ASSESSMENT OF SOUTHWESTERN NOVA SCOTIA (4X) SNOW CRAB

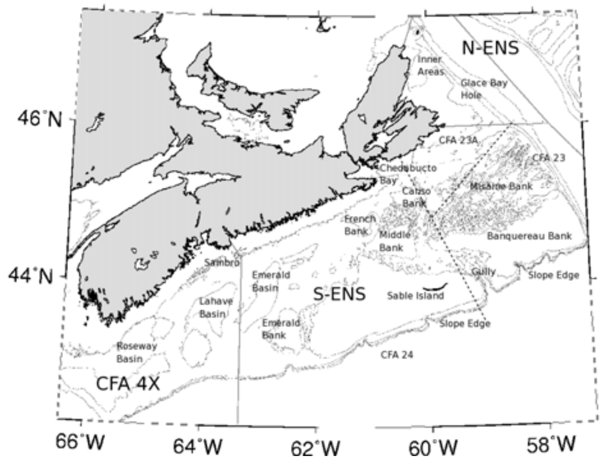


Figure 1: Map of Crab Fishing Areas (CFAs) since 2005.

Context

The snow crab fishery has been active since the late 1970s in Nova Scotia. Currently, it exploits the full spatial extent of the species on the Scotian Shelf. Since 1998, the fishing grounds have been subdivided into various management 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 South-East Nova Scotia (S-ENS). In the NAFO Div. 4X area, directed harvesting of snow crab began in 1994 and became a commercial fishery in 2000 when the majority of Eastern Nova Scotia (ENS) management approaches were also adopted.

Since the demise of the groundfish, snow crab have become an important macro-invertebrate on the Scotian Shelf. They are numerous in deep, soft-bottom substrates ranging from 60 to 280m and at temperatures less than 6°C. The higher and more variable bottom temperatures encountered in Area 4X delimits the southern-most extreme of their spatial distribution in the Northwest Atlantic. However, the capacity of snow crab to move large distances and the presence of core areas suitable for both immature (warmer nursery-type areas) and mature (colder areas) snow crab suggests that these risks can be reduced if responsible and conservative fishery practices are implemented.

In support of the fishery, DFO Maritimes Fisheries and Aquaculture Management requested from DFO Science an assessment of resource status and the consequences of various harvest levels for the coming fishing season. This report is a scientific overview of the assessment and projections undertaken in support of the fishery. Commercial catch rates and other fishery statistics are reported and an assessment of the status of 4X snow crab is made from fishery independent surveys using indicators of abundance; reproductive potential; recruitment; and exploitation rates. Harvest advice for 2007 is also provided. Supplemental information from the ENS assessment is included due to the intimate relationship between ENS with area 4X snow crab, and the requirement of an integrated assessment, that adopts a precautionary, ecosystem-based approach.

SUMMARY

- Landings in 2006 were 319t (TAC of 337.6t) – an increase of 3.6% from 308t in 2005. Average, non-standardized catch rates were 27.7kg/trap, representing a marginal decrease from 28.6kg/trap.
- Soft-shelled crab incidence in the commercial catch of legal sized crab is low, estimated to be 0.05%.
- By-catch levels are low in this fishery, representing approximately 0.324% of annual landings.
- The fishable biomass of snow crab was estimated to be 850t, a 14.1% decline from 990t in 2005.
- In the near-term, recruitment is expected to increase. The leading edge of recruitment should enter in 2007 and full entry in 2010 to 2011.
- In the long-term, the reproductive potential of the Scotian Shelf population has increased with the substantial increase in berried female abundance in all areas. Larval production should continue for another 5 years.
- Relative exploitation rates (RER) were 27% in 2006, relative to 30% in 2005.
- Increasing bottom temperatures on the Scotian Shelf and shrinking of potential habitat is a source of uncertainty that may have particularly negative consequences upon the CFA 4X snow crab.
- Due to the fishing season being just after the moulting period and prior to the mating period, the CFA 4X fishery intercepts newly matured males prior to their having an opportunity to mate. This is a conservation issue that requires a precautionary approach to this fishery.
- Returning immature (pencil-clawed) males provides conservation value, as they would be given an opportunity to reproduce. This can also reduce any negative genetic effects upon size at maturity and increase the yield per individual.
- In light of the poor recruitment, lower fishable biomass, and uncertainties in environmental variability, a precautionary approach is warranted in CFA 4X to stop the decline of fishable biomass and promote recovery. Fishing at a more precautionary level of 20% RER will likely result in a rapid rebuilding of the fishable biomass and thus sustain the fishery further into the future.

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 280m and temperatures from -1 to 6° 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 30mm carapace width (CW) are particularly vulnerable to predation as are soft-shelled crab in the spring moulting season.

Life history characteristics of snow crab are similar in all CFAs. 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 sources 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. 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 55mm CW and mate between winter/spring while the carapace is still soft. 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 generally reproduce twice although a third cycle is possible under very good environmental conditions. The condition of the male deteriorates in the last two years of its life, a stage that is generally associated with a mossy and decalcified carapace.

Fishery

The snow crab fishery on the Scotian Shelf, has been in existence since the late 1970s with landings of less than 1,000t. By 1979, this rose to 1,500t subsequent to which the fishery declined substantially in the mid-1980s. A large pulse of recruitment to the fishery was observed in 1986. Landings increased to record-levels of approximately 10,000t 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)[1]. Fishing for snow crab extended into CFA 4X (NAFO Division 4X), with directed fishing for snow crab beginning in 1994. It was initially managed as an “exploratory fishery” and in 2000 became a commercial fishery. TACs were nominally established independent of scientific advice at 600t. Due to declines in fishable biomass and recruitment throughout the Scotian Shelf, a 200t TAC was suggested for the 2005 season by DFO Science; however, a higher 337.6t TAC was set for 2005 and 2006 (Table 1).

Total landings in 2006 were 319t for CFA 4X, an increase of 3.6% relative to 2005 (Table 1). The CFA 4X fishery did not catch their TAC due to business decisions of some fishers. In comparison, the N-ENS (North-East Nova Scotia) and S-ENS (South-East Nova Scotia) fisheries reported landings of 486t and 4,486t, respectively (Tables 2-3), representing declines of 14 and 30% in reported landings, respectively, due to reduced TACs. The 2006 TACs were 485t and 4510t in N- and S-ENS, respectively (Tables 2-3).

[1] All colour maps have been placed at the end of this report.

Table 1: Summary of snow crab fisheries activity in CFA 4X. From 1994 to 1996, 4 exploratory permits were active with an average of 10.6 t landed each year. Catch rates and calculated effort are for the large trap compliments only. "Year" indicates the year of the start of the fishing season. 2005 was the first year where fishable biomass was determined in area 4X.

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (X1000 trap hauls)
1997	4		42		
1998	4		70		
1999	4		119		
2000	6		213		
2001	8	520	376		
2002	9	600	221	10.1	21.9
2003	9	600	289	12.7	22.8
2004	9	600	422	20.3	20.8
2005	9	337.6	308	28.6	10.8
2006	9	337.6	319	27.7	11.5

Table 2: Summary of snow crab fisheries activity in 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

Table 3: Summary of snow crab fisheries activity in 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	115	6,353	6,407	109.4	58.6
2006	114	4,510	4,486	90.6	49.4

