Eastern Nova Scotia Snow Crab

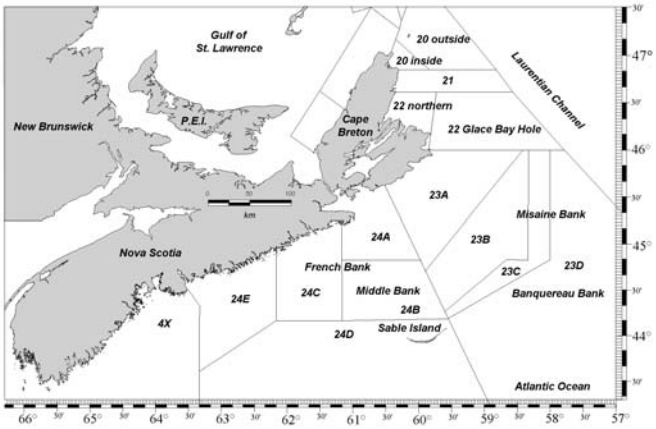

Figure 1: Map of the Scotian Shelf and the crab fishing area (CFA) management units. CFAs 20 to 22 comprise the northern management areas, while CFAs 23 and 24 comprise the southern management areas.

Background

The mandate to assess the status of the snow crab stock resident on the Scotian Shelf was transferred from the Gulf Fisheries Centre (Moncton, NB) to the Bedford Institute of Oceanography (Dartmouth, NS) in 2004.

The snow crab fishery has been in existence since the late 1970s in Nova Scotia. It now exploits the whole spatial extent of the species on the Scotian Shelf. The snow crab has also recently become an ecologically important species as it represents a dominant biomass on the shelf. Exactly what role they play in the Scotian Shelf ecosystem is not understood. Historically, they have been a source of food for the groundfish and a predator of worms, shrimp, molluscs, other benthic invertebrates and even small fish.

The recruitment patterns of this long-lived species (18 years) have however been following a boom-and-bust cycle with no stabilization yet in evidence on the Scotian Shelf. Currently, they seem to have begun the declining phase of this decadal cycle.

Summary

- A total of 9629 t of crab were landed from the Scotian Shelf in 2004. The TAC was 9657 t. These figures are inclusive of the slope areas and exclusive of CFA 4X.
- Catch rates (kg/th) in the northern areas dropped 21% relative to 2003 (from 77 to 61) and are currently at a five-year low. The Glace Bay Hole area continues to be an exception with a 37% increase in catch rates (from 121 to 165). Catch rates in the southern areas increased 7% (from 96 to 103). Shelf-wide, catch rates were 93 kg/th.
- Recruitment into the fishable population has been below average and the lowest in the time-series for the past two years and will likely continue to be so for at least another three to five years. Currently the only areas with recruitment into the fishable biomass are the offshore areas of CFA 23.
- Mature females have been declining in number steadily since the late 1990s due to natural causes. A new pulse is evident that will be more important in 2 to 4 years. These females are currently in the near-shore and the continental slope areas.

- The snow crab population is ageing as a result of decreasing recruitment (old shelled, carapace condition 4 crabs are in greater abundance relative to 2003). This will likely result in elevated natural mortality in 2 to 3 years.
- The environmental conditions (bottom temperatures) have been favourable for the snow crab for the past 16 years. However, concentrations of predatory cod and skate have been observed in areas with large numbers of immature crab.
- Rescaled fishable biomass estimates in the northern areas declined 41% relative to 2003 (from 2760 to 1630 t). In the southern areas, the decline was 15% (from 32750 to 27740 t; inclusive of the slope areas). The slope areas demonstrated a 14% increase (from 4880 to 5570 t).
- Exploitation rates in the northern areas have increased from 48% (2003) to 51% (2004). These rates are the highest on the post-1999 record.
- Exploitation rates in the southern areas have increased from 18% (2003) to 25% (2004), inclusive of the slope areas. The slope areas have increased exploitation rates from 5% (2003) to 6% (2004).
- A reduction in the TAC of the northern areas is highly recommended. If the 2005 exploitation rate is maintained at the 2004 level (51%), the 2005 TAC would be 840 t (a 41% reduction from the 2004 TAC of 1416 t).
- A reduction in the TAC of the southern areas is highly recommended. If the 2005 exploitation rate is maintained at the 2004 level (25%), the 2005 TAC would be 6900 t (a 15% reduction from the 2004 TAC of 8212 t).

Species Biology

The snow crab (*Chionoecetes opilio*, Brachyura, Majidae, O. Fabricius) is a subarctic species with a distribution from northern Labrador to the Gulf of Maine. Habitat preferences are soft mud bottoms. Smaller crabs are found in more complex habitats with shelter. Depths from 60 to 300 m and temperatures from -1 to 6 °C are occupied on the Scotian Shelf. Temperatures greater than 7 °C are 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. The known 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 carapace width is particularly vulnerable to predation as are soft-shelled crab in the spring moulting season.

