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An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2013

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Resource status was evaluated throughout NAFO (Northwest Atlantic Fisheries Organization) Divisions 2HJ3KLNOP4R based on trends in biomass, recruitment, production, and mortality. Multiple indices of these metrics were derived from a suite of data sources that include dockside-monitored landings, harvester logbooks, at-sea observer monitoring, pre- and post-season trawl surveys, broad-scale post-season trap surveys, localized inshore trap surveys, a vessel monitoring system (VMS), and biological and oceanographic sampling data from multiple sources. The resource was assessed separately for offshore and inshore areas of each NAFO division, where applicable (Div. 3KLP4R). Data availability varied among divisions and between inshore and offshore areas within divisions. Trap and trawl surveys indicate that overall the exploitable biomass has changed little since the mid-2000s but that recruitment has recently declined and is expected to decline further in the short-term (2-3 years). The resource has become increasingly concentrated into Divisions 3LNO in recent years, with about three-quarters of both the exploitable and pre-recruit biomass, originating in those divisions in both 2013 post-season surveys. Long-term recruitment prospects are unfavourable in all divisions due to a recent warm oceanographic regime. Trends in indices are described in detail for each division and conclusions are presented with respect to the anticipated effects of short-term changes in removal levels on fishery induced mortality.

Évaluation du stock de crabes des neiges (*Chionoecetes opilio*) de Terre-Neuve-et-Labrador en 2013

RÉSUMÉ

L'état de la ressource dans les divisions 2HJ3KLNOP4R de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) a été évalué en fonction des tendances relatives à la biomasse, au recrutement, à la production et à la mortalité. Les indices multiples de ces paramètres proviennent d'une série de sources de données, notamment des débarquements faisant l'objet d'une vérification à quai, des journaux de bord des pêcheurs, de la surveillance en mer effectuée par des observateurs, des relevés au chalut avant et après la saison de pêche, des relevés au casier à grande échelle après la saison de pêche, des relevés au casier localisés dans les eaux côtières, du Système de surveillance des navires et des données d'échantillonnage biologiques et océanographiques tirées de sources multiples. On a évalué la ressource des zones du large et des zones côtières séparément pour chaque division de l'OPANO, le cas échéant (division 3KLP4R). La disponibilité des données varie en fonction des divisions ainsi qu'en fonction des zones du large et côtières à l'intérieur des divisions. Les relevés au casier et au chalut indiquent que, dans l'ensemble, la biomasse exploitable a peu changé depuis le milieu des années 2000; toutefois, le recrutement a récemment connu un déclin et devrait continuer de diminuer à court terme (deux à trois ans). Au cours des dernières années, la ressource s'est de plus en plus concentrée dans les divisions 3LNO; environ les trois quarts de la biomasse exploitable et de la biomasse des prérecrues provenaient de ces divisions dans les deux relevés après la saison de 2013. Les perspectives de recrutement à long terme sont pessimistes dans toutes les divisions en raison d'un régime océanographique récemment chaud. On décrit en détail les tendances relatives aux indices pour chaque division et on présente des conclusions en ce qui concerne les effets prévus qu'auraient des changements à court terme dans les niveaux de prélèvement sur la mortalité par la pêche.

INTRODUCTION

This document serves to assess the status of the snow crab (*Chionoecetes opilio*) resource surrounding Newfoundland and Labrador (NL) in NAFO Divisions 2HJ3KLNOP4R. The information presented follows from a formal scientific assessment conducted during February 2014, focused upon determining changes in the exploitable biomass of crabs available to the 2014 fishery (commencing in April 2014), as well as to the fisheries of succeeding years.

Snow crab are sexually dimorphic with males normally achieving larger sizes than females. Exploitable crabs consist of large males that have not molted within the past 6-12 months, as recently-molted animals do not yield commercially acceptable meat content. Production of snow crab is largely environmentally driven, with cold temperatures during early life history favouring increased recruitment (Marcello et al., 2012). Growth rates are also affected by temperature, with older age-at-recruitment within a cold regime than within a warm regime, due to a lower frequency of molting in cold conditions (Dawe et al., 2012a). The minimum legal size is 95 mm carapace width (CW). This regulation excludes females from the fishery and ensures a portion of the adult males remain available for reproduction.

Snow crab in Newfoundland and Labrador are part of a larger population in Canadian Atlantic waters, ranging from southern Labrador to the Scotian Shelf (Puebla et al., 2008). However, as movements of individuals within the stock are thought to be limited, assessments are conducted at the NAFO Division level (Fig. 1) with inshore and offshore areas considered separately where applicable. This is intended to partially conform with crab management areas (CMAs, Fig. 2) while accommodating different types and amounts of available information.

The NL snow crab fishery began in 1967 and was limited to NAFO Divisions 3KL until the mid-1980s. It has since expanded throughout divisions 2HJ3KLNOP4R and is prosecuted by several fleet sectors. Management of the increasingly diverse fishery led to the development of many quota-controlled areas with about 2800 license/permit holders under enterprise allocation for 2014. The fishery is prosecuted using conical baited traps set in long-lines ('fleets'). The minimum legal mesh size is 135 mm to allow small crabs to escape. Under-sized and soft-shelled crabs that are captured in traps are returned to the sea and an unknown proportion of those die.

Data from multi-species bottom trawl surveys, conducted during fall in Div. 2HJ3KLNO, spring in Subdiv. 3Ps, and summer in Div. 4R, are examined to provide information on trends in biomass, recruitment, production, and mortality over the time series. Multi-species trawl survey indices are compared with other relevant indices toward inferring changes in resource status for 2014 and beyond. These other indices are derived utilizing data from harvester logbooks, at-sea observers, vessel monitoring system (VMS), the dockside monitoring program (DMP), and inshore and offshore trap surveys, as well as oceanographic surveys.

The snow crab resource declined during the early 1980s but recovered and remained very large throughout the 1990s. More recently, the multi-species trawl surveys indicate the overall exploitable biomass has changed little since the mid-2000s. However, both the trap and trawl surveys indicate that Div. 3LNO has accounted for an increased percentage in recent years, from about 40% in 2008 to 75% in 2013. Survey data also indicate that overall, recruitment is expected to decline in the short term (2-3 years). Furthermore, a recent warm oceanographic regime suggests weak recruitment in the long term. Declines in the exploitable biomass have recently occurred in the northernmost (Div. 2HJ3K) and southernmost (Subdiv. 3Ps) divisions and there are concerns of a forthcoming decline in the most productive divisions (Div. 3LNO).

METHODOLOGY

MULTI-SPECIES TRAWL SURVEY DATA

Data on total catch numbers and weights were derived from depth-stratified multi-species bottom trawl surveys (Fig. 3) conducted during fall in Div. 2HJ3KLNO, spring in Subdiv. 3Ps, and summer in Div. 4R. The trawl used in the spring and fall surveys was changed to a Campelen 1800 shrimp trawl in 1995 and this trawl proved to be more efficient in sampling crabs than the previously used groundfish trawl. The fall post-season trawl survey was conducted annually in all divisions except Div. 2H, where it was executed annually from 1996-1999, bi-annually from 2004-2008, and annually from 2010-2012. Snow crab sampling during spring Div. 3LNOPs surveys did not begin until 1996, and data were only available from summer trawl surveys conducted in Div. 4R since 2004. The catchability of the survey trawl differs by season; spring (pre-fishery) trawl surveys are considered to be the least reliable because some population components are relatively poorly sampled during spring when mating and molting take place, while the fall trawl surveys are thought to have the highest catchability for snow crab. Prior to 2009, survey abundance and biomass indices were calculated based on a set of common strata that were sampled in all years for each seasonal survey and NAFO Division. Due to gradual attrition of common strata over time, a set of “core strata” was selected in 2009 and used for the assessment since (Fig. 3). This core group included strata most consistently sampled throughout the time series, capturing strata that were common to most years, especially recent years, and does not include inshore strata or deep (>730 m) slope edge strata that have not been regularly sampled. For the summer trawl survey in Div. 4R, all strata occurring within the offshore management area were used to calculate abundance and biomass indices since that survey has suffered less from the attrition of strata over time, although some of the southern strata (not considered to represent crab habitat) were missed in 2010. The 2004 Div. 3L fall survey, and the 2006 Subdiv. 3Ps spring survey were incomplete and have been omitted from analyses. In divisions where both a spring and a fall survey are conducted (Div. 3LNO), only data from fall surveys are used in this assessment due to higher trawl catchability.

Snow crab catches from each survey set were sorted, weighed, and counted by sex. Catches were sampled in their entirety or sub-sampled by sex. Sampling of individual crabs of both sexes included determination of carapace width (CW, mm) and (excepting Div. 4R) shell condition. Shell condition was assigned one of four categories:

1. Soft-shelled – These crabs had recently molted, have a high water content and are not retained in the fishery;
2. New-shelled - these crabs had molted in spring of the current year, have a low meat yield throughout most of the fishing season, and are generally not retained in the fishery until fall;
3. Intermediate-shelled – these crab last molted in the previous year and are fully recruited to the fishery throughout the current fishing season;
4. Old-shelled – these crab have been available to the fishery for at least 2 years.

Males that undergo their final (terminal) molt in the spring will remain new-shelled throughout the fishing season of that year and will not be fully hardened until the following year. Therefore, new-shelled legal-sized crabs are not considered to be part of the exploitable biomass, in the current year, although it is recognized that some of these males may be retained by the fishery if it extends late into the season. It is assumed that all males with small chelae molt each spring and so remain new-shelled between molts. In reality, however, an annually variable proportion of small-clawed males will not molt in any given year (‘skip molters’) and so will develop ‘older shells’ between molts. For each year that a crab skips a molt, its eventual recruitment is delayed by a year. Skip-molting is most common in large adolescent males in cold areas (Dawe et al., 2012a).

Males were also sampled for chela height (CH, 0.1 mm). Males develop enlarged chelae when they undergo their terminal molt, which may occur at any size larger than about 40 mm CW. Therefore, only males with small chelae will continue to molt and subsequently recruit to the fishery. A model which separates two 'clouds' of chela height on carapace width data was applied (Dawe et al., 1997) to classify each individual as either adult (large-clawed) versus adolescent or juvenile (small-clawed). This model is defined as:

$CH = 0.0806*CW^{1.1999}$

Maturity status was determined for females and relative fullness and stage of development of egg clutches were assessed. Occurrence of advanced stages of Bitter Crab Disease (BCD), a fatal affliction, was noted in both sexes based on macroscopic examination. In cases of unclear external characteristics, crabs were dissected and classified based on observation of the hemolymph (i.e. 'blood'). Observation of cloudy or milky hemolymph supported the classification of such specimens as infected.

We examined annual changes in biomass indices of legal-sized males, by shell condition, toward evaluating the internal consistency of the data series. Males enter the legal-size group as soft-shelled crabs, after the spring molt, and remain as new-shelled immediate pre-recruits for the duration of the current year's fishery. They begin to contribute to the legal-sized intermediate-shelled group in the following year. Hence we would expect annual changes in biomass to be first seen in soft or new-shelled legal-sized males and to be followed by similar trends in intermediate, and subsequently old-shelled males.

Biomass and abundance indices were calculated from spring and fall surveys using STRAP (Smith and Somerton, 1981), to represent the exploitable and pre-recruit biomass for males and the abundance of mature females. For spring (pre-season) surveys, these indices represent biomass for the immediately upcoming, or on-going, fishery whereas for summer and fall (post-season) surveys they represent biomass for the fishery in the following year. The exploitable biomass index was calculated as the survey biomass index of adult (large-clawed) legal-sized (>94 mm CW) males, regardless of shell condition. Adult males are terminally molted, so that no members of this category would molt in spring and all adults in the fall survey (including new-shelled adults) would be fully recruited to the fishery in the following year. The exploitable biomass index generated from spring survey data includes a component of new-shelled males that would not actually be retained by the fishery in the immediate or upcoming fishery but would be fully recruited to the fishery in the following year. The offshore exploitable biomass for Div. 4R was calculated based strictly on size, as data on shell condition and chela height are not recorded during these summer trawl surveys. Stations within inshore Div. 4R CMAs and CMA 13 (assessed by DFO Quebec Region) were rejected in calculating biomass indices for offshore Div. 4R.

The pre-recruit biomass index was calculated by applying a 19 mm CW growth increment (Hoenig et al., 1994) to all adolescent (small-clawed) males larger than 75 mm CW, caught in the surveys, before applying STRAP. The resultant pre-recruit index, from fall surveys, represents a component of legal-sized (>94 mm CW) males that would be recently-molted, (soft or new-shelled), and not recruited to the fishery of the next year, but would begin to recruit (as older-shelled males) in the following year. However, some of these recently-molted males would have remained adolescent, and so would molt one more time before achieving adulthood and subsequently recruiting to the fishery, as intermediate-shelled males, one additional year later (i.e. 3 years after the fall survey year). The pre-recruit biomass index for Div. 4R was calculated based strictly on size, thus it contains an unknown proportion of sub-legal-sized adult crabs that will never recruit to the fishery. The abundance of mature females could not be calculated using the summer trawl survey in Div. 4R due to the unavailability of maturity data from that survey; a proxy of females ≥30mm CW was used as an index of reproductive potential.

The exploitable and pre-recruit biomass indices and the mature female abundance indices were calculated using the raw survey data. It is known that catchability of crabs by the survey trawl (i.e. trawl efficiency) is lower than 1 and varies with substrate type and crab size (Dawe et al., 2010a). However, trends in raw ('unstandardized') indices are comparable to those in 'standardized' indices (Dawe et al., 2003) that partially account for effects of substrate type and crab size. Projection of biomass indices from the survey year does not account for annual variability in natural mortality or in the proportion of skip-molters in the following spring. It is assumed that all small-clawed males molt each year. The spatial distribution of pre-recruit and exploitable biomass was examined using catch rates (numbers per tow) for each survey set.

The ratio of the annual landings to the exploitable biomass index (projected from the fall survey of the previous year) was calculated by NAFO Division to provide an index of exploitation rate. This index overestimates absolute exploitation rate because the survey index underestimates absolute biomass. It is recognized that annual changes in these ratios may be due to changes in catchability (i.e. trawl efficiency) rather than exploitation rate. However, we feel that long-term trends provide a useful indication of trends in exploitation rates. Inshore commercial catches and data from inshore survey strata in Div. 2HJ3KLNOP were not included in calculating the ratios because those areas were not surveyed in all years. In Div. 4R, inshore strata have been consistently surveyed in some bays, and the catches from these strata have been removed from offshore exploitation rate indices.

To examine size composition of males, STRAP was applied to trawl survey catches grouped by 3 mm CW intervals to reflect total population abundance indices. In Div. 2HJ3KLNOP, each size interval was partitioned, based on chela allometry, between juveniles plus adolescents (small-clawed) versus adults (large-clawed).

To investigate the possible effect of thermal regime on snow crab production or early survival we compared trawl survey exploitable biomass indices with lagged (lag of best fit) thermal indices for offshore areas in each of Divisions 2J, 3K, 3LNO (as a group) and Subdiv. 3Ps. Fishery catch per unit effort (CPUE) indices are correlated with exploitable biomass indices from the trawl surveys and provide longer time series, thus similar comparisons were made between thermal habitat indices and fishery CPUE indices. We used two indices of thermal regime, mean bottom temperature and area of cold bottom water distribution (snow crab thermal habitat index). Bottom temperatures used were from shallow strata in each division (<200 m in Div. 2J and 4R, <300 m in 3K and <100 m in Div. 3LNOPs) because settlement of early benthic stages occurs primarily in shallow areas, inshore and on banks (Dawe and Colbourne, 2002). The thermal habitat index was calculated as the percentage of the area surveyed that was covered by cold water of temperatures <2 °C in Div. 2J3K, <0 °C in Div. 3LNO and <1 °C in Subdiv. 3Ps. No thermal habitat index was calculated for Div. 4R due to insufficiency of data. Mean bottom temperatures and thermal habitat indices for Div. 2J3K were derived using data from fall surveys, whereas those from Div. 3LNOPs were derived using data from spring surveys and year-round data from Station 27, a frequently sampled oceanographic station located 10 nm off St. John's, Newfoundland.

FISHERY LOGBOOK DATA

Data on commercial catch (kg) and fishing effort (number of trap hauls) were obtained from vessel logbooks. These data were compiled by the Statistics Division, Policy and Economics Branch, Newfoundland Region of Fisheries and Oceans Canada. CPUE (kg/trap haul) was calculated by year and NAFO Division, and by CMA where applicable. CPUE is used as an index of biomass, but it is unstandardized in that it does not account for variation in fishing practices (e.g.: soak time and mesh size). However, raw CPUE has been shown to trend similarly to standardized and modeled CPUE that incorporate these variables (unpublished data). Long-term trends in logbook CPUE are presented, as a fishery-based index of trends in biomass, for comparison with other fishery-based and survey indices.

The number of trap hauls from logbooks was calculated for each division on a weekly basis to compare the seasonality of the distribution of fishing effort among years to CPUE. CPUE was calculated on a weekly basis to assess fishery performance throughout the season in inshore areas each year. Similarly, weekly CPUEs were compared against the weekly cumulative catch to assess the performance of the fishery against the level of removals in inshore areas each year. Logbook CPUEs were also mapped for 10’ x 10’ (nautical minutes) and 2.5’ x 2.5’ cells in the offshore and inshore areas respectively, encompassing the entire fishery distribution each year, and used to qualitatively assess area-specific fishery performance within each division.

The spatial extent of annual fishing effort for inshore and offshore areas of each division was calculated from commercial logbooks. Sets were assigned to 5’ x 5’ cells based on logbook co-ordinates. The annual ratio of the total number of cells with fishing effort (≥1 set) to the total number of cells in each area was used as an index of spatial expansion or contraction and compared with trends in fishery CPUE.

CPUE indices in offshore areas were correlated against annual bottom temperature and habitat indices in each division at lags of best-fit, to assess the effect of thermal regime during early life history on future fishery success.

OBSERVER CATCH-EFFORT AND AT-SEA SAMPLING DATA

Set and catch data were available from the Observer Program for the same time series as those from the multi-species surveys (1995-2012), but at-sea sampling data have only been collected since 1999. Levels of sampling are generally highest in offshore Div. 3KLNO due to high observer coverage in those areas (Fig. 4). Sampling has been consistently low in inshore CMAs and virtually absent throughout Divisions 2H and 4R. The observer set-and-catch database included details about number and location of traps, landed catch (kg), and discarded catch (kg) for each set observed. An observer-based CPUE index (kg. landed/trap haul) was calculated from observer data for comparison with inshore and offshore logbook CPUE. This catch rate index was based on set and catch estimates from 1995-1998, when no detailed sampling was conducted, whereas it has since been based on detailed sampling of individual crabs.

For offshore areas, where data permitted, a pre-recruit fishing mortality index (PFMI) was developed based on the ratio of the observed catch rate of pre-recruits discarded in the fishery to the preceding trawl survey biomass index of pre-recruits. This index is defined as;

$$PFMI = S\left(\frac{DPI_t}{PBI_{t-1}}\right)$$

where DPI is the catch rate (kg/trap haul) of measured under-sized adult males and under-sized, and soft-shelled, pre-recruits discarded in the fishery, in year t, calculated from observer sampling data. PBI is an index of the biomass of pre-recruits and under-sized adult males (t x 1000) from the preceding survey; i.e. the fall survey of the previous year for Div. 2HJ3KLNO or the spring survey of the same year for Subdiv. 3Ps. S is a scaling factor to account for incomplete and annually variable levels of observer coverage, defined as:

$$S = \frac{Total\ Landings}{Observed\ Landings}$$

The PFMI overestimates pre-recruit mortality because the PBI underestimates pre-recruit biomass, as a result of low catchability of pre-recruits by the survey trawl. However, it is felt that long-term trends in this index provide a useful indication of trends in pre-recruit mortality. In both inshore and offshore areas, the percent discarded (by weight) is viewed as an index of wastage in the fishery. It provides an indication of the level of wastage associated with catching and releasing of pre-recruits in the fishery, and is not necessarily proportional to the mortality rate on the pre-recruit population.

Data from biological sampling by observers was also used to quantify the catch components, discarded or retained, in the fishery. Entire trap catches of males were sampled for carapace width (mm) and shell condition. Shell condition categories differed slightly from those used for trawl surveys, in that categories of crabs not recently molted (intermediate-shelled and old-shelled in trawl surveys) were pooled into a single category. These biological sampling data were used to identify specific categories of discards (i.e. ‘undersized’ and ‘soft’ legal-sized). Also, seasonal trends in the percentage of soft-shelled crabs were described. Discarding of recently-molted (especially ‘soft’) immediate pre-recruits is believed to impose a high mortality on those individuals. A soft-shell protocol was implemented in 2004 to close specific small fishing areas when the percentage of soft-shell crab reached 20%. This was reduced to 15% for offshore Div. 3LNO in 2009-10.

VESSEL MONITORING SYSTEM (VMS) AND DOCKSIDE MONITORING PROGRAM (DMP) DATA

Data on hourly offshore vessel positions from VMS, and landed catch from DMP, were obtained from the Fisheries Management Branch and the Policy and Economics Branch, Statistics Division, Newfoundland Region of Fisheries and Oceans Canada. These datasets were merged based on vessel registration number (VRN), year, month, and day. A CPUE index (kg/fishing hr.) was calculated by year and NAFO Division, as described by Mullowney and Dawe (2009). Fishing hours were screened based on location and speed from hourly positional signals. Signals occurring at 0.1 – 3.0 knot speeds were accepted as fishing signals.

VMS-based CPUE is used as an index of biomass and compared with commercial logbook and observer-based CPUE indices; VMS-based CPUE, like the other CPUE indices, is unstandardized in that it does not account for variation in fishing practices (e.g.: soak time and vessel drift) (Mullowney and Dawe, 2009). Trends in VMS-based CPUE are used as the primary catch rate index only for offshore areas where all fleet sectors are required to use VMS (Div. 3KLNOP4R). Analogous to depletion indices developed from logbook data in inshore areas, VMS CPUE was calculated on a weekly basis to assess fishery performance throughout the season in offshore areas each year. Similarly, weekly CPUEs were compared against the level of cumulative catch to assess the performance of the fishery in relation to the level of removals in offshore areas each year.

INSHORE TRAP AND TRAWL SURVEYS

Data were available from inshore Div. 3K trap surveys that were carried out in White Bay and Notre Dame Bay during 1994-2013. There were no surveys in either bay in 2001, and no survey was conducted in Notre Dame Bay in 2009 or 2011. The survey has consistently occurred in late August – mid September and occupies 5 of the inshore fall multi-species survey strata (Fig. 5) with set locations randomly distributed within each stratum, and stratum-specific set allocations weighted by area. Each set includes 6 traps, with crabs sampled from three largemeshed (commercial, 135 mm) and three small-meshed (27 mm) traps. Catch rate indices (kg/trap haul) of legal-sized males were calculated by shell category (new-shelled recently-molted versus older-shelled), and size distributions were described by claw type (small-clawed juveniles plus adolescents versus large-clawed adults). Mortality was also inferred from levels of BCD observed in these surveys.

Data were also available from two inshore trap and trawl surveys (1979-2013) within Div. 3L (Bonavista and Conception Bays) and one within Subdiv. 3Ps (Fortune Bay, 2007-2013) (Fig. 5). These surveys were conducted in different seasons; spring (Fortune Bay – 3Ps), summer (Bonavista Bay – 3L), and fall (Conception Bay – 3L). The Fortune Bay survey covered three depth strata while the Bonavista and Conception Bay surveys covered only the deepest stratum in each bay where the commercial fishery was thought to concentrate. All surveys utilized traps of various mesh sizes for each set, including two small-meshed (27 mm) traps. For each survey series, catch rate indices and size distributions were produced as described above for the inshore Div. 3K trapping surveys, and prevalence of BCD was recorded. The trawling portion of these surveys utilized a survey trawl with small rock-hopper footgear that is believed to have a a higher capture efficiency for snow crab than the Campelen 1800 trawl used in the offshore multi-species surveys. No survey was conducted in Fortune Bay in 2008, and the trawling portion of the survey in 2009 was omitted from analyses due to gear mis-configuration in that year. Furthermore, a new vessel was commissioned to conduct these inshore trawl surveys in 2012. As it was deemed to have a different catchability than the previous vessel, the most recent survey indices are not comparable to historical data. With an insufficient time series of only two years using the new vessel, these trawl survey data were omitted from this assessment.

POST-SEASON TRAP SURVEY

Data were examined from industry-DFO Collaborative Post-Season (CPS) trap surveys in Div. 2J3KLOPs4R (Fig. 6). These surveys, funded by the Fisheries Science Collaborative Program (FSCP), were examined for the first time in 2006. They were initiated following the 2003 fishery and conducted annually thereafter, beginning Sept. 1 each year. The surveys, conducted by snow crab harvesters accompanied by at-sea observers, focus on commercial (i.e. deep) fishing grounds within individual CMAs, and as such are more spatially-limited than the multi-species trawl surveys. Survey stations are fixed and generally follow a grid pattern, with a maximum station spacing of 10’ X 10’ (Fig. 6). At each station, 6 (inshore) or 10 (offshore) commercial (135 mm mesh) crab traps are set in a fleet. All crab caught are sexed and counted. Biological sampling of male crab is conducted at-sea, by observers, from one trap at each station. Sampling includes determination of carapace width, shell condition, leg loss, and presence of BCD. Small-meshed traps are included at selected stations to collect information on pre-recruits and females. Biological sampling of males from small-meshed traps includes determination of chela height. However, due to temporal and spatial inconsistencies in the distribution of small-mesh traps, indices are not available for all areas in all years. Furthermore, small-meshed traps do not adequately sample pre-recruit crabs in some areas due to a survey design that focuses on sampling of exploitable crabs, with limited sampling of shallow-water small-crab habitat.

For analysis of catch rates (numbers per trap), a set of core stations was selected from the survey (Fig. 6) due to incomplete and spatially variable survey coverage each year. Biomass indices derived from this survey were based on a stratification scheme introduced into the assessment of 2010 (Mullowney et al., 2012a) (Fig. 6). In previous years, the multi-species trawl survey stratification scheme was used to derive biomass estimates from the CPS trap survey (Dawe et al., 2011). However, it was abandoned due to poor and non-random spatial coverage of the stratification template by the CPS survey. The depth-based stratification scheme closely conforms with all stations occupied in inshore and offshore management areas of each division since 2004. The boundary of each stratum extended 5nm outside the outermost stations of each survey grid. The set of strata used was common to all years for each zone. Exploitable and pre-recruit biomass indices were calculated from trap survey catch rates using STRAP in a fashion similar to its application to the multi-species survey data, modifying the program with respect to the area-depth stratification scheme and applying an effective area fished of 0.0053 km² (Dawe et al., 1993), analagous to the area swept by a single trawl survey tow, to extrapolate trap catch rates across the total survey area. Trends in the pre-recruit biomass index from this survey are biased in that chela height is not determined. Although sub-legal-sized terminally-molted adults will never recruit or contribute to the future exploitable biomass, they are included in the size-based pre-recruit biomass index from the trap survey. An examination of shell conditions of 76-94mm CW males from this survey was introduced in the previous assessment were used to infer the proportion of pre-recruit-sized crabs that remain adolescent and will continue to molt. This assumes that old-shelled pre-recruit-sized crabs would have a higher likelihood of being terminally molted adults than would new-shelled crabs of the same size.

RESULTS AND DISCUSSION

DIVISION 2HJ3KLNOPS4R

The Fishery

The fishery began in Trinity Bay (Management area 6A, Fig. 2) in 1967. Initially, crabs were taken as gillnet by-catch but within several years there was a directed trap fishery in inshore areas along the northeast coast of Div. 3KL (Fig. 1) from spring through fall. Until the early 1980s, the fishery was prosecuted by approximately 50 vessels limited to 800 traps each. In 1981, fishing was restricted to the NAFO Division where the license holder resided. During 1982-1987, there were major declines in the resource in traditional areas of Div. 3K and 3L while new fisheries started in Div. 2J, Subdiv. 3Ps, and offshore Div. 3K. Since the late 1980s, the resource and fishery scales has increased in these areas. Commercial quota allocations for Div. 4R began in the early 1990s and in Div. 2H in 2008, although there were prior small-scale exploratory fisheries in these areas.

Licenses supplemental to those of groundfish were issued in Div. 3K and Subdiv. 3Ps in 1985, in Div. 3L in 1987, and in Div. 2J in the early 1990s. Since 1989, there has been a further expansion in the offshore. Temporary permits for inshore vessels <35 ft., introduced in 1995, were converted to licenses in 2003 and exploratory licences in the offshore were converted to full-time licenses in 2008. There are now several fleet sectors and about 2,800 license holders in the fishery, with several rationalization initiatives gradually reducing the number of active licenses in recent years. In the late 1980s, quota control was initiated in all management areas of each division. All fleets have designated trap limits, quotas, trip limits, fishing areas within divisions, and differing seasons. Mandatory use of the electronic vessel monitoring system (VMS) was fully implemented in all offshore fleets in 2004 to more stringently ensure compliance with fishing area regulations.

The fishery was traditionally prosecuted during summer and fall but has become earlier in recent years and is now primarily prosecuted during spring and early summer. Late fishing seasons are believed to contribute to a high incidence of soft-shelled immediate pre-recruits in the catch. The fishery can be delayed in northern divisions (Div. 2HJ3K) due to ice conditions in some years. Such severe ice conditions can affect the spatial distribution of fishing effort and fishery performance. The fishery can also be delayed for other reasons such as price disputes, which are commonplace.

Historically, most of the landings have been from Div. 3KLNO. Landings for Div. 2HJ3KLNOP4R (Table 1, Fig. 7) have remained at 50,000 – 53,000 t since 2007. However, Div. 3LNO has accounted for a steadily increasing percentage in recent years, from about half in 2009 to two-thirds in the past two years.

Effort, as indicated by estimated trap hauls, approximately tripled throughout the 1990s (Dawe et al., 2004) primarily due to vessels <35 feet long, with temporary seasonal permits, entering into the fishery. The distribution pattern has since remained broad-based, with only slight annual changes in recent years (Fig. 8). A reduction of fishing along the slope edges occurred in Divs. 2HJ3KOPs after 2003. Effort expenditure increased greatly in offshore Div. 3K from 2008 to 2009 and remained relatively high since (Fig. 8). Effort within the inshore areas of Div. 4R had become increasingly contracted and highly aggregated throughout the 2000s, but the fishery has re-emerged in recent years. Notable changes in 2013 were the complete abandonment of the Div. 2H fishery and a major reduction in fishing effort in the northernmost areas of Div. 2J.

Biomass

The fall distributions of exploitable (legal-sized adults, Fig. 9) and pre-recruit (>75 mm adolescents, Fig. 10) males throughout NAFO Div. 2HJ3KLNO in 2013 were generally similar to the patterns observed when biomass levels were higher during the late 1990s, as previously described by Dawe and Colbourne 2002, with some notable exceptions. Large males have consistently been virtually absent over a broad area of the shallow (<100m) southern Grand Bank throughout the time series. The abundance of largest males (Fig. 9) has been lower in the northernmost areas (Div. 2J3K) in the past three years than during 2008-10, while relatively consistent levels have occurred in the southernmost areas (Div. 3LNO). Survey catch rates of pre-recruit males (Fig. 10) have been lower everywhere during the past three years than from 2008-10. Following a reduction in 2011-12, there was a general increase in smallest males (< 60mm CW) in 2013, particularly in the northernmost extremities (Fig. 11). Finally, there has been a marked decrease in abundance of mature females across the entire survey area in the past four years (Fig. 12).

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-1998, Fig. 13). It declined from the late 1990s to 2003 and then increased. The overall exploitable biomass has changed little since the mid-2000s. However, both the trap and trawl surveys indicate that Div. 3LNO has accounted for a steadily increasing percentage in recent years, from about 40% in 2008 to 75% in 2013.

Production

Recruitment

Overall recruitment is expected to decline in the short term (2-3 years). Trap and trawl survey biomass indices of pre-recruits (Fig. 13) increased from 2006-2007 to 2009-2010 due to increases in the South (Div. 3LNOPs). Survey biomass indices of pre-recruits have recently declined in all areas except Div. 2HJ and both surveys indicate that Div. 3LNO has accounted for an increased percentage of pre-recruits in recent years (Fig. 13).

It is inferred that there is higher uncertainty associated with the pre-recruit index than with the exploitable biomass index. This difference in uncertainty is not due to differences in precision of estimates but primarily related to differences in molt status between the two groups. The exploitable biomass index is comprised exclusively of males that were terminally-molted adults in the surveys, whereas the pre-recruit index includes a large component of males that were adolescents as small as 76 mm CW during the surveys. The projection of the pre-recruit index assumes that all those adolescents will molt, survive, grow by 19 mm CW, and subsequently recruit over the following two years, involving yet an additional molt for those that remained legal-sized adolescents, as older-shelled males. In reality, the biomass of new-shelled pre-recruit crabs is greatly affected by annual variability in natural mortality, growth increment, and proportions that do not molt. These variables currently cannot be predicted and hence are not accounted for.

Low bottom temperatures promote terminal molt at small sizes in snow crab, resulting in relatively low recruitment and yield-per-recruit from a given year class (Dawe et al., 2012a). However, recruitment is more strongly affected by the positive effects of a cold regime on year class production (Dawe et al., 2008; Marcello et al., 2012) than it is on the negative effects of a cold regime on size-at-terminal molt. Cold conditions early in the life history are associated with the production of strong year classes and subsequent strong recruitment.

Temperatures on the Newfoundland Shelf were below normal in most years from the mid-1980s to about 1995 (Colbourne et al., 2013). These were years of high crab productivity that led to high commercial biomass and catch rates during the late 1990s. A recent warm oceanographic regime suggests weak recruitment in the long term. The ocean climate indices have varied considerably over the past decade, introducing uncertainty beyond the short term, but the overall trend is warming, with record warm conditions in 2011 (Fig. 14). The degree of decline in spatial extent of cold water reflected in the habitat indices appears to have been less severe in the southern divisions (i.e. Div. 3LNOPs), but a declining trend has occurred everywhere since the late 1980s or early 1990s. Fishery CPUE in all divisions has generally maintained oscillatory patterns reflecting the ocean climate signal at lags of 6-10 years (Fig. 15). Despite a high level of annual variability, the broad-scale reductions in cold water coverage imply a forthcoming decline in abundance in all components of this stock (Mullowney et al., 2014a). STRAP analysis reveals there have been two major pulses in abundance of small crabs occurring along the NL shelf, with the most recent one during 2000-2002 (Fig. 16).

Although there is a high degree of uncertainty in annual catchability of the survey trawl, and catchability of smallest crabs is believed to be especially poor, size frequency distributions of males (Fig. 17-18) show the decrease in abundance of pre-recruit (>75mm CW adolescent) males that has occurred in recent years and suggest a paucity in abundance of smallest crabs along the NL shelf since about 2003.

Reproduction

The abundance of mature females (Fig. 19) captured during the fall trawl survey was highest in 1995 and declined precipitously to 1998. It varied without trend for most of the 2000s but increased sharply in 2008. It declined to its lowest level in 2012 and remained low in 2013. The percentage of mature females carrying full clutches of viable eggs has remained high (i.e. exceeding 80%) in all years. The effects of reduced abundance of mature females on subsequent recruitment are not presently known but may be a cause for concern.

Mortality

Bitter Crab Disease (BCD) has been observed in snow crab, based on macroscopic observations, at generally low levels throughout 1996-2013. The prevalence and distribution of this parasitic disease throughout the Newfoundland and Labrador Shelf has been described in detail by Dawe (2002) and appears related to circulation features (Dawe et al, 2010b) and the density of small crabs (Mullowney et al., 2011). This density-dependent disease is thought to moderate the strength of recruitment pulses occurring in the population.

The disease, which is fatal to crabs, primarily occurs in new-shelled crab of both sexes and appears to be acquired during molting (Dawe, 2002). It is unknown how well observed disease prevalence in trawl samples represents true prevalence in the population, as diagnosis has been based on recognition of external characteristics in chronic cases. However, it seems likely that recorded observations underestimate true prevalence.

There had been a broadly-distributed incidence of bitter crab disease during 1996-2006, but the distribution became limited to localized aggregations at low prevalence, primarily in Div. 3KL, in 2007 (Fig. 20) and has been low since. In 2010, there appeared to be a substantial increase in the distribution and prevalence of BCD in offshore Div. 3K. However, this increase was attributed to Technican error and deemed anomalous. The virtual absence of BCD across most of the survey area in recent years is positive in that it reflects a reduced level of mortality in the population, but it is negative in that it reflects a reduced overall abundance of small crabs and diminishing recruitment prospects.

DIVISION 2HJ

The Fishery

The Division 2HJ fishery occurs in offshore regions of central and southern Labrador in CMAs 1 and 2 (Fig. 21). The bathymetry is characterized by a series of shallow water offshore banks separated by deep channels. The fishery in Div. 2H is small relative to Div. 2J. There had been exploratory fisheries in Div. 2H since the mid-1990s and a commercial TAC was first established in 2008. The history of fishing in 2J is longer, extending back into the early 1980s. Landings in Div. 2HJ (Table 2, Fig. 22) peaked in 1999 at 5,400 t, declined to 1,500 t in 2005, and increased by 60% to 2,400 t in 2008. They decreased by 45% since 2008, to 1,380 t. The TAC has not been taken in the past three years due to shortfalls in the northernmost areas. Meanwhile, effort increased by 55% to 2011 before decreasing by 23% in 2012. Total effort in 2013 is unknown as only about half of the logbooks were returned.

Commercial CPUE is usually best reflected by the logbook index in this area because observer coverage is low and many vessels are not equipped with VMS. Logbook CPUE has oscillated over the time series (Table 2, Fig. 23), initially decreasing from 1991 to 1995, and increasing to a peak in 1998. It declined steadily from 1998 to a record low level in 2004 and then increased to a peak in 2008. CPUE declined steadily by half from 2008 to 2011, was unchanged in 2012, and increased in 2013. However the magnitude of the 2013 increase is uncertain because both the VMS and logbook indices are based on data from only about half of the fishery and observer coverage was low.

The 2013 fishery was concentrated in Hawke Channel, while the Cartwright channel in northern Div. 2J was virtually abandoned (Fig. 24). This constituted an unusual departure from the typical pattern of concentration in both channels. Annual effort distribution in Div. 2H has been variable, likely reflecting the low biomass of crab in that division. In 2013 there was no effort expended above the Div. 2H line.

The 2010-2012 fisheries began in early May and virtually all effort was expended by about mid-August (i.e. week 14) each year (Fig. 25). However, the pace of the 2013 fishery was quicker, with about 90% of the effort expended by mid-July (i.e. week 10).

Biomass

Commercial CPUE has oscillated over the time series and appears to be improving from a 2011-12 low, as indicated by all three indices (Fig. 23). Increases in CPUE were most notable in the southern portion of the division, with the Cartwright Channel appearing to perform relatively poorly as in the previous two years (Fig. 26). The spatial coverage of the fishery has been inversely related to commercial CPUE (Fig. 27). The percentage of cells occupied by the fishery declined sharply from a peak in 2011 to a historical low in 2013. The general inverse relationship between spatial coverage of the fishery and commercial CPUE reflects harvester searching behaviour, with the necessity to search for new or alternate fishing grounds when catch rates are low or in decline. Accordingly, the low spatial coverage in 2013 is indicative of a situation whereby little searching was required to find commercial concentrations of crab. This is in stark contrast to the situation of the 2011 fishing season, when a high level of searching was required to harvest the quota.

Weekly CPUE trends are normally highest during the early portion of the season and tend to decline during the first 4-5 weeks of fishing each year (Fig. 28). Catch rates normally remain low thereafter during the fishing season, although in some years they may increase slightly later in the season under reduced effort. The typical weekly pattern occurred in 2013, with catch rates consistently above levels of the previous two years. In relation to cumulative removals, the 2013 fishery appeared to perform especially well early on (Fig. 28), but the analysis suffers from an unusually low level of logbook data in 2013 thus the trend is considered preliminary.

Size distributions from at-sea sampling by observers (Fig. 29) suggest the entry of a recruitment pulse into the exploitable biomass during 2007-2009 and another one in 2012-2013, with an increase in abundance of new-shelled legal-sized crabs during those periods. However, the magnitude of the 2013 increase is uncertain as catch rate estimates of legal-sized crab from observer set and catch data were much lower than those determined through sampling of the catch (Fig. 30). Nonetheless, the evidence of increased catch rates of soft-shell crab in the catch in 2012, followed by new-shelled crabs in 2013, typifies the pattern expected as a modal group enters into the exploitable biomass and subsequently ages. It is believed that the catchability of soft-shelled crabs increases when the ratio of soft- to older-shelled crabs is high, with large older-shelled crabs out-competing their soft-shelled counterparts for baited traps. If the pattern holds, the expectation for the 2014 fishery would be a higher proportion of older-shelled crabs in the catch.

The post-season trawl survey exploitable biomass index decreased steadily, by 92%, from 1998 to 2002 (Table 3, Fig. 31). It increased from 2002 to peak in 2006 but remained below pre-2002 levels. The exploitable biomass, as indicated by the post-season trawl survey, declined steadily from 2006 to 2011 and has changed little since. The post-season trap survey index (Fig. 31) decreased since 2011, but this index is considered less reliable than the trawl survey index because of limited spatial coverage by the trap survey in this area. The trap survey was incomplete in 2008 and 2009. The trawl survey indicates that the exploitable biomass has contracted southward in recent years, with virtually none of the exploitable biomass in Div. 2H since 2011, and catches almost exclusive to the Cartwright and Hawke Channels.

The increase in the fall survey exploitable biomass index from 2002-2006 and from 2011-2013 (Fig.31) appear small relative to the increases in CPUE indices (Fig. 23). This likely reflects the positive effects of recent management changes in the fishery as described earlier.

Production

Recruitment

Recruitment declined from 2006 to 2011 and changed little since; prospects are uncertain in the short term (2-3 years). The post-season trawl survey pre-recruit index (Table 3, Fig. 33) has changed little since 2005. The post-season trap survey index has declined since 2011. Similar to the pattern observed for legal-sized crabs, the capture of pre-recruit males in the fall trawl survey has been almost exclusive to the Cartwright and Hawke Channels in most recent years (Fig. 34). However, in 2013 very few pre-recruit crabs were captured in the Hawke Channel.

Males enter the legal-size group as soft-shelled crabs, after the spring molt, and begin to contribute to the legal intermediate-shelled group in the following year. Trends in the biomass index by shell condition reflect this process in that the biomass of new-hard-shelled males peaked in 1997-1998 whereas that of intermediate-shelled males peaked in 1998-1999 (Fig. 35). The biomass index of new-hard-shelled males dropped sharply in 1999, whereas that of intermediate-shelled crabs declined steadily during 2000-2002. The biomass of new-hard-shelled crabs increased steadily from 2002-2006 while the biomass of older-shelled crabs has remained low. This suggests that the fishery has been highly dependent upon immediate recruitment, which has gradually increased since 2011. Shell condition-specific indices of legal-sized males from the CPS trap survey (Fig. 36) are consistent in showing a marginal increase in new-shelled crabs in recent years, with a marginal decrease in old-shelled crab catch rates.

The size compositions from fall multi-species surveys for Div. 2H (Fig. 37) show a clear picture of a recruitment pulse entering into legal-size from 2004-2008 and dissipating since. This recruitment pulse was first tracked in 2001 with crabs ranging from about 21-36mm CW. In Div. 2J the picture is less clear. The data indicate that most of the relatively abundant sub-legal-sized adolescent males evident in 2004 achieved legal size in 2005-2007, with the abundance of most sizes of legal-sized crabs having since declined (Fig. 38). The size distributions suggest the abundance of smallest males (<50 mm CW) has been low in most recent years, with the exception of an increased catch rate of very small (i.e. <20mm CW) crabs in 2013. With the lack of year-to-year coherence in modal progression throughout the time series, caution is warranted in interpreting any improved long-term prospects from the emergence of this mode at this point in time. Size frequency distributions from the CPS trap survey, in Div. 2J, show a depleted biomass of all sizes of crabs since 2007 (Fig. 39). The predominance of new-shelled crabs in the catch is indicative of the reliance on immediate recruitment in this fishery and a persistent low level of residual biomass.

The catch rates of total discards in Div. 2J decreased substantially between 2004 and 2006, varied without trend until 2010, and increased until 2012 (Fig. 40). The increase in discard rates up to 2012, comprised predominately of soft-shell crabs, is consistent with other fishery data (Fig. 23, 29-30) in suggesting increased recruitment into the exploitable biomass in 2013. This does not fully correspond with survey data, which show little change in recruitment in recent years.

A recent warm oceanographic regime suggests weak recruitment in the long term. The ocean climate indices have varied considerably over the past decade (Fig. 14-15), introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2010 and 2011. Fishery catch rates have consistently maintained a positive oscillatory relationship with the climate signal, most significant at a seven year lag (Fig. 15). As the effect of climate on survival is believed to occur in the first couple of years following settlement (Mullowney et al., 2014a), the lag of 7 years implies a relatively quick progression of crabs through successive sizes into the exploitable size group (i.e. 8 to 9 years post-settlement) and a low level of skip-molting in these relatively warm waters (i.e. Dawe et al., 2012a) (Fig. 14).

Reproduction

The abundance of mature females captured in the trawl survey had been relatively low during 2010-12 but the point estimate increased sharply in 2013 and was associated with a relatively high level of variance (Fig. 41). Mature females are generally captured in shallower water than pre-recruit and legal-sized males as can be seen in 2008 and 2009 when high mature female catch rates occurred on top of the Hamilton Bank and in shallow waters off the headlands of southern Labrador (Fig. 42). The biggest increases in 2013 occurred in shallow waters on the Hamilton Bank. The percentage of mature females carrying full clutches of viable eggs (Fig. 41) has varied over the time series but been near or above 90% for the past seven years. It is unknown to what extent changes in abundance of mature females may affect subsequent abundance of settling megalopae or (ultimately) fishery recruitment.

Mortality

Exploitation

The exploitation rate index declined from 2003-2007 and then increased steadily from 2007 to 2012 before decreasing in 2013 (Fig. 43). Maintaining the current level of fishery removals would likely have little effect on the exploitation rate in 2014.

Indirect Fishing Mortality

The pre-recruit fishing mortality rate index has been at its highest level, since 2004, during 2011 and 2012 but decreased by more than half in 2013 (Fig. 43). The percentage of the catch handled and released in the fishery decreased from 35% in 2012 to 20% in 2013 (Fig. 43), implying a decrease in pre-recruit mortality.

Snow crabs that are caught and released as under-sized or legal-sized soft-shelled males in the fishery are subject to multiple stresses and have unknown survival rates. Time out of water, air temperature, water temperature and shell hardness all influence the mortality level on discarded snow crab (Miller, 1977). Other environmental factors such as wind speed, sunlight, and size of the crab may also influence survivability (Dufour et al., 1997). Poor handling practices such as prolonged exposure on deck and dropping or throwing crab induces limb loss and also leads to increased mortality levels associated with catching and discarding crabs. Recently-molted (soft-shell) snow crab are subject to more damage and mortality than hard-shelled crab (Miller, 1977, Dufour et al., 1997). Soft-shell crab prevalence was low in all weeks of the 2013 fishery, following relatively high levels that exceeded the 20% closure threshold during the latter portions of the fisheries of the previous two seasons (Fig. 44).

Prevalence of soft-shelled legal-sized males is a function of both fishery timing and exploitable biomass level. Mortality on soft-shelled males can be minimized by fishing before soft-shell crabs are capable of climbing into traps and further reduced by maintaining a relatively high exploitable biomass level. When catch rates of large hard-shelled crabs are maintained at a high level soft-shell crab encounters in the fishery are consistently low. The high soft-shell prevalence in the late stages of the fishery in some recent years highlights the risk associated with continuing to fish when catch rates of hard-shelled crabs are low. In the case of the Div. 2J fishery, data from 2005, 2011, and 2012 suggest that soft-shell crabs begin to become more prevalent when fishery catch rates drop below about 7 kg/trap (Fig. 44).

The soft-shell protocol was introduced in 2005 to protect immediate pre-recruits from handling mortality by closing localized areas (70 sq. na. mi. grids) for the remainder of the season when a threshold level of 20% soft-shell, of the legal-sized catch, is reached. However, it has become evident that this protocol, as implemented, is inappropriate and ineffectual in controlling handling mortality. This is largely due to very low observer coverage, together with the decision to treat unobserved grids as if they had no problem. In addition, failure to draw inferences from samples smaller than the minimum required has frequently resulted in failure to invoke the protocol even when it is clear that the level of soft-shell crabs has exceeded the threshold. These shortcomings undermine the intent of the protocol. Also, when soft-shell crab is widespread, grid closures can result in concentration of fishing effort in other areas with high but unobserved prevalence. This is particularly problematic in Div. 2HJ where the fishery has become concentrated in two localized areas, the Hawke and Cartwright Channels, such that there is limited ability of fishing fleets to avoid areas of high soft-shell crab prevalence.