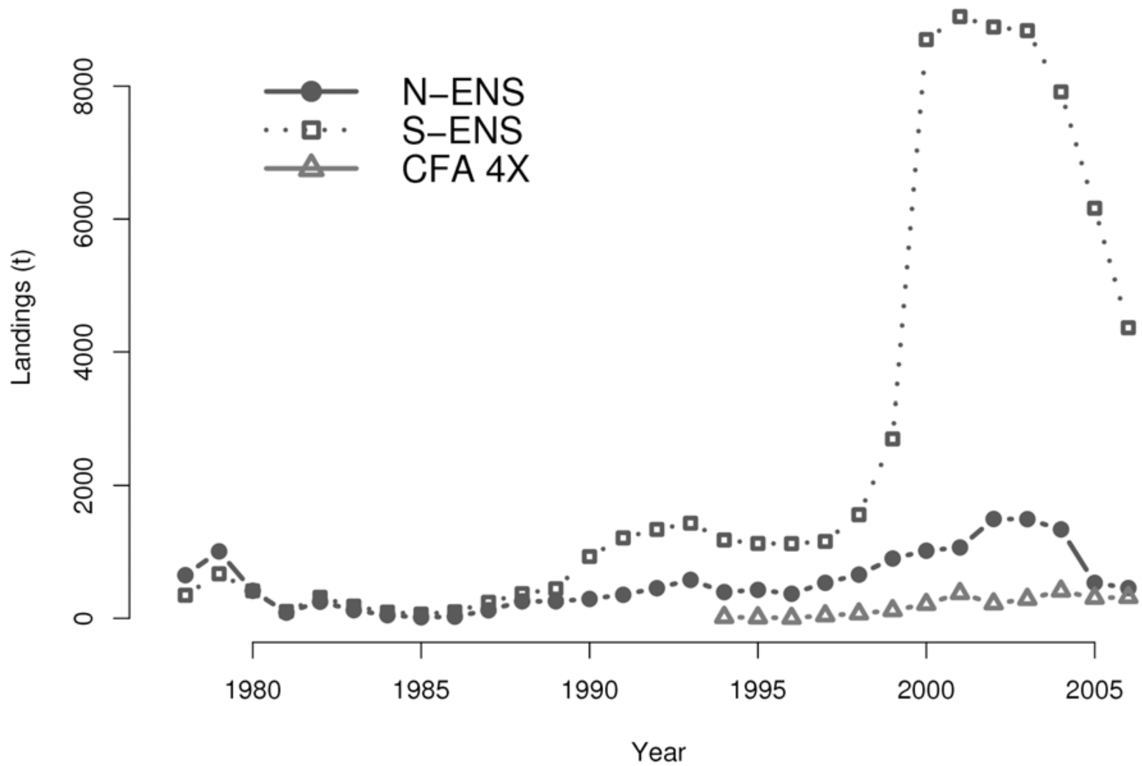


Figure 2: Temporal variations in the landings (t) of snow crab on the Scotian Shelf. Note the sharp increase in landings associated with large increases to TACs and a doubling of fishing effort in the year 2000. The landings follow the TACs with little deviation, except for CFA 4X (and so are not shown).

Overall, the spatial distribution of fishing effort continued to increase in offshore areas and decline in inshore areas throughout the Scotian Shelf (Map 2). In CFA 4X, most of the effort contracted to the area immediately near Sambro with an estimated 11,500 trap hauls – an increase of 6.5% relative to 2005 (Table 1; Figure 3). In comparison, a total of 13,700 and 49,400 trap hauls were applied in N- and S-ENS, respectively, in 2006 (Tables 2-3).

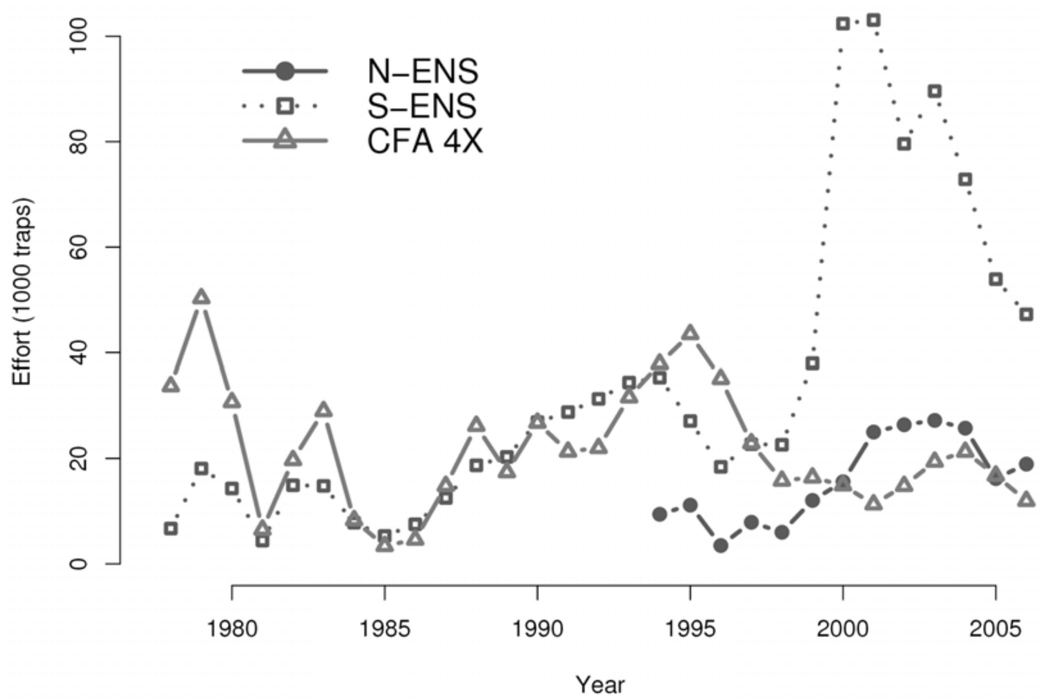


Figure 3: Temporal variations in the fishing effort, expressed as the number of trap hauls. Note the doubling of effort in the year 2000.

The catch rate in CFA 4X was 27.7 kg/trap, a marginal 3% decline relative to 2005 (Table 1). The catch rates were highest near the Sambro area (Map 3). In comparison, catch rates in N- and S-ENS were 35.6 and 90.6 kg/trap (Tables 2-3; Figure 4).

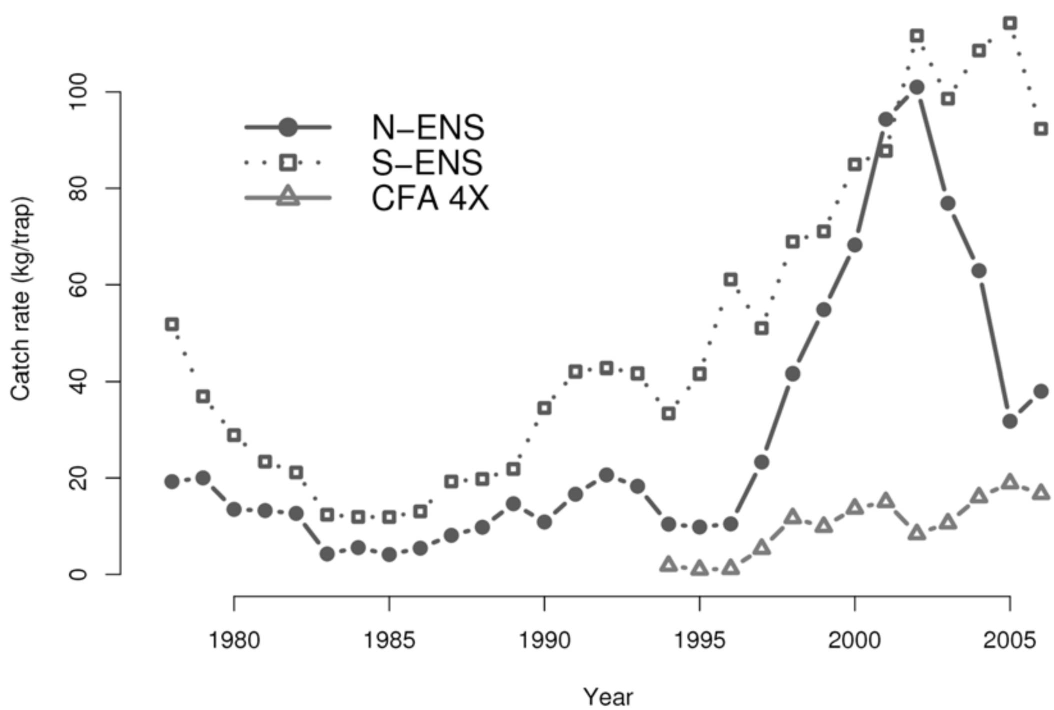


Figure 4: Temporal variations in catch rates of snow crab on the Scotian Shelf, expressed as kg per trap haul. Trap design and size have changed over time. No corrections for these varying trap-types nor soak time and bait-type have been attempted

In CFA 4X, the moult structure of legal sized snow crab has been dominated by CC3 (CC = carapace condition) males in the historical record (Table 4, Figure 5). While a small pulse of CC2 crab was observed in 2005, very few were observed in 2006. Almost no crab were observed in CC4 or CC5.

Table 4: Carapace condition of crab ≥ 95mm CW (percent by number) over time for CFA 4X from at-sea-observed data.

Year	**Carapace Condition**				
	1	2	3	4	5
2004	0.3	1.5	94.1	4.0	<0.1
2005	<0.1	11.5	85.3	3.1	0
2006	<0.1	0.3	98.2	1.4	0

In comparison, both N- and S-ENS demonstrate a more diverse moult structure which while still dominated by CC3 crab, also show an important number of CC4 and CC5 crab (Tables 5-6; Figure 5).