Snow crab generally produce 35,000 to 46,000 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. Crab 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 crabs generally 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.

Females reach a final size of approximately 55 mm 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 for another 5 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.

The Fishery

History

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 (93000 t in 2001). In Nova Scotia, the fishery has been in existence since the late 1970's with landings at levels of < 1000 t. By 1979, this rose to 1500 t subsequent to which the fishery declined substantially in the mid-1980s. A large pulse of recruitment to the fishery was observed in 1986. Landings have since been increasing and are presently at record-levels of approximately10000 t each year (Figure 2).

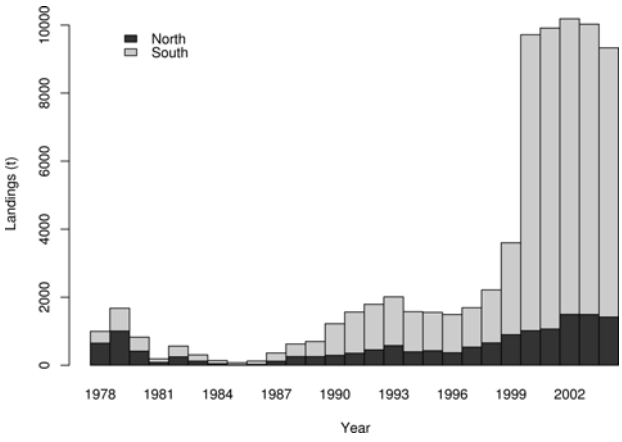

Figure 2. Annual landings (t) of snow crab caught on the Scotian Shelf. Note the sharp increases in landings in 2000 associated with increases in TACs.

The Scotian Shelf has been subdivided into numerous management areas (Figure 1). The management of these fisheries was initially based on effort controls (season, licence, trap limits) from 1982 to 1993. Additional management measures were introduced from 1994 to 1999: IBQs (individual boat quotas), TACs (total allowable catches), 100% dockside monitoring, mandatory logbooks, at-sea monitoring by certified observers and the introduction of sub-areas to ensure the spatial distribution of fishing effort. Voluntary management measures requested by fishermen were also introduced such as a shortened fishing season and reduced numbers of traps (CFA 21).

In 1998 and 1999, landings doubled with new temporary allocations being granted in CFAs 20, 23 and 24 to fishing grounds outside of the traditional fishing grounds. In 1999, trawl surveys were used for the assessment of the snow crab stock on the Scotian Shelf. The presence of unexploited south-east areas of the shelf was identified. Subsequently, TACs increased from 900 t to 1015 t in the north and from 2700 t to 8800 t in the south between the years 1999 to 2000. Following voluntary trap surveys in 2000, additional allocations (200 t) were made in 2001 and 2002 which were increased to 300 t in 2003. The post-1998 period was one of rapid expansion of the spatial extent of exploitation.

In 2004, due to signs of poor recruitment and consistently lower catch rates in most areas, a reduction in TACs was recommended and implemented. The management measures for 2004 are provided in Table 1.

Table 1. Management measures in 2004. CFAs 23 and 24 were granted season extensions in 2004. A 300 t TAC for the slope areas are not included in these figures.

Area	Season	Licenses (Perm)	Traps (Perm)	TAC (t; Perm)	Licenses (Temp)	Traps (Temp)	TAC (t; Temp)
20	July 22-Sept 15	5	30	102	5	30	57
21	July 22-Sept 15	32	25	490			
22 Inner	July 22-Sept 15	21	30	429			
22 Outer	July 22-Sept 15	16	30	338			
23	June 1-Oct 18	31	45	2552	34	45	1744
24	June 1/July 1–Nov 12	33	45	2342	33	45	1303

Landings

The total landings of snow crab from the Scotian Shelf (including the slope and excluding the 4X areas) was 9629 t, relative to 10318 t in 2003 (reflective of the reduced TAC of 9657 t). Landings for the northern areas (CFAs 20 to 22) were 1417 t. Landings for CFAs 23 and 24 were 7914 t. The landings from the allocations associated with the ENS slope trap survey were 179 t for CFA 24 (3 participants) and 118 t CFA 23 (2 participants).

Catch Rates

Catch rates (kg/th; Table 2) in the northern areas dropped 21% relative to 2003 (from 77 to 61) and are currently at a five-year low. The Glace Bay Hole area was an exception with an increase of 37% in catch rates (from 121 to 165). In the southern areas, catch rates increased 7% since 2003 (from 96 to 103). Highest catch rates were observed in CFAs 23B, 23C, 24B and 24D. The total catch rate for all of CFA 23 increased from 2003 to 2004 (99 to 114), while the total catch rate for CFA 24 has remained the same for 2003 and 2004 at approximately 92 kg/th (Table 2). The expansion to offshore fishing grounds complicates the interpretation of these rates as indices of population size. This expansion was most evident between 2002 and 2004 (Figure 5). The catch rate for the Scotian Shelf (exclusive of CFA 4X) was 93 kg/th, derived from approximately 100,200 trap hauls (Figures 3, 4). Season extensions were granted in the southern areas in 2004.

