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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2009/053

ASSESSMENT OF NOVA SCOTIA (4VWX) SNOW CRAB

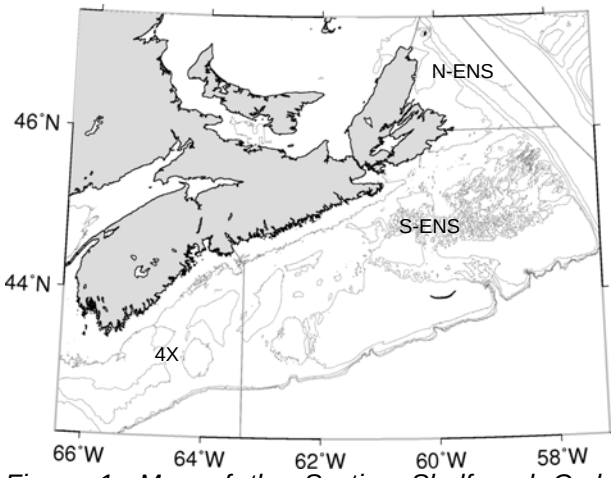

Figure 1. Map of the Scotian Shelf and Crab Fishing Areas (CFA).

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 280 m 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 ate-1990s.

The fishery has been in existence since the early 1970s in Nova Scotia. It exploits the whole spatial xtent of the species on the Scotian Shelf. The management of the snow crab fisheries on the Scotian helf was initially based on effort controls (season, license, trap limits) from 1982 to 1993 with harvesting uring June-November of hard-shelled males larger than 95 mm CW (carapace width). Additional anagement measures were introduced from 1994 to 1999: IBQs (individual boat quotas), TACs (total llowable catches), 100% dockside monitoring, mandatory logbooks and at-sea monitoring by certified bservers. In 2005, many Crab Fishing Areas (CFAs) and subareas were merged with the resulting ivisions being N-ENS (formerly CFAs 20-22), S-ENS (formerly 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 ollowing spring. Vessel Monitoring Systems (VMS) have become a requirement in S-ENS.

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.

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SUMMARY

- Landings in 2008 for N-ENS and S-ENS were 238 t and 8,253 t, respectively, and they were 230 t in CFA 4X for the 2008/9 season, all within their respective TACs of 244, 8,316, and 230 t. These changes in landings represent increases of 2%, 67% and 5% in N-ENS, S-ENS and 4X, respectively, relative to the previous fishing year.
- Season extensions were granted in all CFAs (except in CFA 4X) against the advice of DFO Science and the consensus decision of Industry Advisory Panels. This was a conservation concern due to elevated soft-shell capture towards the latter part of the season.
- Average, non-standardized catch rates in 2008 were 33.7 kg/trap haul and 96.1 kg/trap haul in N- and S-ENS, and 29.1 kg/trap haul in 4X in 2008/2009 – representing an increase of 43%, a decrease of 4% and an increase of 61%, respectively, relative to the previous year. Much of the increase in N-ENS was due to higher catch rates in the test spring fishery.
- The soft-shelled crab discard represented up to 119 t (49% of landings) and 1,088 t (13% of landings) being subjected to potential handling mortality in N- and S-ENS, respectively. 4X discard rates of soft crab are very low. Almost no soft crab were observed in the spring fishery in N-ENS.
- The post-fishery fishable biomass of snow crab was estimated to be 3,200 t in N-ENS (with a 95% confidence range of: 2,500 to 4,000 t), representing a 200% increase from the previous year. In S-ENS, the post-fishery fishable biomass was 54.3×10^3 t (with a 95% confidence range of: 41.4 to 71.4×10^3 t), representing a 0.3% decrease. In CFA 4X, the pre-fishery fishable biomass was 360 t (with a 95% confidence range of 200 to 350 t), representing a 12.5% increase. Re-scaled fishable biomass estimates were 1,070, 54.5×10^3 and 320 t for N-ENS, S-ENS and CFA 4X, respectively, in 2007.
- The main pulse of male recruitment continues to grow and is currently centered over an 80 mm CW modal group (instars 11-13). The leading edge of recruitment entered in 2007 and full entry is expected by 2010/2011. Recruitment beyond 2014 is uncertain but positive signs were evident.
- The return of immature crab to the water by the fishery is an important conservation measure that will enhance the mid-term (2-3 year) sustainability of this fishery.
- The reproductive potential of the Scotian Shelf population remains strong with berried female abundance in all areas. Strong larval production should continue for another 2-3 years based on current berried female levels.
- 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.
- A general increase in viable snow crab habitat has been observed since the mid-1990s in N-ENS and S-ENS, while there has been a decline in CFA 4X since the late 1990s. The temperatures within viable snow crab habitat has been stable although stronger inter-annual variability has been evident in CFA 4X, especially since the mid-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 less than 0.005% in ENS and less than 0.5% in CFA 4X of annual landings, mostly of other crustacean species.
- Relative exploitation rate (by biomass) in N-ENS was 7% in 2008, relative to approximately 18% in 2007. A moderate increase in TAC is recommended contingent upon management measures to lower the handling of soft-shell crab.
- Relative exploitation rate (by biomass) in S-ENS was 13% in 2008, relative to approximately 8% in 2007. The snow crab in S-ENS can be considered to be in a healthy state. A moderate increase in TAC is recommended contingent upon the better adherence of the

fleet to the soft-shell protocol and a fixed season duration policy. Shifting the season earlier in the year may help reduce the handling of soft shelled snow crab.
- Relative exploitation rate (by biomass) in CFA 4X was 38% in 2008/2009 relative to 50% in the previous fishing year. A status-quo TAC is recommended until the strength of recovery can be verified.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*, 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.

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 mostly from the offshore areas (Map 1). However, near-shore landings appeared to increase in 2008. Landings were 238 t in N-ENS and 8,316 t in S-ENS for 2008, and they were 230 t in 4X for 2008/2009 (Tables 1, 2, and 3). These landings represent increases of 2% and 67% in N-ENS and S-ENS, respectively, and an increase of 5% in 4X, relative to their previous respective seasons.

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
2008	78	244	238	33.7	7.0

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	115	4,950	4,942	100.1	49.3
2008	115	8,316	8,253	96.1	85.9

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		
1999/00	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	230	220	18.1	12.1
2008/09	9	230	230	29.1	6.3

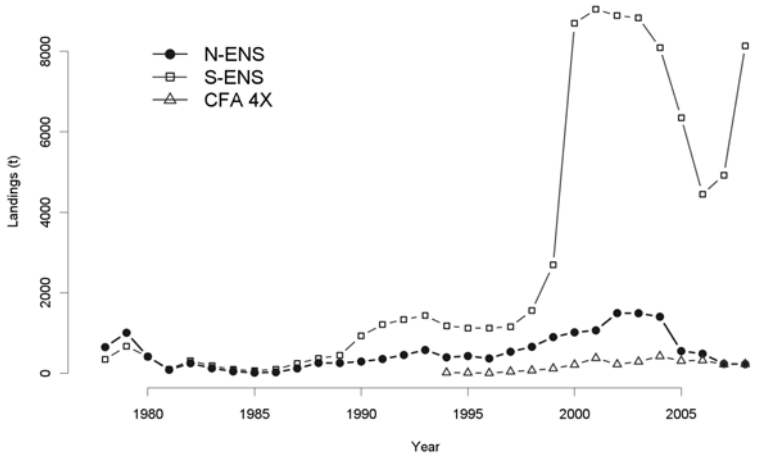


Figure 2. Temporal variations in the landings (t) of snow crab on the Scotian Shelf. Note the sharp increase in landings associated with large increases to TACs and a doubling of fishing effort in the year 2000. The landings follow the TACs with little deviation and so are not shown. For CFA 4X, the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

The spatial distribution of fishing effort returned to the effort distribution observed earlier in the decade. There was increased effort near-shore and dispersed fishing effort in S-ENS relative to 2006 and 2007 (Map 2) with minimal effort on the offshore-slope areas. In 2008, a total of 7,038 and 85,914 trap hauls were applied in N- and S-ENS, respectively. This represents a decline of 29% and an increase of 74%, respectively, from 2007 (Tables 1 and 2; Figure 3). In 4X, two trap complements were used in 2006: 60 large traps (7 licences) or 200 small traps (2 licences). In 2007, all fishing effort occurred with the 60 trap complement of large traps. In 2007/2008, a total of 12,100 trap haul equivalents (catch rate for large traps applied to entire landings) were applied as compared to 6,300 in 2008/2009 season, a decrease of 48% (Table 3; Figure 3).

