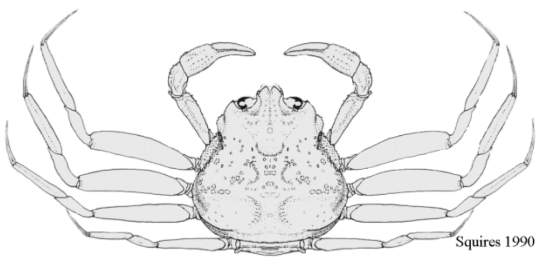
ASSESSMENT OF NOVA SCOTIA (4VWX) SNOW CRAB



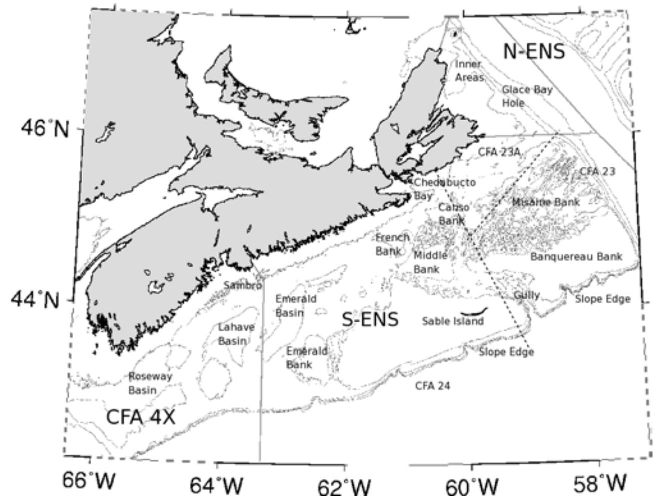


Figure 1. Map of the Scotian Shelf and Crab Fishing Areas (CFA).

Context

Snow Crab have been a dominant macro-invertebrate in the Scotian Shelf Ecosystem (SSE) since the decline of the groundfish. 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 SSE Snow Crab are in the southern-most extreme of their spatial distribution in the Northwest Atlantic.

The fishery has been in existence since the early 1970s in Nova Scotia. The management of the Snow Crab fisheries in the SSE 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 carapace width (CW). 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. In 2005, many Crab Fishing Areas (CFAs) and subareas were merged with the resulting divisions being N-ENS (formerly CFAs 20-22), S-ENS (CFAs 23, 24), and 4X (Figure 1).

In support of the fishery, DFO Maritimes Fisheries and Aquaculture Management requests from DFO Science an annual assessment of resource status. This document is a scientific overview of the assessment. An assessment of the status of 4VWX Snow Crab is based on fishery independent surveys using indicators of abundance, reproductive potential, recruitment, and exploitation rates. Commercial catch rates and other fishery statistics are reported. Harvest advice for the next year is provided.

This Science Advisory Report is from the February 25, 2014, Assessment of Nova Scotia (4VWX) Snow Crab. Additional publications from this process will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- Landings in 2013 for N-ENS and S-ENS were 783 and 11,309 t, respectively, and they were 118 t in 4X for the 2012/13 season, representing an increase of 17%, a decrease of 3% and a decrease of 66% relative to the previous year, respectively. Total allowable catches (TACs) in 2013 were 783,11,311 and 263 t in N-ENS, S-ENS and 4X, respectively.
- Non-standardised catch rates in 2013 decreased by 10% in N-ENS, increased by 6% in S-ENS and decreased by 57% in 4X, relative to the previous year.
- In N-ENS, the estimated soft shell crab discard (% of total landings) decreased to 3.4% in 2013 as compared to 8.9% in 2012. This is substantially lower than previous levels (111% in 2007), due to an increase in spring fishing and an ageing fishable stock. In S-ENS, 2013 estimated soft shell discards decreased from 2012 from 6.3 to 1.7% of the TAC. The shift towards earlier fishing seasons has improved soft shell crab handling rates in both N- and S-ENS though continued diligence is important to protect incoming recruitment. Soft shell discards in 4X are negligible, in large part due to a fall / winter fishery.
- The post-fishery fishable biomass decreased by 17% in N-ENS and by 1% in S-ENS relative to 2012. In 4X, the preliminary pre-fishery fishable biomass decreased by 56% relative to 2011/2012, but further analysis of the 4X survey data is required, pending the outcome of the 2013/14 fishing season.
- The recruitment index varies by region. In N-ENS there was an increase in recruitment to near the high levels observed in 2008 which may be due to a net immigration of recruits. Consistent levels of recruitment in S-ENS, based on the post-2004 (stable survey design) time series, continue to 2013. Recruitment in 4X is low and variable, although there was an increase in the index between 2012 and 2013.
- Female Snow Crab abundance and associated egg production in all areas continue to decline after reaching highs in 2007/2008. Egg production is now below the long-term mean; however, it is expected to increase in the next 2-4 years due to an increase in immature female crab, particularly in N-ENS.
- Sex ratios (proportion female) are now male-dominated in N-ENS, are stabilizing at low levels in S-ENS and are increasing at more moderate levels in 4X.
- Bycatch levels are extremely low in this fishery. In N-ENS and S-ENS, combined estimates of bycatch were 0.01% of Snow Crab landings. Crab Fishing Area (CFA) 4X shows higher (relative to ENS) bycatch rates at 2 % of Snow Crab landings.
- High relative densities of predators (based on Snow Crab trawl survey, e.g. Thorny Skate) were found in some areas with high densities of immature Snow Crab, however, predators remain at levels well below those historically reported. Increased predation may lower future recruitment to the fishable biomass and affect movement patterns of Snow Crab.
- Average bottom temperatures in 2013 were generally cooler than 2012 in all areas; although a warming trend since the early 1990s should be noted. Within the survey sets in each of the Snow Crab areas average bottom temperatures were generally stable with long-term means of 3.4, 3.8 and 6.1°C in N-ENS, S-ENS and 4X, respectively. The current mean temperature in 4X remains above the temperature preference for Snow Crab.

- A reference points-based Precautionary approach (PA) has been implemented in this fishery. The Limit reference point (LRP) is 25% of carrying capacity and the Upper stock reference (USR) is 50% of carrying capacity. The Target Removal reference is 20% of the fishable biomass in each area and the Removal reference is not to exceed F_{MSY}. Various secondary (population and ecosystem) indicators are taken into consideration for management decisions.
- In N-ENS, fishable biomass (FB) has been stable and in the “healthy” zone (FB > USR) over the past four years. However, in the medium to long-term, there is a need to be mindful of the gap in the size-frequency distribution, suggesting limited local recruitment in the near future. This could limit the scope for flexibility in harvest strategies in this area without immigration from other areas. Combining the desire to protect the immigrant recruits and fish the ageing fishable biomass suggests a status quo to marginal decrease in TAC is recommended.
- In S-ENS, the population is considered to be in the “healthy” zone (FB > USR). As the fishable biomass continues to be near historically high levels, with a stable size distribution of immature male crab suggesting that positive recruitment is expected for at least the next three to four years. There is considerable scope for flexibility in harvest strategies. A status-quo to a marginal increase in TAC is recommended.
- In 4X, fishable biomass is in the “cautious” zone (FB < USR), potentially resulting from environmental influences in the recent years. As recruitment and potential immigration into the 2014/2015 season is uncertain, a very conservative harvest strategy is recommended, pending further analysis and the outcome of the 2013/14 fishing season.

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 preference is for soft mud bottoms. Smaller crabs are found in more complex habitats with shelter. Commercial crab (male, >95 mm carapace width; CW) in large numbers are found at depths from 60 to 280 m and temperatures from -1 to 6°C on the Scotian Shelf Ecosystem (SSE). 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 Atlantic Halibut, skates (especially Thorny Skate), Atlantic 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. Snow Crab have been a dominant macro-invertebrate in the SSE since the decline of the groundfish during the late 1980s and early 1990s. The SSE Snow Crab are in the southern-most extreme of their spatial distribution in the Northwest Atlantic.

Fishery

The Snow Crab fishery in eastern Canada began in 1960 with incidental bycatches 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. The Scotian Shelf Snow Crab fishery lands only males with carapace width ≥ 95 mm. There is also a concerted effort to avoid areas of newly moulted (soft shelled) crab and to discard immature males. Total landings increased to record-levels of approximately 10,000 t each year in the early 2000s and have surpassed these previous highs since 2009 (Figure 2). In 2005, many Crab Fishing Areas (CFAs) and subareas were merged with the resulting divisions being N-ENS (North-Eastern Nova Scotia, formerly CFAs 20-22), S-ENS (South-Eastern Nova Scotia, CFAs 23, 24), and 4X (Figure 1). Landings in 2013 for N-ENS and S-ENS were 783 and 11,309 t, respectively, and they were 118 t in 4X for the 2012/13 season, representing an increase of 17%, a decrease of 3% and a decrease of 66% relative to the previous year, respectively. Total allowable catches (TACs) in 2013 were 783 t, 11,311 t and 263 t in N-ENS, S-ENS and 4X, respectively (Figure 2, Tables 1-3).

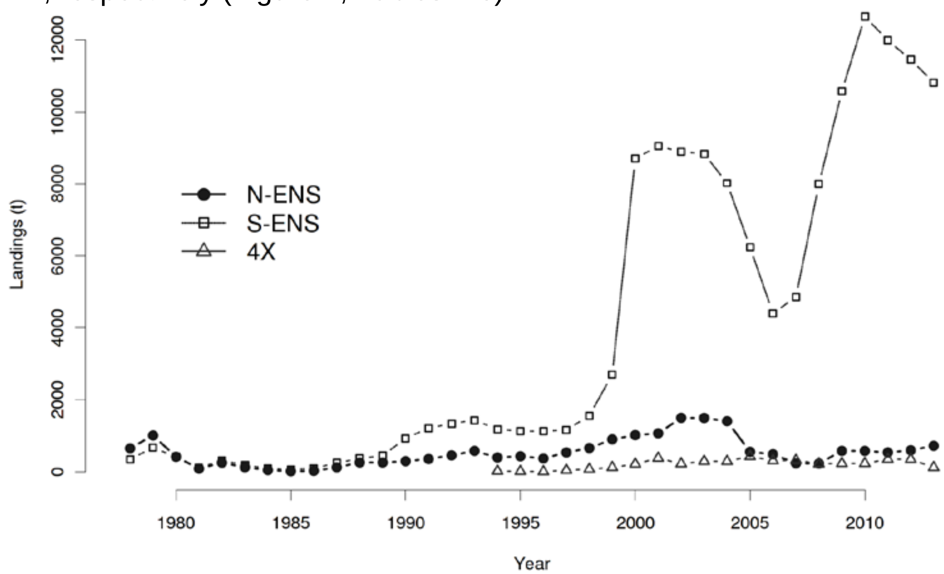


Figure 2. Temporal variations in the landings (t) of Snow Crab on the Scotian Shelf. The landings follow the TACs with little deviation, so the TACs are not shown. For 4X, the year refers to the starting year of the season.

