ASSESSMENT OF NOVA SCOTIA (4VWX) SNOW CRAB

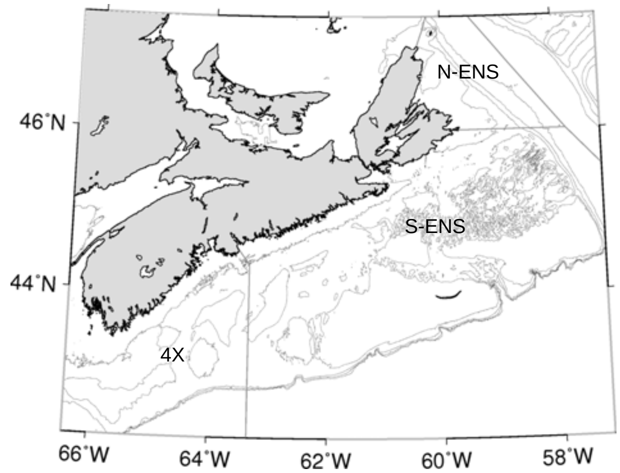


Figure 1. Map of the Scotian Shelf and Crab Fishing Areas (CFA).

Context

Since the demise of the groundfish, snow crab have become a dominant macro-invertebrate on the Scotian Shelf. They are observed in large numbers in deep, soft-bottom substrates ranging from 60 to 280m and at temperatures generally less than 6°C. The 4VWX snow crab are on the southern-most extreme of their spatial distribution in the Northwest Atlantic. In most exploited areas, a general decline in the abundance of snow crab has been observed on the Scotian Shelf since their peak abundance in the late-1990s.

The fishery has been in existence since the early 1970s in Nova Scotia. It exploits the whole spatial extent of the species on the Scotian Shelf. Since 1998, the fishing grounds have been subdivided into three assessment areas (Figure 1). The management of the snow crab fisheries on the Scotian Shelf was initially based on effort controls (season, license, trap limits) from 1982 to 1993 with harvesting during June-November of hard-shelled males larger than 95 mm CW (carapace width). Additional management measures were introduced from 1994 to 1999: IBQs (individual boat quotas), TACs (total allowable catches), 100% dockside monitoring, mandatory logbooks and at-sea monitoring by certified observers. More recently, Vessel Monitoring Systems (VMS) have become a requirement in S-ENS. In 2005, many Crab Fishing Areas (CFAs) and subareas were merged with the resulting divisions being N-ENS (CFAs 20-22), S-ENS (CFAs 23, 24), and 4X (Figure 1). All areas have a summer focused fishery with the exception of 4X whose season extends from late fall to the following spring.

In support of the fishery, DFO Maritimes Fisheries and Aquaculture Management requests from DFO Science an annual assessment of resource status and the consequences of various harvest levels for the coming fishing season. This document is a scientific overview of the assessment and projections undertaken in support of the fishery. Commercial catch rates and other fishery statistics are reported. An assessment of the status of 4VWX snow crab is made from fishery independent surveys using indicators of: abundance; reproductive potential; recruitment; and exploitation rates. Harvest advice for the next year is provided.

SUMMARY

- Landings in 2007 for N-ENS and S-ENS were 233 t and 4942 t, respectively, and 317 t in CFA 4X for the 2006/2007 season, all within their respective TACs of 244, 4950, and 337.6 t. These changes in landings represent a decline of 52% in N-ENS and increases of 10% and 4% in S-ENS and 4X, respectively, relative to 2006.
- Average, non-standardized catch rates in 2007 were 23.6 kg/trap and 100.1 kg/trap in N- and S-ENS, and 27.7 kg/trap in 4X in 2006/2007 – representing a decrease of 34%, an increase of 10% and a decrease of 3%, respectively.
- The soft-shelled crab discard represents up to 271 t (116% of landings) and 353 t (7% of landings) being subjected to potential handling mortality in N- and S-ENS, respectively. 4X discard rates of soft crab are very low.
- The post-fishery fishable biomass of snow crab was estimated to be 970 t in N-ENS (with a 95% confidence range of: 730 to 1,230 t) and 41,590 t in S-ENS (with a 95% confidence range of: 37,260 to 46,320 t) and 1,030 t in CFA 4X (with a 95% confidence range of: 470 to 1,710 t) – representing a 29% increase, a 47% increase and no change, respectively. Fishable biomass estimates were 570, 28,200, and 1,030 t for N-ENS, S-ENS and 4X, respectively, in 2006.
- The main pulse of male recruitment of the Scotian Shelf population continues to grow and is currently centered over a 68 mm CW modal group (instars 11/12). The leading edge of recruitment entered in 2007 and full entry is expected by 2011. Recruitment after 2014 is uncertain.
- The reproductive potential of the Scotian Shelf population has increased with a substantial increase in berried female abundance in all areas. Larval production should continue for another 4 years.
- The numerical abundance estimates of old males (CC5) are currently below the detection limit on the Scotian Shelf surveys and low as well (approximately 1% or less) in the at-sea observed data (<10% of landings observed in all areas).
- A general trend of increasing temperatures since the early 1990s along the Scotian Shelf represents an additional source of uncertainty as this may limit the potential habitat available to snow crab. In 2007, bottom temperatures in all areas were at or below the 38-year mean. CFA 4X has in particular demonstrated stronger inter-annual variability since the late 1990s.
- Potential predators of immature and soft-shelled snow crab continue to be found in areas with high densities of immature snow crab. This adds uncertainty to the potential strength of future recruitment to the fishable biomass.
- By-catch levels are very low in this fishery between 0.015 to 0.325% of mean annual landings, mostly of other crustacean species.
- Relative exploitation rate (by biomass) in N-ENS was 24% in 2007. A range between 10 to 20%, depending upon the strength of recruitment, may help ensure the long-term sustainability of this fishery. A decrease in TAC is recommended until the fishable biomass has increased sufficiently to reduce soft-shell catches and associated potential mortality, unless other management measures can be implemented to lower the handling of soft-shell crab.
- Relative exploitation rate (by biomass) in S-ENS was 10% in 2007. A range between 10 to 30%, depending upon the strength of recruitment, may help ensure the long-term sustainability of this fishery. The snow crab in S-ENS can be considered to be in a healthy state. An increase in TAC is recommended.
- Relative exploitation rate in CFA 4X in 2006/07 was 23%, though due to the very specific spatial extent of the fishery, realized exploitation rates are likely higher. No additional incremental increase to the 2007/08 TAC is recommended. A maintenance or reduction of this TAC is recommended for the 2008/09 season.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*, Brachyura, Majidae, O. Fabricius) is a subarctic species with a distribution from northern Labrador to near the Gulf of Maine. Habitat preferences are soft mud bottoms. Smaller crabs are found in more complex habitats with shelter. Commercial crab in large numbers are found at depths from 60 to 280 m and temperatures from -1 to 6 °C on the Scotian Shelf. Temperatures greater than 7 °C are known to be detrimental to snow crab. The primary food items of crab are shrimp, fish (capelin and lumpfish), starfish, sea urchins, worms, detritus, large zooplankton, other crabs, ocean quahaug, molluscs, sea snails and sea anemones. Predators of snow crab are halibut, skates (especially thorny skate), cod, seals, American plaice, squids, and other crabs. Crab in the size range of 3 to 30 mm CW are particularly vulnerable to predation as are soft-shelled crab in the spring moulting season.

A female snow crab produces from 16,000 to 160,000 eggs in the spring which are brooded by the mothers for up to 2 years, depending upon ambient temperatures, food availability and maturity status. Eggs are hatched from late spring to early summer when they become pelagic (zoea stages 1 and 2 and the intermediate megalopea stage) feeding upon plankton. After 3 to 5 months in the pelagic stage, they settle to the bottom in late autumn and winter. In the early bottom dwelling postlarval stages (“instars”), crab moult approximately twice a year. Snow crab generally moult once a year from the 5th instar up to a terminal moult (instars 9 to 14 for males and 9 to 11 for females). Snow crab can become sexually mature by the 9th instar. Prior to the terminal moult, male crab may skip a moult in one year to moult in the next. Male snow crab reach legal size by the 12th instar, representing an age of approximately 9 years since settlement to the bottom and 11 years since egg extrusion. Some males of instar 11 will also be within legal size.

Females begin to moult to maturity at an average size of approximately 55 mm CW and mate between winter/spring while the carapace is still soft (prior to the prosecution of the fishery in ENS). Complex behavioural patterns have been observed: the male helps the female remove her shell during her moult, protects her from other males and predators and even feeds her (indirectly). Pair formations (mating embrace where the male holds the female) have been seen to occur up to 3 weeks prior to mating. Upon larval release, males have been seen to wave the females about to help disperse the larvae. Females are selective in their mate choice and may die in the process of resisting mating attempts from unsolicited males. Males compete heavily for females and often injure themselves (losing appendages) while contesting over a female. Once terminally moulted, snow crab can live up to 6 years under optimal conditions. This means that females can reproduce two or more times, depending upon environmental conditions. The carapace condition rapidly deteriorates in the last years of its life, a stage that is generally associated with a mossy and decalcified carapace.

