in 2002 (72.3 k/th) decreased by 22.4% compared to the 2001 level of 88.5 kg/th, but slightly higher than 2000 (64.1 kg/th, Table 5). CPUEs greater than 40 kg/th were homogeneously distributed over the entire Area 19, but high CPUEs greater than 80 kg/th significantly decreased compared to the 2001 season (Fig. 8). The weekly CPUE (Fig. 21) started at 113 kg/th during the first week of the fishery and had gradually decreased to 14 kg/th by the 9th fishing week. The weekly trend in the fluctuation of the mean CPUE was identical to the 2000 season. The fishing effort (46,828 trap hauls) was comparable to the 2001 season (Table 1). Contrary to the historical fishing trend, the fishing effort was widely spread all over Area 19 including the northern (hard bottom) zone (Fig. 5).

Sea sampling provided a good coverage of the main fishing grounds in the western Cape Breton (Areas 18 and 19) fisheries in 2002 (Fig. 2). In Area 19, a total of 257 traps were sampled (4.9% coverage) in 143 trips out of 2,912 trips with 10,159 males measured. The coverage by observers was comparable to that in 2001 (233 traps in 128 trips with 9,299 males measured amongst 2,920 trips). The weekly percentage of soft-shelled crabs (Fig. 21) was negligible throughout the season. The seasonal average percentage of soft-shelled crabs (3.5%) decreased significantly from 2001 (6.5%) and in 2000 (5.6%) (Table 5, Fig. 23).
The seasonal catch composition from the observer data (Table 6) is identical between the last two seasons, except for a slight increase in the percentages of skip molters and pigmy crabs. In 2001, the percentage of commercial-sized adult males (Table 7) of carapace conditions 1 and 2 (8.3%) decreased significantly compared to the 2000 season (16.6%), but maintained the same level in 2002 (8.8%). This percentage does not necessarily coincide with soft-shelled crab

percentages, because the soft-shelled crab percentage includes all male crabs caught by trap, whereas the carapace condition was estimated based on the commercial-sized males only. The percentage of commercial-sized crab (carapace condition 4) has continuously increased between 1997 and 2001, but significantly dropped to 20.6% in 2002. Commercial-sized crabs with a carapace condition 5 have been at a stable level between 0.3 and 0.8% in the past four seasons. The mean CW has been continuously decreasing since 1995 from 120.5 mm to 110.0 mm (Fig. 24). In addition, a bi-modal distribution pattern has appeared since 2000 compared to a uni-modal distribution pattern in 1997-1999 (Fig. 25) with a pronounced decrease in the larger-sized component towards 2002. Decomposition of the histograms in 2002 into carapace conditions (Fig. 26) showed that the larger mode group was comprised of more new crabs (carapace conditions 1 and 2) than the smaller mode group (mainly carapace conditions 3, 4 and 5). This phenomenon may have been caused by size-preferential fishing activity or size-dependent catchability difference. The mean size may continue to decrease in the future until new waves of recruitment to the fishery arrive.

Trawl survey: The commercial biomass index (B) at the time of the survey (without considering the natural mortality) was estimated at 4,930t (±30%), which was a decrease of 5 and 20% from the 2001 (5,214 t ± 32%) and 2000 (6,210 t ± 18%) estimates, respectively (Table 8, Fig. 27). The three main patches of concentrations were observed in the southern, middle and northwestern parts of the Area showing a similar pattern compared to that of 2001 (Fig. 15). The index of recruitment to the fishery (R) was estimated at 2,947 t (± 47%), which was comparable to the level of 2001 (2,927 t ± 47%). The 2002 recruitment index represents 60% of the total commercial biomass index. In 2001, the abundance indices of future recruitment to the fishery, both R-3 and R-2, were observed at their highest level since 1991 reaching 21.8 and 14.1 million, respectively (Fig. 28). In 2002, the abundance index of R-3 slightly decreased to 19.4 million, whereas R-2 (14.3 million) was at a comparable level to that of 2001. As the biomass index of recruitment decreases, the catch composition of the 2003 season will shift towards older crabs. In addition, with the arrival of an increased abundance of prerecruits (R-2 and R-3), a high incidence of soft/white crab is anticipated if the fishing effort is too high. The biomass index of very old crab, which has continuously increased between 1999 and 2001, has dropped drastically from 206 t (± 96%) in 2001 to 27 t (±134%) in 2002.

Size frequency distributions of crab caught in the trawl survey (Fig. 29) have been available since 1991. In Area 19, the size distribution pattern seemed to be different compared to that of Area 12. There have been uninterrupted appearances of small instars (absence of trough) throughout the years since we did the survey. There was also no evidence of a lack of medium-sized adolescents during these years. In 1991 and 1992, the progression of modes was not apparent. Since 1993, a continuous appearance of many instars and their progression (growth) has been observed. In 1996, six distinct modes (21.5 mm CW, 30.5 mm CW, 42.5 mm CW,

60.5 mm CW, 77.5 mm CW and 93.5 mm CW) of adolescent males corresponding to instars VI, VII, VIII, X, XI and XII were observed. Although the general tendency for the progression of modes was observed between 1996 and 1999, the density of each instar cannot be properly investigated due to the *Nephrops* trawl net selectivity. The continuous appearance of small instars in this Area may be explained by: (1) the larvae hatched from females in other Areas may be transported towards the southeastern Gulf (J. Chassé, pers. comm.) or (2) the movement of smaller-sized instars from the southwestern to the southeastern area of the southern Gulf of St. Lawrence (Moriyasu et al., 2001). The hypothesis of larval transportation towards the southeastern Gulf from the southwestern Gulf may compensate for years of low recruitment within the southeastern unit, which may result in a continuous supply of larval settlement in this area. Although smaller instars (VI, VII and VIII) seemed to appear in abundance, a lower abundance of instars IX and X may result in a decline of fishable stock in the future. This sign of future decline in commercial stock appeared in the abundance index of R-3 in 2002. However, these instars were observed in the adjacent Area 18 (Fig. 19). The migration of these instars towards Area 19 might sustain a higher biomass index in Area 19 in the future.

Movement of adult males in the southeastern Gulf of St. Lawrence:
Seasonal movement between Areas 12 and 19 was elucidated by the comparison of results between regular September 2001 and June 2002 surveys, which showed an incoming biomass to Area 19 after September and prior to the 2002 fishing season. The September 2001 survey estimated the biomass of commercial-sized adult males at 5,214t (±32%), whereas the 2002 June survey estimate was at 5,890t (±23%). The geographic distribution of commercial-sized adult males showed a dispersed pattern in September 2001, while the distribution in June 2002 showed a crab concentration into the Cape Breton trough (Area 19)(Fig. 30). The increase in biomass of commercial-sized adult males from September 2001 to June 2002 together with the significant change in their geographic distribution pattern provides a clear evidence of seasonal migration of commercial-sized adult males toward the Cape Breton trough (Area 19) prior to the summer fishing season. This may be one of the reasons for a much higher level of CPUE in Area 19 compared to that in Area 12.

The cause of this seasonal migration of adult males into the Cape Breton trough (Area 19) is uncertain. Differential changes in bottom water temperature in the shallower part and in the Cape Breton trough in the southeastern Gulf of St. Lawrence may affect the seasonal distribution of crabs. There was evidence of a gradual bottom temperature warming in Areas 18 and 19 between July 2001 and June 2002 by 1-1.5°C. However, this is rather abnormal in temperature variation and not a recurring temperature fluctuation over years and may not be a cause of this migration. Based on the available temperature data, there is no evidence for a strong seasonal cycle in the deep waters of the Cape Breton trough or in depths

below 100 m in Areas 18 and 19 (K. Drinkwater, pers. comm.). As the mature (primiparous and multiparous) and pubescent females are concentrated in the Cape Breton trough (Figs. 31 & 32), the seasonal concentration of adult males into the Cape Breton trough may be a mating migration as observed in other regions in Atlantic (Taylor et al., 1985; Lovrich et al., 1995) although the direction of migration from shallower to deeper waters in the southeastern Gulf as opposed to deeper to shallower waters in other locations.

The exploitation index used for the 2002 season at 63% (= 3,280t / 5,214t) was overestimated and should has been considered to be 56% (= 3,280t / 5,890t). However, we do not feel that readjusting the exploitation index by considering incoming biomass from Area 12 would vary depending on the stock abundance within and outside Area 19 and incur an overexploitation of the stock and is therefore, not recommended.

The commercial biomass index in the southeastern Gulf of St. Lawrence and also in the Cape Breton corridor has been continuously increasing since the mid 1990's (Fig. 33). In Area 19 and in the Cape Breton corridor, there was a slight decrease of the commercial biomass over the last three years, which was compensated by a higher biomass in Area F (Hébert et al., 2003) and extremely high biomass in Area 18 in 2002 (Fig. 33). Concurrently, the number of fished grids and the total landings in the Cape Breton corridor has been increasing (Fig. 34). The commercial biomass index in the Cape Breton corridor for the 2002 season was estimated at 3,219 t (± 48%). The landings registered during the 2002 season in this area were estimated at 1,830 t, resulting in an exploitation index of 57% (without considering commercial biomass migration toward the Cape Breton trough).

The amount of commercial-sized adult males migrating from the Cape Breton corridor toward Area 19 in the spring-summer and their dispersion over the Cape Breton corridor, presumably in the fall, may differ from year to year depending on the biomass level, the fishing effort and its distribution pattern in each fishing unit in the southeastern Gulf of St. Lawrence.

Sex ratio in the southeastern Gulf of St. Lawrence:

The abundance index of adult males ≥ 95 mm CW (Fig. 35) increased from 13 to 24 million of individuals from 1991 to 1992. From 1992 to 1995, the abundance index decreased from 24 to 10 million (Fig. 35). Since 1995, the abundance index has continuously increased to reach 27 million in 2002 (Fig. 35). The abundance index of total adult males followed similar pattern as the adult males ≥ 95 mm CW (Fig. 35) and reached 48 million individuals in 2002 (Fig. 35).

The abundance index of pubescent females decreased from 2 to 1 million from 1991 to 1992 and has increased until 1994 to reach 15 million, then decreased to 10 million in 1995 (Fig. 35). From 1995 to 2000, the abundance index increased from 10 to 19 million (Figs. 35). The abundance index decreased to 10-12 million

in 2001-2002. In 2002, the main concentrations of pubescent females in the southeastern Gulf of St. Lawrence were located in the Cape Breton trough (Fig. 31).

The abundance index of spawning females was at its highest level (72 million) in 1991, but decreased significantly to 48 million in 1992 and again to 28 million in 1993 (Fig. 35). The abundance index of these females fluctuated between 27 and 38 million until 2000. The index has increased to 40 million in 2001 and to 43 million in 2002. The main concentrations of spawning females in 2002 were located mostly in Areas 18 and 19 (Fig. 35).

The sex ratio, within the southeastern Gulf, between pubescent females and all adult males or adult males ≥ 95 mm CW has always been close to or less than 1 female vs. 1 male (1F:1M) ratio since 1991 (Fig. 36). For the spawning females, the ratio was highly biased towards female dominance (6F vs. 1M in 1991 and 4F vs. 1M in 1995). Except for these two years, the ratio varied between 3F:1M (1997-1999) and 2F:1M (1992-1994, 2000-2002) (Fig. 36).

The current abundance of pubescent females in the southeastern Gulf is relatively high and recently, there is a sign of increase in abundance of mature females. Therefore, there is no sign of decline in spawning population for the near future. Orensanz et al. (1998) stated that ‘‘crab stocks offer a unique opportunity to monitor and timely detect signs of recruitment overfishing and depensation directly, based on expedient and objective analysis of female clutch size variation in time and space‘‘. Hébert et al. (2003) showed that a biased sex ratio may result in a lesser reproductive output (less fecundity), especially in multiparous females. The sex ratio in the southeastern Gulf seems to be in a better level compared to the southwestern Gulf (Hébert et al., 2003). However, there was no assessment of reproductive output (e.g. fecundity study) in the southeastern Gulf of St. Lawrence, and the population reproduction potential cannot be fully evaluated. In addition, there is no evidence of local spawning stock vs. recruitment relationship i.e., the early benthic stages on the western Cape Breton fishing grounds may always be fed by larval drifting from other areas. In this context, until the spawning stock vs. recruitment relationship is clearly established, it is recommended to apply a conservative approach in order to promote the enhancement of reproductive potential at a pan-Atlantic level. In the southeastern Gulf of St. Lawrence, an upward trend in abundance of pubescent and new mature females has been occurring, which suggests a necessity for the protection (i.e. lower exploitation) of the larger males with carapace conditions 3 and 4 (the most reproductive group of adult males) to ensure the maximum fertilization of brood. Any increase in exploitation compared to the current level in the southeastern Gulf of St. Lawrence may not improve population reproductive potential in the future.

Uncertainty

Since we first estimated the commercial biomass index in 1991, we have not considered any natural mortality in our projection. We have also assumed that the catchability of the trawl is 100% for commercial-sized crabs. As such, the biomass projection should be considered as a relative abundance, although managers and clients have been using the mid-values of our estimates as absolute abundances. Some concern was expressed during a recent Zonal Assessment Process meeting held in Newfoundland in January 2002 (reference) about this issue. Although complementary information concerning possible losses has been presented at the Regional Assessment Process (RAP) meetings since 1999, it is felt that discrepancies between the expected and observed values from the simple forward projection model be explicitly considered as the natural mortality in the assessment process. According to Wade et al. (2003), the natural mortality for commercial-sized crabs was estimated from 26 to 40% between the time of the survey and the following fishing season. It is important that the abundance and biomass indices of the different categories of crabs should not be considered as the absolute values since the natural mortality, the emigration or immigration of crabs after the survey and the catchability of the trawl are not considered in the biomass estimation.

Environmental conditions

Environmental factors, such as water temperature, can affect the molting and reproductive dynamics as well as the movement of crab. According to Tremblay (1997), the annual water temperature on the bottom of the Scotian Shelf has been showing a decreasing trend since 1984, which should be favorable to an expansion of the snow crab habitat. Drinkwater et al. (2003) also reported that the bottom temperatures over most of the southern Gulf of St. Lawrence are less than 3 °C, which is considered ideal thermal habitats for snow crab. Tremblay (1997) reported that snow crab was more abundant near the southern limit of the Scotian Shelf where the bottom temperatures were less than 3 °C. Water temperature data collected by Swain (1993) revealed that the bottom temperatures in deeper waters of Area E are higher (1 to 5 °C) than traditional crab grounds (-1 to 0 °C) in Area 12 (50 to 100 m). Drinkwater et al. (2003) reported that the bottom temperatures in areas 18 and 19 are typically 1°-2 °C warmer than the traditional crab grounds in Area 12. For example, approximately 80% of the trawled area during the snow crab survey in Area 12 in 2002 was coverted by water of temperatures of < 1.5 °C whereas in Areas 18 and 19, it was < 3 °C. Near-bottom temperatures at most depths in Areas 18-19 during 2002 were generally observed to be warmer than the long-term (1971-2000) average and increased relative to 2001. This is consistent with the decrease in the Gulf wide snow crab habitat index (area of the bottom covered by water temperatures between –1 and 3 °C) and the increase in the average temperature within this area. In spite of the increase, the temperature conditions are still considered favorable for snow crab.

Prognosis

Area 18

Negative elements:

- The mean size of commercial-sized crabs in sea samples has been decreasing since 1995.

Alarming elements:

- The relative abundance of future recruits is at its highest level since 1993, which will result in a high incidence of soft-shell/white crabs during the 2003 fishing season depending on the fishing effort (quota).

Positive elements:

- The biomass/abundance indices of adult legal-sized males projected for 2003 increased significantly.
- The abundance of future recruitment slightly increased despite of very large confidence intervals.
- There is a good potential of increasing abundance of commercially exploitable crab for a couple of years although this depends largely on the extent of fishing effort in the adjacent fishing Areas (Areas 12 and 19) and also on the seasonal movement of crab in and out of the area.

Recommendations:

- For 2003, it is strongly recommended that the fishery be partially or totally closed as soon as the catches of soft/white shelled crabs exceed 20% in order to protect the future recruitment to the fishery.
- It is difficult to suggest a sound long-term fishing strategy for Area 18, because the main fishing activities occur in a limited portion of the Area (about 2-3 10'x10' grids at most) and of probable active seasonal movement between Areas 18, 19 and 12. Although the survey biomass index of commercial-sized crabs was estimated at its highest observed level, the exploitation strategy for next year should be set to allow an accumulation of residual biomass.

Area 19

Negative elements:

- The 2002 survey commercial biomass index decreased by 5 and 20% compared to the 2001 and 2000 survey estimates, respectively.
- The mean size of commercial-sized crabs in sea samples has been decreasing since 1995.

Alarming elements:

- Increasing abundance of pubescent females and decreasing abundance of most fertile males (adult males of carapace conditions 3 & 4) are simultaneously occurring in this Area. As such, extensive exploitation of the stock may not be beneficial to the long-term reproduction of the stock.
- The CPUE in 2002 (72.3 kg/th) decreased compared to the 2001 season (88.5 kg/th).
- High abundance of prerecruits together with a decreasing trend in commercial biomass index may result in a high incidence of soft-shelled/white crabs during the next couple of years depending of the exploitation level (quota).
- The sex ratio seems to be at a better condition level compared to the southwestern Gulf of St. Lawrence population (but see #2 in negative elements).

Positive elements:

- The relative abundance of prerecruits (R-2) was at its highest level ever recorded since the beginning of the survey. In addition, the prerecruits (R-3) decreased slightly from that in 2001, which could maintain the level of recruitment for a couple of years.

Recommendations:

- For 2003, it is strongly recommended to follow the soft-shelled crab protocol in order to protect the future recruitment to the fishery.
- Although the survey biomass index of commercial-sized crabs remained relatively high at a level above the 1993-1998 average, the exploitation strategy for next year should be set to allow an accumulation of residual biomass.
-

Research Recommendations

- The results of the trawl net efficiency and crab mortality projects conducted in the southern Gulf of St. Lawrence have to be applied to the southeastern stock in order to improve abundance estimations;
- Double trawl survey (regular fall and pre-fishery spring surveys) provided important information on the seasonal movement of adult males and is worth trying regularly in the future to verify the seasonal migration and to quantify the incoming migration into the Cape Breton gully (Area 19);
- Enhance monitoring of the key events on the population reproductive output has to be done in the southeastern Gulf of St.-Lawrence (fecundity, spermathecal load, recruitment to the early benthic stages).

Acknowledgements

The authors wish to thank P. DeGrâce, C. Sabean, and R. Ruest (DFO, Moncton, N.B.) for their assistance in preparing the manuscript. We also wish to thank Drs J. Chassé, K. Drinkwater (DFO, Halifax, N.S.) and Dr. B. Sainte-Marie (DFO, Mont-Joli, Que.) for their valuable information.

References

Anonymous, 1996. Fisheries Management Plan. Area 19 snow crab 1996 to 2001. DFO. Integrated Fisheries Management Plan.

Anonymous, 2001. Southern Gulf snow crab. DFO Science Stock Status Rep. 2001/C3-01.

Conan, G.Y. & Comeau, M. 1986. Functional maturity of male snow crab, (*Chionoecetes opilio*). Can. J. Fish. Aquat. Sci. 43: 1710-1719.

Conan, G. Y. & Maynard, D.R. 1987. Estimates of snow crab (*Chionoecetes opilio*), abundance by underwater television – a method for population studies on benthic fisheries resources. J. Appl. Ichtyol. 3: 158-165.

Conan, G.Y., Comeau, M. Gosset, C., Robichaud, G. & Garaïcoechea, C. 1994. The Bigouden *Nephrops* trawl, and the devismes trawl, two otter trawls efficiency catching benthic stages of snow crab (*Chionoecetes opilio*), and the American lobster (*Homarus americanus*). Can. Tech. Rep. Fish. Aquat. Sci. 1992.

DeGrâce, P., Hébert, M., Wade, E., Surette, T. & Moriyasu, M. 2001. Assessment of the 2000 snow crab (*Chionoecetes opilio*) fisheries off western Cape Breton (Areas 18 and 19). DFO. Can. Sci. Adv. Sec. Res. Doc. 2001/016.

Drinkwater, K.F., R. G. Pettipas, & W.M. Petrie. 2003. Temperature conditions on the Scotian Shelf and in the southern Gulf of St. Lawrence during 2002 relevant to snow crab. DFO. Can. Sci. Adv. Sec. Res. Doc. 2003/014.