Table 1. Summary of Snow Crab fisheries in N-ENS.

Year	Licences	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (x1000 trap hauls)
1999	78	900	899	55	16.4
2000	79	1,015	1,017	68	14.9
2001	80	1,065	1,066	94	11.3
2002	80	1,493	1,495	101	14.8
2003	80	1,493	1,492	77	19.4
2004	79	1,416	1,418	61	23.4
2005	78	566	562	31	18.4
2006	78	487	486	36	13.7
2007	78	244	233	24	9.9
2008	78	244	238	34	7.0
2009	78	576	579	76	7.6
2010	78	576	576	55	10.5
2011	78	534	536	110	4.8
2012	78	603	603	117	5.1
2013	78	783	783	106	7.4

Table 2. Summary of Snow Crab fisheries in S-ENS (- equals no data).

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (X1000 trap hauls)
1999	-	2,700	2,700	71	38.0
2000	158	8,799	8,701	85	102.4
2001	163	9,023	9,048	88	103.1
2002	149	9,022	8,891	112	79.6
2003	145	9,113	8,836	99	89.6
2004	130	8,241	8,022	106	76.0
2005	114	6,353	6,407	110	58.5
2006	114	4,510	4,486	91	49.4
2007	115	4,950	4,942	100	49.3
2008	115	8,316	8,253	96	85.9
2009	116	10,800	10,645	90	118.8
2010	116	13,200	13,150	103	128.3
2011	116	12,120	12,135	106	118.8
2012	116	11,707	11,733	98	120
2013	116	11,311	11,309	104	108.7

Table 3. Summary of Snow Crab fisheries in 4X (- equals no data).

Year	Licenses	TAC (t)	Landings (t)	CPUE (kg/trap haul)	Effort (X1000 trap hauls)
1997/08	4	-	42	-	-
1998/09	4	-	70	-	-
1999/2000	4	-	119	-	-
2000/01	6	-	213	-	-
2001/02	8	520	376	-	-
2002/03	9	600	221	10	21.9
2003/04	9	600	289	13	22.8
2004/05	9	600	413	20	20.8
2005/06	9	337.6	306	29	10.8
2006/07	9	337.6	317	28	11.5
2007/08	9	230	220	18	12.1
2008/09	9	230	229	28	8.0
2009/10	9	230	229	36	6.4
2010/11	9	346	345	38	9.0
2011/12	9	346	344	29	11.8
2012/2013	9	263	118	13	9.6

In 2013, the spatial distribution of landings was focused on mid-shore and offshore areas in S-ENS although additional effort was observed in the near-shore. In N-ENS more effort was focused on the inner gutter than Glace Bay Hole area in N-ENS (Maps 1, 2). There was negligible effort on the offshore-slope areas of S-ENS in 2013. Movement of commercial crab between S-ENS and N-ENS has been observed.

Non-standardised catch rates in 2013 were 106 kg/trap haul in N-ENS, 104 kg/trap haul in S-ENS, and 13 kg/trap haul in 4X – representing an decrease of 10%, an increase of 6% and a decrease of 57%, respectively, relative to the previous year (Tables 1-3, Figure 3, Map 3).

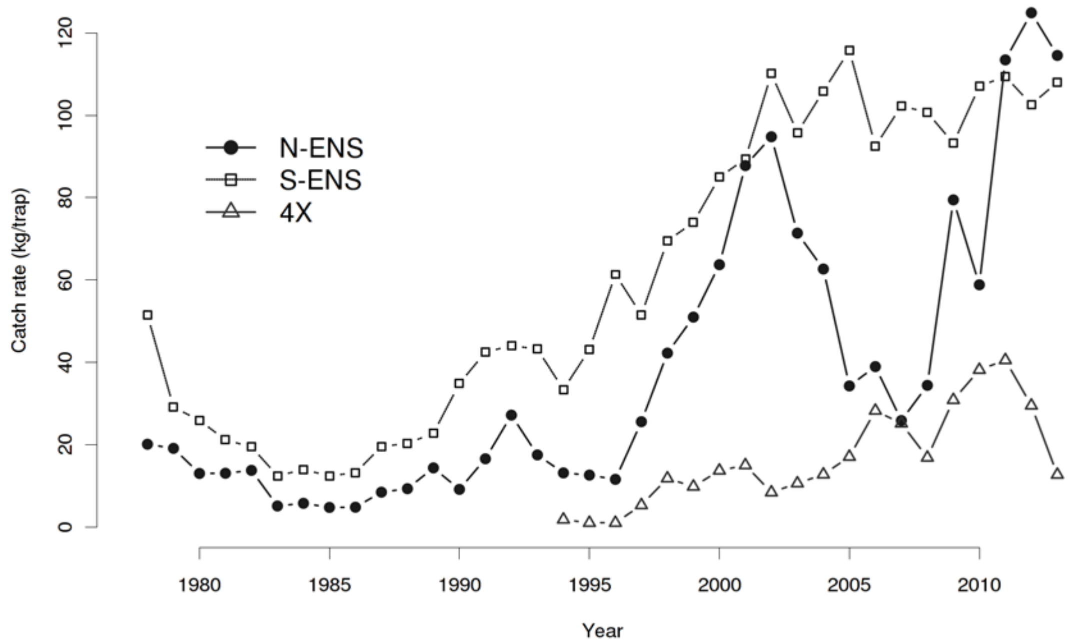


Figure 3. Temporal variations in catch rates of Snow Crab on the Scotian Shelf, expressed as kg per trap haul. Trap design and size have changed over time. No corrections for these varying trap-types nor soak time and bait-type have been made.

Carapace condition (CC) defines the approximate age (since terminal moult) of the terminally moulted crab based on the relative development and subsequent decay of the carapace. CC1 signifies a newly moulted crab, soft shelled, with no epibiont growth. The oldest carapace condition CC5 signifies extensive shell decay where there is no expectation of survival into the next year. In N-ENS, CC1 and CC2 crab collectively represented approximately 3% of the total catch (Figure 4), down from 8.9% in 2012. This is a substantial reduction from 2008 and before, when most (or all) of the landings came from the summer fishing season. The spring season (2008-present) was adopted to reduce fishing intensity in this summer season and also to encourage fishing during the earlier period when newly molted crab are too weak and soft to easily enter into traps. After a successful trial in 2008, the majority of landings (> 65%) from N-ENS were caught during the spring season from 2009 to present (with a high of 91% in 2010). Less than 1% of the catch was CC1 or CC2 in the 2013 spring fishery. There has been a shift towards larger animals in N-ENS catches in the past three years suggesting higher survival of immature crab (lack of handling mortality of soft-shelled crab) and a decreased dependence on newly recruited animals. There were few sub-legal sized crab in N-ENS commercial catches as compared to S-ENS, which may indicate reduced recruitment in future seasons (but see below). There was an increase in CC4 and CC5 crab (particularly CC4) in the area, suggesting that the fishable crab in the area are ageing.

In S-ENS, the occurrence of CC1 and CC2 crab in 2012 (0.2% and 2.6%, respectively) was lower than that observed in 2012 as there were 10% CC2 in 2012 (Figure 4). Hard shell crab dominated the catch with 95% CC3 and 2.5% CC4. CC5 levels were again negligible.

In 4X for the 2012/13 season, CC1 and CC2 crab collectively represented less than 1% of the total catch, comparable to 2011/2012. The commercial catches are heavily dominated by CC3 and CC4 crab with a combined percent of > 97%. The data from 4X are not directly comparable to ENS as their fishing season is disjunct from that of N- and S-ENS. This fall / winter 4X fishery continues to show negligible levels of soft crab.

CC5 crab represented less than 2% of the total observed catch in all areas. The abundance estimates of old male crab (CC5) has been stable in the long-term record and below the detection limit on the Scotian Shelf surveys.

In N-ENS, the estimated soft shell crab discard rate (% of total landings) decreased to 3.4% in 2013 as compared to 8.9% in 2012. This was substantially lower than previous levels (111% in 2007), due to an increase in spring fishing and an ageing fishable stock. In S-ENS, 2013 estimated soft shell discards decreased from 2012 from 6.3 to 1.7% of the TAC. A reduction in at-sea observer coverage in S-ENS may make commercial catch composition results for S-ENS not as directly comparable as in past years. The shift towards earlier fishing seasons has improved soft shell crab handling rates in both N- and S-ENS though continued diligence is important to protect incoming recruitment. Soft shell discards in 4X are negligible, in large part due to a fall / winter fishery.