Natural mortality rates of snow crab on the Scotian Shelf have not been estimated. However, mortality rates (including by-catch, illegal landings, soft-shell handling mortality, predation, agonistic behaviour, disease, old-age) for legal sized crab resident in the southern Gulf of St. Lawrence have been estimated to be within the range of 26 to 48% per annum. This may be an overestimate for the Scotian Shelf as very few natural predators for large snow crabs currently exist; soft-shell catch is generally lower; and the number of mature females is lower resulting in reduced agonistic behaviour.

Fishery

The snow crab fishery in eastern Canada began in 1960 with incidental by-catches by groundfish draggers near Gaspé, Quebec. Its development was slow until the 1980s when it began expanding rapidly to become one of the largest fisheries in Canada, in terms of landings and landed value. On the Scotian Shelf, the fishery has been in existence since the early 1970s with landings at levels of 1,000 t. By 1979, this rose to 1,500 t subsequent to which the fishery declined substantially in the mid-1980s. A large pulse of recruitment to the fishery was observed in 1986. Total landings increased to record-levels of approximately 10,000 t each year in the early 2000s (Figure 2). The spatial distribution of total landings has shifted from being mostly derived from inshore areas in the past (2000-2002) to presently being derived mostly from the offshore areas (Map 1). In 2007, landings were 233 t in N-ENS, 4942 t in S-ENS and 317 t in 4X for 2006/2007 (Tables 1, 2, and 3), representing a decline of 52%, and increases of 10% and 4%, respectively, relative to 2006.

Table 1. Summary of snow crab fisheries activity of N-ENS.

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (x1000 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	94.3	11.3
2002	80	1,493	1,495	101.0	14.8
2003	80	1,493	1,492	76.8	19.4
2004	79	1,416	1,418	60.6	23.4
2005	78	566	562	30.6	18.4
2006	78	487	486	35.6	13.7
2007	78	244	233	23.6	9.9

Table 2. Summary of snow crab fisheries activity of S-ENS. Catch rates and trap hauls for 2001 to 2004 are calculated excluding slope area landings and effort as they were design-constrained trap surveys; however, these landings are included in total landings and TACs. These slope allocations were for 200 t in 2001-2002 and 300 t in 2003-2004.

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (x1000 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	9,023	9,048	87.8	103.1
2002	149	9,022	8,891	111.7	79.6
2003	145	9,113	8,836	98.6	89.6
2004	130	8,241	8,022	105.6	76.0
2005	114	6,353	6,407	109.5	58.5
2006	114	4,510	4,486	90.9	49.4
2007	114	4,950	4,942	100.1	49.3

Table 3. Summary of snow crab fisheries activity of CFA 4X. From 1994 to 1996, 4 exploratory permits were active with an average of 10.6 t landed each year. Catch rates are for the large trap complements only. Calculated effort represents the large trap complement catch rate applied to all landings.

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (x1000 trap hauls)
1997/08	4		42		
1998/09	4		70		
1999/2000	4		119		
2000/01	6		213		
2001/02	8	520	376		
2002/03	9	600	221	10.1	21.9
2003/04	9	600	289	12.7	22.8
2004/05	9	600	413	20.3	20.8
2005/06	9	337.6	306	28.6	10.8
2006/07	9	337.6	317	27.7	11.5
2007/08	9		94.3 (mid –season)		

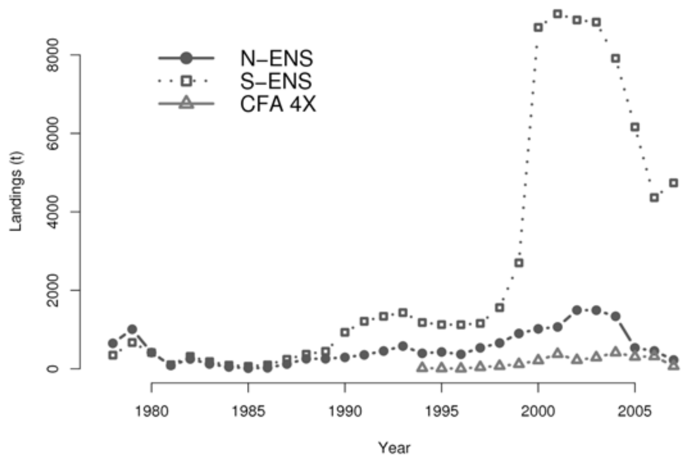


Figure 2. Temporal variations in the landings (t) of snow crab on the Scotian Shelf. Note the sharp increase in landings associated with large increases to TACs and a doubling of fishing effort in the year 2000. The landings follow the TACs with little deviation and so are not shown. For CFA 4X, the year refers to the starting year.

The spatial distribution of fishing effort continued to increase in offshore areas and decline in inshore areas (Map 2). The effort on the offshore-slope areas was minimal in 2007. In 2007, a total of 9,880 and 49,345 trap hauls were applied in N- and S-ENS, respectively. This represents declines of 28% and 0.1%, respectively, from 2006 (Tables 1 and 2; Figure 3). In 4X, two trap complements are used: 60 large traps (7 licences) or 200 small traps (2 licences). A total of 11,500 trap haul equivalents (catch rate for large traps applied to entire landings) were applied in the 2006/2007 season as compared to 10,800 in 2005/2006 season, an increase of 7% (Table 3; Figure 3).

In 2007, the non-standardized catch rate for N-ENS was 23.6 kg/trap, a 34% decrease from 35.6 kg/trap in 2006 (Table 1; Figure 4). In S-ENS, the catch rate was 100.1 kg/trap, a 10% increase from 90.9 kg/trap in 2006 (Table 2; Figure 4). In 4X, the catch rate for the large traps was 27.7 kg/trap, a decrease of 3% from 28.6 kg/trap in the 2005/2006 season (Table 3; Figure 4).

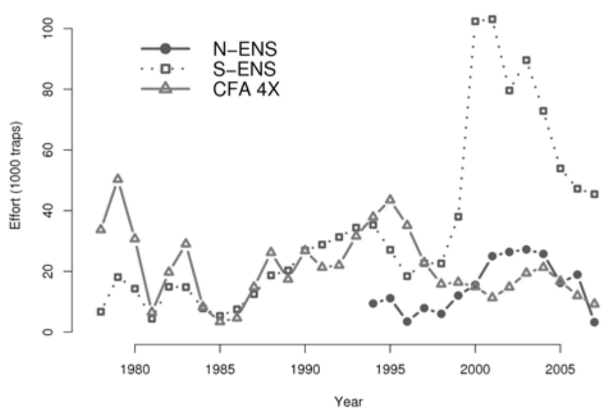


Figure 3. Temporal variations in the fishing effort, expressed as the number of trap hauls. Note the doubling of effort in the year 2000. For CFA 4X, year refers to the starting year of the season.

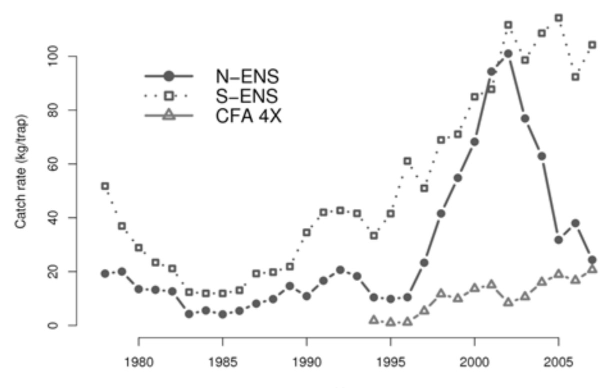


Figure 4. Temporal variations in catch rates of snow crab on the Scotian Shelf, expressed as kg per trap haul. Trap design and size have changed over time. No corrections for these varying trap-types nor soak time and bait-type have been attempted.

In N-ENS, the moult structure of male legal-sized snow crab observed at sea was dominated by CC1 (41%) crab, representing an extremely high (relative to historical records and other areas) proportion of the catch to be composed of these handling-sensitive crab. CC2 crab increased in proportion as well to 13% (relative to 10% in 2006). CC3 (38%) and CC4 (8%) crab have declined in relative abundance since 2006 (92% and 13%, respectively) potentially indicating elevated exploitation rates relative to recruitment rates in the area. CC5 crab declined marginally in relative numbers from 1% in 2006 to 0.7% in 2007. With the decline in the fishable biomass, newly moulted (CC1 and CC2) crab have become an increasingly important component of the fished biomass for N-ENS (Figure 5). That is, N-ENS is heavily reliant upon new recruitment.

In S-ENS, the moult structure of all snow crab observed at sea was comparable between 2006 and 2007 (Figure 5). In the legal-sized fraction, CC1 and CC2 crab represented 8.8% and 15%, respectively, of the observed catch. Hard-shelled crab dominated the catch: 58% CC3 and 15.9% CC4. However, the increase in CC4 (7.3% in 2006 to 15.9% in 2007) and CC5 (0.4% in 2006 to 1.6% in 2007) suggests that exploitation rates may now be appropriate as more crab are maturing to later moult stages, reversing a trend in reduced late stage (CC4 and CC5) crab observed since 2004.