In 2008, the non-standardized catch rate for N-ENS was 33.7 kg/trap haul, a 43% increase from 23.6 kg/trap haul in 2007 (Table 1; Figure 4). In S-ENS, the catch rate was 96.1 kg/trap haul, a 4% decrease from 100.1 kg/trap haul in 2007 (Table 2; Figure 4). In 4X, the catch rate was

29.1 kg/trap haul, an increase of 61% from 18.1 kg/trap haul in the 2007/2008 season (Table 3; Figure 4).

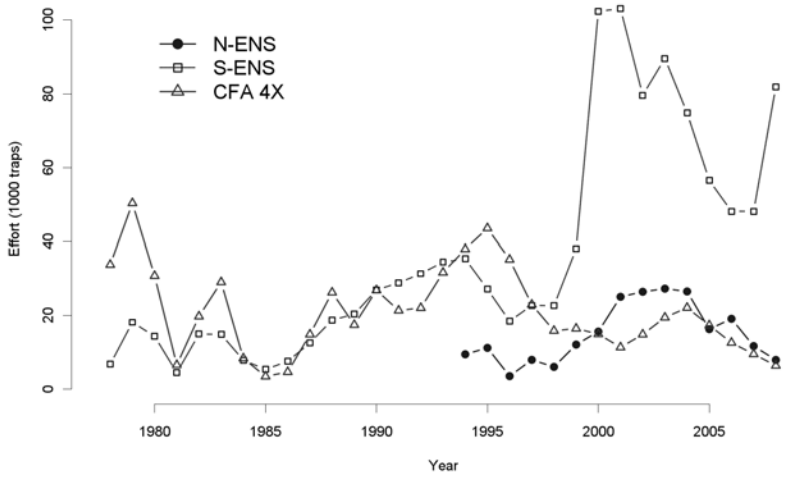


Figure 3. Temporal variations in the fishing effort, expressed as the number of trap hauls. Note the doubling of effort in the year 2000. For CFA 4X, year refers to the starting year of the season.

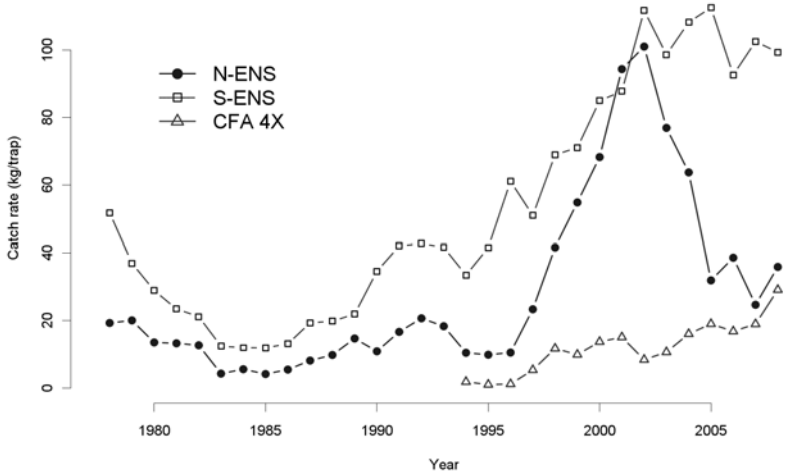


Figure 4. Temporal variations in catch rates of snow crab on the Scotian Shelf, expressed as kg per trap haul. Trap design and size have changed over time. No corrections for these varying trap-types nor soak time and bait-type have been attempted.

In N-ENS, CC1 (carapace condition 1) crab represented 24% of the total observed catch, decreasing from 44% in 2007. CC2 crab represented 6% of the total catch, a decrease from 14% in 2007. These decreases are largely attributable to the creation of a spring fishery in 2008 that landed 35% of the landings, with less than 2% of the catch being CC1 or CC2. CC3 (63%) crab have increased in relative abundance since 2007 (35%). CC4 and CC5 crab levels remained essentially constant at 7% and 1%, respectively (Figure 5). N-ENS continues to be heavily reliant upon new recruitment.

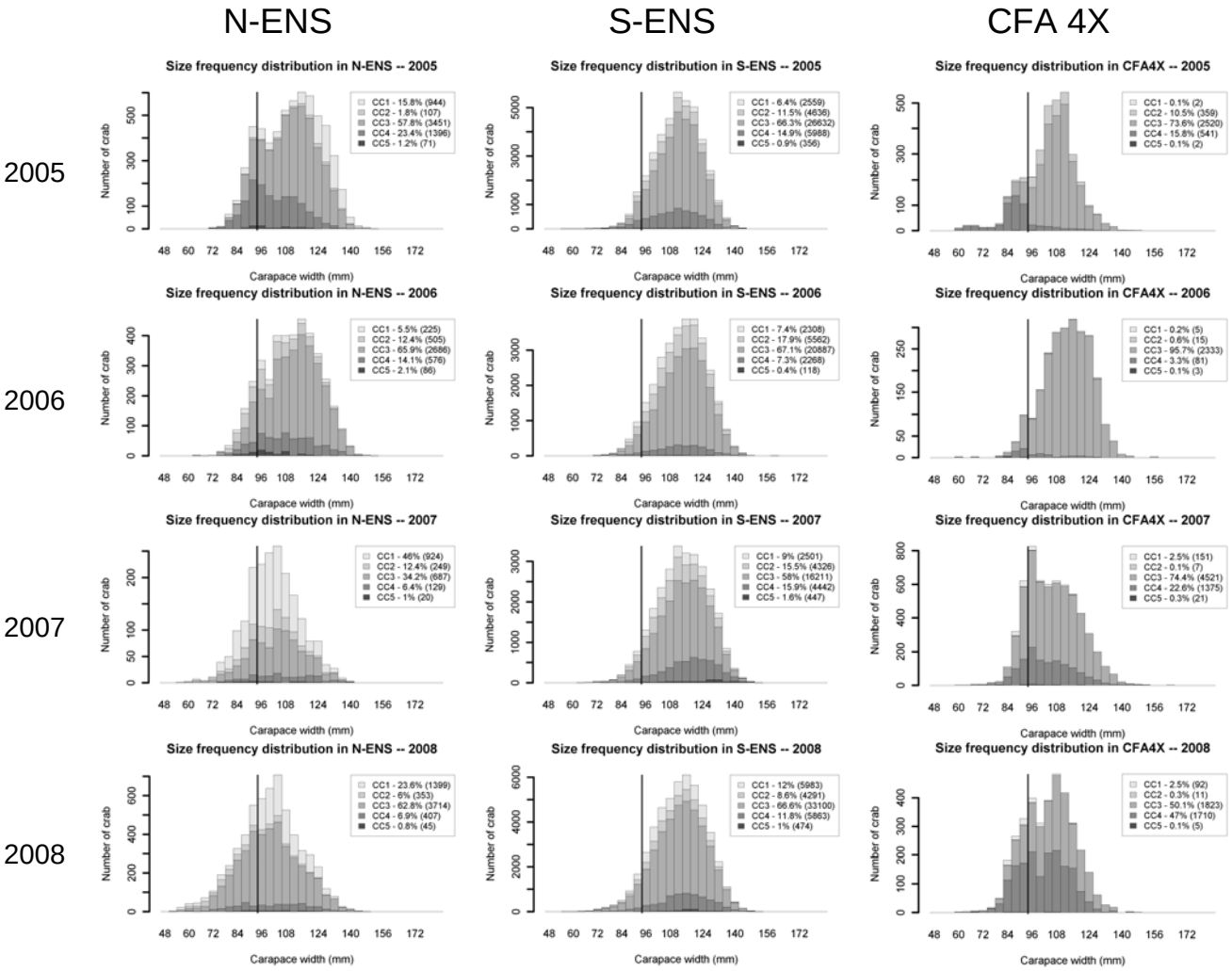


Figure 5. Size frequency distribution of all at-sea-observer monitored snow crab broken down by carapace condition (CC). For CFA 4X, the year refers to the starting year of the season. Vertical lines indicates 95 mm carapace width.

In S-ENS, the moult structure of the catch observed at sea was comparable between 2007 and 2008 (Figure 5). In the legal-sized fraction, CC1 and CC2 crab represented 12% and 9%, respectively, of the observed catch. Hard-shelled crab dominated the catch: 67% CC3 and 12% CC4. CC5 crab represented approximately 1% of the total observed catch.