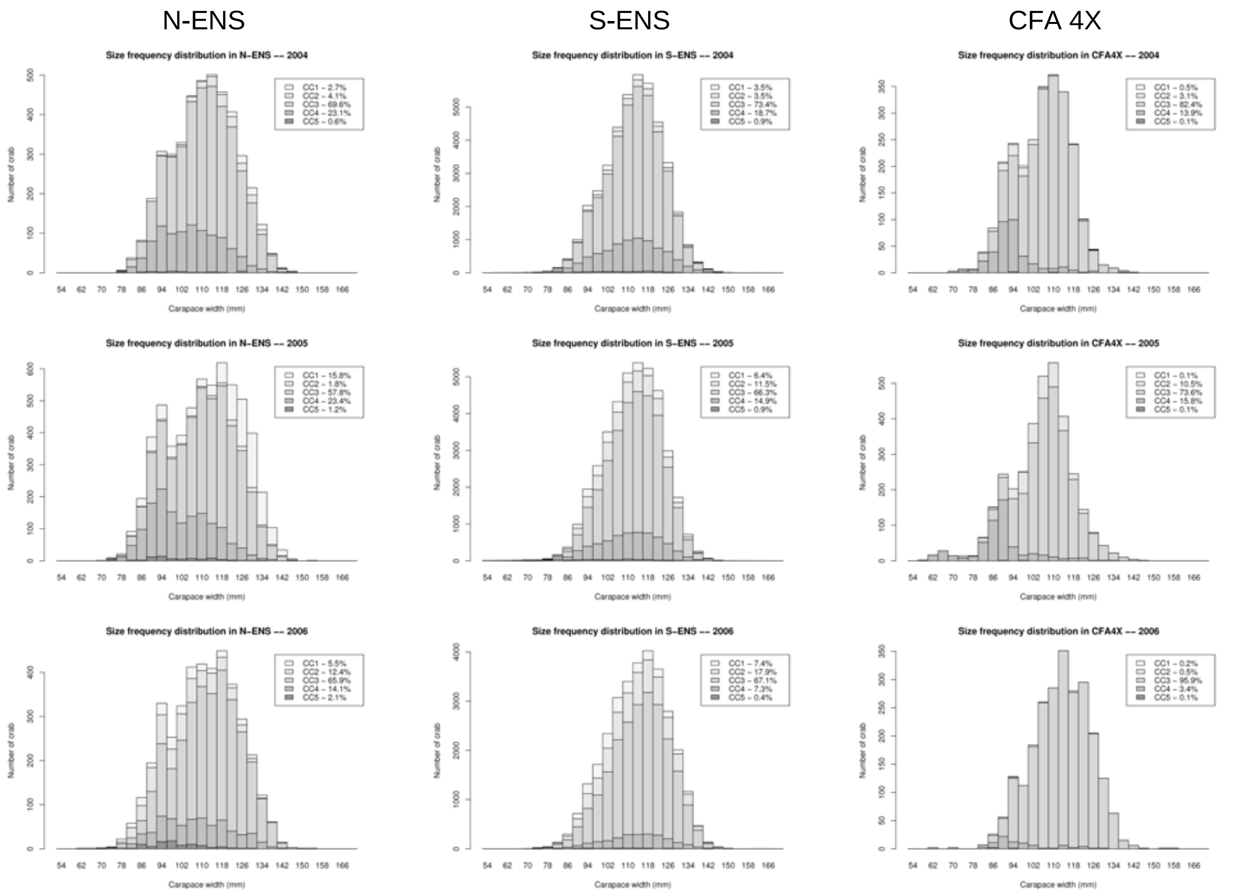


Figure 5: Size frequency distribution of at-sea-observer monitored snow crab broken down by carapace condition.

Table 5: Carapace condition of crab ≥ 95mm CW (percent by number) over time for N-ENS from at-sea-observed data.

Year	**Carapace Condition**				
	1	2	3	4	5
2004	2.5	4.9	72.5	19.8	0.4
2005	18.1	2.1	61.0	18.0	0.8
2006	3.8	9.7	71.4	13.5	1.6

Table 6: Carapace condition of crab ≥ 95mm CW (percent by number) over time for S-ENS from at-sea-observed data.

Year	**Carapace Condition**				
	1	2	3	4	5
2004	3.2	3.6	74.5	18.0	0.7
2005	5.9	11.0	68.2	14.3	0.7
2006	5.9	17.3	69.3	7.2	0.3

The occurrence of soft-shelled crab in CFA 4X is extremely low (Table 7) due to the fishing season that avoids the period of increased activity of newly moulted males during the summer. However, it must be emphasised that this fishing practice in CFA 4X is intercepting the majority of large newly matured males before they have had the opportunity to mate in early spring. This is an important consideration for conservation. In comparison, soft-shell catches are higher in N- and S-ENS (4.1% and 6.4%, respectively) due to their earlier season, successfully avoiding this conservation issue. However, soft-shelled crab discards represents up to 20 t, 278t and < 1t being potentially killed from handling mortality alone in N-, S-ENS and CFA 4X, respectively.

Table 7: The incidence of soft-shelled crab (percent, by number) in the legal-sized commercial catch.

Year	N-ENS	S-ENS	CFA 4X
2004	2.46	2.39	0.32
2005	18.07	5.22	0.04
2006	4.14	6.37	0.05

By-catch rates have been very low in this fishery CFA 4X over the past three years (0.324% of landings), being primarily represented by other crab species (Northern stone, Jonah, toad). In comparison, the ENS by-catch rate is even lower (0.022% of landings), being represented primarily by crabs, some demersal fish such as wolffish (spotted and striped), and halibut. Leatherback turtle entanglement on buoy lines has been observed on occasion in ENS (3 cases in 3 years), but in all cases, they were released with little to no visible harm. As CFA 4X is a small fishery relative to ENS, the estimated by-catch in CFA 4X is also much smaller and derived from a smaller number of species (mostly crab). However, the at-sea observer coverage was low in CFA 4X, reducing the reliability of the above estimates.

ASSESSMENT

Stock Trends and Current Status

Fishable Biomass

In CFA 4X, the fishable biomass was estimated to be 850t (95% confidence range of 700 to 1,000t; Figure 6; Map 4). This represents a decline of approximately 14.1% from approximately 990t in 2005. In comparison, N- and S-ENS, fishable biomass of snow crab was estimated to be 720t and 25,400t, respectively. In all areas, fishable biomass has been declining since peaks in early 2000s. Only in S-ENS has an increase in fishable biomass been observed in 2006.

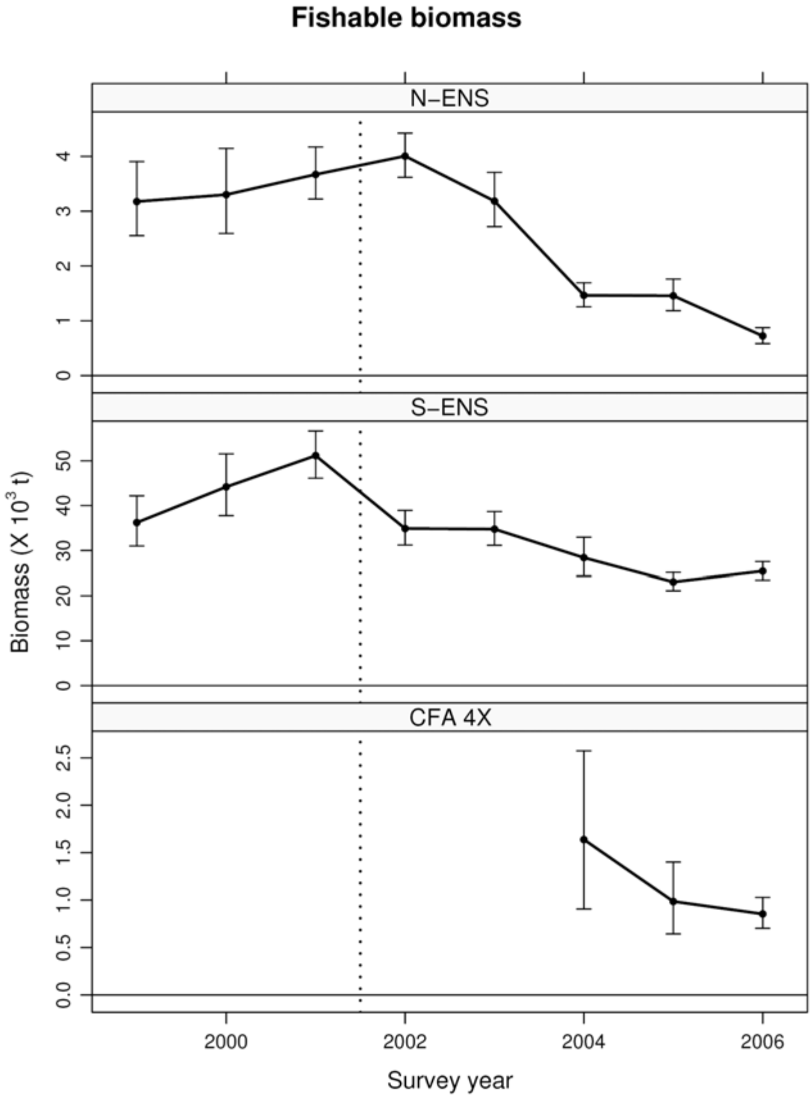


Figure 6. Fishable biomass over time from kriged estimates. Vertical line represents the shift in survey timing from spring to autumn.