In CFA 4X, the moult structure of legal sized snow crab has been dominated by CC3 crab in the historical record. While a small pulse of CC2 crab was observed in 2005/2006, very few were observed in 2006/2007. Almost no CC4 or CC5 crab were observed.

The soft-shelled crab discard represents up to 271 t (116% of landings) and 353 t (7% of landings) being subjected to potential handling mortality in N- and S-ENS, respectively. The N-ENS soft-shell incidence occurred predominantly throughout the inside fishing grounds of the northern basin of N-ENS and predominantly in inshore areas of S-ENS (Figure 6). In 4X, discard rates of soft-shell crab are very low.

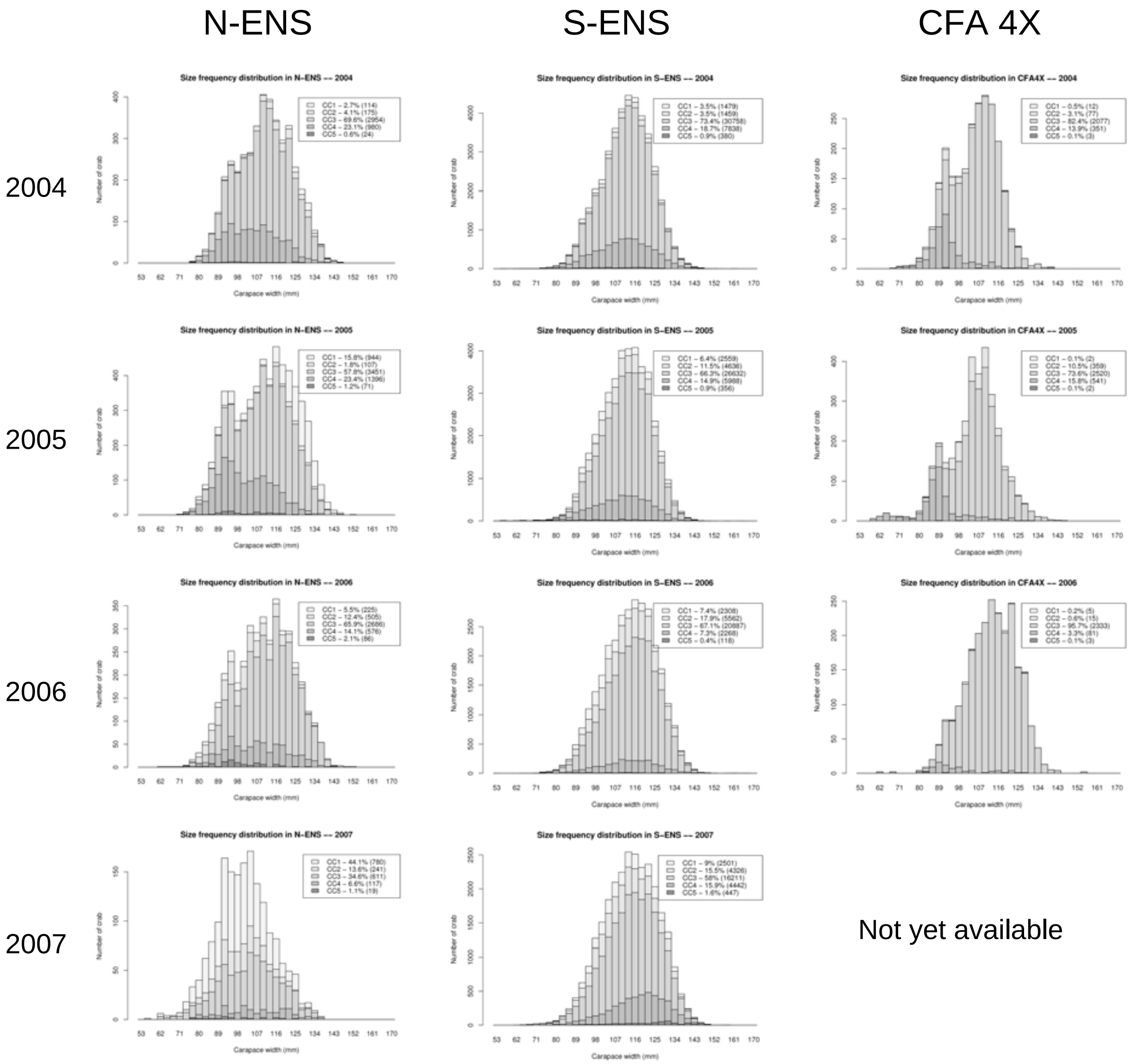


Figure 5. Size frequency distribution of all at-sea-observer monitored snow crab broken down by carapace condition. For CFA 4X, the year refers to the starting year of the season.

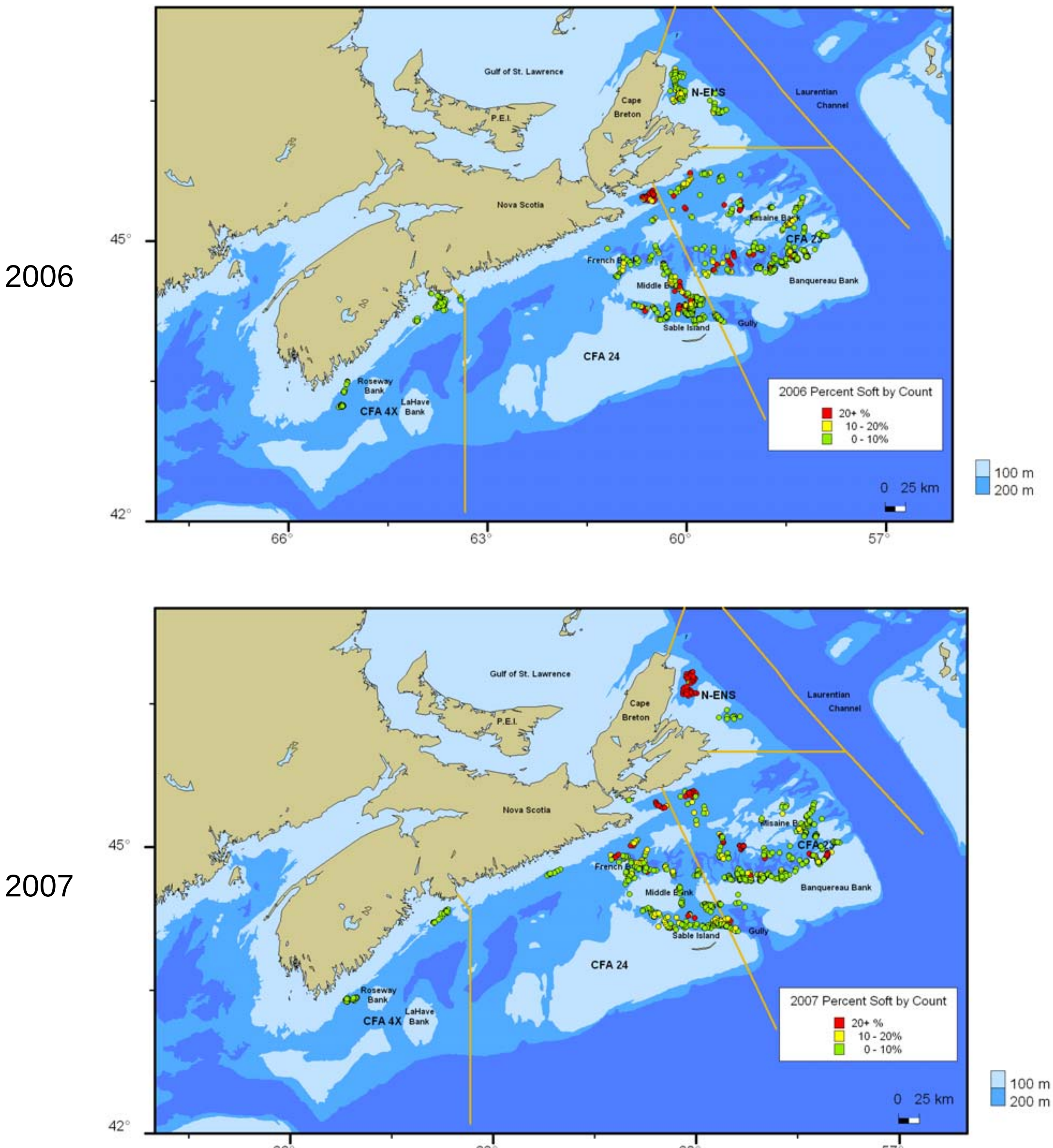


Figure 6. Location of soft-shell snow crab occurrence in the commercial fishery. For CFA 4X, the year refers to the end year.

ASSESSMENT

Stock Trends and Current Status

Fishable Biomass

The fishable biomass is defined as that segment of the snow crab population biomass that is male, mature, larger than 95 mm CW and hard-shelled (with a durometer measure of 68 mm or greater).