In CFA 4X, CC3 crab generally dominates the observed catch. This was again the case in 2008. However, the relative proportion of CC4 crab observed increased from 3% in 2007 to 21% in 2008. This may be indicative of decreased exploitation and/or changing fishing grounds.

The soft-shelled crab discard represents up to 119 t (49% of landings) and 1,088 t (13% 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 during the traditional summer fishery, whereas almost no soft crab were captured in the spring fishery. In S-ENS, soft shell catches generally occurred throughout all fishing areas (Figure 6). In 4X, discard rates of soft-shell crab are very low.

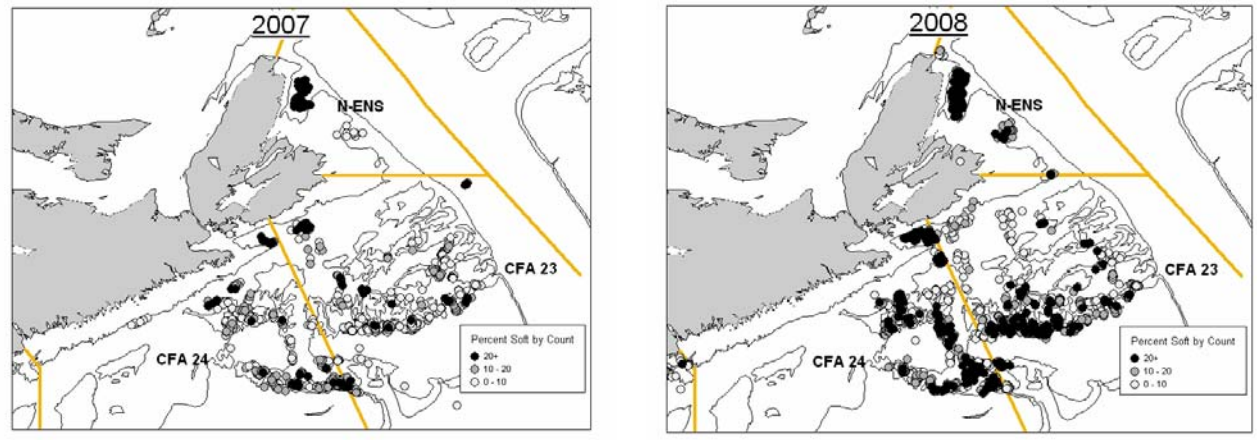


Figure 6. Location of soft-shell snow crab occurrence in the commercial fishery. For CFA 4X, the year refers to the end year.

ASSESSMENT

Stock Trends and Current Status

Fishable Biomass

The fishable biomass is defined as that segment of the snow crab 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 2008 post-fishery fishable biomass was estimated to be 3,200 t (with a 95% confidence range of 2,500 to 4,000 t; Figure 7; Map 4), a 200% increase relative to the 2007 estimate of 1070 t. The increases were observed mostly in the northern basin of N-ENS.

In S-ENS, the 2008 post-fishery fishable biomass was estimated to be 54.3×10^3 t (with a 95% confidence range of 41.4 to 71.4×10^3 t; Figure 7; Map 4), a 0.3% decrease relative to the 2007 estimate of 54.5×10^3 t.

In CFA 4X, the 2008 pre-fishery fishable biomass was estimated to be 360 t (with a 95% confidence range of 200 to 350 t; Figure 7; Map 4), a 12.5% increase relative to the 2007 pre-fishery fishable biomass of 320 t.

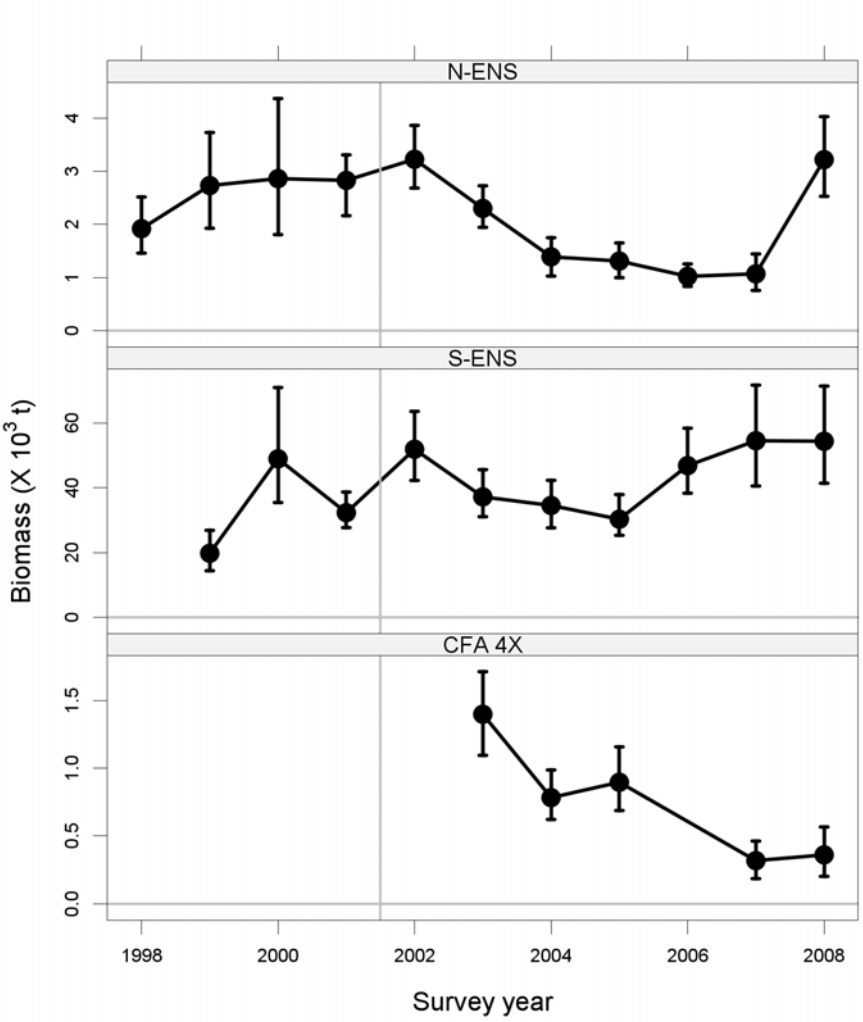


Figure 7. Fishable biomass over time from kriged estimates. Vertical line represents the shift in survey timing from spring to autumn.

Recruitment

The index of recruitment (CC1 and CC2 crab, > 95 mm CW) to the fishable biomass since 2005 has been increasing in both N- and S-ENS and is extremely variable in CFA 4X (Figure 8). 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 continues to grow and is currently centered over a 80 mm CW modal group (instars 11-13; Figure 9a). The leading edge of recruitment entered in 2007 and full entry of this modal group is expected by 2010/2011. Recruitment beyond 2014 is uncertain, but positive signs were evident in all areas except CFA 4X. N-ENS, in particular, showed signs of recovery after 5-6 years of little or no new crab recruiting to the fishery (attributable to high exploitation rates and/or handling mortality; Figure 8).