Recruitment

The pulse of immature male crab detected in 2003 and 2004 continue to grow and propagate throughout the Scotian Shelf populations (Figure 7; Map 5). They are currently in the size class centered over the 54 mm CW mode (instars 9/10) which can be expected to fully enter the fishable biomass in 2010/2011. The leading edge of this mode should begin to enter the CFA 4X fishery in 2007. However, the strength of this entry is weaker that that observed in S-ENS (Figure 8).

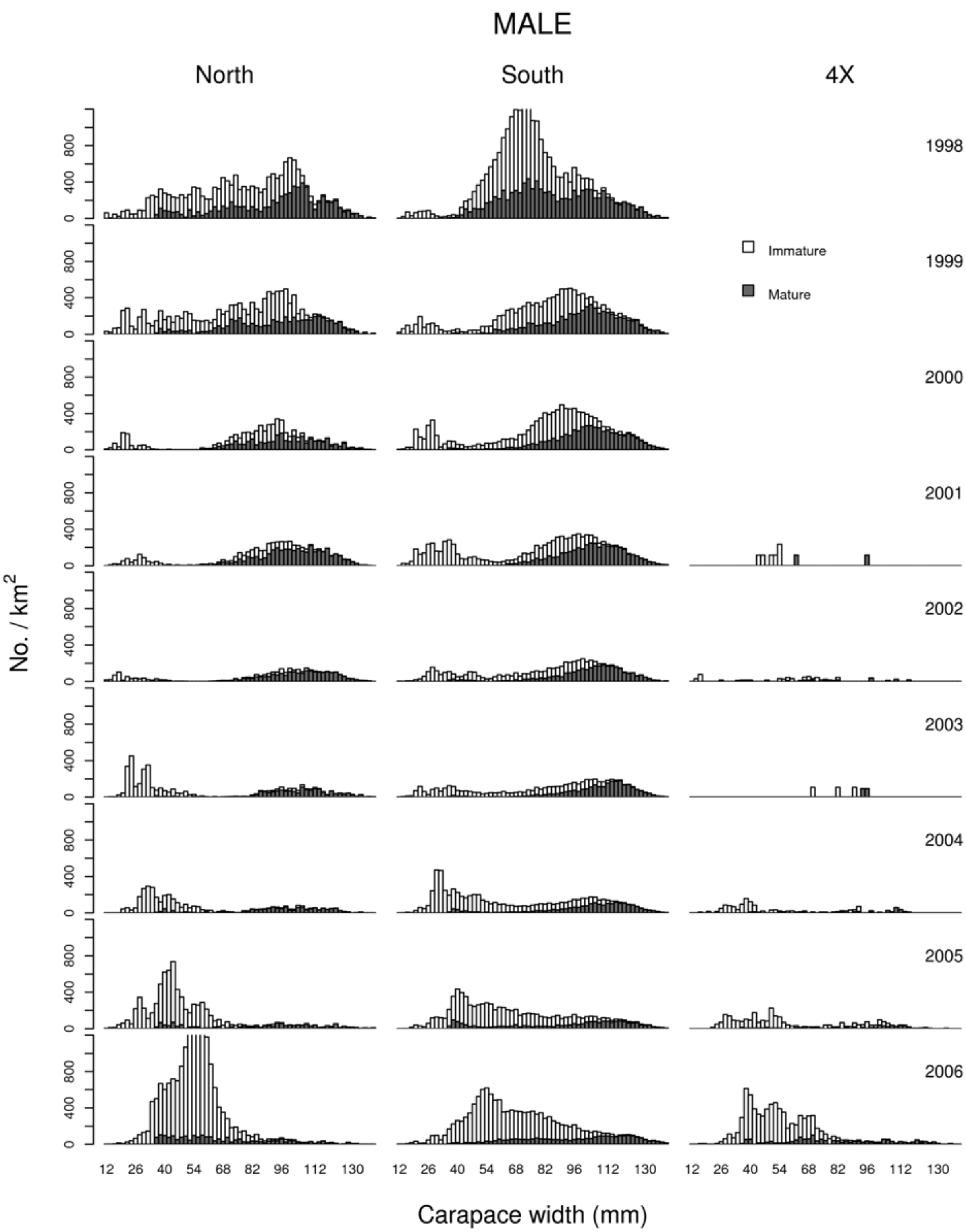


Figure 7. Size-frequency histograms of carapace width of male snow crab. Note the increasing numbers of juvenile crab, 2 to 4 years from entering morphometrically mature size classes. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure therefore provides information about the relative numbers within a given year for these areas.

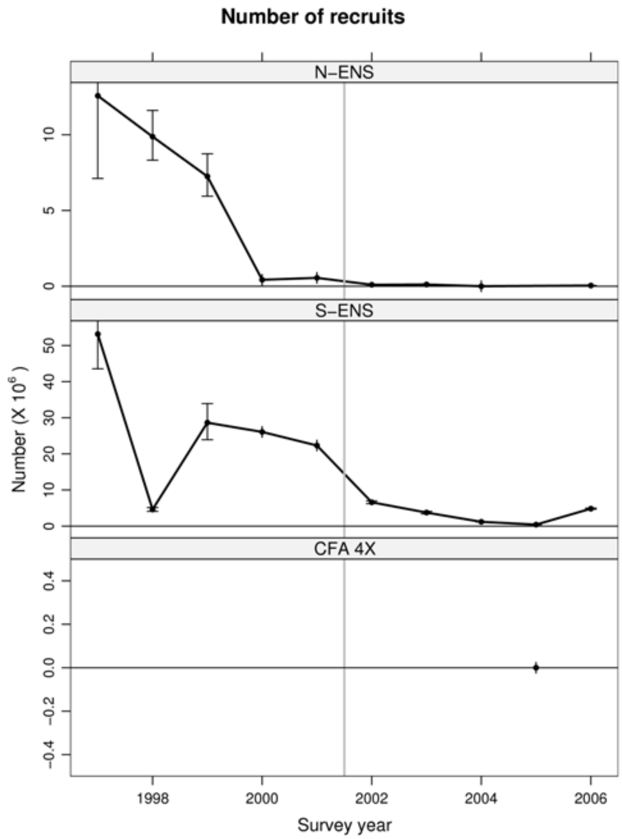


Figure 8. Recruitment (males larger than 95mm CW and soft-shelled) expected into the mature stage in the next year. This expectation does not include immature males that will moult into the fishable sizes in the spring moult. As this recruitment has been low for the last 4 to 5 years, the fishery has been increasingly dependent upon immature males. Vertical line represents the shift in survey timing from spring to autumn.

Low numbers of immature crab in size classes just prior to entry into the fishable biomass have been observed in most areas since the early 2000s (Figure 7) and particularly in CFA 4X and N-ENS. A large abundance of immature crab exists that should begin a strong entry into the fishable biomass in 2008, contingent upon the degree of movement into or out of CFA 4X.

Reproduction

Large scale maturation of the female snow crab population was detected in 2005 and 2006 in all areas (Figures 10 and 11; Map 6). This trend should continue for another 4 to 6 years as the snow crab population has entered a very important reproductive mode as berried females continue to increase (Figure 10). Larval production should, therefore, continue for at least another 5 years. Further, for the first time since the late 1990s, a more heterogeneous (mixed) spatial distribution of sexes was observed: pockets of male dominated areas were mixed with pockets of female dominated areas (Map 7). During mating periods, mature crab would, therefore, be able find mature females with minimal movement. Unfortunately, an increase in sex ratios in CFA 4X (and also N-ENS) is due to not only an increase in the number of reproductive females, but also a decline in the number of (*large) mature* males. This can have numerous negative conservation consequences upon the future reproduction in N-ENS and CFA 4X.