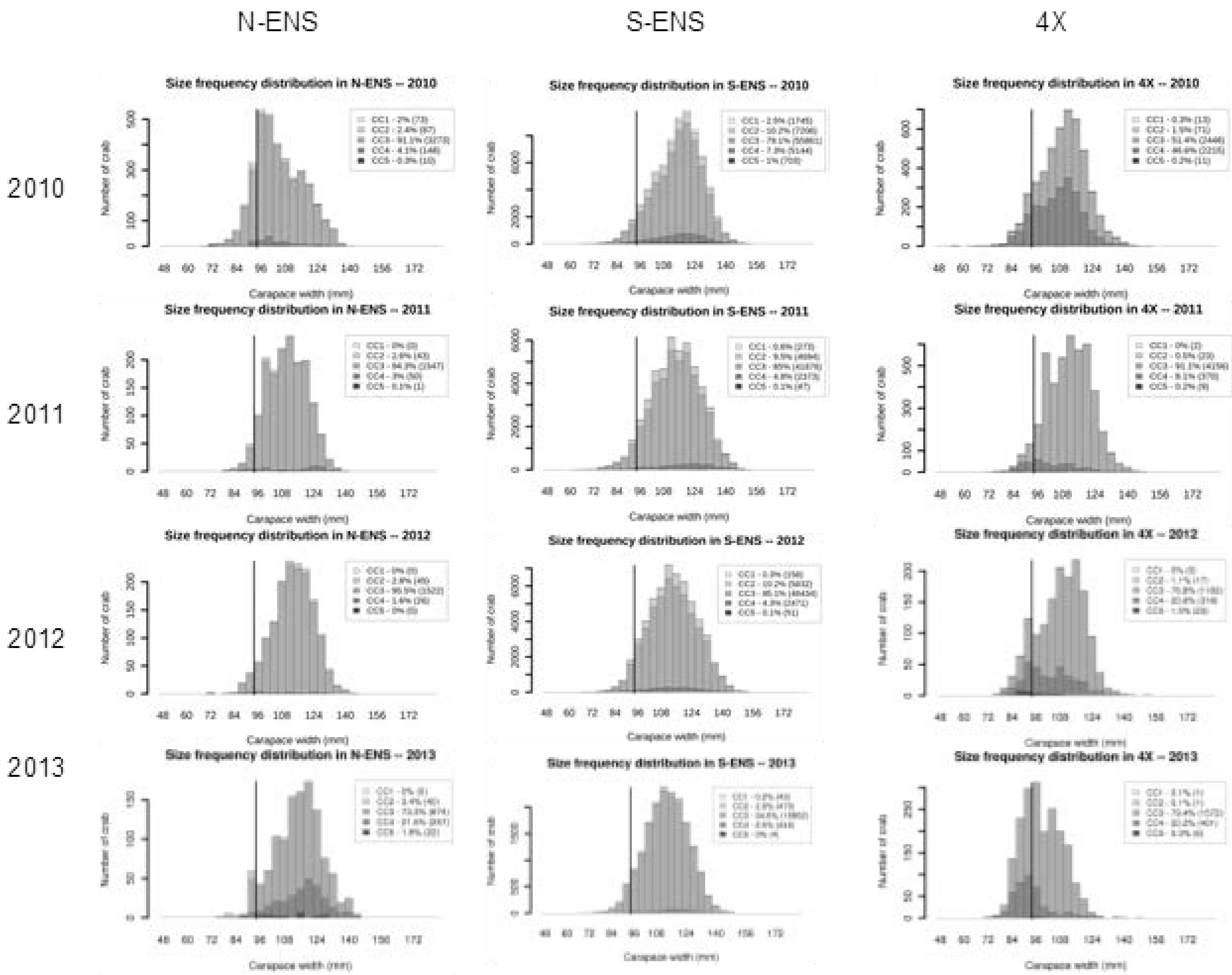


Figure 4. Size frequency distribution of all at-sea-observer monitored Snow Crab broken down by carapace condition. For 4X, the year refers to the starting year of the season. Vertical lines indicate 95 mm CW, minimum legal commercial size.

ASSESSMENT

Stock Trends and Current Status

Fishable Biomass Index

The fishable biomass (Figure 5, Map 4) 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 or greater).

In N-ENS, the post-fishery fishable biomass index of Snow Crab in 2013 was 3,190 t, relative to 3,840 t in 2012, representing a 17% decrease.

In S-ENS, the post-fishery fishable biomass index of Snow Crab in 2013 was estimated to be 41.9×10^3 t, relative to 42.4×10^3 t in 2012, representing a 1% decrease.

In 4X, the pre-fishery fishable biomass index was 510 t, relative to 1160 t in 2011/2012, representing a 56% decrease; however, these estimates should be considered preliminary, pending further analysis of survey and commercial fishing data.

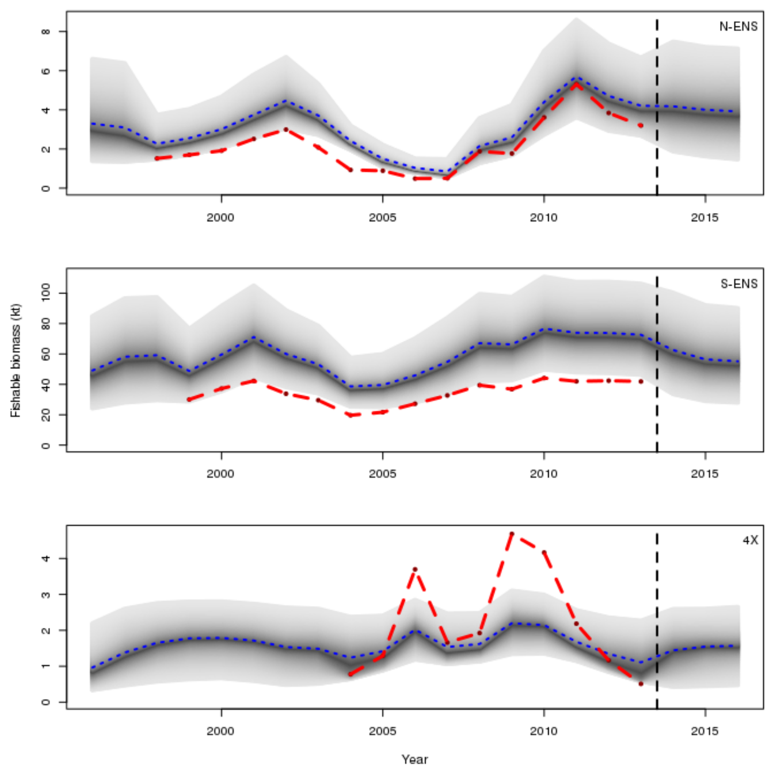


Figure 5. Time-series of fishable biomass. The fishable biomass index is shown in red dashed lines. The posterior mean fishable biomass estimated from the biomass dynamics model are shown in blue stippled lines. The density distribution of posterior fishable biomass estimates are presented (gray) with the darkest area being medians and the 95% Credible Intervals. A three year projection assuming a constant exploitation strategy of 20% is also provided.

Recruitment

The patterns in recruitment index into the fishable biomass (mature CC1 and CC2, > 95 mm CW with hardness < 68; Figure 6; Map 5) vary by region. In N-ENS there was an increase in recruitment to near the high levels observed in 2008. These crab do not appear in previous size frequency data, suggesting the immigration of recruits. Consistent levels of recruitment in S-ENS based on the post-2004 (stable survey design) time series continue to 2013. Recruitment in 4X is low and variable, although there was an increase between 2012 and 2013. In all management areas, most of this recruitment was observed on the core fishing grounds.

In terms of size structure (Figure 7), a strong size-class of male crab, first detected in 2003 (30 to 40 mm CW) began entry into fishable sizes by 2007 in S-ENS, 2008 in N-ENS and 2009 in 4X. In N-ENS, a pulse of crab was detected in the 20-40 mm CW range as it was in 2011, likely resulting from females reproducing in 2008-2010. The “gap” in the smaller size classes of crab which widened from 20-50 mm in 2010, 20-60 mm in 2011 to 20-85 mm in 2012, began to decrease in 2013 as some of the small crab increase in size. The lack of sub-legal Snow Crab in N-ENS will likely result in depressed recruitment in the next several years; without continued immigration and residence of crab from the higher abundance adjacent crab fishing areas (CFAs 19 and 23).

In S-ENS, the presence of small immature Snow Crab spanning almost all size ranges (20-95 mm CW) observed by the survey also suggests that recruitment to the fishery is probable for the next 4-5 years and beyond.

Area 4X shows minimal potential for internal recruitment to the fishery for the foreseeable future. Movement has likely been an important source of crab in the past; however, the low abundance of both the mature and immature crab in the adjoining portion of Area 24 and erratic temperature fields in 4X create strong uncertainties for the future.

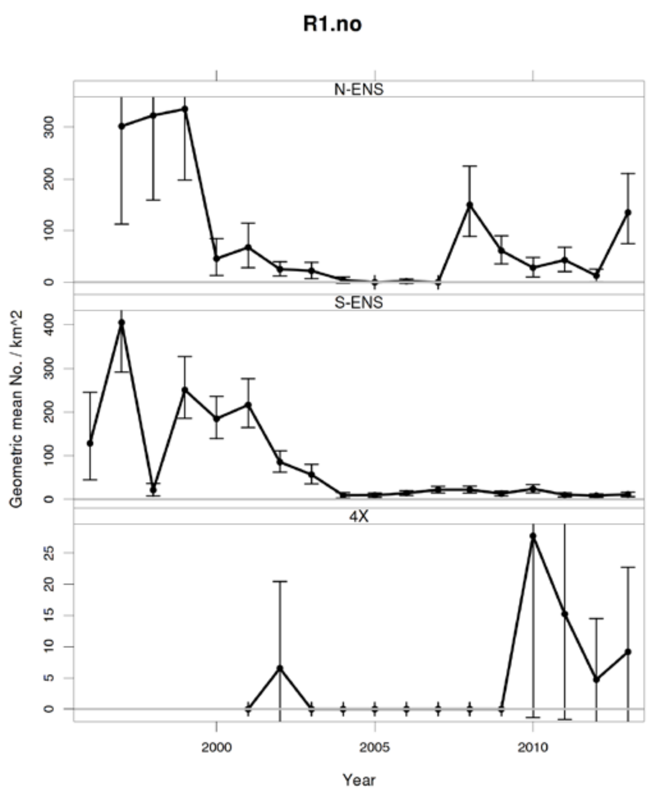


Figure 6. Expected recruitment (males larger than 95 mm CW and soft-shelled) into the mature stage in the next year. As surveys are conducted in the autumn (since 2002/2003), the majority of recruitment into the fishable biomass has already occurred. This figure shows the additional recruitment expected that has not yet become part of the fishable biomass. Error bars are 95% confidence intervals about the estimated density.