Table 2. Catch rates (kg/th) by management areas.

CFA	2000	2001	2002	2003	2004
N-ENS	68	94	101	77	61
S-ENS	85	88	110	96	103
CFA 20	47	66	68	44	27
CFA 21	65	95	97	78	51
CFA 22	78	107	120	93	100
CFA 23	83	82	117	99	114
CFA 24	86	99	103	92	92
CFA 20 I	57	92	102	48	27
CFA 20 O	36	46	39	13	No fishing
CFA 22 I	68	90	116	81	77
CFA 22 O	104	137	127	121	165
CFA 23A	103	113	142	94	112
CFA 23B	100	98	134	120	126
CFA 23C	66	136	108	135	123
CFA 23D	62	47	77	72	93
CFA 24A	82	109	132	79	82
CFA 24B	100	126	138	134	129
CFA 24C	90	98	93	86	69
CFA 24D	83	89	89	126	131
CFA 24E	51	66	55	46	38

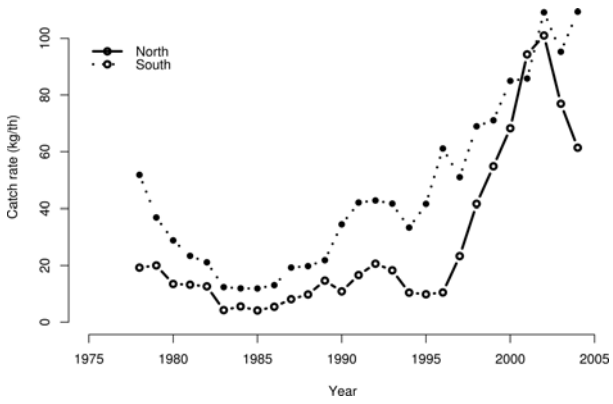

Figure 3. Catch rates (kg/th, where 'th' is trap haul). Note the large increases since the mid-1980s in both northern (dark) and southern (light) CFAs. Declining trends are evident the northern areas.

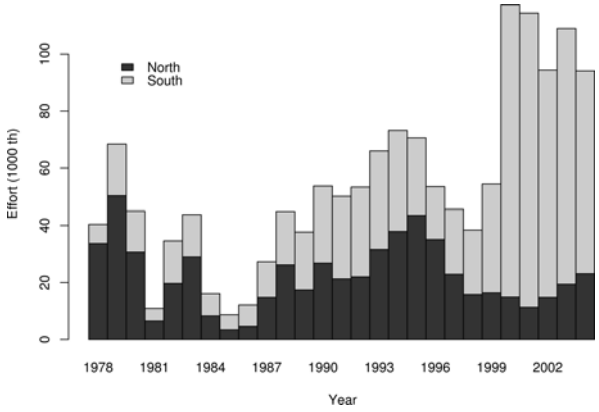

Figure 4. Fishing effort (number of trap hauls) on the Scotian Shelf. Note the decrease in the mid-1980s with the demise of the snow crab stocks and the sharp increase in 2000 with large increases in TACs.

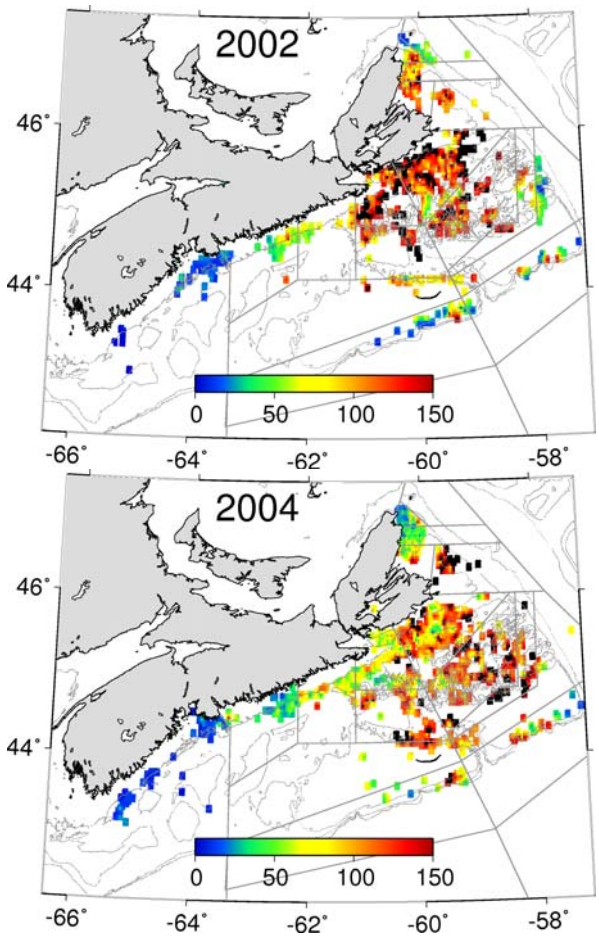

Figure 5. Map of catch rates (kg/th) on the Scotian Shelf for the years 2002 and 2004. Decreases in catch rates were evident in most inshore areas. Higher catch rates were generally observed in offshore areas (black areas indicate >150 kg/th). Note: original figures in colour.