Emlen, S.T. & Oring, L.W. 1977. Ecology, sexual selection, and the evolution of mating systems. Science, New York, 197: 215-223.

Foyle, T.P., Hurley, G.V. & Taylor, D.M. 1989. Field testing shell hardness gauges for the snow crab fishery. Can. Ind. Rep. Fish. Aquat. Sci. 193.

Hébert, M., Gallant, C.,Chiasson, Y., Mallet, P., DeGrâce, P. & Moriyasu, M. 1992. Le suivi du pourcentage de crabes mous dans les prises commerciales de crabe des neiges (*Chionoecetes opilio*) dans le sud-ouest du golfe du Saint-

Laurent (zone 12) en 1990 et 1991. Rapp. Tech. Can. Sci. Halieut. Aquat. 1886.

Hébert, M., Wade, E., DeGrâce, P., Biron, M., Hébert, A. & Moriyasu, M. 1997. Évaluation de 1996 du stock de crabe des neiges (*Chionoecetes opilio*) dans le sud du golfe du Saint-Laurent (zones 12, 18, 19, 25/26, E et F). Can. Sci. Adv. Secr. Res. Doc. 97/86.

Hébert, M., Wade, E. & Moriyasu, M. 2002. Assessment of the western Cape Breton snow crab fisheries (Areas 18 and 19) winch the southeastern Gulf of St. Lawrence unit in 2001. Can. Sci. Adv. Secr. Res. Doc. 2002/014.

Hébert, M., Wade, E. & Moriyasu, M. 2003. The 2002 assessment of snow crab, *Chionoecetes opilio*, in the southern Gulf of St. Lawrence (Areas 12, E and F). Can. Sci. Adv. Secr. Res. Doc. 2003/016.

Leslie, P.H. & Davis, D.H.S. 1939. An attempt to determine the absolute number of rats on a given area. J. Anim. Ecol. 8: 94-113.

Lovrich, G.A., Siante-Marie, B. & Smith, B.D. 1995. Depth distribution and seasonal movement of *Chionoecetes opilio* (Brachyura: Majidae) in Baie Sainte-Marguerite, Gulf of Saint Lawrence. Can. J. Zool. 73: 1712-1726.

Moriyasu, M. & Lanteigne, C. 1998. Embryo development and reproductive cycle in the snow crab, *Chionoecetes opilio* (Crustacea: Majidae), in the southern Gulf of St. Lawrence, Canada. Can. J. Zool. 76: 2040-2048.

Moriyasu, M., Davidson, L.-A., Lanteigne, M., Biron, M., Comeau, M., Hébert, M., Savoie, F., Surette, T., Wade, E. & Sabean, C. 2001. Current knowledge on the commercially important invertebrate stocks (Lobster, Snow crab and Sea Scallop) in the proposed oil and gas exploitation sites in the southern Gulf of St. Lawrence, Sydney Bight and adjacent area. Can. Sci. Adv. Secr. Res. Doc. 2001/111: 1-75.

Orensanz, J.M., Armstrong, J., Armstrong, D. and Hilborn, R. 1998. Crustacean resources are vulnerable to serial depletion- the multifaceted decline of crab and shrimp fisheries in the Greater Gulf of Alaska. Rev. Fish Biol. Fish. 8: 117-176.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada, 191.

Rondeau, A. & Sainte-Marie, B. 2001. Variable mate-guarding time and sperm allocation to by male snow crabs (*Chionoecetes opilio*) in response to sexual competition, and their impact on the mating success of females. Biol. Bull. 201: 204-217.

Sainte-Marie, B., Raymond, S. & Brêthes. J. -C. 1995. Growth and maturation of the benthic stages of male snow crab, *Chionoecetes opilio* (Brachyura: Majidae). Can. J. Fish. Aquat. Sci. 52: 903-924.

Sainte-Marie, B., Urbani, N., Hazel, F. Sévigny, J.-M. & Kuhnlein, U. 1999. Multiple choice criteria and the dynamics of assortive mating during the first breeding period of female snow crab *Chionoecetes opilio* (Brachyura, Majidae) Mar. Ecol. Prog. Ser. 181: 141-153.

Sainte-Marie, B., Sévigny, J.-M. & Carpentier, M. 2002. Interannual variability of sperm reserves and fecundity of primiparous females of the snow crab, *Chionoecetes opilio*, in relation to sex ratio. Can. J. Fish. Aquat. Sci. 59: 1932-1940.

Swain, D. P. 1993. Age and density-dependent bathymetric pattern of Atlantic cod (*Gadus morhua*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci., 50: 1255-1264.

Taylor, D.M., Hooper, R.G. & Ennis, G.P., 1985. Biological aspects of the spring breeding migration of snow crab, *Chionoecetes opilio*, in Bonne Bay, Newfoundland (Canada). Fish. Bull. 83: 707-711.

Tremblay, M.J. 1997. Snow crab (*Chionoecetes opilio*) distribution limits and abundance trends on the Scotian Shelf. J. Northw. Atl. Fish. Sci. 27: 7-22.

Wade, E., Surette, T., Apaloo, J. & Moriyasu, M. 2003. Estimation of mean annual natural mortality for adult male snow crab, *Chionoecetes opilio*, in the southern Gulf of St. Lawrence. Can. Sci. Adv. Secr. Res. Doc. 2003/016.

Table 1. Catches, fishing efforts and catch per unit of effort (CPUE) in Area 18 between 1986 and 2002.

Year	Catch (t)	Effort (ths)	CPUE (kg/th)	Soft crab %
1986	618	14372	43.0	-
1987	626	9766	64.1	-
1988	669	10790	62.0	-
1989	669	11463	58.1	-
1990	662	15691	42.2	24,8 (f)
1991	187(s)/ 668(f)	6091(s)/ 9346(f)	30.7(s)/ 72.2(f)	18.0(s)/ 5.7(f)
1992	741	14820	50.0	1.4 (s)/5.6 (f)
1993	748	13271	55.5	10.4
1994	734	12363	59.4	7.2
1995	693	20662	33.5	8.2
1996	306	14421	21.2	20.5
1997	406	22431	18.1	13.0
1998	289	16092	18.0	17.1
1999	407	11788	34.5	3.2
2000	472	14696	32.1	8.4
2001	251	16446	15.3	8.6
2002	487	26414	18.6	5.0

s: spring season; f: fall season

Table 2. The catch composition (%) during sea sampling in Area 18 in 2002 and 2001.

2002

	Soft-shelled			Hard-shelled			Total		
	S	L	Tot	S	L	Tot	S	L	Tot
Legal size	1.0	4.5	5.5	5.0	38.6	43.6	6.0	43.1	49.1
Sub-legal size	0.1	0.1	0.2	3.6	47.1	50.7	3.8	47.1	50.9
Total	1.1	4.5	5.7	8.6	85.7	94.3	9.8	90.2	100.0

S: adolescent, L: adult, Tot: total

2001

	Soft-shelled			Hard-shelled			Total		
	S	L	Tot	S	L	Tot	S	L	Tot
Legal size	1.3	3.6	4.9	2.7	46.9	49.6	4.0	50.5	54.5
Sub-legal size	0.5	0.4	0.9	2.5	42.1	44.6	3.0	42.5	45.5
Total	1.8	3.9	5.7	5.3	89.0	94.3	7.1	92.9	100.0

S: adolescent, L: adult, Tot: total

Table 3. The overall composition of carapace conditions for adult males ≥ 95 mm CW in Area 18 from sea samples collected since 1999.

Carapace conditions/ Conditions de carapace	1999	2000	2001	2002
1	0.7	2.2	2.7	5.4
2	6.0	5.8	7.3	8.9
3	33.3	22.4	18.2	64.8
4	58.5	60.1	69.5	20.2
5	1.5	9.5	2.3	0.7
Total	100	100	100	100

Table 4. Biomass index for different stage of male snow crab with 95 % confidence limits in Areas 18.

Year	Area 18		
	B	R	0B
1992*	**1,278** ±1,171	-	-
1993	**1,256** ±1,043	**753** ±439	**59** ±122
1994	**1,195** ±1,060	**426** ±294	**45** ±34
1995	**582** ±229	**318** ±179	**110** ±57
1996	**970** ±523	**703** ±375	**57** ±83
1997	**N/D**	**N/D**	**N/D**
1998	**N/D**	**N/D**	**ND**
1999**	**593** ±428	**260** ± 237	**2** ± 2
2000**	**508** ± 563	**286** ± 566	**50** ± 29
2001	**1,063** ± 1,227	**817** ± 1,009	**76** ± 145
2002	**3,438** ± 1,674	**3,293** ± 1,577	**-**

B: CW ≥ 95 mm with a hard carapace (projected); R: Annual recruitment to the fishery (projected); OB: CW ≥ 95 mm with a very old carapace (direct).

* Survey conducted between the two fishing seasons.
** Biomass estimates from the “Den C. Martin“ without adjustment of net efficiency change.

Table 5. Catches, fishing efforts and catch per unit of effort (CPUE) and average percentage of soft-shelled crab in Area 19 between 1986 and 2002.

Year	Catch (t)	Effort (# of trap haul)	CPUE (kg/trap haul)	Soft-shelled %
1987	1151	37987	30.3	-
1988	1337	22794	58.7	-
1989	1334	29978	44.5	-
1990	1333	28422	46.9	19.4
1991	1337	16733	79.9	5.1
1992	1678	17140	97.9	6.6
1993	1678	18204	92.2	1.9
1994	1672	24495	68.3	5.5
1995	1575	24854	63.4	3.5
1996	1342	24583	54.6	10.8
1997	1386	21930	63.2	11.1
1998	1988	31232	63.1	11.2
1999	1979	19088	103.7	4.1
2000	3225	55977	64.1	5.6
2001	3910	46251	88.5	6.5
2002	3279	43662	72.3	3.5

s: spring season; f: fall season

Table 6. The catch composition (%) during sea sampling in Area 19 in 2002 and 2001.

2002

	Soft-shelled crabs			Hard-shelled crabs			Total		
	S	L	Tot	S	L	Tot	S	L	Tot
Legal size	0.3	2.2	2.4	4.2	64.0	68.2	4.5	66.1	70.6
Sub-legal size	0.0	0.0	0.0	2.7	26.7	29.4	2.7	26.7	29.4
Total	0.3	2.2	2.5	6.9	90.6	97.5	7.2	92.8	100.0

S: adolescent, L: adult, Tot: total

2001

	Soft-shelled crabs			Hard-shelled crabs			Total		
	S	L	Tot	S	L	Tot	S	L	Tot
Legal size	0.7	4.7	5.4	3.2	70.7	73.9	3.9	75.4	79.3
Sub-legal size	0.3	0.1	0.4	1.7	18.6	20.3	2.0	18.7	20.7
Total	1.0	4.8	5.8	4.9	89.3	94.2	5.9	94.1	100.0

S: adolescent, L: adult, Tot: total

Table 7. The overall composition of carapace conditions for adult males ≥ 95 mm CW in Area 19 from sea samples collected since 1998.

Carapaceconditions/ Conditions de carapace	1999	2000	2001	2002
1	0.3	2.0	1.8	3.2
2	4.2	14.6	6.5	5.6
3	45.2	26.9	31.3	70.2
4	49.8	55.8	60.1	20.6
5	0.5	0.8	0.3	0.5
Total	100	100	100	1000

Table 8. Biomass index for different stage of male snow crab with 95 % confidence limits in Area 19.

Year	Area 19		
	B	R	0B
1991*	**5459** ±1942	**1279** ± 374	-
1992*	**5226** ± 2205	**1762** ± 885	-
1993	**2300** ± 621	**672** ± 184	**114** ± 117
1994	**2598** ± 1045	**836** ± 227	**110** ± 74
1995	**1825** ± 376	**280** ± 131	**223** ± 71
1996	**2190** ± 600	**965** ± 435	**292** ± 95
1997	**3160** ± 749	**1953** ± 469	**0** ± 0
1998	**3152** ± 1091	**1901** ± 1092	**38** ± 125
1999**	**5351** ± 1584	**1830** ± 966	**1** ± 1
2000**	**6210** ± 1118	**4328** ± 952	**126** ± 49
2001	**5214** ± 1689	**2927** ± 1373	**206** ± 197
2002	**4,930** ± 2560	**2,947** ± 2402	**27**± 63

B: CW ≥ 95 mm with a hard carapace (projected); R: Annual recruitment to the fishery (projected); OB: CW ≥ 95 mm with a very old carapace (direct).

* Survey conducted between the two fishing seasons.
** Biomass estimates from the “Den C. Martin“ without adjustment of net efficiency change.

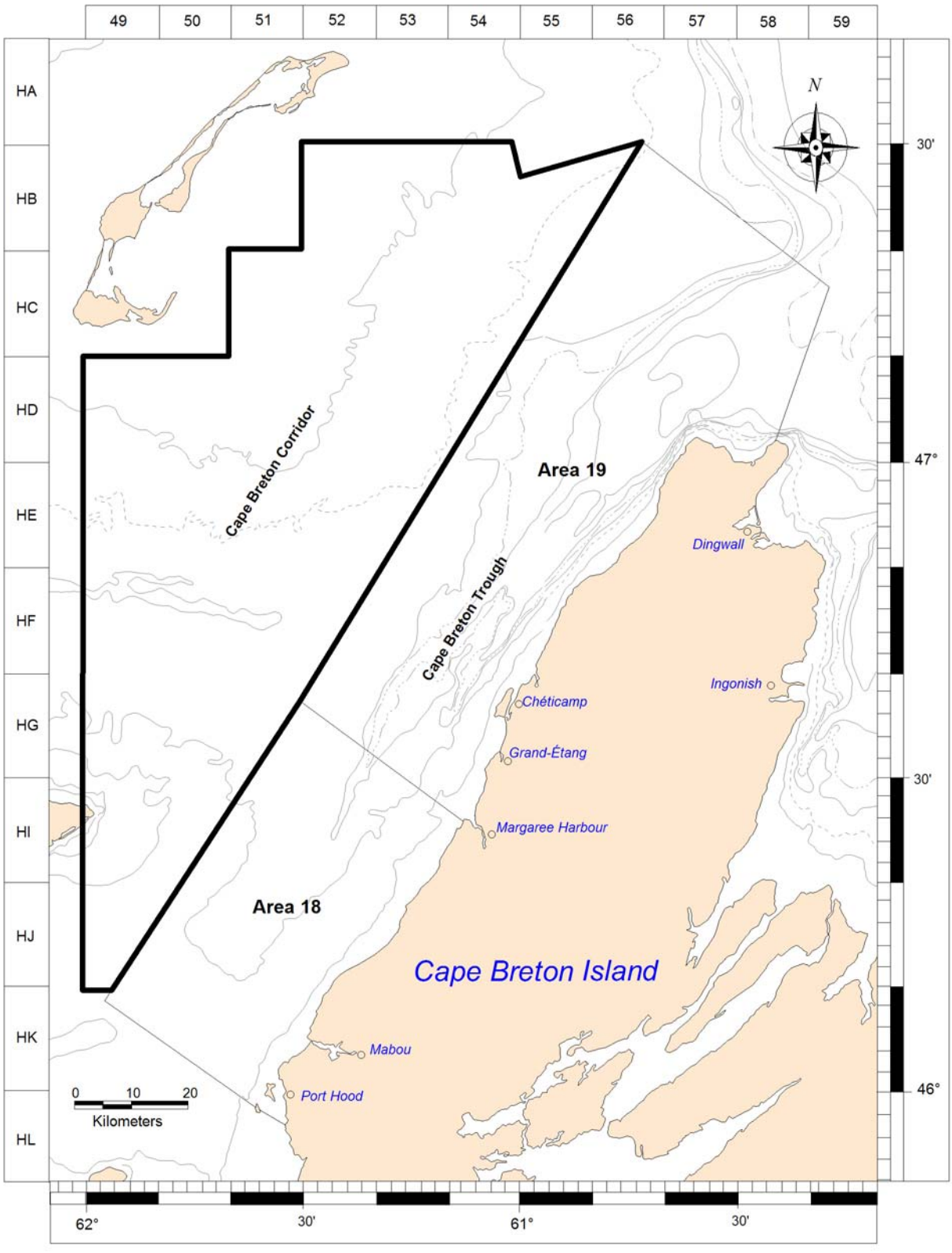


Figure 1. Western Cape Breton snow crab management Areas 18 and 19 and the Cape Breton Corridor (Area 12) in the southeastern Gulf of St. Lawrence (Cape Breton Corridor is shown by a bolded line).

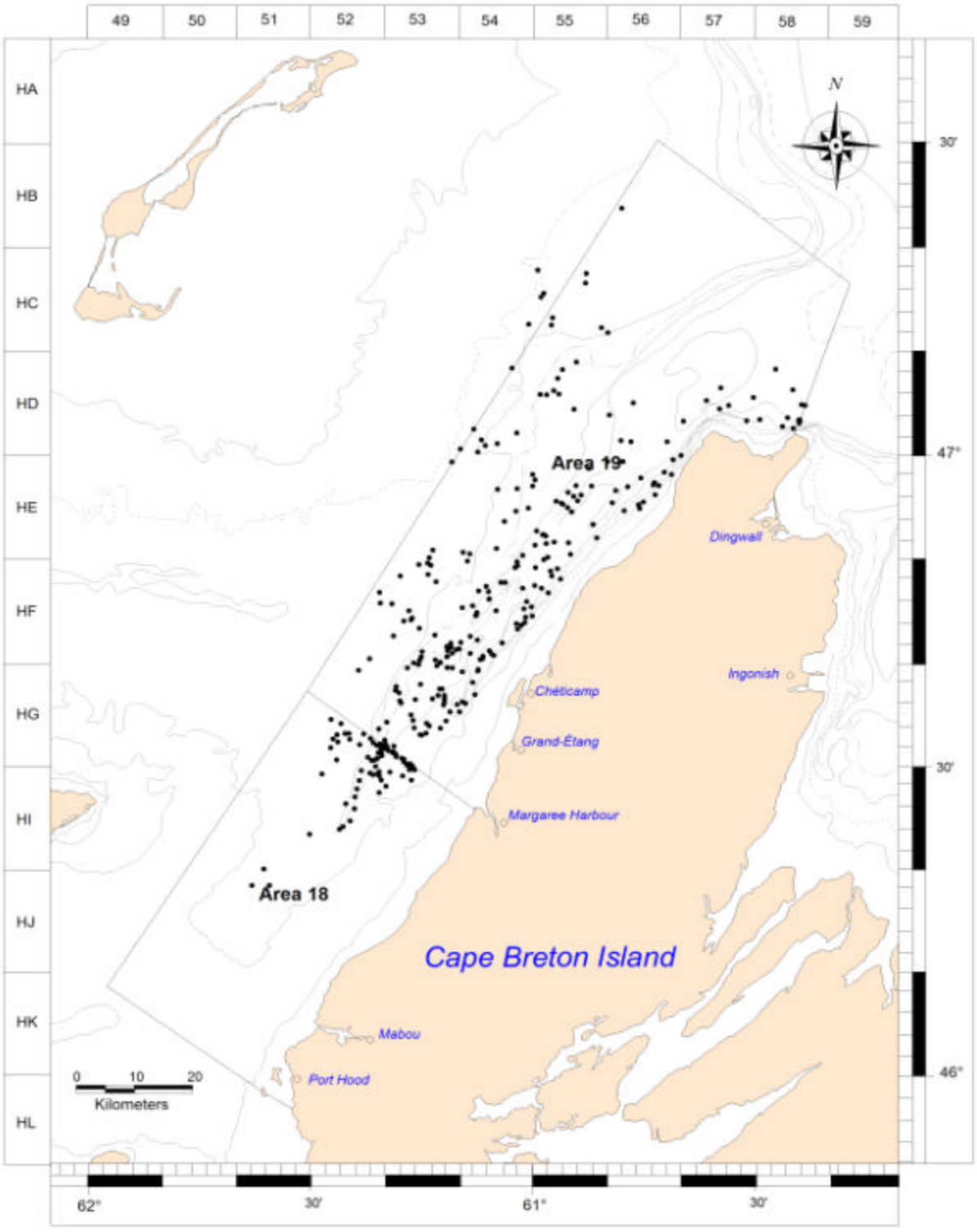


Figure 2. Locations of traps sampled aboard commercial vessels by at-sea observers in Areas 18 and 19 during the 2002 fishing season.