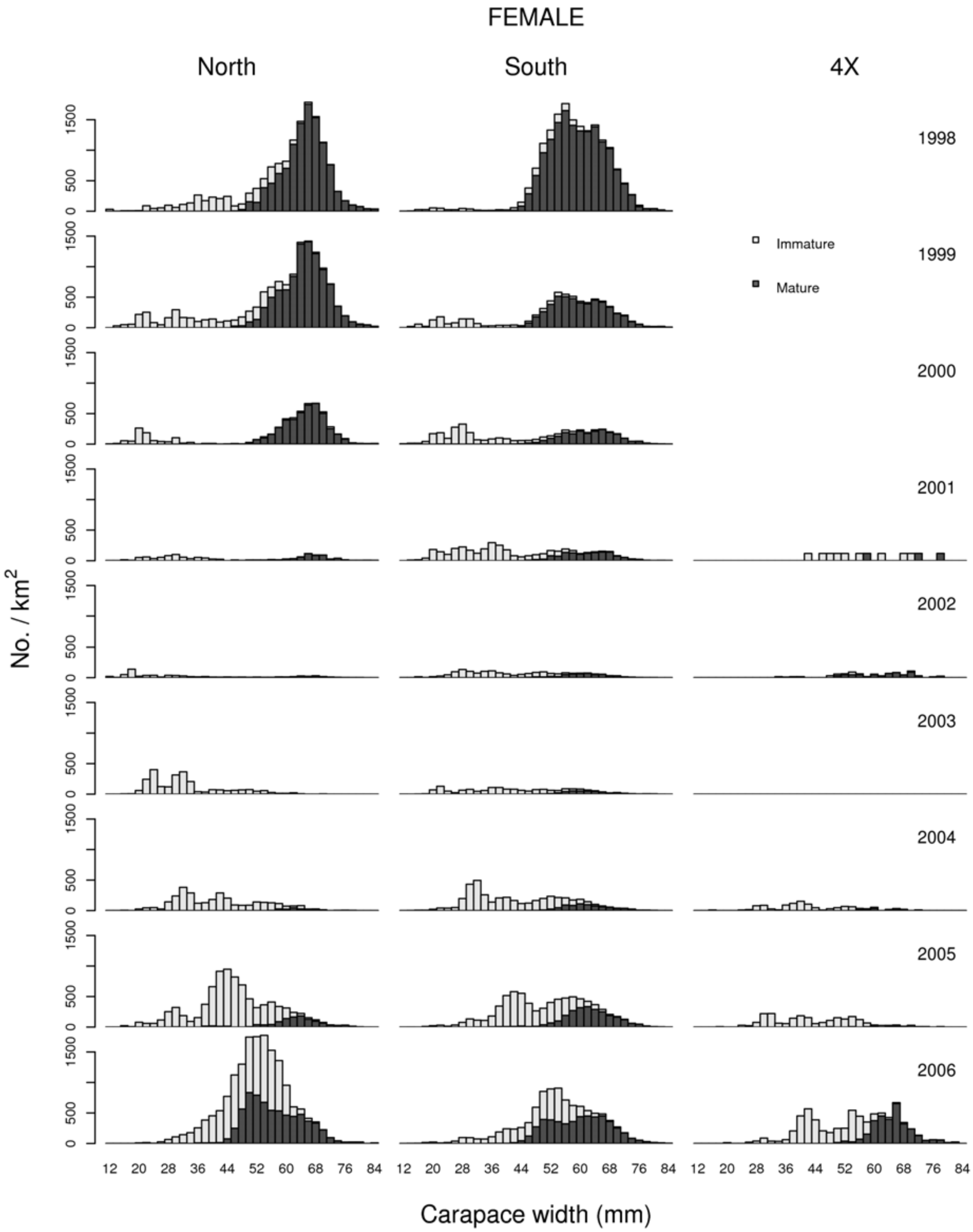


Figure 9. Size-frequency histograms of carapace width of female snow crab. Note that for S-ENS and CFA 4X (but not N-ENS), the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure, therefore, provides information about the relative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

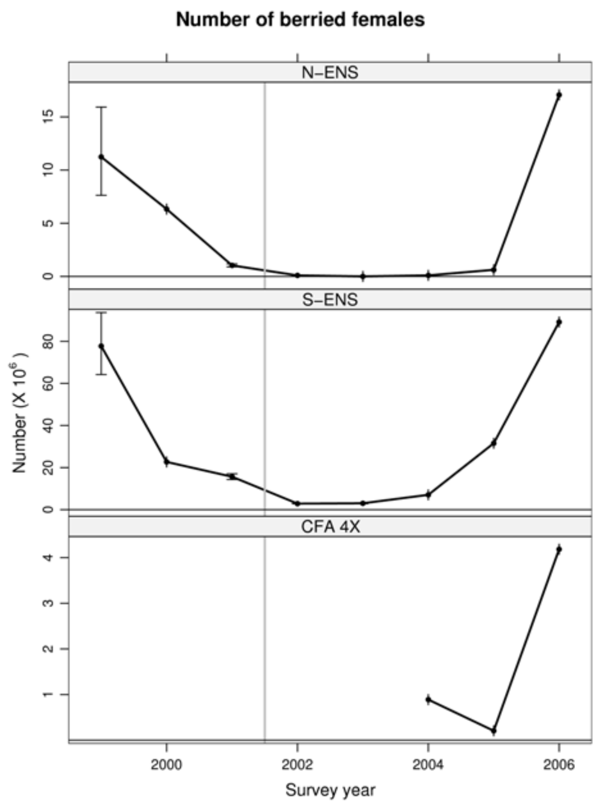


Figure 10. Numerical densities of the berried female snow crabs on the Scotian Shelf (number/km^2). Note the important increase seen since 2005 in all areas of the Scotian shelf. Vertical line represents the shift in survey timing from spring to autumn.

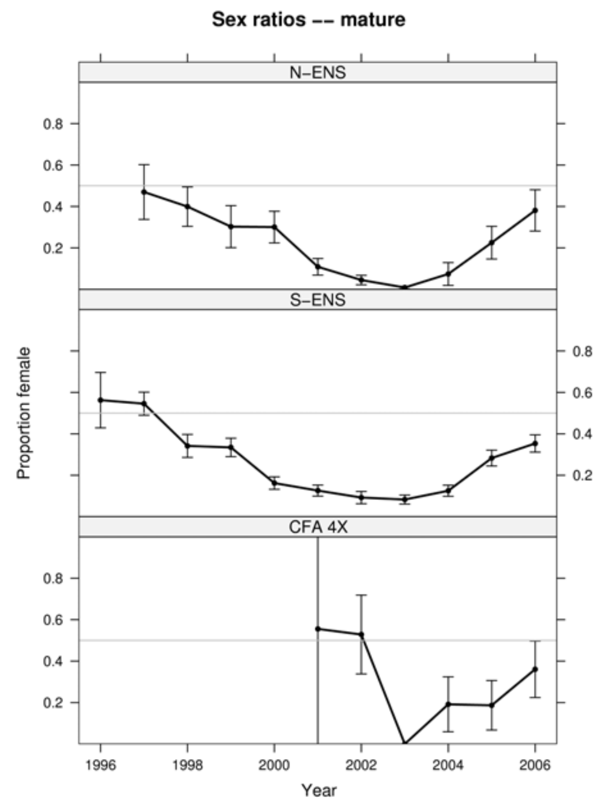


Figure 11. Sex ratios (% female) of mature snow crab. Since 2000, most of the Scotian Shelf was uniformly male dominated. A slight amelioration of the mature sex ratio was observed in 2004. This trend has continued and currently, the whole of the shelf can be seen to be entering a reproductive mode.

Exploitation Rate

The abundance of CC4 crab is very low and of CC5 crab is 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. This is particularly the case in CFA 4X.

Relative exploitation rates ($\text{Landings}_{(t)}$ / [$\text{Landings}_{(t)}$ + Fishable $\text{biomass}_{(t)}$]) or RER in CFA 4X for 2006 was 27% marginally less than the 2005 rate of 30% (Table 8). This RER is close to those of N-ENS (30 to 40%) even though CFA 4X is the least productive and most marginal temperature area on the Scotian Shelf (Figure 12). Spatially explicit RER in the primary fishing grounds were likely much higher due to the highly targeted exploitation patterns in area 4X (Maps 1-3).

Table 8. Relative exploitation rates ($Landings_{(t)}$ / [$Landings_{(t)}$ + Post-fishery fishable $biomass_{(t)}$]) in CFA 4X. Note: 2006 estimates are not available until after the 2007 surveys are completed.

Year	Landings (t)	Post-fishery fishable biomass (t)	Relative exploitation rate (%)
2003	289	NA	NA
2004	422	1640	15
2005	308	990	30
2006	319	850	27