Resource Status

Recruitment

The average size of mature crab has been increasing steadily since the main wave of recruitment into the mature population began in the late 1990s. The snow crab has since been ageing with little recruitment into the mature population. Old shelled, carapace condition 4 crabs are relatively more abundant relative to 2003 and may result in elevated natural mortality in 2 to 3 years time.

Size frequency distributions of males (Figure 6) indicate that the 2003 modes at 20 and 30 mm CW (representing instars 6 and 7, respectively) have successfully moulted into the 30 and 38 mm CW modal groups in 2004. Based upon established growth patterns, these two modes should reach legal size in five and four years, respectively. However, another weaker mode near 50mm CW has become evident (instar 9) and will likely reach legal size in approximately three years. Very little recruitment in the intervening years is expected.

The numerical abundance of potential recruits (R1 to R3; potential recruits in 1 to 3 years) continued to decline into 2004. R1 recruitment into the fishable population is poor. It has been below average and the lowest in the time-series for the past two years (Figure 7). This trend will continue for at least another three to five years, based upon the size-frequency distributions. Currently, the only areas where recruitment will likely be found in the next year (R1) are in the offshore areas of CFA 23, amounting to a total of approximately 0.25 crab/km^2.

Mature females have been declining in number steadily since the late 1990s due to natural causes as this is a male-only fishery (Figure 8). The two modes evident in 2003, centered upon 20 and 30 mm CW (instars 6 and 7, respectively) have moulted successfully into the 30 and 40 mm CW size classes in 2004 and will likely reach terminal moults in 4 and 3 years, respectively. A third

mode centered over the 50 mm CW size range (instar 9) was also evident in 2004 and will likely reach terminal moult in two years. The first tentative signs of rejuvenation of mature females were observed with the increase in number of smaller mature females, centered upon the nearshore areas of CFAs 23A and 24A (near Chedabucto and Gabarus Bays) and the continental slope areas.