Measures should be taken to ensure representative observer coverage and analysis so as to better quantify prevalence of soft-shell crabs in the fishery.

An area of Hawke Channel has been closed to all fisheries except snow crab from 2003 to 2012 ("Hawke Box" - Fig.21). CPUE has trended similarly inside and outside the closed area since its inception (Fig. 45). The prolonged tight agreement of CPUE inside versus outside the closure implies that other fisheries that do not target snow crab do not represent a major source of snow crab mortality. A recent study on the effectiveness of this closed area concluded that the Hawke Box has failed to protect pre-recruit crabs largely due to an intensification of the crab fishery inside of it in the years surrounding closure. There were high discard rates of soft-shell crab, at 50-75% of the catch, during 2002-2004 leading to a long-term reduction in snow crab productivity in the Hawke Channel (Mullowney et al., 2012b).

Natural Mortality

BCD occurs almost exclusively in recently-molted crabs (Dawe, 2002, Mullowney et al., 2011). Overall, prevalence has generally been low in this area and most apparent in small new-shelled crabs of 40-59 mm CW with about 2-3%occurrence in most years, excepting 1999 and 2008, when 18% and 16% respectively of new-shelled adolescents, in that size group, were visibly infected (Fig. 46). BCD has been absent in Div. 2J in the past two years, consistent with a low density of small crabs and poor long-term recruitment prospects, which are being driven by the recent warm oceanographic regime.

DIVISION 3K OFFSHORE

The Fishery

The Division 3K offshore fishery occurs off the northeast coast of Newfoundland, predominately concentrated in the deep trenches of the Funk Island Deep and St. Anthony Basin, situated between near-shore shallow regions and the Funk Island Bank (Fig. 47). It incorporates CMAs 3BC, 4, and a portion of 3A. Landings most recently peaked at 13,300 t in 2009 but declined by 51% to 6,500 t in 2012 before increasing to 6,600 in 2013 (Table 4, Fig. 48). The TAC was fully subscribed in 2013 for the first time since 2009. Effort most recently peaked in 2009 and has since declined by 33% (Table 4, Fig. 48). Commercial CPUE (Table 4, Fig. 49) indicates substantial deterioration of fishery performance in recent years. It declined by half from 2008 to 2011 and increased slightly since 2012.

There have been notable changes in the distribution of the Division 3K offshore fishery in recent years with effort having been particularly intense during 2009-2012 and appearing to diminish slightly in 2013 (Fig. 50). The most distinctive increases, beginning in 2009, occurred in the northwest portion of the division, in and around the St. Anthony Basin, and throughout the Funk Island Deep in the central portion of the division. Along with a resource issue, as indicated by an inability to reach the decreasing TAC in most recent years, the broader-scale distribution of effort could be partly due to early season ice coverage (especially in 2009) or application of the soft-shell protocol which alters the spatial distribution of effort and may adversely affect fishery performance. These factors may have also contributed to an extension to depths greater than those usually fished, such as the mid portions of the Funk Island Deep, during the fishery of some recent years.

The temporal distribution of the fishery has changed little in the past three years and is earlier than it historically was (Fig. 51). The fishery, in recent years, has been completed by mid-June or early July (i.e. weeks 10-12).

Biomass

The exploitable biomass remains low relative to the late 2000s. A deterioration of fishery performance occurred throughout the division from 2008-12 but showed some slight improvements in most areas in 2013 (Fig. 52), most notably in the western portions of the offshore. The spatial coverage of the fishery has been inversely related to commercial CPUE since 1995 (Fig. 53). The percentage of available cells occupied by the fishery increased abruptly in 2009, exceeding 40% for the first time since 2004, and has since remained high (at about 38-45% each year) while CPUE has declined and remained at a low level.

VMS-based CPUE was higher throughout the season in 2013 than during the previous two years (Fig. 54). Although initial CPUE was low relative to most years, the index did not decline over time or with accumulating removals as it usually did, remaining at about 200 kg/hour during all weeks of the season. This could indicate the fishery did not deplete the resource as greatly during 2013 as in most recent years.

Size distributions from at-sea sampling by observers (Fig. 55) show that modal CW has not changed since 2007. Generally, successive decreases across the entire size range of legal-sized crabs occurred from 2007-11, with little change since. The decline occurred in both the new-shelled and old-shelled components of the legal-sized population but was particularly evident in new-shelled crabs beginning in 2009. The observed catch rates of legal-sized old-shelled crabs have changed little since 2010 while the catch rates of legal-sized new-shelled crabs have been at their lowest levels since observer sampling began (Fig. 56). This suggests a low and diminishing level of immediate incoming recruitment into the fishery in recent years.

The exploitable biomass, as indicated by the post-season trap and trawl surveys, declined by more than two thirds since 2008. The post-season trawl survey exploitable biomass index decreased from its highest level in the late 1990s to its lowest in 2003, before increasing to 2007 (Table 5, Fig. 57). The post-season trap survey exploitable biomass index increased in 2006. Both indices remained high to 2008. There is a suggestion from the spatial distribution of exploitable crabs in the trawl survey that the resource became increasingly concentrated in 2013 (Fig. 58) when exploitable crabs were near-exclusive to the western fringes of the St. Anthony Basin and Funk Island Deep.

Production

Recruitment

Recruitment declined after 2008 and prospects remain poor in the short term (2-3 years). Post-season pre-recruit biomass indices from both trap and trawl surveys have decreased by about 70% since 2008 (Table 5, Fig. 59). The decrease in pre-recruit abundance has occurred throughout the offshore (Fig. 60). This recent decrease in recruitment was likely exacerbated by a high handling mortality on soft-shelled immediate pre-recruits in the fishery, particularly in 2009 when the biomass index of new-shelled legal-sized crabs decreased abruptly by more than half (Fig. 61). Catches of new- and older-shelled exploitable crabs in both the trawl and trap (Fig. 62) surveys have since been more stable but continue to show overall decreasing trends.

Size frequency distributions from the post-season trawl survey (Fig. 63) showed a clear decrease across the entire size range of crabs from 2008-11, with a slight increase in abundance of smallest crabs (i.e. <30mm CW) in 2013. Although there is a high level of annual variability in distribution of abundance by size, there has clearly been a substantial decline in all sizes of crabs in the population over the nineteen year survey series. Productivity in the stock was lower throughout the 2000s than in the 1990s (Mullowney et al., 2014a). This is primarily a function of warming waters during that period. Large-mesh size frequency distributions from the shorter CPS trap survey time series agree in showing a clear dissipation of all sizes of crabs in the population since the mid-2000s (Fig. 64).

A lack of coherence in annual catch rate distribution and patterns in the small-mesh traps (Fig. 65) likely reflects the spatially limited distribution of these traps and deployment in depths beyond those normally associated with small crab habitat. Some of these trap locations were re-assigned in 2013 to try to improve congruence in this data series moving forward.

The observed catch rate of under-sized crabs in the fishery has changed little since at-sea sampling began in 1999 (Fig. 66), remaining about 1 kg/trap each year. Legal-size soft-shell crab discards have shown more variability and account for the bulk of discards in most years. Discards of these crabs were at a time series low in 2013. The previous lows of soft-shell incidence during 2006-2008 were associated with a high exploitable biomass (Fig. 59) and CPUE (Fig. 51) while the 2013 low is associated with a low exploitable biomass and CPUE. With no indication of a strong exploitable biomass to impede soft-shell crabs from trapping, this implies especially poor recruitment prospects for 2014.

In a positive response to the diminishing recruitment prospects, there appears to have been a reduction in the level of wastage occurring in the fishery. For example, the 2009 peak in soft-shell discards was associated with the abrupt decline in new-shelled legal-sized crabs in the fall trawl survey (Fig. 61), a pattern that was not repeated in 2013. Following the relatively high levels of discards in 2011-12, the 2013 biomass of recently-recruited crabs in the trawl survey remained at a similar level to the preceding four years.

A recent warm oceanographic regime suggests weak recruitment in the long term. The ocean climate indices have varied considerably over the past decade (Fig. 14-15), introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2010 and 2011. Although a looser fit than all other divisions, fishery catch rates have maintained a positive oscillatory relationship with the climate signal, most significant at an eight year lag (Fig. 15). This implies a relatively quick progression of crabs through successive sizes into the exploitable size group (i.e. 9 to 10 years from settlement to fishery) and a low level of skip-molting in these relatively warm waters (i.e. Dawe et al., 2012a) (Fig. 14).

Reproduction

The abundance of mature females captured by the multi-species trawl survey has been low in the past five years (Fig. 67) while the percentage of mature females carrying full clutches of viable eggs has remained high, at 80-100%, in all years. The recent decrease in abundance of mature females in the trawl survey has occurred throughout the offshore (Fig. 68). The implications of annual changes in abundance of mature females on production of early-life stages and subsequent recruitment are unknown.

Mortality

Exploitation

The trawl survey-based exploitation rate index was at its highest level since 2004 in 2010-2011 (Fig. 69). It decreased in 2012 before increasing again in 2013. Maintaining the current level of fishery removals would likely result in an increase in the exploitation rate in 2014.

Indirect Fishing Mortality

The pre-recruit fishing mortality rate index increased from 2007 to 2011 but decreased in 2012 before increasing again in 2013 (Fig. 69). The percentage of the catch handled and released in the fishery decreased from about 20% in 2012 to about 10% in 2013 (Fig. 69), implying a decrease in pre-recruit mortality. The increases in percent discarded during 2009-12 likely reflect the generally high levels of soft-shelled crabs encountered for long periods of the fishing season in some of those years, especially 2012 (Fig. 72). Since 2005, there has been a general trend for soft-shell crab occurrences to increase with time throughout the season. During 2012, weeks 8 through 12 (i.e. early-June to mid-July) all experienced soft-shell catch rates in the order of 20-95% of the catch. Grid closures due to the soft-shell protocol may have contributed to this situation. The massive expanse of fishing grounds in Div. 3K and associated high number of grids (i.e. several hundred potentially fished each year) coupled with low observer coverage makes effective application of the protocol especially difficult in this area and is probably helping to promote a continuation of fishing during periods of high soft-shell crab incidence.

A portion of the Funk Island Deep in the south of Div. 3K offshore (Fig. 47) was closed to gillnet fisheries in 2002 and all fisheries except snow crab during 2005-2013. The fishery had performed better inside than outside this area prior to its closure. Rather than increased CPUE, there has been little difference in fishery performance inside versus outside since 2005 (Fig. 71). This is likely due to large increases in snow crab fishing effort inside the exclusion area in some years since its implementation (Fig. 50). High levels of exploitation by the crab fishery are likely preventing this area from being effective at protecting pre-recruit crabs. This situation is similar to the outcome of the Hawke Box closure area in Div. 2J (Mullowney et al., 2012b), and re-iterates that levels of pre-recruit mortality imposed by other fisheries appear to be of little concern relative to the levels imposed by the crab fishery itself.

Natural Mortality

Prevalence of BCD, from multi-species trawl survey samples (Fig. 72), has been higher in this division than anywhere else. Maximum levels during 1996-1998, 2008, and 2013, were in the order of 8-20% in 40-75 mm CW new-shelled males. The high 2010 values were deemed anomalous due to Technician error. Prevalence had been virtually absent during 2011-12. Although the lower prevalence levels during 1998-2012 are consistent with a decline in the density of small crabs and reduced long-term recruitment prospects associated with the warming oceanographic regime (Mullowney et al. 2014b), the re-emergence of this density dependent disease in 2013 could indicate some forthcoming improvements, although more data are needed to verify.

There is concern by industry that increased predation by cod (*Gadus morhua*) has contributed to the recent declines in snow crab biomass in Division 3K. Although snow crab have been shown to contribute only minimally to the diet of cod in offshore portions of the northeast Newfoundland shelf (Dawe et al. 2012b), the importance of snow crab in the diet of cod showed a moderate increase in 2012 and little change in 2013. The recent increase seemed to be driven by an increase in the incidence of large cod (>65cm) eating snow crab in Div. 3K. Chabot et al. (2008) showed that cod gape size limited the ability of small cod to prey upon snow crab in the Gulf of St. Lawrence, with large crab (i.e. >65mm CW) virtually immune to cod predation. Accordingly, a lag of several years would be expected from the time any changes in predation on small crabs affects the exploitable biomass or fishery CPUE. Although climate appears to be the primary driver of snow crab resource declines (Mullowney et al., 2014a), the issue of predation could become more important if the abundance of large cod continues to increase.

DIVISION 3K INSHORE

The Fishery

The Division 3K inshore fishery occurs in CMAs 3B, 3C, and 3D in bays and adjacent to the northeast coast of Newfoundland (Fig. 73). Landings (Table 6, Fig. 74) have oscillated since

1995 with recent peaks in 2003 and 2009. They increased from 2,200 t in 2005 to 2,900 t in 2009. They declined by 34% from 2,900 t in 2009 to 1,900 t in 2012 and 2013. The TAC was fully subscribed in 2013 for the first time since 2009. Effort increased by 70% from 2008 to 2011 before declining by 40% to 2013 (Table 6, Fig. 74). Fishery CPUE has oscillated since 1990, most recently at a low in 2011 and is presently increasing (Fig. 75).

With limited room for spatial expansion in most CMAs, the fishing pattern has remained relatively consistent in recent years (Fig. 76). However, there have been notable changes in intensity in recent years, most notably an increase throughout Green and Notre Dame Bays (CMAs 3C and 3D) during 2010-11 that has since been reduced. The temporal distribution of the fishery has varied over the past five years, with 2011 and 2013 being early seasons (Fig. 77). In all years, the bulk of effort is expended by mid-late July (i.e. weeks 14-15), but in 2011 and 2013 the fishery was all but complete by about mid-June (i.e. weeks 10-11).

Biomass

Commercial CPUE (Table 6, Fig. 75) increased sharply from 2005 to a record high level in 2008, it declined by more than half from 2008 to 2011, and increased over the past two years. Spatiotemporally, CPUE in Green and Notre Dame Bays (CMAs 3C and 3D) has trended together and generally reflected the offshore, while the White Bay (CMA 3B) trend has behaved independently (Fig. 78). For example, a broad-scale decreasing trajectory was experienced throughout Green and Notre Dame Bays, along with the offshore, during 2009-11, with all areas since having realized modest gains. In contrast, White Bay has experienced more rapid and annually variable changes in CPUE, being at highs in 2008-09, 2011, and 2013, and at lows in 2010 and 2012. Spatially, these rapid ups and downs in CPUE have affected the whole of White Bay each year.

A high level of bias created by spatiotemporal inconsistency in the distribution of observer coverage among CMAs (Fig. 79) creates uncertainty in observer-based CPUE at the divisional level. CMA 3C (Green Bay) has received consistently high levels of observer coverage since the mid-2000s whereas the other CMAs have been more annually variable (Fig. 79). The screening criteria employed for this assessment was a minimum of four weeks coverage in any given CMA in any given year. When coverage was sufficient, observer CPUE trends have reflected commercial logbook CPUE in all areas and years (Fig. 80). The synchronicity of Green and Notre Dame Bays can be seen in the three oscillations that have occurred since the late 1980s, most recently reflecting a gradual improvement. Meanwhile, the spurious decline in White Bay in 2010 was associated with a high incidence of soft-shell crab in the fishery in that year, which resulted in early closure and the quota not fully subscribed. Observer data verify the substantial improvement in CPUE since then.

The spatial coverage of the fishery has been inversely related to commercial CPUE from 1996-2013 (Fig. 81). In recent years the fishery was most spatially broad-based with about 33% of the grounds covered in 2011. This has subsequently decreased to about 25% in 2013, in opposition to the improving trend in CPUE.

CPUE indices in this division show a pattern of depletion throughout the season in all recent years (Fig. 82). Trends in weekly commercial CPUE indicate that the fishery performed most poorly throughout the season in 2011, with 2012 and subsequently 2013 faring better in all weeks and at all levels of removals.

The exploitable biomass, as indicated by the post-season trap survey index, decreased from 2007 to 2009 and since fluctuated (Fig. 83). There is considerable variability among management areas over the time series, but all three areas experienced decreases in 2013. The 2009 and 2011 index values have been questioned in previous assessments due to low capture efficiency of traps, particularly in White Bay, in 2009 (Mullowney et al., 2013), and unusually long soak times and poor trap performance in 2011, again most specific to White Bay (Mullowney et al., 2014b). Despite the annual variability and uncertainty associated with annual index values, long-term trends are beginning to reflect the exploitable biomass trend in the offshore (Fig. 57), most recently at a high during 2006-2008.

Production

Recruitment

Recruitment prospects are poor in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased by more than half in 2013 to its lowest level in the time series (Fig. 84). The percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, has changed little in the past four years (Fig. 84).

The CPS trap survey catch rates of new-shelled legal-sized males, constituting immediate recruitment for the fishery, has changed little since 2004, remaining at about 6 kg/trap (Fig. 85). Size frequency distributions from the CPS trap survey (Fig. 86) have shown increases and decreases across the entire size range of crabs on an annual basis in recent years, which could reflect annually variable capture efficiency (i.e. q). For example, increases occurred in all sizes of crabs in 2010 and 2012 relative to their preceding years. Catch composition should not be affected by annual changes in capture efficiency, with the 2013 distribution being comprised of a higher proportion of older-shelled crabs in the population than the preceding five years, implying a reduced level of immediate recruits in the population.

Mortality

Exploitation

The trap survey-based exploitation rate index has changed little throughout the time series (Fig. 87). However, there was considerable variability among management areas, with the index decreasing sharply in one area (CMA 3B) while increasing in another (CMA 3C) in 2013. The unusually high value in White Bay (CMA 3B) in 2012 was a function of the anomalously low 2011 exploitable biomass index. Maintaining the current level of removals would likely result in little change in the exploitation rate in 2014.

Indirect Fishing Mortality

Spatiotemporal inconsistencies in the distribution of observer coverage do not allow for a reliable index of discards at the divisional level. Data are insufficient to estimate the pre-recruit fishing mortality rate index.

Natural Mortality

BCD prevalence has been monitored by DFO trap surveys in White Bay and Notre Dame Bay (Fig. 88-91) since 1994. BCD has consistently occurred at much higher prevalence levels in these inshore Div. 3K trap survey samples than in the offshore Div. 3K Campelen trawl survey samples (Fig. 72). This likely reflects differences in catchability of diseased animals between traps and trawls (based on comparative trap/trawl sampling), but it may also in part reflect higher prevalence in inshore than offshore areas. In White Bay, prevalence has been periodic, with two distinct pulses of infection over the time series (Fig. 88). Peaks in prevalence have occurred in successively deeper strata at one to two year time lags. BCD prevalence patterns in White Bay are thought to reflect the relative abundance of small to mid-sized adolescents, and the time lag effect across strata likely reflects an ontogenetic movement of crabs to deeper waters over time (Mullowney et al., 2011). In 2009-2013, BCD prevalence in all three White Bay strata was low, likely indicating that a recent pulse of adolescents has now progressed through the most susceptible size range. In Notre Dame Bay, there have also been two pulses of infection (Fig. 89), but no clear difference in timing between strata as in White Bay. Prevalence originally peaked in 1996, and most recently in 2004-2006. Interestingly, from 2006-2008, prevalence was highest in large adolescents in shallow stratum 611, as opposed to smaller adolescents in deeper stratum 610 (Fig. 89). The whole of Notre Dame Bay was not surveyed in 2009 and deep stratum 610 was missed in 2011 due to inclement weather, thus reliable interpretation of recent trends is not possible.

The suggestion that the most recent pulse of recruitment has now progressed through the population in White Bay can be seen in size-specific infection rates of crabs by stratum, with the 2004-2008 peaks having now dissipated (Fig. 90). This is not so clear in Notre Dame Bay where the shallow stratum 611 has shown oscillations, highest in 2006 and 2009 in adolescent males, but stratum 610 has been more steady-state (Fig. 91).

Spatial Variability: Trends by CMA

CMA 3B (White Bay)

There has been relative stability in the TAC since the mid-2000s, which has been maintained at 460 t since 2011, and no issues landing it with the exception of 2010 (Fig. 92). Effort had been constant at about 200,000 trap hauls per annum from 2005-2009 but has become variable since. This is reflected in CPUE, which has become sporadic in recent years, featuring a sharp decrease to 3kg/trap in 2010 followed by a non-uniform increase to a high level of 14 kg/trap in 2013 (Fig. 80). The 2010 phenomenon reflected a high incidence of soft-shell crab in the fishery and an early fishery closure. Observer sampling does not fully reflect the high incidence of soft-shell crab (Fig. 93), likely due to low coverage levels and biases in the deployment and sampling schemes. The 2013 in-season population showed a high abundance of both new- and old-shelled crab centred at a mode of about 101-107mm CW (Fig. 93-94). The recent lack of trend in fishery CPUE has corresponded to catch rates of new-shelled crabs in the CPS trap survey (Fig. 95), at a one year lag. The very high level of new-shelled legal-sized crabs in the 2012 CPS survey, followed by a return to a more normal level, is consistent with the DFO trap survey, which also showed exceptionally high catch rates of new-shelled legal-sized crabs in all three strata in 2012 (Fig. 96). Both surveys indicate that the abundance of older-shelled legal-sized crabs is now beginning to increase following the recruitment influx in 2012 (Fig. 95-96). Overall survey catch rates of legal-sized crab remain at a relatively high level. The agreement of the two surveys assures some confidence in expecting positive results from the fishery in the short term. Size frequency distributions from large-mesh traps in the CPS survey (Fig. 97) reflect the progression of modal size from about 90mm CW in 2009 to 104-107mm CW in 2012, indicative of the recruitment pulse that has entered into the exploitable size group. The subsequent aging of shells in 2013 suggests the recruitment pulse may now be near-fully entered into the exploitable size group. This appears consistent with the dissipating signal of under-sized adolescent crabs in small-mesh trap size frequencies from the DFO survey in recent years (Fig. 98). With no subsequent recruitment pulses evident in these data, recruitment is likely to decrease beyond the short-term. The sharp decline in percent discarded in the fishery in 2013 (Fig. 99), during which time there was little soft-shell, is also consistent with a reduction in the abundance of sub-legal-sized crabs in suggesting a forthcoming recruitment decline. Longer-term recruitment prospects are unknown, but decreased levels of BCD in small and intermediate-sized adolescents during the past five years (Fig. 88, 90) are congruent with the small mesh size frequencies in signaling a lack of small crabs in the population. The elevated BCD levels in 2005-2008 likely signified the emergence of the recruitment pulse that is presently contributing to the exploitable biomass. Observer discard data demonstrate that the anomalous drop in CPUE in 2010 was associated with an above normal level of soft-shell crabs (Fig. 100), which has not been an issue since.

The early closure of the fishery in 2010 was a proactive conservative measure that has been rewarded with a subsequent improvement in the fishery. The concern of a forthcoming recruitment decline due to a lack of small crabs in the population is not exclusive to White Bay. It is a broad-scale concern for the stock in virtually all areas of the NL shelf, driven by warming waters (Mullowney et al., 2014a).

CMA 3C (Green Bay)

TACs have been reduced in recent years from 740 t in 2009 to 495 t in 2013 (Fig. 101). Despite these reductions, the fishery has not taken the TAC in four years. However, effort has been greatly reduced during the past two years (Fig. 101) and fishery CPUE, which has oscillated since the late 1980s, has shown some improvements since the 2011 low (Fig. 80). Observer sampling shows the catch is consistently dominated by old-shell crabs (Fig. 102), and a persistent knife-edge effect occurs at legal-size in size frequency distributions in recent years (Fig. 103). This suggests a very high level of exploitation in this area. There had been discrepancies between in-season fishery and post-season survey trends from 2009-11, with an increasing signal in abundance of new-shell legal-sized crabs in the CPS survey (Fig. 104-105) that did not conform with the deterioration of the fishery. However, survey data now show a depleted resource in the past two years, with catch rates at about 3 kg/trap. The reasons for the discrepancies between in-season and post-season catch rate indices in those years are unknown. Small-mesh traps in the CPS survey (Fig. 106) indicate that the majority of a pulse of adolescents that had been approaching legal-size during 2010-2011 terminally molted as under-sized adults during the past two years. Consistently, observer sampling shows that most of the sub-legal-sized crabs captured in the fisheries of recent years are old-shell, and discards in 2013 wear near-exclusive to under-size old-shell crabs (Fig. 107). The percentage of the catch discarded has been consistently high, at or above 30% in all years (Fig. 107). An analysis of weekly percentages of soft-shell crab in the fishery reveals a situation whereby soft-shell crab incidence remained very low throughout the season in 2013 while fishery catch rates were low (Fig. 108). This does not bode well for short-term recruitment prospects, as one would expect soft-shell crab, if they were sufficiently present, to start trapping under such low fishery catch rates. Overall, most data suggest there has not been a high level of recruitment in this area since the mid-2000s and prospects are poor in the short term. Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

CMA 3D (Notre Dame Bay)

TACs have been reduced from 1730 t in 2009 to 968 t in 2013 and the fishery took the TAC in 2013 for the first time in four years (Fig. 109). Total effort did not decline with the reductions in removals during 2009-2011 but has in the past two years. Accordingly, CPUE, which has oscillated since the mid-1980s, has shown some marginal improvements in the past two years (Fig. 80). Observer sampling suggests that the improvement in CPUE is attributable to the emergence of a recruitment pulse into the exploitable biomass, with increased catch rates of soft-shell legal-size crab in 2011 followed by increased catches of new-shelled crabs during the past two seasons (Fig. 110-111). This is consistent with the CPS survey which has captured more new-shelled legal-sized crabs in the past two years (Fig. 112). Data from the DFO trap survey have been incomplete in some recent years but indicate a large increase in catch rates of new-shelled legal-sized crabs from 2010 to 2012 and a considerable decrease in 2013 (Fig. 113). Large-mesh trap size frequencies from the CPS survey show relative consistency, or slight increases, in the abundance of most sizes of legal-sized crabs in the past three years (Fig. 114), while small-mesh traps from the DFO survey showed increased catch rates of legal-sized and sub-legal-sized adolescents in 2012, particularly in deeper stratum 610 (Fig. 115). Together, these surveys are suggesting a slight increase in recruitment recently. However, short-term prospects do not appear to be promising. Observer discard monitoring shows that most of discards have been under-sized crabs in the past two years, and the overall catch rate of those has now declined to a very low level (Fig. 116). Furthermore, an analysis of weekly percentages of soft-shell crab in the fishery reveals a situation whereby soft-shell crab incidence remained very low throughout the season in 2013 while fishery catch rates were relatively low (Fig. 117). This does not bode well for short-term recruitment prospects. One would expect soft-shell crabs, if they were sufficiently present, to start trapping under such low fishery catch rates, particularly in the late season. Overall, the prognosis for this area is poor in the short term. Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

DIVISION 3LNO OFFSHORE

The Fishery

The Division 3LNO offshore fishery occurs on and surrounding the Grand Bank off Newfoundland's southeast coast (Fig. 118). It is a massive, shallow, cold, and productive environment that encompasses CMAs NS, MS, MSex, 3Lex, 3Lex3N, 3Lex3O, 8B, 3L200, 3N200, and 3O200. Since the late 1990s, there have been an estimated 1.2-2.2 million trap hauls per annum, with this division alone accounting for 40-50% of landings from the Newfoundland and Labrador region. Landings decreased by 11% from 24,500 t in 2006 to 21,900 t in 2009 and then increased by 20% to 26,300 t in 2013 (Table 7, Fig. 119). Effort increased by 83% from 2000 to 2008 and has since declined by 32% (Table 7, Fig. 119). VMS-based CPUE declined to its lowest level in 2008, and has since increased steadily to its highest level in the time series (Table 7, Fig. 120).

Since 2008, most of the effort has been expended across the northern portion of the Grand Bank and along the Div. 3N slope edge (Fig. 121). There have been some minor changes in the distribution of fishing in recent years, such as a reduction in effort in the extreme northern portion of the area along the Div. 3KL line, the emergence of a pocket of effort in the central portion of the Grand Bank to the northeast of the Whale Deep, and an increase in effort inside of the Whale Deep area of Div. 3O. With the exception of 2010, the fisheries of the past five years have been similarly timed, beginning in early- to mid-April (i.e. weeks 1-2) with most effort expended by early- to mid- July (i.e. weeks 14-15) (Fig. 122).

Biomass

In 2010, notable increases in CPUE occurred across most of the northern Grand Bank and along the Div. 3N slope while declines occurred in the Whale Deep (Fig. 123). Since then, further increases have occurred in most of the area with virtually the entire northern expanse and eastern slope edges experiencing very high catch rates, while the Whale Deep and central portions of the Grand Bank have continued to perform poorly. The spatial coverage of the fishery has been inversely related to commercial CPUE since 1999 (Fig. 124). The percentage of available cells occupied by the fishery increased from 2006-09 as CPUE declined, but since decreased while CPUE has increased.

VMS-based CPUE has shown a great deal of weekly variability during the past five years but was clearly higher in 2013 than in any of the previous four seasons (Fig. 125). There has been no suggestion of resource depletion, during the fishery, in any of the past five years, with no decline in CPUE as removals have accumulated. In 2013, fishery CPUE remained above 500 kg/hour while over 20,000 t of snow crab was removed.

Size distributions from at-sea sampling by observers reflected a platykurtic population in 2007, with no obvious primary mode (Fig. 126), but the shape and magnitude of the distributions has changed substantially since. In 2008, there was a shift in concentration, with a primary mode occurring at about legal-size. This shift coincided with an increase in the magnitude of catch rates for crabs from about 80-98mm CW, likely indicating the entry of a recruitment pulse into legal size. Since then, the mode has gradually progressed to about 104-107mm CW and catch rates of all sizes of legal-sized crabs have increased. There appears to have been a continued slow progression of recruitment into the exploitable population and establishment of a strong residual biomass over the past four years. Observer sampling data indicate that a relatively large increase in CPUE in 2010 was primarily due to an increase in new-shelled legal-sized crabs (Fig. 127), which remained similar in magnitude until 2012 before decreasing in 2013, when the proportion of old-shell animals increased. The sharp 2012 increase in CPUE was due to increased catch rates of old-shell crabs, which now comprise a higher proportion of the population. This suggests that most of the recent recruitment pulse has moved into the exploitable size group.

The indices of exploitable biomass from post-season trap and trawl surveys diverged during 2009 to 2011 with the trap index increasing and the trawl index declining (Table 8, Fig. 128). However, both indices have since increased slightly. It is believed that the trend in the trap survey index better reflects the trend in the exploitable biomass because it is supported by the increasing fishery performance during that time (Fig. 120). The trawl survey index (Table 8, Fig. 128) may have been inflated during 2008-2010 by increased survey trawl efficiency. Spatially, there has been little change in the distribution of exploitable crabs captured in the trawl survey in recent years, with highest catch rates occurring along the northern portion of the Grand Bank and along the Div. 3N slope (Fig. 129), consistent with the spatial pattern of fishery performance (Fig. 123).

Production

Recruitment

Biological data from several sources indicate that recruitment will likely decrease in the short term. There is no evidence of any increase in the pre-recruit biomass indices in the past three years (Table 8, Fig. 130), with decreases in abundance of pre-recruit crabs throughout the division (Fig. 131). Crabs that comprised the basis of the high pre-recruit indices during 2008-10 have now grown and are contributing to the high biomass of new-shelled legal-size crabs in the exploitable size group, evident in both the trawl (Fig. 132) and trap (Fig. 133) surveys. This can be seen in size frequency distributions from the trawl surveys, which indicate that a modal group of adolescents present in 2008-10 has now fully recruited to the exploitable size group (Fig. 134). The trap survey similarly reflects this, with a reduction in abundance of under-sized soft- and new-shelled crabs in the past three years in large-mesh size frequency distributions (Fig. 135). Further, there is no indication of another emergent mode of very small (<40 mm CW) males in the trawl survey, that last peaked in 2001-2003, representing the most recent recruitment pulse (Fig. 134). Finally, there has been no evidence of another incoming recruitment pulse in small-meshed trap size distributions, which clearly showed progression of the most recent recruitment pulse (Fig. 136).

The inference of a decline in short term recruitment is further supported by data from observer at-sea sampling that showed a decline in the percentage of the catch discarded since 2008 (Fig. 137). The reduction in catch rates of soft-and new-shelled crabs in the discard data stress the point that there are now fewer potential pre-recruit crabs in the system.

Beyond the short term, things are less clear. The 2013 small-mesh size frequencies in the CPS trap survey are showing the emergence of another recruitment pulse of small males centred at 47-50mm CW (Fig. 136). This mode is not detected in the trawl survey (Fig. 134). More data are needed to verify if this apparent large pulse of adolescent crabs will become widespread, as the spatial distribution of these traps in the survey is limited and this signal is currently being near-fully driven by a few stations near the Whale Deep in Div. 3O.

A recent warm oceanographic regime suggests weak recruitment in the long term. The ocean climate indices have been highly variable in recent years (Fig. 14-15). It is unknown how this variability will affect incoming recruitment. The best-fit lag of 10 years between the climate and CPUE indices implies a relatively long lead time from settlement to exploitable size (i.e. 11-12 years). This likely reflects a high degree of skip-molting in these relatively cold waters (i.e. Dawe et al., 2012a) (Fig. 14). A similarly long lead time occurs in the Southern Gulf of St. Lawrence, physically akin habitat to the Grand Bank (i.e. large, shallow, cold expanse), where it can take twelve or more years for male snow crab to grow to commercial size (DFO, 2014).

Reproduction

The abundance of mature females has been near its lowest level for four consecutive years (Fig. 138). The percentage of mature females carrying full clutches of viable eggs has exceeded 80% from 2002-2010 but been at lower levels of 60-70% in two of the past three years (Fig. 138). It is unknown what effect, if any, a reduced level of abundance and/or fecundity will have on future stock productivity as it is not known to what extent larval supply regulates stock size.

Mortality

Exploitation

The exploitation rate index increased decreased marginally in 2013 (Fig. 140). Maintaining the current level of removals would likely result in little change in the exploitation rate in 2014.

Indirect Fishing Mortality

The pre-recruit fishing mortality rate index decreased from 2008 to 2011 , increased in 2012 and changed little in 2013 (Fig. 140). The percentage of the catch handled and released in the fishery decreased from about 20% in 2008 to 9% in 2013 (Fig. 140), implying a decrease in pre-recruit mortality.

The threshold for soft-shell crab closures was changed from 20% to 15% in 2009 in Div. 3LNO. The prevalence of soft-shelled crab in the catch throughout the season is typically negligible until mid- to late-July (i.e. week 15-16) (Fig. 141), later than in Divs. 2J or 3K. (Fig. 44, 70). Soft-shell crab prevalence tends to increase slightly near the end of the season each year but does not commonly approach levels to invoke fishery closures. This likely reflects the persistence of a healthy residual biomass of large males in this area. Logically, there must be a high abundance of soft-shell crab in this area to sustain such a large population of crabs and fishing pressure, yet it is rarely observed.

Natural Mortality

BCD generally occurs at lower levels in Div. 3L than in Div. 3K, and has been virtually non-existent in Div. 3NO. Prevalence (in new-shelled males) from offshore Div. 3L fall multi-species trawl surveys (Fig. 142) has been variable, with highest incidence during the early- to mid-2000s. The high prevalence levels during the mid-2000s were likely reflective of a high density of 40-75mm CW crabs, which subsequently materialized into the recent recruitment pulse that has enhanced the exploitable biomass. The lower prevalence levels of recent years are consistent with the decreased short- and long-term recruitment prospects resulting from a warming oceanographic regime.

DIVISION 3L INSHORE

The Fishery

The Div. 3L inshore fishery occurs in coastal bays and near-shore regions of the east coast of Newfoundland, within 25 nm of headlands (Fig. 143). It incorporates CMAs 5A, 6A, 6B, 6C, 8A, and 9A. All but CMAs 6C and 8A are further sub-divided into inner and outer management areas. Landings increased by 19% from 6,100 t in 2005 to 7,300 t in 2010, and have since changed little, at 7,600 t in 2013 (Table 9, Fig. 144). Effort increased from 2008 to 2010 and has since declined steadily (Table 9, Fig. 144). CPUE increased sharply since 2011 to its highest level, after varying about the long term average for the previous 5 years (Table 9, Fig. 145). There has been little change in the distribution of the fishery over the past six years (Fig. 146), but subtle changes include a reduction of effort in the outer portion of Bonavista Bay (CMA 5A) in the past three years, and the emergence of effort in the outer portion of St. Mary's Bay (CMA 9A) coupled with a reduction of effort inside the Bay since 2009. Most of the bays and coastal areas of Div. 3L receive considerable fishing effort each year, with little room for expansion within most CMAs. The temporal distributions of the 2011 to 2013 fisheries were very similar, and earlier, than in 2009-10 (Fig. 147). The fishery has typically commenced in mid-April and most effort has been expended by about the end of June in recent years (i.e. week 12).

Biomass

CPUE increased to its highest level since 1995 in 2013 (Table 9, Fig. 145). This increase reflects increased catch rates throughout most of the division (Fig. 148). All bays, particularly the outer portions of them, had relatively high catch rates in 2013. This is indicative of an overall broad-scale trend that has occurred throughout the offshore region of Div. 3LNO as well (Fig. 123).

A high level of bias created by spatiotemporal inconsistency in the distribution of observer coverage among the inshore CMAs (Fig. 149) creates uncertainty in observer-based CPUE at the divisional level, and does not allow for interpretation of observer-based CPUE in some individual CMAs. It also creates gaps in some years within CMAs where data series' are adequate for analysis (Fig. 150). In 2013, the deployment scheme was particularly inadequate for assessment purposes. Only one CMA (8A) met the criteria of a minimum of four weeks coverage, and this area did not have an established time series for comparative analyses. Accordingly, no observer data were used in the assessment of this division this year. The reasons for the deficiencies in the spatiotemporal observer deployment scheme in 2013 are unknown.

There has been a general inverse relationship between the areal extent of the fishery and commercial CPUE since 1995 (Fig. 151). The sharp increases in CPUE in 2012, and subsequently in 2013, were opposed by a reduction in areal extent of the fishery. However, overall, there has been limited change in the spatial extent of the fishery since 2002. The areal distribution consists of two distinct levels, with about 30-45% of available cells occupied each year from 1995-2001 and about 60-80% of cells occupied each year thereafter. This is attributable to an expansion of effort throughout the inshore of Div. 3L beginning in 2002, which was most pronounced in coastal regions of the Northeast Avalon and the western half of Conception Bay (Dawe et al., 2003). This sharp increase in spatial coverage of the fishery in 2002 was followed one year later by a sharp decrease in CPUE (Fig. 145), and the fishery has only recently begun to experience catch rates comparable to the pre-expansion period.

CPUE indices have typically shown a pattern of depletion throughout the season in recent years (Fig. 152). CPUE tends to be highest at the beginning of the season, ranging from about 12-16 kg/trap, and declines thereafter, generally finishing at about 8 kg/trap (Fig. 152). The 2012 and 2013 fisheries performed better throughout the season than the 2009-2011 fisheries, in relation to fishery weeks and cumulative removals (Fig. 152), and the slopes of the curves appear lower, implying less depletion of the exploitable biomass by the fishery in the past two years.

The post-season trap survey index suggests that the exploitable biomass increased steadily since 2008 to its highest level in the time series, with considerable variability among management areas (Fig. 153). With the exception of Bonavista Bay (CMA 5A), the CMA-specific indices are high in all areas compared to the time series established since 2004. In 2012 the greatest increase occurred in Conception Bay (CMA 6B) while in 2013 the greatest gain was realized in Trinity Bay (CMA 6A).

Production

Recruitment

Recruitment has declined slightly since 2010, although there is considerable variability among management areas, and is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in 2013 (Fig. 154). The pre-recruit biomass index in this area is dominated by old-shelled crabs and their proportion has increased in recent years, particularly in 2012-2013 (Fig. 154). It is believed that most of those are terminally-molted and will never contribute to the exploitable biomass.

The recent decline of recruitment as crab move into the exploitable size group can be seen by catch rates of new-shell legal-size males, which most recently peaked in 2010 (Fig. 155). This has subsequently been followed by increases in old-shelled males, with the 2013 level the highest in the time series (Fig. 155). The increases in exploitable biomass appear to be more a function of a high residual biomass than incoming recruitment. A mode of new-shelled crabs present at 92mm CW in 2010 and 2011 has now progressed into legal-size and the proportion of new-shelled crabs in the catch has dissipated across the entire size range in the past two years (Fig. 156). This is consistent with the most recent recruitment pulse now near-fully contributing to the exploitable biomass, as also seen in the offshore (Fig. 135-136).

Mortality

Exploitation

The post-season trap survey-based exploitation rate index has changed little over the time series, with considerable variability among management areas (Fig. 157). Maintaining the current level of fishery removals would likely result in little change in the exploitation rate in 2014.

Indirect Fishing Mortality

Spatiotemporal inconsistencies in the distribution of observer coverage do not allow for a reliable index of discards at the divisional level. Data are insufficient to estimate the pre-recruit fishing mortality rate index.

Natural Mortality

The trend in prevalence of BCD from the DFO trap survey in Conception Bay (Fig. 158) was somewhat similar to that from the multi-species trawl surveys throughout offshore Div. 3L (Fig. 142), but at higher levels of prevalence, with highest prevalence during 2004-2005. Prevalence generally increased to 2000 before decreasing sharply in 2001. It increased during 2002-2005 before decreasing to 2007 and remained low since. The elevated prevalence levels of 2003-2006 are consistent with the subsequent improvements in exploitable biomass and fishery performance in recent years.

Spatial Variability: Trends by CMA

CMA 5A (Bonavista Bay)

TACs and landings have been regularly maintained at about 1,100-1,400 t throughout the 2000s, with the exception of 2007-2010 when 1,500-1,600 t of crabs were removed annually (Fig. 159). These increased removals were initially associated with stable effort (Fig. 159) and increased CPUEs (Fig. 150), but effort began to increase and catch rates to decline in 2009. Effort peaked and CPUE was most recently at a low in 2011, but effort has since decreased and CPUE has increased over the past two years. The recently improved CPUE has been associated with an increase in recruitment into the exploitable size group, evident by large increases in catch rates of new-shell legal-size crabs in both the CPS (Fig. 160) and DFO (Fig. 161) trap surveys in 2011. The large recruitment influx of 2011 occurred across the entire size range of crabs (Fig. 162). Subsequently, the proportion of old-shell crabs in the catch has increased across all sizes. This recruitment event resulted in the 2012 exploitable biomass index achieving a recent high (Fig. 153), but the 2013 index is down and there is uncertainty regarding recruitment prospects in the short term. Although large-mesh traps in both surveys show a marked decrease in catch rates of new-shell legal-size crabs since 2011, at about 2009-2010 levels, small-mesh trap size frequencies in the DFO survey indicate potential for another group(s) of adolescent males to contribute to the exploitable biomass in the near future; a strong signal of adolescent males was present from about 77-104mm CW in 2013. Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

CMA 6A (Trinity Bay)

TACs and landings have been increasing since 2009, to historical highs of about 1,200-1,300 t in recent years (Fig. 164). However, this increased pressure on the resource has been opposed by steady or declining effort (Fig. 164), and CPUE has gradually increased to about 11 kg/trap during the past two years (Fig. 150). Resource status has been difficult to assess from large-mesh traps in the CPS survey in recent years, especially with the lack of trend in new-shell legal-size crabs (Fig. 165-166). The gradual increase in catch rates of old-shell crabs in the survey (Fig. 165) is consistent with trends occurring with fishery CPUE and in the broader scope of resource status in Divisions 3LNO inshore and offshore in general. Although there is annual variability in catch rates in the CPS survey, modal analysis from both large- (Fig. 166) and small-mesh (Fig. 167) traps indicates a recruitment pulse has progressed into the exploitable size group from about 2008-10, which is responsible for the high estimate in the exploitable biomass index in 2013 (Fig. 153). The entry of this recruitment pulse can be seen from the modal shift in new-shell legal size crabs in large-mesh traps, from about 95mm CW in 2008 to 100mm CW in 2011, and a subsequent aging of shells for most individuals in the population (Fig. 166). This recruitment pulse had been tracked in small-mesh size frequency distributions since 2005, when it was centred at about 60mm CW. With the last strong signal from this pulse occurring in 2010, when the mode was centred at about 86mm CW, it appears recruitment will decline in the short term. This scenario of a recently improving exploitable biomass and diminishing short term recruitment prospects is consistent with virtually all areas of Divisions 3LNO. Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

CMA 6B (Conception Bay)

Fishery data are very positive. TACs and landings have gradually increased from about 1,100 t in 2004 to 1,500-1,600 t in 2013 (Fig. 168). This has been associated with steadily declining effort (Fig. 168) and increasing CPUE (Fig. 150), which reached a historical high of 19 kg/trap in 2013. The exploitable biomass index has been very high in the past two years (Fig. 153), associated with high catch rates in both the CPS (Fig. 169) and DFO (Fig. 170) trap surveys. Both surveys are consistent in showing increases in catch rates of old-shell legal-size crabs in recent years, but there is disagreement in the signal of new-shell legal-size (i.e. recently recruited) crabs. This could reflect spatial inconsistency, with the DFO survey isolated to a single stratum in the inner portion of the bay and the CPS survey more spatially encompassing. Despite the biomass being high and the fishery performing at a high level in recent years, it has not been possible to track modes or recruitment pulses in either large- (Fig. 171) or small-mesh (Fig. 172-173) traps from either survey. The catches have consistently been dominated by adult crabs, even for under-sized individuals, since 2007 when the last strong signal of adolescents was present. Although the reason for this phenomenon is unknown, it could reflect a high level of competition for baited pots, with a high abundance of adult crabs across the entire size distribution in this bay prohibiting small adolescents from trapping. All size frequency distributions indicate the abundance of legal-sized adult crabs has increased over the past three years. The disagreement in trend of catch rates of new-shell legal-size crabs between the two surveys (Fig. 169-170) makes projection of short term recruitment prospects uncertain and long-term recruitment prospects are unknown, although broad-scale climate indices are not favourable.

CMA 6C (Northeast Avalon)

TACs and landings have remained relatively fixed at 1,400-1,600 t since 2005 (Fig. 174). During that time effort plateaued at a high in 2009-10 but since decreased by half (Fig. 174). CPUE about doubled from 2010-12 and remained at a high level of 15 kg/trap in 2013 (Fig. 150). The recent increases in CPUE were associated with increasing catch rates of both new- and old-shelled legal-sized crabs in the CPS survey from 2008-12 (Fig. 175), which led to the exploitable biomass being at its highest levels since the trap survey began during the past two years (Fig. 153). Although the exploitable biomass remains high, recruitment into it is expected to occur in the short term, with a sharp decrease in the abundance of new-shell legal-size crabs in the 2013 survey (Fig. 175) accompanied by a decrease in the abundance of potential pre-recruits. This can be seen by the four year decline in the pre-recruit biomass index in this area (Fig. 154) as well as a dominance of old-shell crabs in pre-recruit-sized (i.e. 76-94mm CW) animals in 2013 (Fig. 176), which are likely terminally-molted. Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

CMA 8A (Southern Avalon)

TACs and landings have increased from about 800 t in 2005 to 1,200 t in 2012-13 (Fig. 178). This has been associated with effort that has increased markedly, doubling from 2006 to a historical high in 2013 (Fig. 178). CPUE in this area remains high (i.e. > 15 kg/trap), but with a presently declining trend this management area is countering the catch rate trends observed in all other inshore areas (Fig. 150) as well as the broader scope of the offshore (Fig. 123). The inference is that the fishery has been particularly aggressive in this area. An assessment of resource status from the CPS trap survey in this area is not possible due to incoherence and annually rapid fluctuations in catch rates of all sizes of crabs (Fig. 180). Short- and long-term recruitment prospects are unknown.

CMA 9A (St. Mary's Bay)

TACs and landings have steadily increased from about 200 t in 1999 to 700 t in 2013 (Fig. 181). Effort has grown steadily during that period but CPUE has remained between 15-22 kg/trap each year (Fig. 150). A recent recruitment pulse that has contributed to the recently increasing exploitable biomass (Fig. 153) has now near-fully entered into legal size, clearly evident is both large-(Fig. 183) and small-mesh (Fig. 184) size frequency distributions. Recruitment prospects are poor in the short-term. The reduction in the pre-recruit biomass index in the past four years (Fig. 154) reflects the dissipation of a large pulse of recruitment. The mode of adolescents that had been centred at about 77mm CW in 2009-10 is now at about legal-size and greatly reduced in abundance (Fig. 184). Long-term recruitment prospects are unknown, but broad-scale climate indices are not favourable.