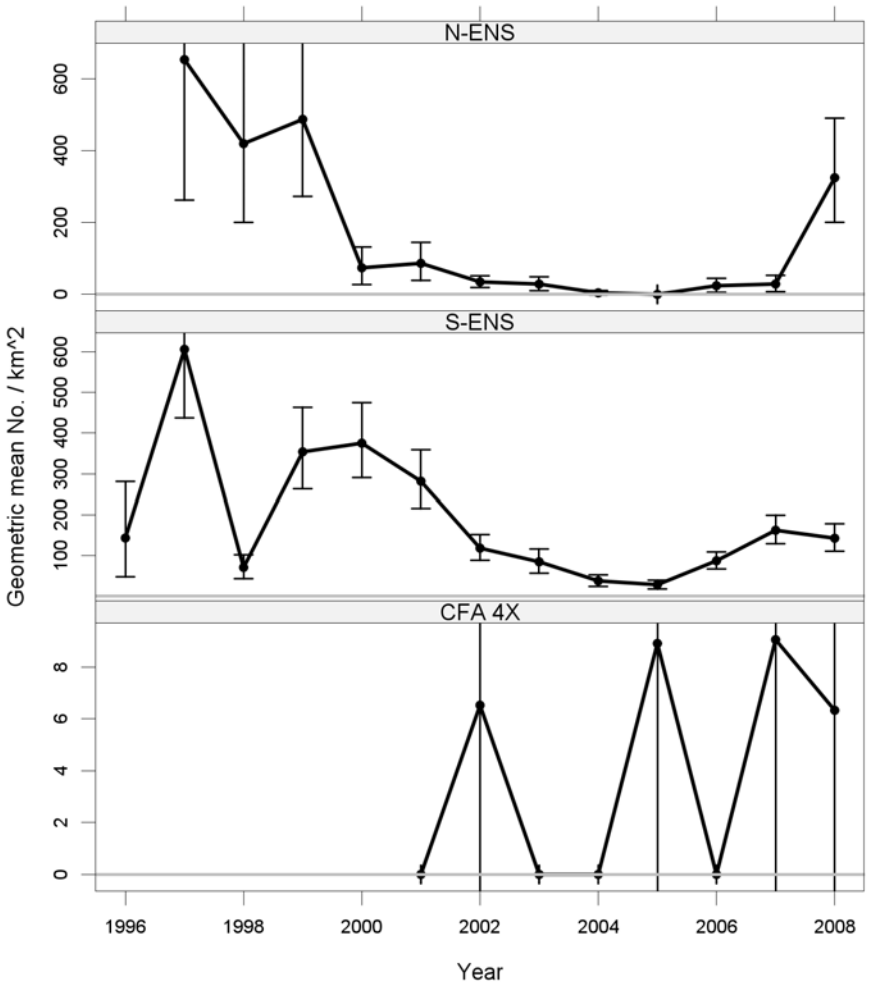


Figure 8. Expected recruitment (males larger than 95 mm CW and soft-shelled) into the mature stage in the next year. Vertical lines represent 2 standard errors.

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 remains strong with berried female abundance in all areas. Strong larval production should continue for another 2-3 years (Figure 10) based on current levels of berried females. 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 2007/2008 (Maps 6, 7). Isolated concentrations of mature females (Figure 11, Map 6) were also found in CFA 4X.

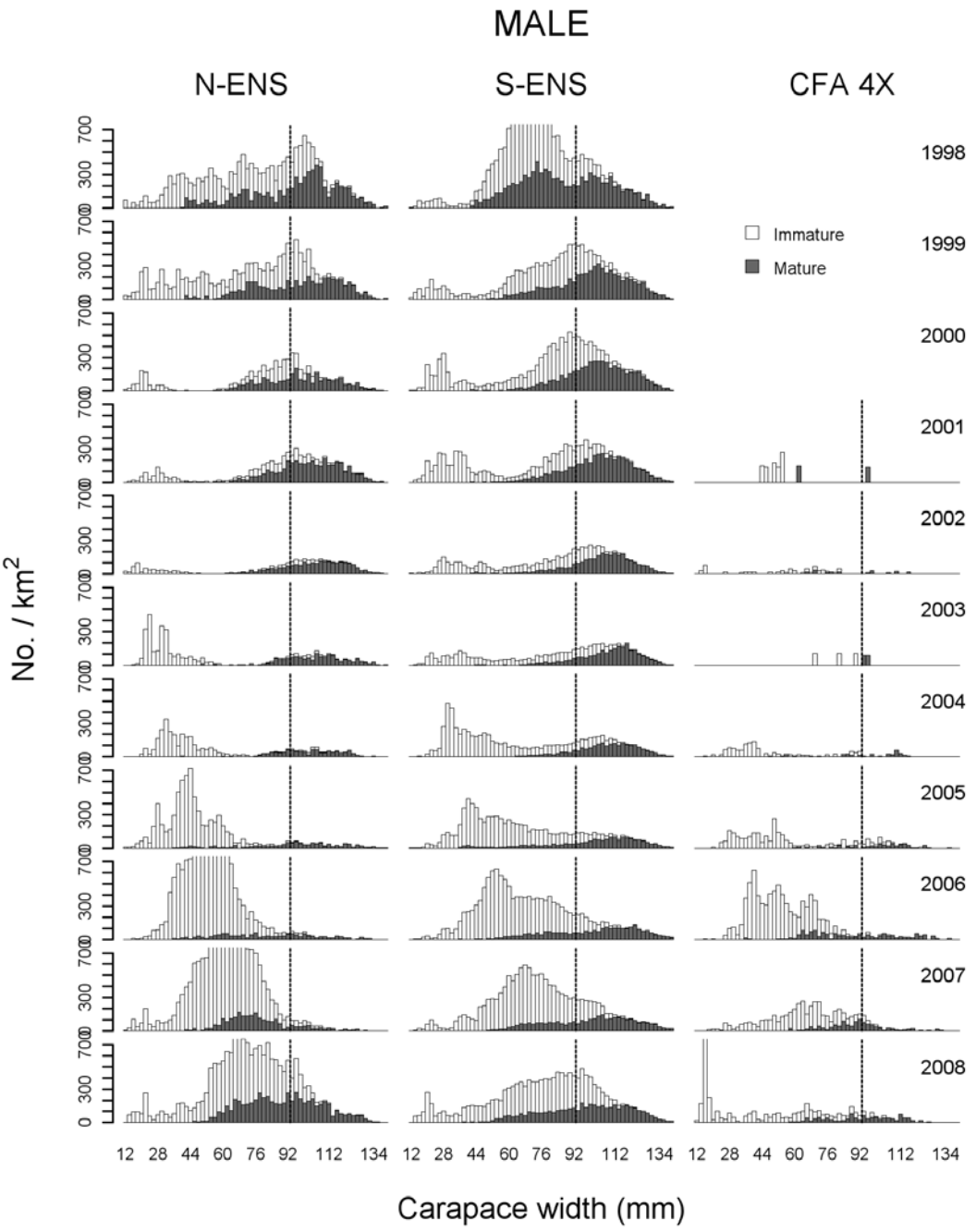


Figure 9a. Size-frequency histograms of carapace width of male snow crabs. Note the increasing numbers of juvenile crab, 1 to 3 years from entering morphometrically mature size classes. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a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