In N-ENS, the 2007 post-fishery fishable biomass of snow crab was estimated to be 970 t (with a 95% confidence range of 730 to 1,230 t; Figure 7; Map 4), a 29% increase relative to the 2006 estimate of 750 t. The increases were observed in the northern basin of N-ENS.

In S-ENS, the 2007 post-fishery fishable biomass of snow crab was estimated to be 41,590 t (with a 95% confidence range of 37,260 to 46,320 t; Figure 7; Map 4), a 47% increase relative to the 2006 estimate of 28,200 t.

In CFA 4X, the pre-fishery fishable biomass was estimated to be 1,030 t (with a 95% confidence range of: 470 to 1,710 t; Figure 7; Map 4). This represents no significant change relative to 2006 (pre-fishery); however, the uncertainty of the 2007 estimate was double that of 2006.

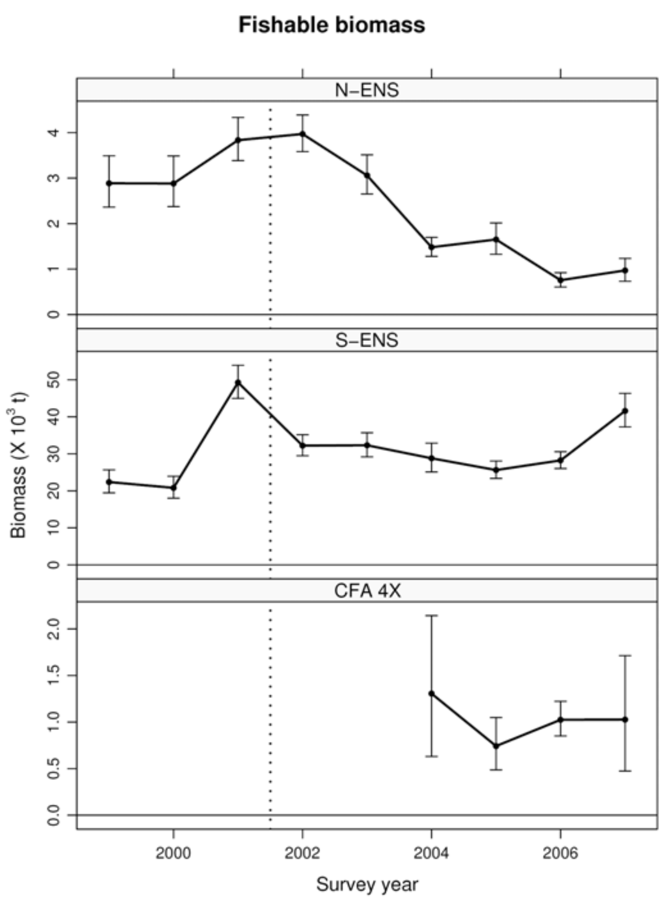


Figure 7. Fishable biomass over time from kriged estimates. Vertical line represents the shift in survey timing from spring to autumn.

Recruitment

The index of recruitment (CC1 and CC2 crab) to the fishable biomass since 2005 has been increasing in both N- and S-ENS and extremely variable in CFA 4X (Figure 8). Recruitment to fishable biomass in S-ENS is centered over Chedabucto Bay and the area north of Sable Island. The inshore areas of the northern basin in N-ENS continue to show signs of positive recruitment (Map 5).

The main pulse of male recruitment of the Scotian Shelf population continues to grow and is currently centered over a 68 mm CW modal group (instars 11/12; Figure 9a). The leading edge of recruitment entered in 2007 and full entry is expected by 2011. Recruitment after 2014 is uncertain. This recruitment is currently strongest in S-ENS (Figure 8).

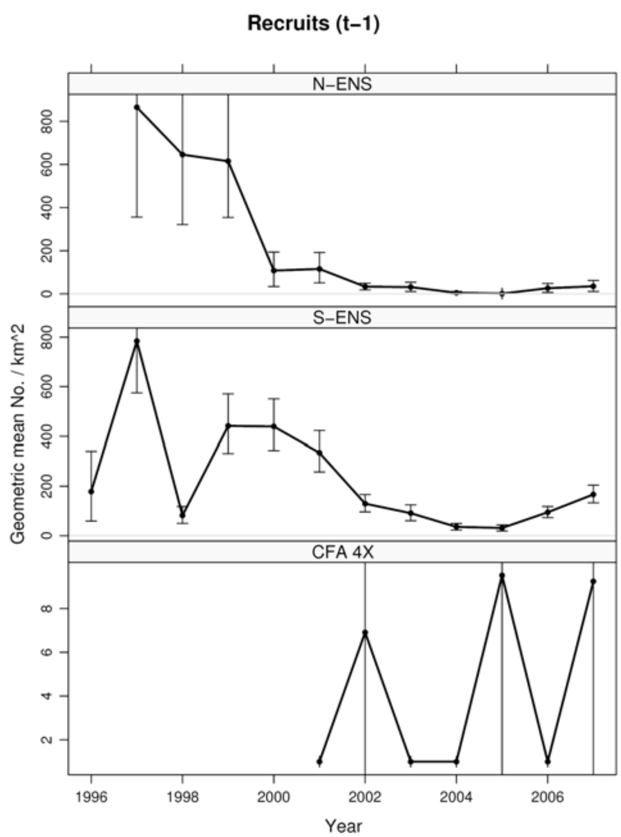


Figure 8. Expected recruitment (males larger than 95 mm CW and soft-shelled) into the mature stage in the next year. As this recruitment has been low for the last 4 to 5 years, the fishery has been increasingly dependent upon immature males. Vertical lines represent 2 standard errors.

Reproduction

The strong year-classes of immature females (Figure 9b) have mostly entered their mature reproductive phases. The reproductive potential of the Scotian Shelf population has increased with a substantial increase in berried female abundance in all areas. Larval production should continue for another 4 years. An increase in the number of berried females has also continued (Figure 10). Most of the mature females are currently located in the inshore areas of S-ENS as well as the main fishing grounds in N-ENS; these were therefore the core areas where larval production occurred in 2006/2007 (Map 6). Isolated areas of high concentrations of mature females (Figure 11, Map 6) were also found in CFA 4X.

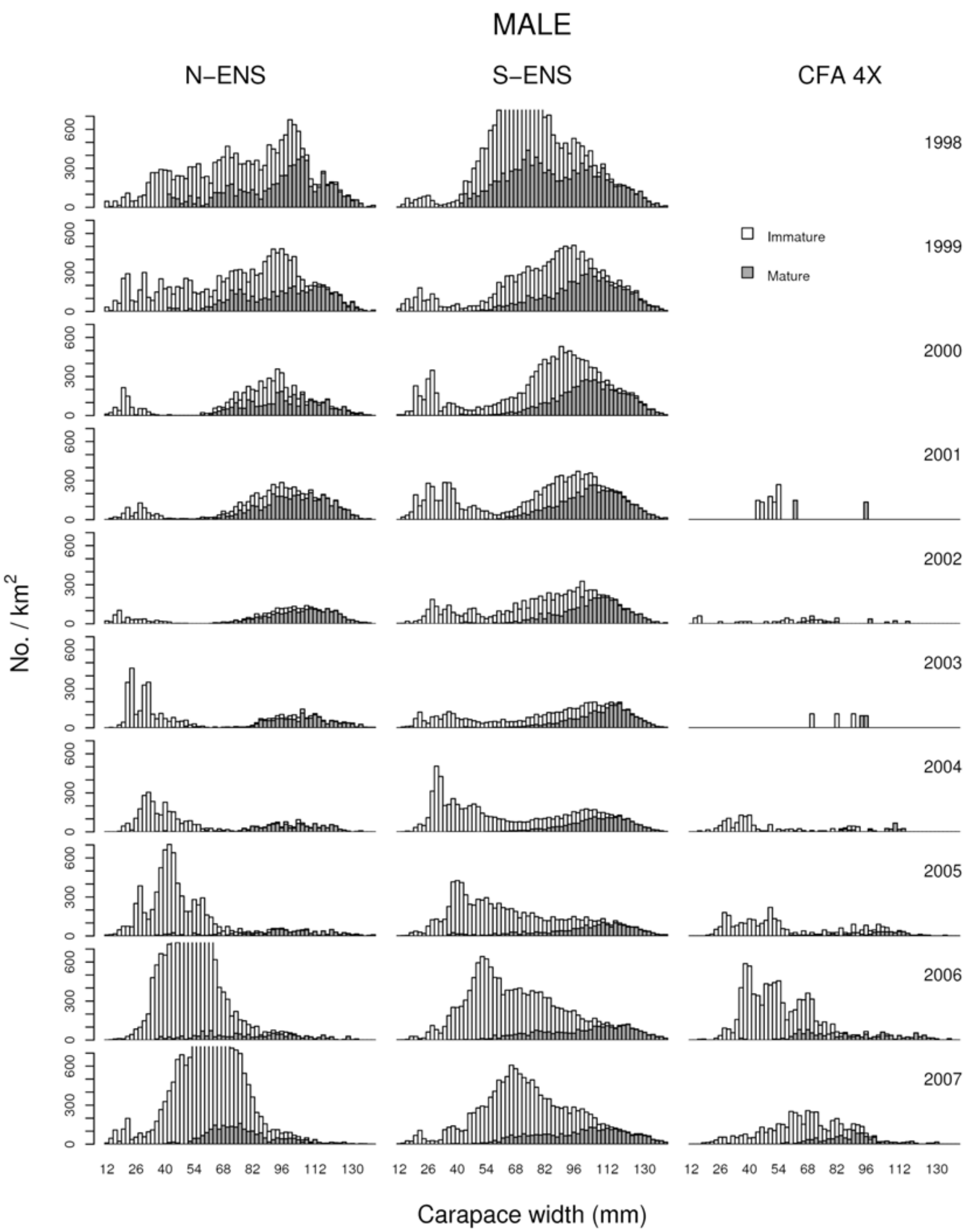


Figure 9a. Size-frequency histograms of carapace width of male snow crabs. Note the increasing numbers of juvenile crab, 1 to 3 years from entering morphometrically mature size classes. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year.