SUBDIVISION 3PS OFFSHORE

The Fishery

The Subdiv. 3Ps offshore fishery occurs off the south coast of Newfoundland in shallow areas associated with the St. Pierre and Green Banks (Fig. 185). It incorporates CMAs 10BCD, 10X, 11S, and 11Sx. Landings (Table 10, Fig. 186) almost doubled from 2,300 t in 2006 to a peak of 4,200 t in 2011, before declining by 16% to 3,500 t in 2013. Effort (Table 10, Fig. 186) increased by 76% from 2008 to a record high level in 2013. CPUE increased from 2005 to 2009 and has steadily declined since, to about its previous lowest level (Table 10, Fig. 187). There is strong agreement among all three indices on the trend in CPUE since 2004.

The spatial distribution of the fishery has remained similar over the past six years (Fig. 188) but there have been some subtle changes. In most years, the bulk of fishing effort is expended in the Halibut Channel between the St. Pierre and Green Banks (Fig. 188). In 2012-13 pockets of effort emerged in a previously un-fished area in shallow water along the southern tip of the St. Pierre Bank as well as in the northeastern portion of the division along the Div. 3O boundary line. Effort has also been less intense in the outermost portion of the Halibut Channel, along the edges of the St. Pierre and Green Banks, in recent years. The fishery in Subdiv. 3Ps offshore tends to occur earlier than in northern divisions due to a lack of spring ice coverage off the south coast. However, the temporal distribution of the 2013 was delayed relative to most recent years, not starting until the third week of April (Fig. 189). This was due to a price dispute. The fishery ended by about the end of June (i.e. week 12-13), similar to most years.

Biomass

Declines in CPUE occurred throughout the offshore in the past three years but have been most extreme in the furthest offshore areas (Fig. 190). The offshore fishery has performed much worse than the inshore fishery in recent years. The spatial coverage of the fishery has generally been inversely related to commercial CPUE since 1999 (Fig. 191). The percentage of available cells occupied by the fishery increased steadily from 1995 to an initial peak in 2002. It then declined gradually in 2003 and 2004 before increasing sharply to its highest level of 75% in 2005. This is likely attributable to a high incidence of soft-shelled crab in the fishery in 2005 (Dawe et al., 2006). The spatial index declined sharply in 2006 but has since steadily increased to a recent high. This indicates an increased element of searching activity by harvesters in recent years.

Catch rates have shown high levels of weekly variability, but generally reflect a pattern of the fishery performing poorer throughout the duration of the season in the past two years than it did in the previous three (Fig. 192). In terms of cumulative removals, the 2013 fishery performed most poorly within the five year time series, particularly during the early portion of the season (Fig. 192).

Size distributions from at-sea sampling by observers (Fig. 193) show an exploitable biomass that has become depleted in recent years. There was little change in the shape or magnitude of the distributions during 2008-10, but since then the abundance of most sizes of legal-size crabs has become progressively reduced each season. The catch was also dominated by new-shell crabs in 2013, indicative of the fishery becoming more highly dependent upon immediate recruitment, with an erosion of the residual component of the exploitable biomass. In terms of total catch, observer sampling shows a population that was most recently at a high from about 2008-11 and is now in decline (Fig. 194). This secondary high in abundance was much lower than the initial high of the late 1990s and early 2000s and was associated with much lower fishery catch rates (Fig. 187). However, quota and removal levels were very similar between the two periods (Fig. 186). Nonetheless, despite prosecution being more aggressive in the most recent period the fishery has consistently avoided soft-shell crab encounters (Fig. 193-194), implying efficient exploitation of the resource in terms of yield-per-recruit.

The exploitable biomass, as indicated by both the spring trawl survey and the post-season trap survey indices, increased steadily from 2006 to 2009 before declining rapidly to its lowest level in 2013 (Table 11, Fig. 195). Both surveys indicate the biomass decreased throughout the area since 2009, particularly abruptly in 2013 (Fig. 195). Spatially, the decline occurred first in the furthest offshore areas and followed in succession shoreward (Fig. 196). Few exploitable crabs were captured anywhere in the trawl survey in 2013.

Production

Recruitment

Recruitment has recently declined and is expected to decline further in the short term (2-3 years). Pre-recruit biomass indices from both trap and trawl surveys declined sharply from 2009 to their lowest levels in 2013 (Table 11, Fig. 197). Similar to exploitable crabs, both surveys are consistent in showing the decline (Fig. 197), and there is a general pattern of decreasing catch rates of pre-recruit crabs occurring first in the furthest offshore areas and eroding successively shoreward since 2009 (Fig. 198).

This recent decline in recruitment is reflected in a decrease in biomass of new-shelled legal-sized crabs beginning in 2010 and the subsequent decrease in older-shelled beginning in 2011. This phenomenon is apparent in both the trawl (Fig. 199) and the CPS trap (Fig. 200) surveys. Total catch rates of exploitable-size crabs were at historical lows in both surveys in 2013.

Size distributions from the spring trawl survey showed a modal group of adolescent crabs, approaching legal-size in 2007-2009, that has since dissipated (Fig. 201). The advancement of this recruitment pulse into legal-size is also reflected in CPS trap survey size frequencies (Fig 202), which showed an increasing abundance of new-shelled crabs ranging from about 95-110mm CW during those years and a subsequent decline. The 2012-13 size frequency distribution portrays a greatly reduced abundance of all sizes of crabs in the population. In terms of absolute abundance, it is unknown how large the mode of crabs at about 18-24mm CW in the spring trawl survey during 2009-12 is due to poor capture efficiency by the survey trawl, but small-mesh traps in the CPS trap survey indicate the emergence of a mode of adolescent males centred at about 47mm CW in 2013 (Fig. 203). A similar phenomenon was seen in Div. 3LNO (Fig. 136), thus it is possible that the currently bleak short-term prospects could improve if this recruitment pulse is spatially broad-based and continues to build and progress through sizes in the next few years. At present, there is no indication of improved recruitment prospects for the fishery evident in the small-mesh size frequencies, with a low abundance of pre-recruit-sized crabs in 2013, virtually all of which were terminally-molted adults (Fig. 203).

A recent warm oceanographic regime suggests weak recruitment in the long term. Fishery CPUE is most significantly inversely related to the habitat index of bottom temperature at a lag period of seven years (Fig. 15). The temperature indices imply some variability in recruitment beyond the short term (Fig. 14-15). However, the overall trend is warming, with near record warm conditions in 2011. The best-fit lag of seven years implies a relatively quick progression of crabs from settlement to fishable size in this area (i.e. 8-9 years). However, a high percentage of crabs appear to terminally molt at small size in Subdiv. 3Ps (i.e. Fig. 203).

Reproduction

The abundance of mature females captured in the spring trawl survey increased sharply in 2002, and has since declined to a very low level (almost zero) during the past three years (Fig. 205). This reduction in abundance of mature females has occurred throughout the offshore (Fig. 206). There is high annual variability in the percentage of females carrying full clutches of viable eggs but it has remained above 80% each year since 2007 (Fig. 205). The reasons for the negative trends in abundance of mature females in recent years are unknown, and it remains unclear if it will have an effect on future stock productivity.

Mortality

Exploitation

The spring trawl survey-based exploitation rate index more than doubled from 2009-2012, before doubling again in 2013 (Fig. 207). Maintaining the current level of fishery removals would increase the exploitation rate in 2014.

Indirect Fishing Mortality

The pre-recruit fishing mortality rate index, as indicated by the spring trawl survey index, has increased steadily since 2009 to about its previous highest level (Fig. 207). The percentage of the total catch handled and released in the fishery declined from about 45% in 2005 to 20% in 2013 (Fig. 207), implying a decline in pre-recruit mortality. Thus, the recent increase in the PFMI reflects the declining pre-recruit biomass more than increased discard levels of under-sized crabs. The percentage of the catch discarded in Subdiv. 3Ps is generally higher than in other divisions as it includes a larger component of under-sized crabs, an unknown but high portion of which is comprised of small adults that will never recruit to the fishery. Soft-shelled crab has been consistently low in the observed catch in all years since 2005 (Fig. 208). The 2013 scenario of a low level of soft-shell crabs in the catch associated with low fishery catch rates in the late season does not bode well for recruitment prospects, as with a low level of competition one would expect soft-shell crabs to trap at this time if they were sufficiently present.

Natural Mortality

Small-meshed trap data from the CPS trap survey indicates that BCD has been detected, at low prevalence levels in offshore Subdiv. 3Ps in 2005-2006, but not in 2007-2013 (unpublished data).

SUBDIVISION 3PS INSHORE

The Fishery

The Subdivision 3Ps inshore fishery occurs in near-shore regions off the south coast of Newfoundland (Fig. 209). It incorporates CMAs 10A, 11E, and 11W. Placentia Bay (CMA 10A), to the east of the Burin Peninsula constitutes the primary fishing grounds. Landings (Table 12, Fig. 210) peaked at 3,500 t in 1999 and then declined to 2005. They more than tripled from 700 t in 2005 to 2,500 t in 2011 and remained at that level since. Effort declined substantially in 2005 and has since varied without trend (Table 12, Fig. 210). CPUE increased steadily from 2005 to 2010, changed little in 2011-2012, and then decreased slightly in 2013 (Table 12, Fig. 211).

The spatial distribution of the fishery has experienced only subtle annual changes over the past six years (Fig. 212). Most effort is expended in Placentia Bay (CMA 10A, Fig. 209) with Fortune Bay (CMA 11E, Fig. 209) representing a secondary source of effort. The commercial fisheries in CMAs 11E and 11W were closed in the 2000s but re-established in 2011. A small-scale monitoring fishery occurred each year in the interim. Within CMA 11E there has been an emergence of effort in a coastal fjord (known as Connaigre Bay) in the northwest of the management area since 2007 (Fig. 212) while effort in CMA 11W has been variable, being virtually non-existent from 2008-2009, with light effort since (Fig. 212). Meanwhile, a small fleet allocated quota on the northwest portion of the St. Pierre Bank that did not fish that area from 2006-2008 has resumed fishing along the slope edge during the past five years (Fig. 212). Temporally, similar to the offshore, the 2013 fishery was delayed relative to most previous years due to an industry price dispute. The fishery began in the third week of April and was finished by about late July (i.e. week14), several weeks behind the pace of recent years. As in the offshore, overall, the management shift toward a spring fishery has been more successful in Subdiv. 3Ps inshore than in most other divisions. This is likely attributable to the lack of spring ice cover.

Biomass

There had been little change in CPUE throughout most of the inshore during 2009-12, but in 2013 catch rates were notably lower throughout Placentia Bay (Fig. 214). A high level of bias created by spatial and temporal inconsistency in the distribution of observer coverage among the various CMAs (Fig. 215) creates uncertainty in observer-based CPUE at the sub-divisional level, and especially compromises interpretation of CPUE at the CMA level in all but Placentia Bay (Fig. 216). Observer data confirmed the marked decrease in CPUE in Placentia Bay in 2013.

The spatial coverage of the fishery has been inversely related to commercial CPUE since 1995 (Fig. 217), although the relationship has begun to erode in recent years. With about 14-16% of the grounds covered each year, the percentage of available cells occupied by the fishery has been unchanged in the past five years while the CPUE trend has been more dynamic.

Trends in commercial CPUE throughout the season (Fig. 218) indicate that 2013 CPUE was the lowest it's been since 2009 during all parts of the season. The difference between weekly values from 2012 to 2013 was the largest year-to-year directional change observed in the time series. Despite this drop in catch rates, however, there was no strong indication of severe depletion of the resource, with catch rates remaining constant in all weeks and at all levels of removals.

The exploitable biomass, as indicated by the post-season trap survey index, increased substantially between 2006 and 2010, changed little in 2011-2012, then decreased by half in 2013 (Fig. 219). A large decrease occurred in both Placentia and Fortune Bays.

Production

Recruitment

Recruitment decreased substantially in 2013 and is expected to remain low in the short term (2-3 years). The pre-recruit biomass has been declining since 2007 (Fig. 220). The pre-recruit biomass index includes a high and increasing proportion of small adults in this area that will never recruit to the fishery. The abundance of new-shell legal-sized males in the exploitable biomass has been highly variable in recent years but appears to have peaked in 2010 (Fig. 221). It was very low, at about 1 kg/trap in 2013. Meanwhile, the abundance of old-shell crabs in the survey has remained steady at about 4-5 kg/trap since 2008. Size frequency distributions from large-mesh traps in the CPS survey (Fig. 222) show the dissipation of a prolonged period (from about 2007-12) of incoming recruitment into the exploitable biomass in 2013, with nearly all crabs in the population being old-shell. Short term prospects appear poor while longer-term recruitment prospects are uncertain.

Mortality

Exploitation

The post-season trap survey-based exploitation rate index has changed little in the past six years (Fig. 223). Maintaining the current level of fishery removals would increase the exploitation rate in 2014.

Indirect Fishing Mortality

Spatiotemporal inconsistencies in the distribution of observer coverage do not allow for a reliable index of discards at the divisional level. Data are insufficient to estimate the pre-recruit fishing mortality rate index.

Natural Mortality (BCD)

Small-meshed trap data from the collaborative post-season trap survey indicates that BCD was occasionally detected, at low levels prior to 2004 in inshore Subdiv. 3Ps, but absent since (unpublished data).

Spatial Variability: Trends by CMA

CMA 10A (Placentia Bay)

Following a period when quotas could not be taken during the mid-2000s, TACs and landings have increased from about 900-1000 t in 2008 to 2,200 t in the past three years (Fig 224). Meanwhile, effort remained steady at about 140,000 trap hauls annually from 2008-12 before increasing in 2013. This resulted in a 25% decrease in CPUE in 2013, following a period of little change at a high level of 14-16 kg/trap from 2009-12 (Fig. 216). In-season sampling by observers showed a reduction in catch rates of old-shelled crabs in 2013 compared to the preceding two years, but the overall abundance of crabs remained high relative to the mid-2000s. The reduced catch rates in 2013 were most attributable to the largest crabs in the population, particularly those greater than about 101mm CW (Fig. 226). The extent of decrease was greater in the post-season trap survey, which showed a large decrease in the abundance of new-shell legal-size crabs in the population, which constitute immediate recruitment for the 2014 fishery, to a very low level of 1 kg/trap (Fig. 227). Meanwhile, the old-shell component of the exploitable biomass decreased in 2013 for the first time in four years. Size frequency distributions from the CPS survey indicate poor short-term recruitment prospects, with virtually no new-shell crabs in the mix, and a population becoming depleted, with reduced catch rates of all sizes of crabs. This reflects a lack of recruitment in recent years, evident by a lack of adolescents in the population since 2007, clearly visible in small-mesh size frequencies from the CPS survey. Furthermore, fishery discards have been comprised almost entirely of under-size old-shell crabs in recent years (Fig. 230), reflecting the lack of adolescents and recruitment in the population. Although the trend of virtually no soft-shell crab being encountered in the fishery in recent years (Fig. 231) reflects little wastage of the resource, it is also indicative of poor short term recruitment prospects. Longer term recruitment prospects are uncertain, but broad-scale climate indices are unfavourable.

CMA 11E (Fortune Bay)

A commercial TAC was re-established in 2011 following the designation of a monitoring fishery from 2004-2010 (Fig. 232). Landings in the area have been slowly increasing from 170 t in 2008 to 290 t in 2013 (Fig. 232) while effort has been unchanged and CPUE has been gradually increasing (Fig. 216). This reflects the growth of the exploitable biomass from 2009-12 as seen in both the CPS (Fig. 233) and DFO trap surveys (Fig. 234). However, overall survey catch rates decreased in both surveys in 2013. Size frequency distributions from large-mesh traps in the CPS survey show that the recent entry of recruitment into the exploitable biomass slowed in 2013 (Fig. 235), presumably due to diminishing contribution from the most recent pulse of adolescents that had been tracked in small-mesh size frequencies since 2005 (Fig. 236). The CPS small-mesh trap data indicate poor short term recruitment prospects, with few adolescent crabs captured since 2007, with the same phenomenon evident in small-mesh traps from the DFO trap survey (Fig. 237). All data suggest the most recent pulse of recruitment has now contributed to the exploitable biomass and declines can be expected in the near future. Longer term recruitment prospects are uncertain, but broad-scale climate indices are unfavourable.

CMA 11W (Pass Islands)

A commercial TAC was re-established in 2011 following the designation of a monitoring fishery from 2000-2010 (Fig. 238). Landings have remained constant at 40-50 t for the past five years while effort has fluctuated (Fig. 238). This is reflected in CPUE, which has fluctuated from about 7-10 kg/trap in recent years, including 2013 (Fig. 216). No fishery independent data are available to assess the resource.

DIVISION 4R3PN OFFSHORE

The Fishery

The Division 4R3Pn offshore fishery occurs along the west and southwest coasts of Newfoundland outside of eight nautical miles from the headlands (Fig. 239). The area comprises CMA OS8 and NAFO Subdivision 3Pn. The bathymetry off the west coast is characterized by a shallow water nearshore plateau that borders the deep Esquiman Channel. The bathymetry off the south coast is characterized by the presence of the Burgeo Bank extending through CMA 12A into Subdiv. 3Pn.

Bottom temperatures in this area are the warmest along the NL shelf, and this area is comparatively unproductive for snow crab. Fishery CPUE is consistently low compared to other areas and the fishery tends to be opportunistic in nature, with harvesters choosing to prosecute it when commercial quantities of crab are believed to be present.

Landings declined substantially from 580 t in 2004 to 80 t in 2006 before more than doubling in 2007. They declined by 83% from 190 t in 2007 to a historical low of 30 t in 2010, and increased to 300 t in 2013 (Table 13, Fig. 240). Effort increased by almost a factor of 7 since 2010 (Table 13, Fig. 240). The TAC has not been taken since 2002. VMS-based CPUE declined from 2004 to its lowest level in 2009 before increasing to its highest value in the time series in 2013 (Table 13, Fig. 241).

The fishing pattern has been highly aggregated and limited to the west coast in recent years (Fig. 242). There have been three distinct concentrations of effort in the northern fringes of the division, as well as patches of effort in the central portion outside of Bonne Bay and to the west and south of the Port-au-Port Peninsula. The fishery has started during the first two weeks of April and run about mid- to late- June (i.e. weeks 10-11) since 2009 (Fig. 243).

Biomass

There has been some spatial variability in CPUE in recent years but the general trend had been of a poorly performing fishery throughout the offshore from 2008-11 (Fig. 244). However, localized improvements have occurred in the past two years. In 2012, catch rate increases occurred predominately adjacent to the inshore management areas, particularly outside of Bay St. George in the south and outside CMA 12G in the north. In 2013, an area in the extreme northwest portion of the division performed well. In contrast to other divisions, CPUE and the spatial extent of the fishery have not shown the typical pattern of being negatively related for most of the time series (Fig. 245). Rather, they exhibit more of a direct relationship. We interpret this as reflecting the opportunistic nature of the fishery, with participation increasing when catch rates are good and abandonment occurring when catch rates are poor. Despite this interpretation, it is likely that the reduction in cells fished in the past two years reflects the improvement in CPUE and less need to search for crab.

Relative to the previous four years, commercial CPUE was well above average in 2013, particularly during the early portions of the season (Fig. 246). In terms of cumulative removals, at 100 t of catch the 2013 CPUE was double what it had been in the previous two years (Fig. 246). However, despite these improvements, there is still a strong suggestion of depletion of the resource by the fishery, with the late season CPUE in 2013 being no different than in the previous four years.

The CPS trap survey was incomplete in 2013, which compromises interpretation of trends in the exploitable biomass (Table 14, Fig. 247). However, it is clear that the exploitable biomass remains low relative to other areas. Trawl survey catches are few and localized in the northern portion of the area (Fig. 248). In both surveys the variation among catches is high compared to the mean (Fig. 247). This introduces high uncertainty in interpreting annual changes.

Production

Recruitment

Recruitment prospects are uncertain in the short term (2-3 years). In both surveys the variation among catches is high compared to the mean (Table 14, Fig. 249). Trawl survey catches are few and localized in the northern portion of the area (Fig. 250). This introduces high uncertainty in interpreting annual changes. The incomplete CPS trap survey in 2013 compromises an ability to assess short-term recruitment prospects.

Size frequency distributions from the trawl survey are generally uninformative due to sporadic catches of all sizes of crabs (Fig. 251).

A recent warm oceanographic regime suggests weak recruitment in the long term. CPUE in this, the warmest, area is inversely related to shallow water bottom temperature five years earlier based on a 1989-2009 temperature series (Fig. 252). A more recent temperature series from a nearby oceanographic station (Banc Beauge) trends similarly and shows steady warming since 2008 (Fig. 253). The best-fit lag of five years between bottom temperature and fishery CPUE implies crabs grow to exploitable size in six to seven years post-settlement in this area. This seems unrealistically quick. The data are auto-correlated and the time series is very short for cross-correlation analysis in this area, thus the time lag may be incorrect. Nonetheless, the typical negative relationship between early-life bottom temperature and future fishery performance, present in all areas of the NL shelf as well as in other major snow crab stocks on the global scale (Mullowney et al., 2014a), appears to occur here as well.

Reproduction

Maturities were not assigned to females captured in the summer trawl survey, thus an index of abundance of large (>30mm CW) females was developed as a proxy. This index showed high annual variability (Fig. 254) and catches in the survey trawl tended to be sporadic (Fig. 255). Thus, it was deemed uninformative.

Mortality

Data are insufficient to calculate exploitation rate and pre-recruit fishing mortality rate indices. The effect of maintaining the current level of removals on the exploitation rate in 2014 is unknown.

DIVISION 4R INSHORE

The Fishery

The Division 4R inshore fishery occurs in bays and nearshore areas inside of eight nautical miles from the headlands along the west coast of Newfoundland (Fig. 256). It incorporates CMAs 12C, 12D, 12E, 12F, 12G, and 12H.

Landings declined by 80% from 930 t in 2003 to a historical low of 160 t in 2010 and have since more than tripled to 600 t in 2013 (Table 15, Fig. 257). Effort declined by 69% from 2004 to 2010 and doubled in 2011 before declining by 34% to 2013 (Table 15, Fig. 257). The TAC has not been taken since 2002. CPUE declined by more than half from 2002 to 2007 and changed little to 2010 (Table 15, Fig. 258). It increased sharply since 2010 to a record high level in 2013.

Although some areas are consistently fished each year, there have been several changes in the spatial distribution of the fishery since 2008 (Fig. 259). In the north, CMA 12G (Bonne Bay, Fig. 256) had been closed during 2009-10 but the pocket of effort at the mouth of Bonne Bay fjord has re-emerged in the past three years. In the south, there has been the emergence of effort directly west of the Port-au-Port peninsula in CMA 12D during the past three years, which did not occur during 2008-10, and a broader scale fishery in Bay St. George (CMA 12C) since 2008. Temporally, the fisheries of the past five years, with the exception of 2010, have been similarly timed. They generally begin in the first week of April and most effort is expended by the end of June (i.e. weeks 11-12) (Fig. 260).

Biomass

CPUE increased by different degrees in all CMAs in the past two to three years (Fig. 261-262). Gains have been most substantial in Bay St. George (CMA 12C) and Bonne Bay (CMA 12G) and least substantial in CMA 12H. Similar to the offshore, the spatial extent of the fishery is positively related to CPUE in this division (Fig. 263), which we interpret to reflect an opportunistic fishery that increases or decreases in scale dependent upon catch rates. The rapidly increasing CPUE in recent years had been associated with a rapid expansion in area fished until 2012, but decreased dramatically in 2013. The abrupt decrease in 2013 likely reflected the improved CPUE and reduced searching to find crab.

Commercial logbook CPUE throughout the season in 2013 was higher than in the previous four years (Fig. 264). A low return of logbooks compromises interpretation of fishery performance in relation to cumulative removals, but during 2013 catch rates up to about 150 t of removals were equal to or above those of the preceding seasons (Fig. 264). There was also little suggestion of resource depletion, with no obvious decline in catch rates as the season progressed.

The exploitable biomass, as indicated by the post-season trap survey index, fluctuated from 2006 to 2010,was three times as large in 2011, and changed little in 2012 before decreasing in 2013 (Fig. 265). The greatest decrease occurred in Bay St. George (CMA 12C).

Production

Recruitment

Recruitment prospects are unfavourable in the short term (2-3 years). The trap survey pre-recruit biomass index more than doubled in 2009 and changed little until it decreased substantially to remain below pre-2009 level during 2012-2013 (Fig. 266). The percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, has changed little in the past four years. The CPS trap survey catch rates of new-shelled legal-sized crabs increased substantially from about 3 kg/trap in 2009 to 8 kg/trap in 2011 but has since declined by half. There is little suggestion of a residual biomass in this area, with few old-shell crabs of any size in the population (Fig. 267-268), inferring the fishery is highly dependent upon annual recruitment. The decreases in abundance during the past two years occurred across the entire size spectrum of legal-sized crabs (Fig. 268). Overall, it appears a recent influx of recruitment into the exploitable size group is now diminishing.

Mortality

Exploitation

The post-season trap survey-based exploitation rate index decreased in 2012 and changed little in 2013 (Fig. 269). However there has been considerable variation among management areas. Maintaining the current level of fishery removals would increase the exploitation rate in 2014.

Indirect Fishing Mortality

The observer data are insufficient to estimate the percentage of the catch discarded in the fishery or to infer wastage of pre-recruits. Data are insufficient to estimate a pre-recruit fishing mortality rate index.

Spatial variability: Trends by CMA

CMA 12C + BSG (Bay St. George)

Following a seven year period of landings not approaching the TAC level the fishery has re-emerged in the past three years and the TACs have been taken (Fig. 270). Increased landings, in the order of 160-190 t during the past three years have been associated with declining effort (Fig. 270) and a tripling of CPUE (Fig. 262). This marked improvement in fishery performance has been associated with a substantial increase in the abundance of legal-size crabs in the CPS survey beginning in 2011 (Fig. 271) and the emergence of a recruitment pulse into the exploitable biomass from 2011-13 (Fig. 272). Although some residual biomass is now present, in the form of legal-size old-shell crabs (Fig. 271-272), the total abundance of legal-size crabs was substantially down following the 2013 fishery (Fig. 271-272). Short-term recruitment prospects are not favourable. The recruitment pulse that recently entered the fishery was tracked in small-mesh size frequencies during 2008-11 (Fig. 273), and there is no indication of any subsequent pulses approaching. Long-term recruitment prospects are uncertain but broad-scale climate indices are not favourable.

CMA 12D (Port au Port Bay)

Following a nine year period of the TAC not being taken, the fishery took the entire 76 t quota in 2013 (Fig. 274). The growth in landings, from 6 t in 2010, has been associated with a modest increase in effort during the past three years (Fig. 274), resulting in an increasing CPUE trend (Fig. 262). Although no survey data are available to assess the resource, trends in immediately adjacent areas, as well as in the broader context of Newfoundland and Labrador snow crab, suggest decreasing short-term prospects coupled with an unfavourable warming regime that is negatively affecting long-term productivity.

CMA 12E (Outer Bay of Islands)

The TAC had not been taken from 2005-2011 but fishery landings have increased in recent years and the TAC has been subscribed in each of the past two fishing seasons (Fig. 275). Increased landings, from about 10 t in 2010 to 50 t in 2013, were initially associated with increased effort, which has subsequently declined during the past two years (Fig. 275). Accordingly, fishery CPUE has increased from about 2 kg/trap in 2011 to 8 kg/trap in 2013 (Fig. 262). This increased CPUE reflects an increased abundance of legal-size crabs seen in the CPS survey since 2011 (Fig. 276-277). Although the abundance of crabs is clearly higher than during the mid- to late- 2000s there appears to be little residual biomass in the area, with virtually all crabs in the population being new-shell (Fig. 277). Short-term recruitment prospects are uncertain, but the abundance of legal-size new-shell crabs in the population was unchanged following the 2013 fishery (Fig. 276) suggesting little change in crab available for the 2014 fishery. Long-term recruitment prospects are uncertain but broad-scale climate indices are not favourable.

CMA 12F + BOI (Bay of Islands)

Landings fell well short of the TAC during 2008-12, but with increased landings since 2009 the TAC was taken in 2013 (Fig. 278). The increasing landings were initially associated with increased effort, to a historical high in 2011, but that trend has stopped and effort has declined by half during the past two years (Fig. 278). This has resulted in improved CPUE, which has been 8 kg/trap during the past two seasons (Fig. 262). This increased CPUE reflects an increased abundance of legal-size crabs seen in the CPS survey during the past four years that peaked in 2011 (Fig. 279-280). Although the abundance of crabs is clearly higher than during the mid- to late- 2000s there appears little residual biomass in the area with virtually all crabs in the population being new-shell (Fig. 280). Recruitment prospects for the 2014 fishery appear promising, with little change in the abundance of legal-size new-shell crabs in the population following the 2013 fishery (Fig. 279). The groups of adolescents that have been contributing to the recently improved exploitable biomass were evident in small-mesh traps during 2008-12, but were not present in 2013 (Fig. 281). This could indicate a forthcoming decline after 2014. Long-term recruitment prospects are uncertain but broad-scale climate indices are not favourable.

CMA 12G (Bonne Bay)

The fishery had been under a voluntary moratorium during 2009-10 (Fig. 282). Upon re-opening, 100 t of crab was removed during the 2011-12 fisheries, which was increased to 130 t in 2013 (Fig. 282). Fishery CPUE plummeted from 2003-08 (Fig. 262), invoking the closure, but has been near historical highs since re-opening. The closure was very well timed, as the CPS survey shows that an approaching mode of recruitment began to enter in to the exploitable biomass in 2010 and crabs were able to grow to a large size, achieving a primary mode of 113mm CW in the past two years (Fig. 284). Unfortunately, it appears this mode of recruitment has now fully contributed to the legal-size group, with the peak abundance level of 2012 followed by a decline in 2013 (Fig. 283) and no evidence of recruitment in the small-mesh size frequencies from the CPS survey (Fig. 285). Long-term recruitment prospects are uncertain but broad-scale climate indices are not favourable.

CMA 12H (Northern Peninsula)

Following ten years of not taking the TAC, fishery landings have increased to the TAC level in each the past two years (Fig. 286). Recently increasing landings have been associated with a slow but steady increase in CPUE (Fig. 262), but this area has remained the most marginal fishery of the six inshore management areas consistently fished. Although no survey data are available to assess the resource, trends in immediately adjacent areas, as well as in the broader context of the Newfoundland and Labrador snow crab stock, suggest decreasing short-term prospects coupled with an unfavourable warming regime that is negatively affecting long-term productivity.

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APPENDIX I: TABLES

Table 1: Annual Overall (Divisions 2HJ3KLNOP4R) Total Allowable Catch and Landings by year.

YEAR	TAC(t)	LANDINGS(t)
1995	27,875	31,451
1996	34,864	36,702
1997	42,015	43,345
1998	49,225	50,467
1999	61,806	68,700
2000	51,169	55,151
2001	52,267	56,470
2002	56,981	58,735
2003	56,250	58,330
2004	53,590	55,609
2005	49,978	43,982
2006	46,233	47,257
2007	47,663	50,205
2008	54,338	52,734
2009	54,110	53,440
2010	56,087	52,199
2011	55,559	52,903
2012	52,990	50,474
2013	52,122	50,728

Table 2: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 2HJ.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	CPUE (kg/trap)
1995	3,050	3,189	393,704	8.1
1996	2,800	3,102	326,526	9.5
1997	2,800	3,183	286,757	11.1
1998	3,500	4,098	284,583	14.4
1999	4,655	5,416	401,185	13.5
2000	3,411	3,682	304,298	12.1
2001	3,340	3,754	426,591	8.8
2002	3,381	3,520	577,049	6.1
2003	2,265	2,510	583,721	4.3
2004	1,780	1,925	534,722	3.6
2005	1,425	1,576	297,358	5.3
2006	1,425	2,139	257,711	8.3
2007	1,570	2,523	274,239	9.2
2008	2,466	2,549	240,472	10.6
2009	2,466	2,387	298,375	8.0
2010	2,227	2,131	280,395	7.6
2011	2,197	1,933	371,731	5.2
2012	1,952	1,606	286,786	5.7
2013	1,765	1,379	153,222	9.0

Table 3: Fall multi-species survey exploitable and pre-recruit biomass indices with confidence intervals and mean catch, by year, for Division 2HJ.

EXPLOITABLE CRAB IN 2HJ				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	3472	4806	2138	1.29
1996	6120	8262	3977	1.33
1997	10675	16366	4983	2.68
1998	12691	18249	7132	2.80
1999	6304	8396	4212	1.39
2000	3555	4525	2584	1.13
2001	3249	4078	2421	0.75
2002	852	1312	392	0.27
2003	1015	1686	343	0.32
2004	1466	2082	850	0.32
2005	2009	10750	-6733	0.63
2006	3370	11496	-4756	0.74
2007	2787	4402	1172	0.88
2008	2073	3053	1092	0.48
2009	1464	2566	361	0.46
2010	1387	2027	747	0.31
2011	889	4799	-3021	0.20
2012	1195	8033	-5643	0.26
2013	1527	2804	250	0.34

PRE-RECRUIT CRAB IN 2HJ				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	2031	2943	1119	0.75
1996	2965	4321	1608	0.65
1997	2992	4227	1758	0.75
1998	3392	4544	2239	0.75
1999	1156	1977	335	0.26
2000	1269	1857	681	0.40
2001	1313	3207	-581	0.30
2002	589	2883	-1705	0.19
2003	917	1311	523	0.29
2004	4803	33557	-23951	1.05
2005	1657	3655	-341	0.52
2006	2296	4944	-351	0.50
2007	1306	3042	-429	0.41
2008	1237	4714	-2240	0.29
2009	1675	11754	-8405	0.53
2010	982	4843	-2879	0.22
2011	1732	8450	-4985	0.39
2012	1826	3170	481	0.40
2013	975	1727	223	0.22

Table 4: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 3K Offshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	VMS CPUE (kg/hour)
1995	9,650	10,512	750,857	*n/a*
1996	9,700	11,083	846,031	*n/a*
1997	11,100	11,911	888,881	*n/a*
1998	12,700	14,103	946,510	*n/a*
1999	14,950	17,898	1,345,714	*n/a*
2000	11,218	13,056	1,186,909	*n/a*
2001	11,218	12,519	1,251,900	*n/a*
2002	12,183	12,870	1,191,667	*n/a*
2003	12,783	13,534	1,301,346	*n/a*
2004	12,823	13,584	1,787,368	221.4
2005	10,325	6,449	921,286	196.4
2006	8,295	8,496	745,263	312.0
2007	9,480	9,820	672,603	446.2
2008	12,305	12,292	754,110	415.8
2009	13,505	13,311	1,292,330	278.0
2010	11,720	10,173	1,105,761	235.8
2011	9,613	8,735	1,180,405	196.4
2012	7,318	6,496	914,930	167.9
2013	6,526	6,629	818,395	206.2

Table 5: Fall multi-species survey exploitable and pre-recruit biomass indices with confidence intervals and mean catch, by year, for Division 3K Offshore.

EXPLOITABLE CRAB IN 3K OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	11676	14534	8817	2.84
1996	20234	24352	16116	4.92
1997	18712	22724	14700	4.55
1998	18918	23156	14679	4.60
1999	8674	11366	5982	2.11
2000	9976	12668	7283	2.59
2001	11907	16504	7309	2.90
2002	9042	11742	6342	2.20
2003	3644	4603	2685	0.89
2004	5550	7061	4039	1.35
2005	6969	8897	5041	1.69
2006	10939	13469	8409	2.78
2007	16887	22236	11538	4.11
2008	16157	21399	10914	3.93
2009	7928	10301	5554	1.93
2010	6712	8535	4888	1.63
2011	5863	8207	3518	1.43
2012	5581	6943	4218	1.36
2013	5213	7090	3337	1.27

PRE-RECRUIT CRAB IN 3K OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	7424	9924	4925	1.81
1996	10632	14312	6952	2.59
1997	13405	17865	8945	3.26
1998	9992	13912	6071	2.43
1999	3487	4871	2104	0.85
2000	9608	13251	5965	2.49
2001	6684	8937	4432	1.63
2002	5178	7343	3012	1.26
2003	2461	4047	875	0.60
2004	5378	8989	1767	1.31
2005	5765	7867	3664	1.40
2006	9971	15093	4848	2.53
2007	5256	7199	3313	1.28
2008	8220	12306	4134	2.00
2009	5684	7796	3573	1.38
2010	4030	5839	2221	0.98
2011	4715	7409	2020	1.15
2012	3522	5559	1484	0.86
2013	2295	4119	471	0.56

Table 6: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 3K Inshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	CPUE (kg/trap)
1995	1,800	1,814	221,220	8.2
1996	3,250	3,127	488,594	6.4
1997	3,200	2,885	497,414	5.8
1998	2,690	2,582	452,982	5.7
1999	2,892	3,082	770,500	4.0
2000	2,010	2,084	434,167	4.8
2001	2,210	2,510	278,889	9.0
2002	2,500	2,801	345,802	8.1
2003	2,825	2,975	444,030	6.7
2004	2,770	2,879	543,208	5.3
2005	2,535	2,244	477,447	4.7
2006	2,135	2,248	345,846	6.5
2007	2,270	2,450	247,475	9.9
2008	2,770	2,779	241,652	11.5
2009	2,970	2,873	354,691	8.1
2010	2,720	2,252	402,143	5.6
2011	2,440	2,009	410,000	4.9
2012	2,120	1,894	332,281	5.7
2013	1,923	1,890	248,684	7.6

Table 7: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 3LNO Offshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	VMS CPUE (kg/hour)
1995	5,175	7,212	389,838	*n/a*
1996	7,100	8,494	534,214	*n/a*
1997	13,075	14,293	898,931	*n/a*
1998	13,250	15,111	873,468	*n/a*
1999	24,275	27,329	1,518,278	*n/a*
2000	20,502	22,083	1,150,156	*n/a*
2001	20,465	22,630	1,197,354	*n/a*
2002	22,333	23,528	1,258,182	*n/a*
2003	23,703	24,818	1,451,345	*n/a*
2004	23,703	24,656	1,700,414	479.2
2005	23,703	23,571	1,683,643	454.6
2006	23,703	24,526	1,777,246	432.8
2007	23,703	24,406	2,033,833	425.9
2008	24,148	23,421	2,110,000	322.7
2009	21,769	21,946	1,925,088	334.2
2010	24,835	24,136	1,736,403	390.8
2011	26,100	25,845	1,900,368	413.0
2012	26,490	26,141	1,613,642	441.1
2013	26,643	26,289	1,436,557	519.7

*Table 8: Fall multi-species survey exploitable and pre-recruit biomass indices with confidence intervals and mean catch, by year, for Division 3LNO Offshore. *Survey was incomplete in 2004.*

EXPLOITABLE CRAB IN 3LNO OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	31835	40586	23085	3.09
1996	37462	45020	29905	3.68
1997	24526	30224	18827	2.39
1998	34292	42557	26027	3.33
1999	20816	25153	16478	2.04
2000	15709	20081	11337	1.53
2001	24495	31046	17945	2.38
2002	19295	25305	13286	1.88
2003	15365	19795	10936	1.50
2004	**9641**	**15671**	**3610**	**1.04**
2005	15750	27211	4290	1.53
2006	5023	6537	3510	0.49
2007	9714	14603	4825	0.94
2008	15022	19404	10641	1.46
2009	22406	31978	12834	2.18
2010	17871	27049	8692	1.74
2011	14865	19263	10468	1.45
2012	16007	22946	9069	1.56
2013	18577	27065	10089	1.81

PRE-RECRUIT CRAB IN 3LNO OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1995	17765	23402	12128	1.72
1996	26732	36837	16627	2.62
1997	16272	61798	-29253	1.58
1998	20981	40905	1057	2.04
1999	10947	15720	6175	1.07
2000	9861	13290	6432	1.03
2001	10170	13419	6921	0.99
2002	5617	8558	2677	0.55
2003	8230	14105	2356	0.80
2004	**3849**	**9507**	**-1809**	**0.41**
2005	4552	7025	2079	0.45
2006	2646	3877	1415	0.26
2007	8076	11088	5063	0.78
2008	16372	23253	9492	1.60
2009	19041	26359	11724	1.85
2010	17590	27340	7841	1.72
2011	8816	42503	-24870	0.86
2012	7190	12113	2266	0.70
2013	6062	14319	-2196	0.59

Table 9: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 3L Inshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	CPUE (kg/trap)
1995	6,475	6,795	471,875	14.4
1996	7,675	7,922	665,714	11.9
1997	5,850	6,398	627,255	10.2
1998	7,225	6,882	583,220	11.8
1999	5,350	5,453	482,566	11.3
2000	4,633	4,731	407,845	11.6
2001	5,615	5,543	518,037	10.7
2002	6,540	6,524	582,500	11.2
2003	6,774	6,817	841,605	8.1
2004	6,255	6,420	823,077	7.8
2005	6,045	6,114	745,610	8.2
2006	6,095	6,229	629,192	9.9
2007	6,105	6,485	584,234	11.1
2008	7,033	6,823	554,715	12.3
2009	7,210	7,094	662,991	10.7
2010	7,449	7,284	687,170	10.6
2011	7,122	7,069	648,532	10.9
2012	7,407	7,370	534,058	13.8
2013	7,708	7,603	517,211	14.7

Table 10: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Subdivision 3Ps Offshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	VMS CPUE (kg/hour)
1995	525	894	45,846	*n/a*
1996	1,700	1,665	99,701	*n/a*
1997	2,200	2,370	117,910	*n/a*
1998	3,700	3,257	134,033	*n/a*
1999	4,298	4,307	177,975	*n/a*
2000	4,400	4,386	212,913	*n/a*
2001	4,400	4,403	271,790	*n/a*
2002	4,400	4,357	360,083	*n/a*
2003	3,565	3,750	451,807	*n/a*
2004	2,805	3,419	422,099	216.2
2005	2,800	2,468	398,065	159.6
2006	2,070	2,324	297,949	179.5
2007	2,270	2,816	361,026	200.7
2008	3,230	3,098	279,099	256.3
2009	3,780	3,620	285,039	290.0
2010	4,305	3,874	333,966	276.7
2011	4,515	4,210	434,021	260.3
2012	3,925	3,703	416,067	212.7
2013	3,925	3,537	491,250	198.9

*Table 11: Spring multi-species survey exploitable and pre-recruit biomass indices with confidence intervals and mean catch, by year, for Subdivision 3Ps Offshore. *Survey was incomplete in 2006.*

EXPLOITABLE CRAB IN 3Ps OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1996	4535	7943	1128	1.88
1997	1119	1691	547	0.47
1998	1476	2273	679	0.61
1999	2528	4429	626	1.05
2000	927	1390	465	0.38
2001	500	801	199	0.21
2002	427	618	236	0.18
2003	433	1167	-301	0.18
2004	211	308	114	0.09
2005	503	803	203	0.21
2006	**18**	**74**	**-37**	**0.03**
2007	246	411	81	0.10
2008	379	570	189	0.16
2009	935	1599	272	0.39
2010	790	1313	268	0.33
2011	416	675	158	0.17
2012	354	613	95	0.15
2013	143	219	66	0.06

PRE-RECRUIT CRAB IN 3Ps OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
1996	1839	3582	96	0.76
1997	291	522	59	0.12
1998	601	1086	116	0.25
1999	324	466	181	0.13
2000	235	443	26	0.10
2001	311	614	7	0.13
2002	309	478	140	0.13
2003	97	196	-1	0.04
2004	209	336	82	0.09
2005	437	630	244	0.18
2006	**51**	**122**	**-21**	**0.07**
2007	780	1768	-209	0.32
2008	1058	2966	-849	0.44
2009	1422	2382	462	0.59
2010	460	1038	-117	0.19
2011	194	324	63	0.08
2012	168	328	8	0.07
2013	71	136	7	0.03

Table 12: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Subdivision 3Ps Inshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	CPUE (kg/trap)
1995	1,200	1,035	161,719	6.4
1996	1,350	1,309	73,955	17.7
1997	2,400	2,305	187,398	12.3
1998	2,500	3,367	333,366	10.1
1999	3,701	3,598	342,667	10.5
2000	3,300	3,501	350,100	10.0
2001	3,200	3,436	279,350	12.3
2002	3,200	3,280	410,000	8.0
2003	2,520	2,368	415,439	5.7
2004	1,590	1,301	371,714	3.5
2005	1,300	704	207,059	3.4
2006	975	781	195,250	4.0
2007	975	1,147	204,821	5.6
2008	1,128	1,426	163,908	8.7
2009	1,500	1,939	157,642	12.3
2010	1,900	2,161	154,357	14.0
2011	2,512	2,506	192,769	13.0
2012	2,542	2,522	181,439	13.9
2013	2,542	2,510	216,379	11.6

Table 13: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 4R3Pn Offshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	VMS CPUE (kg/hour)
1999	645	629	149,762	*n/a*
2000	645	674	134,800	*n/a*
2001	635	649	147,500	*n/a*
2002	845	977	195,400	*n/a*
2003	845	610	169,444	*n/a*
2004	838	584	182,500	124.9
2005	845	348	108,750	119.4
2006	675	79	27,241	91.6
2007	540	193	74,231	90.2
2008	540	131	42,258	83.3
2009	418	68	29,565	73.4
2010	418	33	10,000	106.6
2011	414	149	51,379	77.0
2012	418	191	48,974	95.9
2013	418	299	66,444	143.5

Table 14: Summer multi-species survey exploitable and pre-recruit biomass indices with confidence intervals and mean catch, by year, for Division 4R3Pn Offshore.

EXPLOITABLE CRAB IN 4R3Pn OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
2004	111	292	-70	0.19
2005	82	273	-109	0.24
2006	180	431	-72	0.30
2007	92	261	-77	0.15
2008	174	552	-205	0.29
2009	229	1099	-640	0.39
2010	80	188	-28	0.13
2011	365	820	-90	0.61
2012	175	452	-101	0.29
2013	52	277	-173	0.09

PRE-RECRUIT CRAB IN 4R3Pn OFFSHORE				
YEAR	BIOMASS (t)			MEAN (kg/set)
	ESTIMATE	Upper	Lower	
2004	195	917	-527	0.33
2005	14	74	-46	0.04
2006	46	116	-24	0.08
2007	54	260	-151	0.09
2008	52	121	-17	0.09
2009	74	337	-189	0.12
2010	18	52	-16	0.03
2011	94	222	-34	0.16
2012	36	79	-8	0.06
2013	90	377	-197	0.15

Table 15: Annual Total Allowable Catch, Landings, Effort and Catch Per Unit Effort for Division 4R Inshore.