Reproduction

Egg production is now below the long-term mean, however it is expected to increase in the next 2-4 years due to an increase in immature female crab, particularly in N-ENS (Figure 8). Mature female Snow Crab abundance has continued to decline in N- and S- ENS and associated egg production continues to decline after reaching highs in 2007/2008 (Figure 9). Isolated concentrations of mature females exist in all areas with a more diffuse distribution around the CFA 23 / 24 management line and along the southwest coast of Nova Scotia (Maps 6, 7). Sex ratios (proportion female) are now male-dominated in N-ENS, are stabilizing at low levels in S-ENS and are increasing at more moderate levels in 4X (Figure 10).

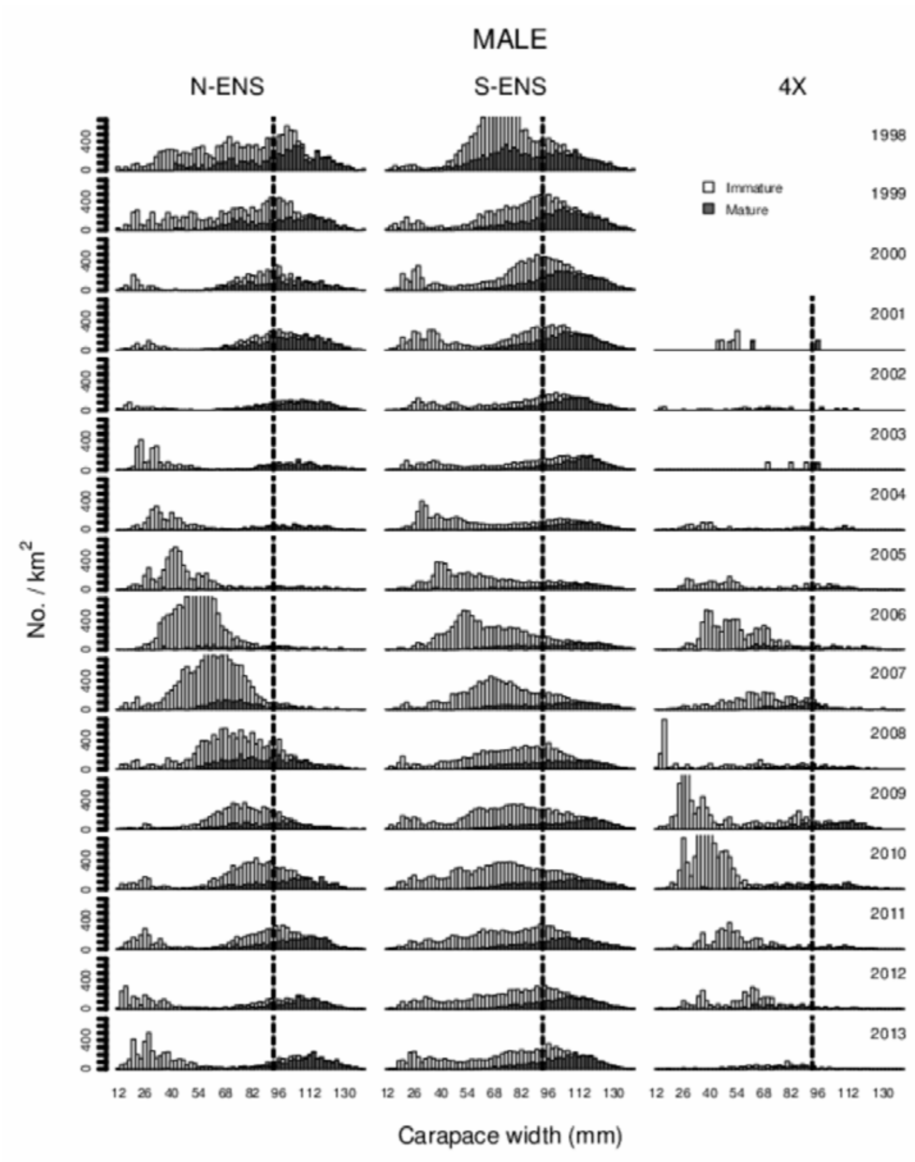


Figure 7. Size-frequency histograms of carapace width of male Snow Crabs. Note the relatively uniform distribution of adolescent crab across all size classes in S-ENS as compared to other areas and previous patterns in S-ENS. Note that for S-ENS and 4X (but not N-ENS) the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year. The vertical line represents the legal size (95 mm).

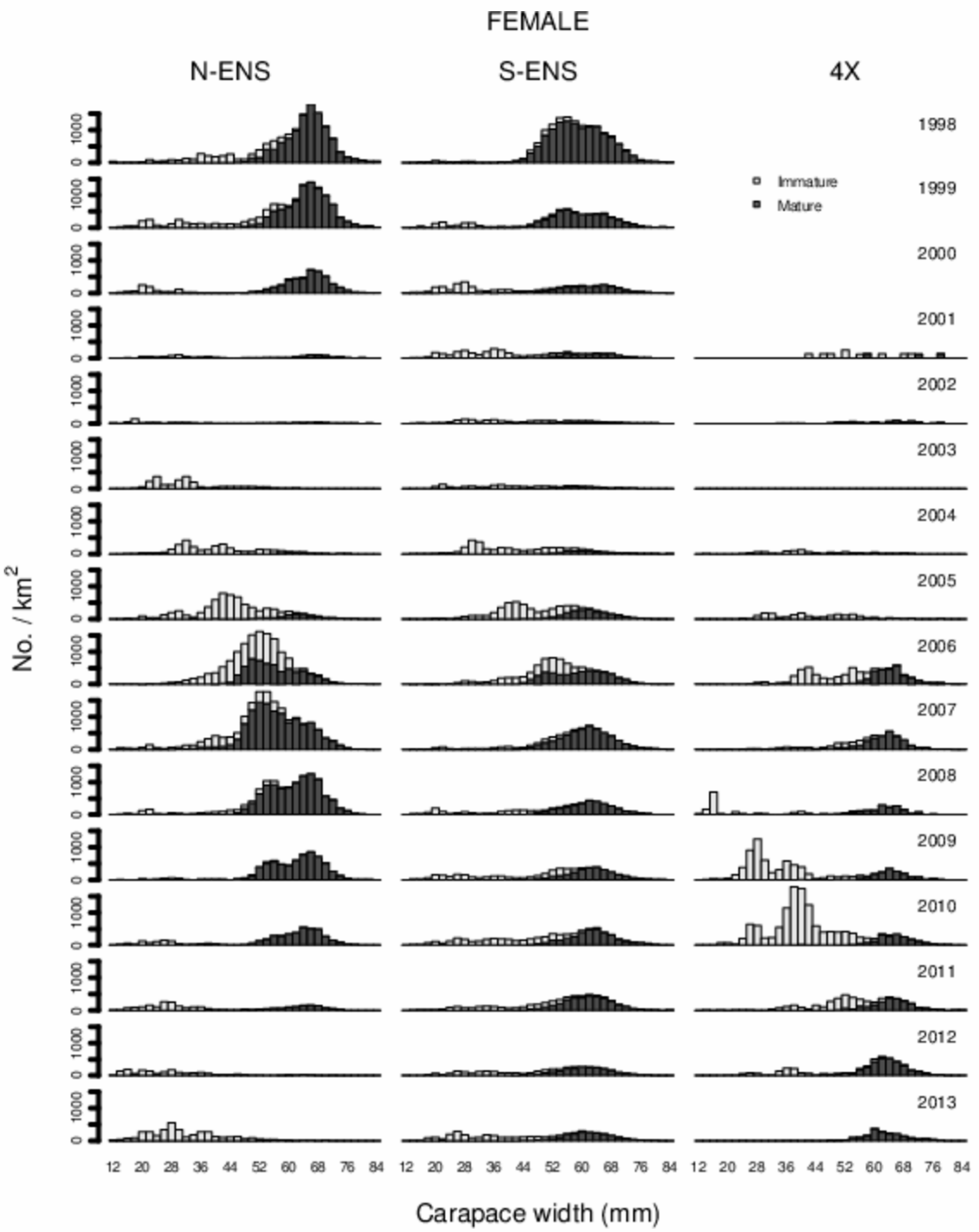


Figure 8. Size-frequency histograms of carapace width of female Snow Crabs. Note that for S-ENS and 4X (but not N-ENS) the spatial extent of the surveys have changed over time, making a direct comparison of numerical density inappropriate. This figure provides information about the relative numbers within a given year.

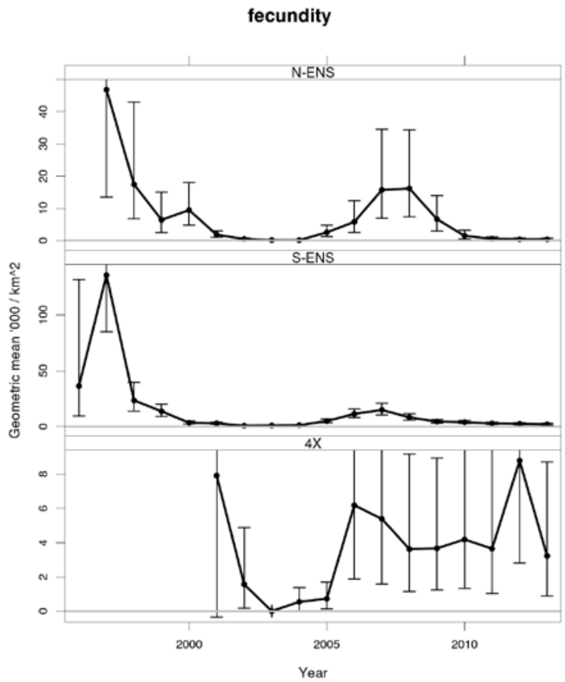


Figure 9. Geometric mean number of eggs produced per km^2 on the Scotian Shelf.