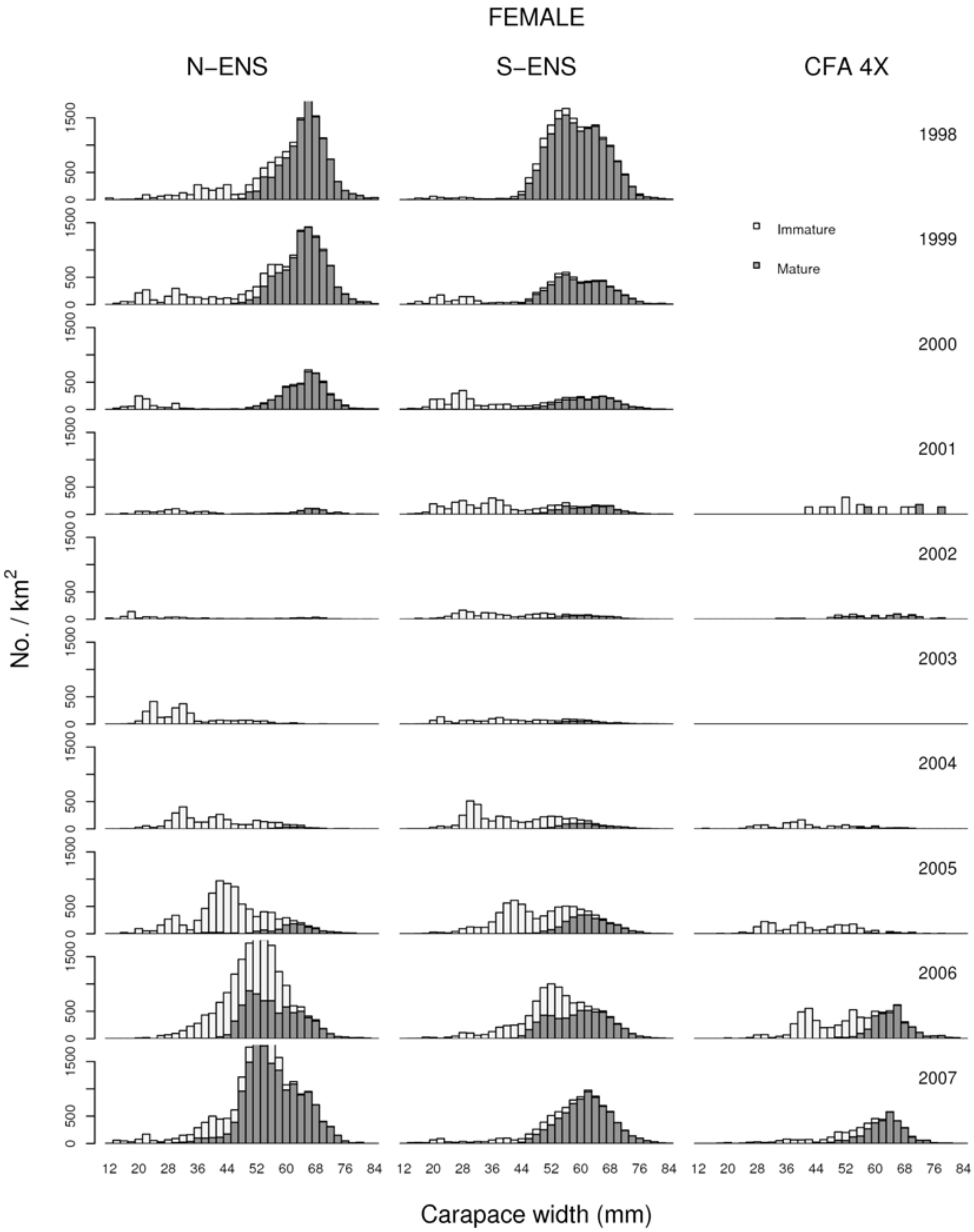
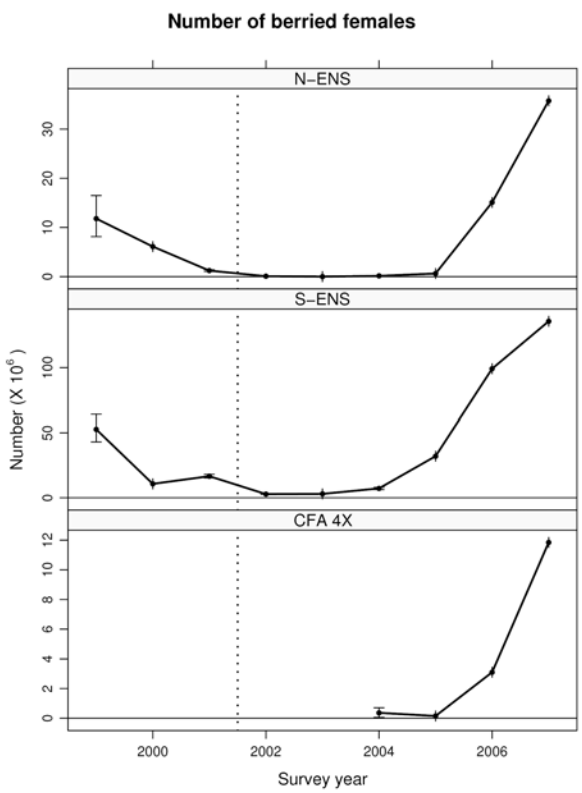


Figure 9b. Size-frequency histograms of carapace width of female snow crabs. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year.



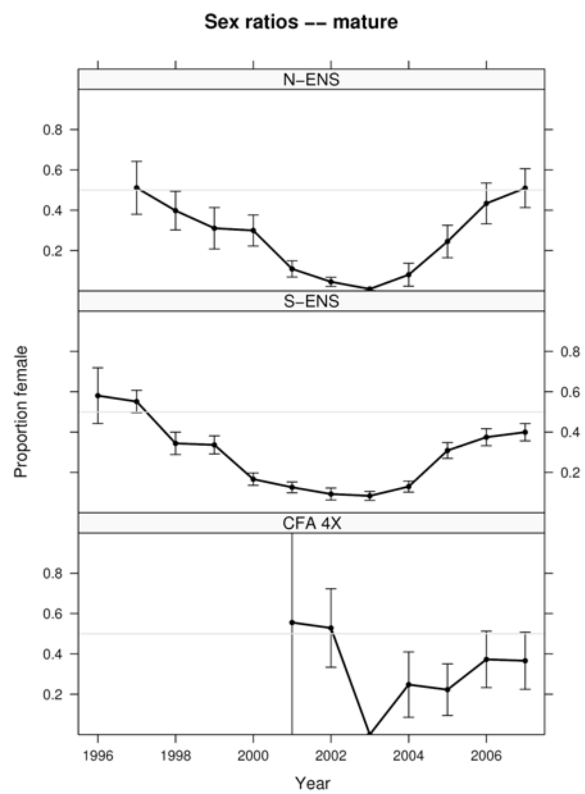


Figure 10. Numerical densities of the berried female snow crabs on the Scotian Shelf (number/km^2). Note the important increase seen since 2005 in all areas of the Scotian Shelf. Vertical line represents the shift in survey timing from spring to autumn.

Figure 11. Sex ratios (% female) of mature snow crab. Since 2000, most of the Scotian Shelf was uniformly male dominated. A slight amelioration of the mature sex ratio was first observed in 2004. This trend has continued and currently, the whole of the shelf can be seen to be entering a reproductive mode.

Relative Exploitation Rate

Relative exploitation rates are defined as $Landings_{(y)}$ / [$Landings_{(y)}$ + Fishable $biomass_{(y)}$], where y is the year.

The numerical abundance estimates of CC5 crab are currently below the detection limit on the Scotian Shelf. Their low representation in survey data and the fishery-observed data (generally less than 1%) may be indicative of high historical exploitation rates upon the hard-shelled phase. However at-sea-observer coverage is low at 10% or less of the total landings in all areas.