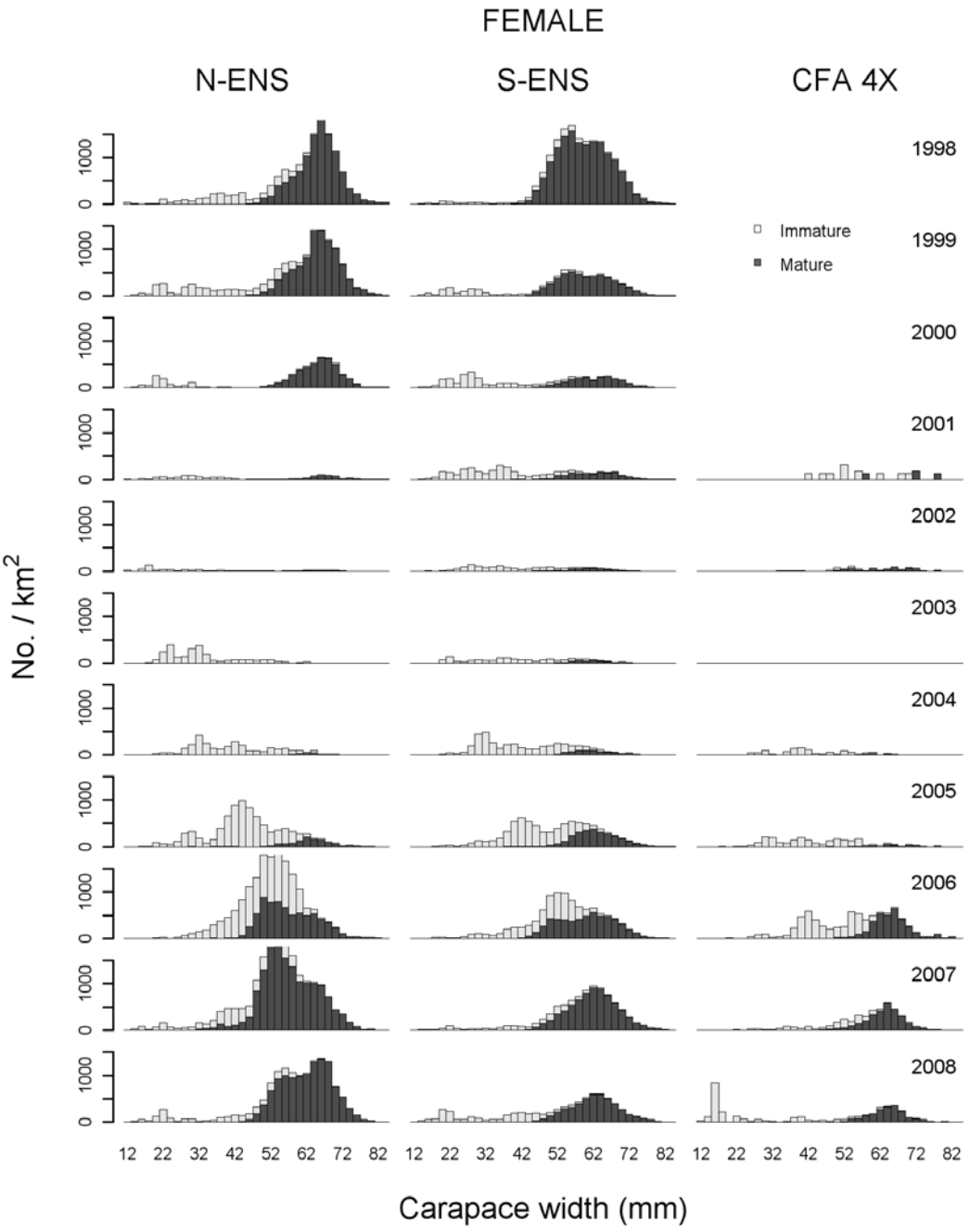


Figure 9b. Size-frequency histograms of carapace width of female snow crabs. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers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

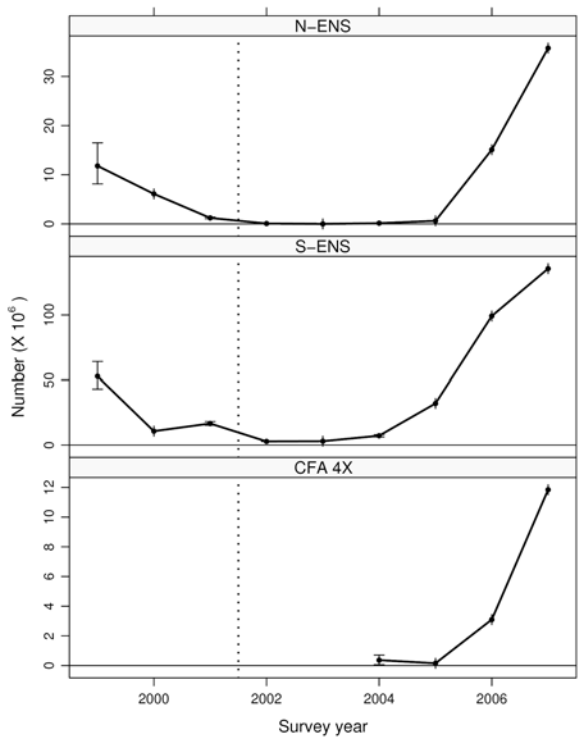


Figure 10. Number of berried female snow crabs on the Scotian Shelf. Note the important increase seen since 2005 in all areas of the Scotian Shelf. Vertical line represents the shift in survey timing from spring to autumn. 2008 data not yet available.

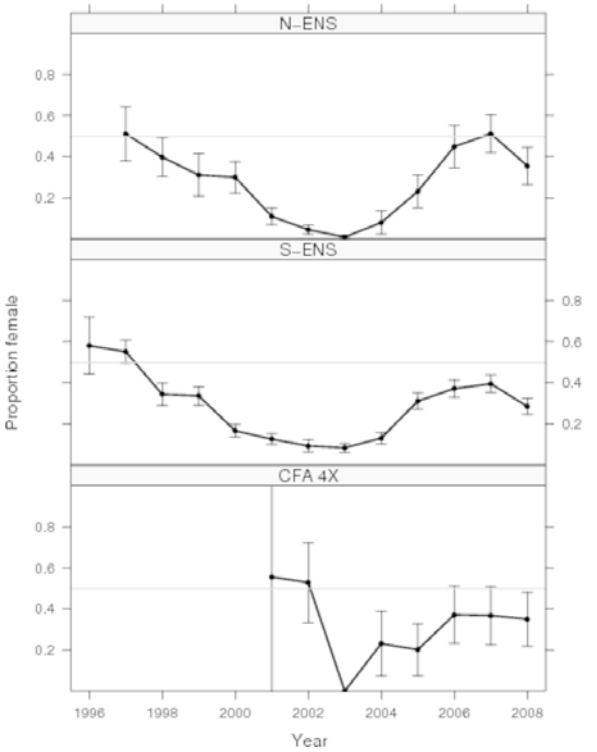


Figure 11. Sex ratios (proportion female) of mature snow crab. Since 2000, most of the Scotian Shelf was uniformly male dominated. A slight amelioration of the mature sex ratio was first observed in 2004. This trend has continued and currently, the whole of the shelf can be seen to be in a reproductive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

Exploitation rates in N-ENS have historically ranged from 30 to 50% before 2007; with a peak level of 50% in 2004. Exploitation has since declined to 7% in 2008, relative to approximately 18% in 2007 (Figure 12). Projections suggest that a range between 10 to 20%, depending upon the strength of recruitment and degree of control of soft-shell damage, may help ensure the long-term sustainability of this fishery.

In S-ENS, exploitation rates have been between 8 to 20% from 2002 to present. In 2008, they were 13%, relative to approximately 8% in 2007 (Figure 12). Projections suggest that a range between 10 to 30%, depending upon the strength of recruitment, and degree of control of soft-shell damage may help ensure the long-term sustainability of this fishery.

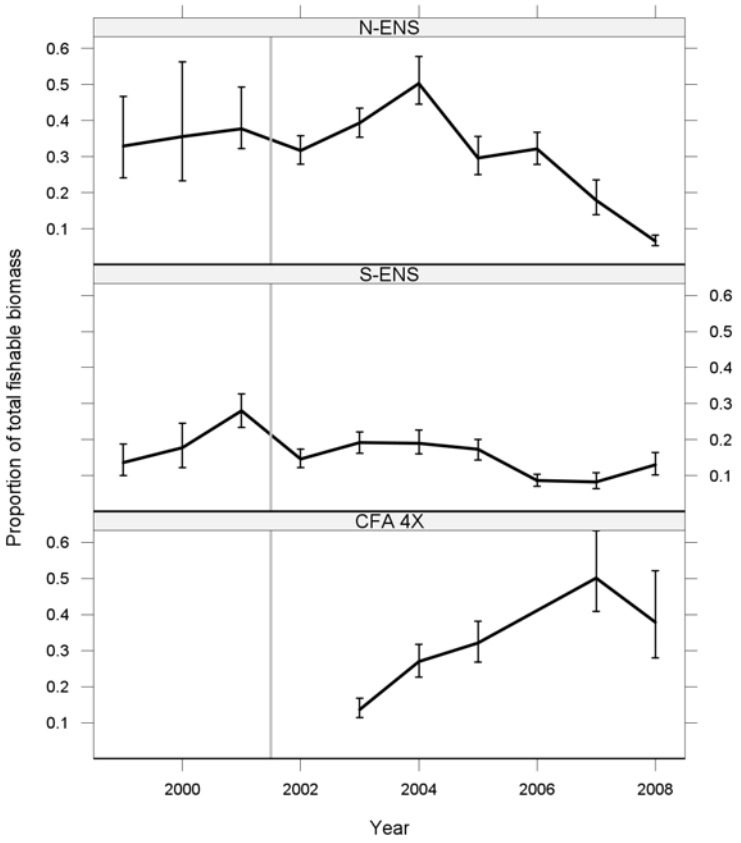


Figure 12. Relative exploitation rate of snow crab. Vertical line represents the shift in survey timing from spring to autumn.

In CFA 4X, exploitation rates have been intermediate between N- and S-ENS, in the range of 30% (Figure 12). However, they have been higher since 2007. They were at 38% in 2008/2009, relative to 50% in the previous fishing year. 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.

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 associated with the groundfish collapse. A trend towards a return to historical states is evident since 2007/2008 (Figure 14). Thus, while the current "ecosystem state" is one that continues to be amenable to the high abundance of snow crab,

there is an increased level of concern that there may be another systemic ecosystem change in the near future.