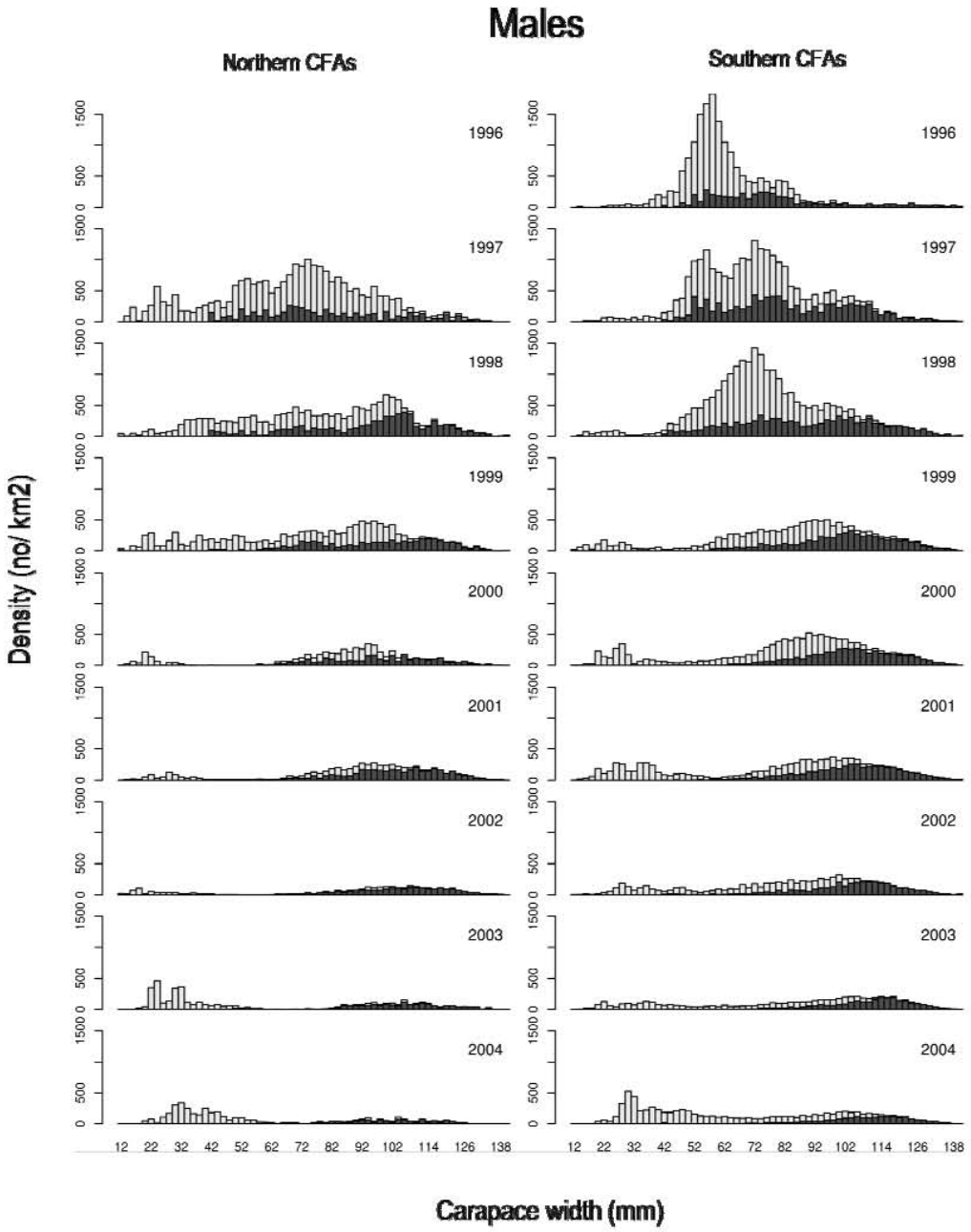

Figure 6. Size (CW; mm) frequency histograms of the mean density of male crab (no. / km^2) for the northern and southern CFAs. Note the synchrony in both areas and the adolescent pulses (light) entering the mature (dark) population, especially in the southern areas.

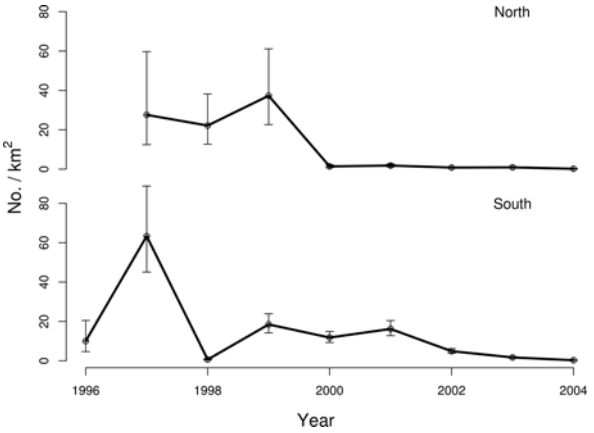

Figure 7. Geometric mean numerical densities (no./km^2) of soft-shelled crab (R1 stage) that will enter the fishery in the next year for the northern (top) and southern (bottom) areas. Currently they are at very low levels and will not be able to compensate the biomass losses that will be associated with the death of carapace condition 5 males this winter. 1 standard error bars are presented.