September 2001

June 2002

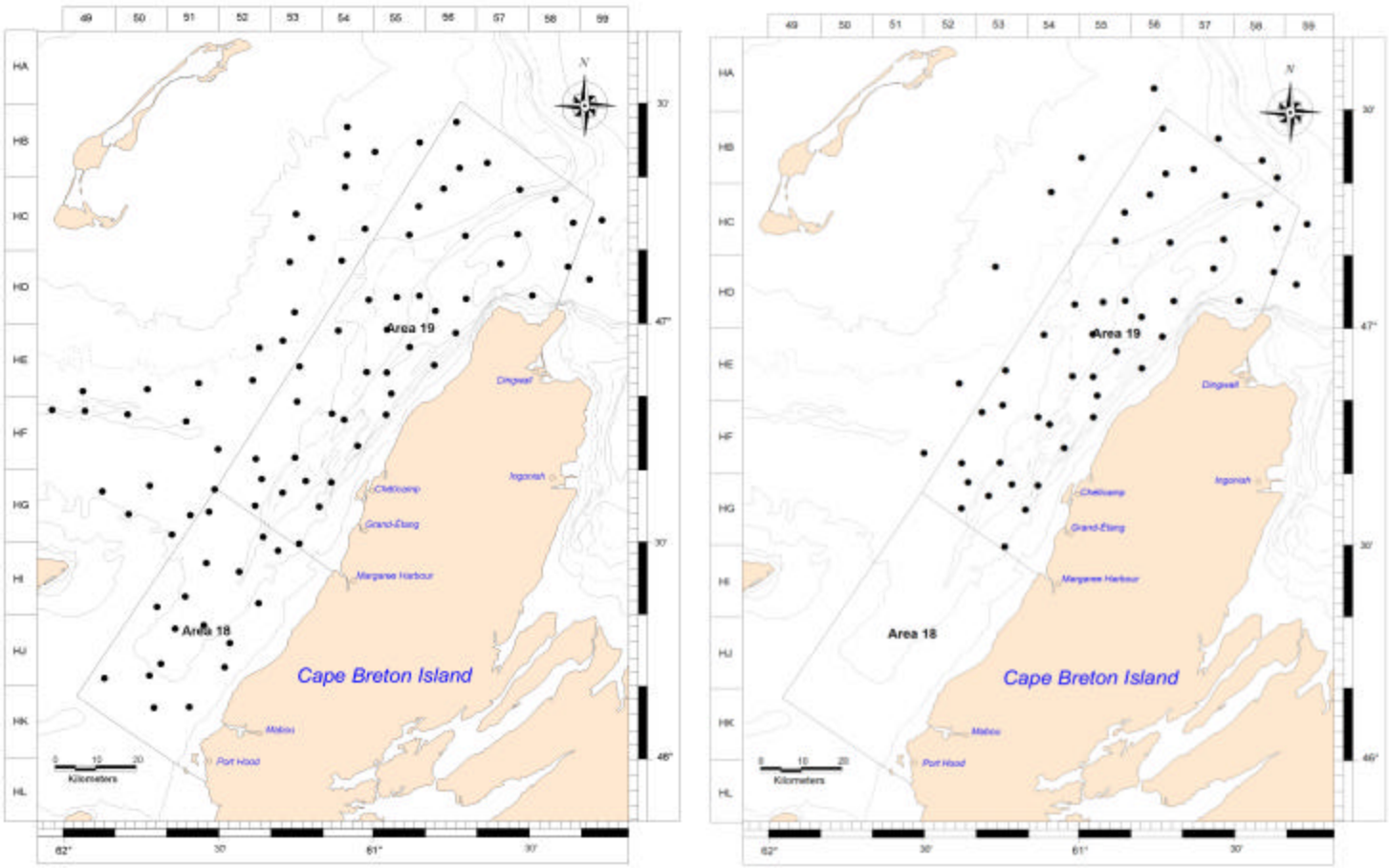


Figure 3. Locations of the September 2001 and June 2002 trawl survey stations in western Cape Breton (Areas 18 and 19 and adjacent zone).

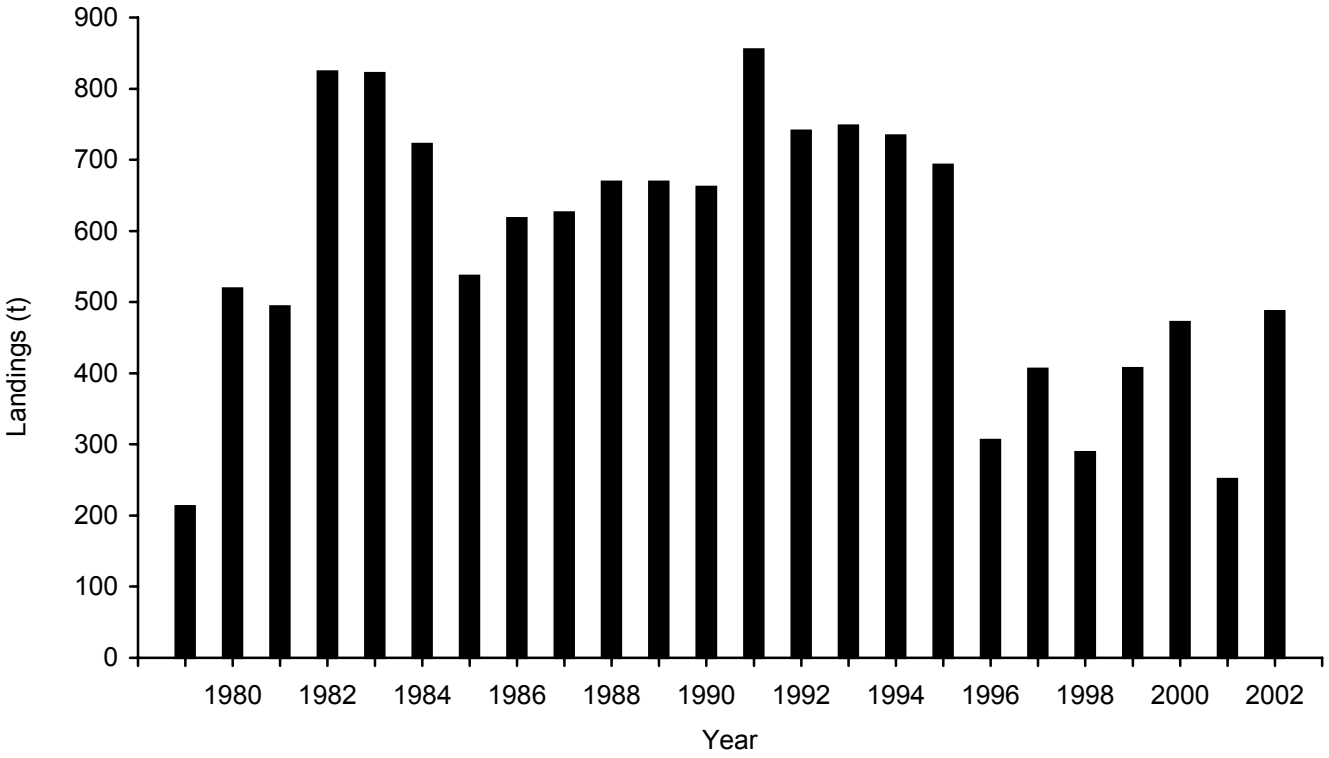
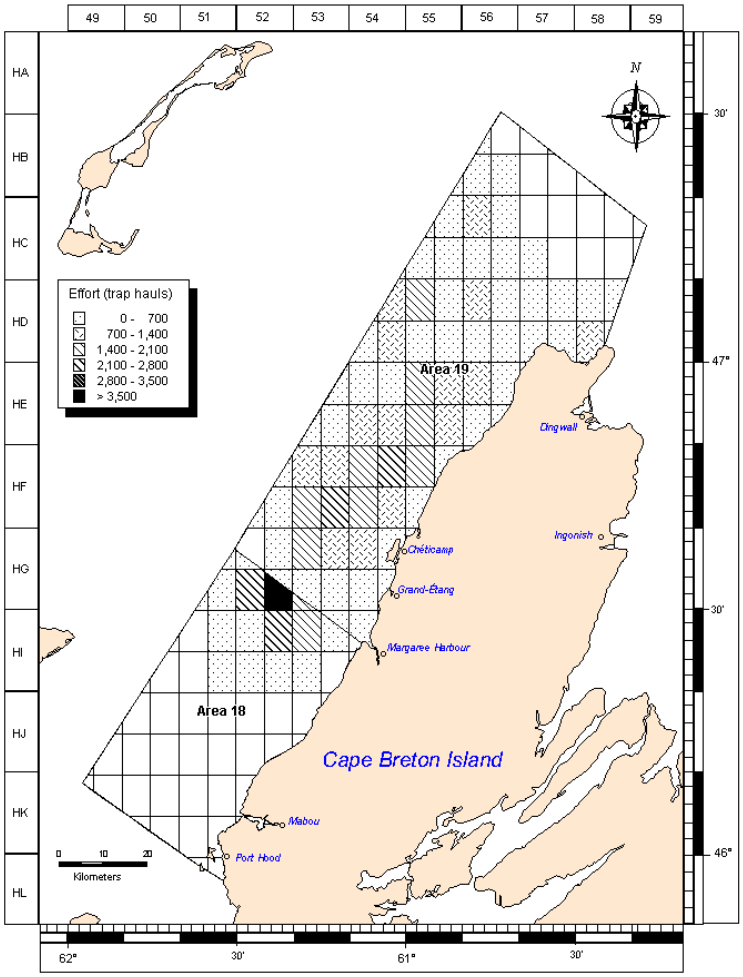


Figure 4. Annual landings in Area 18 between 1979 and 2002.

2001



2002

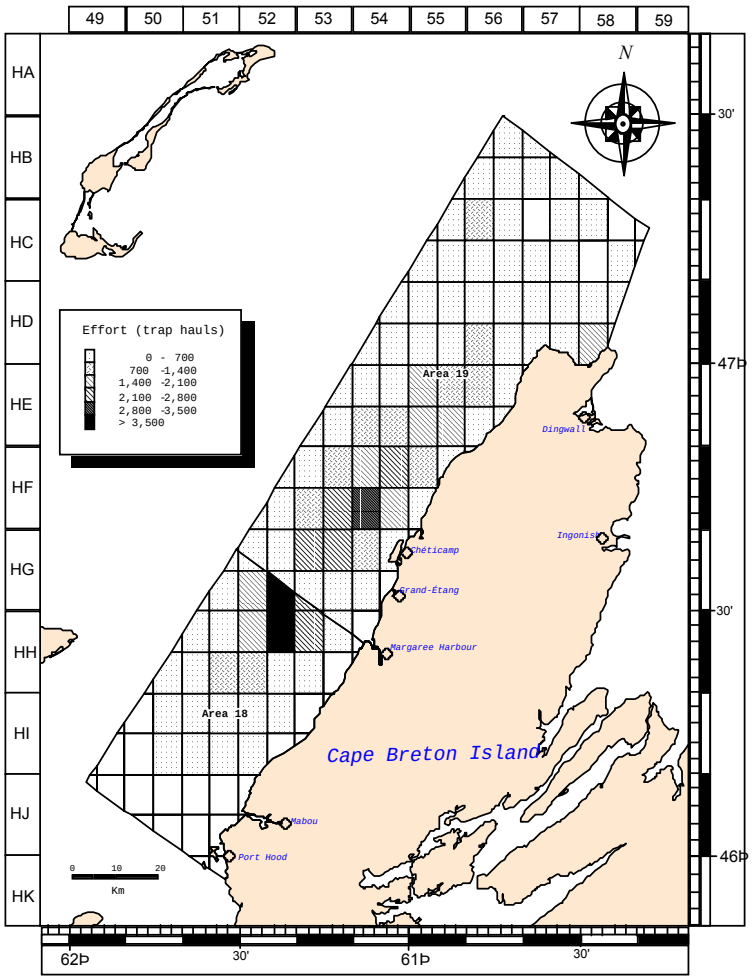


Figure 5. Geographic distribution of fishing effort in Areas 18 and 19 in 2001 and 2002.

2001

2002

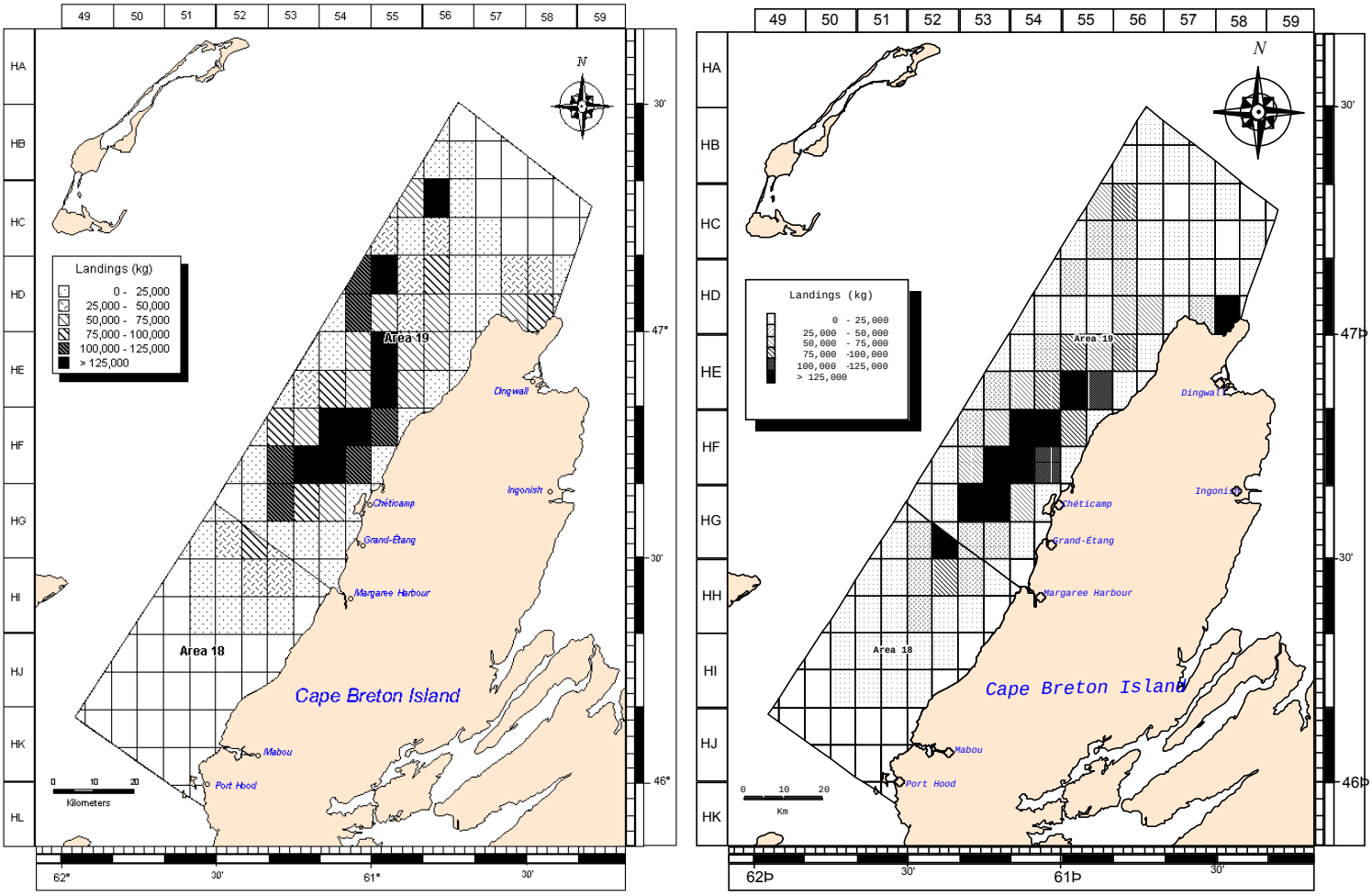


Figure 6. Geographic distribution of landings in Areas 18 and 19 in 2001 and 2002.

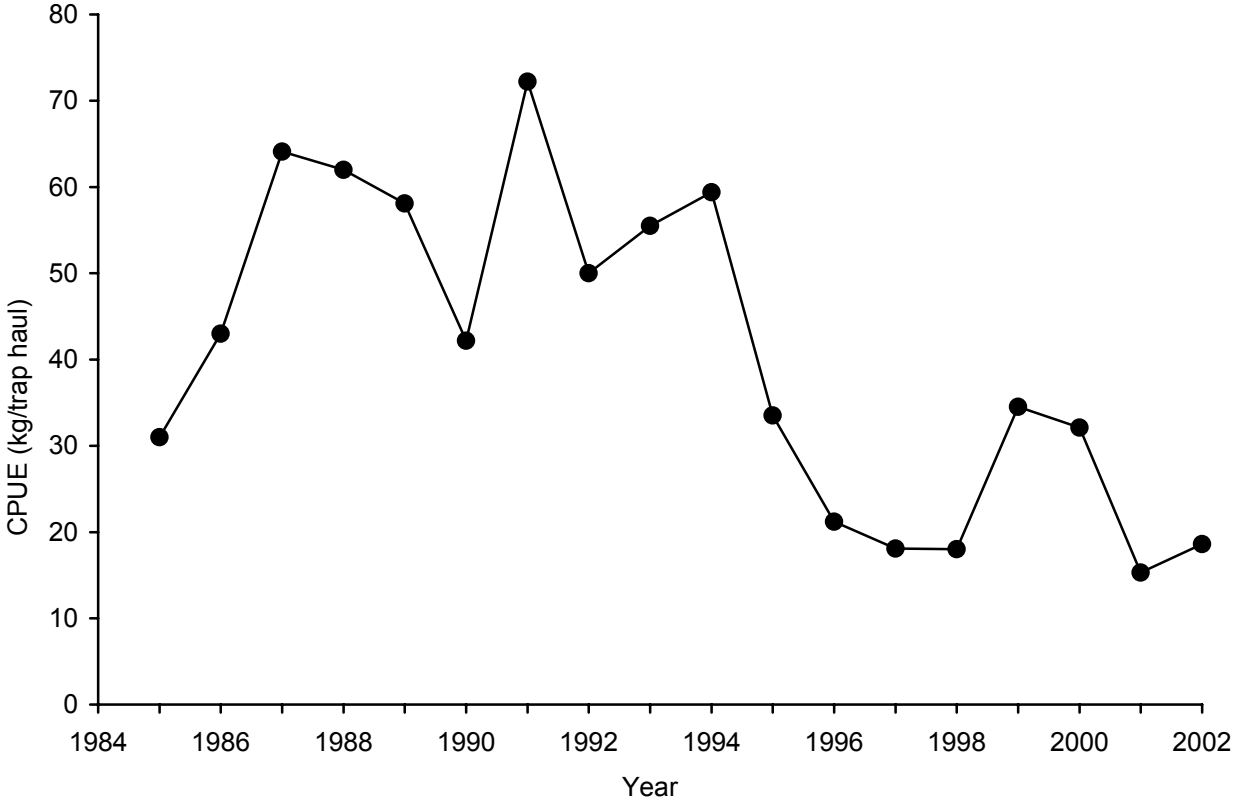


Figure 7. Annual catch per unit of effort (CPUE) in Area 18 estimated from logbook between 1985 and 2002.