YEAR	TAC(t)	LANDINGS(t)	EFFORT (trap hauls)	CPUE (kg/trap)
1998	1,310	1,067	197,593	5.4
1999	690	988	161,967	6.1
2000	785	954	194,694	4.9
2001	909	1,026	183,214	5.6
2002	904	878	104,524	8.4
2003	972	928	116,000	8.0
2004	998	841	133,492	6.3
2005	972	508	80,635	6.3
2006	860	435	72,500	6.0
2007	750	365	101,389	3.6
2008	700	234	49,787	4.7
2009	483	200	48,780	4.1
2010	482	155	41,892	3.7
2011	615	447	95,106	4.7
2012	641	551	68,025	8.1
2013	641	592	62,316	9.5

APPENDIX II: FIGURES

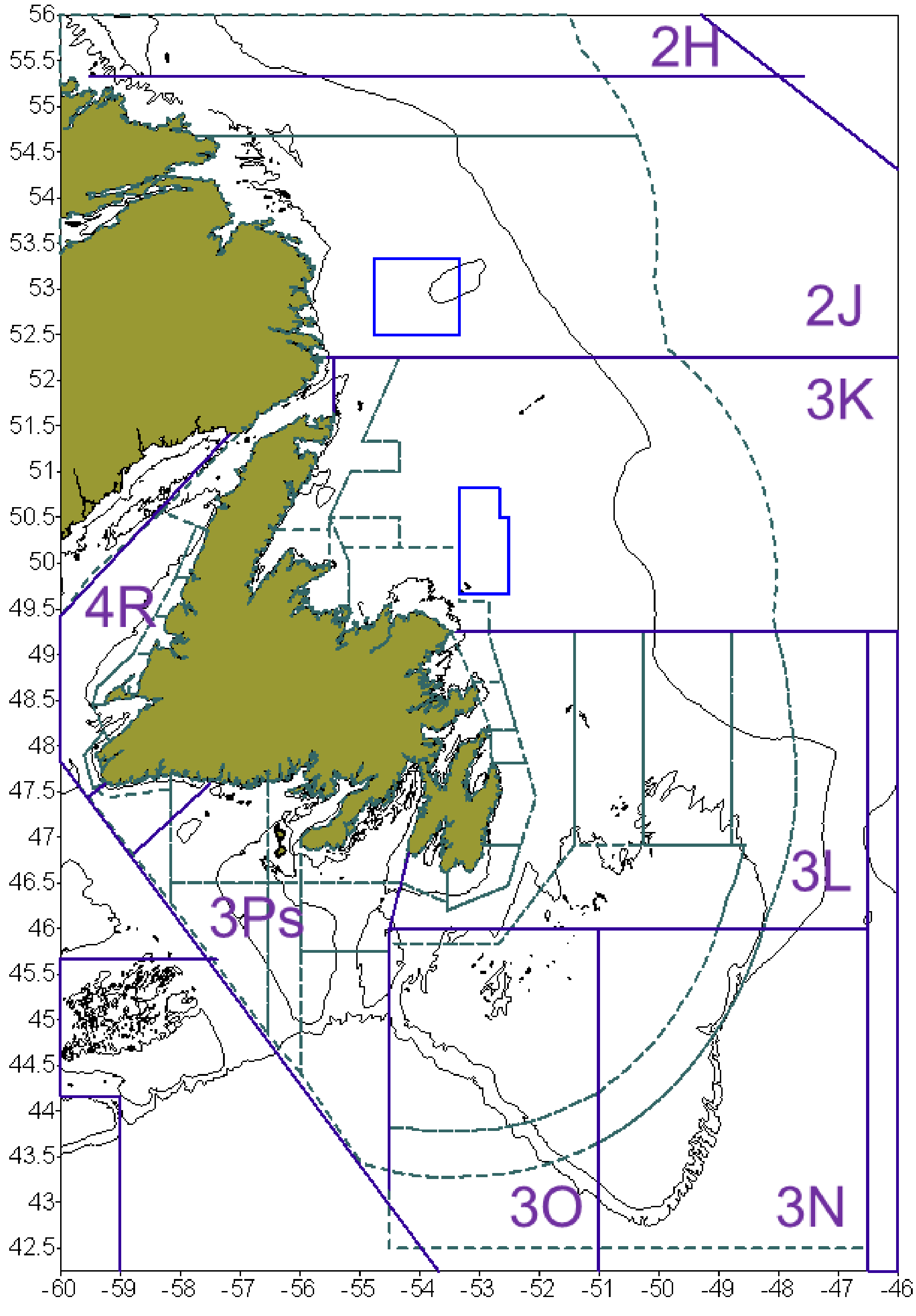

Figure 1: NAFO Divisions (purple lines), Newfoundland and Labrador Snow Crab Management Areas (green lines), trawling and gillnetting closures (blue boxes), and bathymetry of the Newfoundland and Labrador shelf (grey underlay).

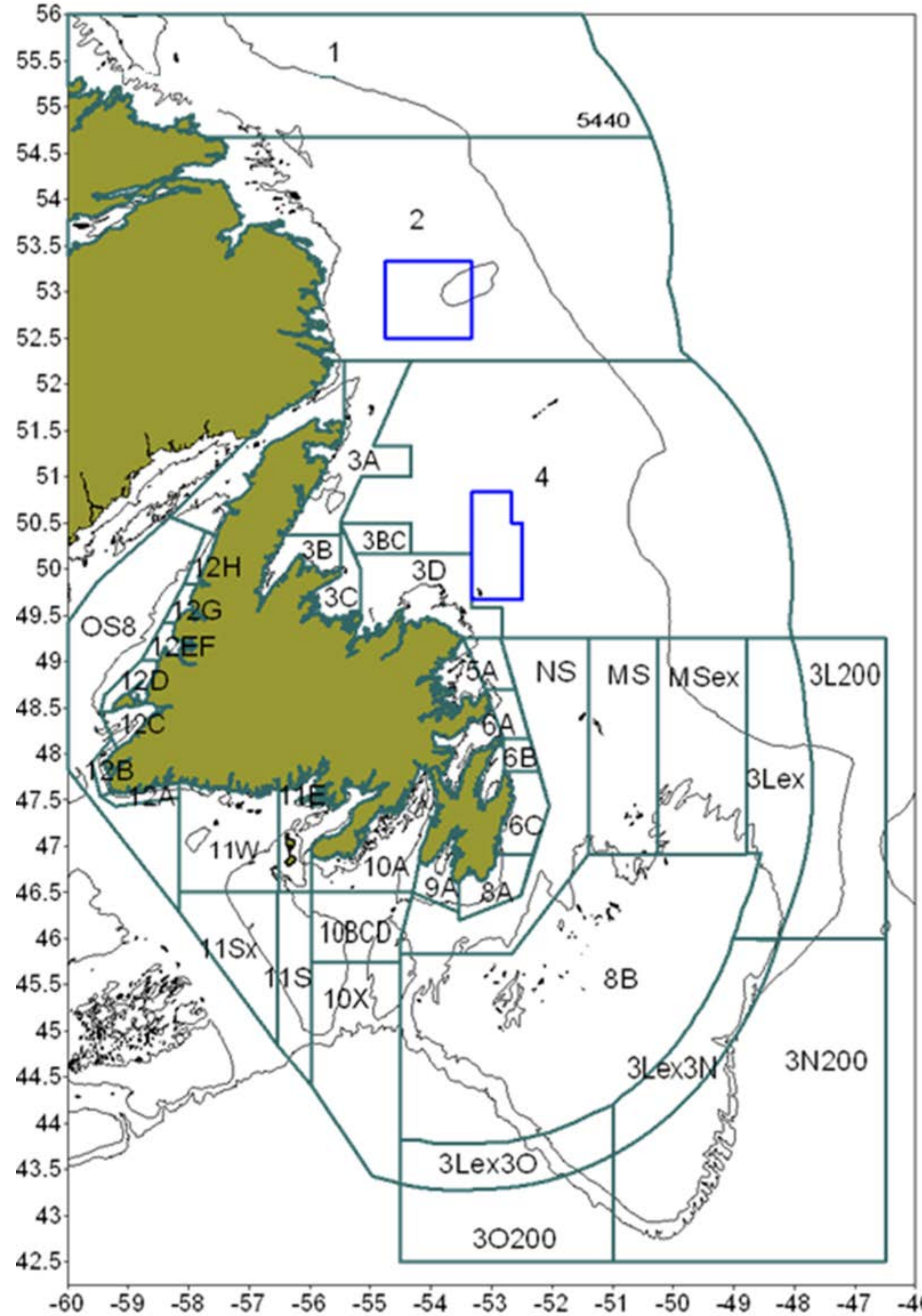

Figure 2. Newfoundland and Labrador Snow Crab Management Areas (CMAs).

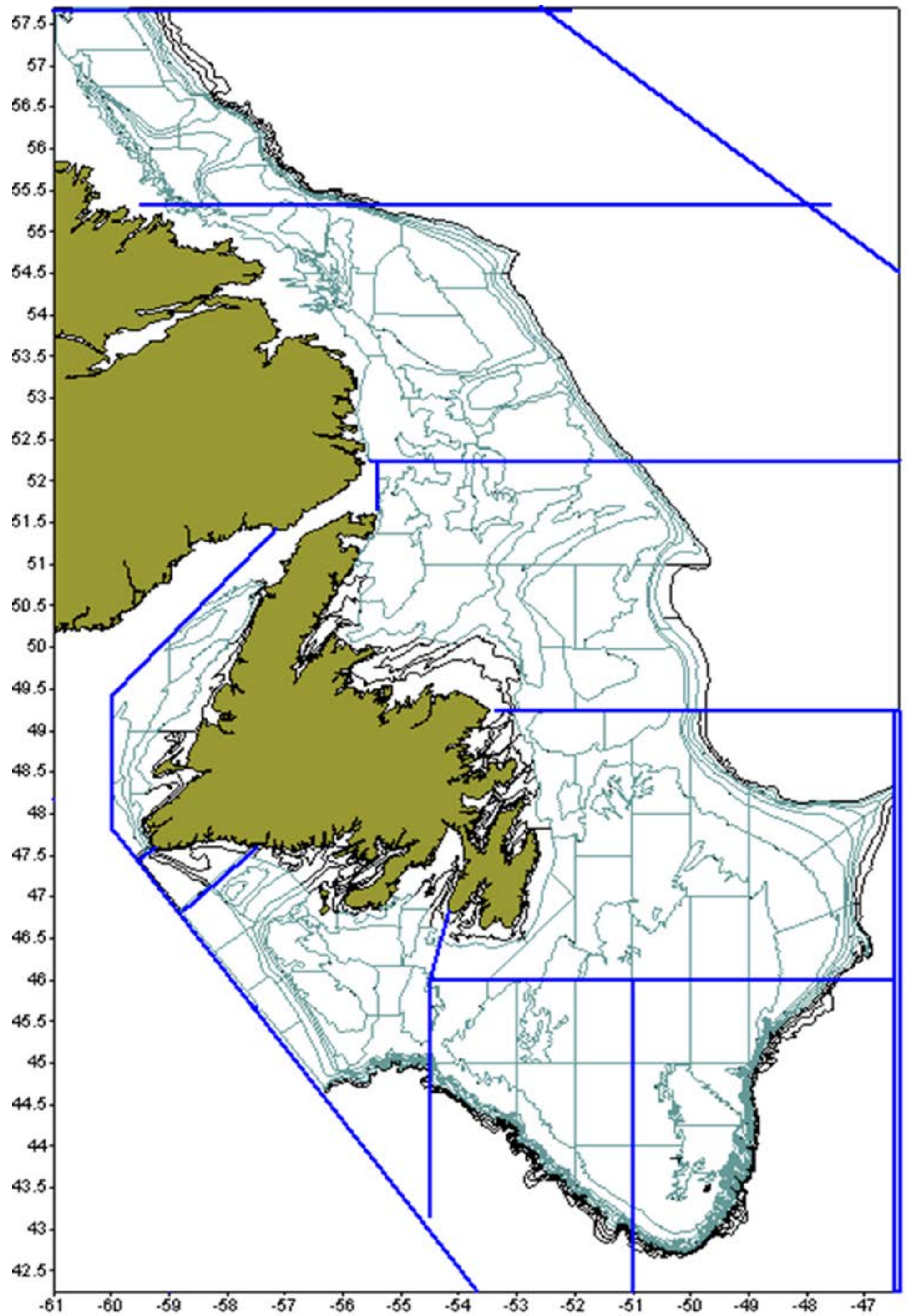

Figure 3: DFO multi-species trawl survey strata. Core strata shown in teal.

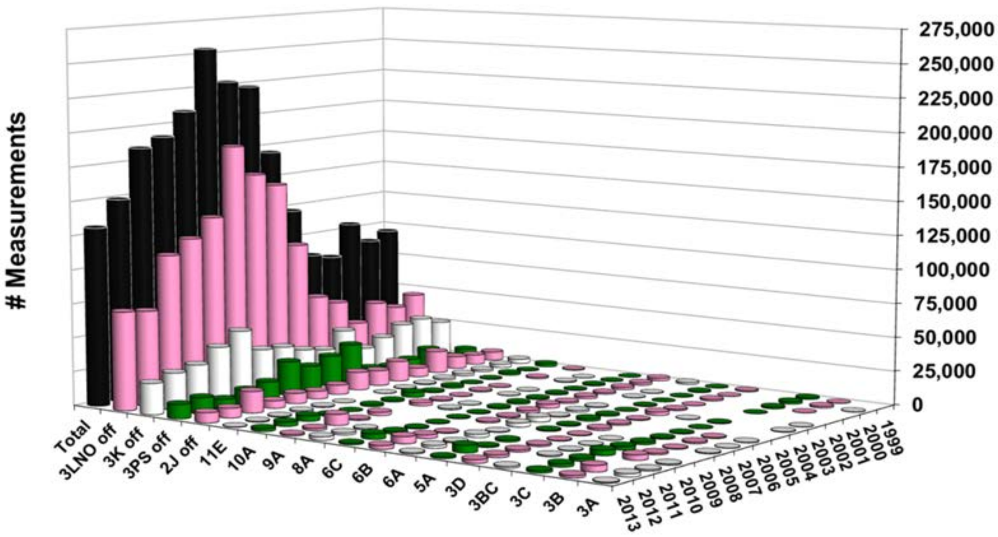

Figure 4: Observer sampling by CMA and year. Data pooled for offshore crab management areas in each Division.

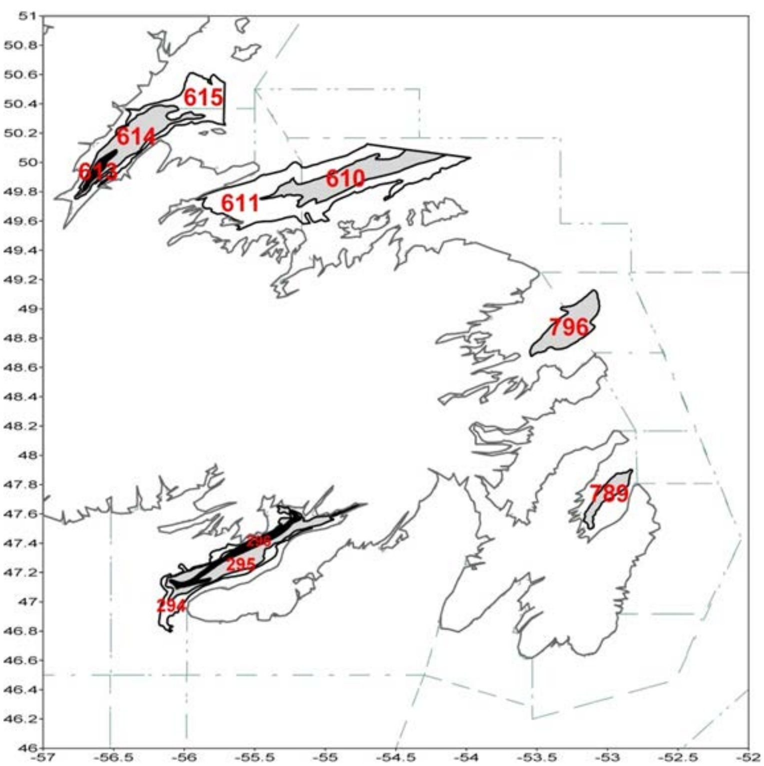

Figure 5: Strata sampled during DFO inshore trap and trawl surveys.

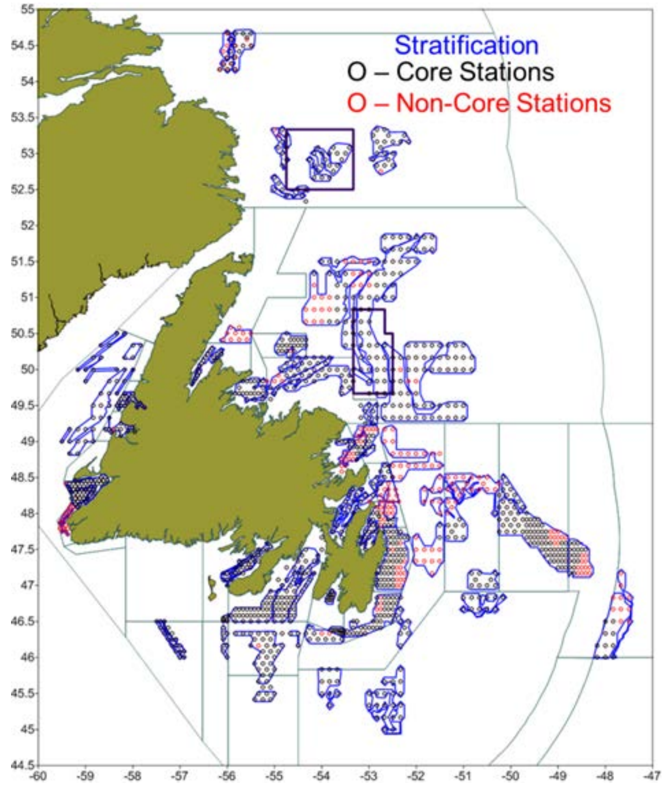

Figure 6: Industry – DFO Collaborative Post-Season trap survey showing occupied and core stations as well as stratification scheme used for data analyses.

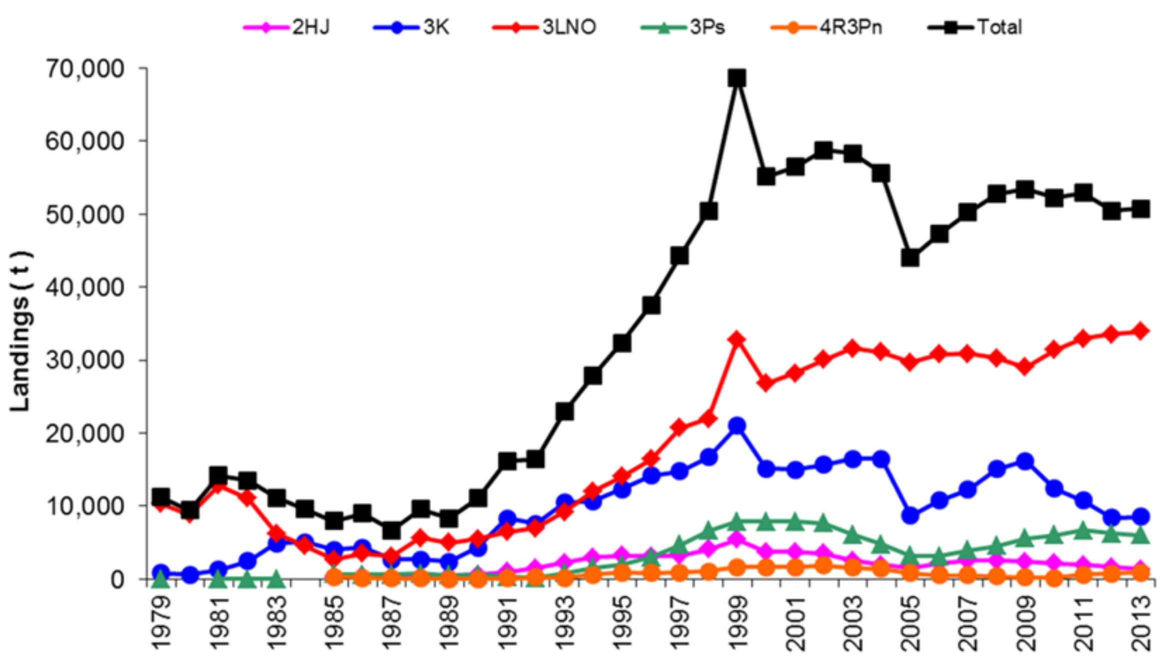

Figure 7: Trends in annual landings by NAFO Division and in total.

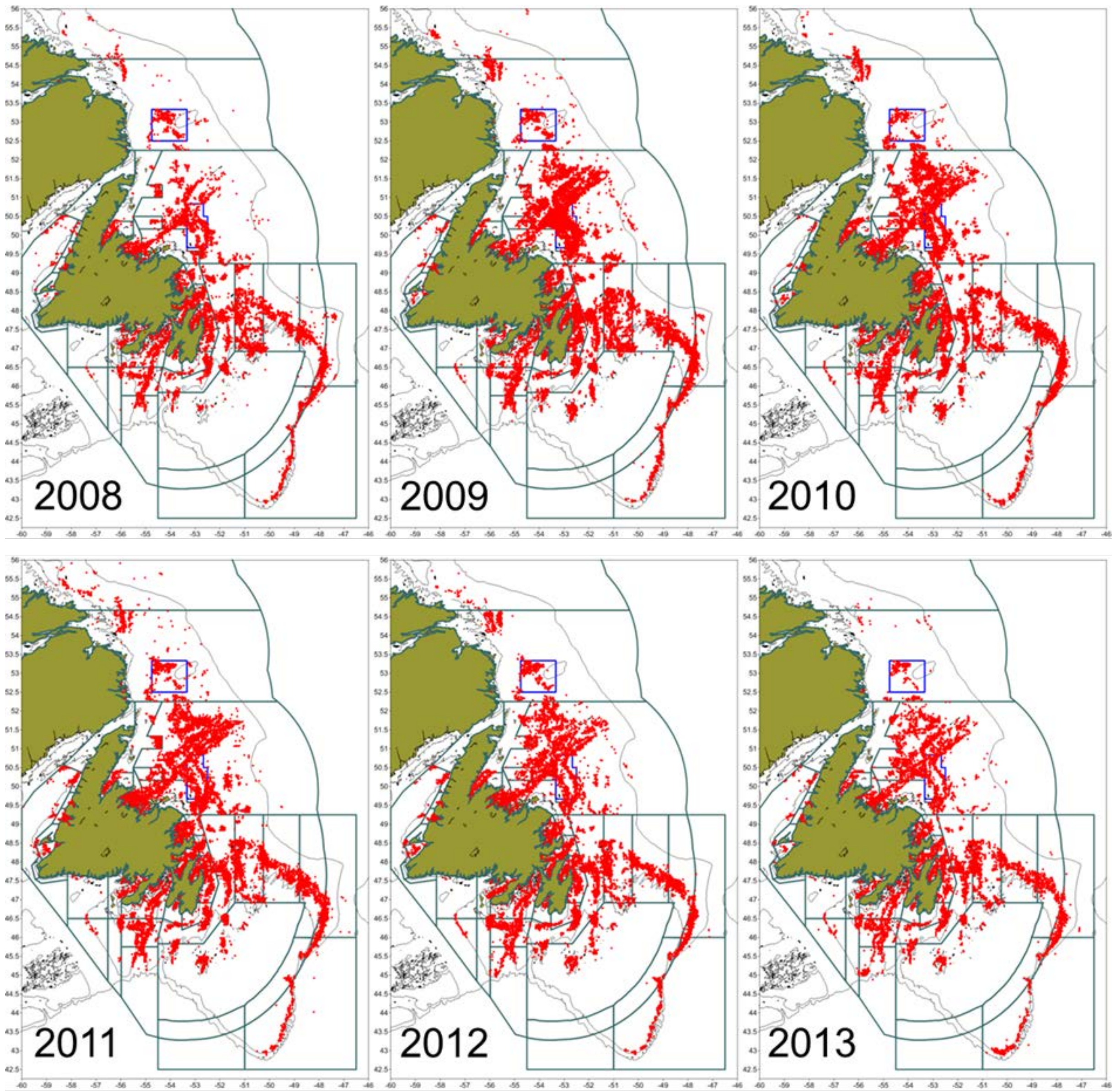

Figure 8: Distribution of logbook fishing effort from 2008-2013.

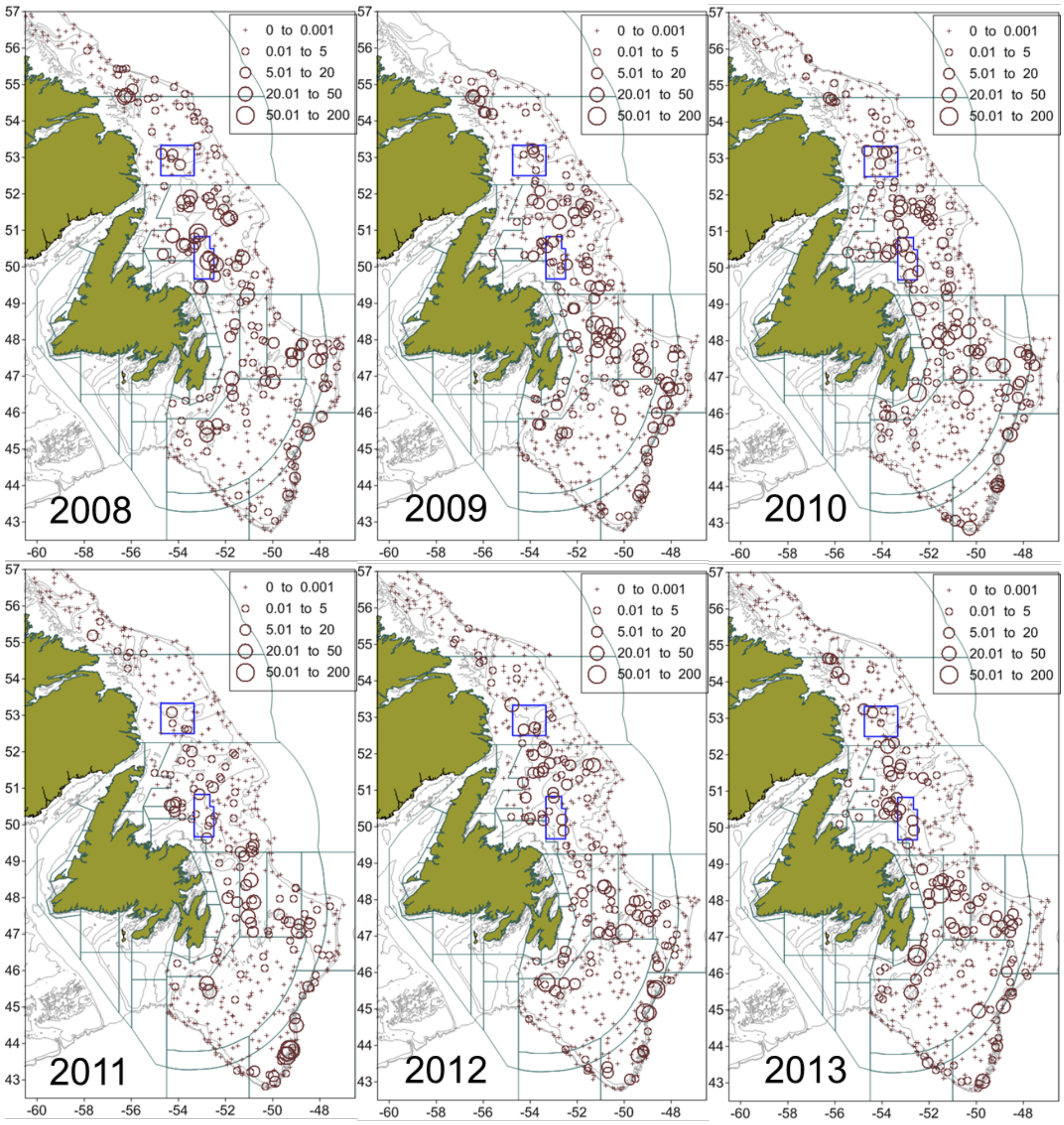

Figure 9: Distribution of exploitable males (> 94mm CW adults) from fall Div. 2HJ3KLNO bottom trawl surveys from 2008-2013.

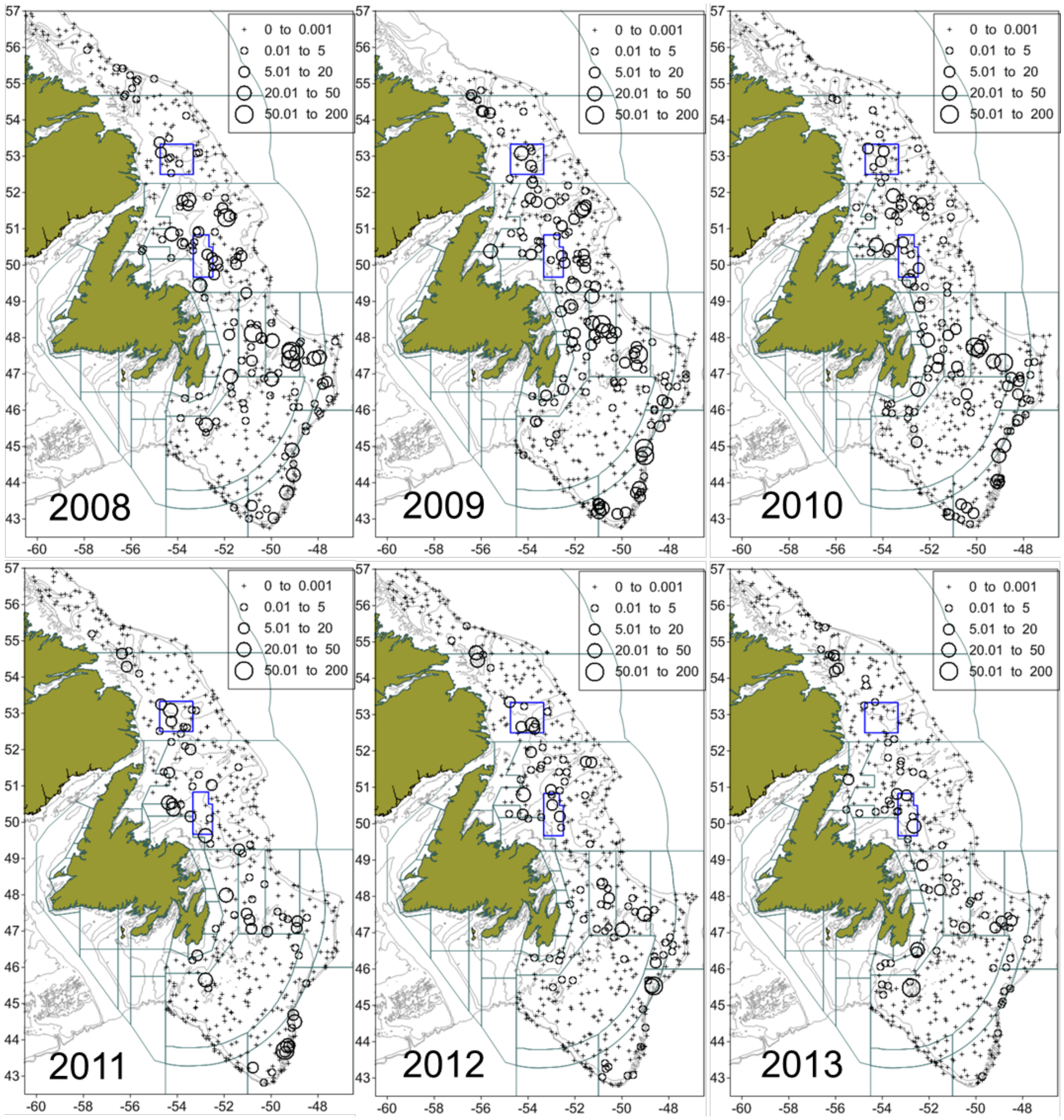

Figure 10: Distribution of pre-recruit males (> 75mm CW adolescents) from fall Div. 2HJ3KLNO bottom trawl surveys from 2008-2013.

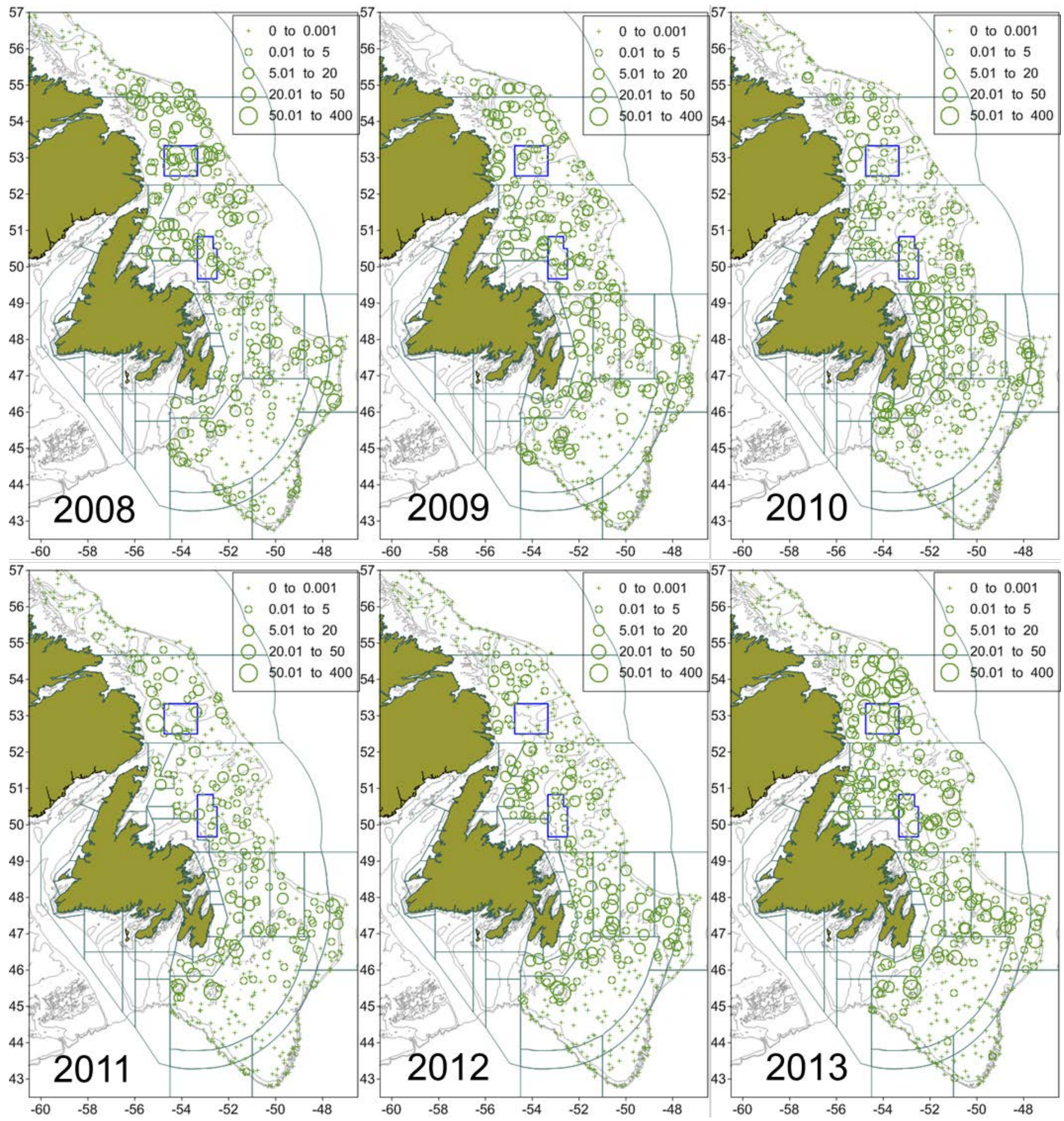

Figure 11: Distribution of small males (< 60mm CW adolescents) from fall Div. 2HJ3KLNO bottom trawl surveys from 2008-2013.

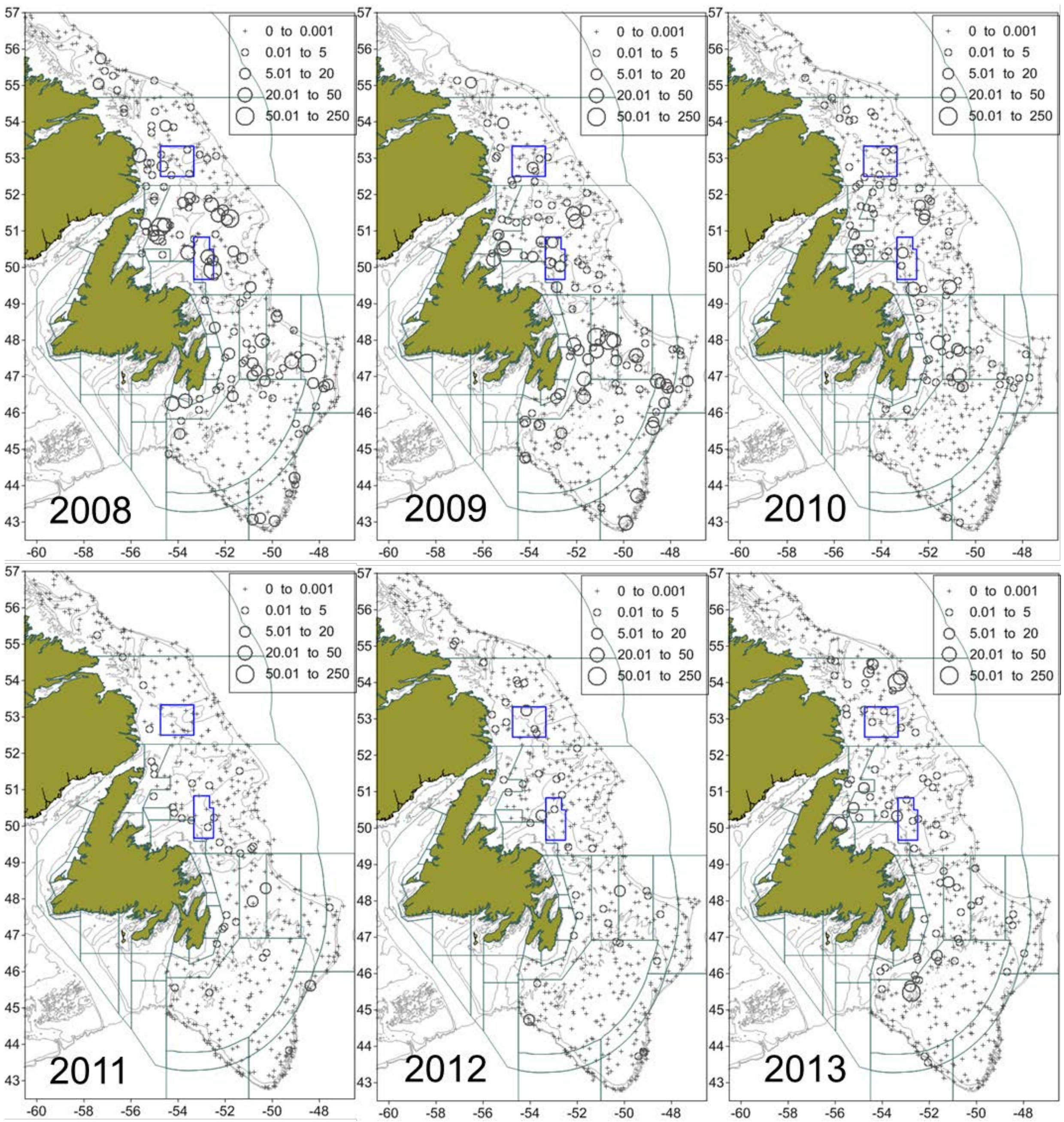

Figure 12: Distribution of mature females from fall Div. 2HJ3KLNO bottom trawl surveys from 2007-2012.

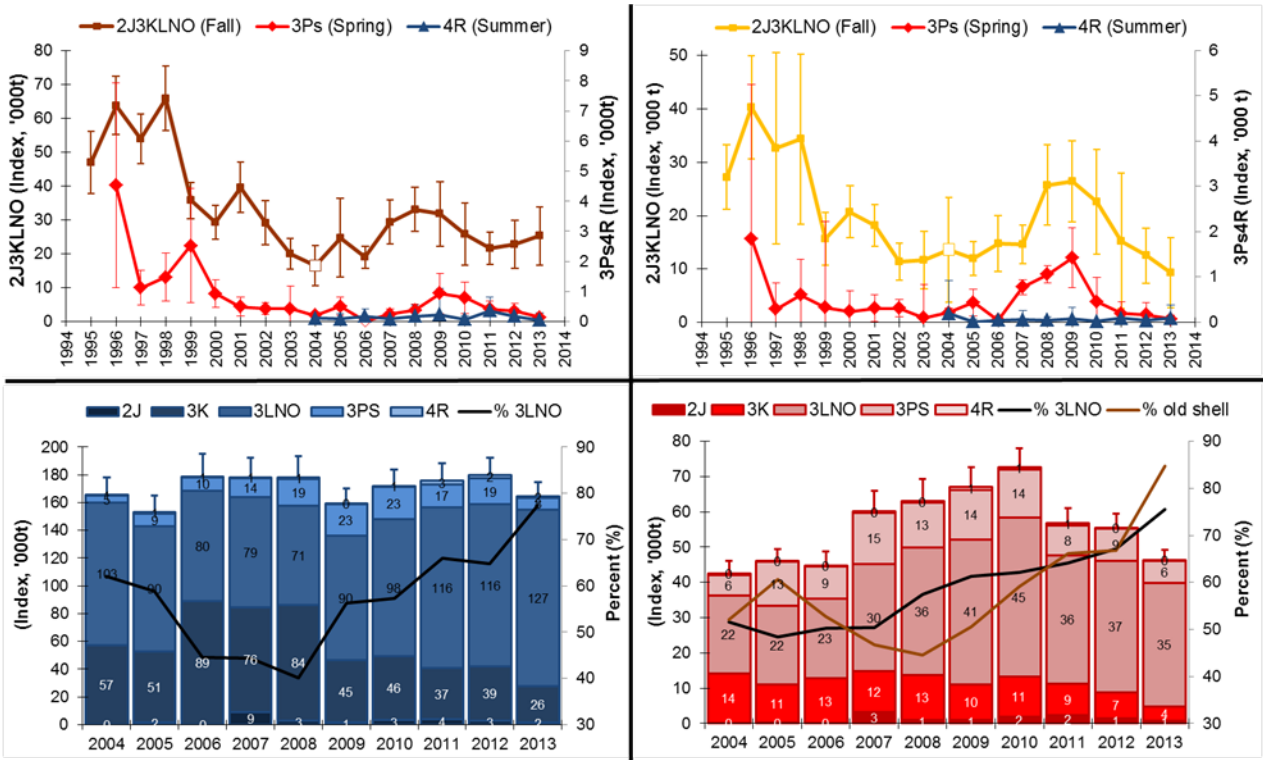

Figure 13: Trends in exploitable biomass indices (left) and pre-recruit biomass indices (right) from multi-species offshore surveys (top) during fall (Division 2HJ3KLNO), spring (Subdivision 3Ps), and summer (Div. 4R) and from fall post-season trap surveys throughout inshore and offshore Div. 2J3KLNOPs4R (bottom). The heavy line overlain on the trap-based indices represents the percentage of the index derived from Div. 3LNO whereas the lighter line represents the percentage of sub-legal-sized crabs that were old-shelled. Note that season-specific trawl survey indices are not additive due to differences in trawl efficiency and open symbols denote incomplete survey years.

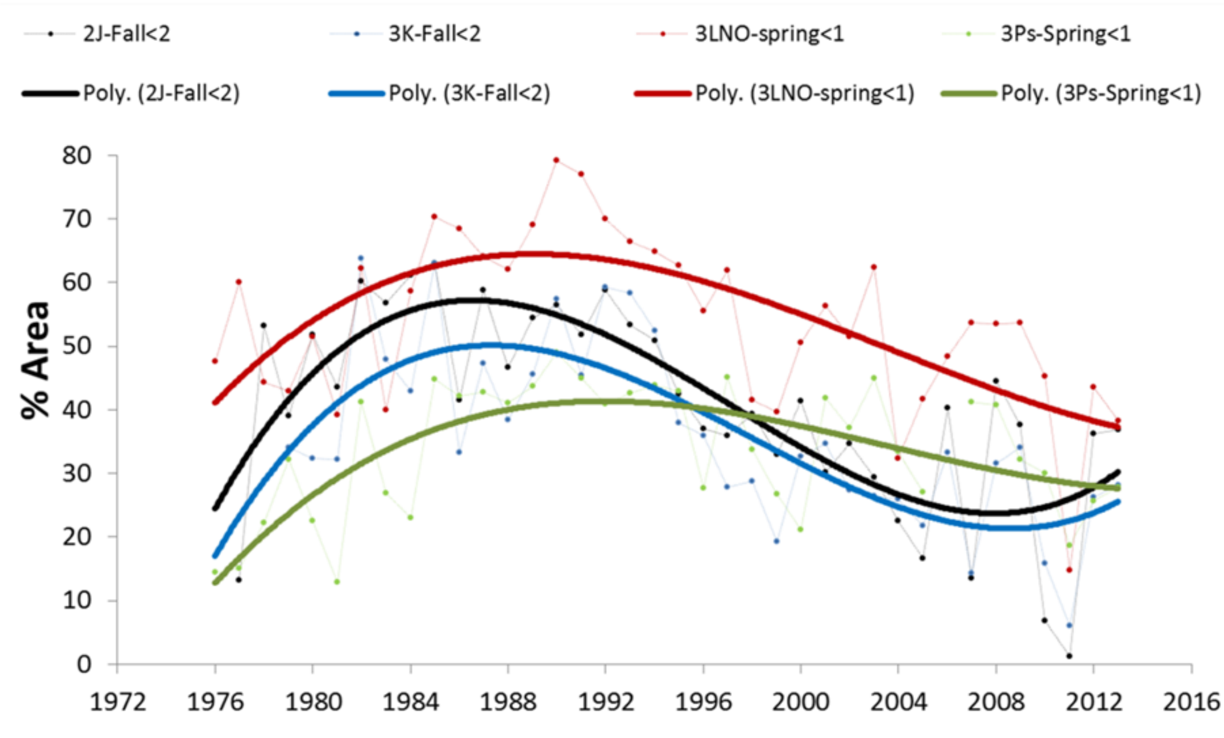

Figure 14: Snow crab thermal habitat indices and third-order polynomial regression models depicting division-specific trends.

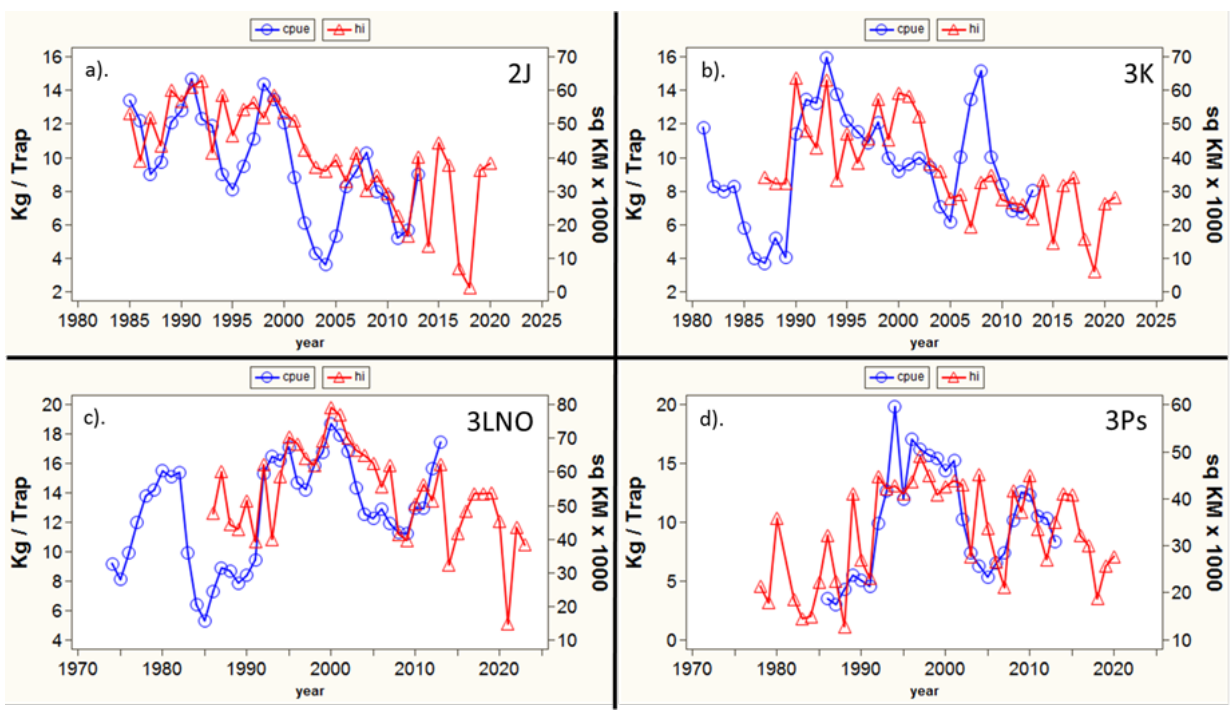

Figure 15. Relationship of CPUE with habitat indices (HI) for Divisions 2J3KLNOPs at delays of 6-8 years for Div.2J3KPs and 10 years for Div. 3LNO. Delay of best fit was determined by pairwise correlation analysis.