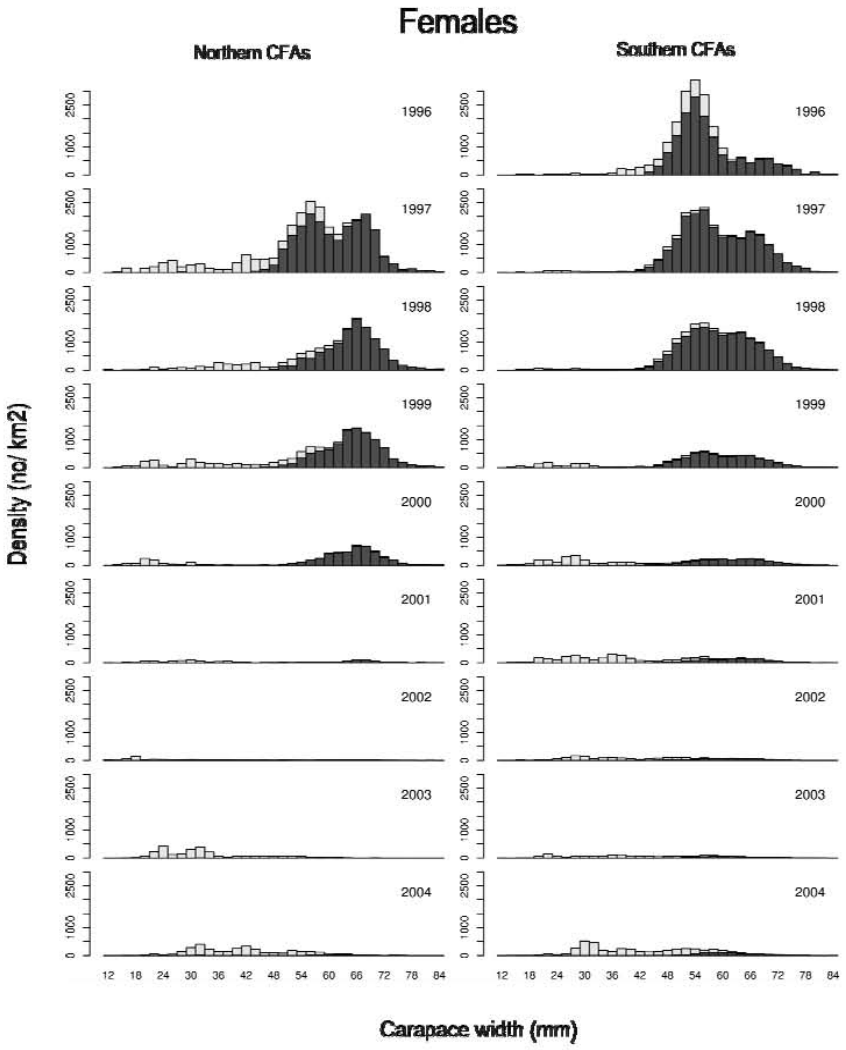

Figure 8. Size (CW; mm) frequency histograms of the mean density of female crab (no./km^2) for the northern and southern CFAs. Note the synchrony in both areas and the adolescent (light) pulses entering the mature (dark) population.

Sex Composition

The numerical proportion of mature females in the mature segment of the snow crab population has been rapidly declining since the late 1990s on the Scotian Shelf (Figure 9). This downward trend has been evident uniformly, throughout the Scotian Shelf for the past four years. The concern is that sexual encounter rates for breeding crab will be very low. In 2004, slight increases the proportion of mature females were evident in a few inshore areas (near Chedabucto and Gabarus Bays, in part due to lower numbers of mature male crab).

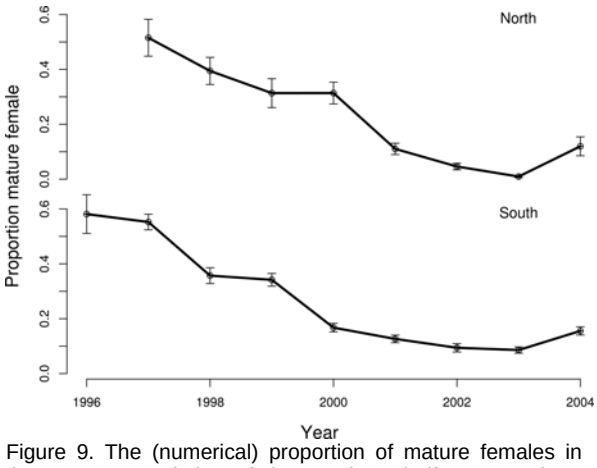

Figure 9. The (numerical) proportion of mature females in the mature population of the Scotian Shelf snow crab. 1 standard error bars are presented.

Fishable Biomass

Fishable biomass estimates in the northern areas declined 41% relative to 2003 (from 2760 to 1630 t; with a 95% confidence interval, CI_{95}: 1350, 1950 t).

In the southern areas the current biomass estimate is 27740 t (inclusive of the slope areas; CI_{95}: 24940 t, 30860 t). This represents a decline of 15% from 2003 (32750 t). The slope areas of CFA 23 was estimated to contain 3150 t (CI_{95}: 2190 t, 4540 t) and in CFA 24 to have 2420 t (CI_{95}: 1540 t, 3790 t). Fishable biomass has been declining since the early 2000s in most areas (Figure 10).

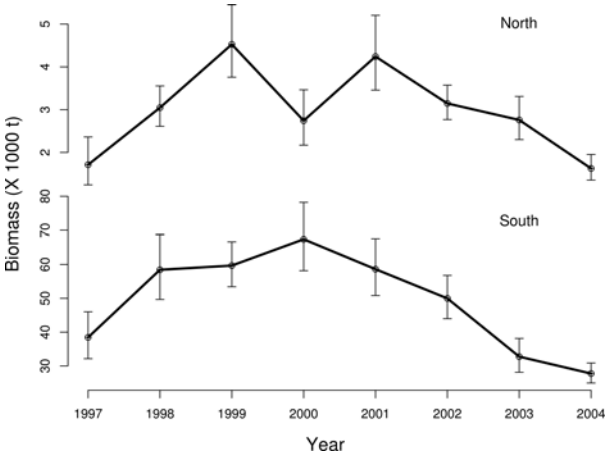

Figure 10. Biomass estimates (X 1000 t) of legal size snow crab on the Scotian Shelf after rescaling historical data to the spatial extent of the 2004 snow crab distributions. Peak levels were estimated at > 4500 t in 2001 for the northern areas and has since been declining at a rate of 940 t/year. Peak levels in southern areas were at > 68000 t in 2000 and has since been declining at a rate of approximately 10000 t/year. 95% confidence intervals are presented.

The spatial distributions of fishable snowcrab biomass were quite consistent in the past two years (Figure 11). Greatest variations generally occurred in the inshore areas. Biomass declines were evident in most areas, with the exception of the more recently exploited slope-edge locations and the area just north of Sable Island.