Exploitation rates in N-ENS have historically ranged from 24 to 48%; in 2007, they were 24% (Figure 12). Projections suggest that a range between 10 to 20%, depending upon the strength of recruitment, may help ensure the long-term sustainability of this fishery.

In S-ENS, exploitation rates have been stable between 10 to 20%; in 2007, they were 10% (Figure 12). Projections suggest that a range between 10 to 30%, depending upon the strength of recruitment, may help ensure the long-term sustainability of this fishery.

In CFA 4X, exploitation rates have been intermediate between N- and S-ENS, ranging between 18 to 36%; in 2006/2007 exploitation rates were 23% (Figure 12). The realized rates are; however, likely to be greater due to the very specific spatial extent of the fishery in area 4X (Maps 1-3). Projections suggest that a range between 10 to 30%, depending upon the strength of recruitment and immigration, may help ensure the long-term sustainability of this fishery.

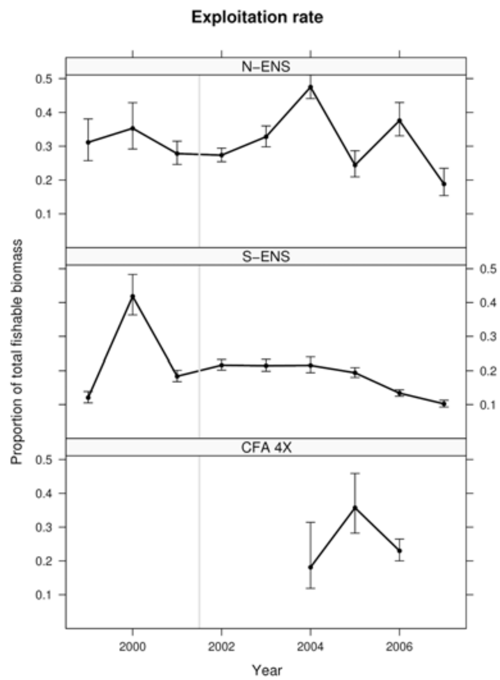


Figure 12. Relative exploitation rate of snow crab. All areas have shown declines since the previous season. Vertical line represents the shift in survey timing from spring to autumn.

Ecosystem Considerations

A multivariate summary of key environmental (climatic), social, economic and fishery-related indicators (Figure 13) suggests that a suite of coherent changes have occurred on the Scotian Shelf since the early 1990s. These latter changes include: changes in the relative abundance of groundfish (declining) and invertebrates (increasing; e.g. snow crab) and their associated landings and landed values; socio-economic changes in ocean use such as Oil and Gas exploration and development (increasing). Gross Domestic Product (GDP) associated with the Oil and Gas sector as well as total Nova Scotia GDP (increasing). Further, the physiological condition of many groups of fish has also been declining and the total number of shellfish closures have increased with time, as has the amount of seismic activity. Increasing ocean colour, abundance of diatoms and dinoflagellates, and declining abundance of *Calanus finmarchicus* were also influential to this axis of variation. The temporal differences along this axis of variation indicates that coherent systemic changes of socio-economic and ecological indicators occurred in the early 1990s with no real return to historical states evident (Figure 14). In other words, this result indicates that the current "ecosystem state" is one that continues to be amenable to the high abundance of snow crab.

Importantly, temperature-related changes were generally orthogonal (independent) to the above changes: e.g., Cold Intermediate Layer temperature and volume, bottom temperatures and variability in bottom temperatures, bottom oxygen concentrations, and sea ice coverage. The temporal variations of this axis indicate that the current ocean-climate has returned to its average state after a decade-long divergence from the late 1980s to the late 1990s.

Figure 13. Sorted ordination of anomalies of key social, economic, and ecological patterns on the Scotian Shelf relevant to snow crab. Red indicates below the mean and green indicates above the mean. Original in colour.

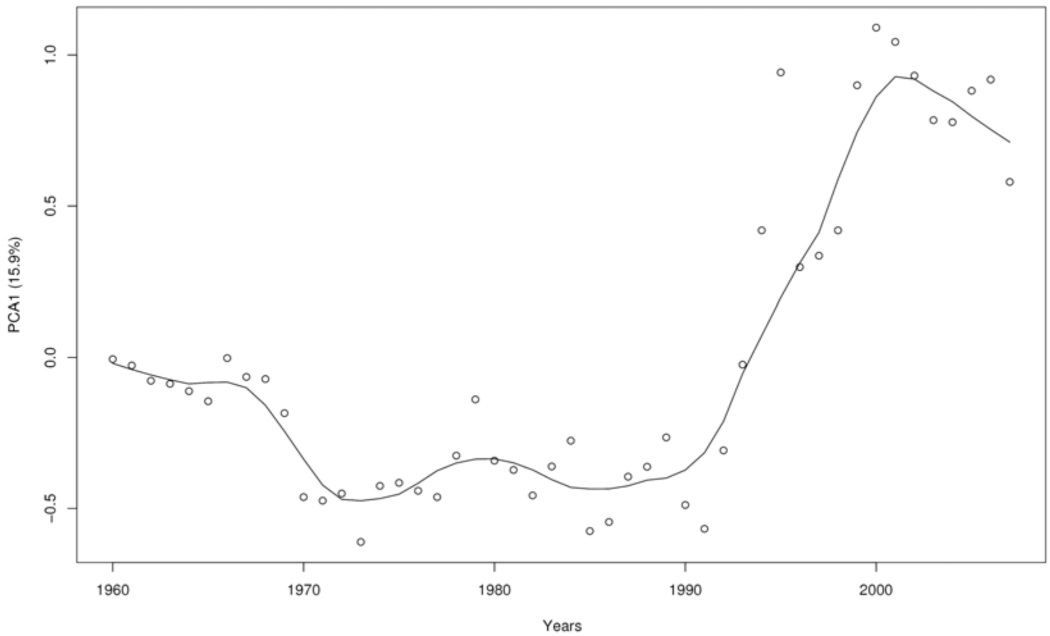


Figure 14: First axis of variation in ordination of anomalies of social, economic and ecological patterns on the Scotian Shelf. Note strong variability observed near the time of the fishery collapse in the early 1990s.

Environmental Variability

The spatial extent of what may be considered potential snow crab habitat based upon bottom temperature and depth preferences in N-ENS has been very stable at a mean of 7.28 × 10^3 km^2 (SD = 0.05 × 10^3 km^2; Figure 15). For S-ENS, the surface area of potential habitat has been much more variable, ranging between 40 to 70 × 10^3 km^2 over the past three decades with a mean of 53.9 × 10^3 km^2 (SD=6.88× 10^3 km^2). In the most recent period, the surface area has increased to above normal levels, 62.3 × 10^3 km^2. In CFA 4X, the southern-most limit of the distribution of snow crab, potential habitat has been most variable, ranging from near 0 to 25 × 10^3 km^2 with a mean of 11.2 × 10^3 km^2 (SD=6.13 × 10^3 km^2). In 2007, the potential habitat was above average in CFA 4X, at 17.36 × 10^3 km^2.

Within the area that may be considered potential snow crab habitat, average bottom temperatures were 3.1, 3.3 and 5.1^{o}C in N-, S-ENS and CFA 4X, respectively (Figure 16). Average bottom temperatures in 2007 were at or below these long-term means. An overall warming trend has been evident since the early 1990s when persistent below-average bottom temperatures were observed in most areas. In CFA 4X, bottom temperatures have been particularly erratic since the late 1990s with large magnitude, cyclic fluctuations (4-year) that have been increasing in amplitude.

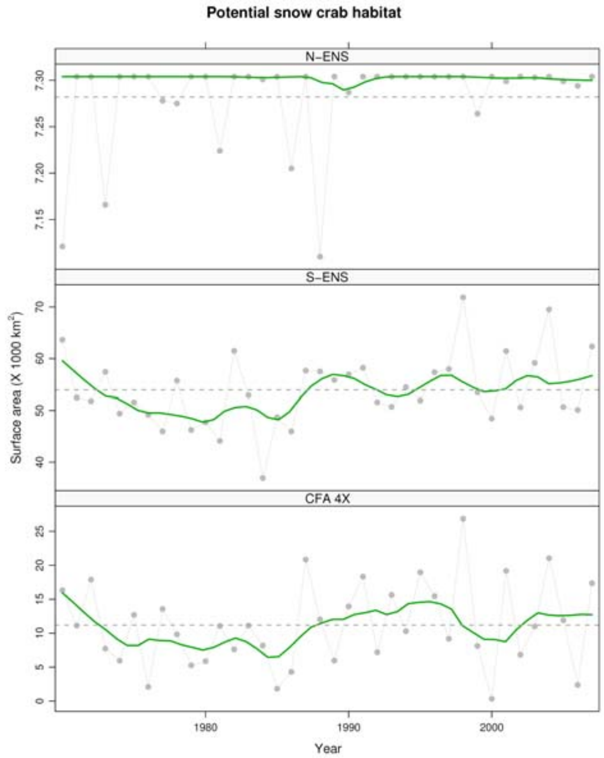


Figure 15. Total surface area of the potential habitat space of snow crab. Increased oscillations are evident since the late 1990s in S-ENS, while in 4X, an increase is evident since the mid-1980s.