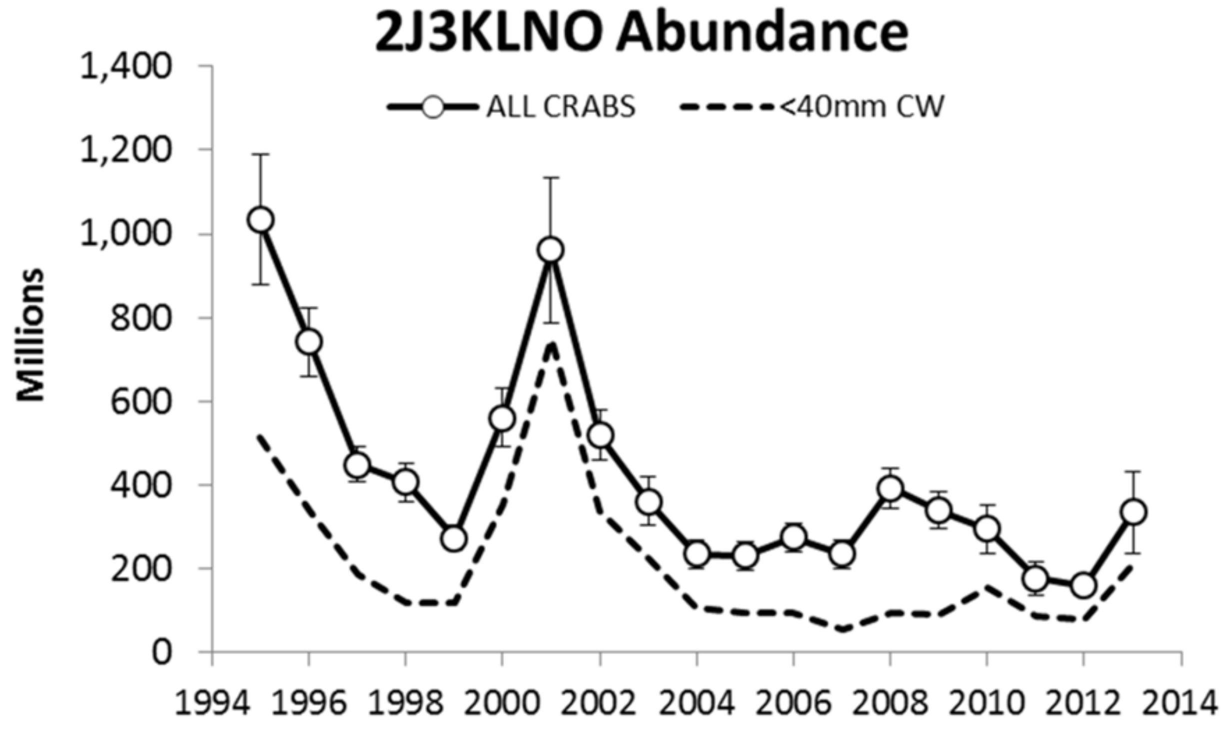

Figure 16: Trends in abundance (index) of all crabs captured in fall Div. 2J3KLNO trawl surveys as well as small (<40mm CW) crabs.

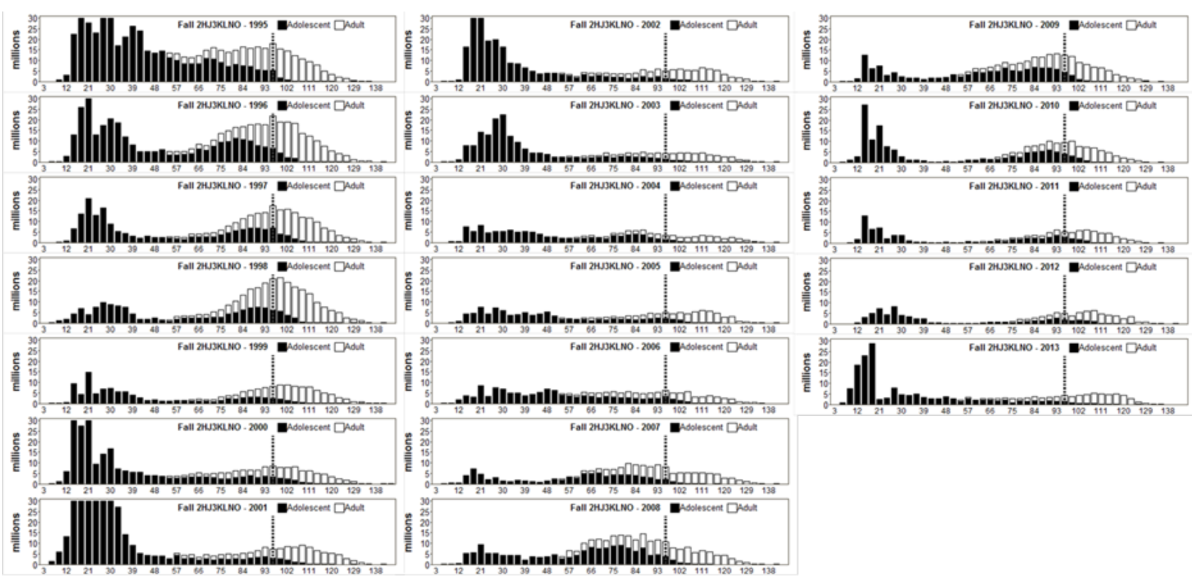

Figure 17: Annual abundance indices since 1995 by carapace width for Div. 2J3KLNO juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys. Abundance is truncated for smallest crabs (< 50mm CW). The minimum legal size is indicated by a vertical dashed line.

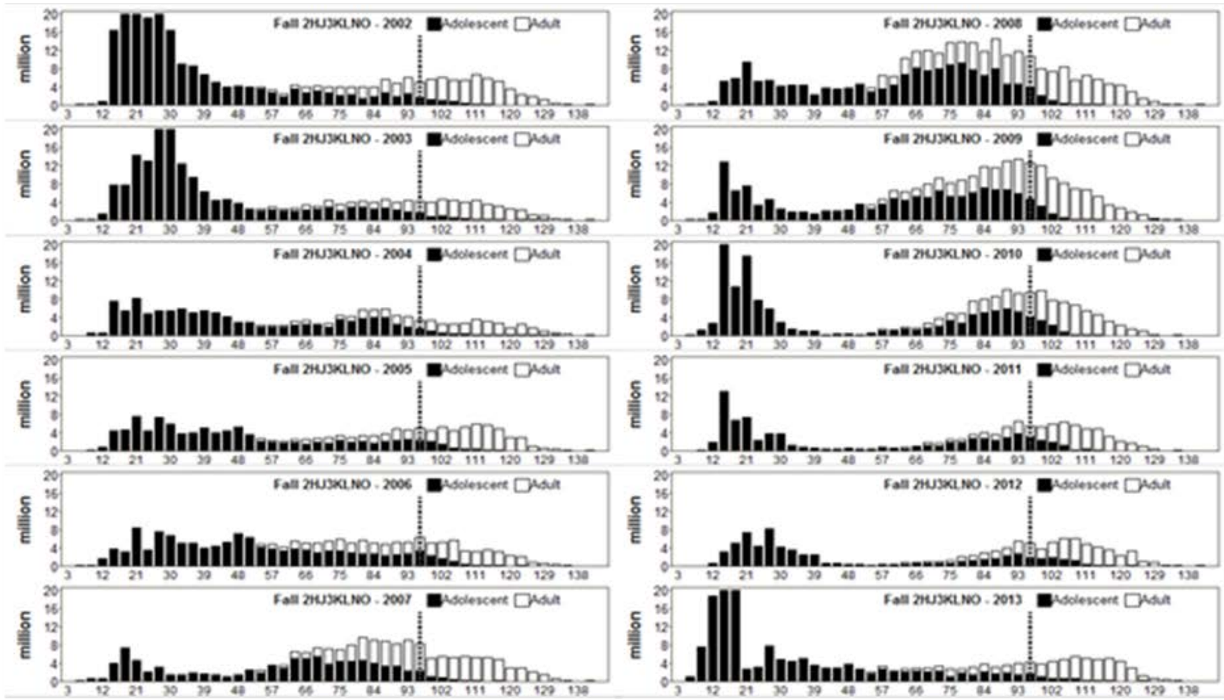

Figure 18: Annual abundance indices since 2002 by carapace width for Div. 2J3KLNO juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys. Abundance is truncated for smallest crabs (< 50mm CW). The minimum legal size is indicated by a vertical dashed line.

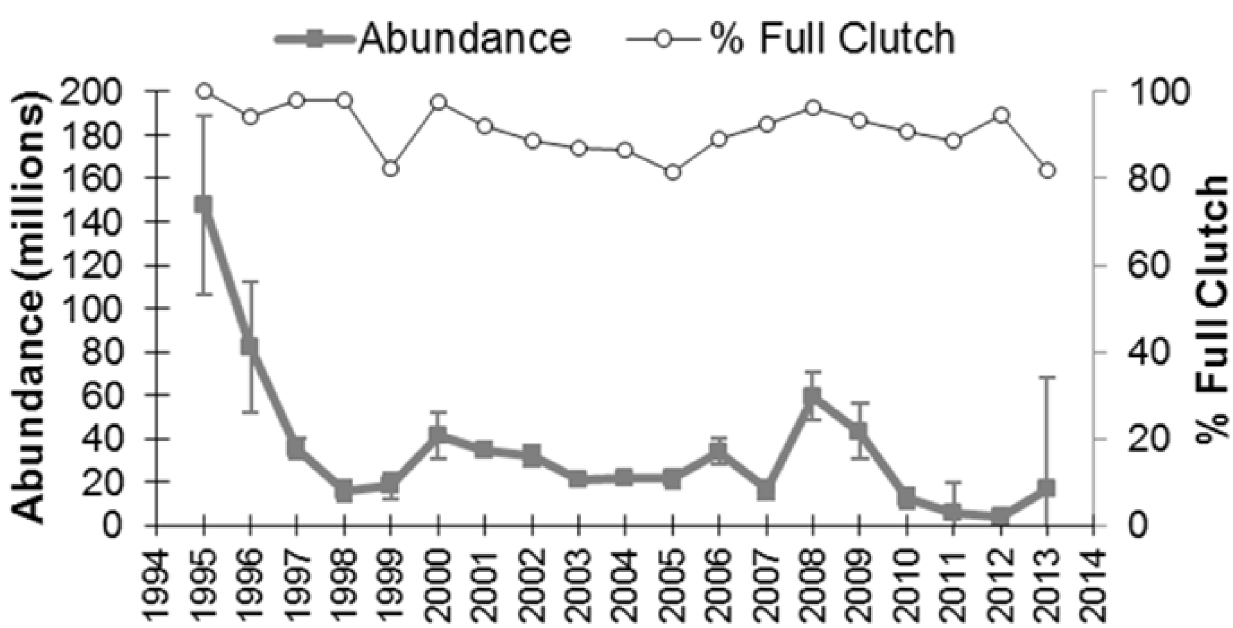

Figure 19: Trends in the mature female abundance index and percentage of mature females bearing full clutches of viable eggs in Div. 2HJ3KLNO from fall multi-species surveys.

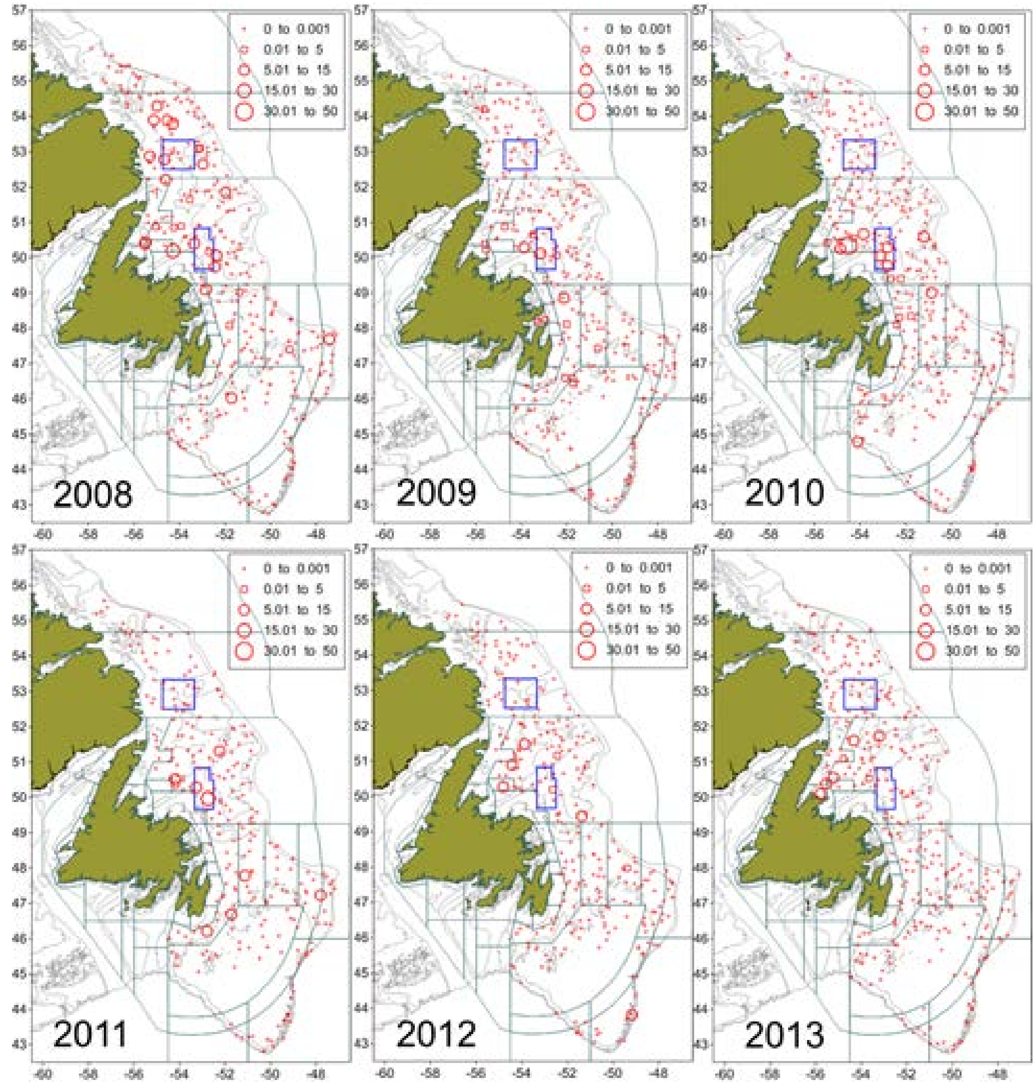

Figure 20: Percentage of fall trawl survey catches of male crabs with BCD from 2008-2013.

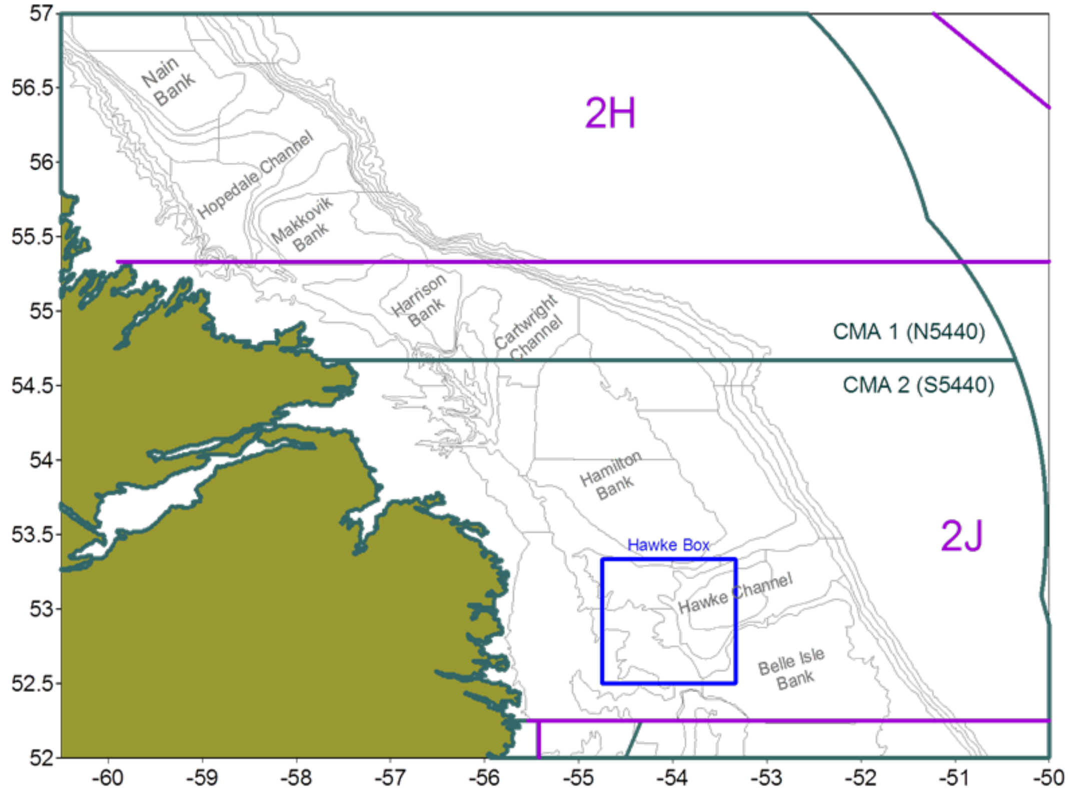

Figure 21: Map of Division 2HJ showing important bathymetric features and the Hawke Channel closed area.

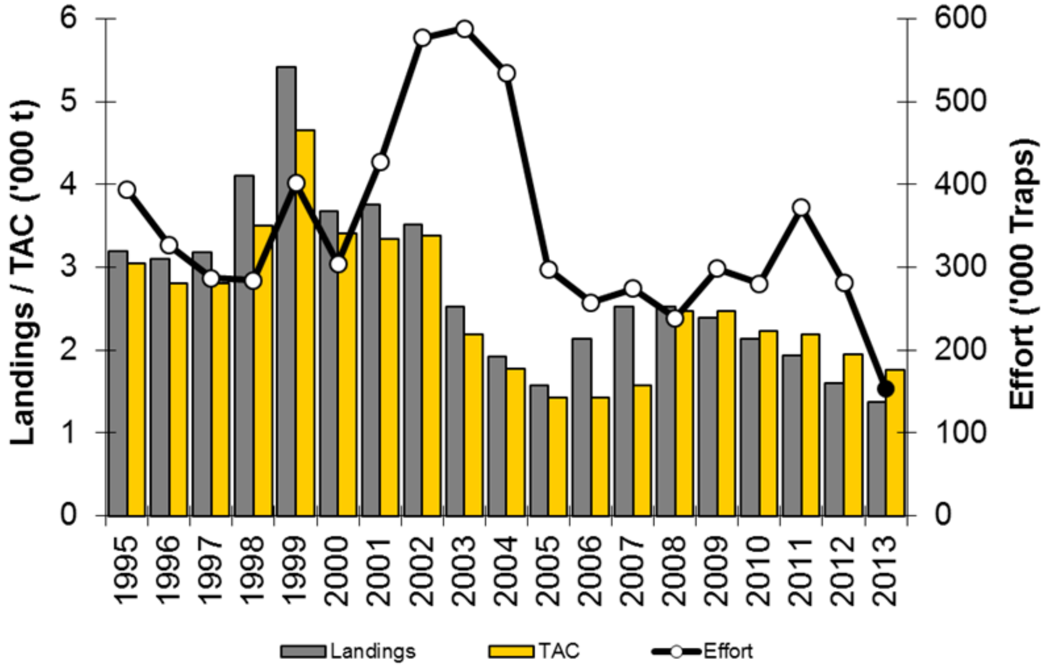

Figure 22: Trends in Div. 2HJ landings, TAC, and fishing effort. (2013 effort preliminary).

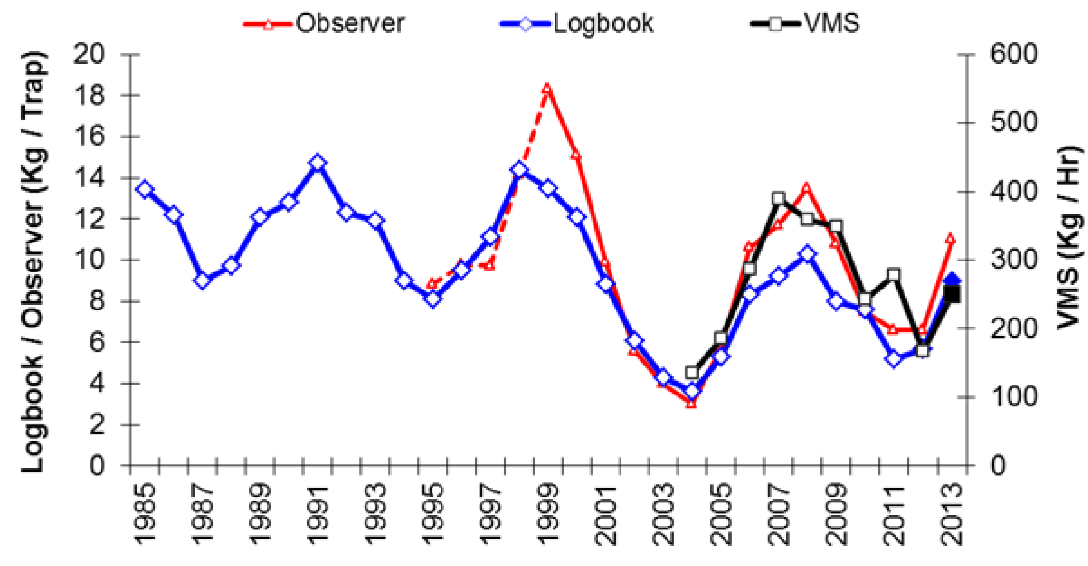

Figure 23: Trends in commercial logbook-based, observer-based, and VMS-based CPUE in the Div. 2HJ fishery. (2013 logbook and VMS CPUE estimates preliminary).

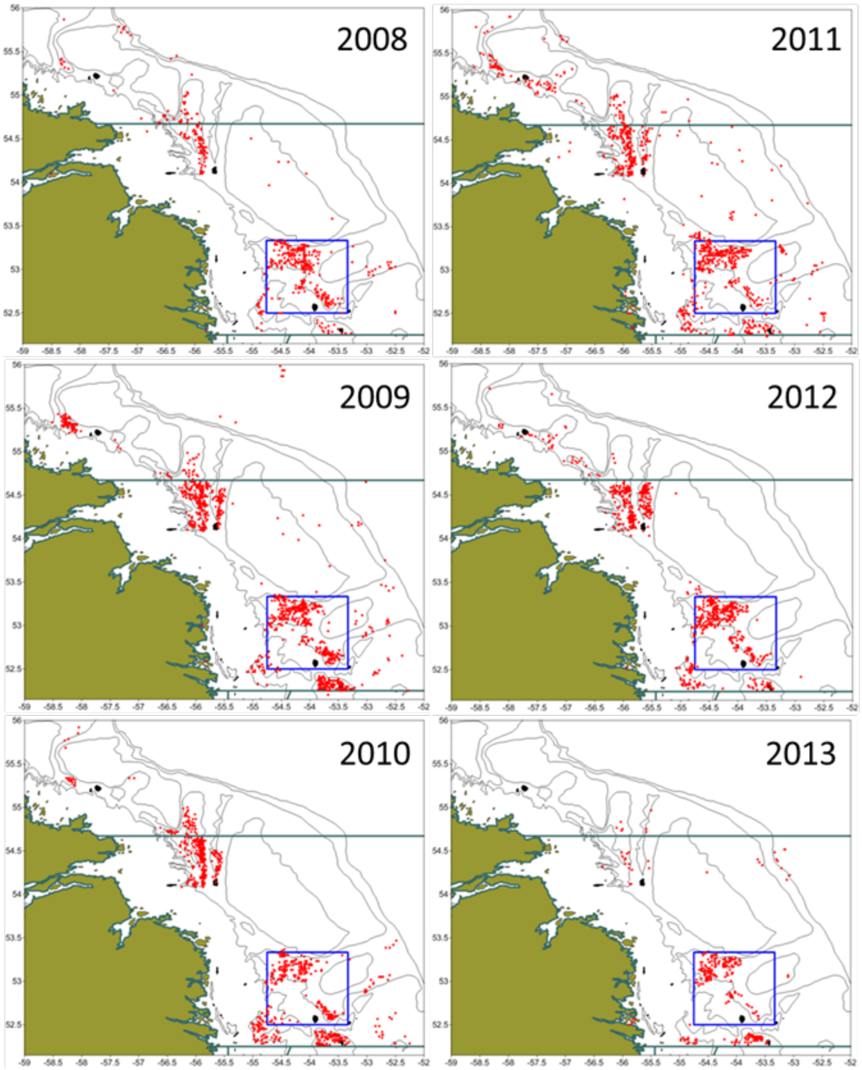

Figure 24: Spatial distribution of Div. 2HJ fishing effort by year.

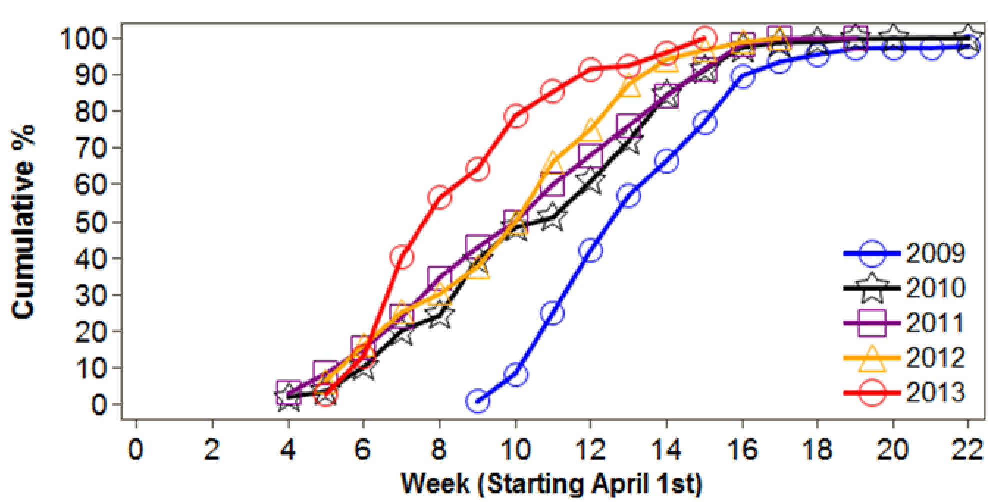

Figure 25: Seasonal trends in weekly fishing effort for Div. 2HJ.

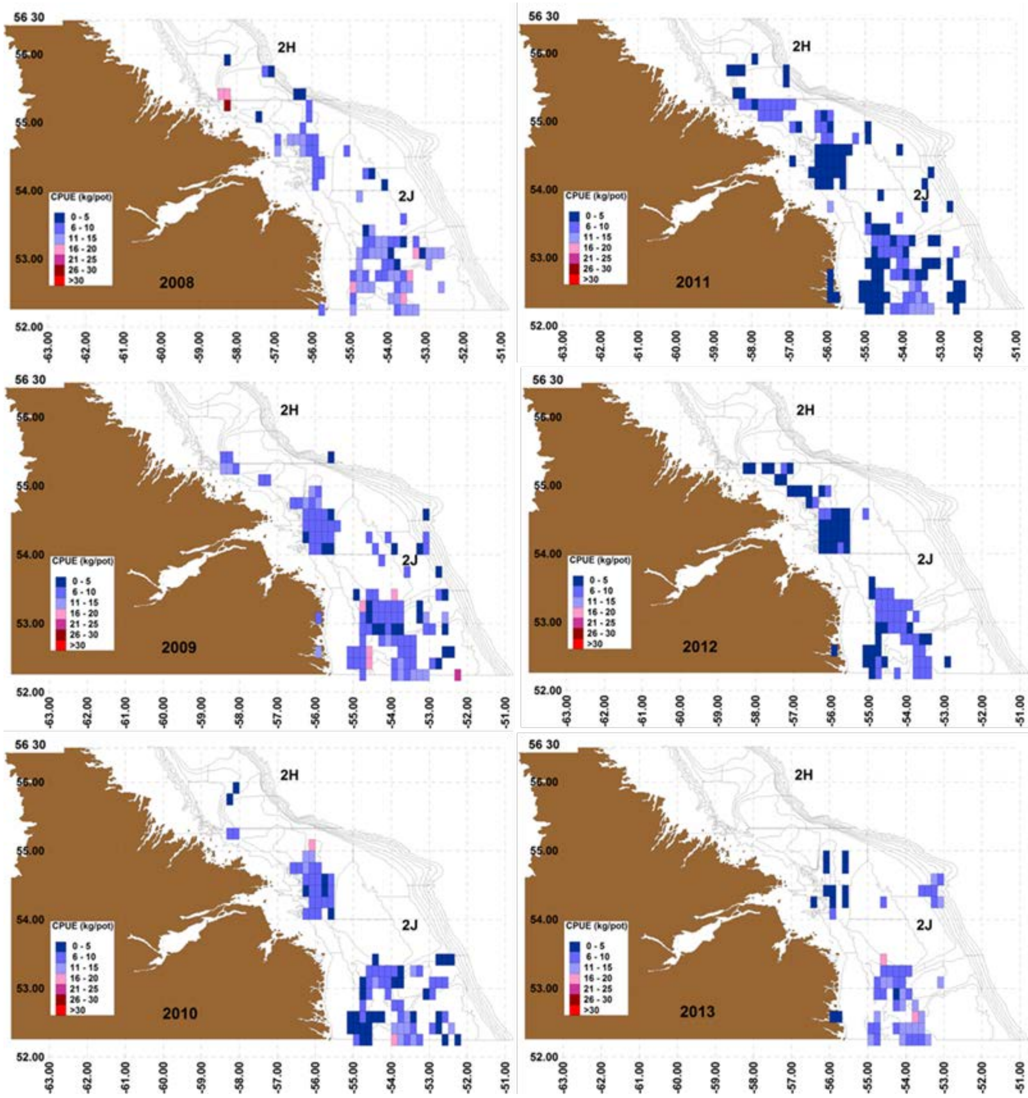

Figure 26: Spatial distribution of Div. 2HJ logbook CPUE by year.

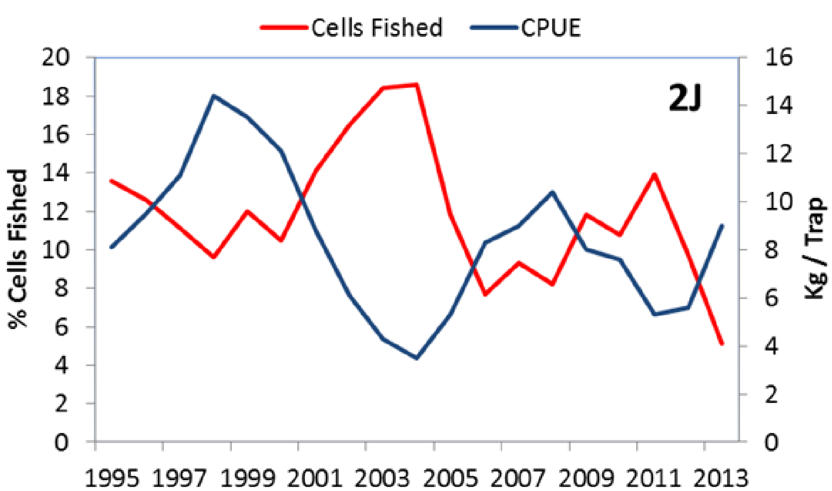

Figure 27: Trends in Div. 2J commercial CPUE vs. the percentage of 5' x 5' cells fished.

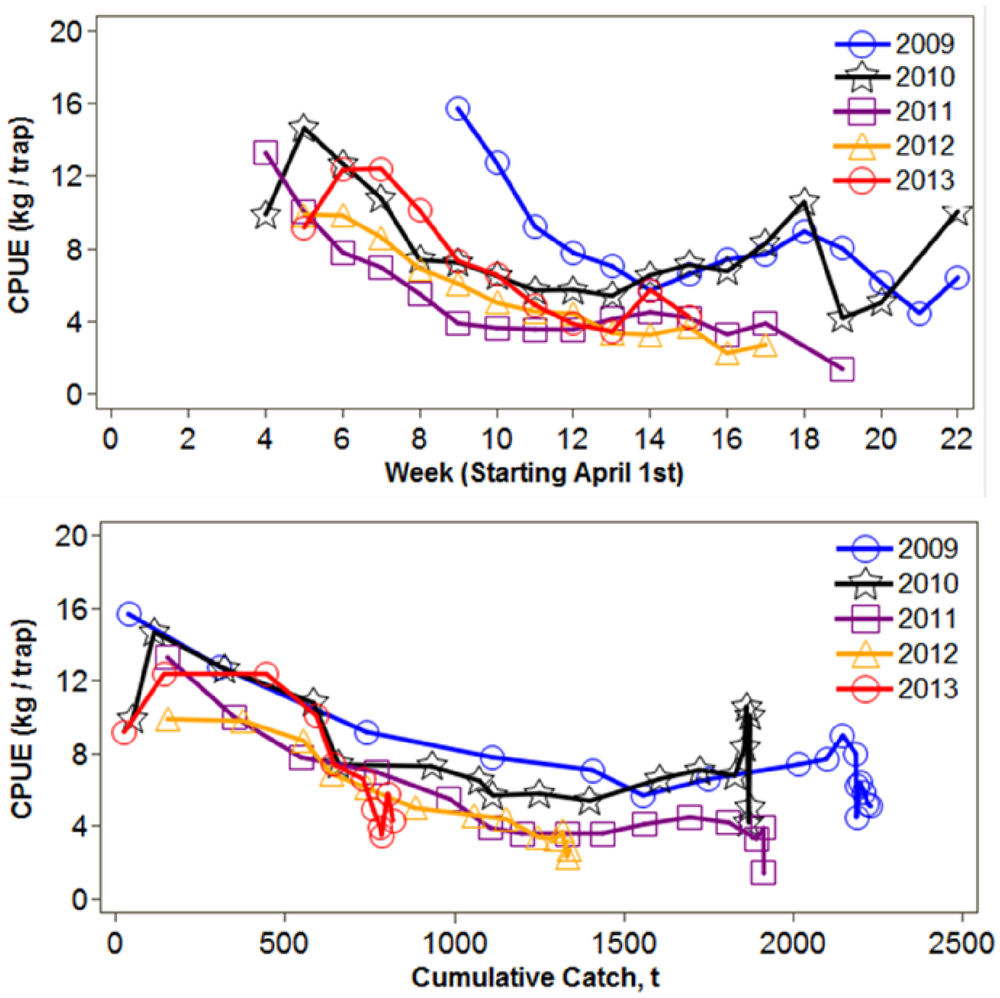

Figure 28: Seasonal trends in logbook CPUE for Div. 2HJ; by week (top), and in relation to cumulative catch (bottom).

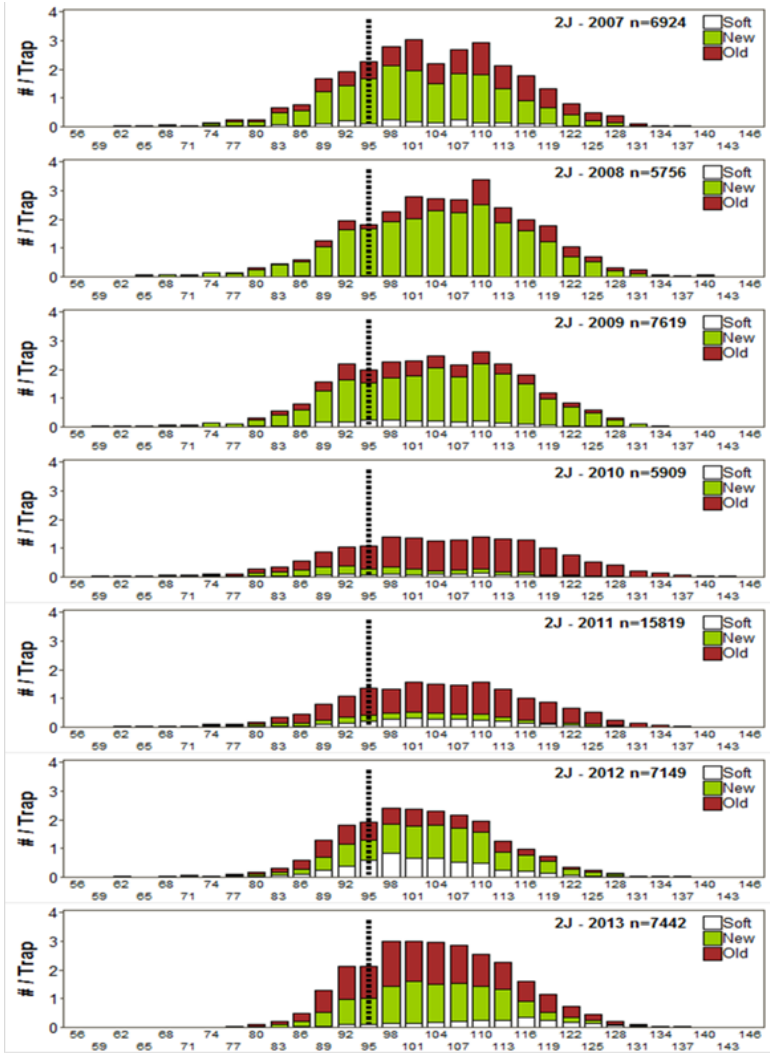

Figure 29: Trends in male carapace width distributions by shell condition from observer at-sea sampling for Div. 2HJ. The vertical dashed line indicates the minimum legal size.

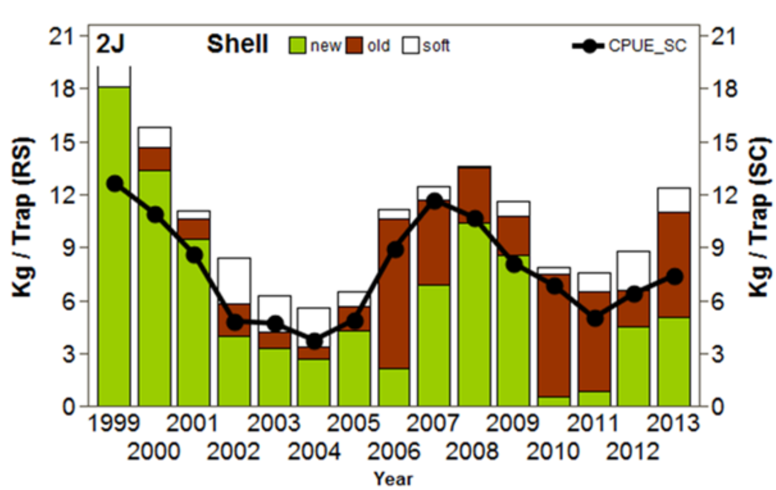

Figure 30: Trends in Division 2HJ observer catch rates of legal-sized crabs by shell condition from at-sea sampling and of all crabs kept based on set and catch records (sc).

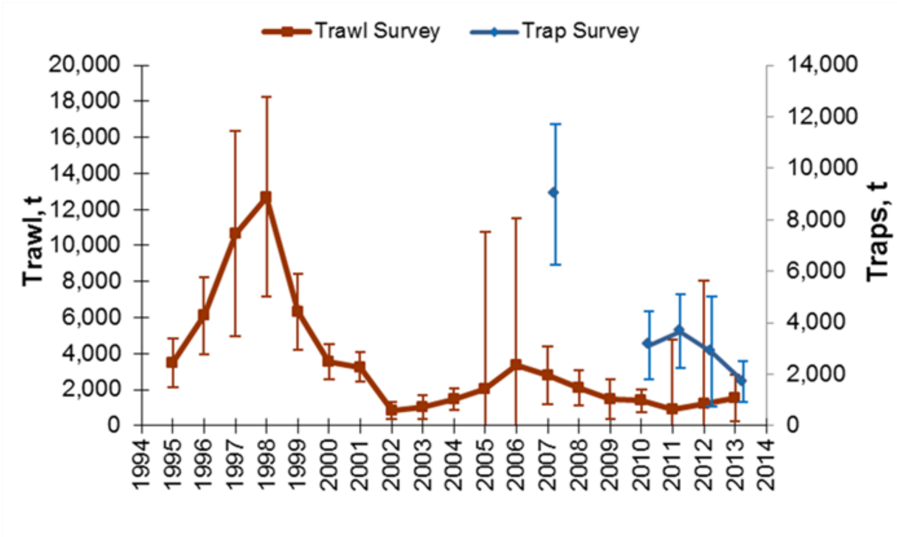

Figure 31: Trends in the Div. 2HJ fall trawl survey exploitable biomass index and the CPS trap survey exploitable biomass index. Only the Hawke Channel was surveyed in the 2008 and 2009 trap surveys.

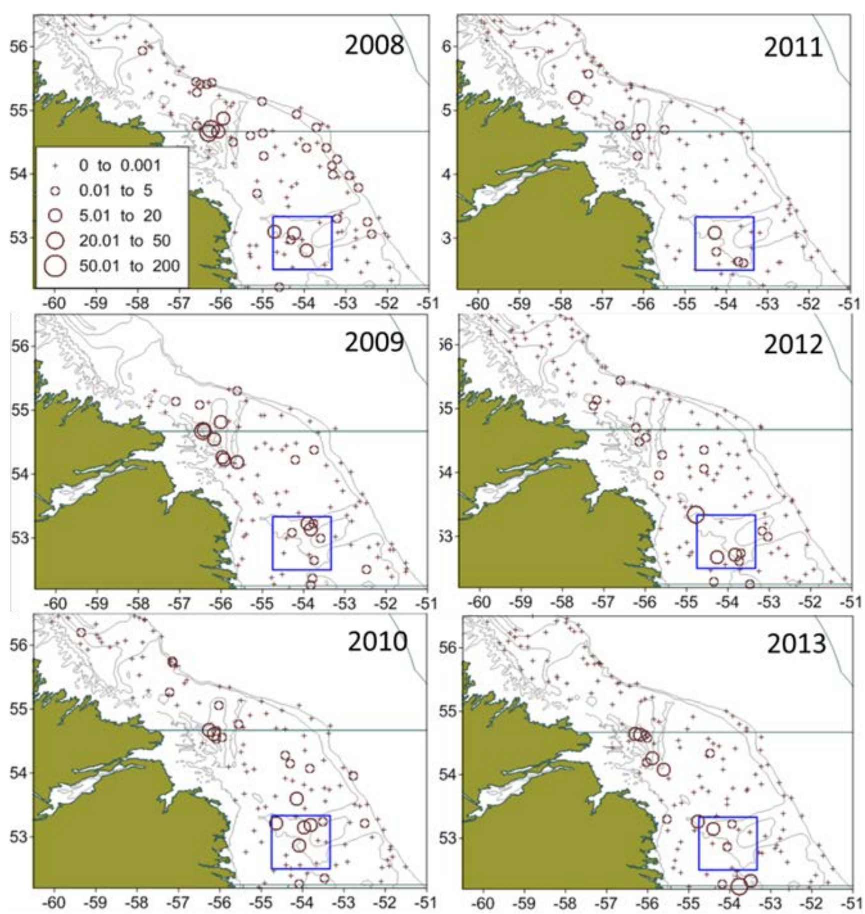

Figure 32: Spatial distribution of catches (number / set) of exploitable males in the Div. 2HJ fall trawl survey.

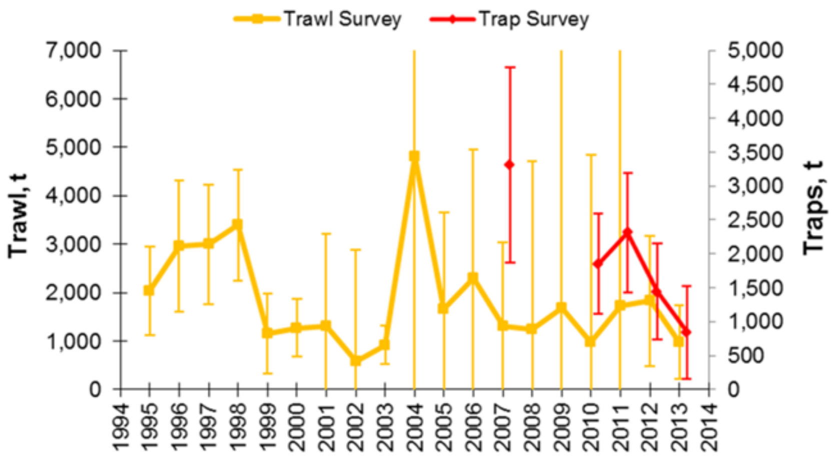

Figure 33: Trends in the Div. 2HJ fall trawl survey pre-recruit biomass index and the CPS trap survey pre-recruit biomass index. Only the Hawke Channel was surveyed in the 2008 and 2009 trap surveys.

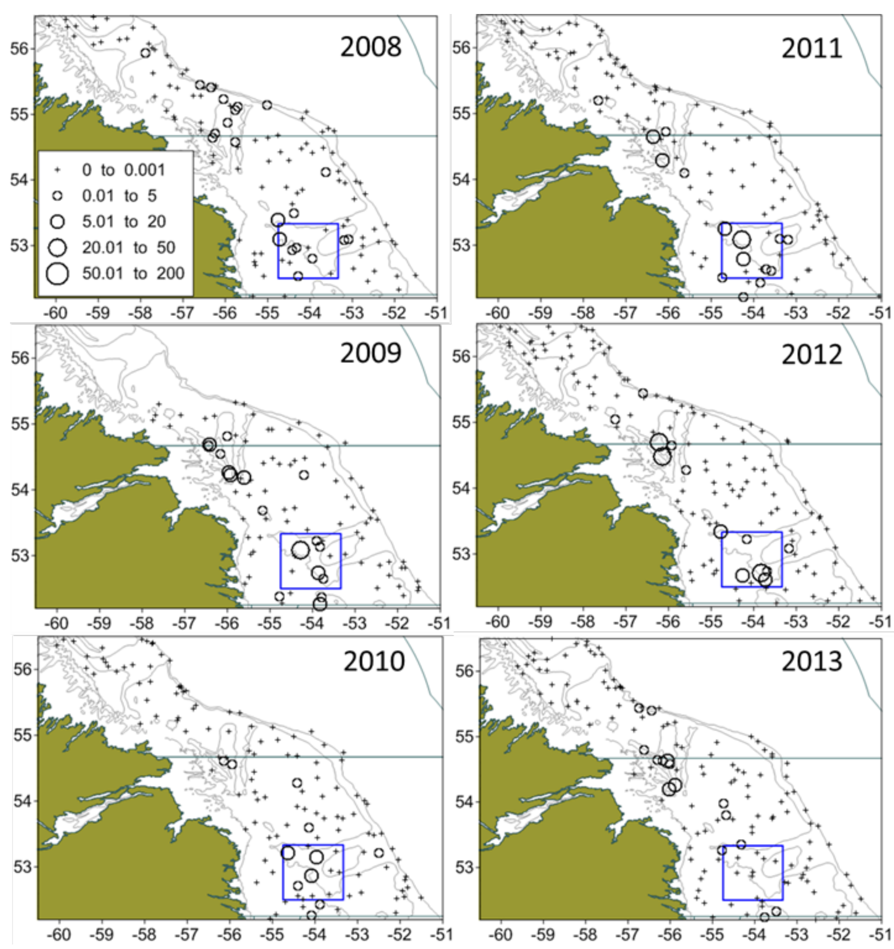

Figure 34: Spatial distribution of catches (number / set) of pre-recruit males in the Div. 2HJ fall trawl survey.

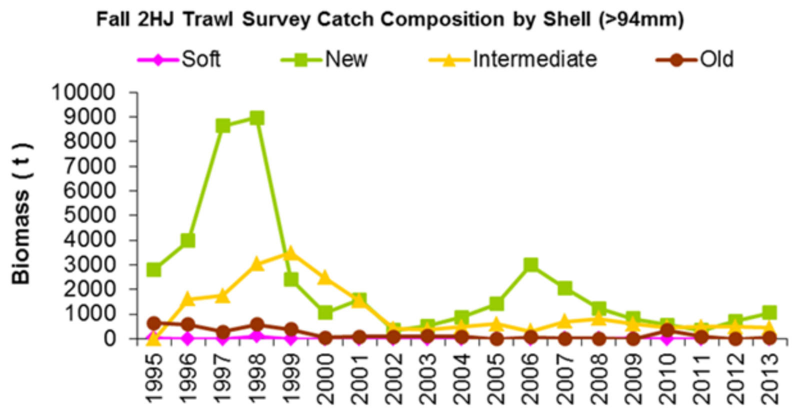

Figure 35: Trends, by shell condition, in biomass of legal-sized males for Div. 2HJ from fall trawl surveys.