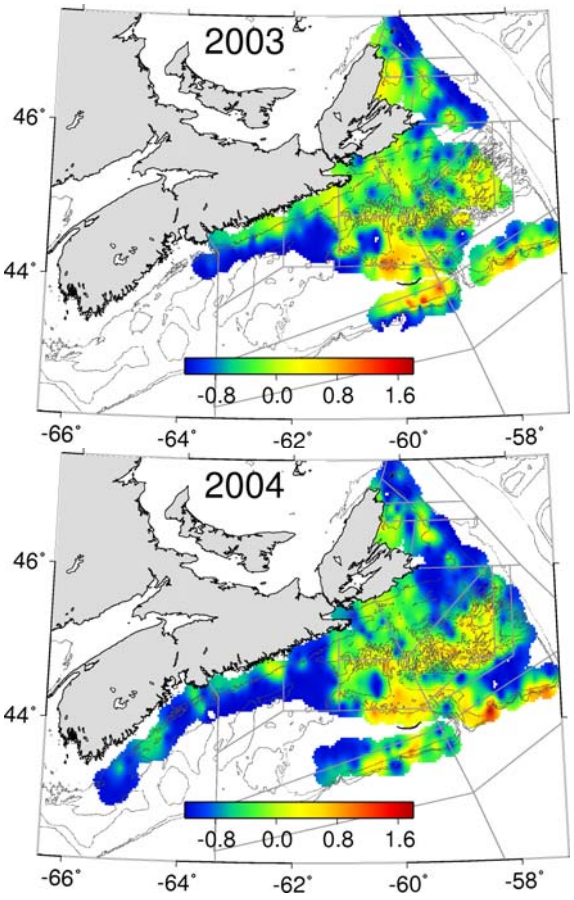

Figure 11. Fishable biomass densities on the Scotian Shelf in 2003 and 2004; $\log_{10}$(t km^{-2}). Note the lower abundance in most inshore areas and the Misaine Bank. Original figures in colour.

Mortality

Natural mortality rates have yet to be computed for the Scotian Shelf snow crab. However, the oldest crab (those in carapace condition 5) will likely die before next year's fisheries activity. Their numbers have been variable over time (Figure 12) and are presently near 0.5 crab/km^2. As recruitment into the 2005 fishery was estimated to be approximately 0.25 crab/km^2, a net decline in the numerical abundance of fishable snow crab is expected in the 2005 fishing season, even without factoring in other sources of natural mortality (predation, food limitation, etc.). In terms of biomass, this decline of approximately 0.25 crab/km^2 represents a net loss of approximately 11 t from the fishable biomass.

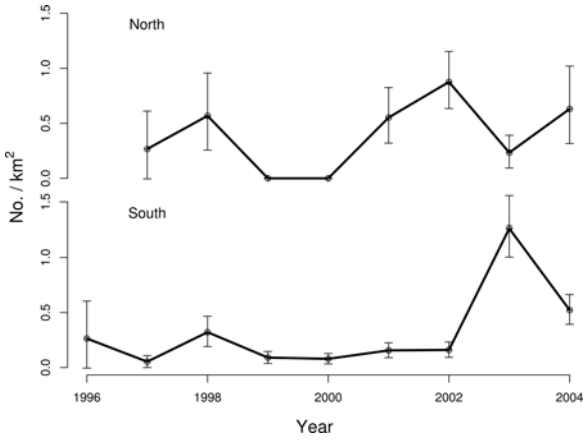

Figure 12. Geometric mean numerical densities of carapace condition 5 males. These crab are expected to die over the winter. 1 standard error bars are presented.

Exploitation rates (landings/biomass) of Scotian Shelf snow crab have been increasing rapidly in the post-1999 record (Figure 13). Exploitation rates have increased from 48% (2003) to 54% (2004) in the northern areas and are currently the highest on record for the Scotian Shelf. In the southern areas, exploitation rates increased from 18% (2003) to 25% (2004) inclusive of the slope areas. The slope areas have increased exploitation rates from 5% (2003) to 6% (2004).

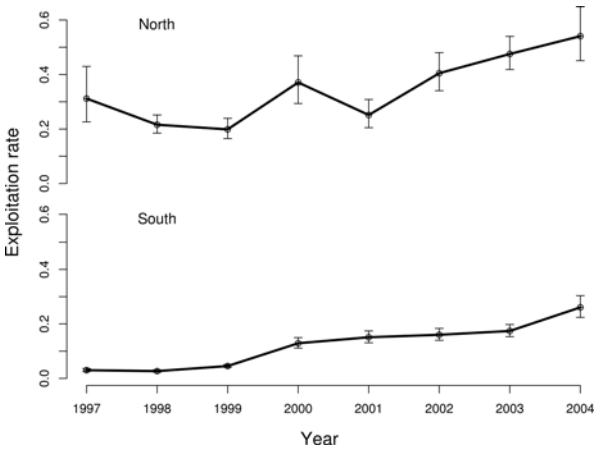

Figure 13. Exploitation rates (landings/biomass) of legal size snow crab has been increasing since 1999 in both the northern and southern areas. 95% confidence intervals are presented.