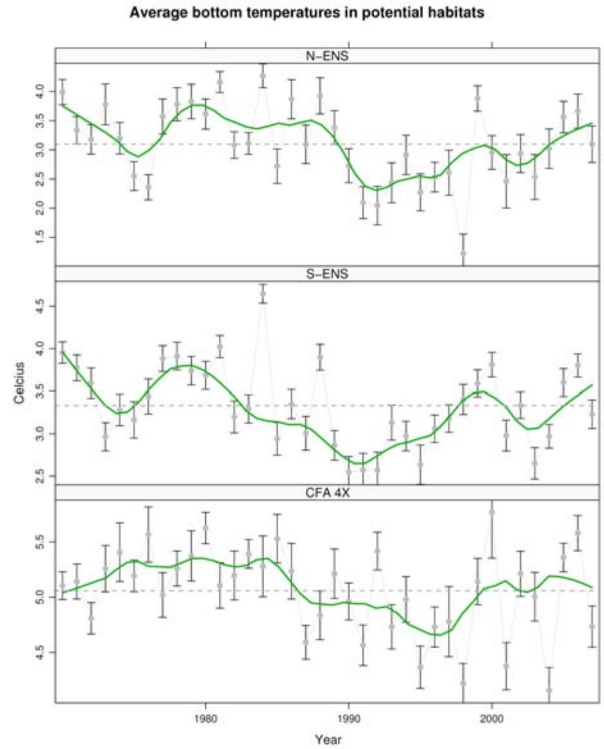


Figure 16. Mean summer/autumn bottom temperatures within the potential habitat space of snow crab. Mean temperatures seem to be increasing in ENS since the cool period of the 1990s though 2007 values may show the beginning of a reversing trend. Note the extreme short-term fluctuations in mean temperatures in the 2000s in the 4X area.

Bottom-up (Resource Limitation)

Food items such as northern shrimp are found in concentrations comparable to the historical average in most core areas of S-ENS (based on snow crab trawl survey; Map 8).

Near the ocean surface, there has been a trend towards increased ocean colour, which is an index of chlorophyll concentrations. Therefore, total primary production may be increasing (in the form of diatoms and dinoflagellates). This is likely enhanced by the reduction in abundance of *Calanus finmarchicus,* an important zooplankton link in the pelagic food web. Whether this elevated primary production reaches the detrital system is not yet known.

Top-down (Predation)

Potential predators of immature and soft-shelled crab have been found in high relative densities (based on snow crab trawl survey) in areas with high densities of immature snow crab (Map 9). This adds uncertainty to the strength of future predicted recruitment into the fishable biomass.

Seals are considered by fishermen to be a potential predator of snow crab and their continued increase in abundance (Figure 13) is a source of concern for many fishers. While they have on occasion been observed with snow crab in their stomachs, it should also be emphasised that the highest concentrations of snow crab are currently found in the immediate vicinity of Sable

Island, an area where the abundance of grey seals are extremely high. The actual evidence indicating that seals have a negative influence upon the snow crab population therefore seems to be minimal. In fact, it is quite possible that seals may be having a positive influence by physically importing food and food waste (organic matter) from other more outlying areas to the immediate vicinity of Sable Island and so indirectly "feeding" the snow crab and also removing potential predators of crab (in both early pelagic and benthic stages).

Lateral (Competition)

Large mature males stabilize the snow crab population by maintaining and occupying prime crab habitats. Large mature males keep at bay potential competitors such as other crab species or even groundfish, and serve as strong mates for the current population pulse of mature females and protectors of the smaller females. Their over-exploitation can have numerous negative biological consequences.

An important consequence of the extended period of very low sex ratios (Figure 11) observed in the early-2000s throughout the Scotian Shelf is that very poor egg and larval production in the system likely occurred for at least a four to five year period. Poor recruitment into the fishable biomass may occur again in the early 2010s as a result. Stabilisation of such strong oscillations in abundance into the future may be possible if reproduction of the currently available females is supported by an adequate population of large males.

Human Influences

Oil and gas development/exploitation continues to occur on the Scotian Shelf near to or upstream of major crab fishing grounds and population centers in both N- and S-ENS. The effects of seismic methods of exploration upon potentially vulnerable components of the snow crab population (eggs, larvae, soft-shelled crab) and the long-term biological effects of development upon this long-lived species are still not known. For example, despite numerous objections, seismic exploration occurred in November 2005 immediately over the Glace Bay Hole and the shallows of the Sydney Bight where immature and female crab are abundant. The long-term consequences of this activity are uncertain.

By-catch levels are very low in this fishery. In ENS, a total of 17,115 t of snow crab was landed with associated estimates of by-catch at 3 t (landings-based) or 3 t (effort-based). This generates 3-year by-catch estimates of 0.015% (landings-based) or 0.018% (effort-based) of crab landings. CFA 4X has by-catch rates an order of magnitude higher (though still very low), with a total estimated by-catch of 3 t associated with 1,049 t of snow crab landings (0.325%). The majority of by-catch for all areas is composed of other invertebrate species (e.g., Jonah crab and American lobster). In the three year record, observers also reported three leatherback turtles as having been entangled in buoy lines. All turtles were reported to have been released with minimal or no damage to the turtle.

By-catch from other fisheries is still not quantified. Damage from trawls is potentially problematic, especially upon the soft-shelled phases of snow crab and in fisheries targeting organisms with habitat preferences similar to snow crab such as shrimp and various flat fish.

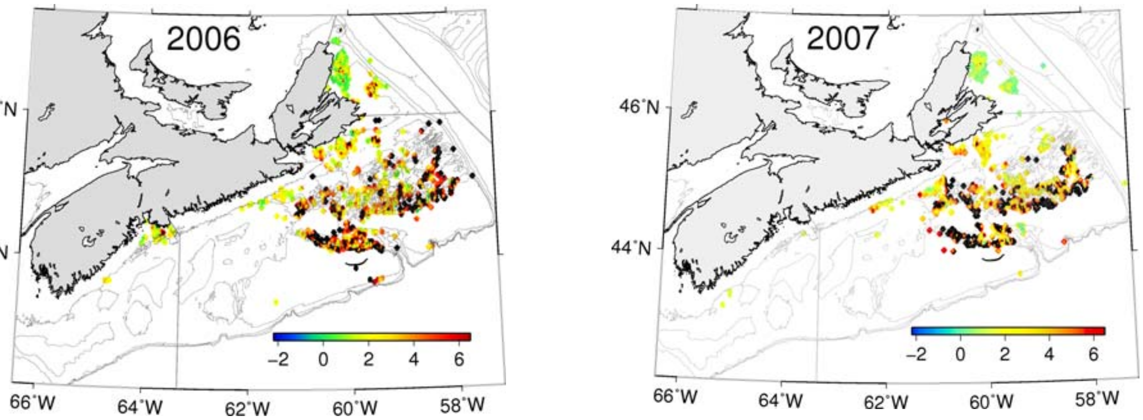
CONCLUSIONS AND ADVICE

High catches of soft-shelled crab will likely continue to be a major issue for the next 3 to 4 years in N- and S-ENS (but not CFA 4X due to their offset fishing season). Timely responses from industry to avoid fishing in areas showing potential or actual high incidence of soft crab must continue if unnecessary mortality of future recruits is to be averted. Unfortunately only the S-ENS has been able to develop a viable soft-shell protocol to address this concern. N-ENS does not have a viable solution at present and viable options for the reduction in soft-shell catches must be implemented now to protect current and future recruitment to the fishery.

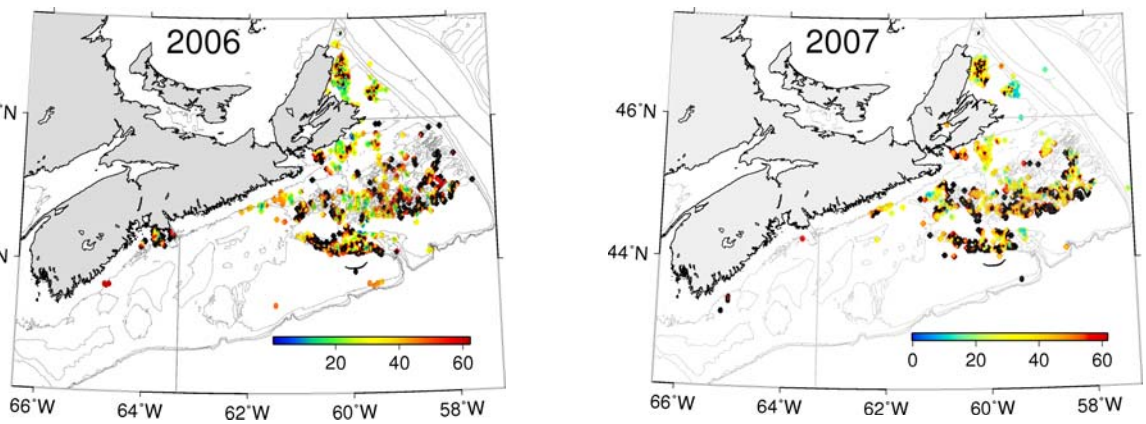
The N-ENS fishable biomass has begun to increase. This should continue to 2011, depending upon the level of soft-shell mortality incurred by the N-ENS fishery. Caution is warranted in 2008 for N-ENS until stronger signs of recovery are observed and the fishable biomass has increased sufficiently to reduce soft-shell catches and potential discard mortality. A decrease in TAC is recommended, unless other management measures can be implemented to lower the handling of soft-shell crab.