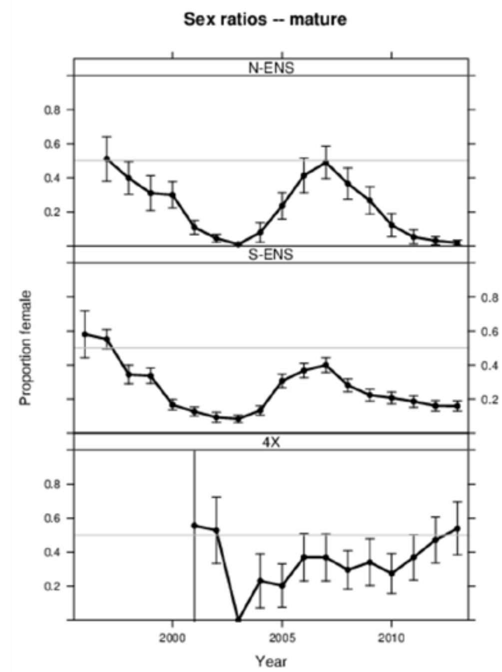


Figure 10. Sex ratios (proportion female) of mature Snow Crab. Since 2000, most of the Scotian Shelf was uniformly male dominated.

Fishing Mortality

The abundance estimates of old male crab (CC5) has been stable in the long-term record and below the detection limit on the Scotian Shelf. Their low representation in the survey data and the fishery-observed data may be indicative of high mortality rates (fishery-based and/or natural).

Fishing mortality in N-ENS has been estimated to have been in the range of 0.1 to 0.9, peaking in 2003 (Figure 11). In 2013, fishing mortality is estimated to have been 0.20 and relatively constant since 2009. The low fishing mortality in 2008 was implemented to reduce soft-shell handling.

Fishing mortality for S-ENS has historically ranged from 0.05 to 0.25, peaking in 2003-2004 (Figure 11). In 2013, fishing mortality is estimated to have been 0.17. Realized exploitation rates are likely higher as not all areas where biomass estimates are provided are fished (e.g., continental slope areas and western, inshore areas of CFA 24).

In 4X, fishing mortality has historically ranged from 0.2 to > 0.4, peaking in 2005 and 2011/12 (Figure 11). In 2012/2013, fishing mortality was 0.14. Realized exploitation rates are likely to be higher, since the computed exploitation rates incorporate biomass from throughout the 4X area and not just the fishery grounds.

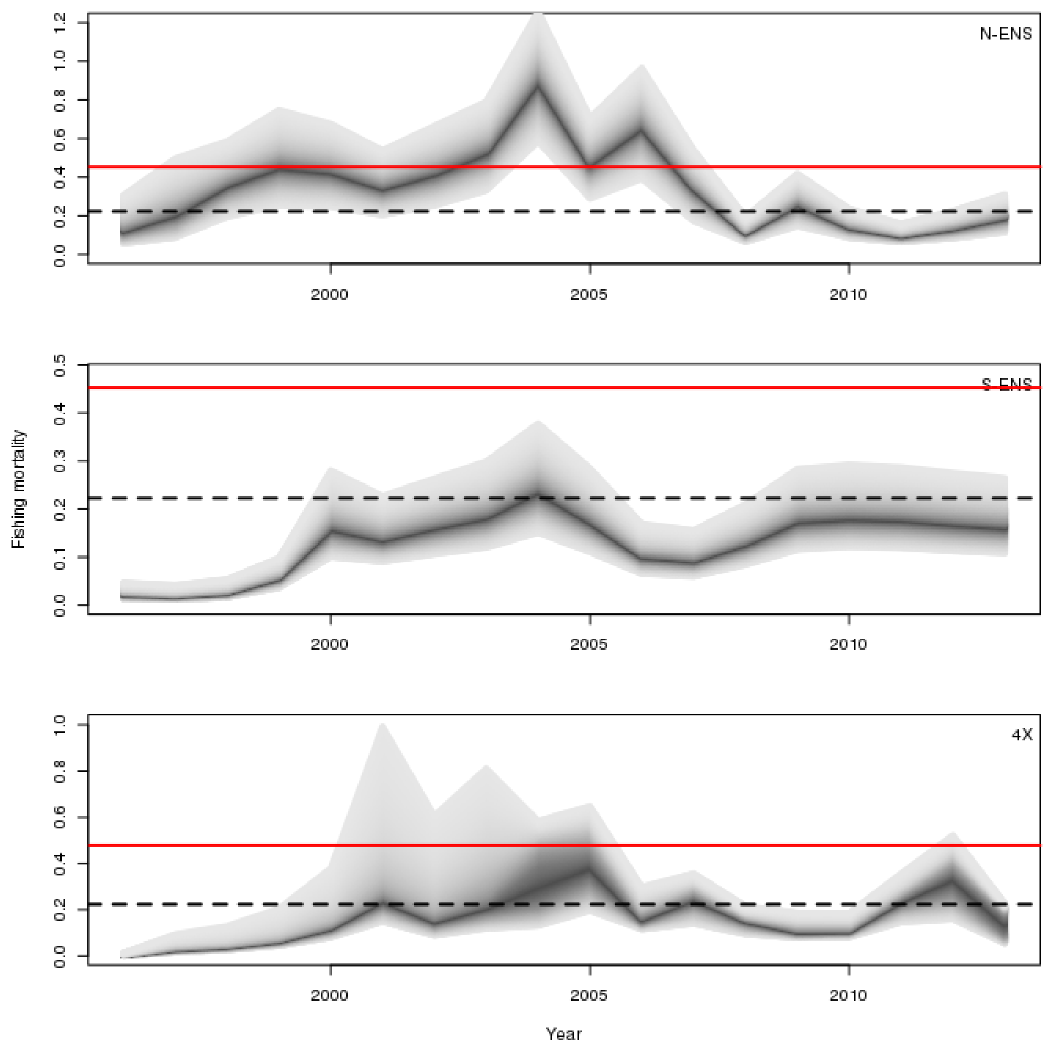


Figure 11. Time-series of fishing mortality for N-ENS, S-ENS and 4X, respectively. Posterior density distributions are presented in gray, with the darkest line being the median with 95% CI. The red line is the estimated F_{MSY} and dark stippled line is the 20% harvest rate.

Ecosystem Considerations

A multivariate summary of key environmental (climatic), social, economic and fishery-related indicators (Figure 12) 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); and Gross Domestic Product (GDP) associated with the oil and gas sector as well as total Nova Scotia GDP (increasing). Further, the mean size of organisms has declined, physiological condition of many groups of fish has declined 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 indicate 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 long-term states is evident since an extreme point in 2008

(Figure 13). Thus, while the current "ecosystem state" is one that continues to be amenable to the high abundance of Snow Crab, there is an increased concern that there may be another systemic ecosystem change in the near future. An increase in groundfish stocks would increase predation upon Snow Crab stocks. Other consequences of such an ecosystem shift could exist for Snow Crab.

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. Temperature anomalies in particular were considered a potential cause of the increase in abundance of Snow Crab in the late 1990s due to Snow Crab being cold-water stenotherms. However, the habitat analysis suggests that potential Snow Crab habitat existed in the 1970s and 1980s, suggesting that their recent increase in abundance is primarily driven by non-environmental factors such as reduced predation mortality and increased survival of early life stages (see section on Environmental Variability).

Figure 12. 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. Updated to 2012.

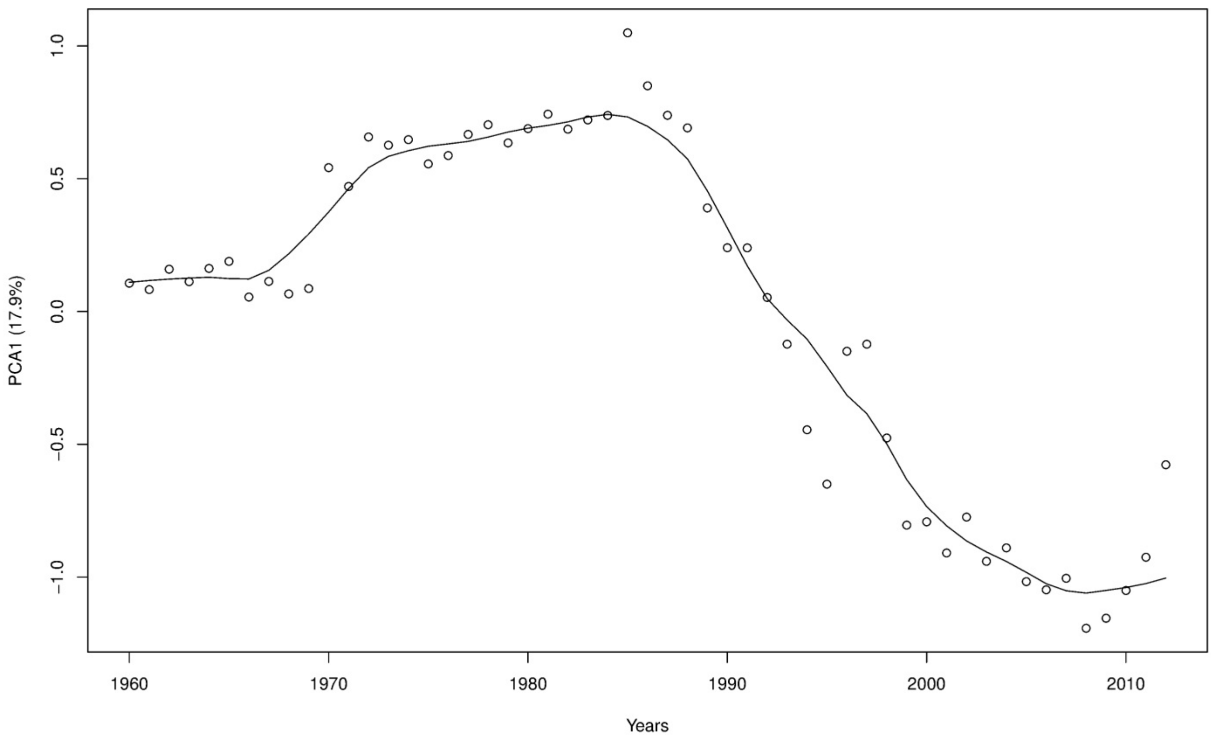


Figure 13. First axis of variation (Principle component axis 1) in ordination of anomalies of social, economic and ecological patterns on the Scotian Shelf. Updated to 2012.