Importantly, temperature-related changes were generally orthogonal (independent) to the above changes: e.g., 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.

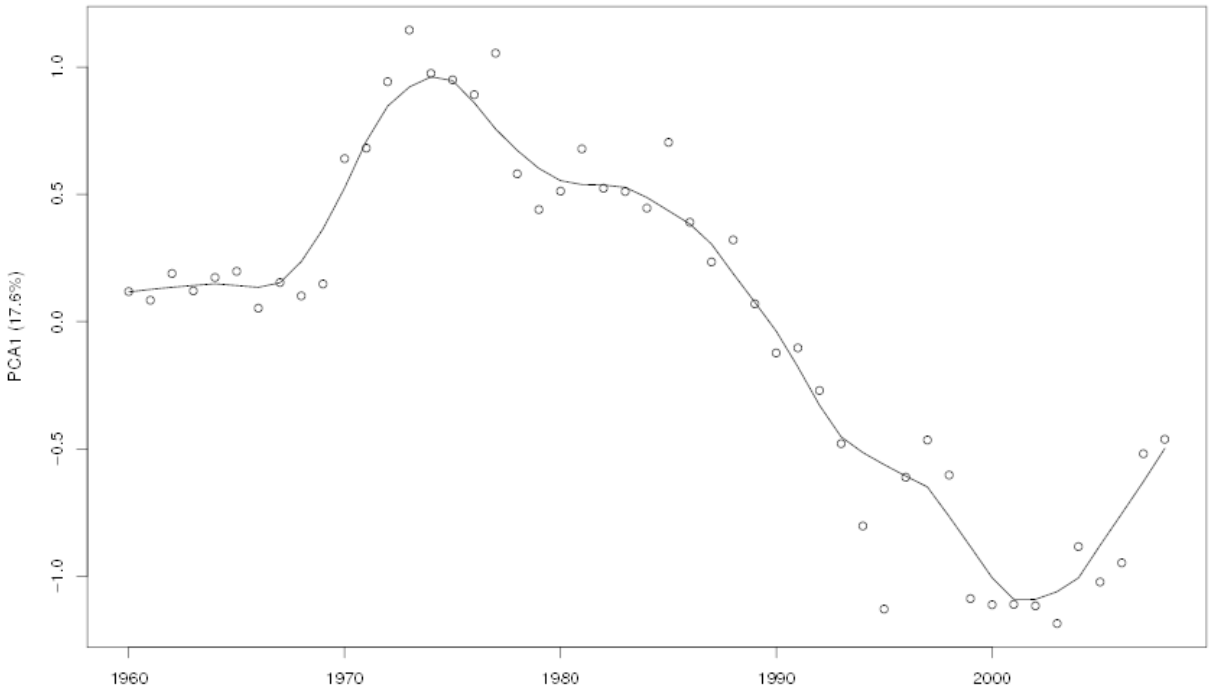


Figure 14: First axis of variation in ordination of anomalies of social, economic and ecological patterns on the Scotian Shelf. Note strong variability observed near the time of the fishery collapse in the early 1990s.

Environmental Variability

The spatial extent of what may be considered potential (viable) snow crab habitat on the Scotian Shelf (Figure 15) has been stable in the historical record. For N-ENS this has ranged between 6 to 9 $\times 10^3$ km^2 (mean = 7.8 $\times 10^3$ km^2, inter-annual standard deviation (SD $_{\text{inter-annual}}$) = 0.6 $\times 10^3$ km^2; Figure 15a). For S-ENS, the surface area of potential habitat has varied with similar oscillations, ranging from between 40 to 70 $\times 10^3$ km^2 since 1950 (mean = 59.7 $\times 10^3$ km^2, SD $_{\text{inter-annual}}$ = 6.2 $\times 10^3$ km^2). In the most recent period, the surface area has been increasing since a low period in the mid-1990s; Figure 15a). In CFA 4X, the southern-most limit of the distribution of snow crab, potential habitat has been variable, ranging from 6 to 13 $\times 10^3$ km^2 (mean = 9.1 $\times 10^3$ km^2, SD $_{\text{inter-annual}}$ = 1.9 $\times 10^3$ km^2). However, there is an important declining trend, evident since the mid-1960s, with periodicities inverse in phase relative to ENS since the mid 1980s (Figure 16a). The temperatures within this viable snow crab habitat have been stable, although stronger inter-annual variability has been evident in CFA 4X since the mid-1990s (Figure 16b).

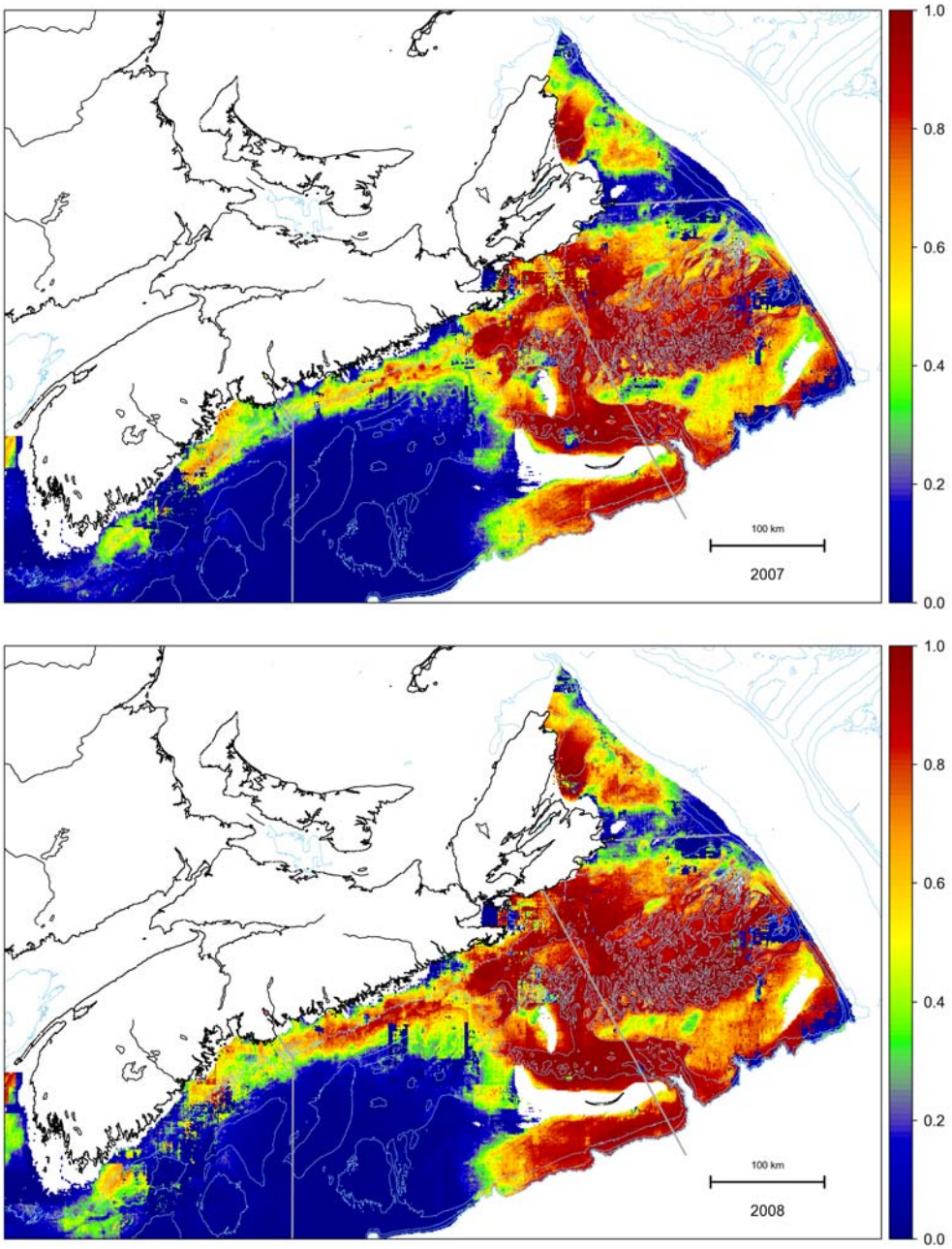


Figure 15. Predicted probabilities of viable habitat for fishable snow crab, or "habitat mask", used for abundance estimation (kriging). Original in colour.

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-ENS, S-ENS and CFA 4X, respectively (Figure 16b). 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.