2001

2002

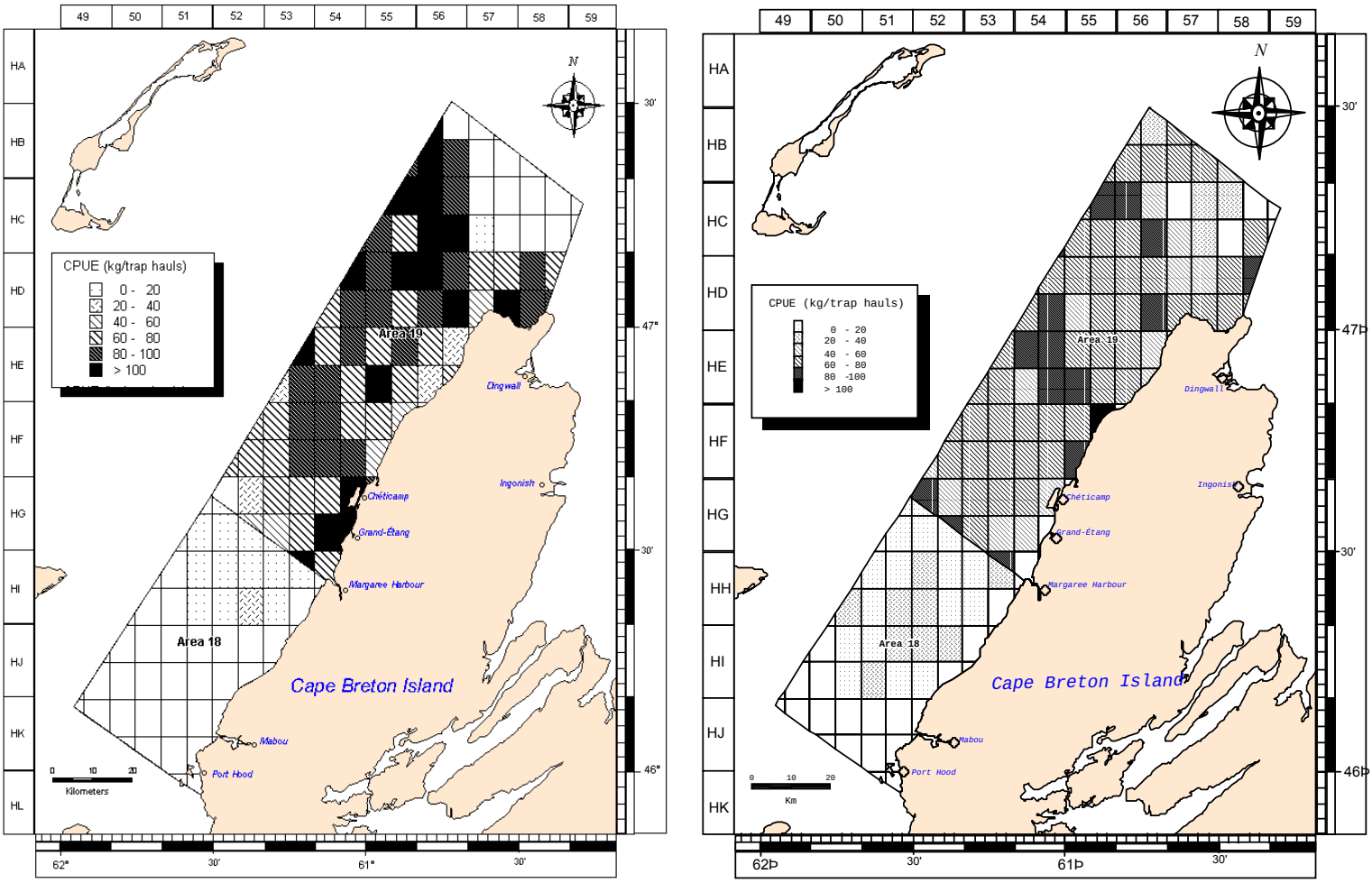


Figure 8. Geographic distribution of mean CPUE (kg/th) in Areas 18 and 19 in 2001 and 2002.

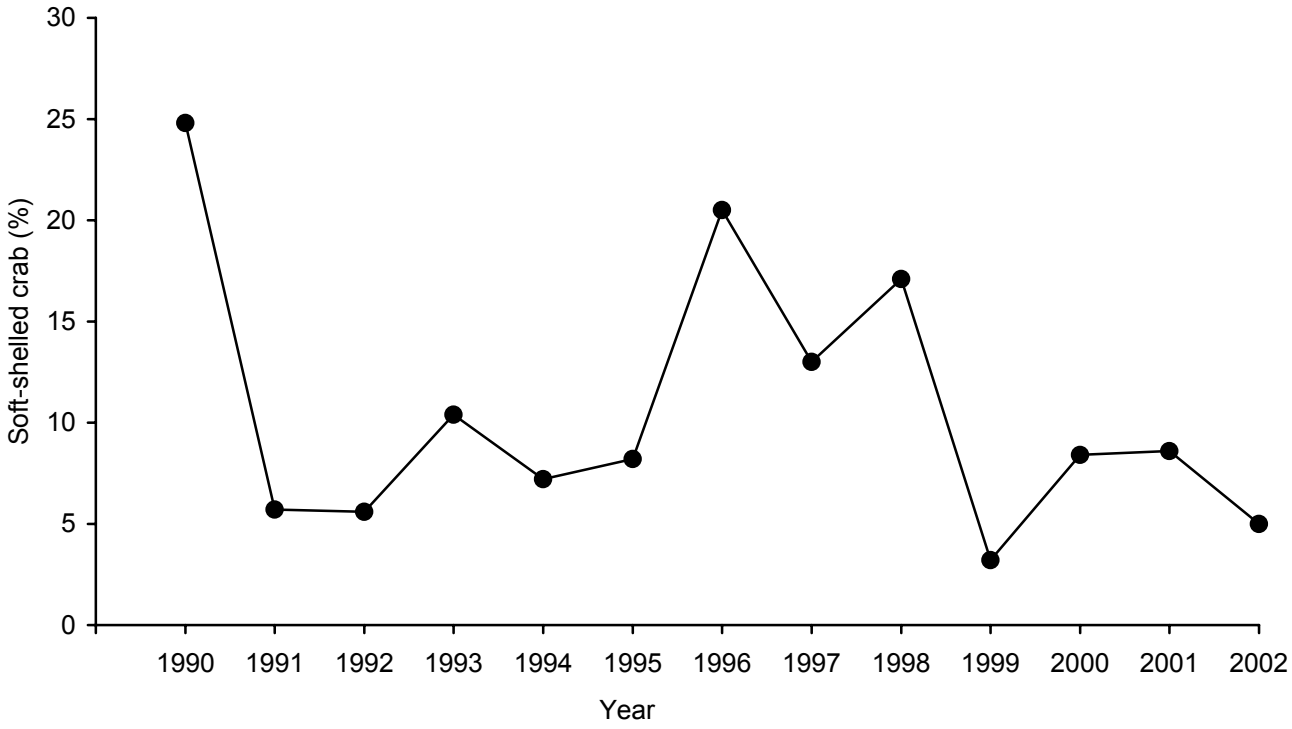


Figure 9. Annual percentage of soft-shelled crab in the catches in Area 18 from 1990 to 2002.

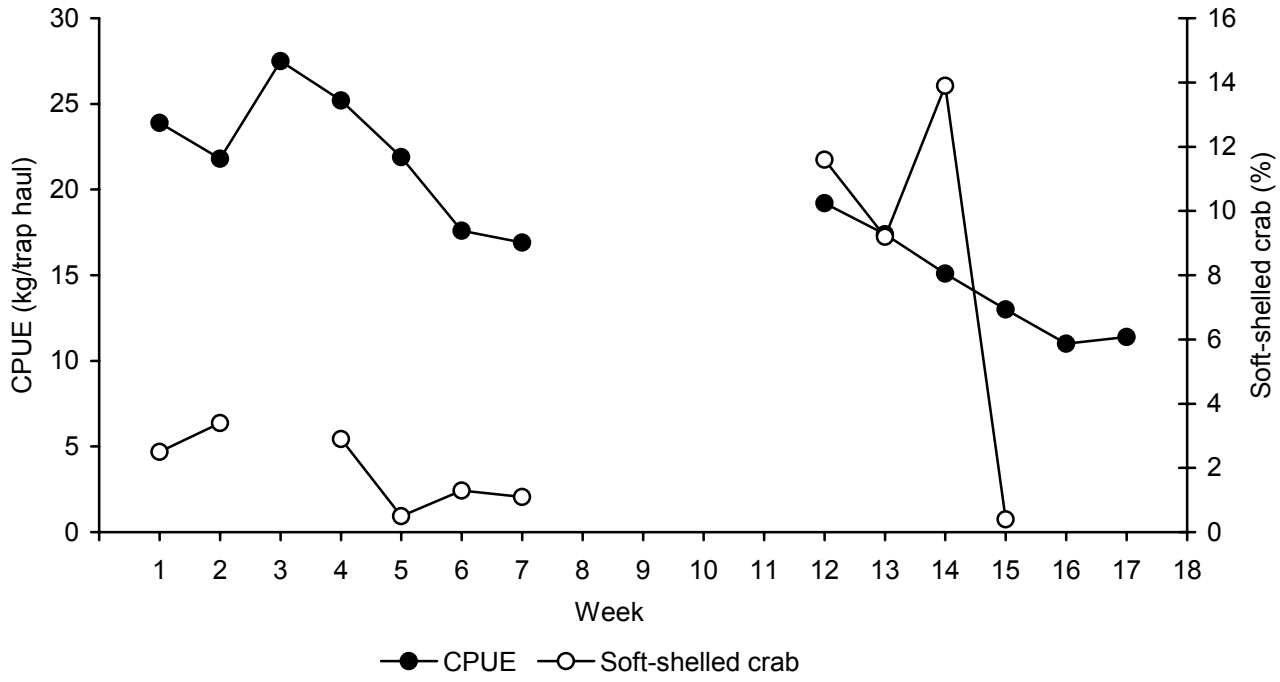


Figure 10. Weekly catch per unit of effort (CPUE) estimated from logbooks and percentage of soft-shelled crabs in Area 18 during the 2002 fishing season.

April 15th to May 31st

July 4th to August 10th

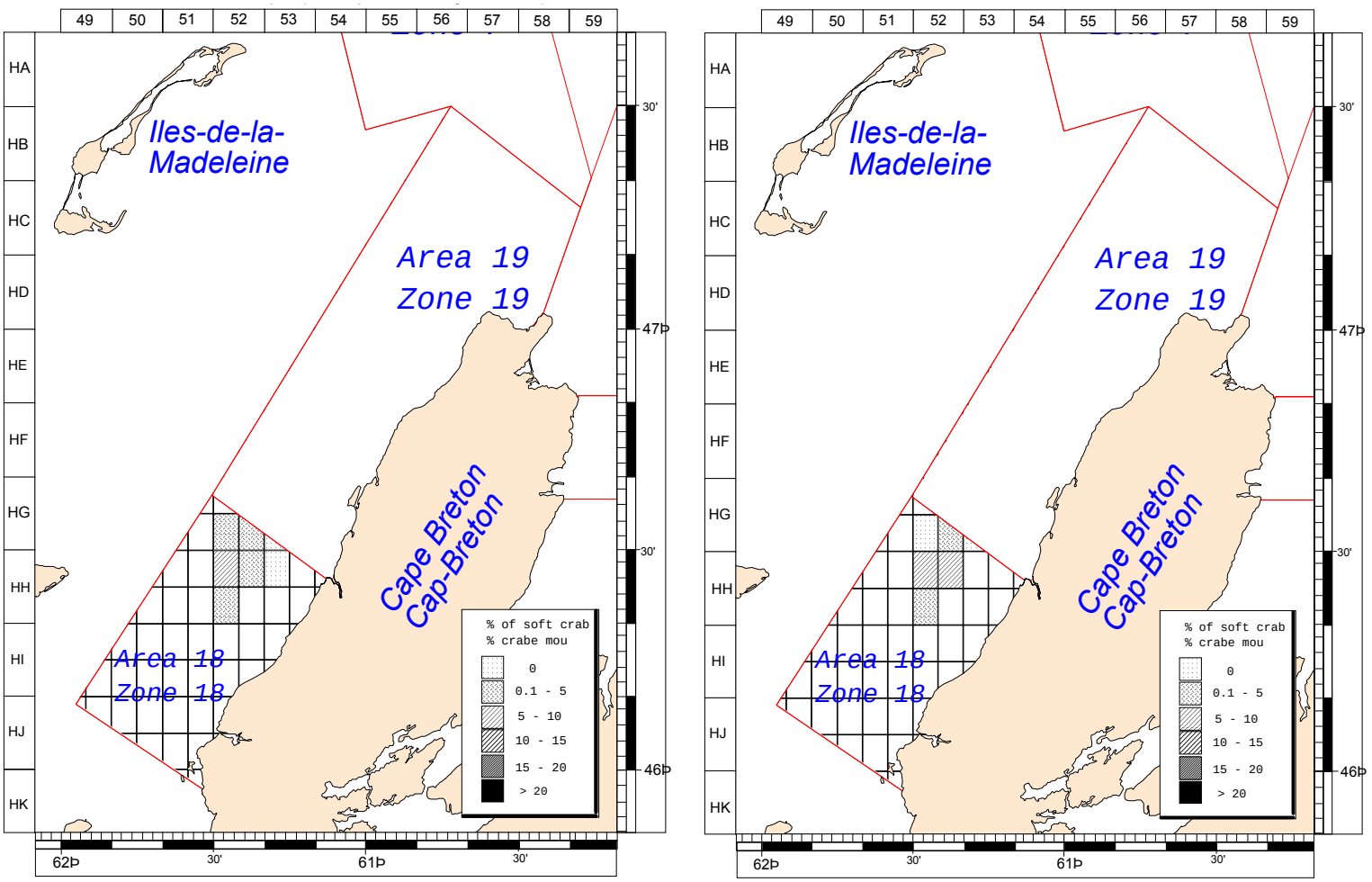


Figure 11. Distribution of soft-shelled crab in Area 18 during the 2002 fishing (April 15th to May 31st and July 4th to August 10th)

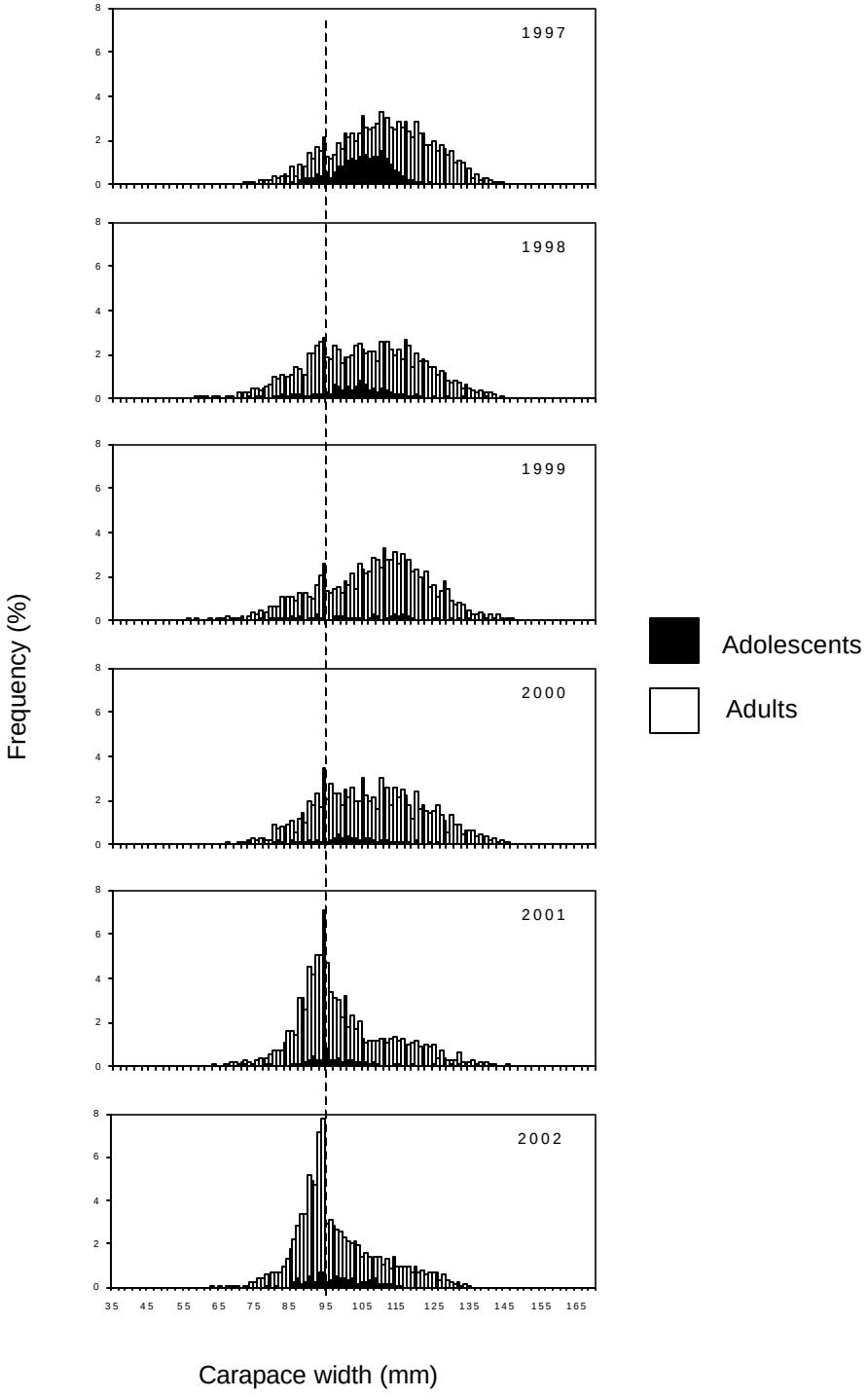


Figure 12. Size frequency distributions of male crabs measured during at-sea sampling in Area 18 between 1997 and 2002 (dotted line indicates the minimum legal size of 95 mm CW).

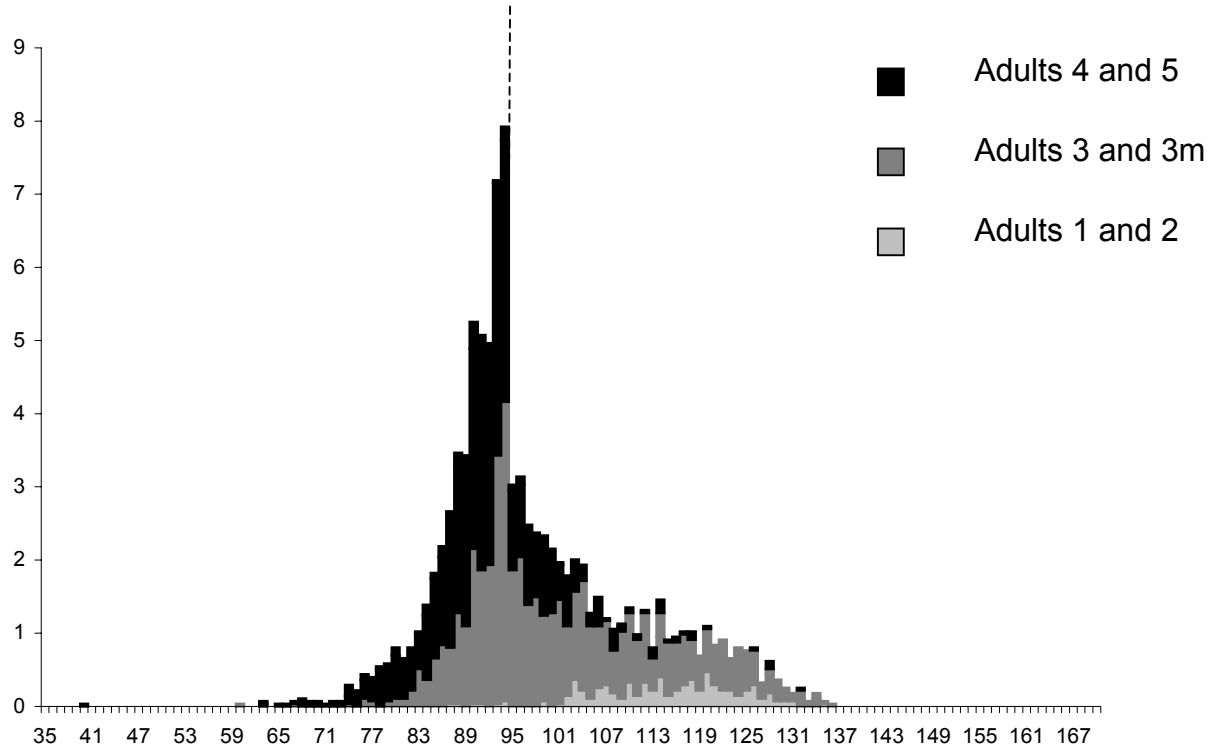


Figure 13. Size frequency distributions of adult male crab by carapace condition in Area 18 during the 2002 fishing season. (dotted line indicates the minimum legal size of 95 mm CW).