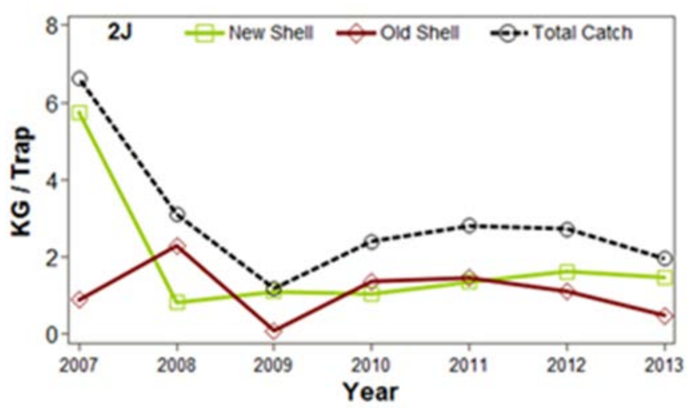

Figure 36: Trends in CPUE by shell condition for legal-sized crabs from core stations in the Div. 2J CPS trap survey.

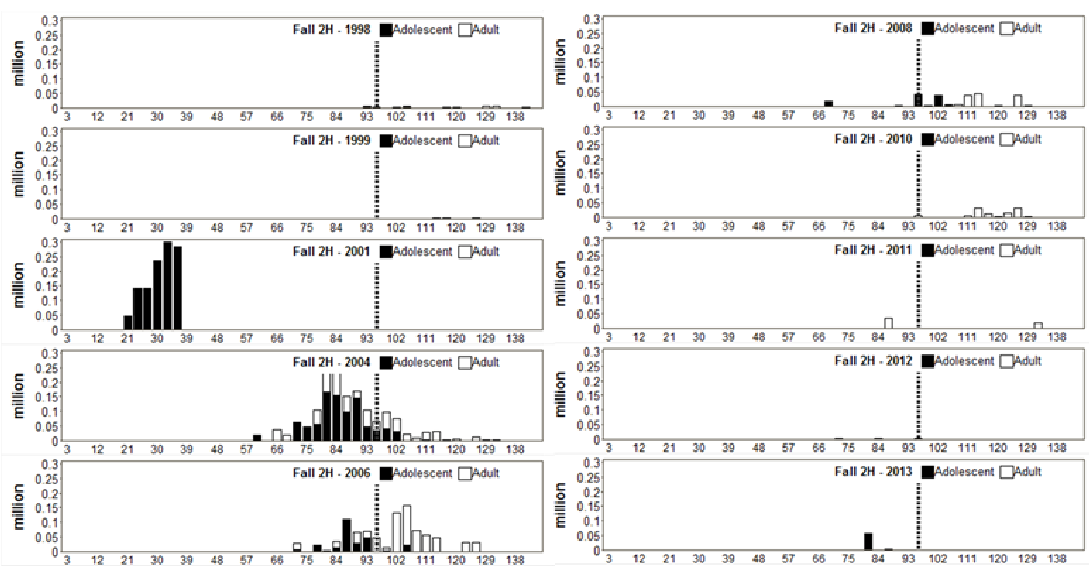

Figure 37: Abundance indices by carapace width for Div. 2H juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys.

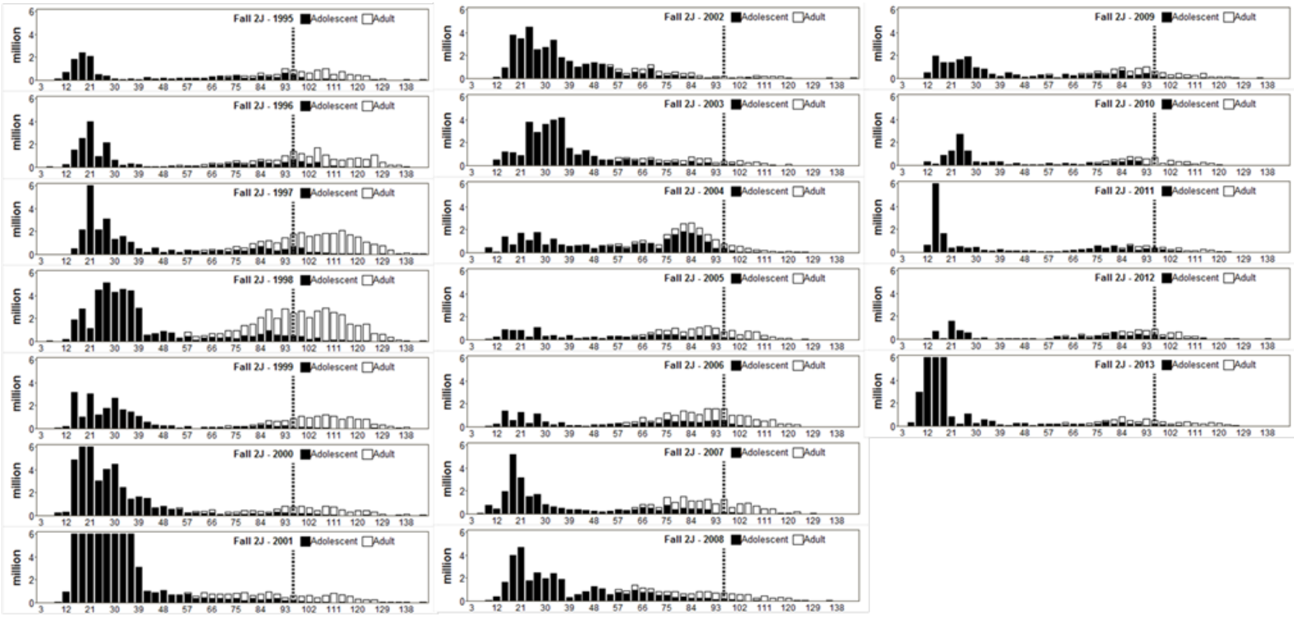

Figure 38. Abundance indices by carapace width for Div. 2J juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys.

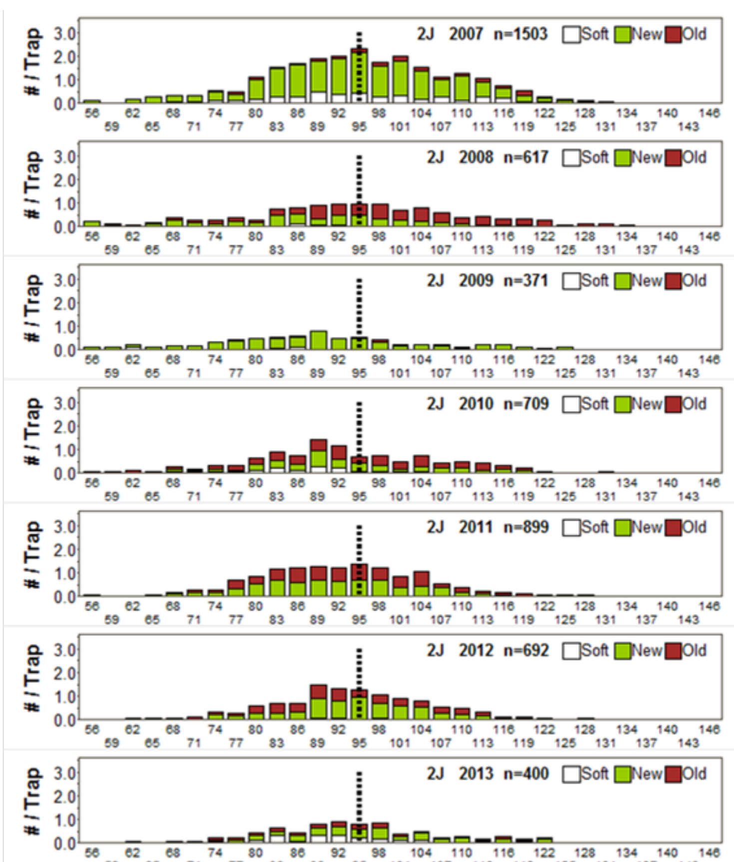

Figure 39: Trends in male carapace width distributions from core stations in the Div. 2J CPS trap survey. The vertical dashed line indicates the minimum legal size.

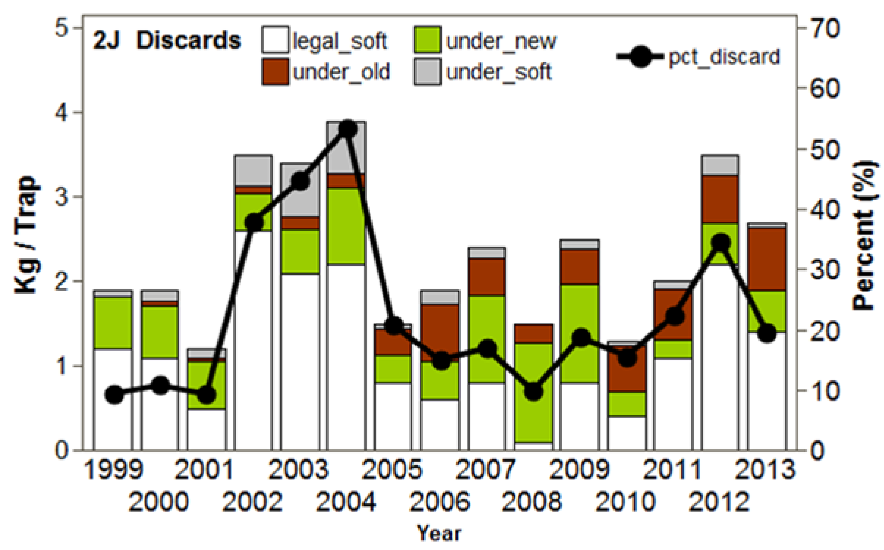

Figure 40: Trends in Division 2J observer catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

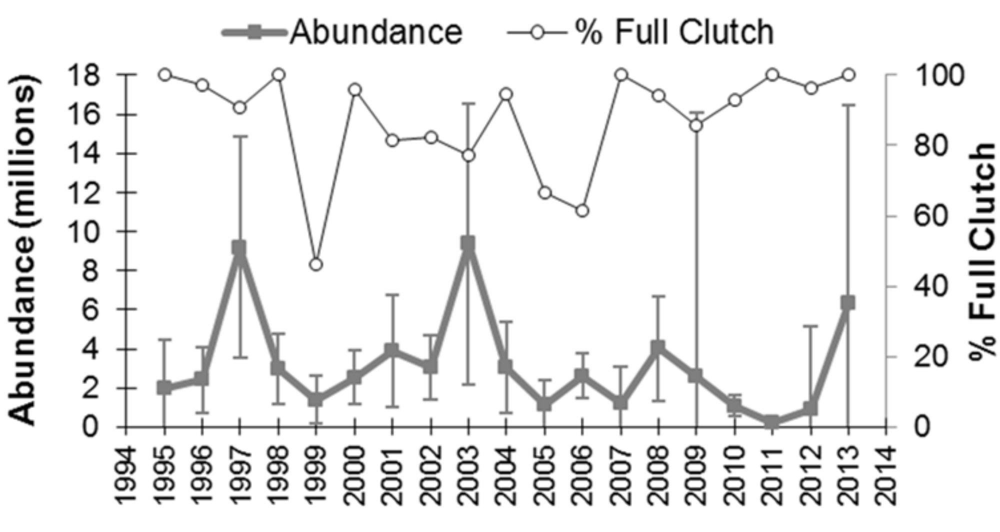

Figure 41: Trends in abundance of mature females as well as the percentage of mature females bearing full clutches of viable eggs in Div. 2HJ from fall multi-species surveys.

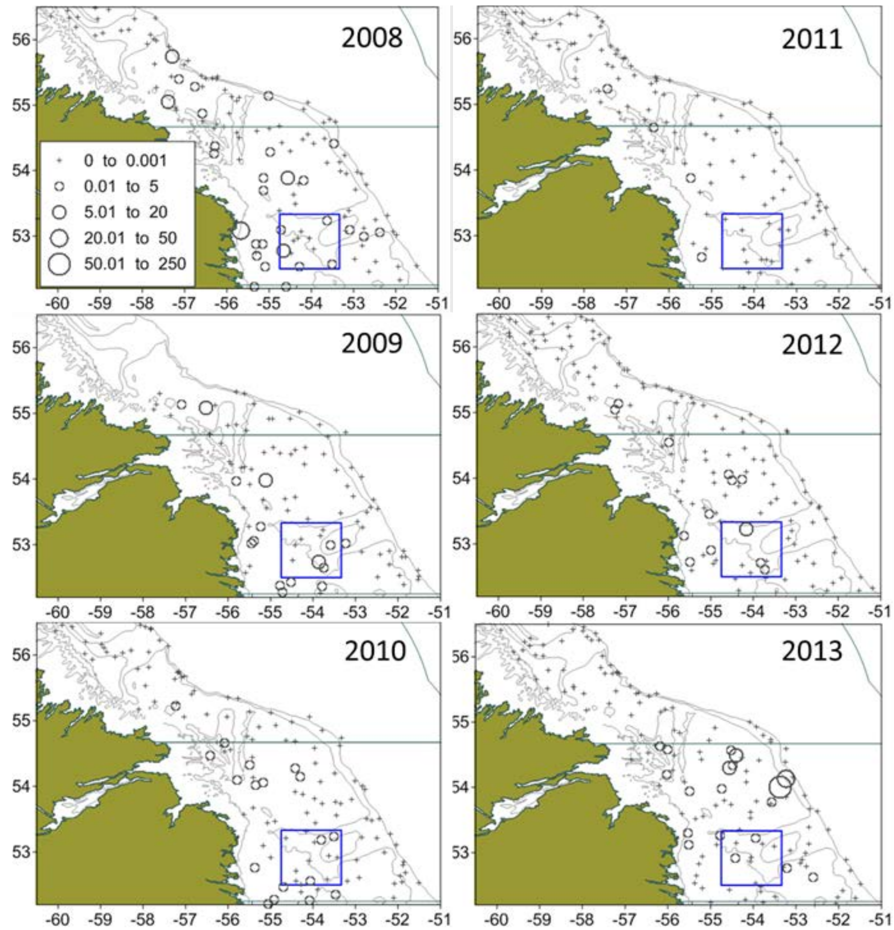

Figure 42: Spatial distribution of catch rates (number / set) of mature females in the Div. 2HJ fall trawl survey.

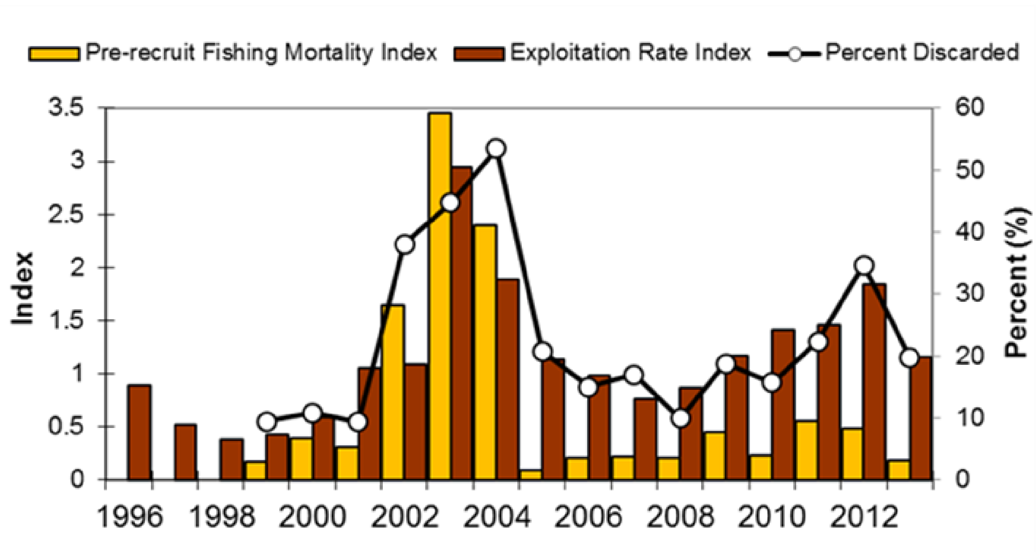

Figure 43: Trends in Div. 2HJ mortality indices (the exploitation rate index and the pre-recruit fishing mortality rate index) and in the percentage of the catch discarded in the fishery.

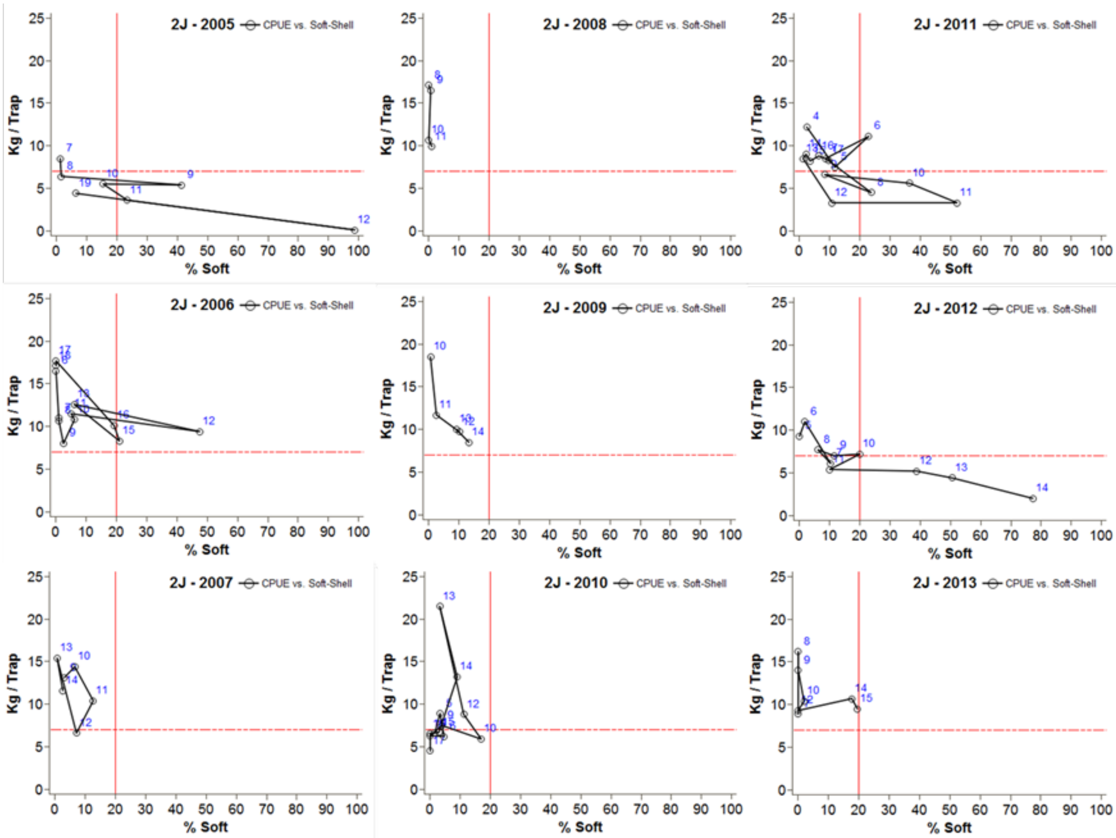

Figure 44: Trends in weekly percentages of kept vs. soft-shell crab in the Div. 2J fishery from at-sea sampling by observers.

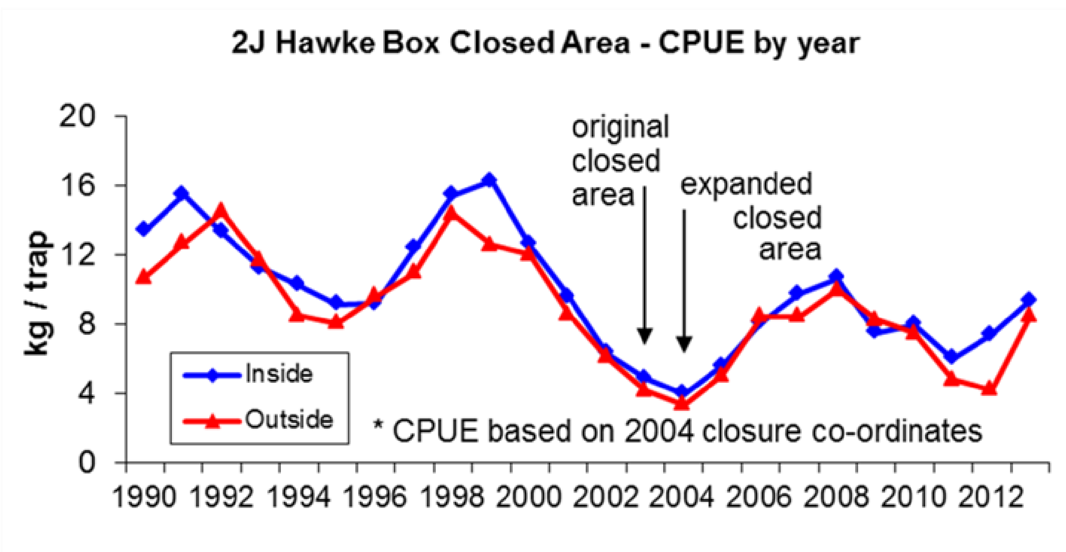

Figure 45: Trends in Div. 2J commercial logbook CPUE inside vs. outside the Hawke Channel closed area.

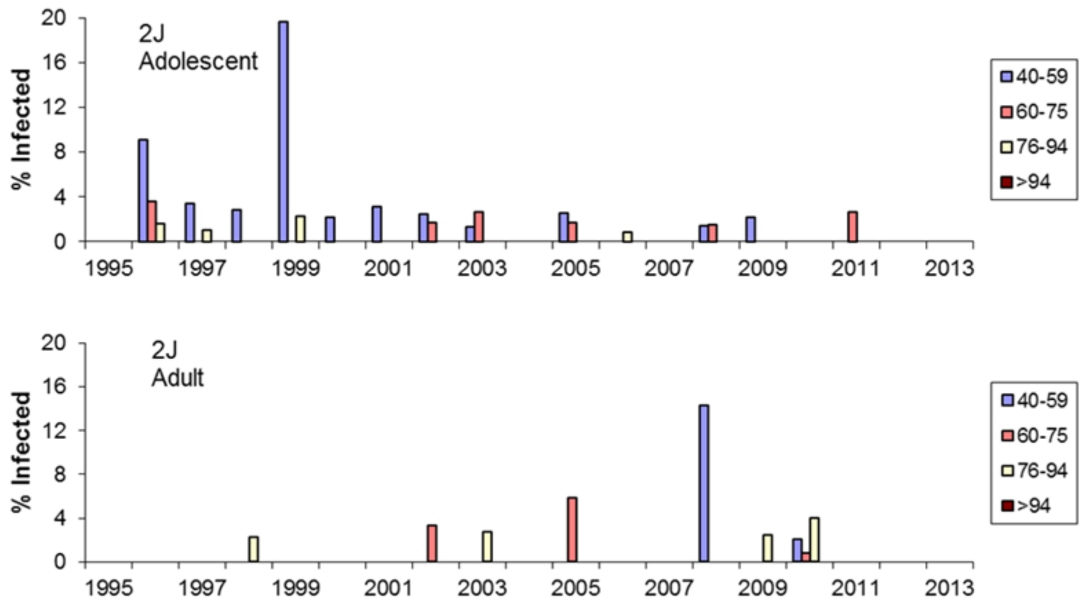

Figure 46: Annual trends in prevalence of BCD in new-shelled adolescent (top) and adult (bottom) males by size group from Div. 2J fall trawl surveys.

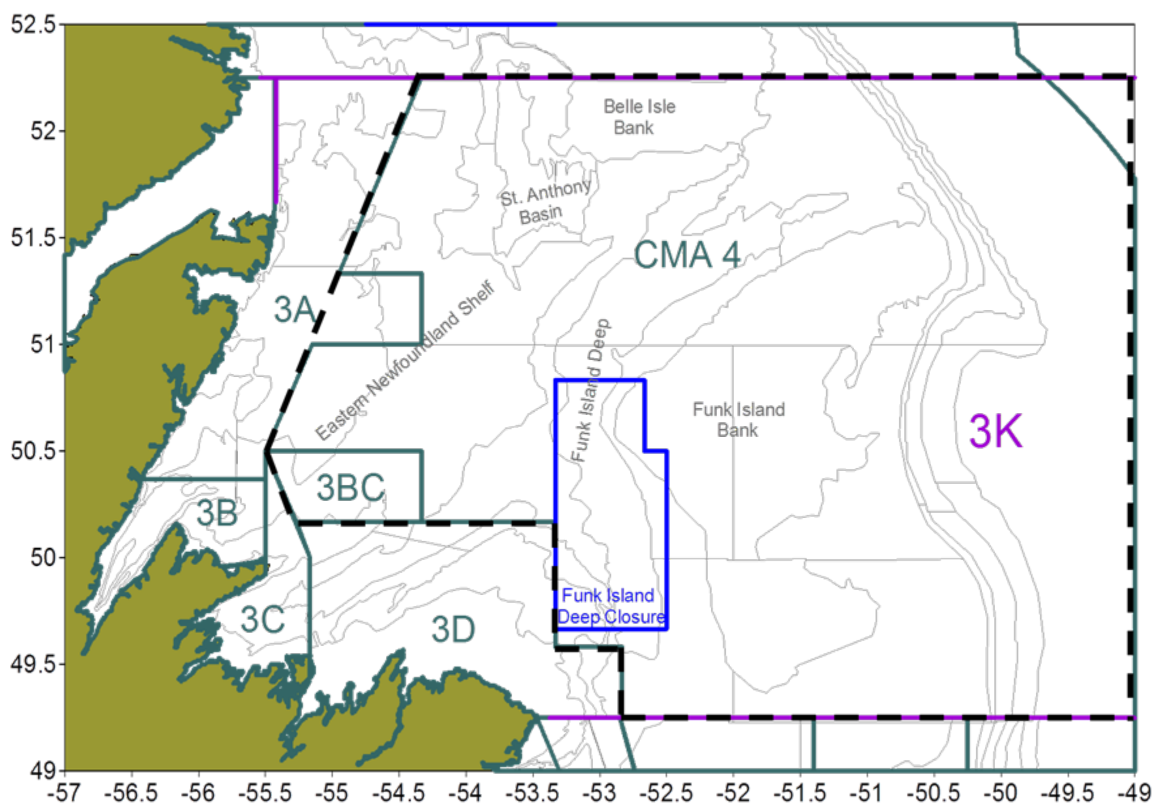

Figure 47: Map of Division 3K showing crab management areas and important bathymetric features as well as the Funk Island Deep closed area (blue box). Dashed perimeter indicates the offshore area.

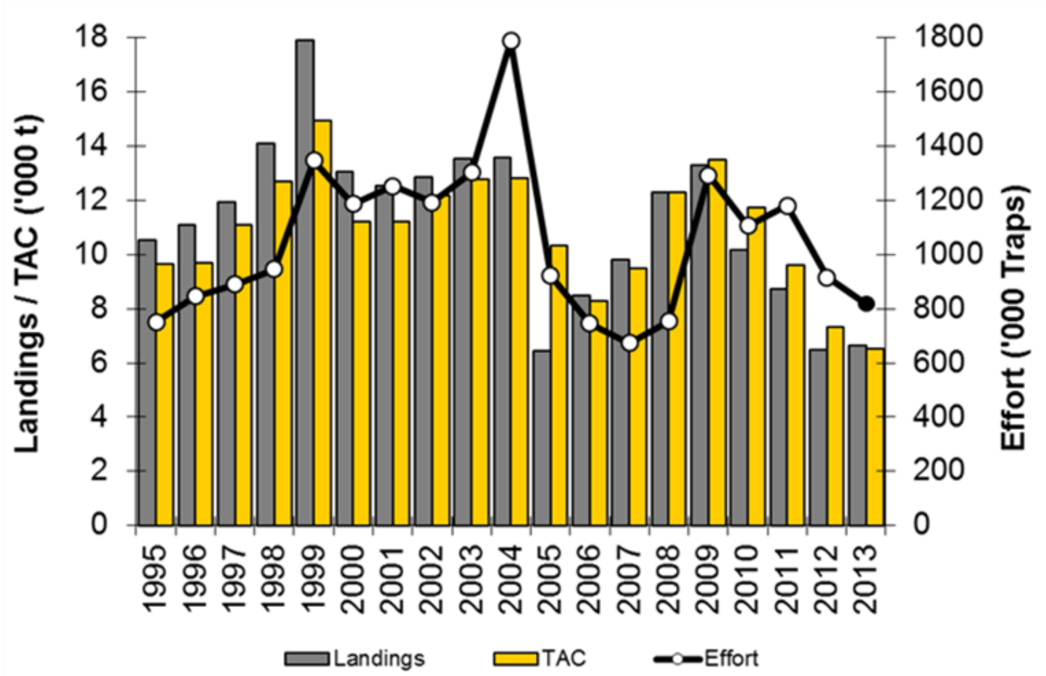

Figure 48: Trends in Div. 3K offshore landings, TAC, and fishing effort. (2013 effort preliminary).

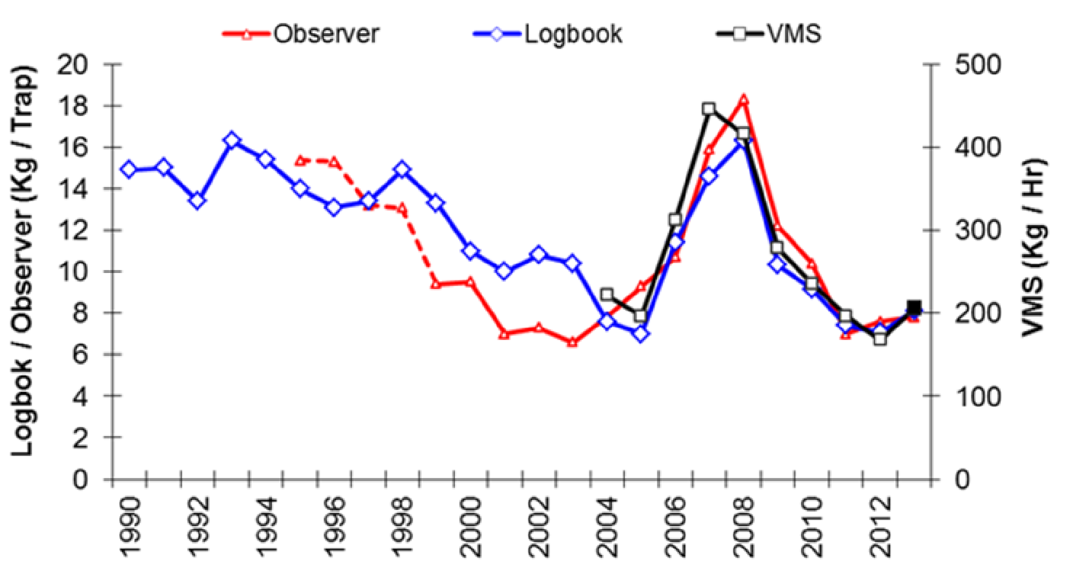

Figure 49: Trends in commercial logbook-based, observer-based, and VMS-based CPUE in the Div. 3K offshore fishery. (2013 logbook and VMS CPUE estimates preliminary).

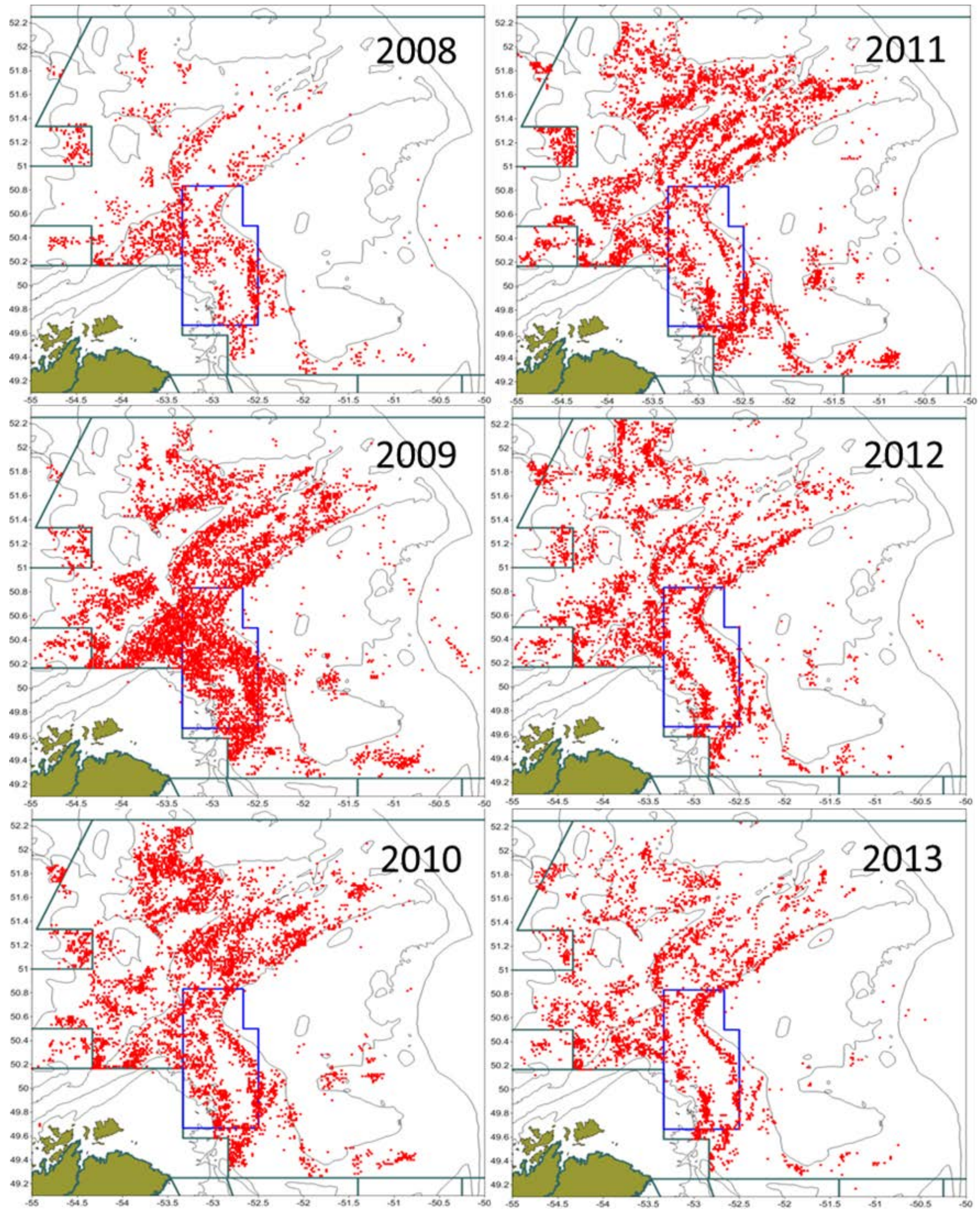

Figure 50: Spatial distribution of Div. 3K offshore fishing effort by year.

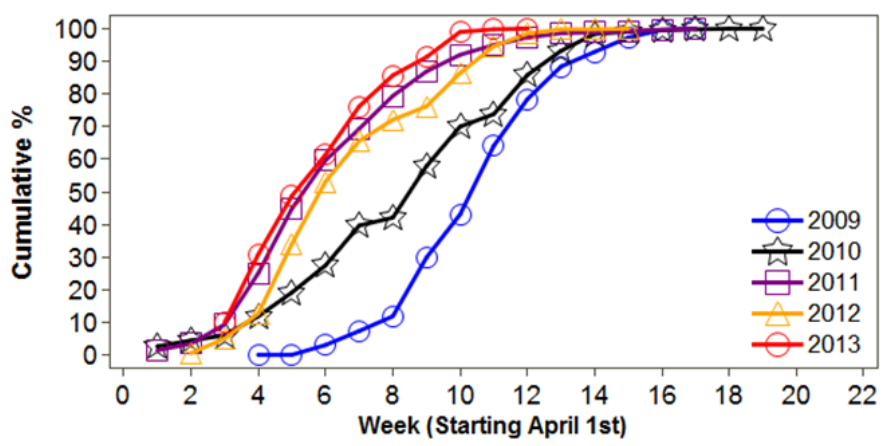

Figure 51: Seasonal trends in weekly fishing effort for Div. 3K offshore.

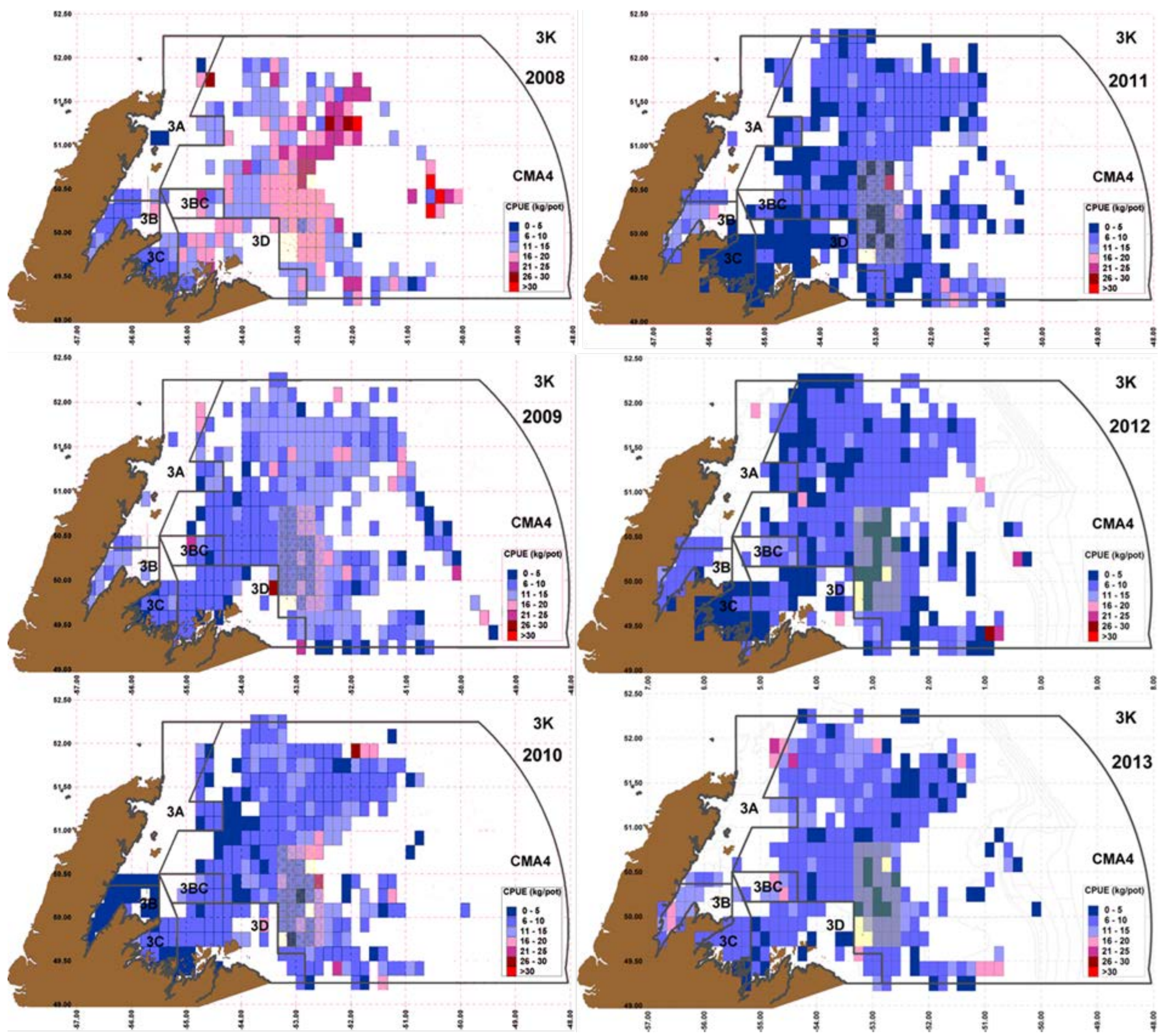

Figure 52: Spatial distribution of Div. 3K logbook CPUE by year.

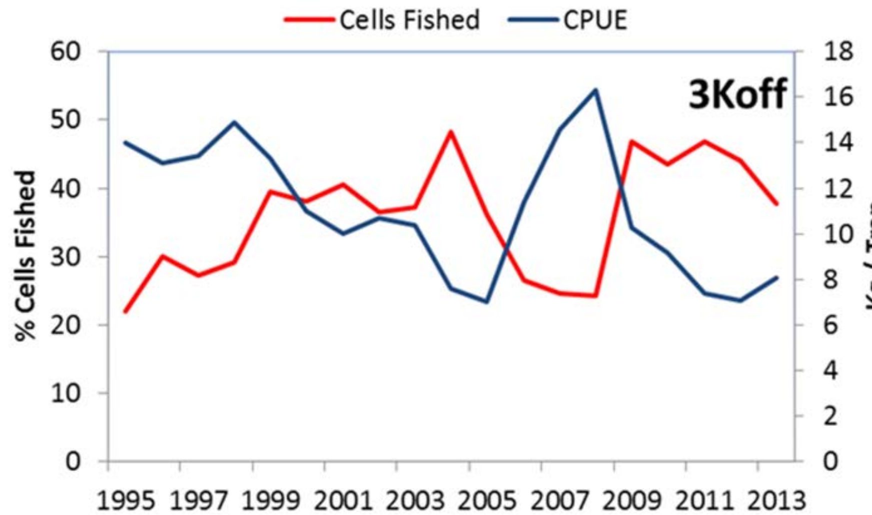

Figure 53: Trends in Div. 3K offshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

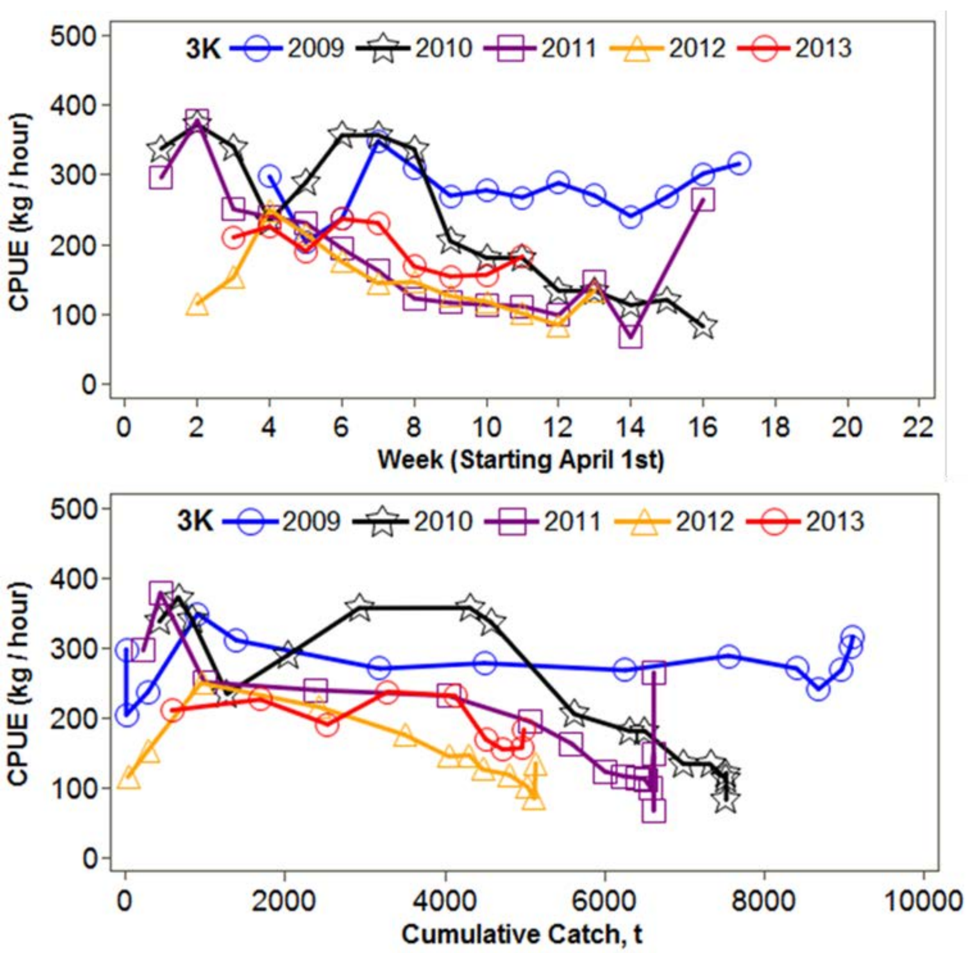

Figure 54: Seasonal trends in VMS-based CPUE for Div. 3K offshore; by week, (top) and in relation to cumulative catch (bottom).

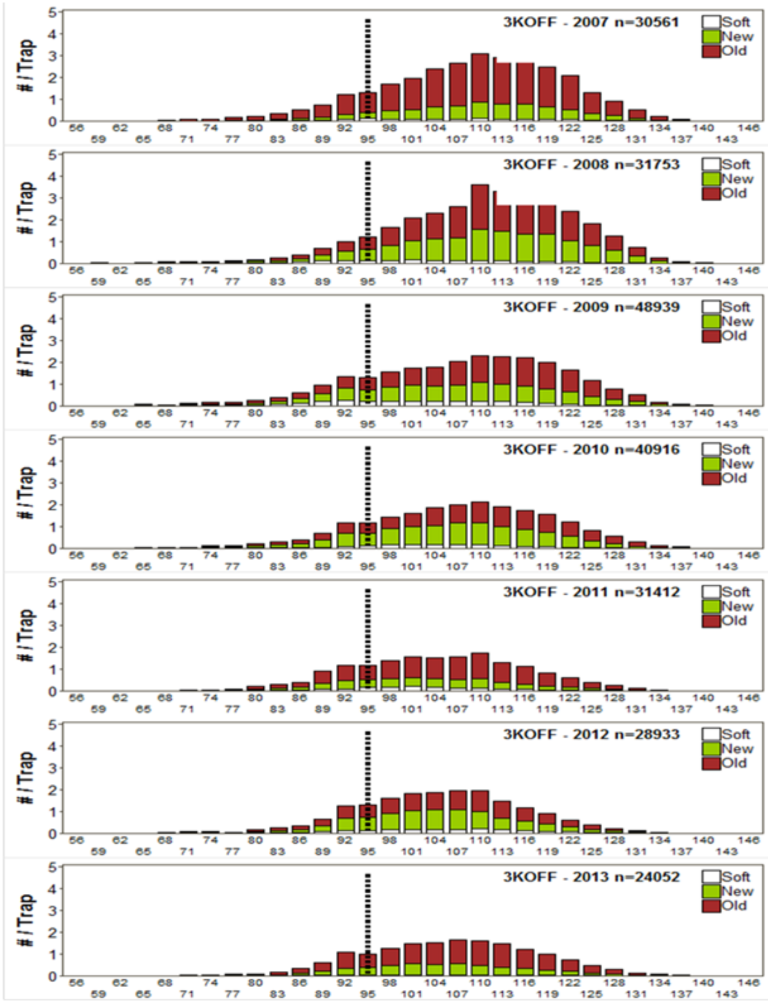

Figure 55: Trends in male carapace width distributions by shell condition from observer at-sea sampling for Div. 3K offshore. The vertical dashed line indicates the minimum legal size.

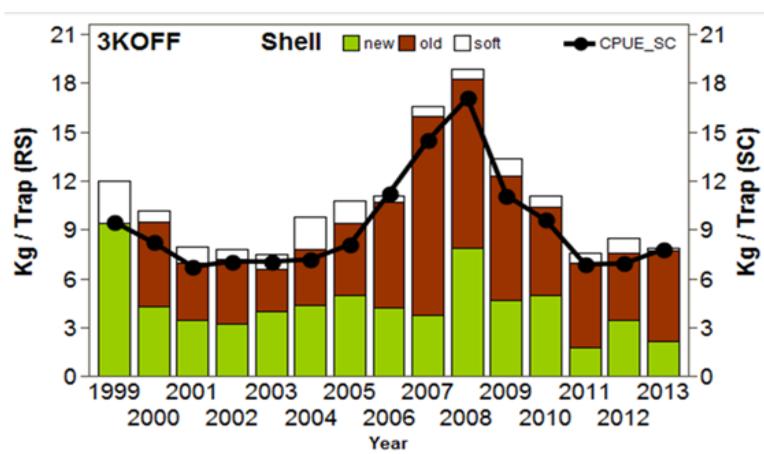

Figure 56: Trends in Division 3K offshore observer catch rates of legal-sized crabs by shell condition category from at-sea sampling and of all crabs kept based on set and catch records (sc).