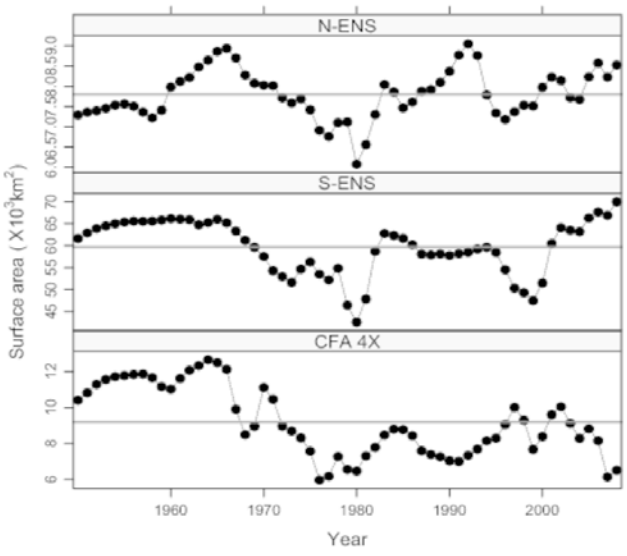


Figure 16a. Total surface area of the potential habitat space of snow crab. Increased amplitude oscillations are evident since the late 1960s in ENS. An increasing trend since the mid-1990s are evident in ENS while in 4X, a decreasing trend is evident since the mid-1960s.

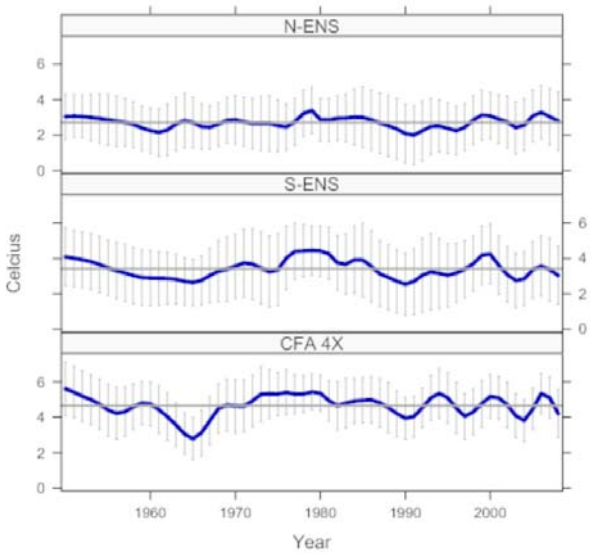


Figure 16b. Mean annual bottom temperatures within the potential habitat space of snow crab.

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 is 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. This would indirectly “feed” the snow crab and also remove 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 habitat. Large mature males keep at bay potential competitors such as other crab species or even groundfish, serve as strong mates for the current population pulse of mature females, and are 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 (DFO 2004, Courtenay et al 2009). Despite such uncertainties and objections from the fishing industry, DFO Science and NGOs (Boudreau et al. 2009), 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 generally abundant.

By-catch levels are very low in this fishery. In ENS, less than 0.005% of landings are other species while in CFA 4X it is about 0.5% of landings. The majority of by-catch for all areas is composed of other invertebrate species (e.g., Jonah crab and American lobster). By-catch is returned to the water by snow crab fishers. In the three year record, observers also reported one leatherback turtle as having been entangled in buoy lines. This turtle was reported to have been released with no damage.

By-catch of snow crab from other fisheries is still not quantified. Trawls can increase mortality, especially upon the soft-shelled phases of snow crab. Bottom damage from the placement of snow crab traps is thought to be minimal.

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. Current soft-shell protocols could be improved to further address this concern. The early season in N-ENS helped reduce soft-shell handling/mortality, but soft-shell capture was still large in 2008. More management measures are required to protect current and future recruitment to the N-ENS fishery.

The N-ENS fishable biomass has begun to recover. Elevated fishable biomass should continue to 2011, depending upon the level of soft-shell mortality incurred by the N-ENS fishery. Caution is still warranted in 2009 for N-ENS as excessive fishing exploitation can substantially reduce

the extent of recovery in N-ENS. A moderate increase in TAC is recommended, contingent upon better management measures that will further reduce handling of soft-shell crab.

The S-ENS fishable biomass decreased marginally. 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 a moderate increase in TAC is recommended. This is contingent upon the better adherence of the fleet to the soft-shell protocol and a fixed season duration policy. Shifting the season earlier in the year may help further reduce the handling of soft-shelled snow crab.

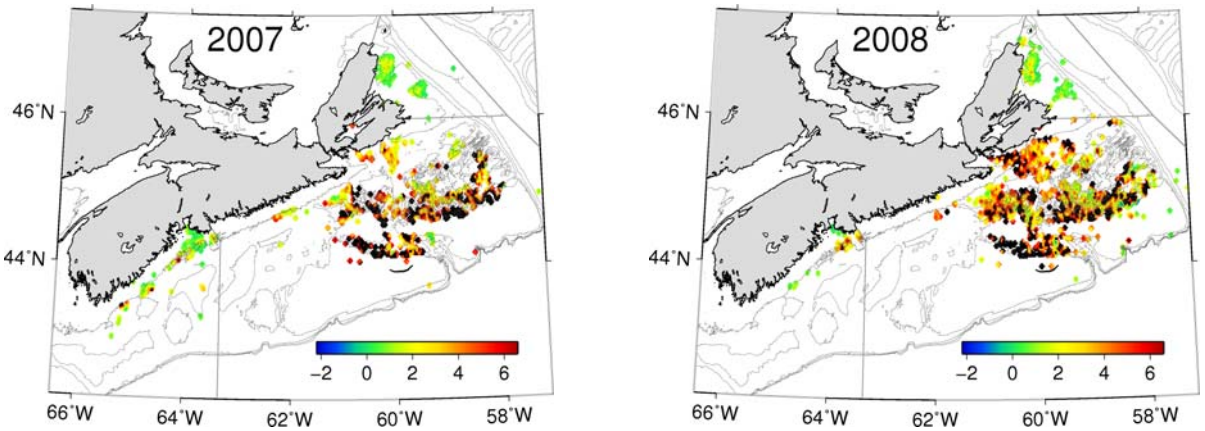
CFA 4X fishable biomass increased. The recovery of fishable biomass has begun but the rate of increase has lagged behind that of N- and S-ENS. Environmental variability is unlikely to be responsible for this delayed recovery as the abundance trends of females match closely with the patterns in N- and S-ENS. Instead, this suggests that the higher exploitation rates (legal and illegal) in CFA 4X may be causing these patterns. A status-quo TAC is recommended until the strength of recovery can be verified.

MANAGEMENT CONSIDERATIONS

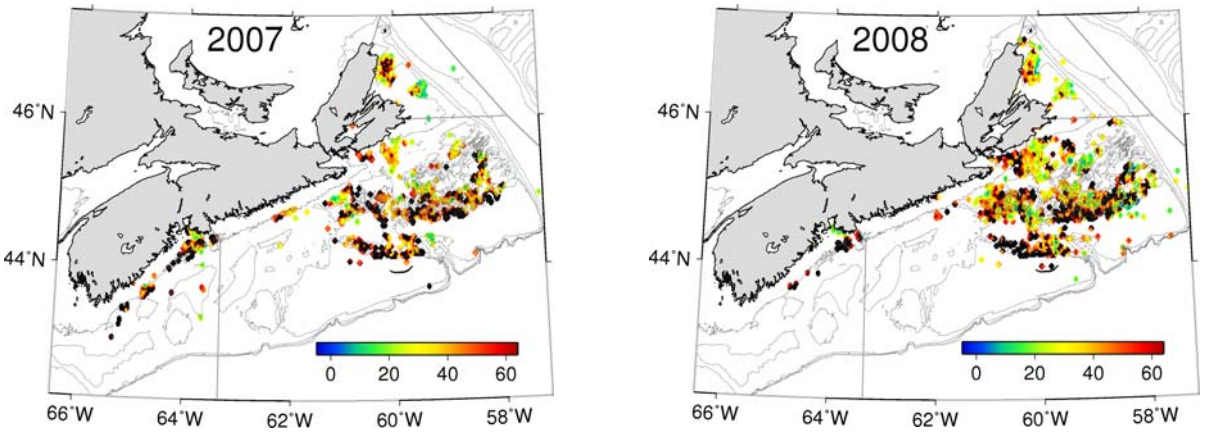
The prompt and careful return of immature crab to the water by the fishery is an important conservation measure that will enhance the mid-term (2-3 year) sustainability of this fishery.