Environmental Variability

Temperature variations within the areas of potential habitat appeared to be robust throughout the historical record (Figure 14). Average bottom temperatures in 2013 were generally cooler than 2012 in all areas; although a warming trend since the early 1990s should be noted. Within the survey sets in each of the Snow Crab areas average bottom temperatures were generally stable with long-term means of 3.4, 3.8 and 6.1°C in N-ENS, S-ENS and 4X, respectively. The current mean temperature in 4X remains above the temperature preference for Snow Crab.

The surface area of potential Snow Crab habitat in the SSE was calculated as the arithmetic mean of the potential habitat area estimated in the previous five years (Figure 15).

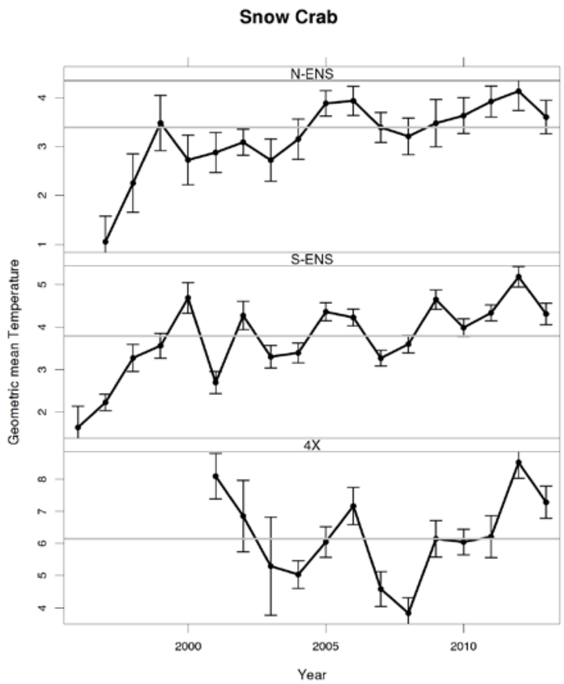


Figure 14. Autumn variations in bottom temperature from the annual Snow Crab survey. The horizontal line indicates the long-term arithmetic mean temperature within each subarea. Error bars are 1 standard deviation. Note increasing temperatures in all areas since the mid-2000s, especially in area 4X.

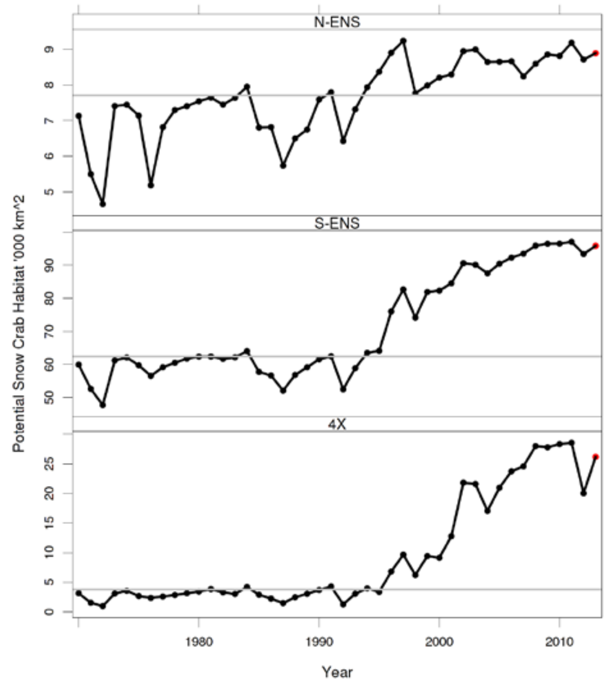


Figure 15. Annual variations in the surface area of potential Snow Crab habitat. The horizontal line indicates the long-term arithmetic mean surface area within each subarea. The estimates for the period from 1998 to the present are based upon Snow Crab surveys while those prior to 1998 are projected using incomplete data (and so less reliable). The surface area of potential habitat is presently above the mean (actually close to the maximum) for the 1998-2011 period. 2013 estimates were obtained as the arithmetic mean of the previous five years.

Bottom-up (Resource Limitation)

Food items such as Northern Shrimp are found in concentrations comparable to the long-term 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)

High relative densities of predators (based on Snow Crab trawl survey, e.g. Thorny Skate) were found in some areas with high densities of immature Snow Crab; however, predators remain at levels well below those historically reported. Increased predation may lower future recruitment to the fishable biomass and affect movement patterns of Snow Crab.

Seals are considered by fishers to be a predator of Snow Crab, and their continued increase in abundance (Figure 12) is a source of concern for many fishers and some scientists. While seals have been observed with Snow Crab in their stomachs, it should also be emphasized that high concentrations of Snow Crab are found in the immediate vicinity of Sable Island, an area where the abundance of Grey Seals is extremely high. The 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 protect them from potential predators of crab (in both early pelagic and benthic stages). Seal predation of groundfish would lower potential lateral competition for Snow Crab food resources.

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 low numbers of females to males (Figure 10) observed in the early-2000s throughout the Scotian Shelf is that poor egg and larval production in the system likely occurred for at least a four to five year period. Poor egg production will likely occur again in the mid-2010s. 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-ENS 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; Boudreau et al, 2009; Courtenay et al. 2009). Seismic exploration occurred in November 2005 and July 2010 immediately over the Glace Bay Hole and the shallows of the Sydney Bight (Hunt Oil 2005; Husky Energy 2010) where immature and female crab are generally abundant. Future seismic work has been proposed throughout the Scotian Shelf in 2015-2018.

Undersea cables have been identified by fishers as a source of concern, in particular, the Maritime Link subsea electrical transmission cables in N-ENS. These two cables, spaced by up to 200 m, may create a barrier to normal Snow Crab movement through static magnetic fields, increased temperature, and induced electrical fields or the physical barriers created as a result of trenching activities and substrate disturbance. At present, there is no information that can be presented to definitively describe their effects upon Snow Crab.

St Ann’s Bank has been identified as an Area of Interest (AOI) for designation as a Marine Protected Area (MPA). The complex consequences of this designation are still to be determined. The presence of a refuge from fishing activities is potentially positive as it could serve as a fallow area. However, if the reserve is disproportionately beneficial to other organisms, be they predators or prey of Snow Crab, the effects upon Snow Crab could be mixed. The long-term effects of the AOI/MPA cannot be determined at this point.

Bycatch / Incidental Catch

Bycatch levels in the SSE Snow Crab fishery have been extremely low in the long-term record. Estimates of bycatch in this fishery are extrapolated from at-sea observer estimates. In ENS, estimates of bycatch were 0.01% of Snow Crab landings (3.8% and 4.5% observer coverage in N-ENS and S-ENS respectively). 4X shows higher (relative to ENS) bycatch rates at 2.1 % of Snow Crab landings (6.9% observer coverage in 4X). The majority of bycatch for all areas is composed of other invertebrate species (e.g., northern Stone Crab and American Lobster) for which higher survival rates can be expected after being released as compared to fin fish discards. In the last three years, at-sea observers reported two Leatherback Sea Turtles as having been entangled in buoy lines, both released alive though bleeding. A dead Basking Shark was observed entangled in buoys lines in 2011 as well as a Humpback Whale in 2012 which was released with little or no harm to the animal.

Bycatch of Snow Crab from other fisheries is still not quantified. Trawls can increase mortality, especially upon the soft-shelled phases of Snow Crab, though the lack of trawl fisheries (other than shrimp trawling) in the majority of Snow Crab habitat on the Scotian Shelf limits this potential damage. Bottom damage from the placement of Snow Crab traps is thought to be minimal.

Sources of Uncertainty

Two primary sources of uncertainty exist with this fishery: environmental uncertainty associated with rapid climate change and uncertainty in the relative abundance of predators (especially cod and skates). To remain adaptive in the face of these significant uncertainties, industry and management must continue to be mindful and vigilant in maintaining a small enough fishery and more generally a smaller human footprint, such that these larger ecosystem uncertainties will not further be exacerbated by our activities. Anecdotal reports from the Snow Crab industry suggest that illegal fishing activities and mis-reporting of catch is high and continue to rise, predominantly in S-ENS. Such activities increase the uncertainty in the stock assessment results and hinder the steps made toward applying a precautionary approach to the management of this resource. By addressing this issue, stakeholders might decrease this source of uncertainty.

Concerns were raised by the fishing industry regarding the impact of seismic activity on local Snow Crab and the potential source of uncertainty it raises for future productivity and the impacts on the stock assessment results.

CONCLUSIONS AND ADVICE

High catches of soft shell crab are a potential issue in N-ENS and S-ENS (but not 4X due to their offset fishing season), depending on the balance of spring or summer fishing activities. 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. An earlier season in N-ENS and S-ENS appeared to significantly reduce soft-shell handling and should continue whenever possible in future years.

A reference points-based Precautionary Approach has been implemented in this fishery. The Limit Reference Point (LRP) is 25% of carrying capacity and the Upper Stock Reference (USR) is 50% of carrying capacity. The target Removal Reference is 20% of the fishable biomass in each area and the Removal Reference is not to exceed F_{MSY}. Various secondary (population and ecosystem) indicators are taken into consideration for management decisions.

In N-ENS, high exploitation rates and limited recruitment caused by handling mortality of soft-shelled crab in the past pushed the N-ENS fishable biomass (FB) to historic lows. In N-ENS, fishable biomass has been stable and in the “healthy” zone (FB > USR) over the past four years. However, in the medium to long-term, there is a need to be mindful of the gap in the size-frequency distribution, suggesting limited local recruitment in the near future. This could limit the scope for flexibility in harvest strategies in this area without immigration from other areas. Combining the desire to protect the immigrant recruits and fish the ageing fishable biomass suggests a status quo to marginal decrease in TAC is recommended.

In S-ENS, the long-term, precautionary approach adopted by the S-ENS fishers since 2004 appears to be creating increased stability in commercial biomass levels and size class structure. This stability is an important consideration, given the continued uncertainty in world markets and the more volatile state of other Atlantic Canadian Snow Crab populations. In S-ENS, the population is considered to be in the “healthy” zone (FB > USR). As the fishable biomass continues to be near historically high levels, with a stable size distribution of immature male crab suggesting that positive recruitment is expected for at least the next three to four years. There is considerable scope for flexibility in harvest strategies. A status-quo to a marginal increase in TAC is recommended.