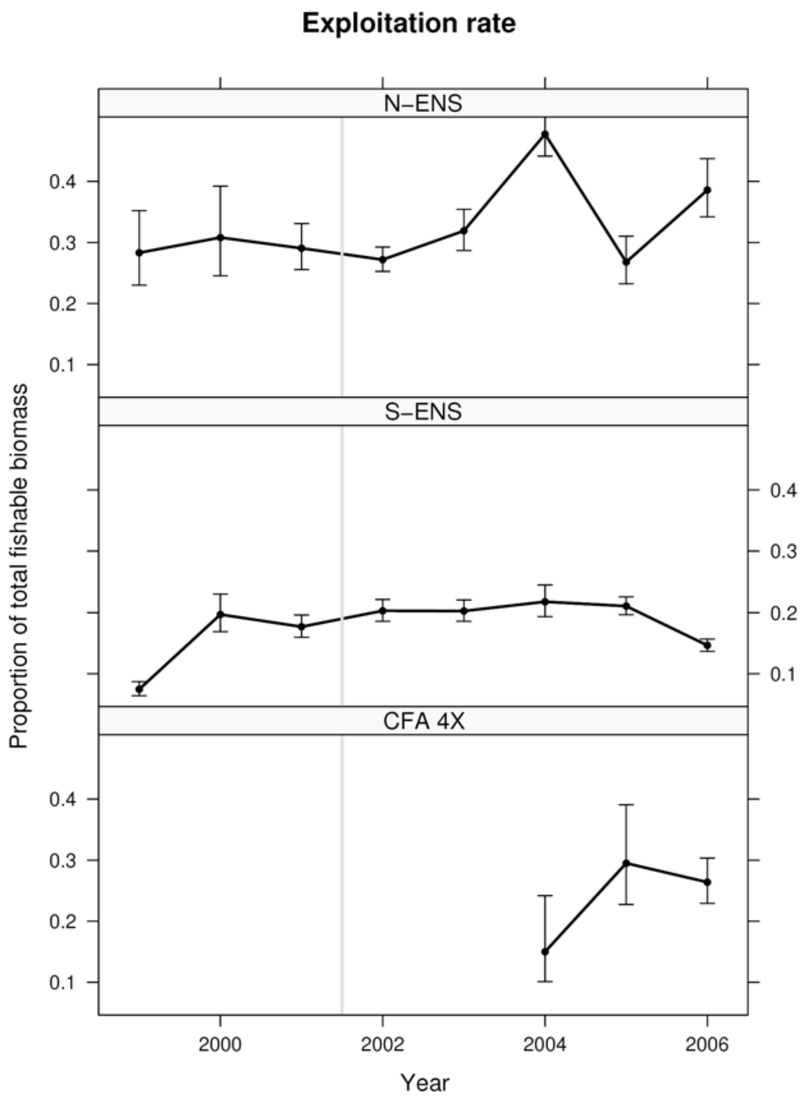


Figure 12. Relative exploitaiton rate ($Landings_{(t)}$ / [$Landings_{(t)}$ + Fishable $biomass_{(t)}$]) of snow crab. Vertical line represents the shift in survey timing from spring to autumn.

Sources of Uncertainty

Ecosystem Considerations

On the Scotian Shelf, a number of inter-related ecological factors influence snow crab abundance and stock status. They can be categorized as: bottom-up factors (limitations of resources such as food and viable habitat), top-down factors (predation, disease, parasitism), lateral (competition between individuals sharing similar niches and habitats), internal (population-dynamic factors that control growth, recruitment, maturity, movement), human (habitat destruction, fishing, by catch, genetic change, transport of invasive species), and environmental variations in abiotic factors such as temperature, salinity and dissolved oxygen concentrations.

Bottom-up (Resource Limitation)

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

Top-down (Predation)

- Potential predators of immature and soft-shelled crab (cod, thorny skate, other groundfish) have been found in high relative densities (in snow crab trawl surveys) in areas with high densities of immature snow crab (Map 9). This adds uncertainty to the strength of future recruitment into the fishable biomass.

Lateral (Competition)

- Large mature males stabilize the snow crab population by maintaining and occupying prime crab habitats, keeping at bay potential competitors in the guise of other crab species or even some groundfish and serve as large and strong mates and protectors of the smaller females. Their over-exploitation can have numerous negative biological and ecological consequences.

Internal (Population Dynamic)

- An important consequence of the extended period of very low sex ratios observed in the early-2000s throughout the Scotian Shelf is that very poor egg and larval production in the system occurred for at least a four to five year period. The consequence of this is that poor recruitment into the fishable biomass may occur again in the early 2010s. Stabilisation of such strong oscillations in abundance into the future can only occur if reproduction of the currently available females is not diminished by a lack of large males.

- The extent of movement between CFA 4X and S-ENS is another source of uncertainty.

Human Influences

- Oil and gas development/exploitation on the Scotian Shelf near to or upstream of major crab fishing grounds and population centers is a concern. Almost all areas on the Scotian Shelf have been subjected to some form of seismic energy (Figure 13). In particular, the influence of particle motion upon semi-buried species such as crab that exist in dense and variable media (at the interface between water and sediment), is not known. CFA 4X has not been directly exposed, but the possibility of expansion of seismic exploration exists. Further, upstream effects (in N- and S-ENS) upon potentially vulnerable components of the snow crab population (eggs, larvae, soft-shelled crab) and the uncertainties associated with the long-term biological effects of development upon this long-lived species are still not known.

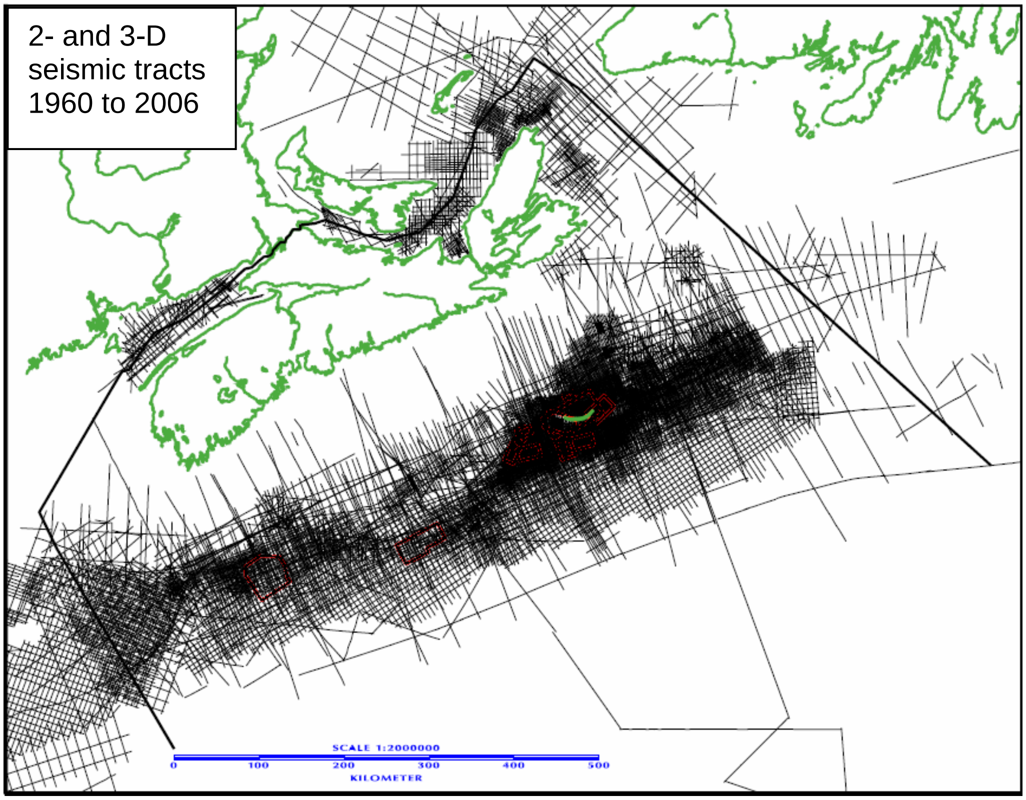


Figure 13. Locations of all seismic exploration tracts on the Scotian Shelf from 1960 to 2006. Source: http://www.offshoreenergyresearch.ca/Events/SeismicInvertebrateResearchWorkshop/tabid/180/Default.aspx

- By-catch of snow crab from other fisheries is not quantified. Damage from trawls, especially upon the soft-shelled phases of snow crab, has been raised by fishers as potentially problematic (e.g., trawl fisheries in CFA 4X, and shrimp trawls in particular for ENS). Inshore lobster and other crab fisheries are known anecdotally to have high catches of adolescent and female snow crab. The extent of illegal use of this snow crab as bait is not known.

Environmental Variability

- The spatial extent of potential snow crab habitat based upon bottom temperature and depth preferences, has been variable in CFA 4X (Figure 14). The surface area of potential habitat in 2006 has declined to near the 36-year mean. Similar changes have been occurring in N- and S-ENS.

- An overall warming of the above habitat space has been occurring since the early 1990s in all areas. In 2006, mean average autumn bottom temperatures were above average in all areas: 5.5°C in CFA 4X (Figure 15). In comparison, N- and S-ENS bottom temperatures were closer to preferred temperatures of 3.6, 3.8°C, respectively. Warm-water (> 10°C; i.e., beyond the thermal preferences of snow crab) incursions into CFA 4X and the offshore-slope areas were observed, forcing most crab in the area to move or die. These temperature forcings were also likely responsible for alterations in the life cycle of the crab in these areas, potentially accelerating their moult cycles.

- These strong variations in the areal extent of potential snow crab habitat in CFA 4X increase the uncertainty associated with fishable biomass estimates for the area.