Season extensions were granted in all CFAs (except in CFA 4X) against the advice of DFO Science and the consensus decision of Industry Advisory Panels. This was a conservation concern due to elevated soft-shell capture towards the latter part of the season and it also interfered with the completion of the trawl surveys.

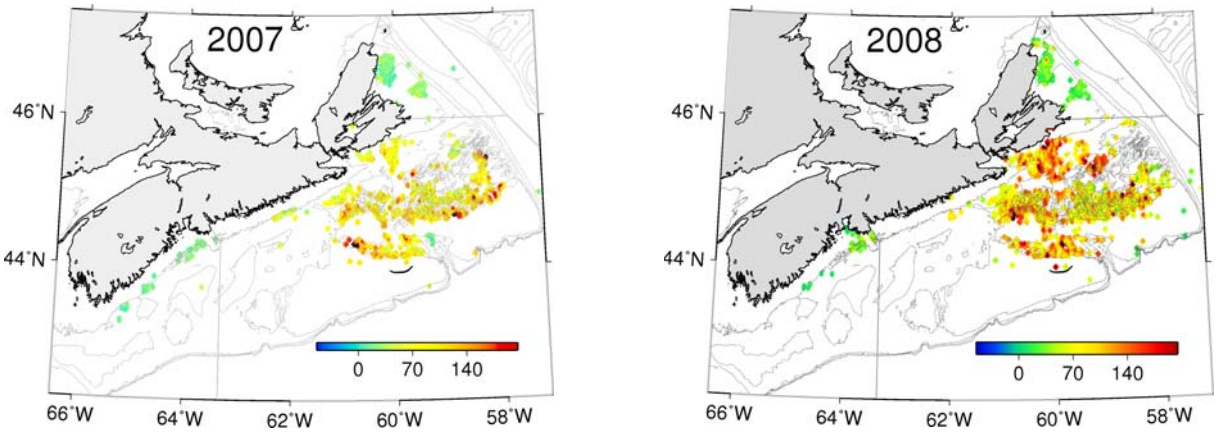
Industry has indicated that the fisheries management decision-making process that involved Ottawa-level approvals delayed the implementation of management measures already agreed upon by industry in 2008 (e.g., fishing seasons). A more rapid response has been requested. To help in such matters, industry also requested that such matters and/or new strategies be discussed/developed immediately after the fishing seasons in both N- and S-ENS.



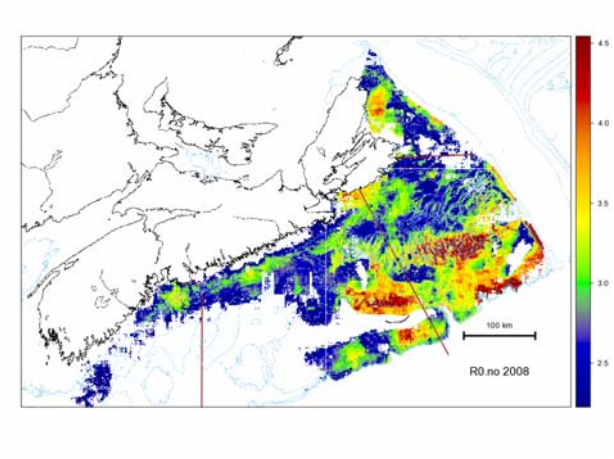
Map 1. Commercial landings (log10; metric tons) in the 2007 and 2008 fishing seasons. Areas in black are off the scale. Original figure in colour.



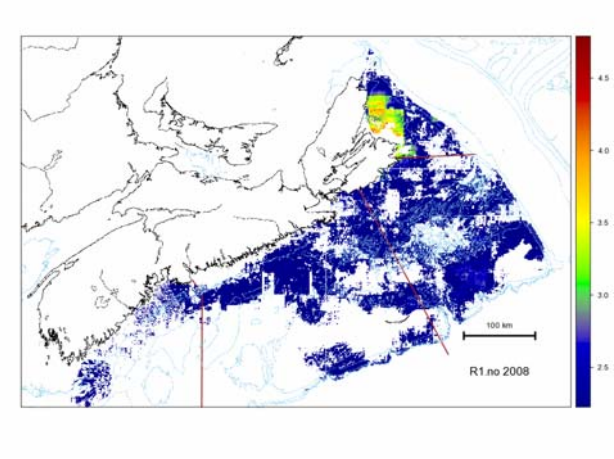
Map 2. Commercial fishing effort from reported logbook positions (total number of trap hauls) in the 2007 and 2008 fishing seasons. Note the reduction in effort in the offshore slope and the near shore in the former CFA 24E. Areas in black are off the scale. Original figure in colour.



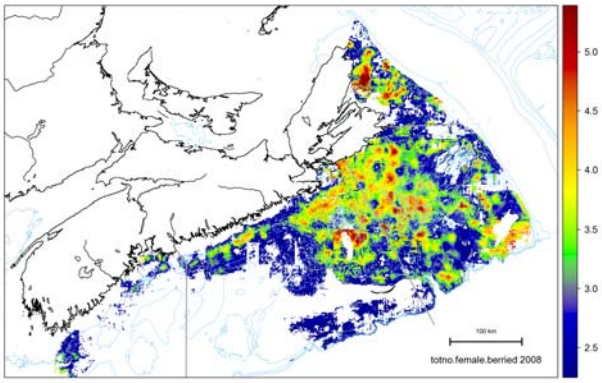
Map 3. Average catch rates (kg/trap haul) of snow crab on the Scotian Shelf in 2007 and 2008. Original figure in colour.



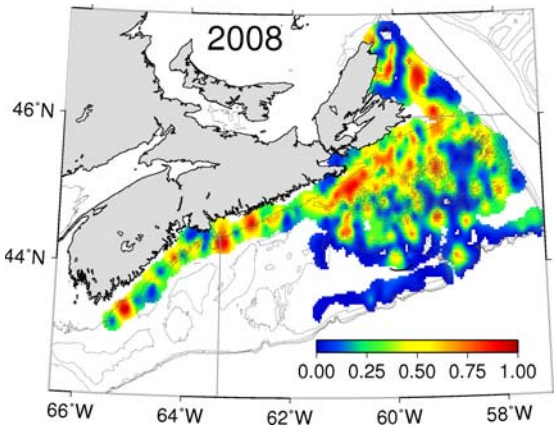
Map 4. Fishable biomass from the 2008 snow crab survey. Log 10 scale. Original figure in colour.



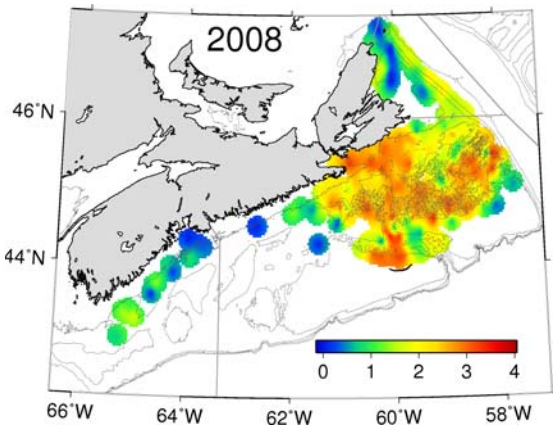
Map 5. Numerical abundance of recruitment of snow crab in 2008. Log 10 scale. Original figure in colour.



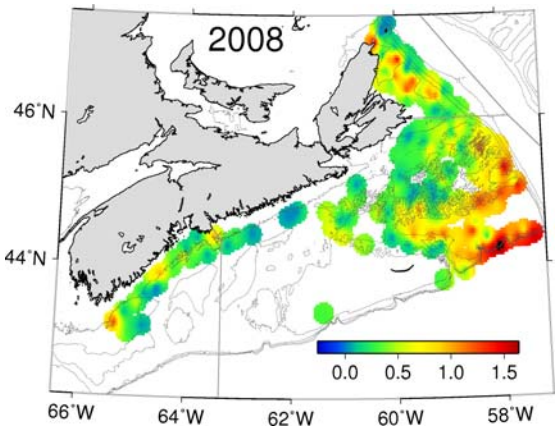
Map 6. Numerical abundance of berried female snow crab in 2008. Log 10 scale. Original figure in colour.



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.

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