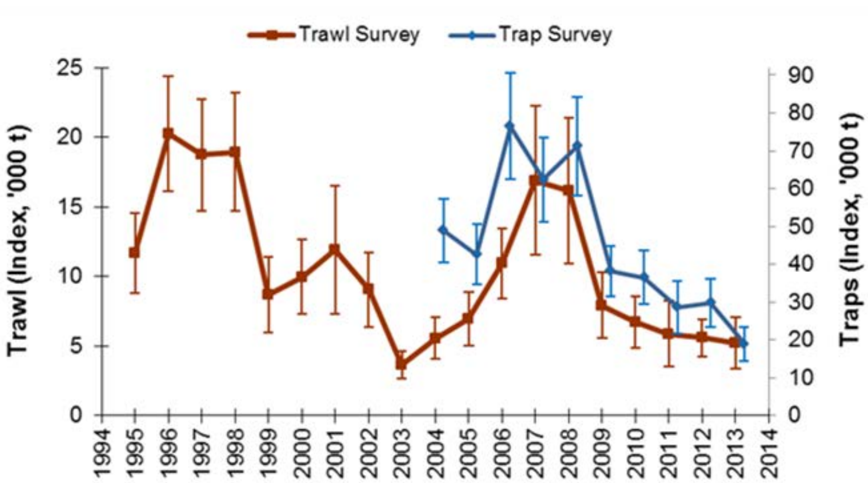

Figure 57: Trends in the Div. 3K offshore fall trawl survey exploitable biomass index and the CPS trap survey exploitable biomass index.

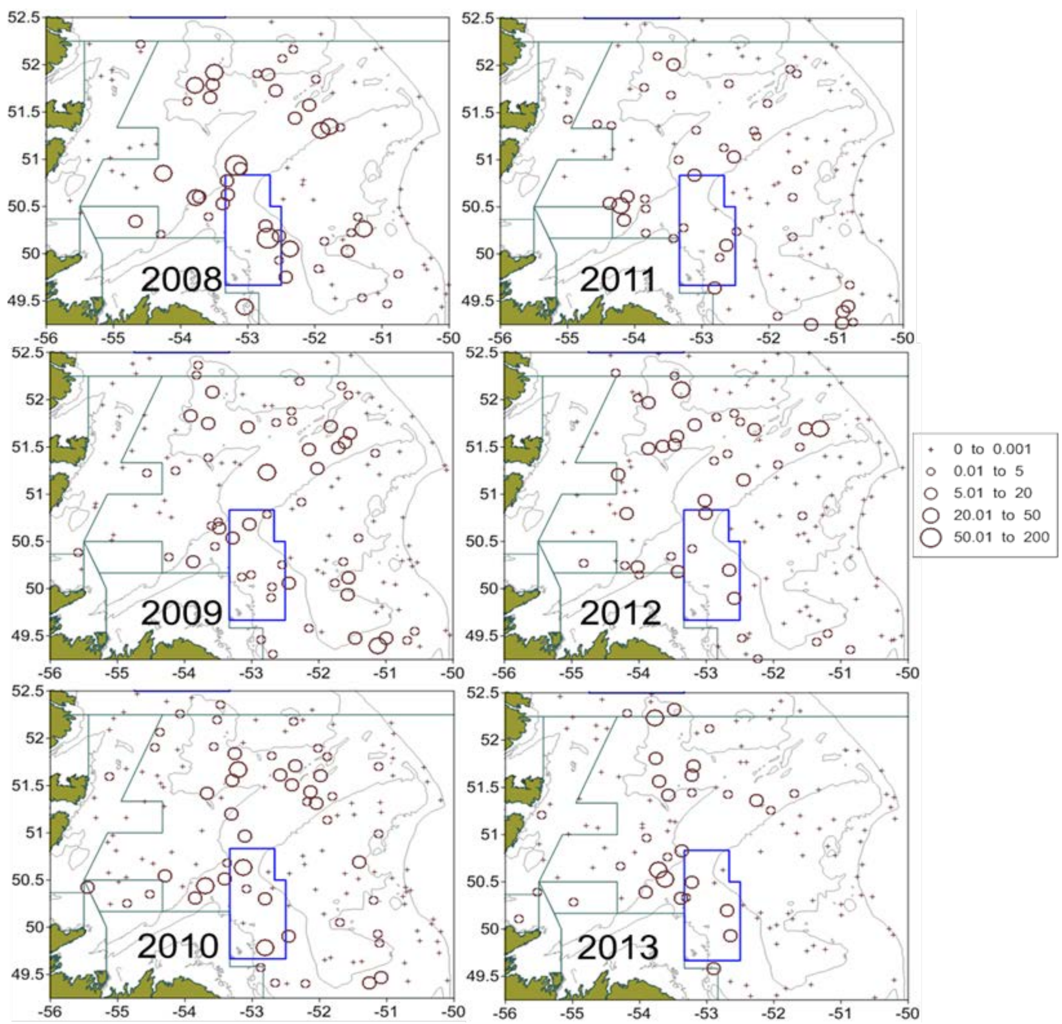

Figure 58. Spatial distribution of catches (number / set) of exploitable snow crab in Div. 3K offshore trawl survey.

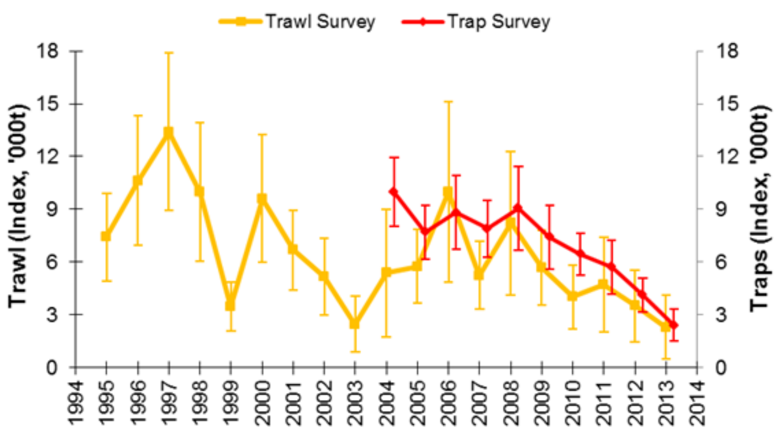

Figure 59: Trends in the Div. 3K fall trawl survey pre-recruit biomass index and the CPS trap survey pre-recruit biomass index.

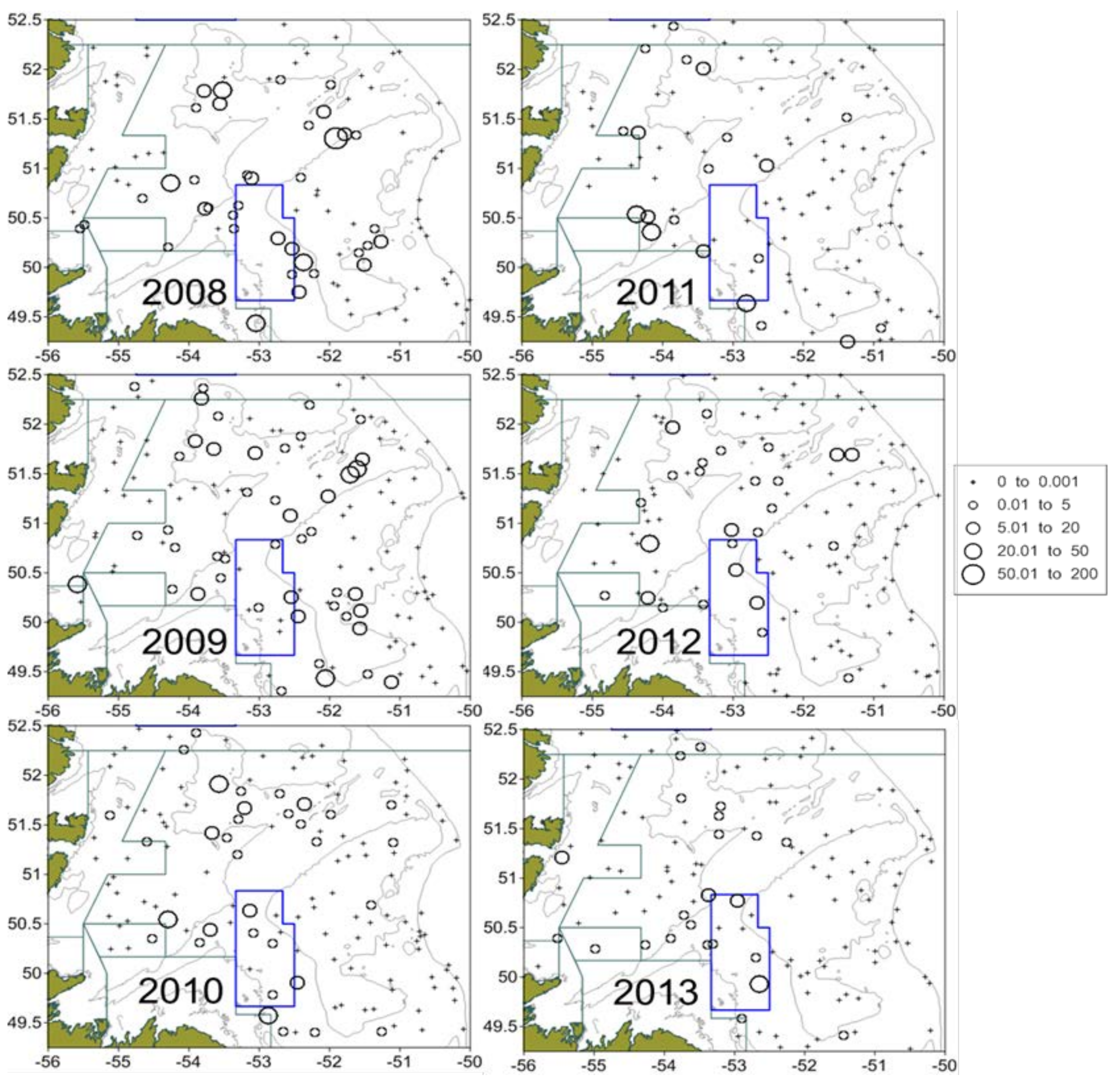

Figure 60. Spatial distribution of catches (number / set) of pre-recruit snow crab in the Div. 3K offshore trawl survey.

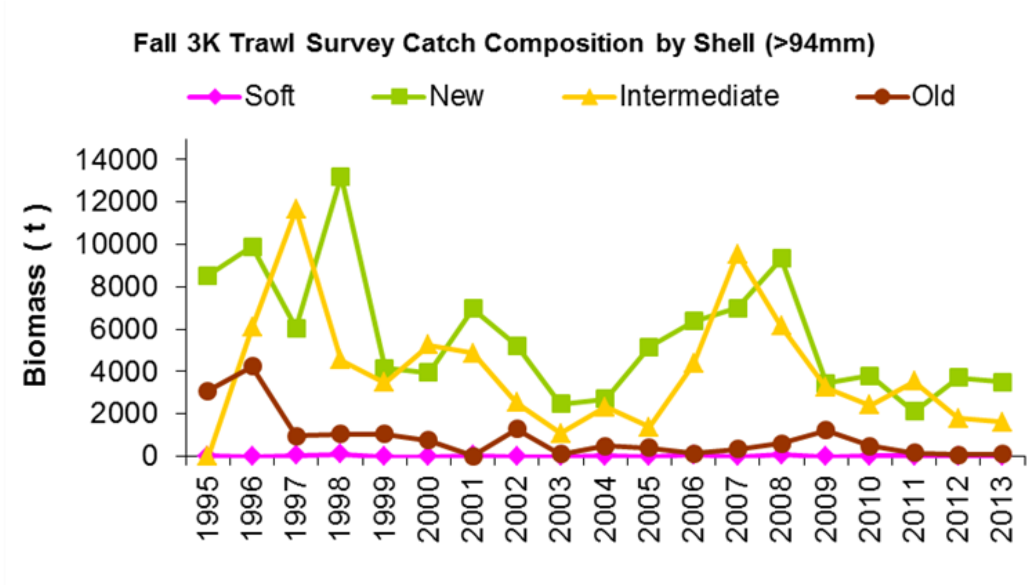

Figure 61: Trends, by shell condition, in biomass of legal-sized males for Div. 3K offshore from fall trawl surveys.

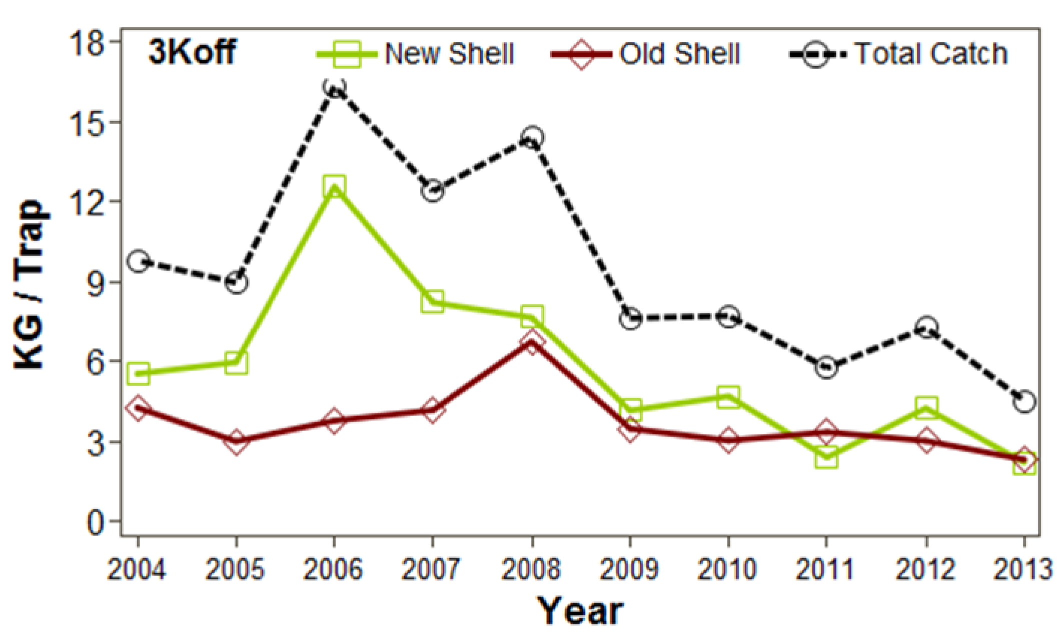

Figure 62: Trends in CPUE by shell condition for legal-sized crabs from core stations in the Div. 3K offshore CPS trap survey.

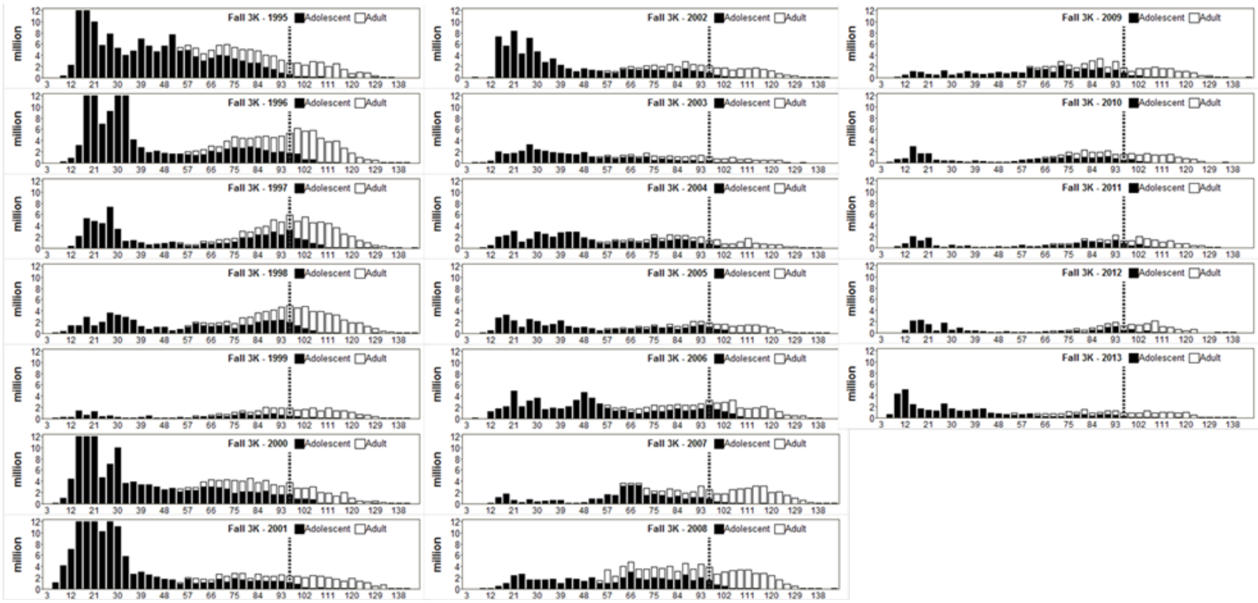

Figure 63: Abundance indices by carapace width for Div. 3K offshore juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys.

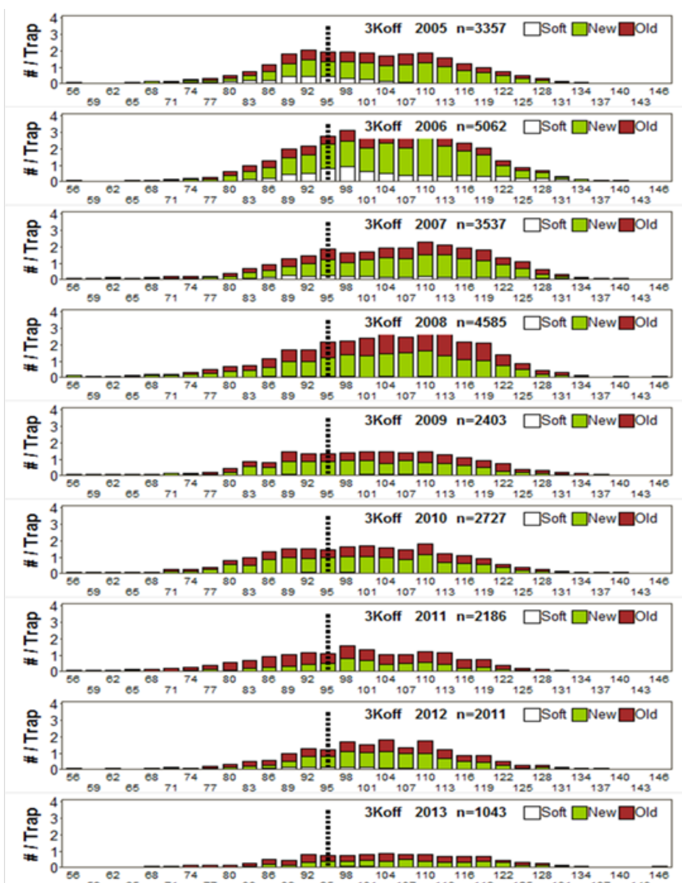

Figure 64: Trends in male carapace width distributions from large mesh traps at core stations in the Div. 3K offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

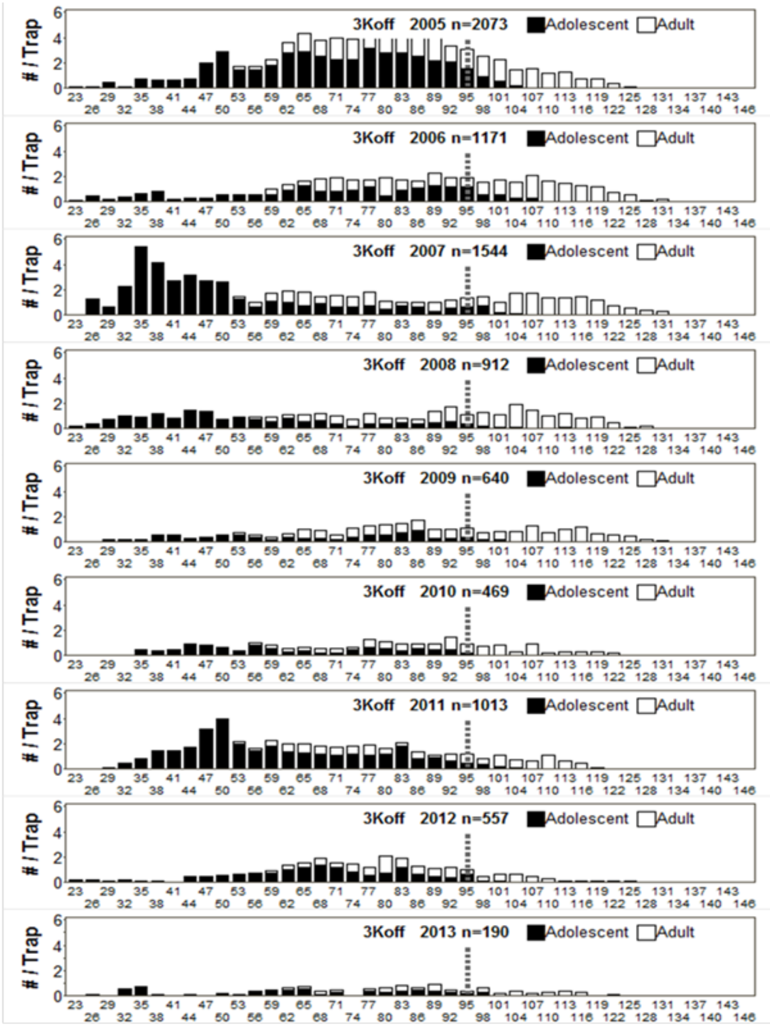

Figure 65: Trends in male carapace width distributions from small-mesh traps in the Div. 3K offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

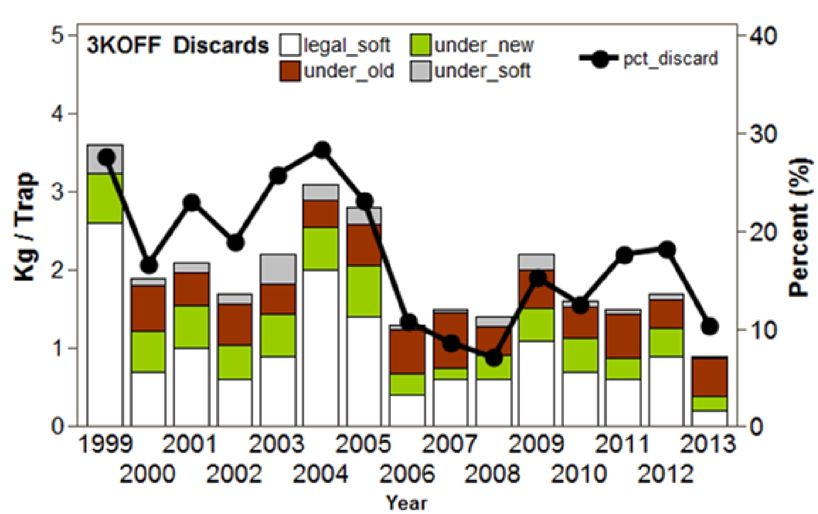

Figure 66: Trends in Division 3K offshore observer catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

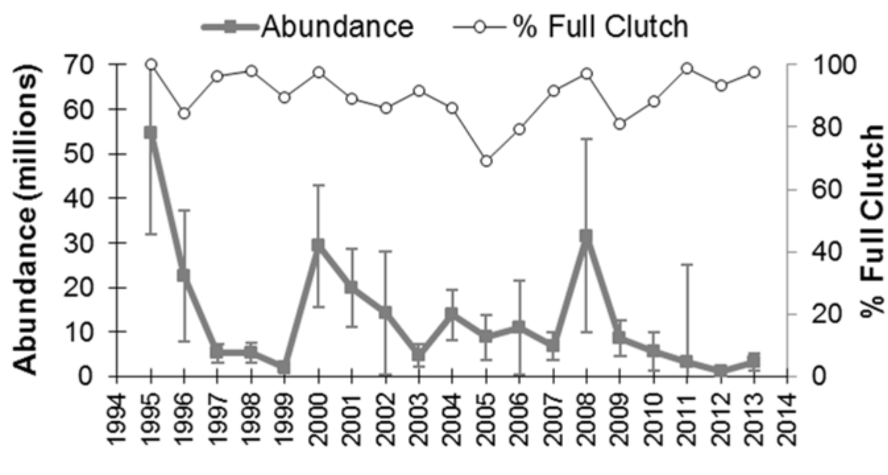

Figure 67: Trends in abundance of mature females as well as the percentage of mature females bearing full clutches of viable eggs in Div. 3K from fall multi-species surveys.

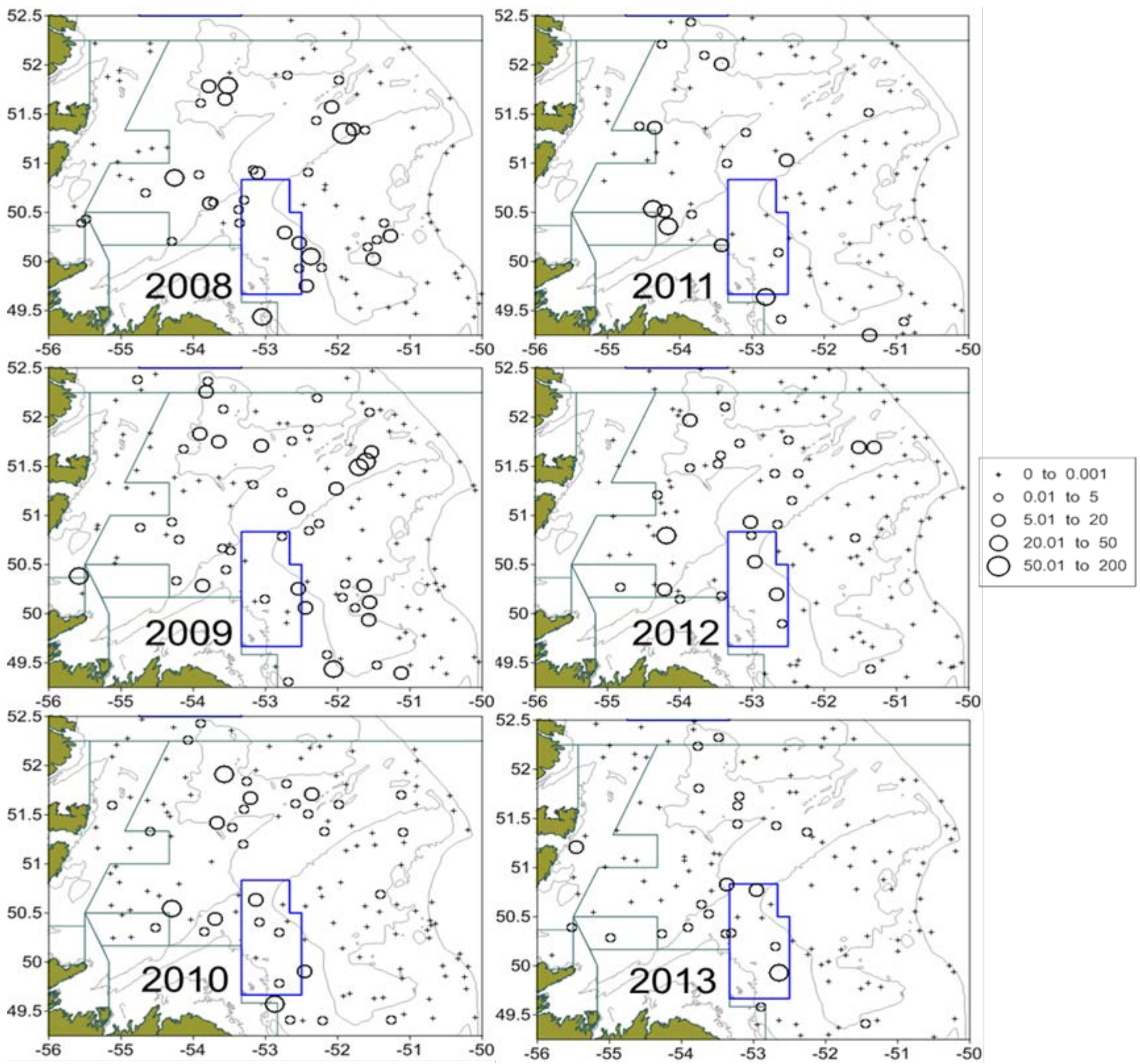

Figure 68: Spatial distribution of catches (number / set) of mature females in the Div. 3K offshore fall trawl survey.

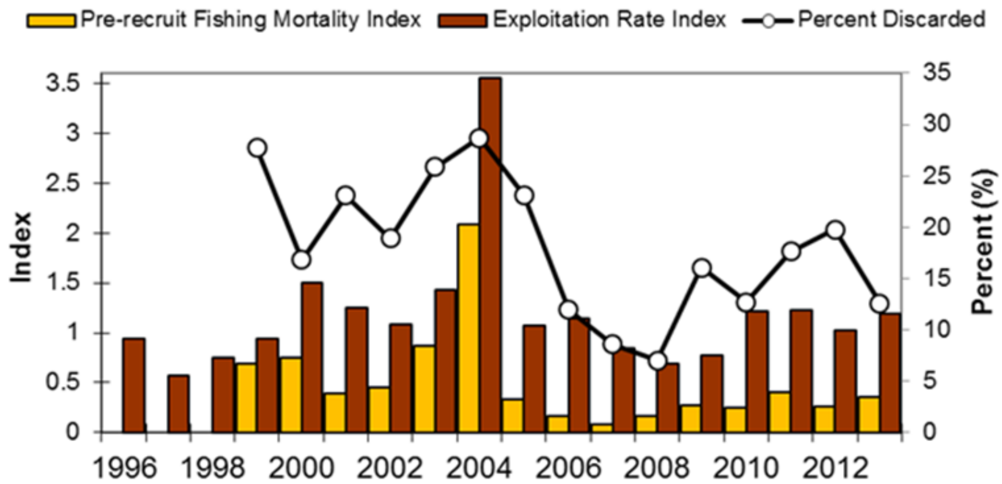

Figure 69: Trends in Div. 3K offshore mortality indices (the exploitation rate index and the pre-recruit fishing mortality rate index) and in the percentage of the catch discarded in the fishery.

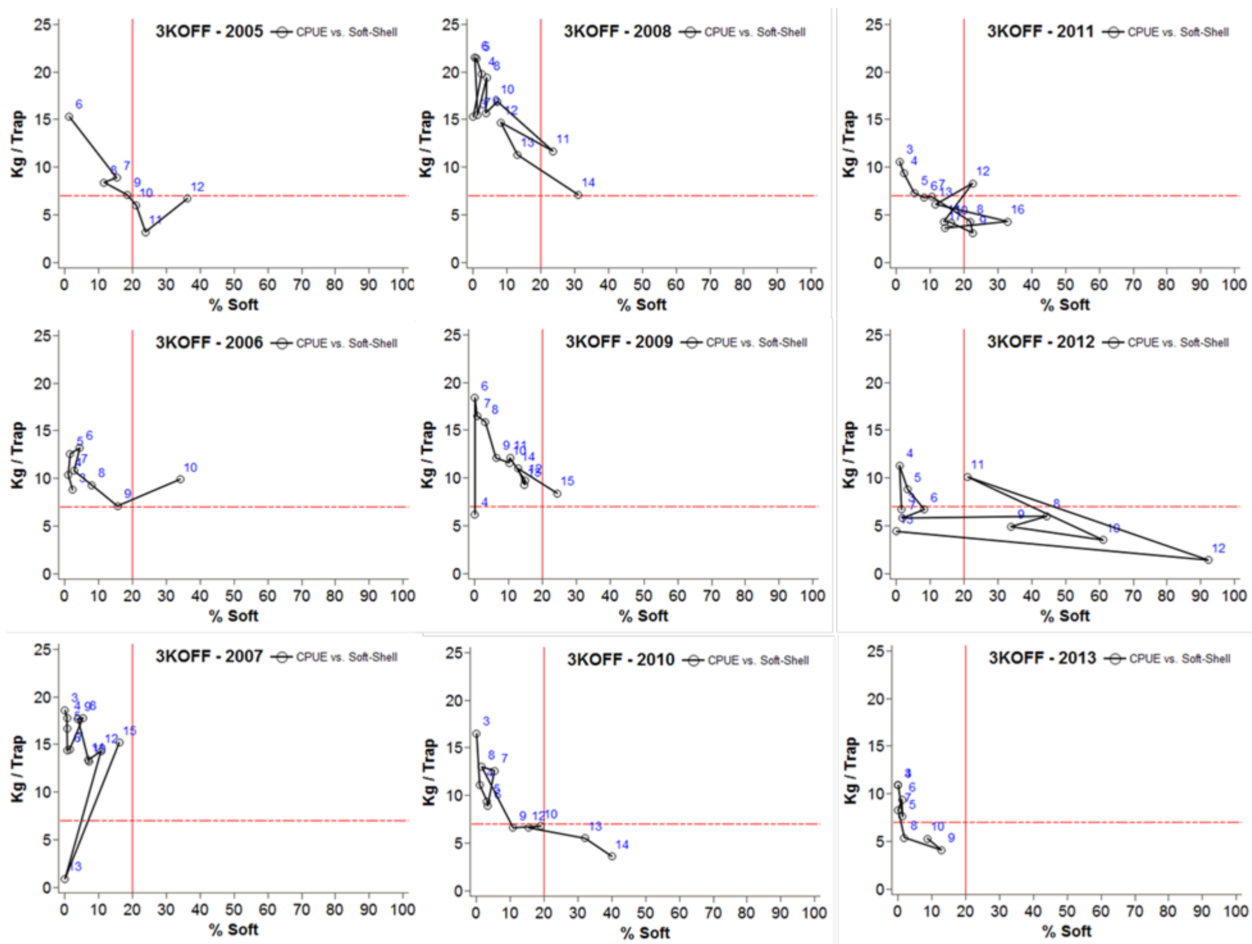

Figure 70: Trends in weekly percentages of kept vs. soft-shell crab in the Div. 3K offshore fishery from observer at-sea sampling by observers.

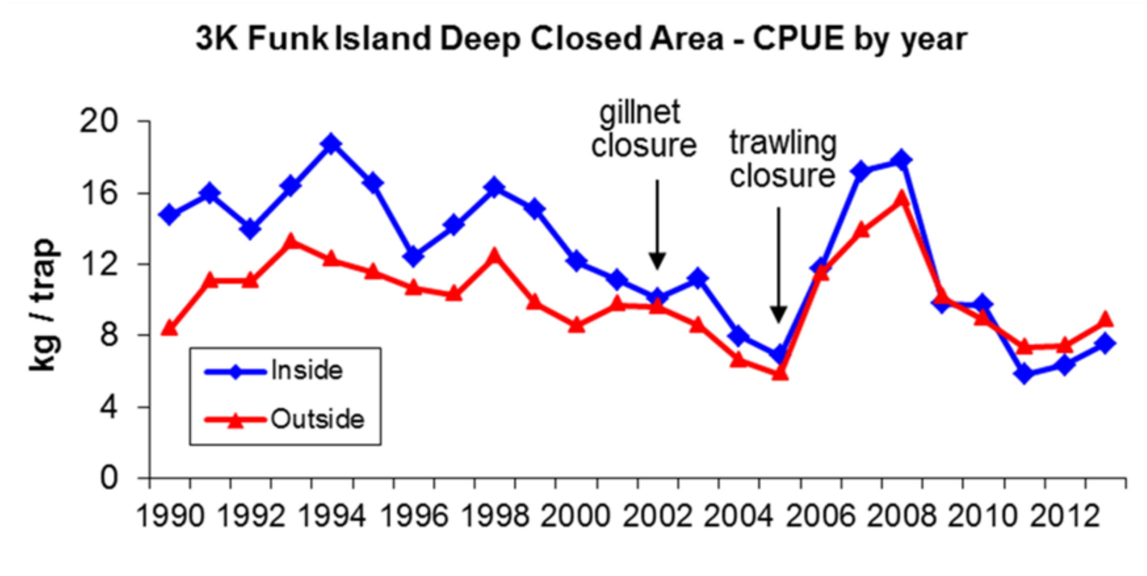

Figure 71: Div. 3K offshore commercial CPUE inside vs. outside the Funk Island Deep closed area.

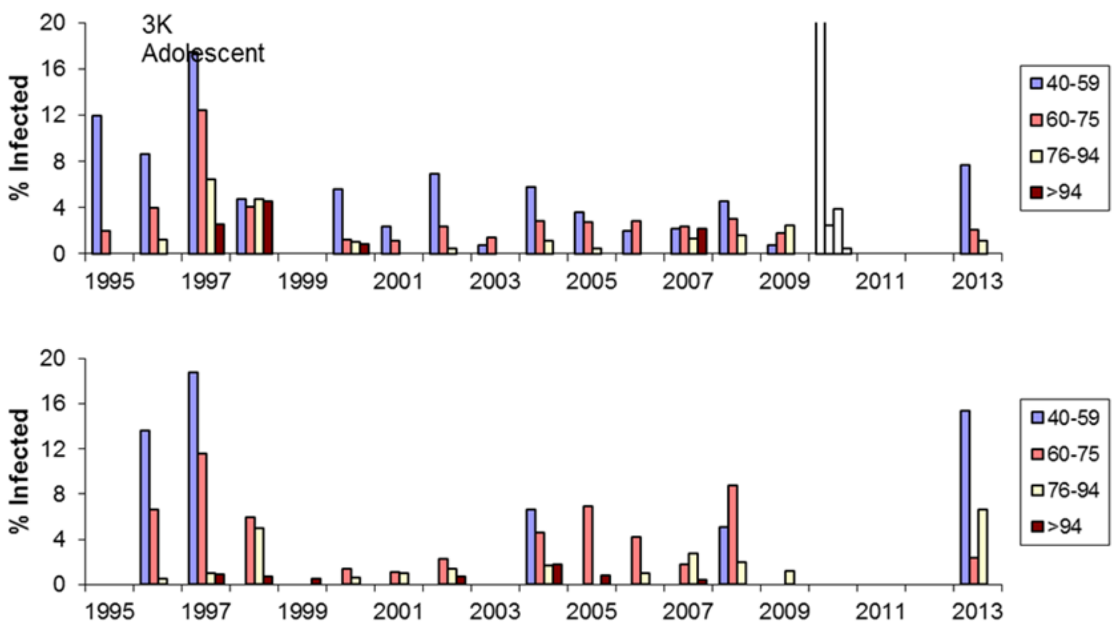

Figure 72: Annual trends in prevalence of BCD in new-shelled adolescents (above) and adult (below) males by size group from Div. 3K fall trawl surveys. The 2010 data are anomalous.

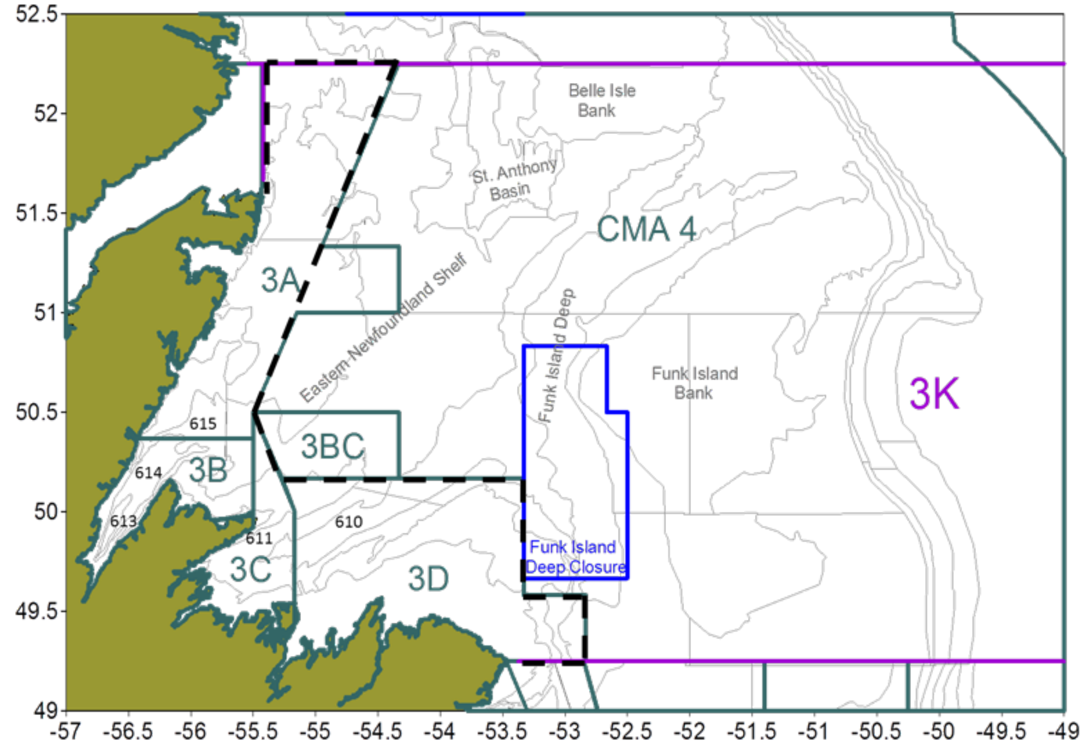

Figure 73: Map of Division 3K showing crab management areas and important bathymetric features as well as the Funk Island Deep closed area (blue box). Dashed perimeter indicates inshore areas.

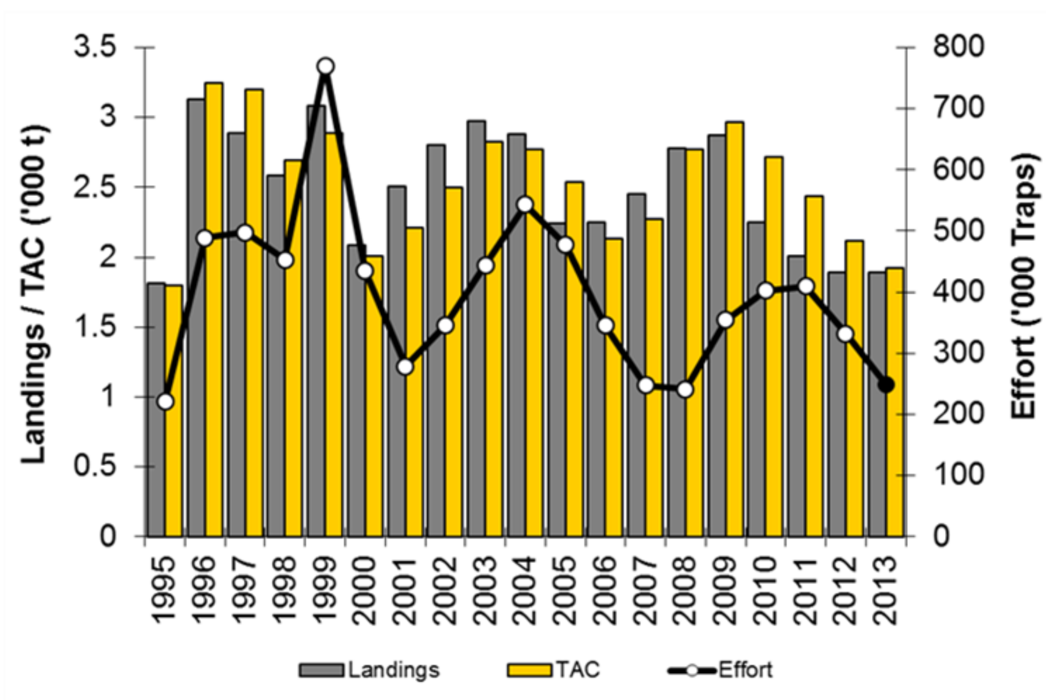

Figure 74: Trends in Div. 3K inshore landings, TAC, and fishing effort. (2013 effort preliminary).

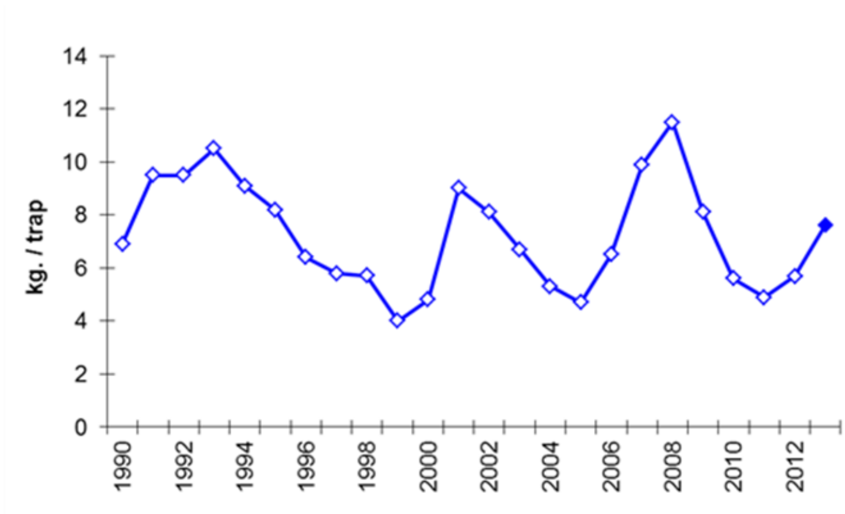

Figure 75: Trends in commercial logbook-based CPUE in the Div. 3K inshore fishery. (2013 estimate preliminary).

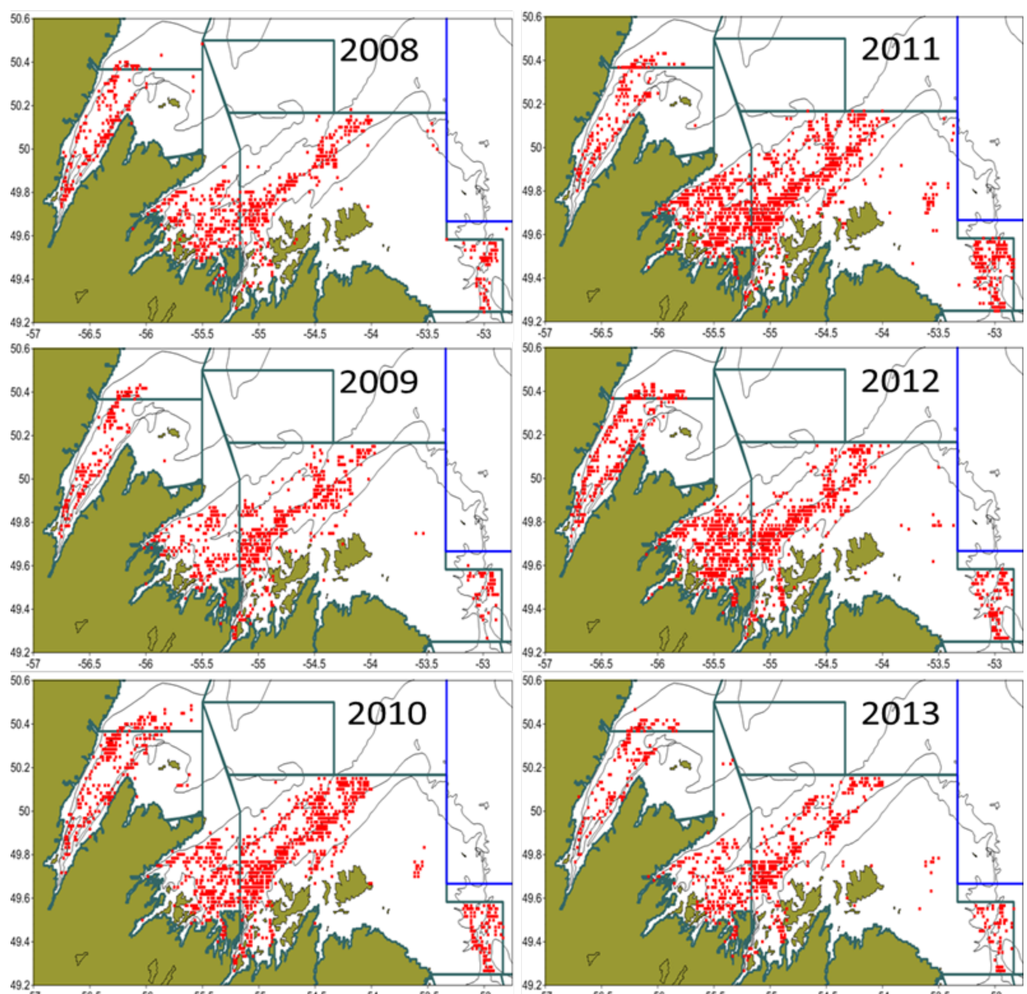

Figure 76: Spatial Distribution of Div. 3K inshore fishing effort by year

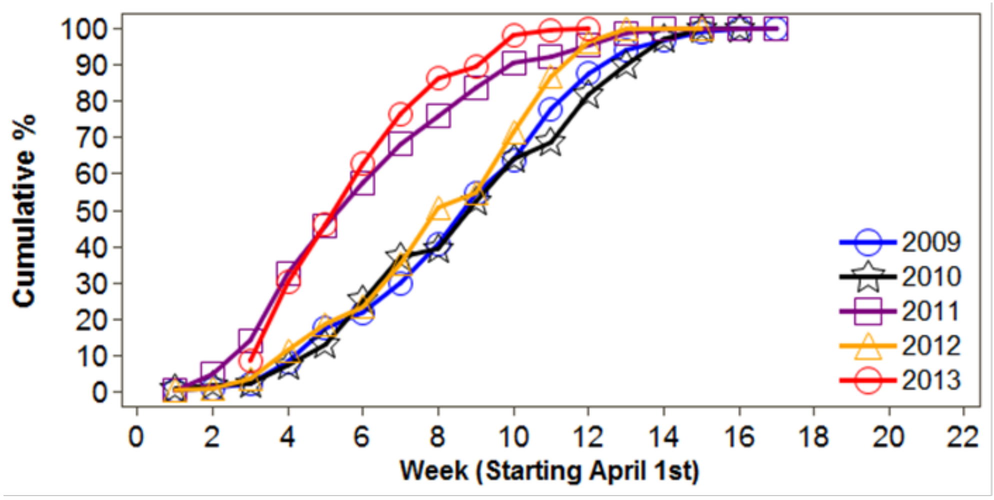

Figure 77: Seasonal trends in weekly fishing effort for Div. 3K inshore.