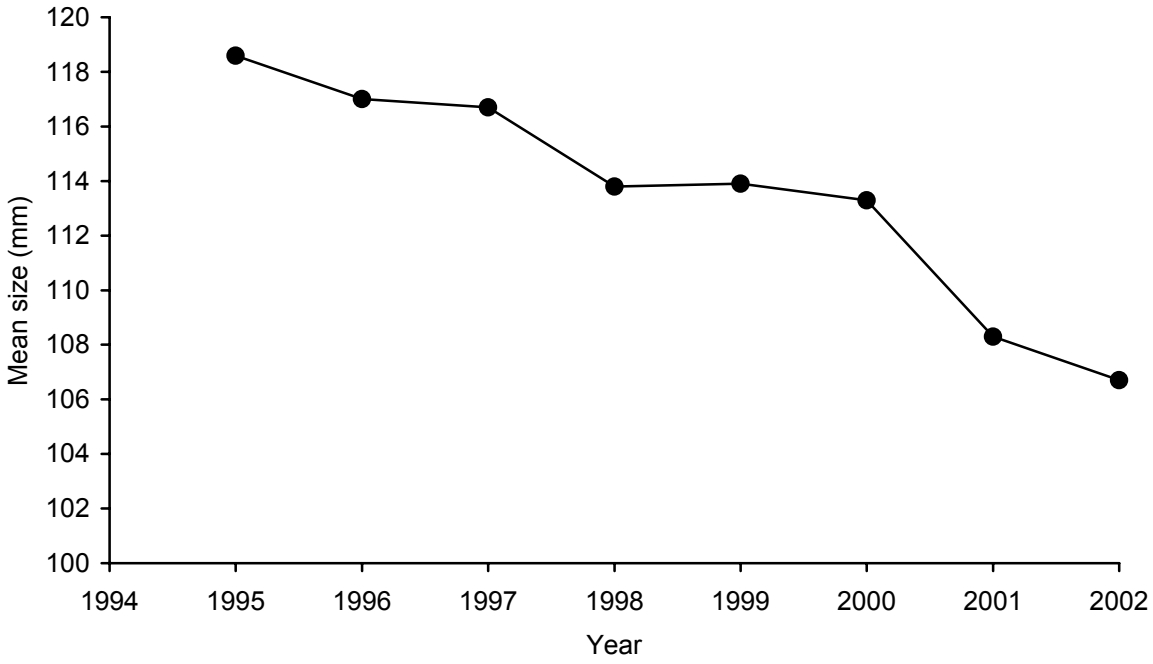


Figure 14. Annual mean size of the commercial catch in Area 18 between 1995 and 2002.

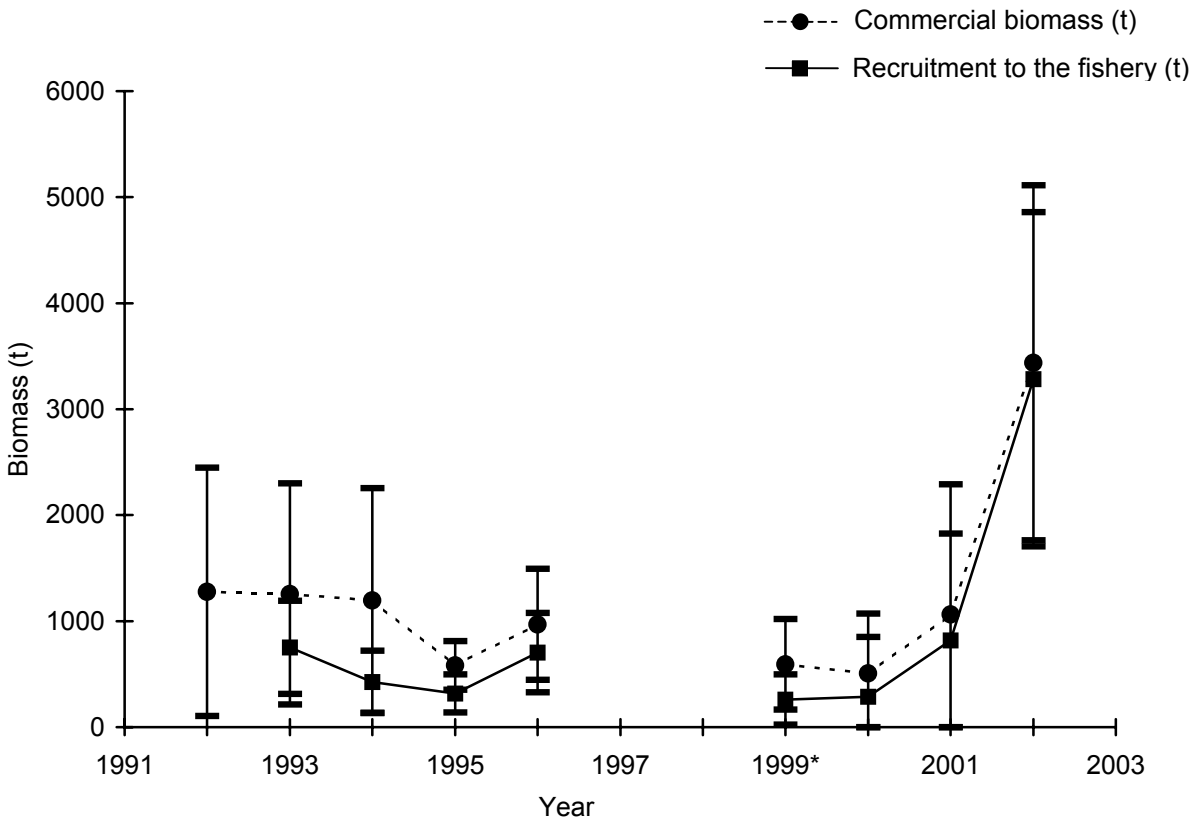


Figure 15. Annual commercial biomass (t) and recruitment to the fishery (t) indices in Area 18 estimated from the trawl survey between 1992 and 2002 (1997-1998 surveys were not conducted).

* Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

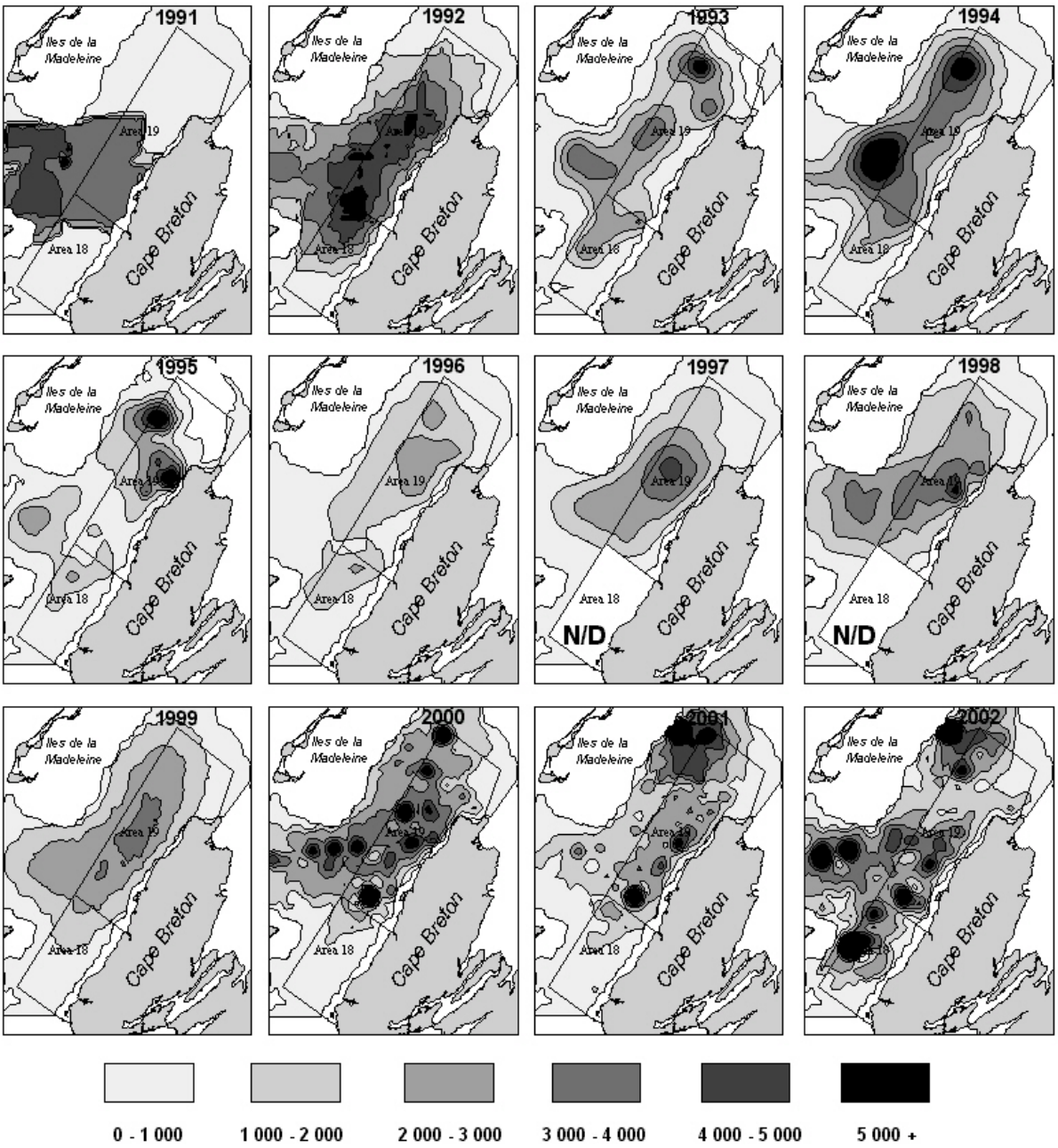


Figure 16. Density contours of adult snow crab of commercial size in Areas 18 and 19 observed in the trawl survey since 1991.

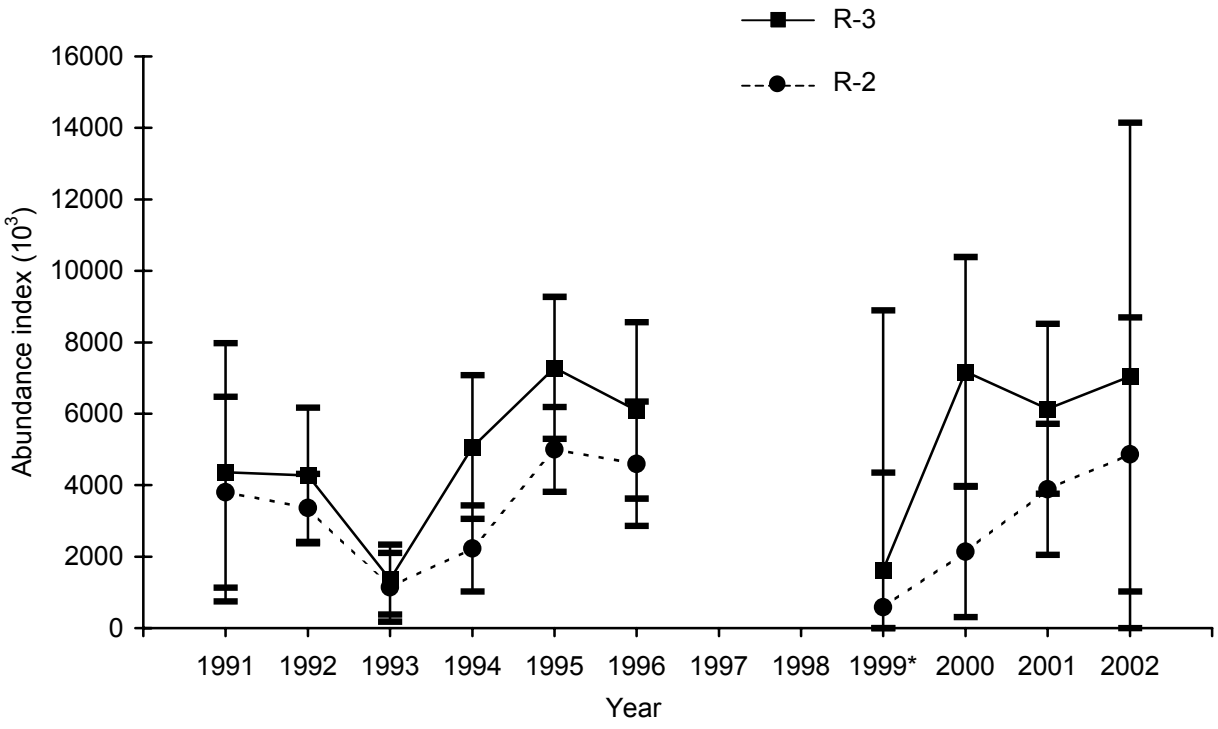


Figure 17. Abundance index of prerecruits R-3 and R-2 in Area 18 between 1991 and 2002 (1997-1998 surveys were not conducted).

* Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

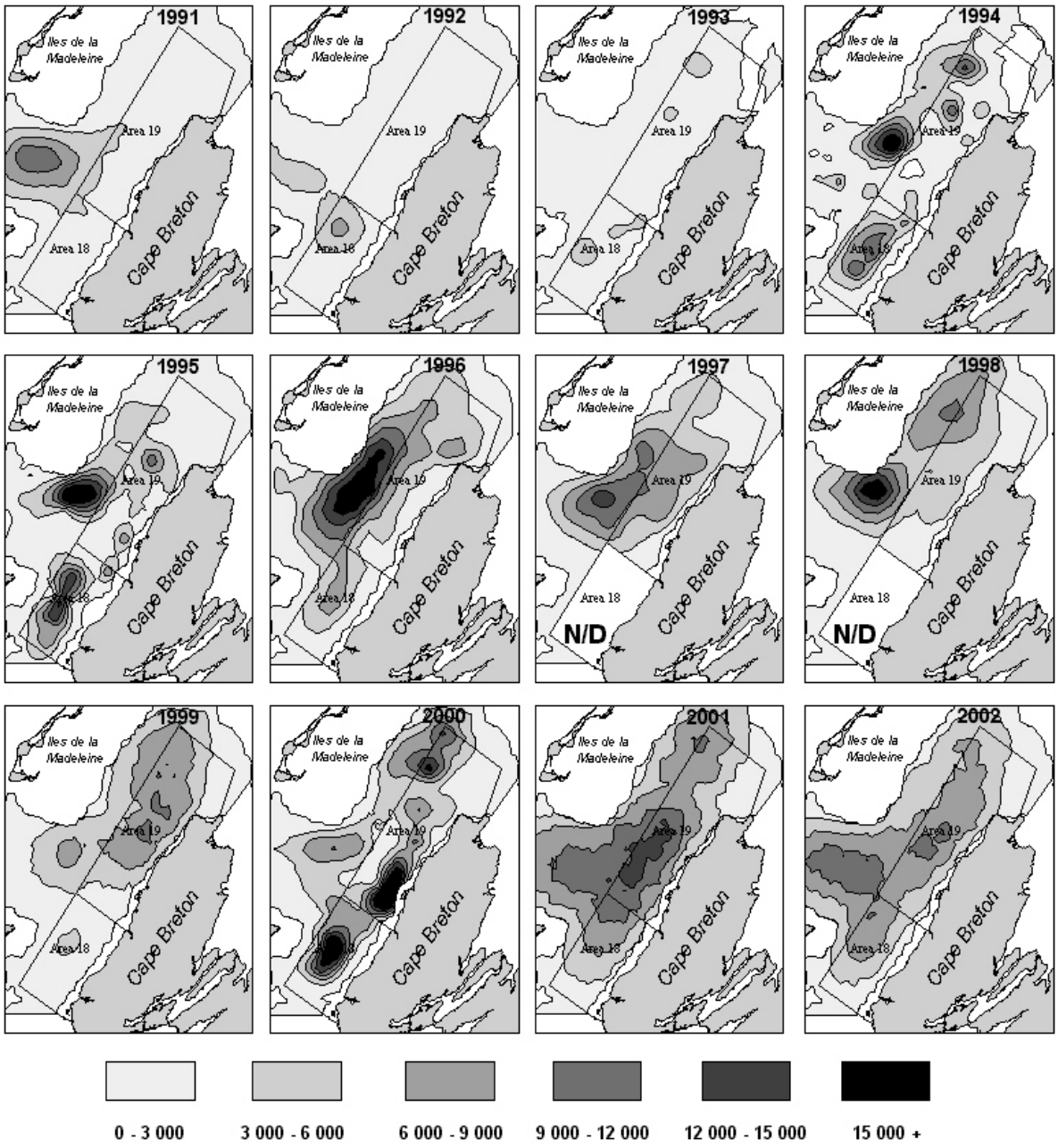


Figure 18. Density contours of adolescent snow crab with CW ≥ 56 mm in Areas 18 and 19 observed in the trawl surveys since 1991.

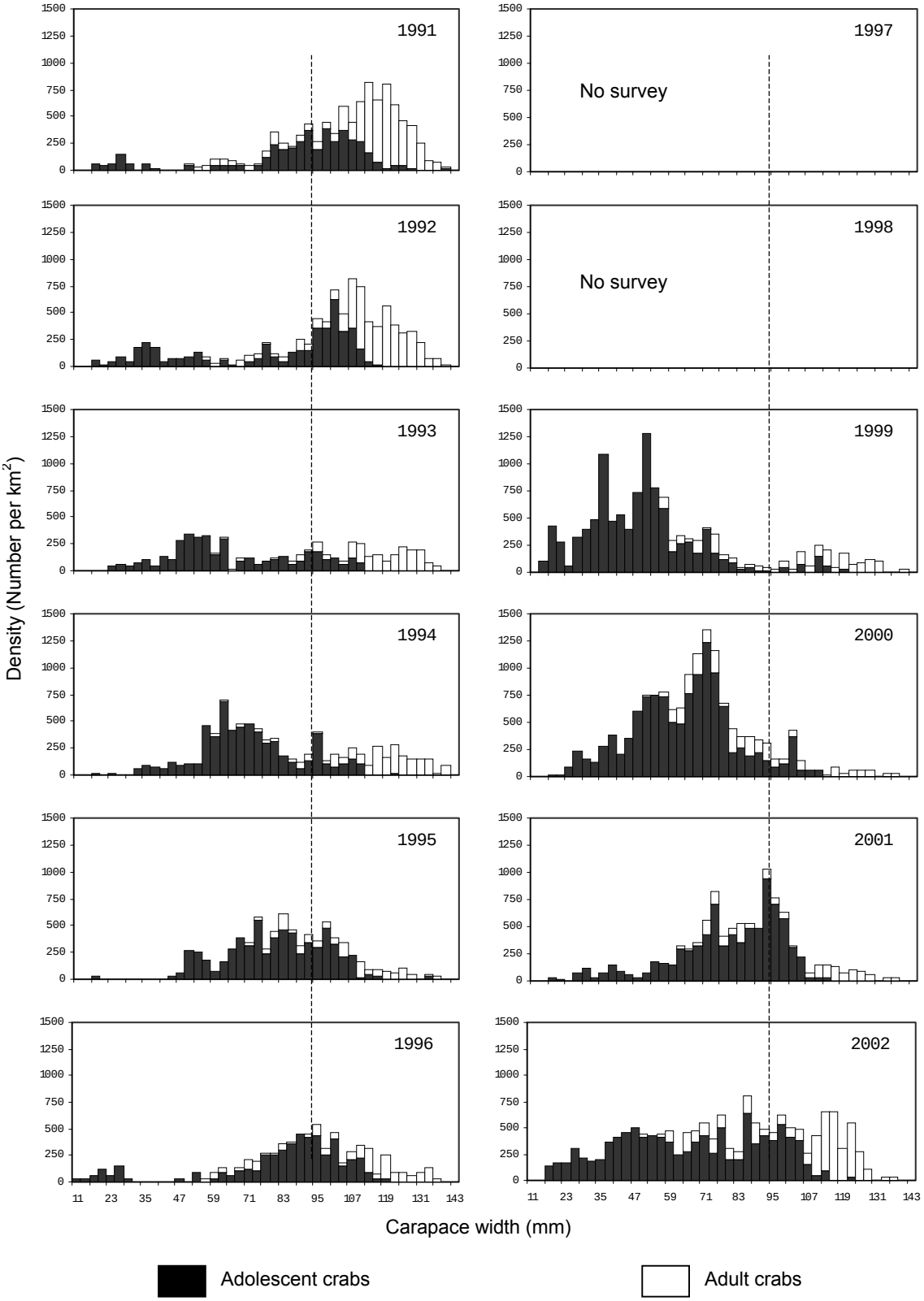


Figure 19. Size frequency distributions of male snow crabs in Area 18 between 1991 and 2002. The 1991-1992 surveys were conducted before the fishing season (dotted lines indicate the minimum legal size of 95 mm CW).