In 4X, existing in more “marginal” environments relative to the “prime” areas of S-ENS and N-ENS, an explicitly precautionary approach towards this fishery is essential. Further, the lower recruitment into the fishable biomass and the large inter-annual temperature variations (especially in 2012) increases the uncertainty associated with this area. Indeed the speculated high natural mortality in 2012 due to the extended period of warm bottom temperatures in the area did appear to occur as most estimates of productivity declined. Soft-shell captures are not a concern in 4X. S-ENS has been assumed to provide a buffer for 4X via immigration as evidenced by a large portion of 4Xs commercial biomass being proximal to the S-ENS line in almost all years. This did not appear to be the case for the past three years, and adds further uncertainty in the stability of the fishable biomass. In 4X, fishable biomass is in the “cautious” zone (FB < USR), potentially resulting from environmental influences in the recent years. As recruitment and potential immigration into the 2014/2015 season is uncertain, a very conservative harvest strategy is recommended, pending further analysis and the outcome of the 2013/14 fishing season.

MANAGEMENT CONSIDERATIONS

Capture of Immature Crab:

The prompt and careful return of immature (small- claw, non-terminally moulted) crab to the water is an important conservation measure that will enhance the mid-term (2-3 year) sustainability of this fishery. This is a measure that needs to continue.

Precautionary Approach:

Many existing measures and fishing practices in the Scotian Shelf Snow Crab fishery are inherently “precautionary” and should be reiterated:

- No removal of female crab. Reproductive potential of spawning stock biomass is not disrupted. Most removals of males occur after mating and sub-legal mature crab (able to reproduce) are never removed.
- Conservative exploitation strategies have generally been the norm, especially in recent years.
- Refugia from directed fishing pressures exist in the Gully MPA, along the continental slope, and much of the western inshore portion of CFA 24.

- Immature and soft-shelled (newly-moulted, easily damaged) crab are not harvested and handling mortality is minimized via area closures and at-sea observer monitoring of soft-shell incidence helping to maximize the potential yield per animal to the biomass.

Harvest control rules (HCR) have been developed which link the biomass reference points to the exploitation reference points (Figures 16, 17). In the Cautious and Healthy zones, actual target harvest rates are shaped by a suite of secondary indicators that provide more complete information on the entire stock's health. These secondary indicators are used to inform management decisions under the HCR linking the stock references to harvest strategies. Secondary indicators include expected recruitment, spawning stock biomass, size and age structure of various stock components, sex ratios, environmental variables, fishery performance and others. If a stock is determined to be in the Critical zone, all fishing activities cease with the belief that this will allow the stock to rebuild.

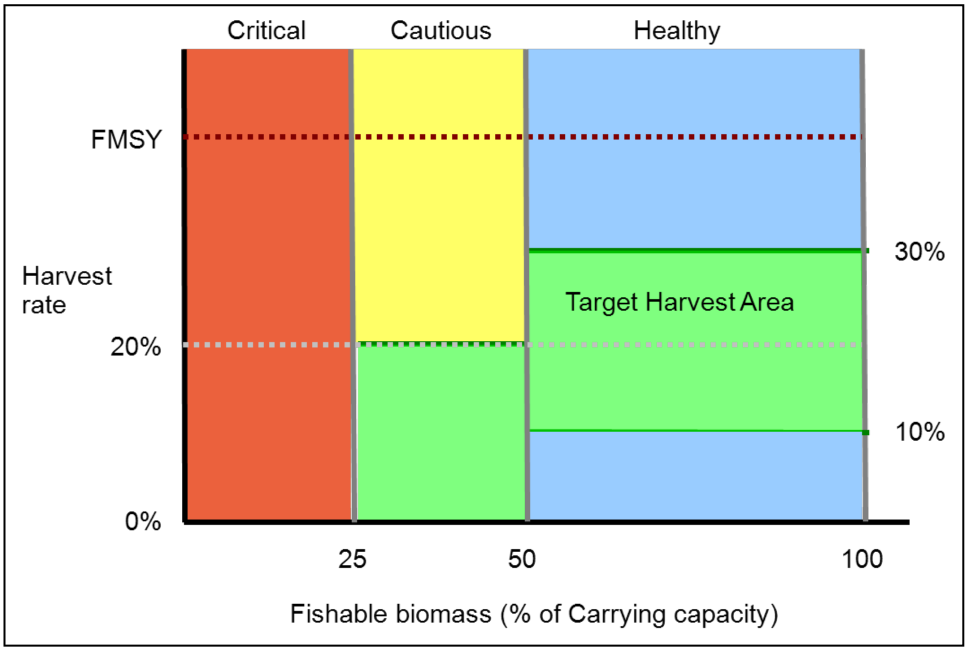


Figure 16. Harvest control rules for the SSE Snow Crab fishery.

The operational reference points associated with the 4VWX Snow Crab fishery are as follows:

*** Lower Stock Reference (LSR)**: 25% of carrying capacity

*** Upper Stock Reference (USR)**: 50% of carrying capacity.

* **Removal Reference (RR)**: not to exceed F_{MSY} **(**where F is the fishing mortality of the legal sized mature male population and MSY is the theoretical Maximum Sustainable Yield**)**

*** Target removal reference (TRR)**: 20% of the fishable biomass (F=0.22). Secondary, contextual indicators are used to alter harvest rates between 10 and 30% of fishable biomass (FB; F=0.11 to F=0.36).

The Harvest Control Rules are, therefore, as follows:

- FB > USR : target exploitation rate of 10% - 30% be utilized, based upon contextual information provided by secondary indicators
- LSR < FB < USR : target exploitation rate of 0% - 20%, based upon contextual information provided by secondary indicators

- FB < LSR : fishery closure until recovery (at a minimum, until FB > LSR)

The current “carrying capacity” of fishable biomass of Snow Crab is estimated to be {and 95% CI}:

- N-ENS: 5.9 {4.2, 8.5} kt
- S-ENS: 76.6 {53.4, 107.8} kt
- 4X: 2.3 {1.7, 3.0} kt

The estimates of F_{MSY} {and 95% CI} were:

- N-ENS: 0.453 {0.38, 0.58}
- S-ENS: 0.453 {0.35, 0.55}
- 4X: 0.478 {0.38, 0.58}

Estimates for 4X should be considered highly uncertain, due to the brevity of their data series.

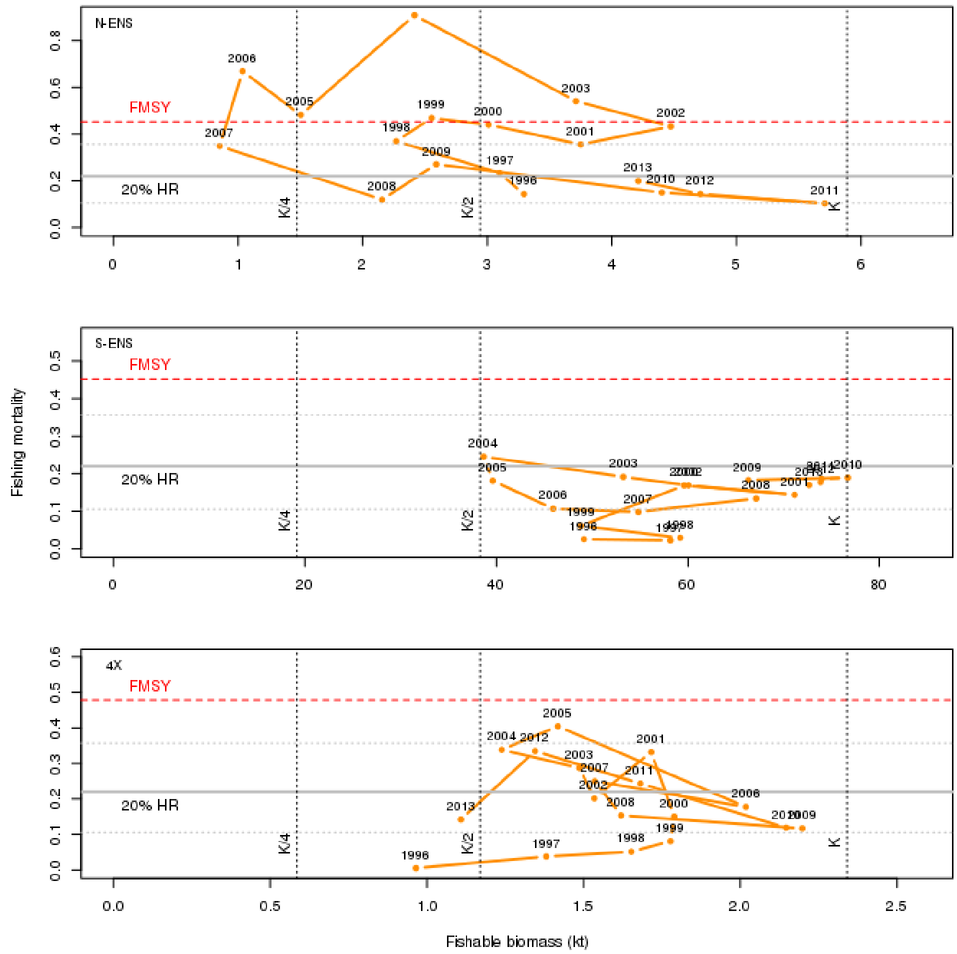
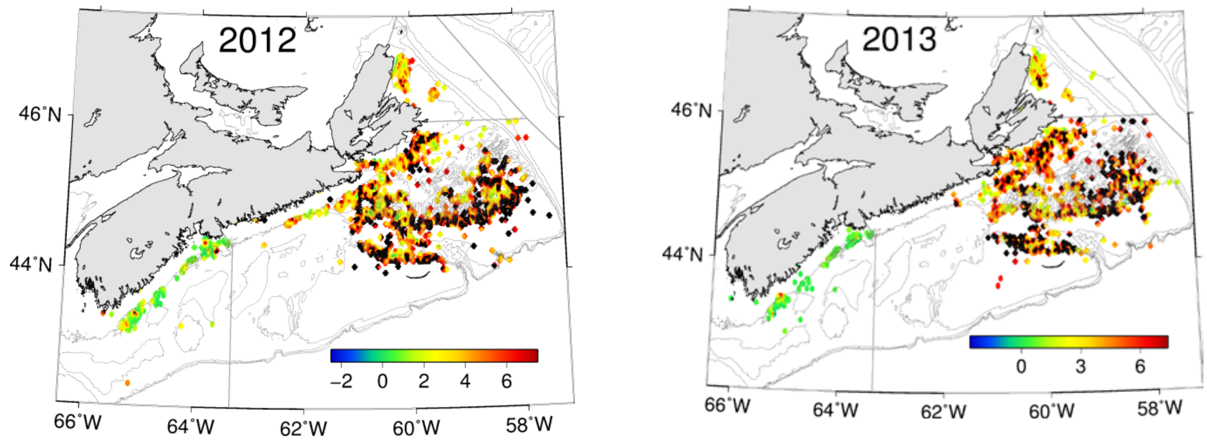
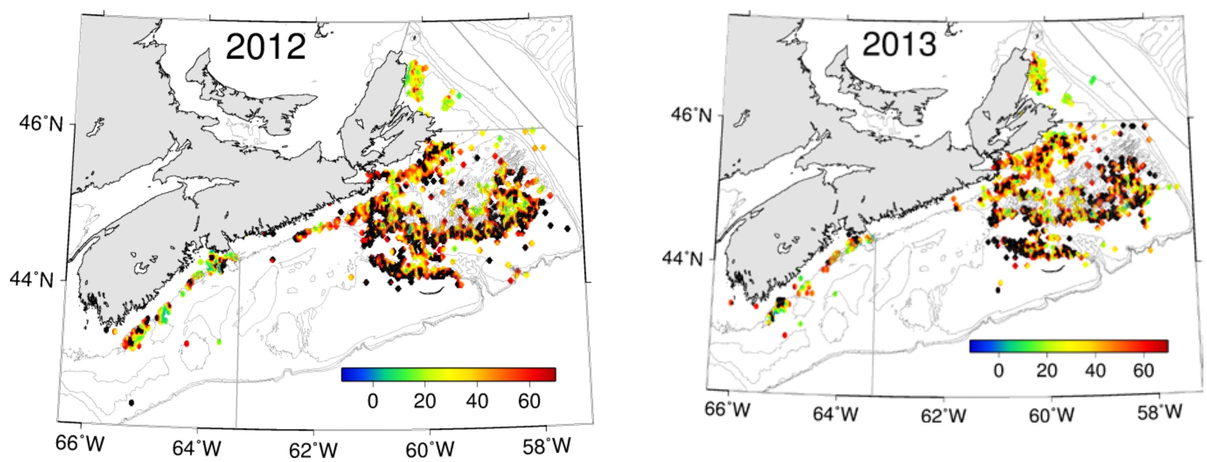