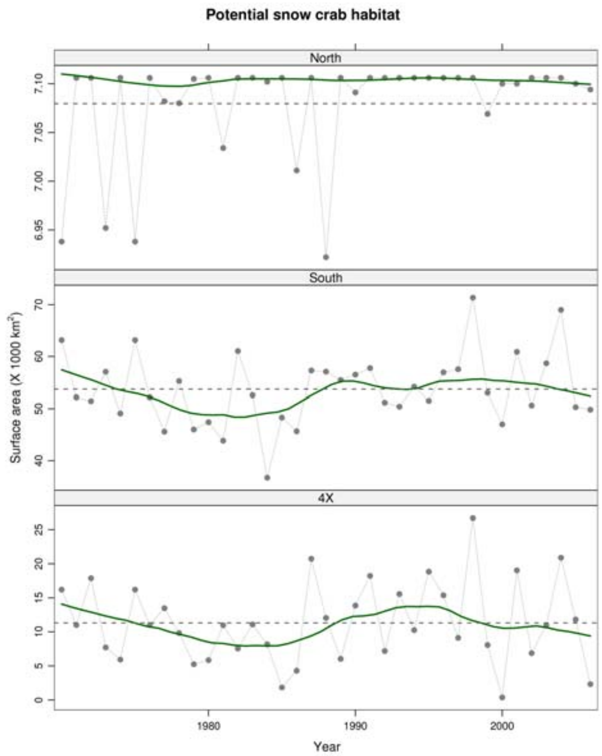


Figure 14. Total surface area of the potential habitat space of snow crab. Increased oscillations are evident since the late 1990s in S-ENS while in 4X, this increase is evident since the mid-1980s.

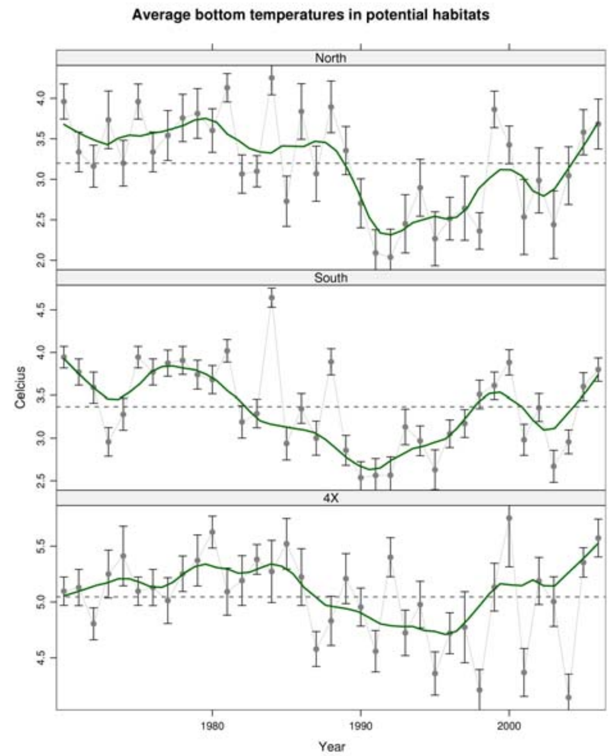


Figure 15. Mean summer/autumn bottom temperatures within the potential habitat space of snow crab. Mean temperatures seem to be increasing in ENS since the cool period of the 1990s. Note the extreme short-term fluctuations in mean temperatures in the 2000s in the 4X area.

CONCLUSIONS AND ADVICE

For CFA 4X, the fishable biomass continued to decline into 2006. This was expected due to poor recruitment and the use of high TACs and RERs in a low productivity area. The beginning of recovery was expected in 2007. However, the strength of this recovery was likely weakened due to high RERs in the area and the interception of newly recruiting males (a consequence of the fishing season occurring during the time of shell hardening). In contrast to the rest of the Scotian Shelf, the CFA 4X fishery is currently operating as a recruitment-fishery.

An examination of fishable biomass projections into the future based upon current trends in recruitment and mortality suggests a more rapid rebuilding of the fishable biomass with lower RERs (Figure 16). Fishing at current RERs of 30% will likely result in a marginal increase in fishable biomass that will likely peak in 2010. Fishing at higher RERs will likely diminish the magnitude of this peak, with a 60% RER likely to resulting in no rebuilding of fishable biomass. Fishing at a more precautionary level of 20% RER will likely result in a rapid rebuilding of the fishable biomass and thus sustain the fishery further into the future.

In light of the poor recruitment, lower fishable biomass, and uncertainties in environmental variability, a precautionary approach is warranted in CFA 4X to stop the decline of fishable biomass and promote recovery.

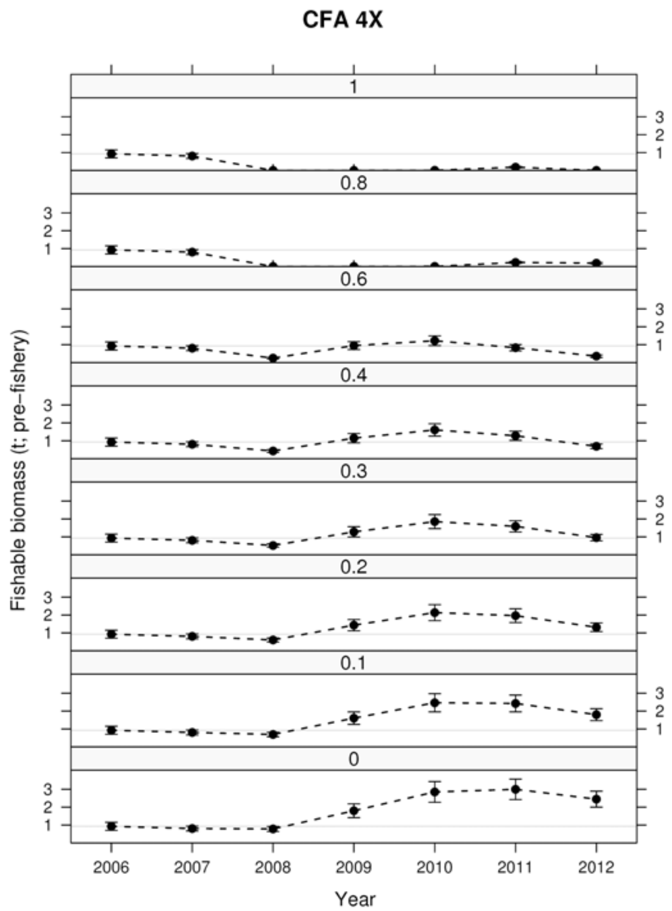
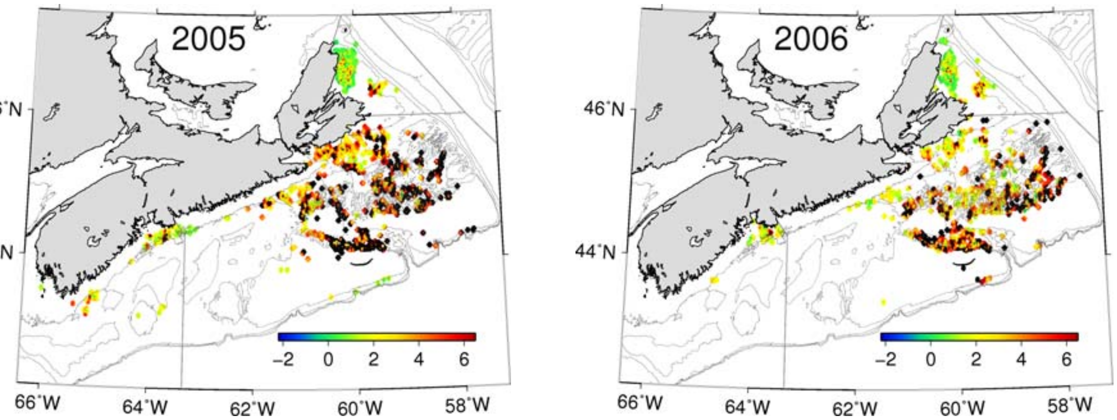


Figure 16. Projections of fishable biomass based upon current patterns of recruitment and mortality. The reference horizontal line is the fishable biomass in 2006. Note: these are heuristic relative trends only. The actual magnitudes of predictions have not been verified due to short time-series.

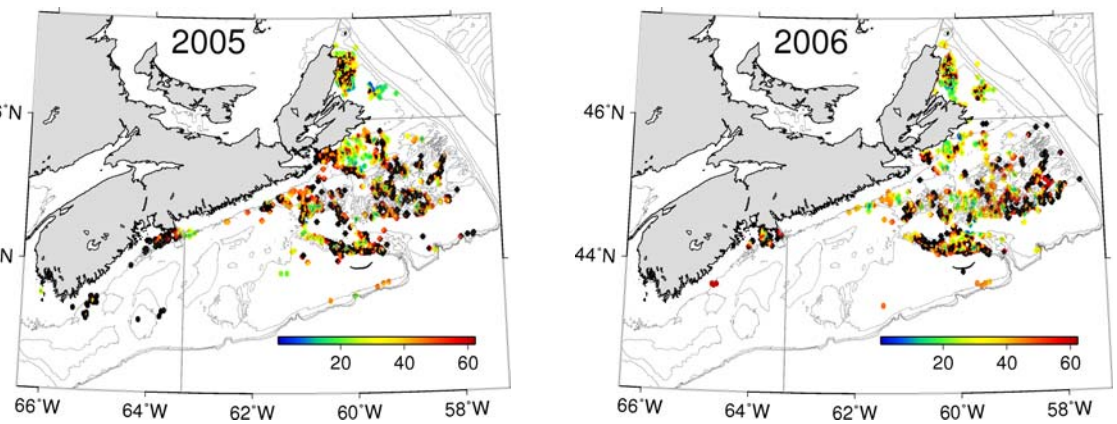
Other Considerations

- The fishing season is just after the moulting period and just prior to the mating period. This results in the fishery intercepting newly matured males prior to their having an opportunity to mate. This is not a conservation issue if RERs are precautionary. However, when RERs are high, this becomes a conservation issue as reproduction is inhibited and rebuilding of fishable biomass is inhibited.