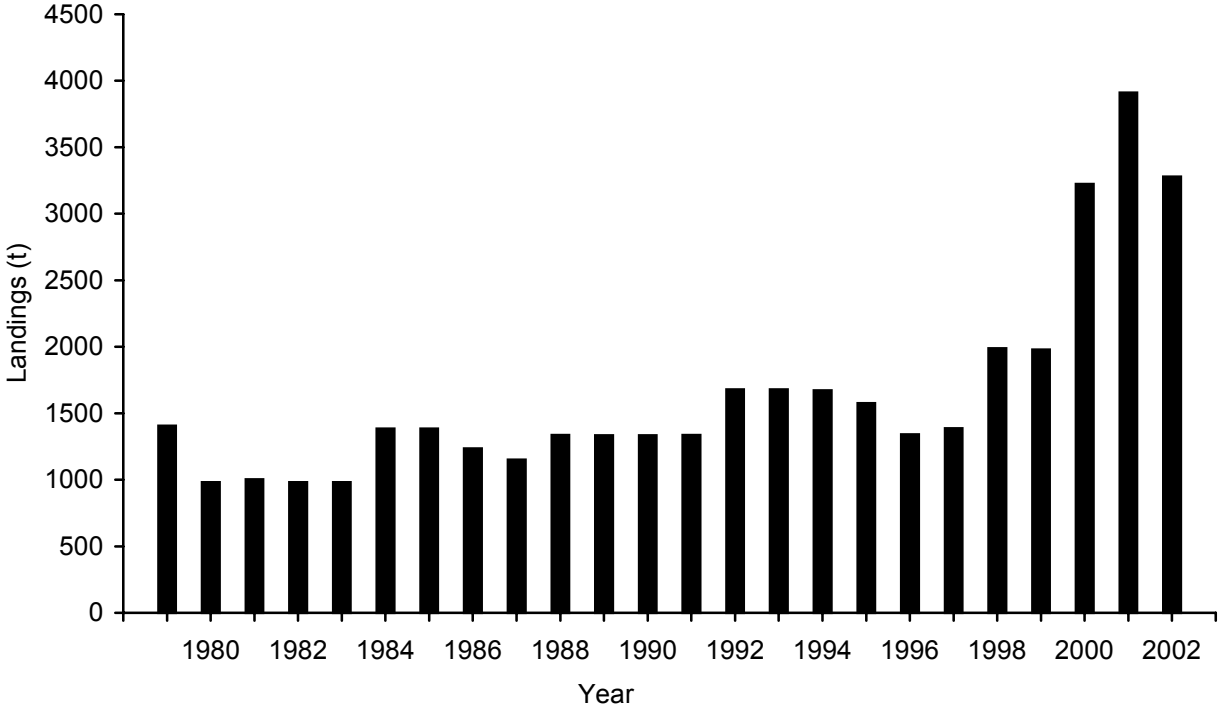


Figure 20. Annual landings in Area 19 between 1979 and 2002.

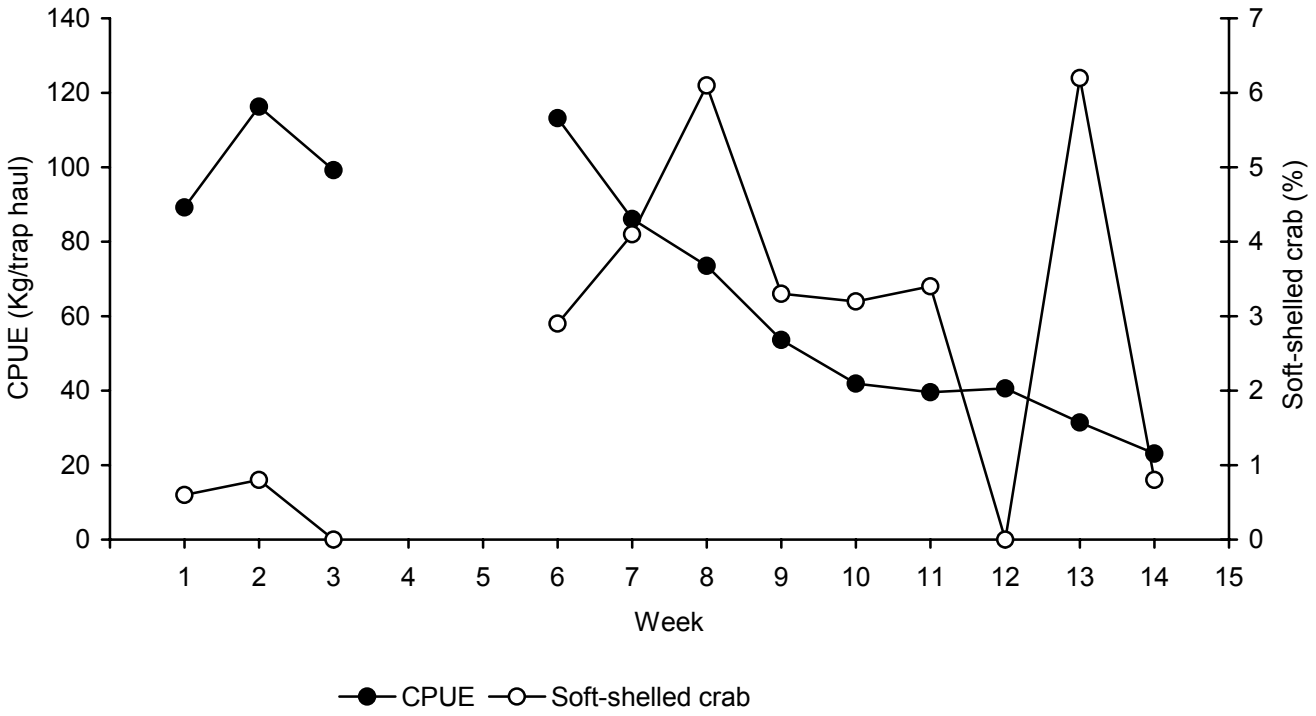


Figure 21. Weekly catch per unit of effort (CPUE) and percentage of soft-shelled crab in Area 19 during the 2002 fishing season.

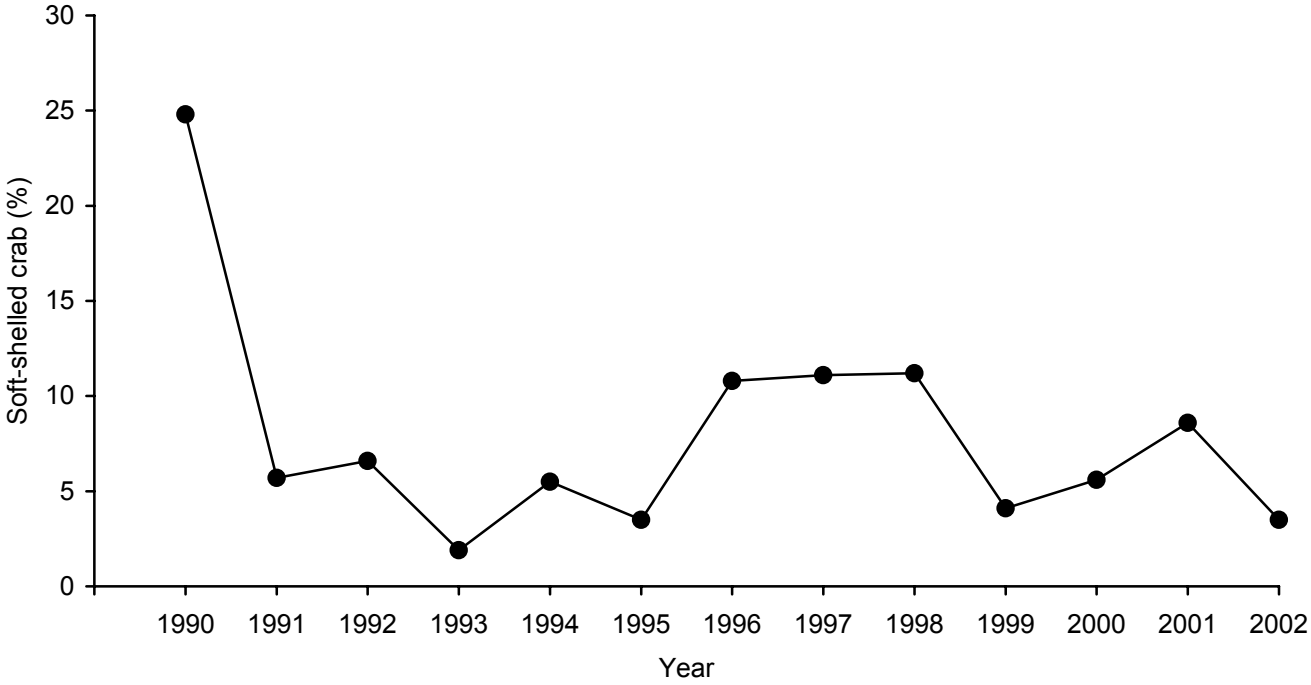


Figure 22. Annual percentage of soft-shelled crab in Area 19 between 1990 and 2002.

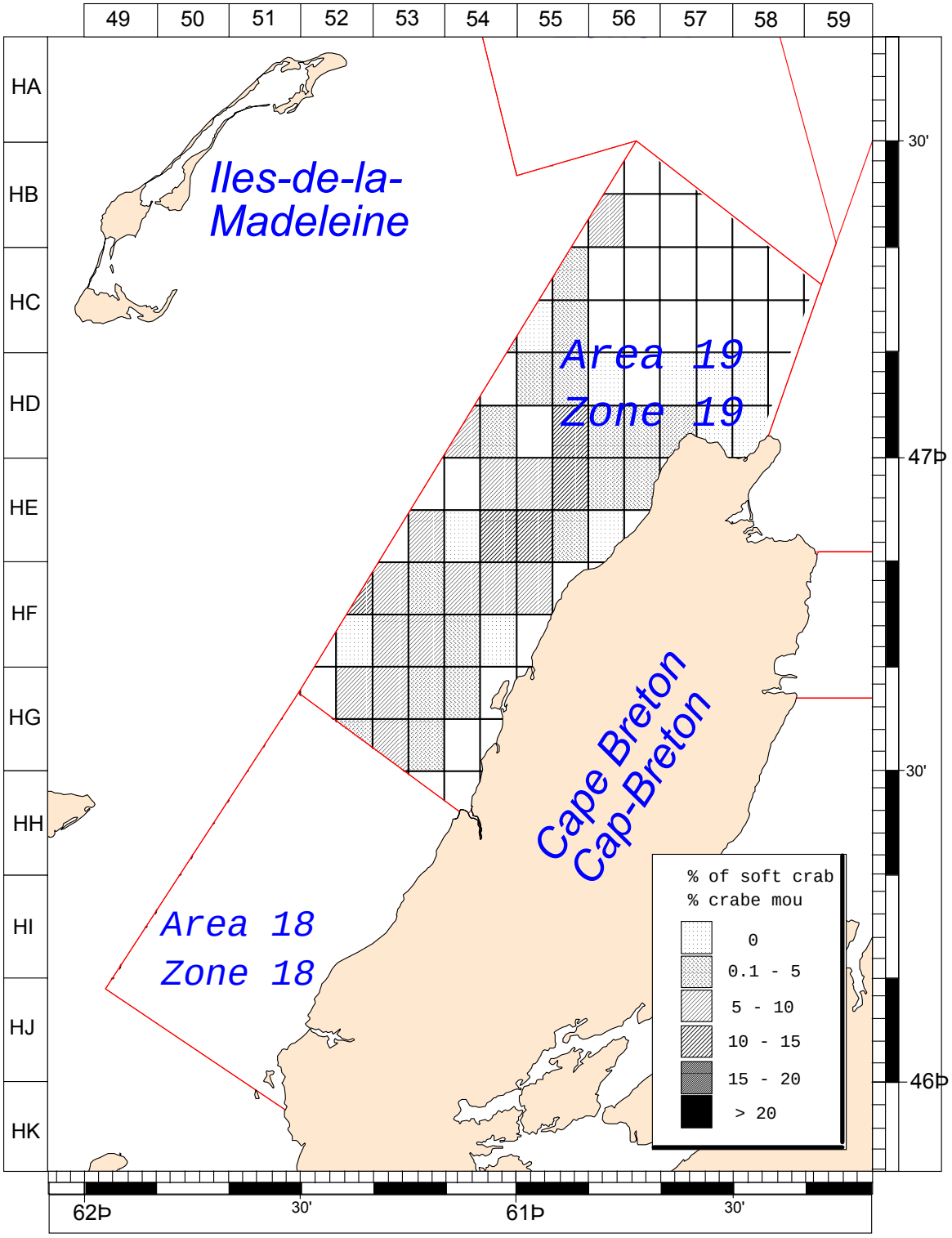


Figure 23. Distribution of soft-shelled crab in Area 19 during the 2002 fishing season.

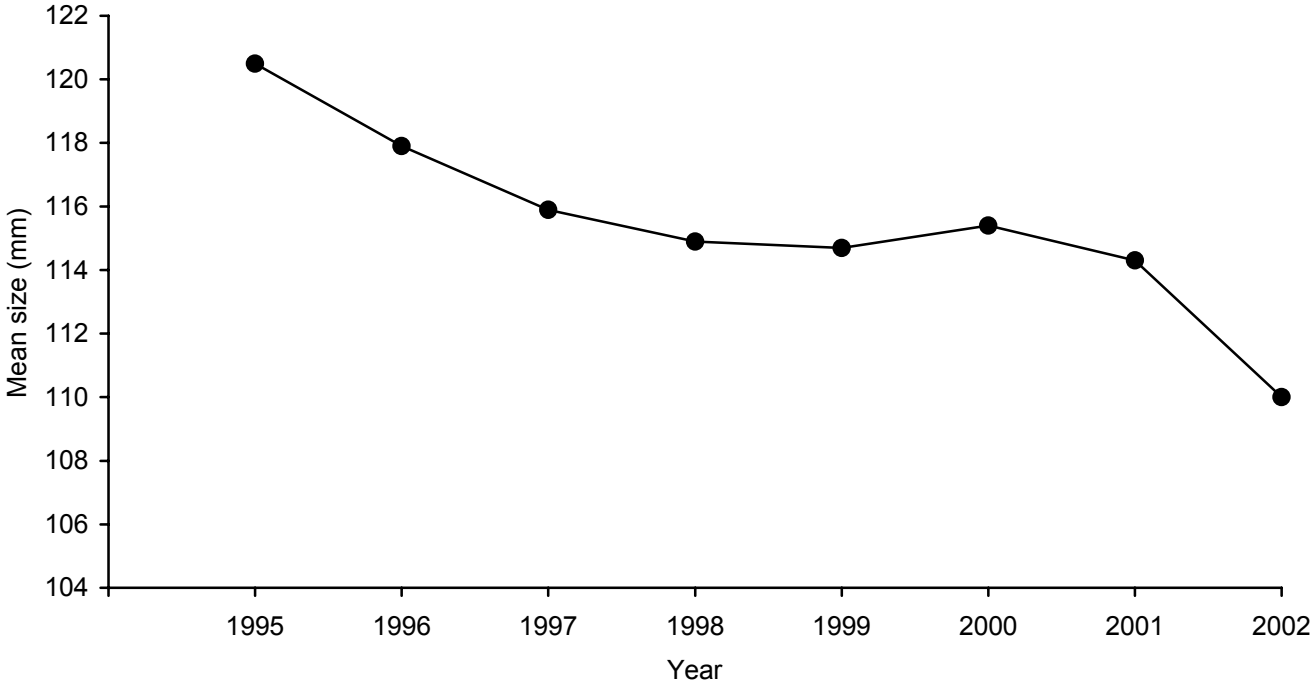


Figure 24. Annual mean size of the commercial catch in Area 19 between 1995 and 2002.

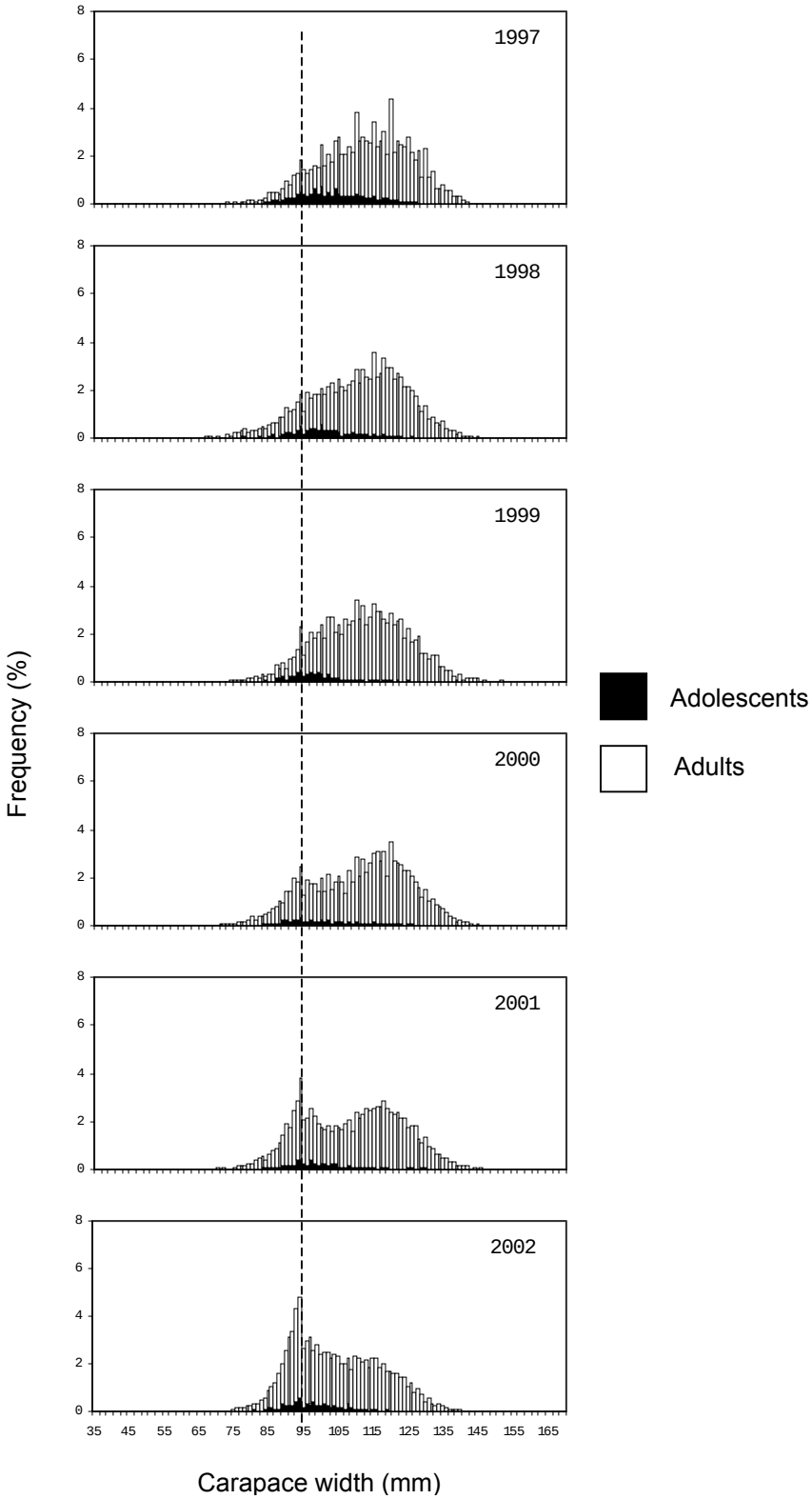


Figure 25. Size frequency distributions of male crabs measured during at-sea sampling in Area 19 between 1997 and 2002 (dotted line indicates the minimum legal size of 95 mm CW).