The S-ENS fishable biomass increased for the second time since the early 2000s. The recovery of the fishable biomass continues as expected. The S-ENS fishable biomass can be considered to be in a healthy state. A positive outlook exists for S-ENS and an increase in TAC is recommended.

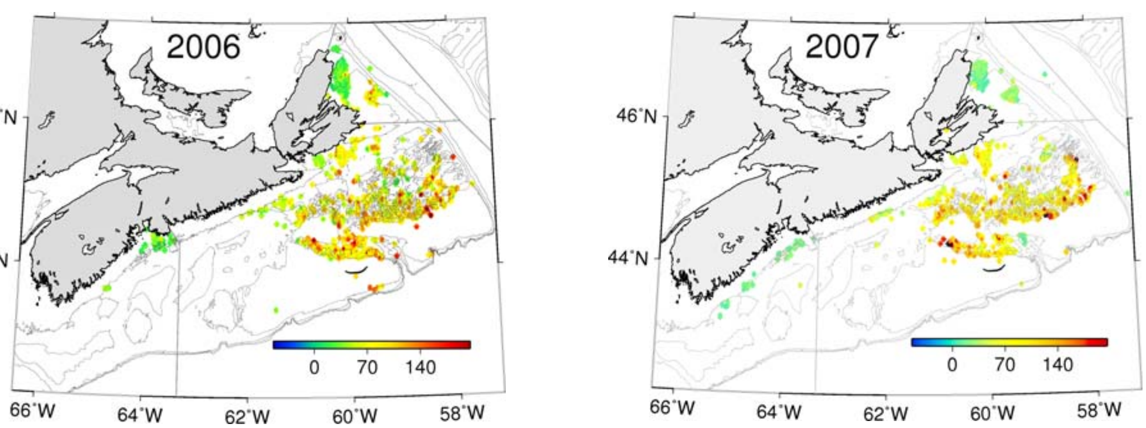
The CFA 4X fishable biomass did not change relative to 2006. However, the very specific spatial extent of the fishery and large environmental variability in CFA 4X suggest a more precautionary approach to exploitation. The reduction in TAC in 2007 was appropriate and no additional incremental increase to the 2007/08 TAC is recommended. A maintenance or reduction of this TAC is recommended for the 2008/09 season.



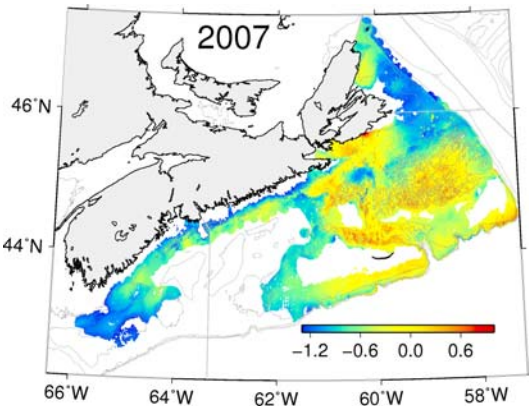
Map 1. Commercial landings (log10; metric tons) in the 2006 and 2007 fishing seasons. Areas in black are off the scale. Original figure in colour.



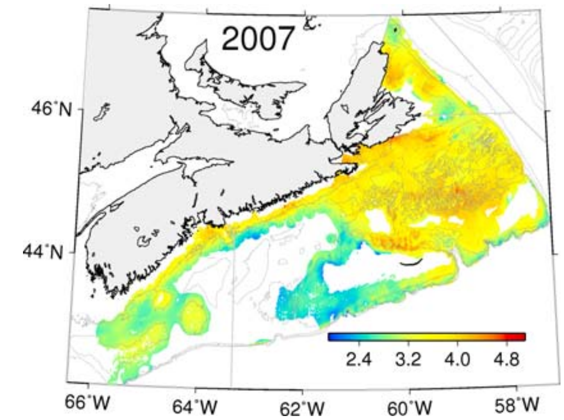
Map 2. Commercial fishing effort from reported logbook positions (total number of trap hauls) in the 2006 and 2007 fishing seasons. Note the reduction in effort in the offshore slope and the near shore in the former CFA 24E. Areas in black are off the scale. Original figure in colour.



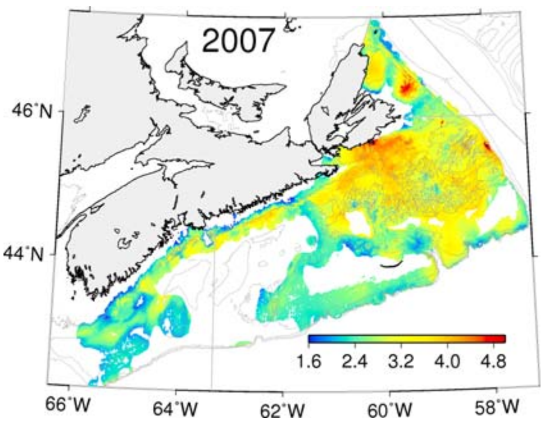
Map 3. Average catch rates (kg/trap haul) of snow crab on the Scotian Shelf in 2006 and 2007. Original figure in colour.



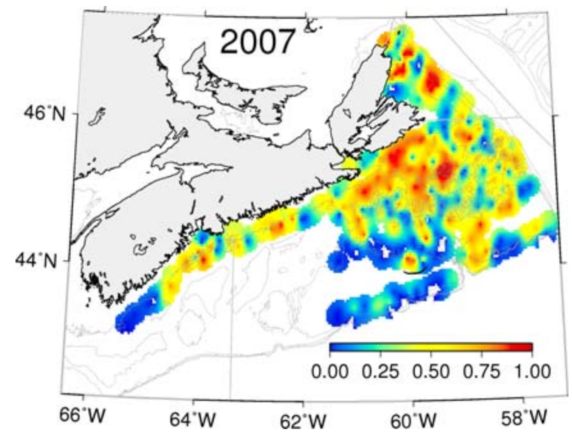
Map 4. Fishable biomass from the 2007 snow crab survey. Log 10 scale. Original figure in colour.



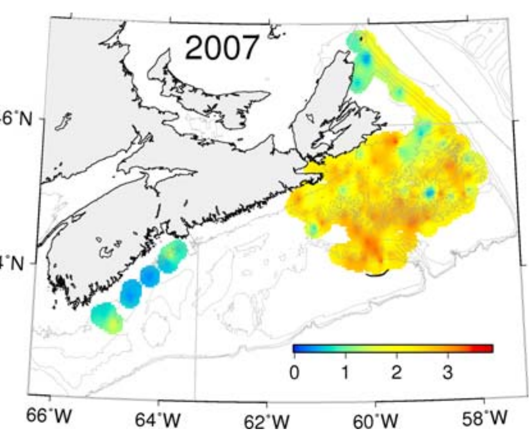
Map 5. Numerical abundance of immature male snow crab. Log 10 scale. Original figure in colour.



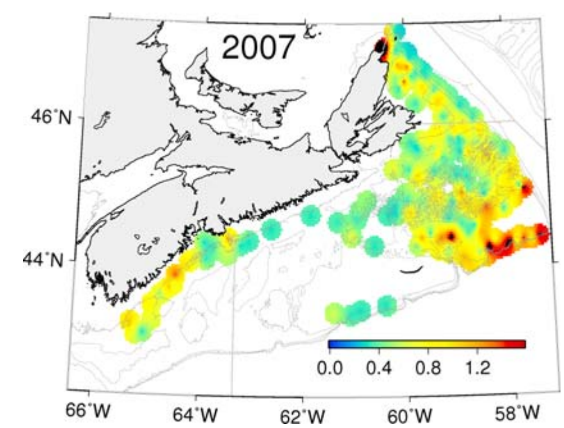
Map 6. Numerical abundance of berried female snow crab. Log 10 scale. Original figure in colour.



Map 7. Proportion of females in the mature population. Note the heterogeneous distribution of sexes in all areas. Original figure in colour.



Map 8. Number of shrimp, a food item of snow crab. Log 10 scale. Original figure in colour.



Map 9. Number of thorny skate, a predator of snow crab. Log 10 scale. Original figure in colour.

SOURCES OF INFORMATION

Choi, J.S., B.M. Zisserson, and P. Kuhn. 2008. Integrated assessment of the snow crab resident on the Scotian Shelf in 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/012.

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