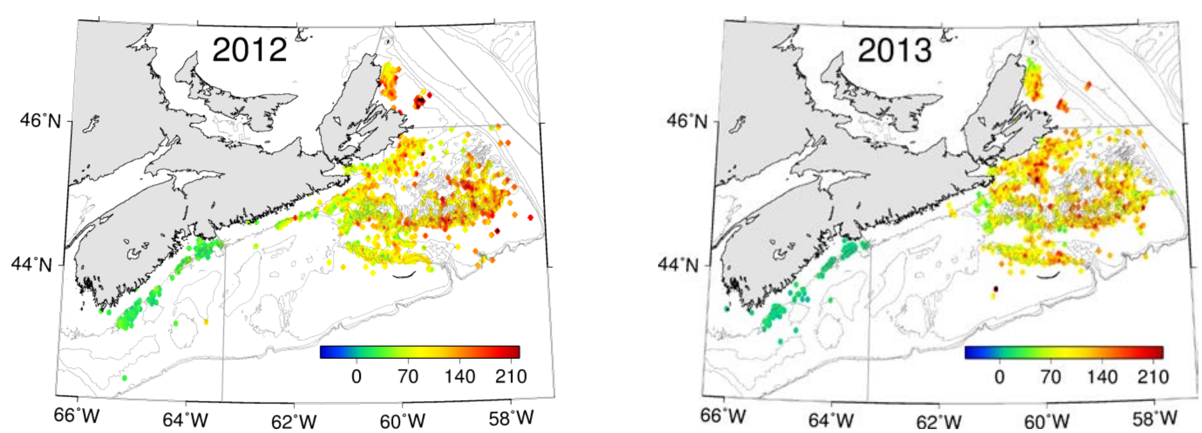
Figure 17. Fishing mortality as a function of fishable biomass for N-ENS (top), S-ENS (middle) and 4X (bottom).



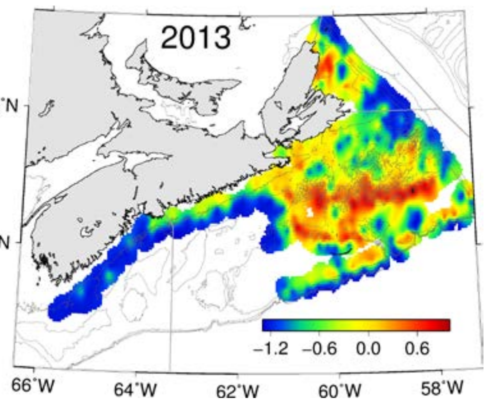
Map 1. Commercial landings (log10; metric tons) in the 2012 and 2013 fishing seasons. Areas in black are off the scale. Original figure in colour.



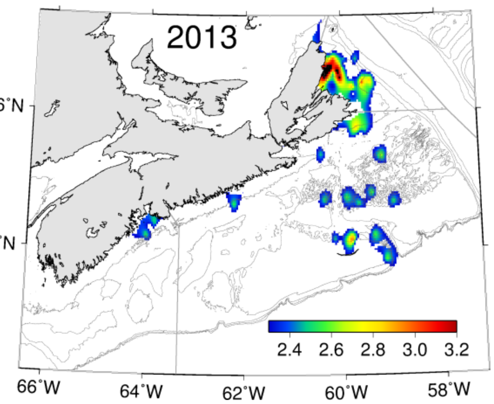
Map 2. Commercial fishing effort from reported logbook positions (total number of trap hauls) in the 2012 and 2013 fishing seasons. Areas in black are off the scale. Original figure in colour.



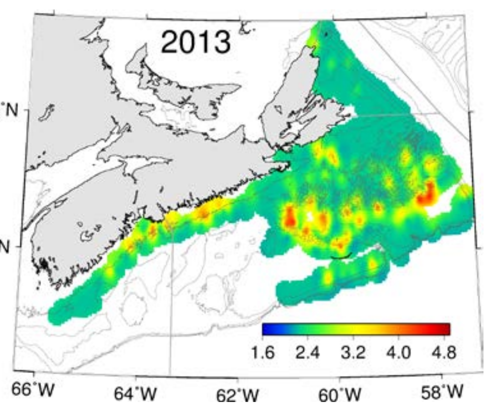
Map 3. Average catch rates (kg/trap haul) of Snow Crab on the Scotian Shelf in 2012 and 2013. Original figure in colour.



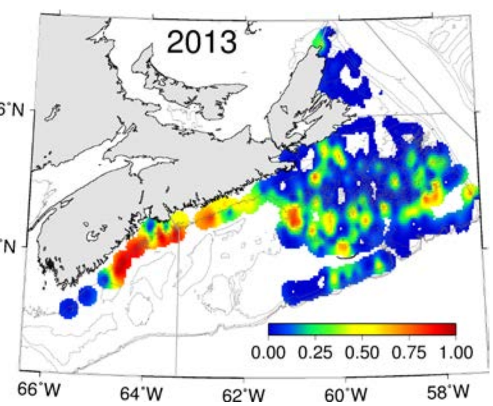
Map 4. Fishable biomass from the 2013 Snow Crab survey. Log 10 scale. Original figure in colour.



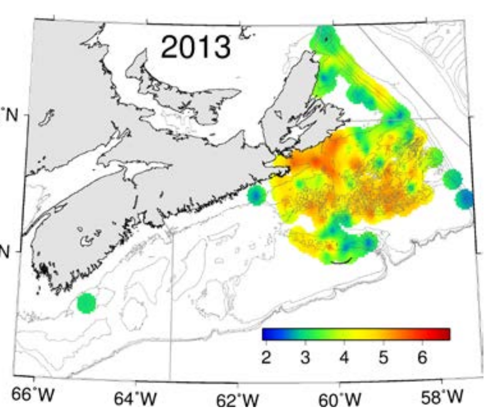
Map 5. Numerical abundance of recruitment of Snow Crab in 2013. Log 10 scale. Original figure in colour.



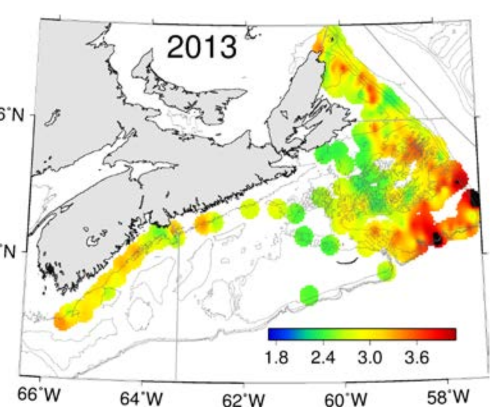
Map 6. Numerical densities of berried female Snow Crab. Log 10 scale. Original figure in colour.



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



Map 8. Number of Northern shrimp, a food item of Snow Crab. Log 10 scale. Original figure in colour.



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

SOURCES OF INFORMATION

This Science Advisory Report is from the 25 February 2014 Assessment of Nova Scotia (4VWX) Snow Crab. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2014. Assessment of Nova Scotia (4VWX) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/033.

Aussi disponible en français :

MPO. 2014. Évaluation du crabe des neiges de la Nouvelle-Écosse (4VWX). Secr. can. de consult. sci. du MPO, Avis sci. 2014/033.