Sources of Uncertainty

There exist many sources of uncertainty in any assessment of a population that is so very widely dispersed with such varied behavioural and population dynamic

complexity as the snow crab. The life cycles of male and female snow crab differ. Males are longer lived (up to 6 years longer) and mature at a later time and larger size than females The intermittent nature of the recruitment pulses of the Scotian Shelf snow crab will cause sex ratios to vary strongly over time making the availability of one or the other sex a limiting factor at some time. Currently, strong spatial segregation of the maturing crabs is evident, with males in the offshore areas and females in the inshore areas (e.g., Chedabucto Bay).

While the adolescent pulses that are expected to enter the fishery in three to five years may have been generated by the snow crab resident on the Scotian Shelf, the evidence is circumstantial due to poor taxonomic resolution of the larvae. However, even without definitive proof of the reproductive potential of the resident snow crab, it must be assumed that they are self-sustaining and not be reliant upon larval drift from the southern Gulf of St. Lawrence. Care must therefore be taken to ensure that the reproductive capacity of the stocks be sustained.

Ecosystem Considerations

The likelihood of the success of the adolescent crab entering the fisheries is contingent upon the continued stability of environmental conditions (e.g., bottom temperatures) as well as the continued low abundances of predatory groundfish on the Scotian shelf. Environmental conditions on the Scotian Shelf (bottom temperatures) have been favourable for snow crab for the past 16 years (Figure 14) and continued to be so in 2004. However, concentrations of predatory cod and skate have been observed in areas with large numbers of immature crab (Figure 15).

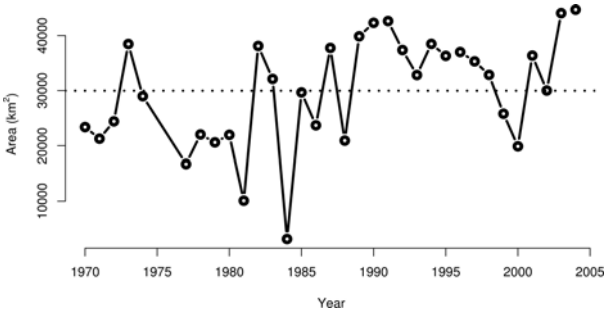

Figure 14. Snow crab habitat index. The surface area of the Scotian Shelf with bottom temperatures in the range of 3 degrees Celsius or less. The habitat index has been consistently above normal (dotted line) since the late 1990s.

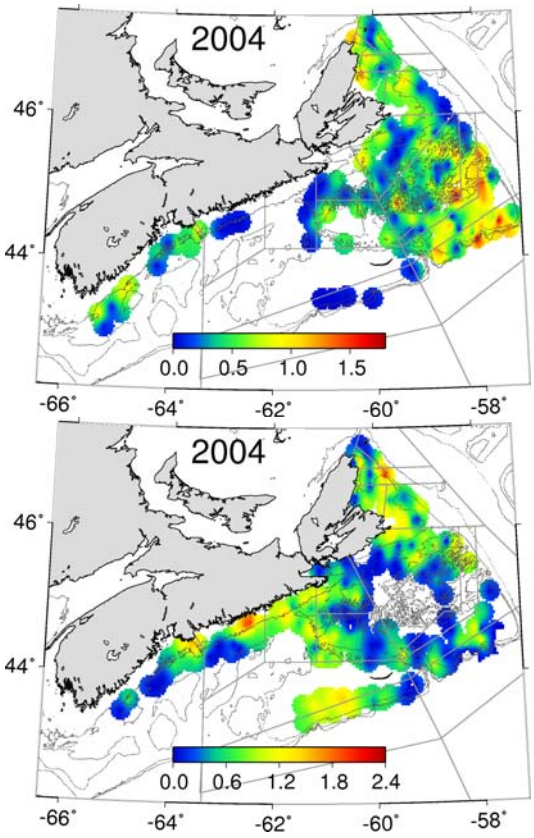

Figure 15. Numerical abundance of thorny skate (top) and Atlantic cod (bottom) found on the 2004 snow crab surveys; $\log_{10}(no/km^2)$. Note the very high concentrations of skate on the offshore areas and cod in the inshore areas. Both are areas of high abundance of immature snow crab. Note: original figures in colour.

Outlook

There is very little recruitment into the fishable biomass expected for the next 3 to 5 years. In fact, net declines in the abundance of fishable snow crab are expected even without fishing due to the very low recruitment and natural mortality of the resident snow crab.

Management Considerations

Reductions in TACs of the northern and southern areas are highly recommended. In the northern CFAs, if the high 2004 exploitation rate (51%) is used as a benchmark, the TAC would be 840 t (a 41% reduction from the 2004 TAC of 1416 t). Similarly, in the southern CFAs, if the 2004 exploitation rate (25%) is used as a benchmark, the TAC would be 6900 t (a 16% reduction from the 2004 TAC of 8212 t).

References

Choi, J.S., B.M. Zisserson, and A.R. Reeves. 2005. An assessment of the 2004 snow crab populations resident on the Scotian Shelf (CFAs 20 to 24). Canadian Science Advisory Secretariat Research Document 2005/028.

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