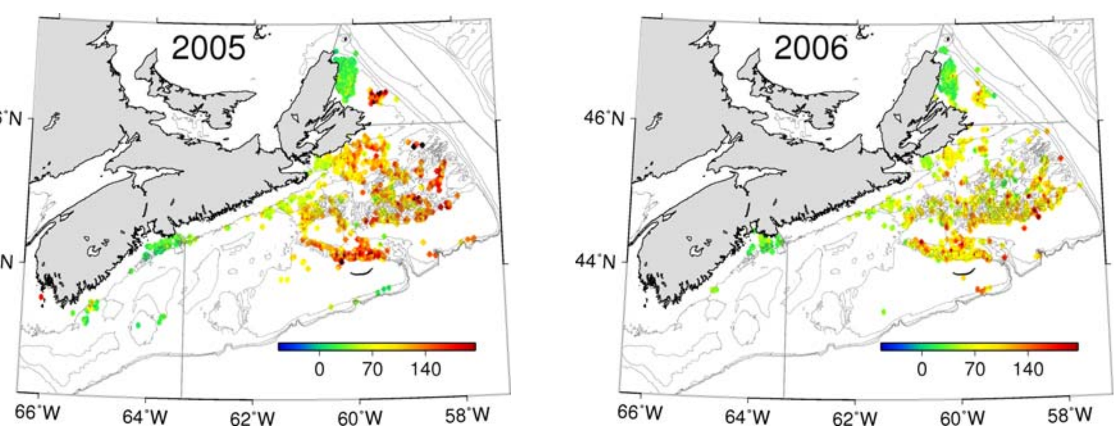
- Returning immature (pencil-clawed) males provides conservation value as they would be given an opportunity to reproduce. This can also reduce any negative genetic effects upon size at maturity and increase the yield per individual.



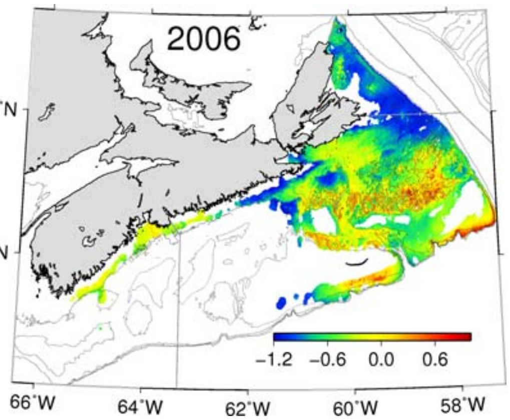
Map 1. Commercial landings (log_{10}; metric tons in each 1 minute square) in the 2005 and 2006 fishing seasons. Areas in black are off the scale. Original figure in colour.



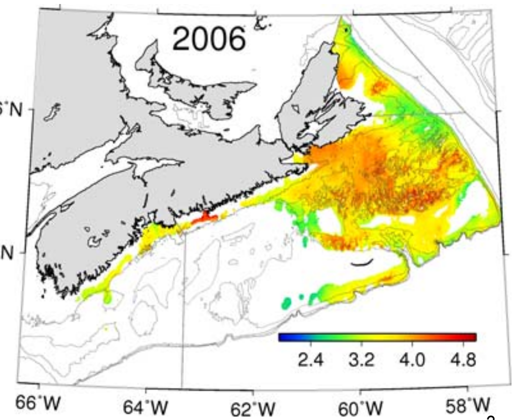
Map 2. Commercial fishing effort from reported logbook positions (total number of trap hauls in each 1 minute square) in the 2005 and 2006 fishing seasons. Note the reduction in effort in the offshore slope and the near shore in the former CFA 24E. Areas in black are off the scale. Original figure in colour.



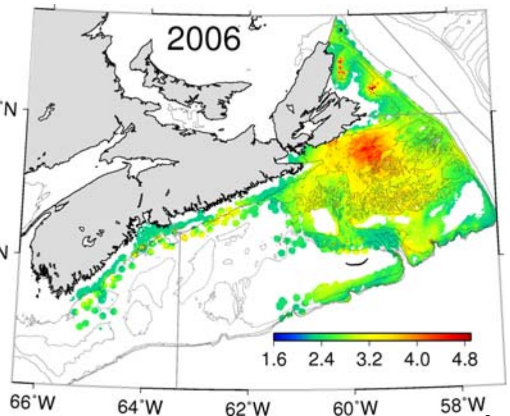
Map 3. Average catch rates (kg/trap haul in each 1 minute square) of snow crab on the Scotian Shelf in 2005 and 2006. Original figure in colour.



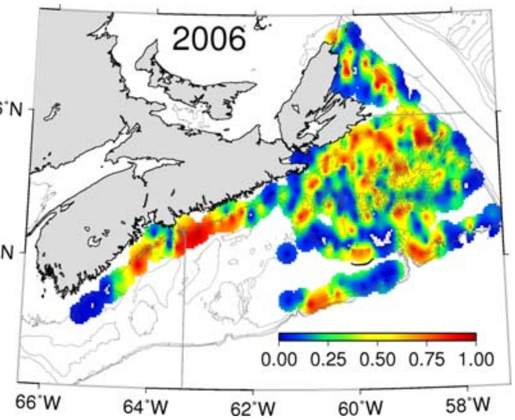
Map 4. Fishable biomass after the 2006 fishery ($Log_{10}(t/km^2)$). Original figure in colour.



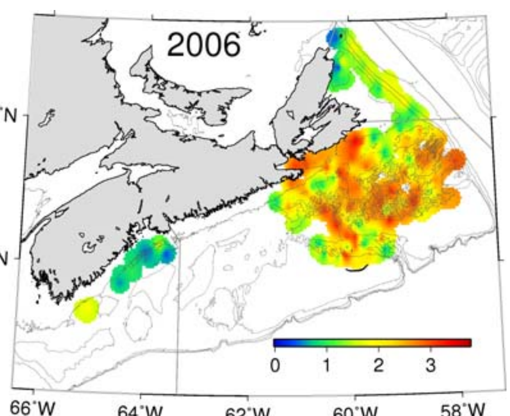
Map 5. Numerical abundance (Log_{10} (no./km^2)) of immature male snow crab. Original figure in colour.



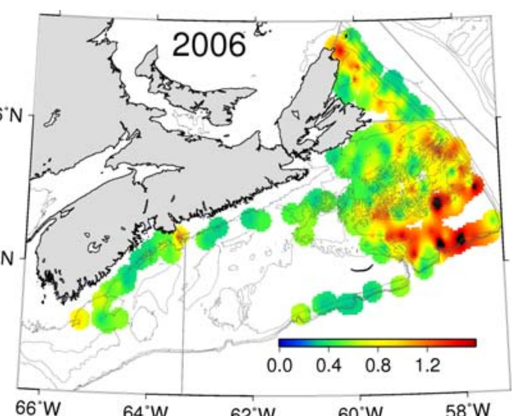
Map 6. Numerical abundance (Log_{10} (no./km^2)) of berried female snow crab. Original figure in colour.



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



Map 8. Number of shrimp (Log_{10} (no./km^2)), a food item of snow crab. Original figure in colour.



Map 9. Number of thorny skate (Log_{10} (no./km^2)), a predator of snow crab. Original figure in colour.

FOR MORE INFORMATION

Contact: Jae S. Choi / Ben M. Zisserson
Population Ecology Division
Bedford Institute of Oceanography
1 Challenger Drive
Dartmouth, N.S., B2Y4A2

Tel: (902) 426-1616 / 9325
Fax: (902) 426-1843
E-Mail: ChoiJ@mar.dfo-mpo.gc.ca / ZissersonB@mar.dfo-mpo.gc.ca

This report is available from the:

Centre for Science Advice,
Maritimes Region and Gulf Region
Department of Fisheries and Oceans
P.O. Box 1006, Stn. B203
Dartmouth, Nova Scotia
Canada B2Y 4A2

Phone number: 902-426-7070
Fax: 902-426-5435
e-mail address: XMARMRAP@mar.dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas

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