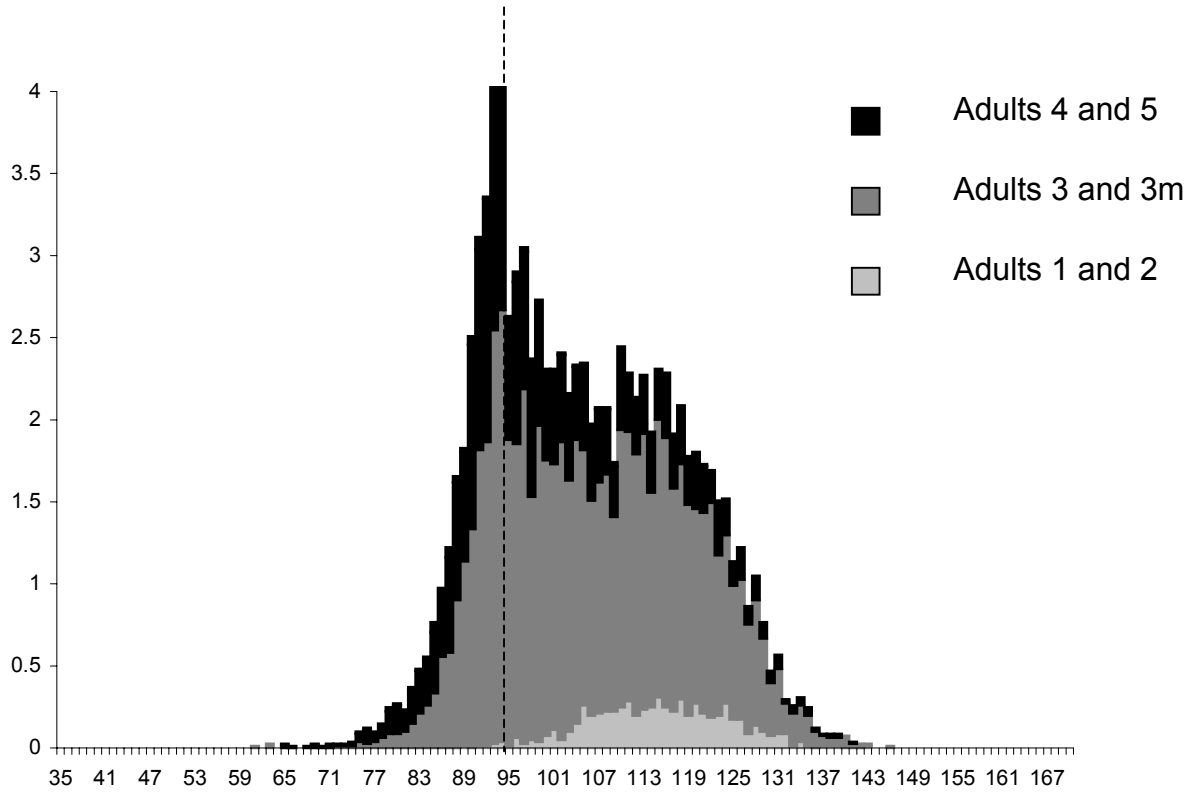


Figure 26. Size frequency distributions of adult male crab by carapace condition in Area 19 during the 2002 fishing season (dotted line indicates the minimum legal size of 95 mm CW).

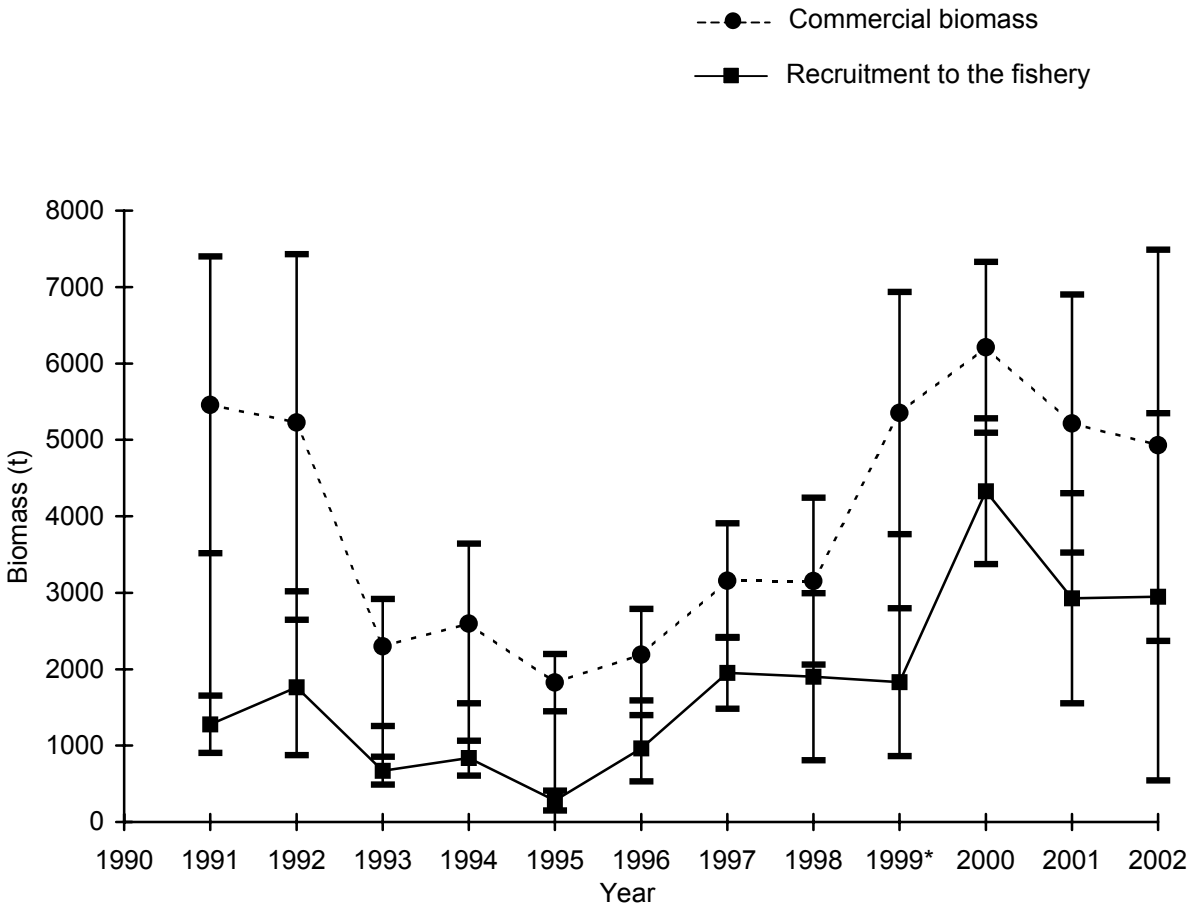


Figure 27. Annual commercial biomass (t) and recruitment to the fishery (t) indices in Area 19 between 1991 and 2002 (1991-1992 trawl surveys were conducted before the fishing season).

* Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

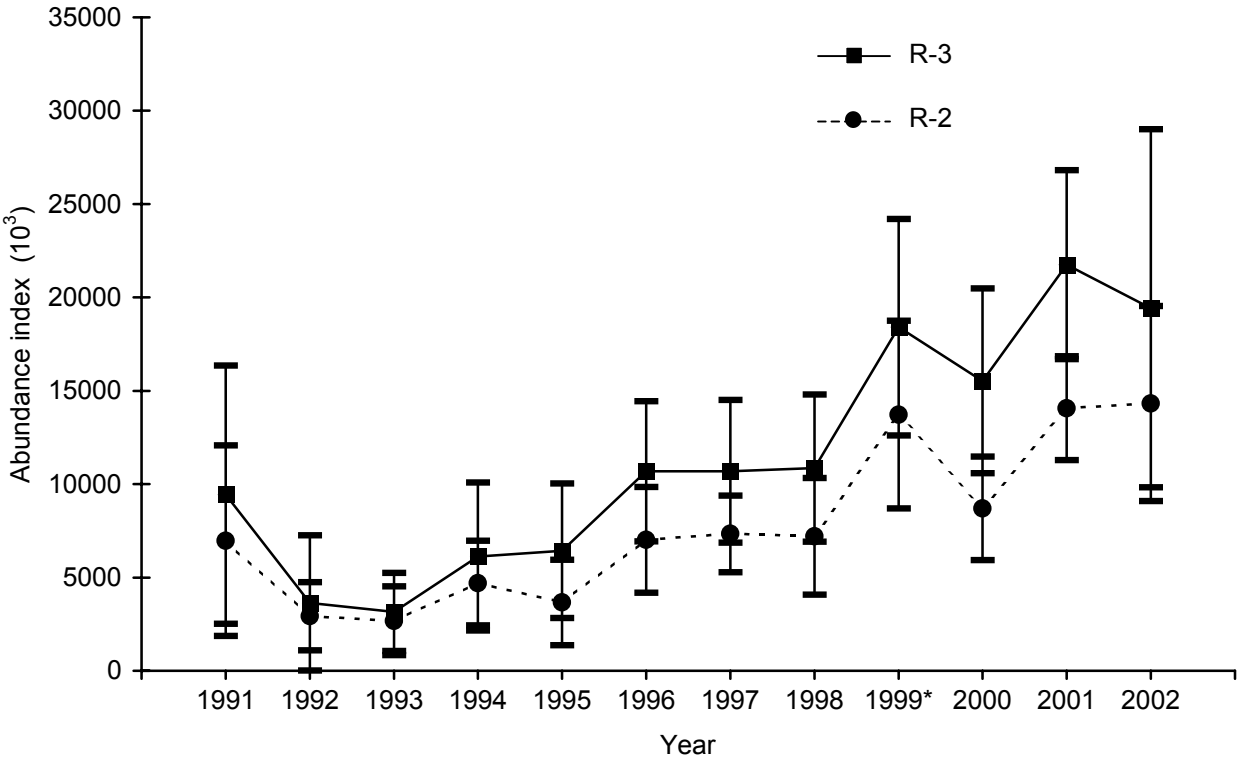


Figure 28. Abundance index of prerecruits R-3 and R-2 in Area 19 between 1991 and 2002.

* Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

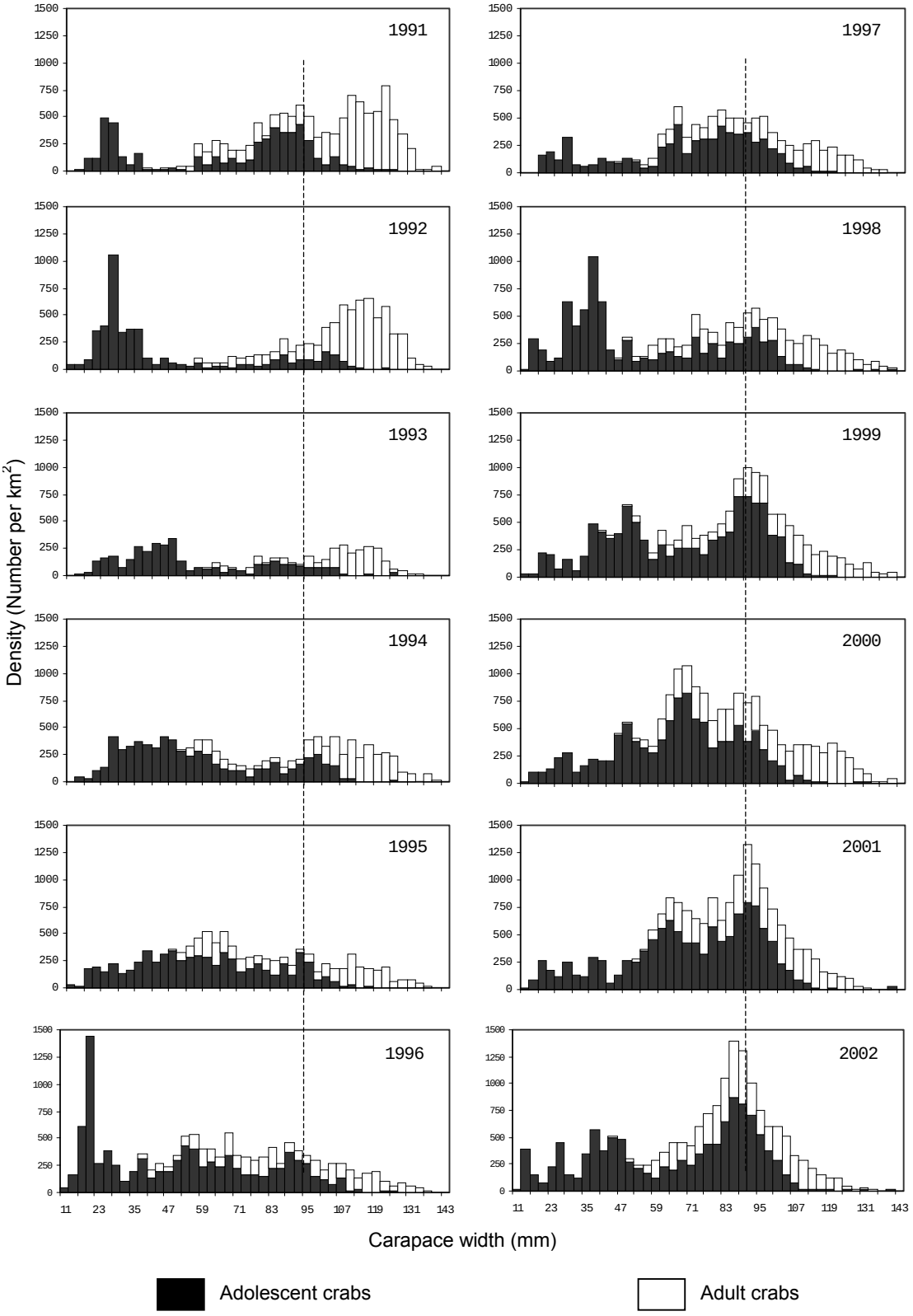
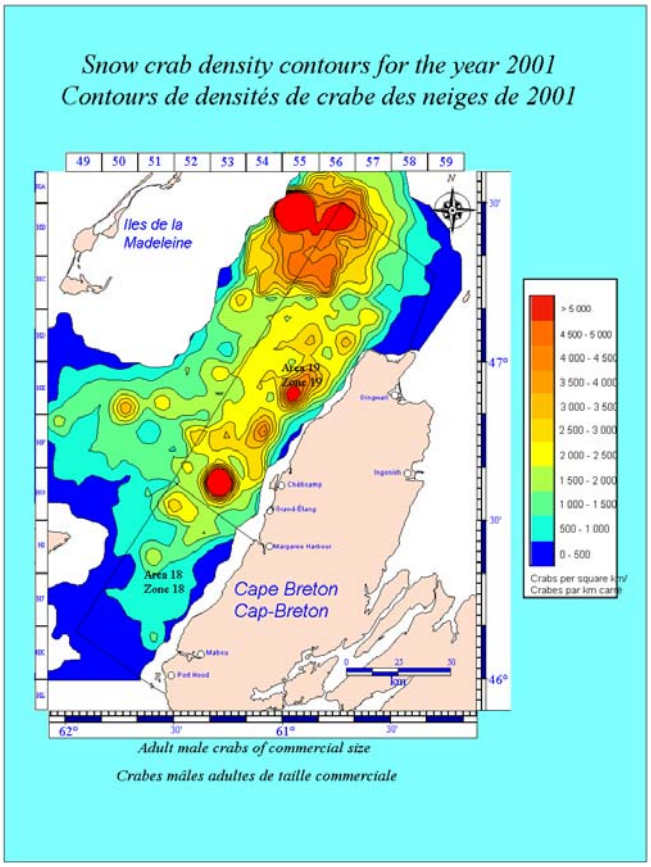


Figure 29. Size frequency distributions for male snow crabs in Area 19 between 1991 and 2002. The 1991-1992 trawl surveys were conducted before the fishing season (dotted lines indicate the minimum legal size of 95 mm CW).

Septembre 2001

June 2002



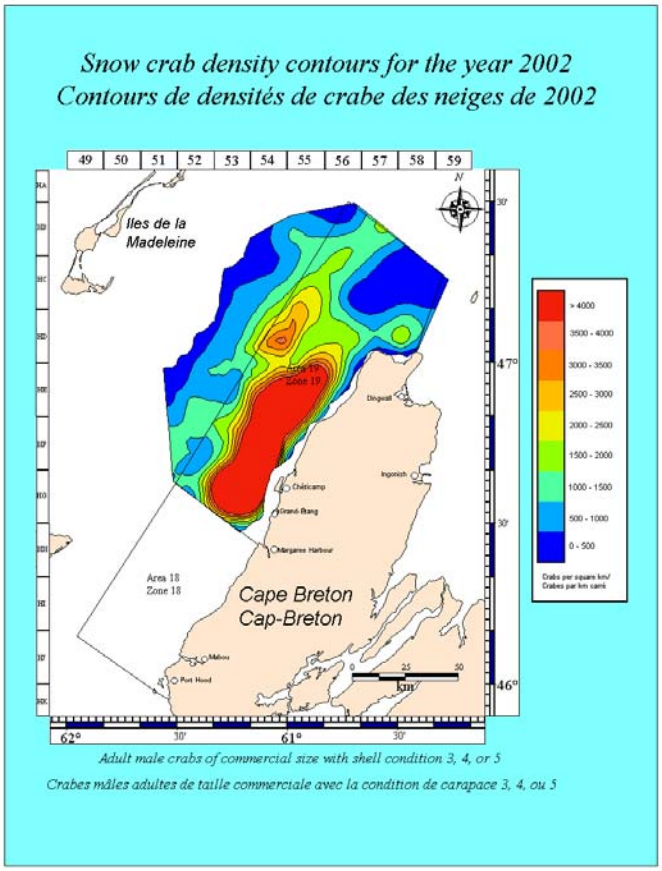


Figure 30. Locations of the September 2001 and June 2002 trawl survey stations in western Cape Breton (Areas 18 and 19 and adjacent zone).

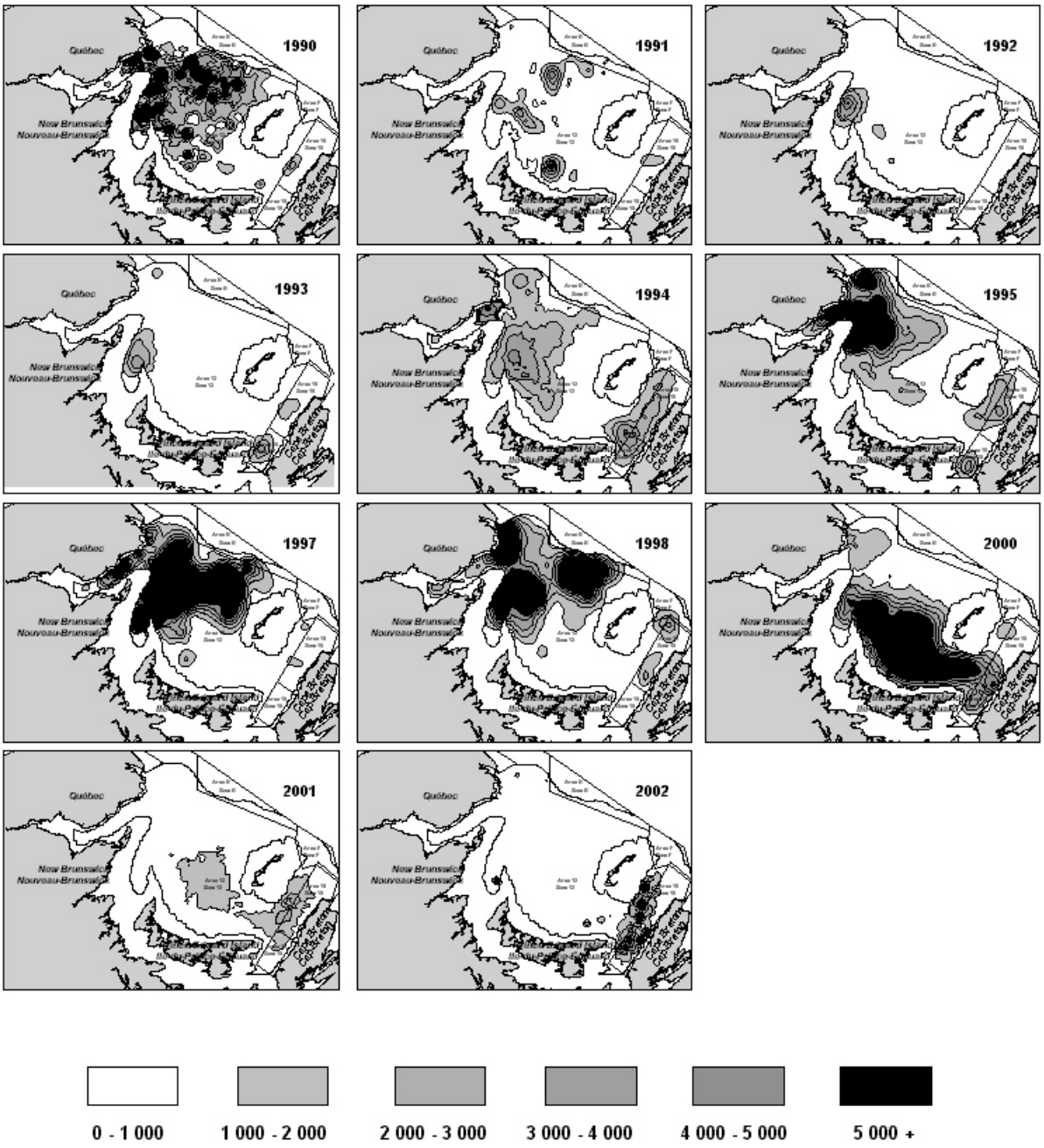


Figure 31. Density contours for pubescent females based on the trawl survey between 1990 and 2002 in the southern Gulf of St. Lawrence.

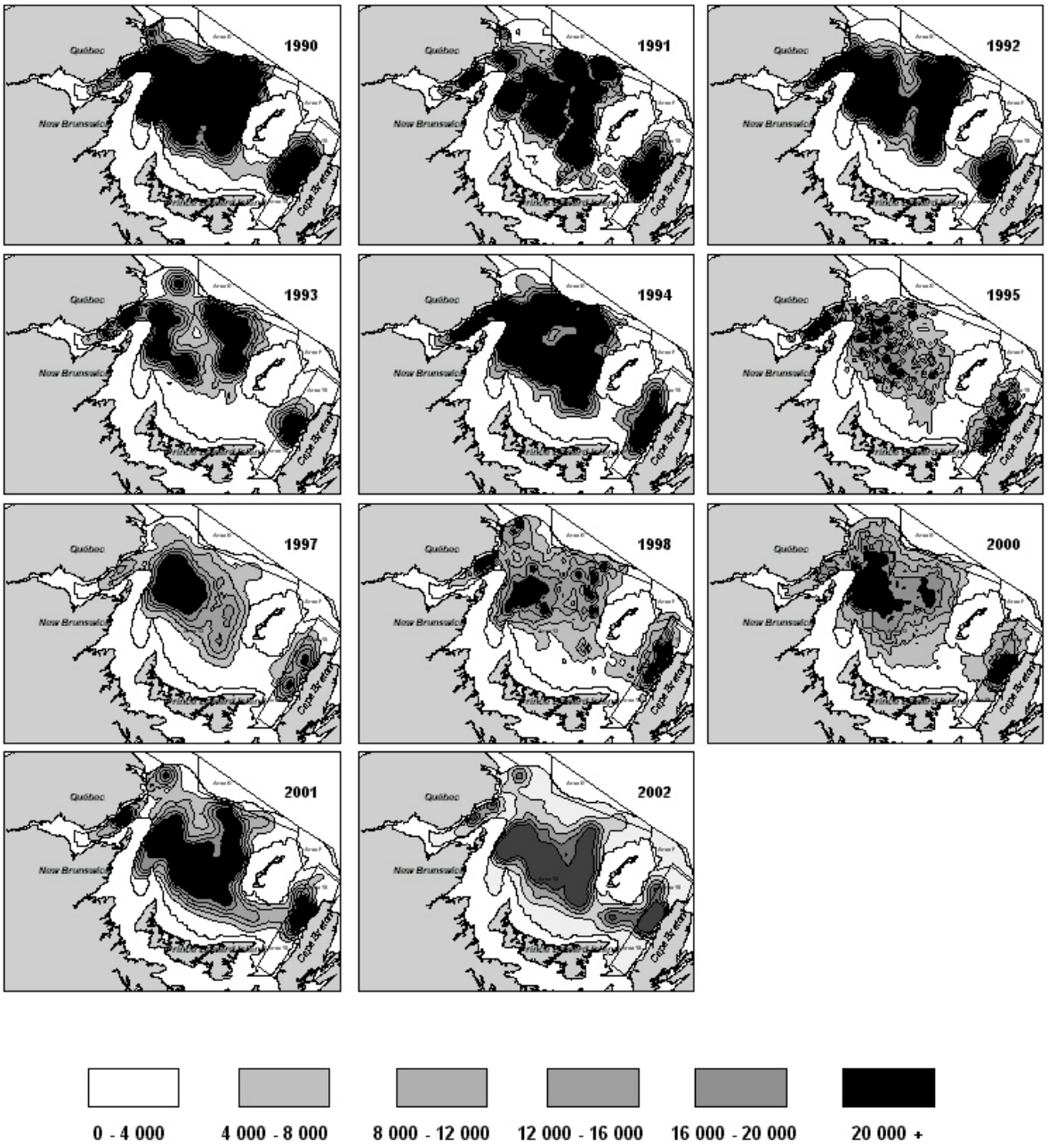


Figure 32. Density contours for mature females based on the trawl survey between 1990 and 2002 in the southern Gulf of St. Lawrence.

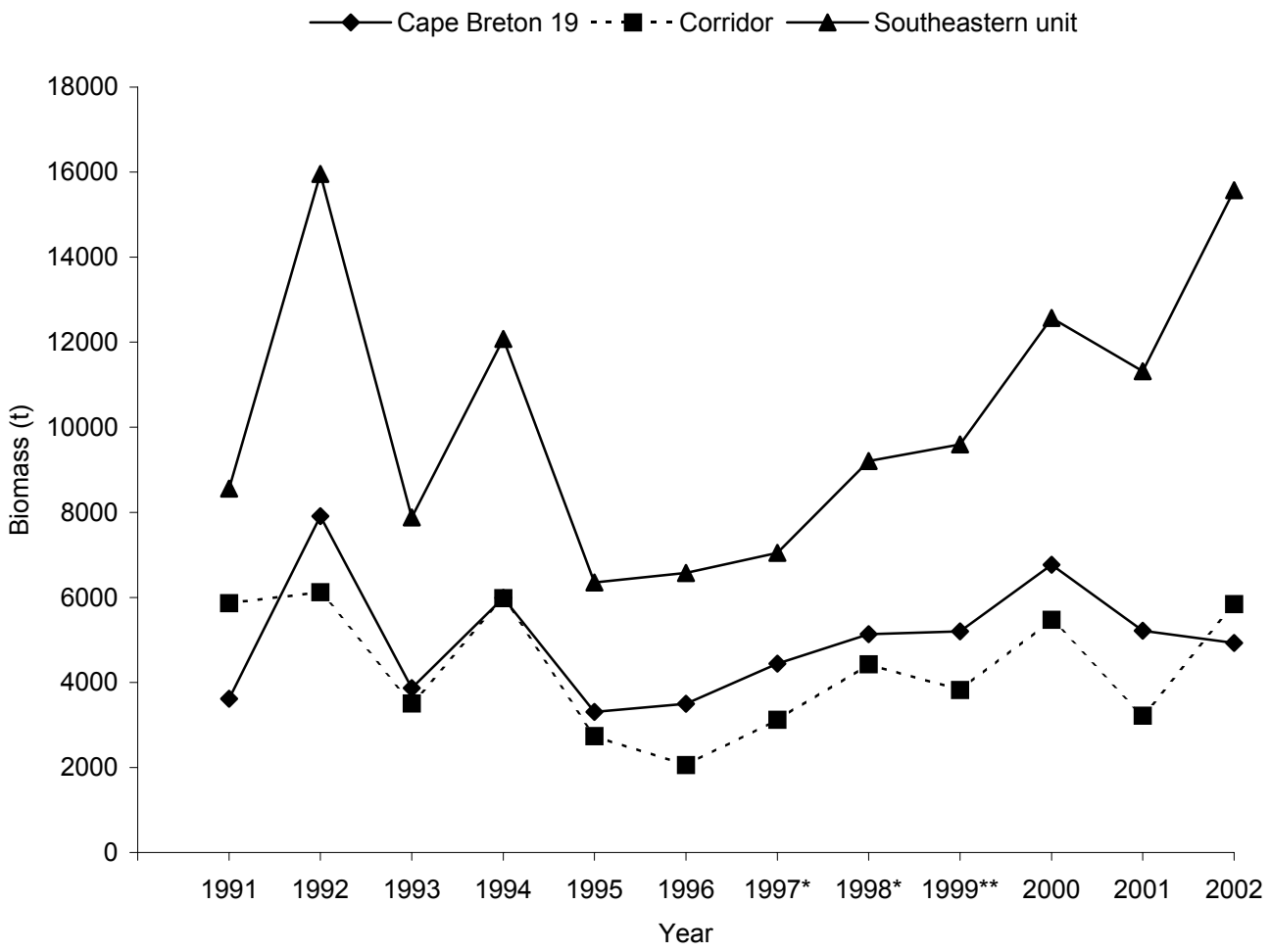


Figure 33. Abundance of adult males ≥ 95 mm CW within the southeastern unit of the southern Gulf of St. Lawrence between 1991 and 2002

* no survey was done in 1997-1998 in Area 18.
** Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

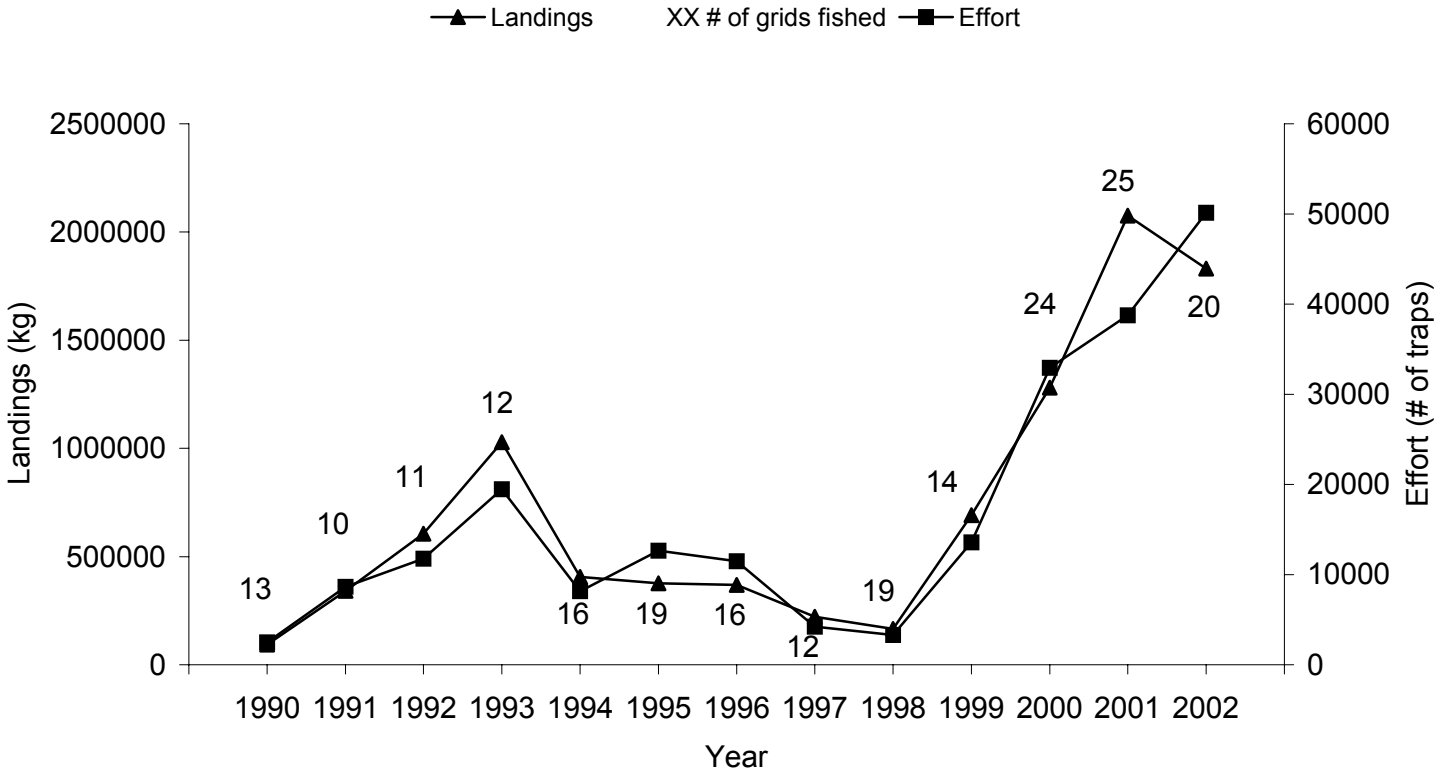


Figure 34. Landings, fishing effort and numbers of grids fished in the Cape Breton Corridor from 1990 to 2002.

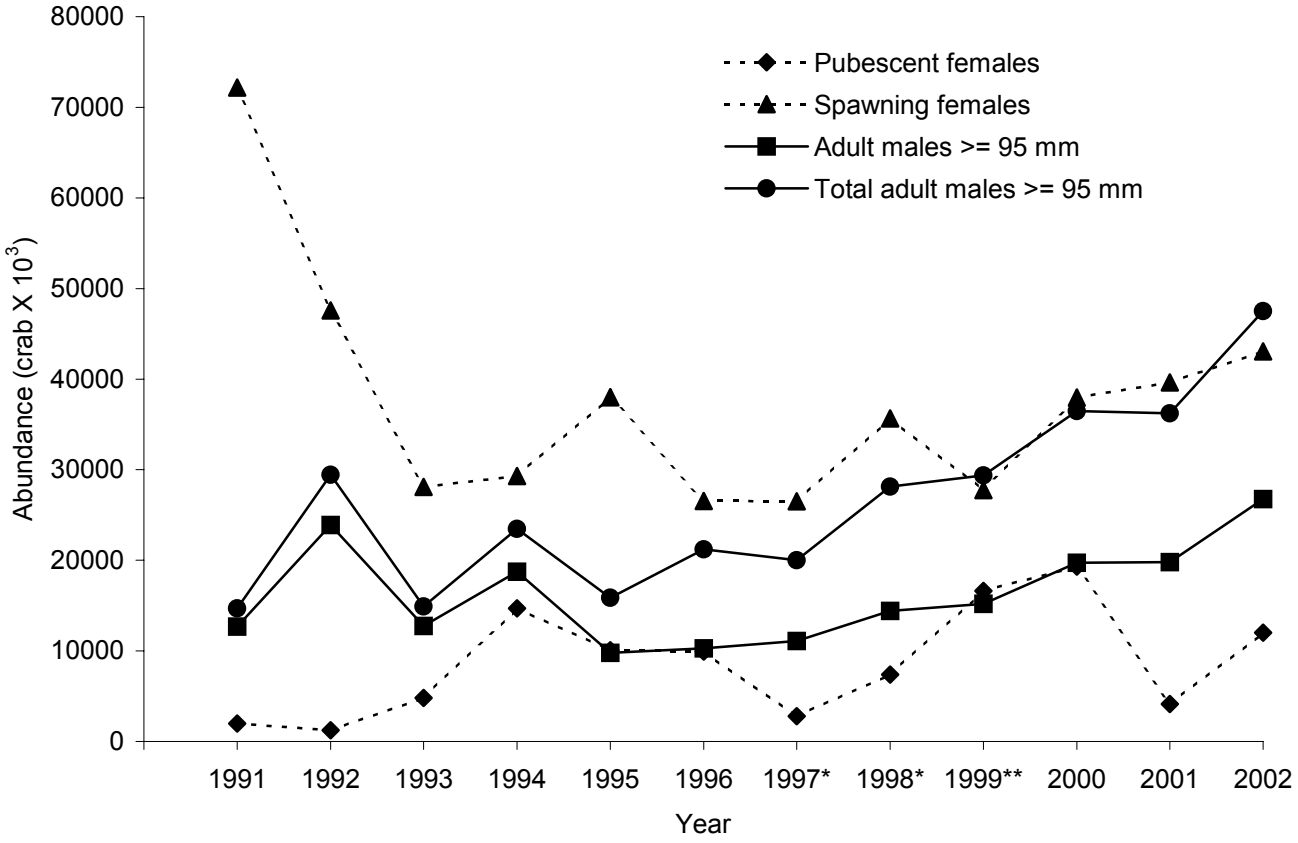


Figure 35. Abundance index of pubescent females, spawning females, adult males ≥ 95mm CW and total adult males in the southeastern Gulf of St. Lawrence between 1991 and 2002.

* no survey in Area 18 between 1997-1998.
** Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.

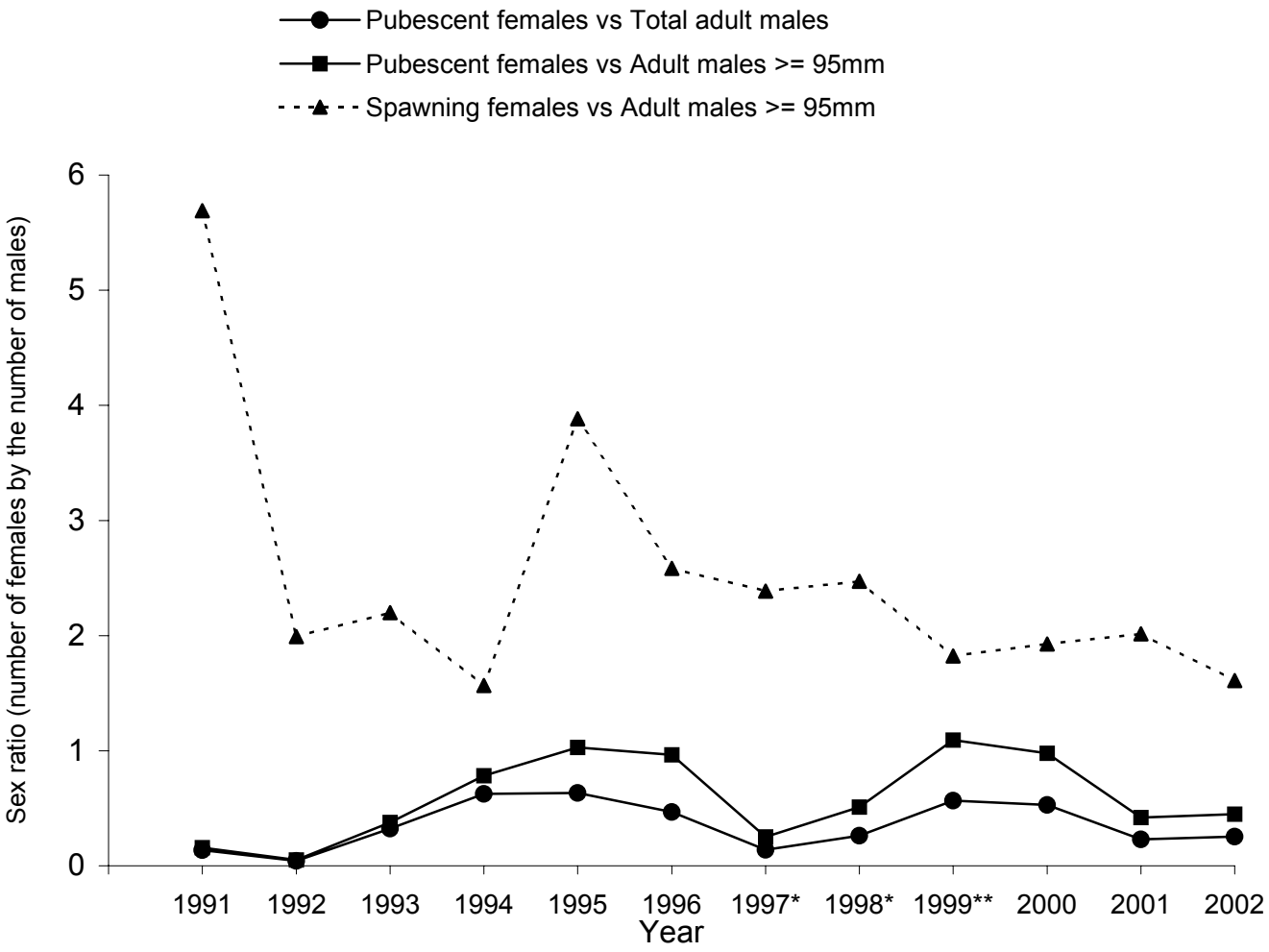


Figure 36. Sex ratio (pubescent females vs total adult males, pubescent females vs adult males ≥ 95 mm CW and spawning females vs adult males ≥ 95 mm CW) in the southeastern unit of the southern Gulf of St. Lawrence between 1991 and 2002.

* no survey in Area 18 between 1997-1998.
** Abundance index in 1999 may not be reliable due to the malfunction of the Netmind system.