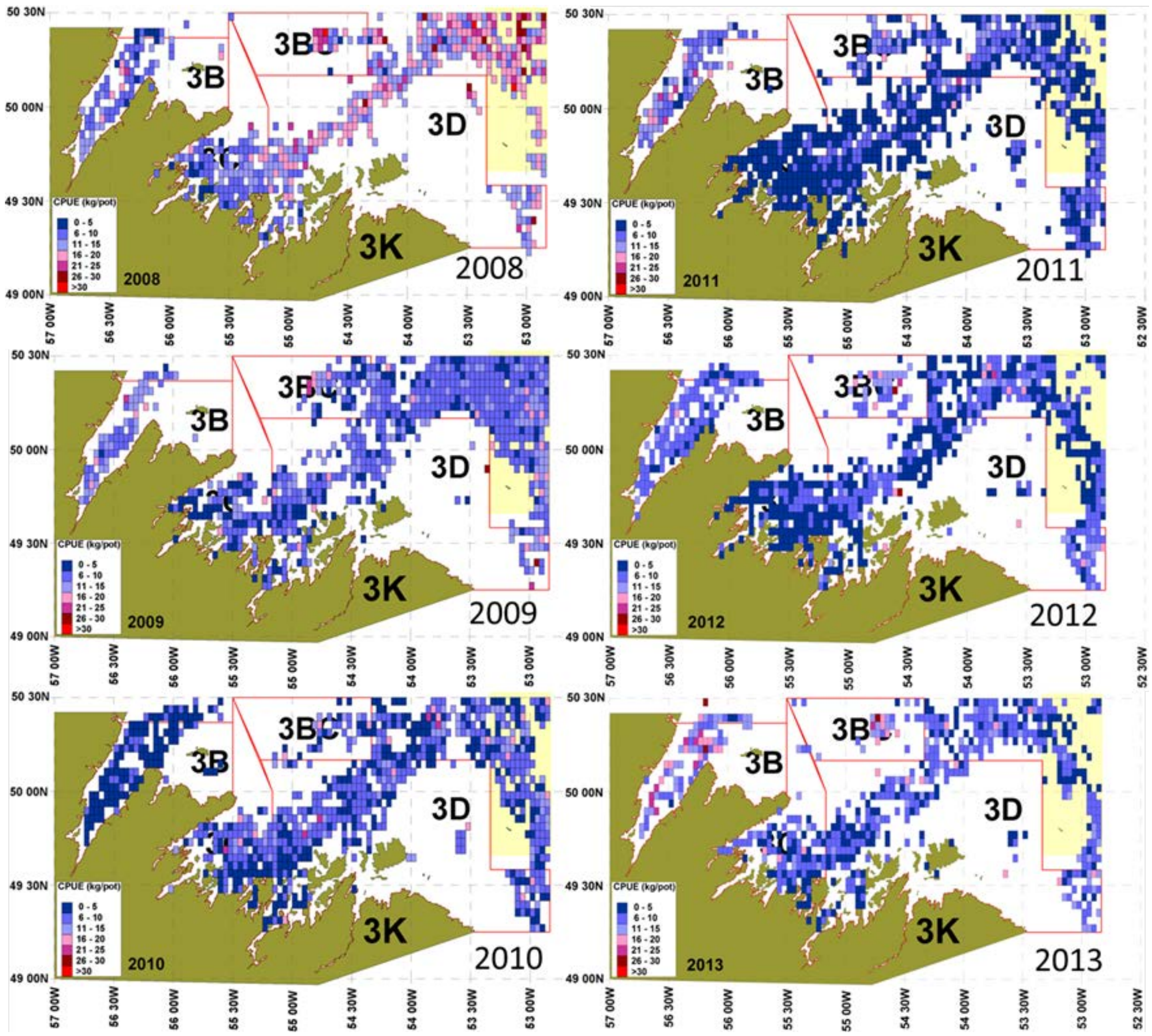

Figure 78: Spatial distribution of Div. 3K inshore logbook CPUE by year.

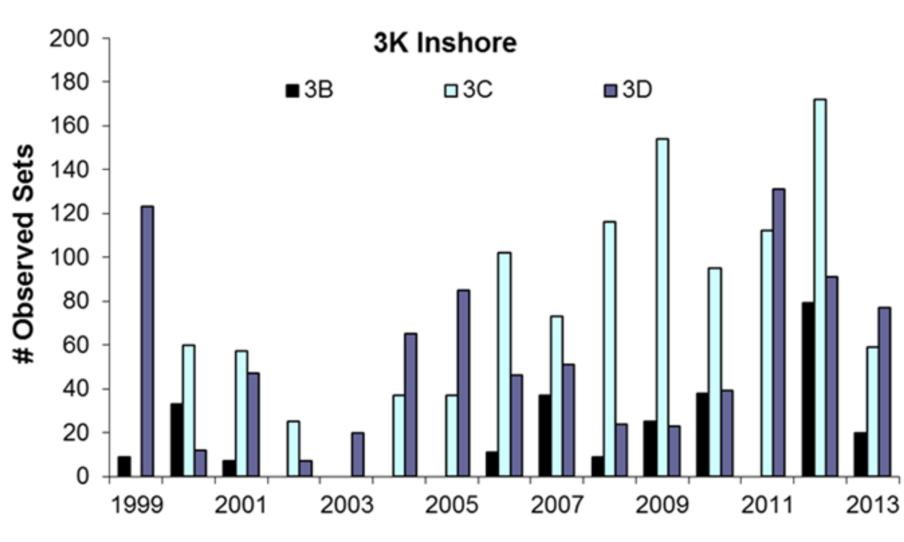

Figure 79: Trends in number of observed sets by Crab Management Areas and year in Division 3K inshore.

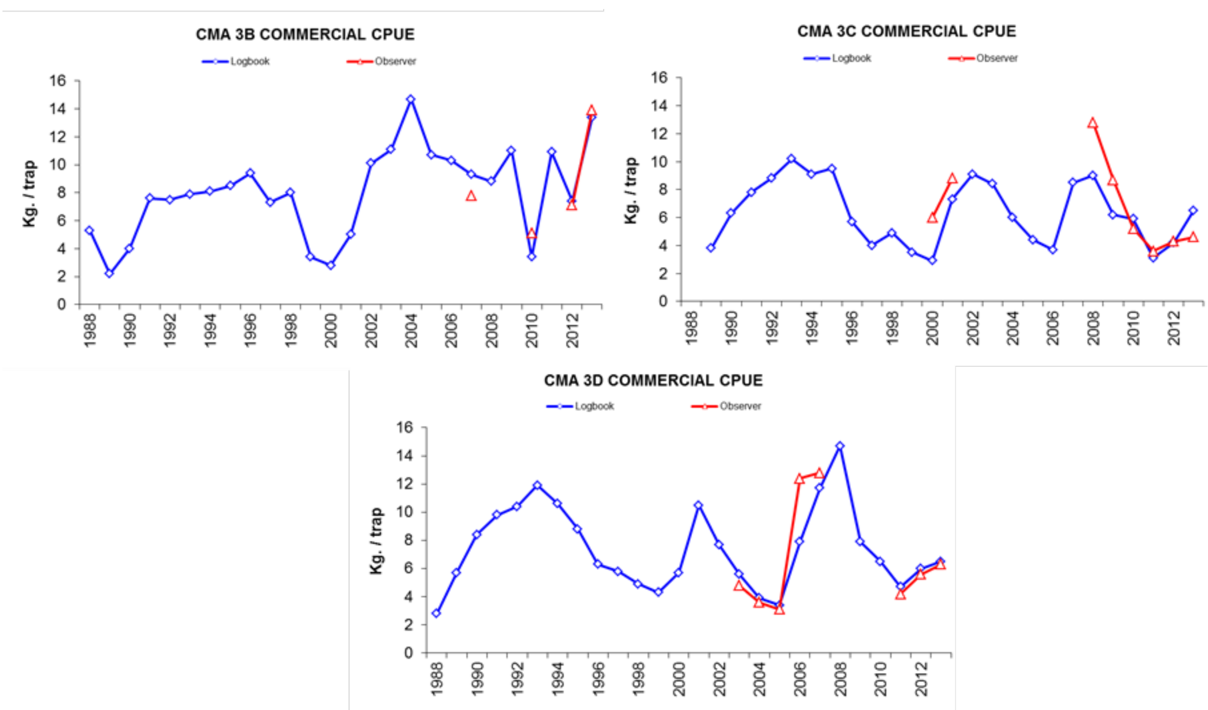

Figure 80: Trends in Division 3K inshore logbook CPUE and observer CPUE by Crab Management Area. (2013 logbook CPUE preliminary).

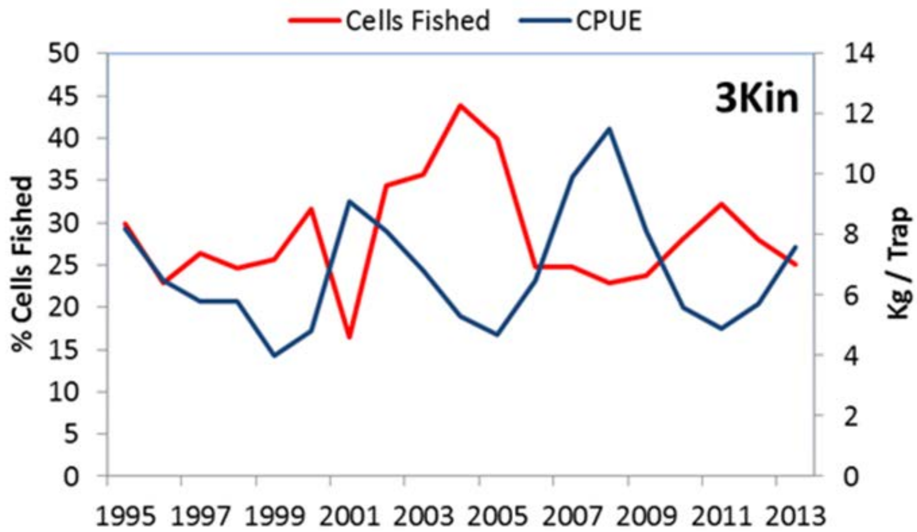

Figure 81: Trends in Div. 3K inshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

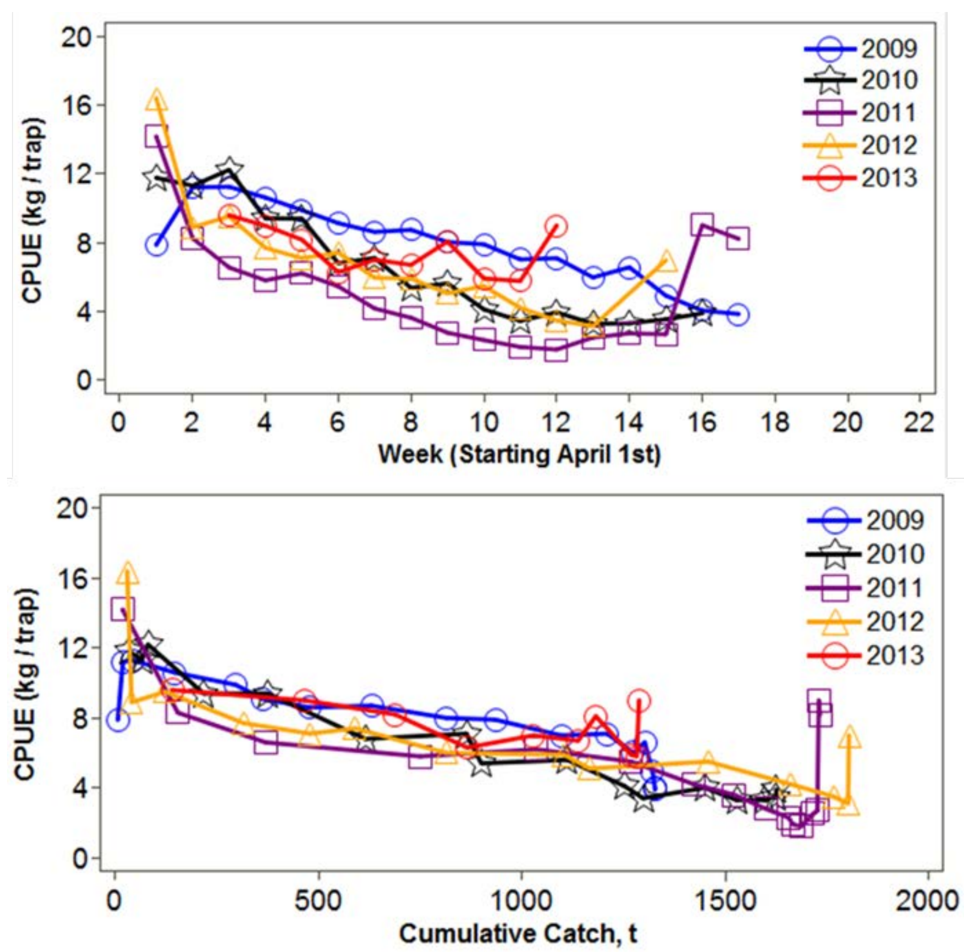

Figure 82: Seasonal trends in logbook-based CPUE for Div. 3K inshore; by week (top), and in relation to cumulative catch (bottom).

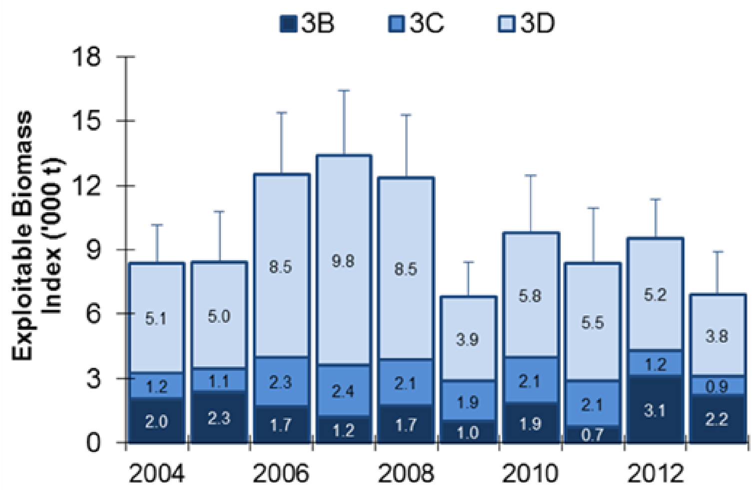

Figure 83: Exploitable biomass indices by management area from the CPS trap survey in Div. 3K inshore.

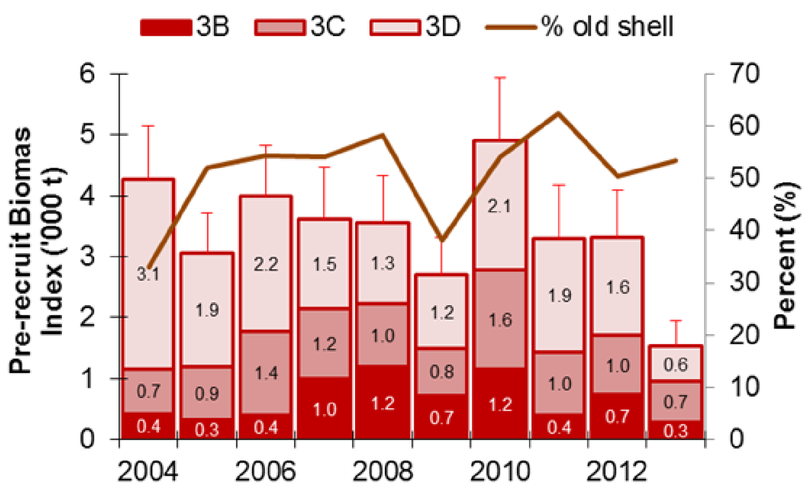

Figure 84: Pre-recruit biomass indices by management area from the CPS trap survey in Div. 3K inshore.

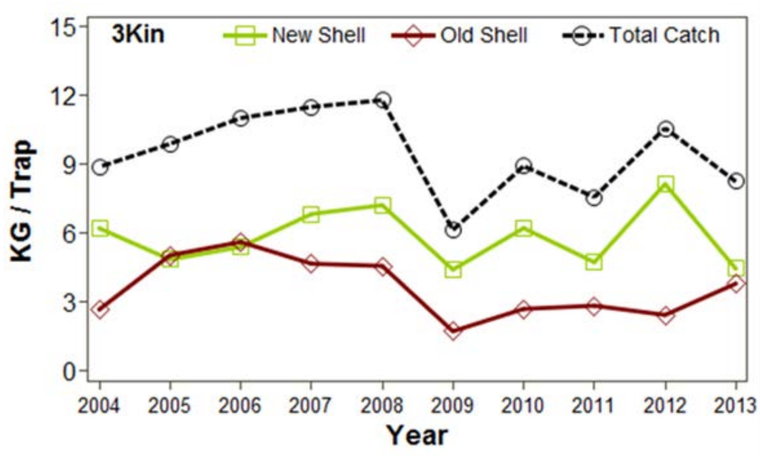

Figure 85: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in Div. 3K inshore.

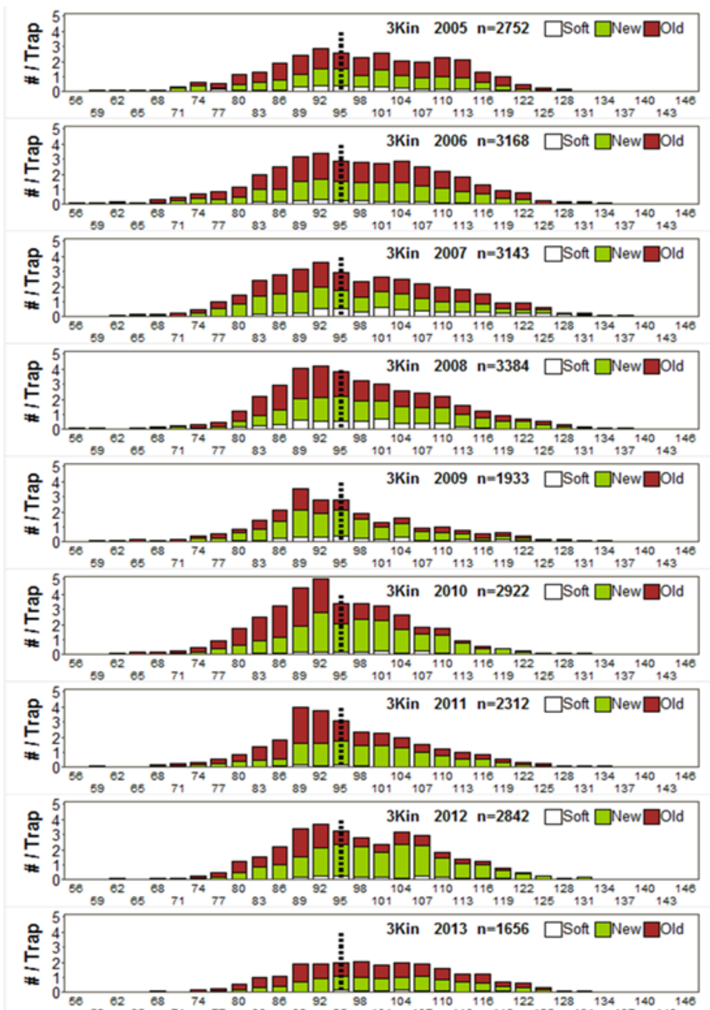

Figure 86: Trends in male carapace width distributions from core stations in the Div. 3K inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

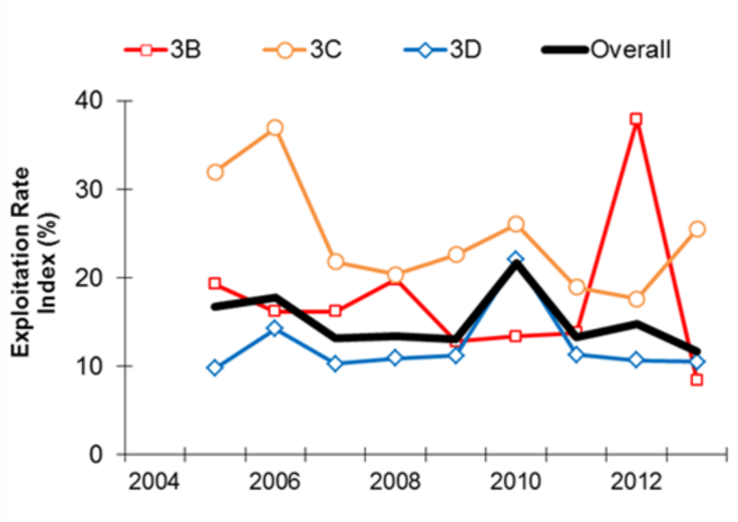

Figure 87: Exploitation rate indices by crab management area as well as overall for Div. 3K inshore based on the CPS trap survey.

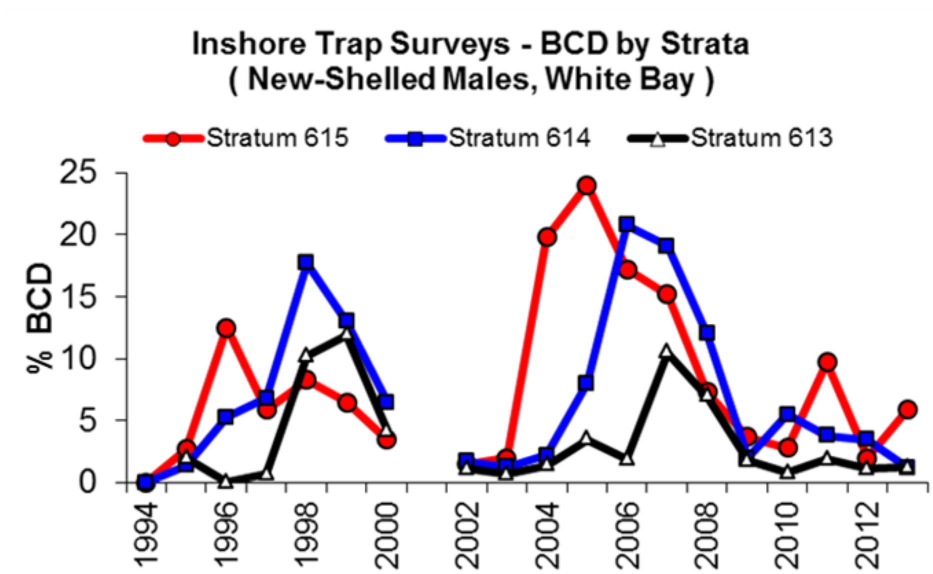

Figure 88: Prevalence of BCD in new-shelled males from Div. 3K DFO inshore trap surveys by stratum in White Bay.

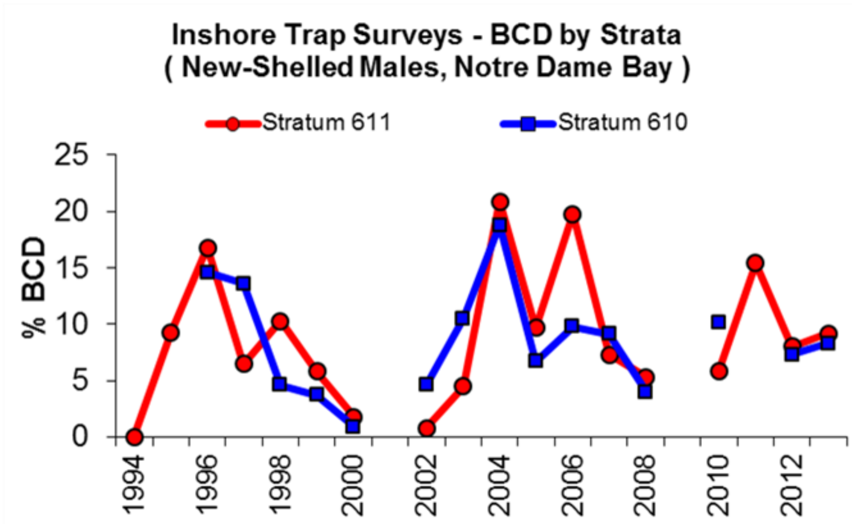

Figure 89: Prevalence of BCD in new-shelled males from Div. 3K DFO inshore trap surveys by stratum in Notre Dame Bay.

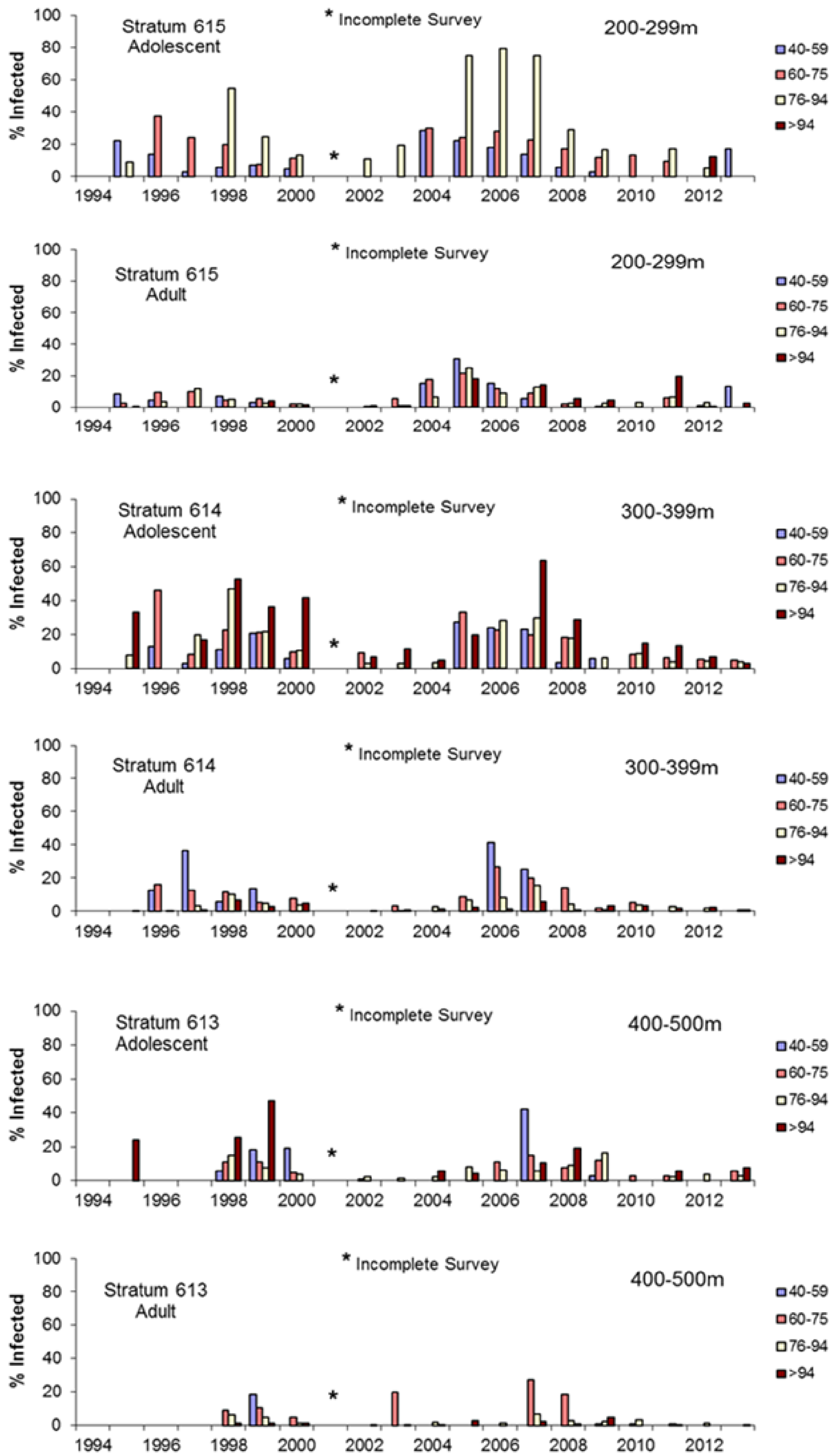

Figure 90: Annual trends in prevalence of BCD in new-shelled males by stratum, year and size group from DFO trap surveys in White Bay; adolescents (above) and adults (below).

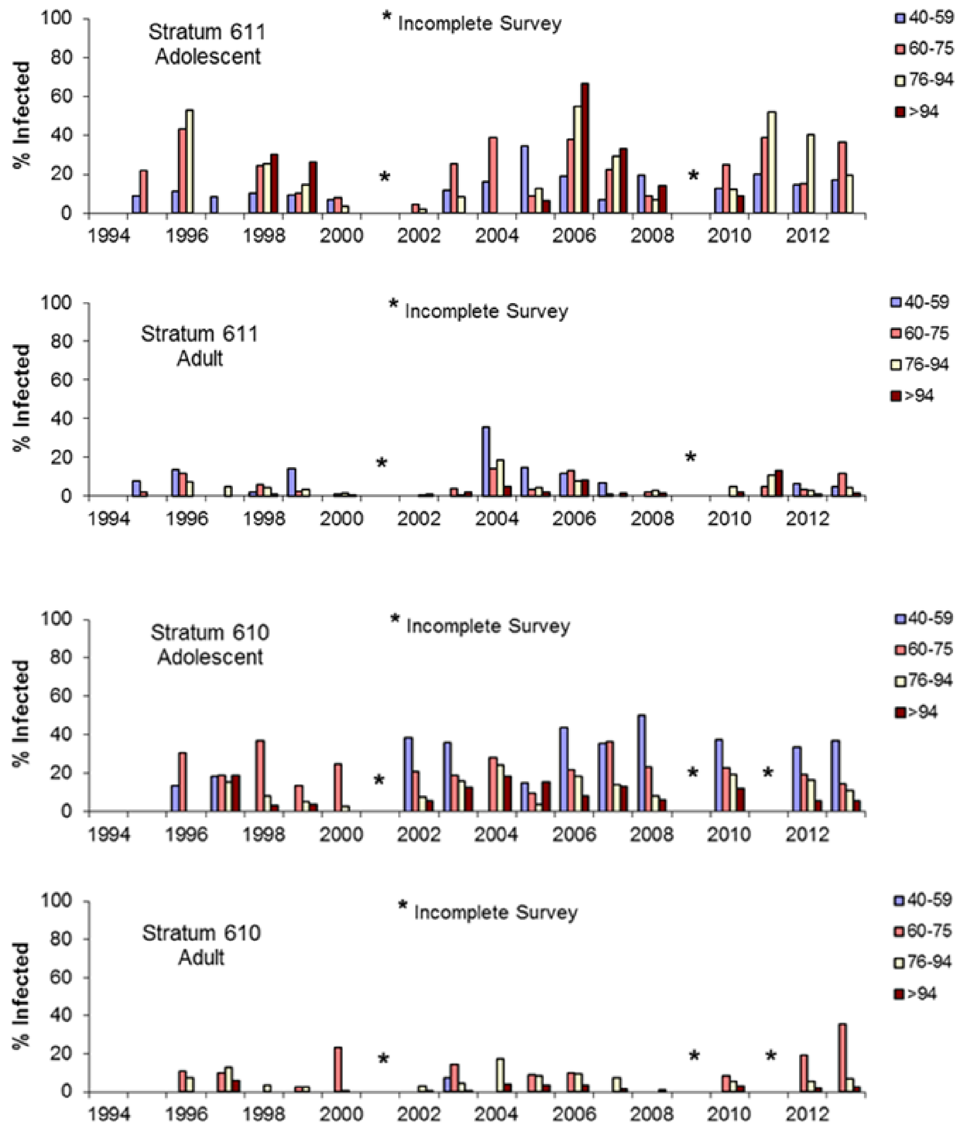

Figure 91: Trends of prevalence of BCD in new-shelled males by stratum, year and size group from DFO trap surveys in Notre Dame Bay; adolescents (above) and adults (below).

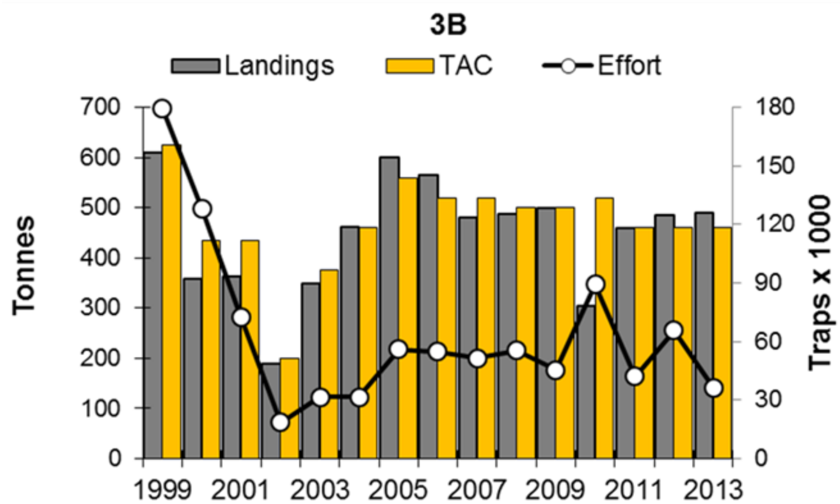

Figure 92: Trends in CMA 3B landings, TAC, and fishing effort. (2013 effort preliminary).

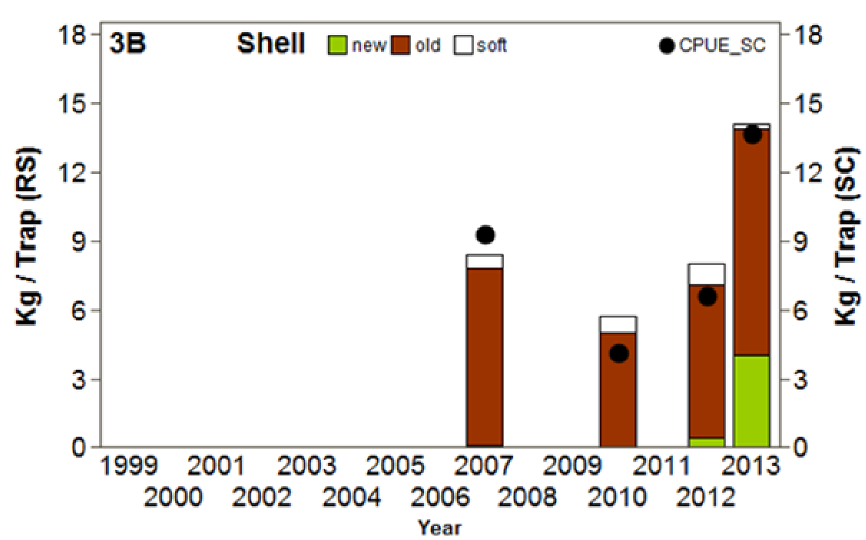

Figure 93: Trends in CMA 3B observer catch rates of exploitable-sized crabs by shell condition category from at-sea sampling.

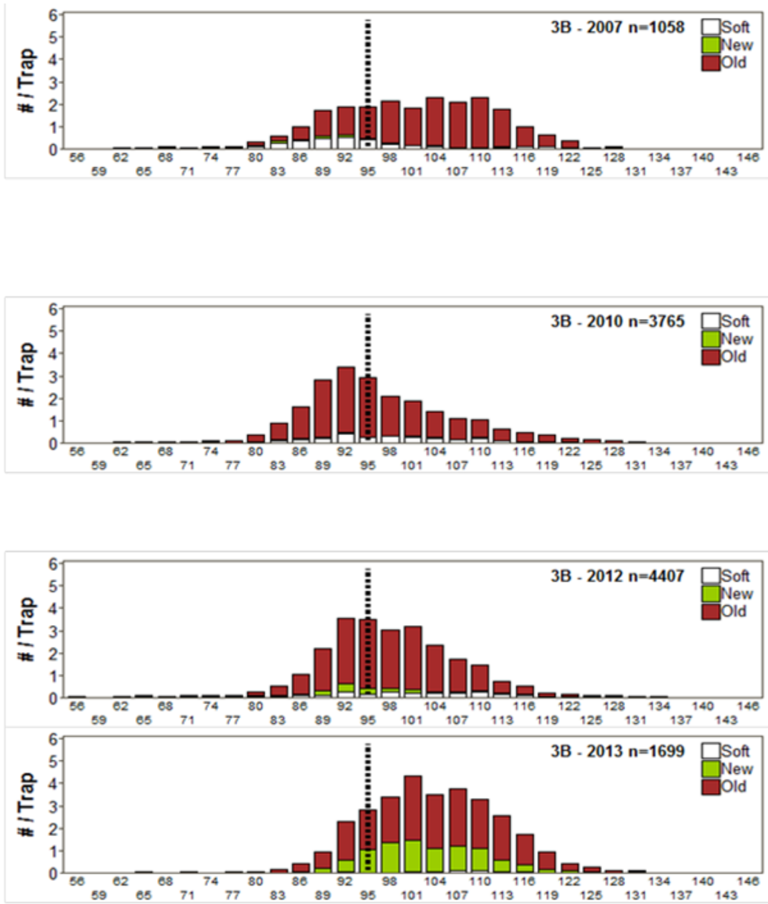

Figure 94: Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMA 3B. The vertical dashed line indicates the minimum legal size.

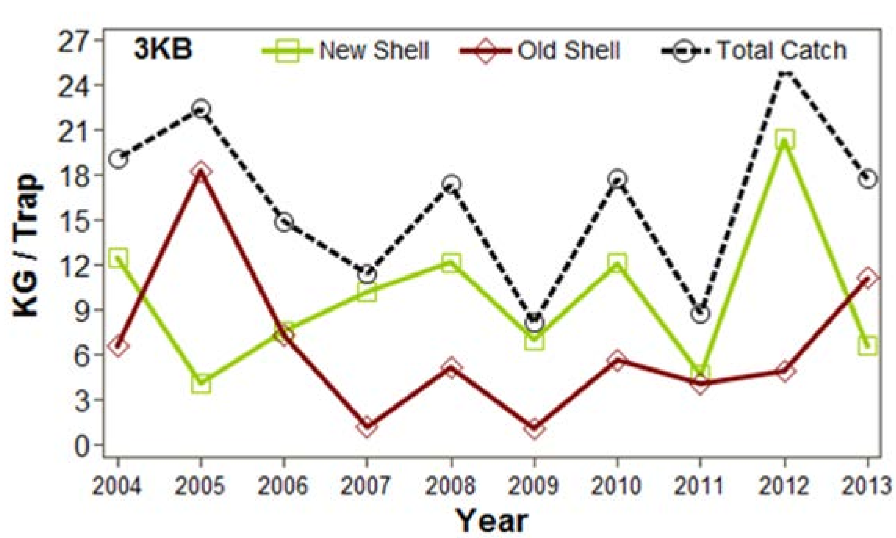

Figure 95: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 3B.

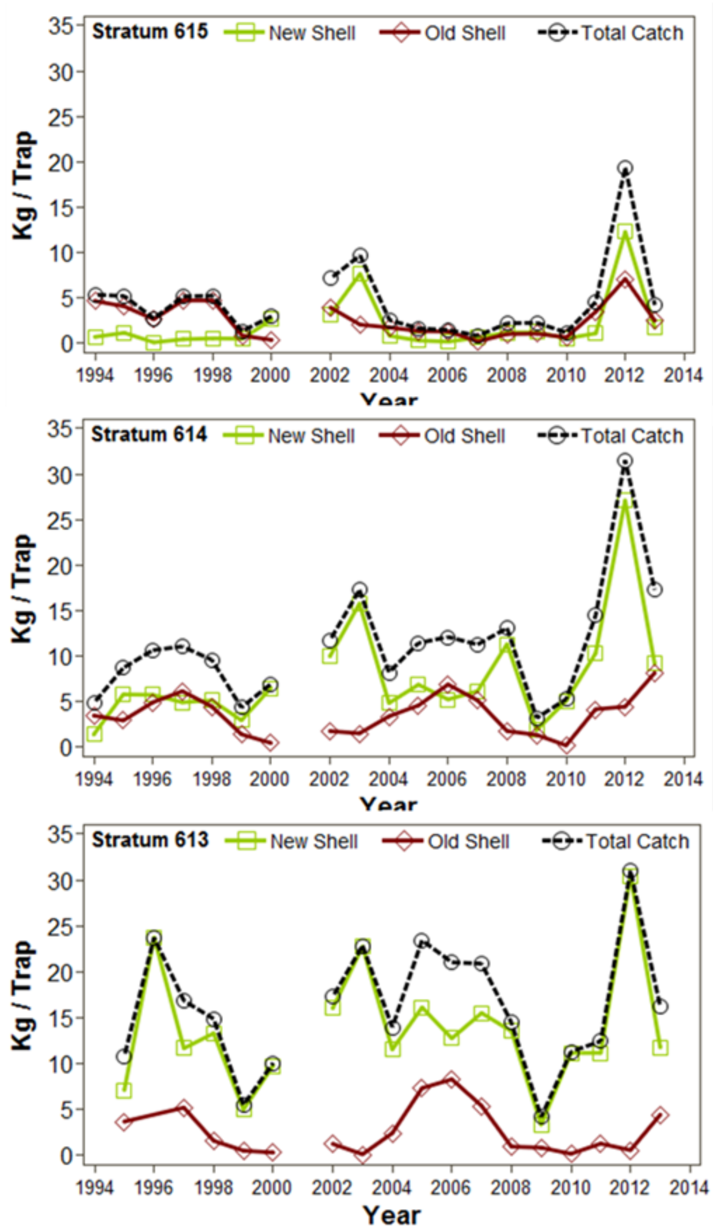

Figure 96: Trends in CPUE by shell condition for legal-sized crabs from strata occupied in the DFO trap survey in White Bay. No survey was conducted in 2001.

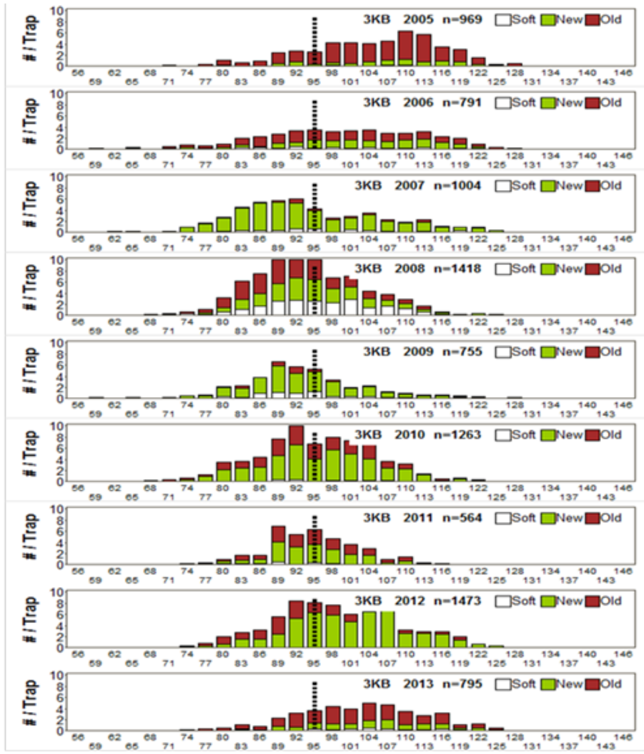

Figure 97: Trends in male carapace width distributions from large mesh traps at core stations in CMA 3B from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

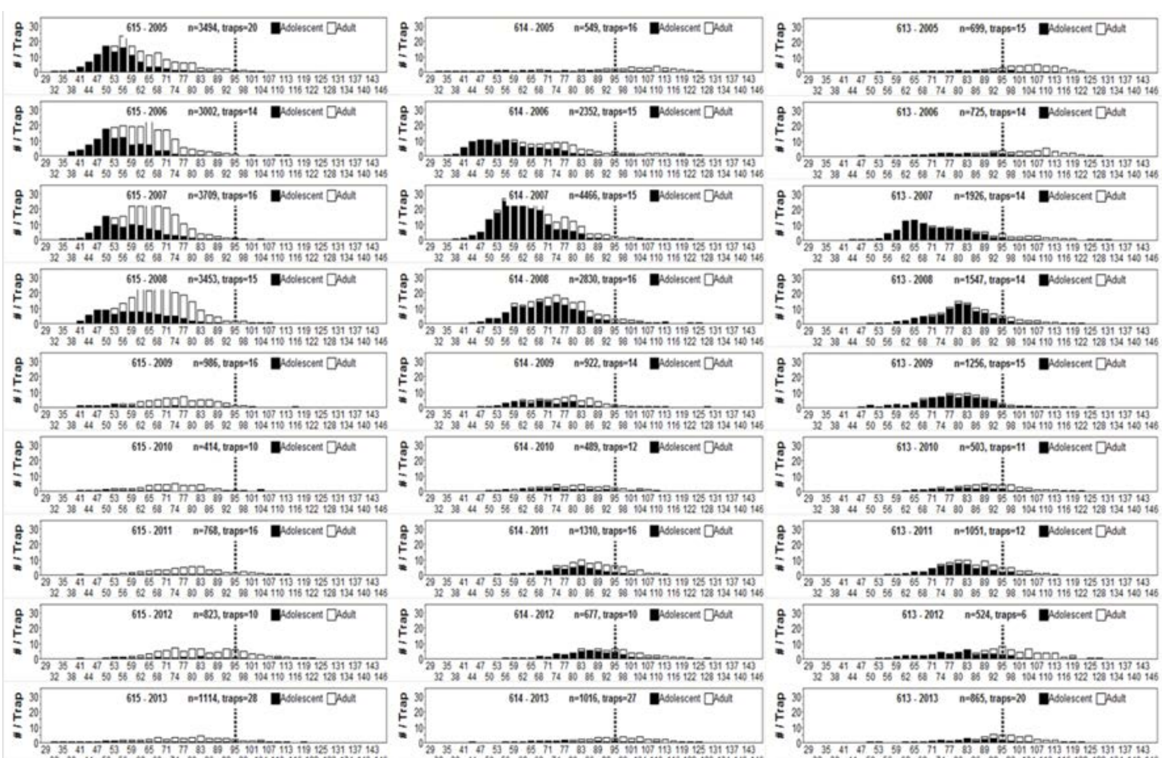

Figure 98: Small-claw (adolescent) vs. large-claw (adult) male catch rates by size from small-mesh traps in the DFO trap survey in White Bay. The vertical dashed line indicates the minimum legal size.

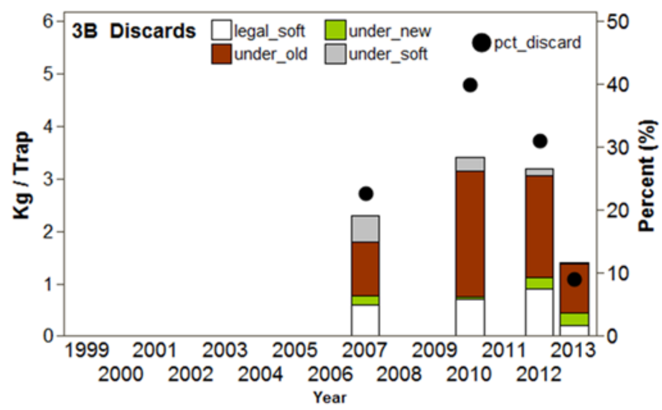

Figure 99: Trends in CMA 3B observer catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

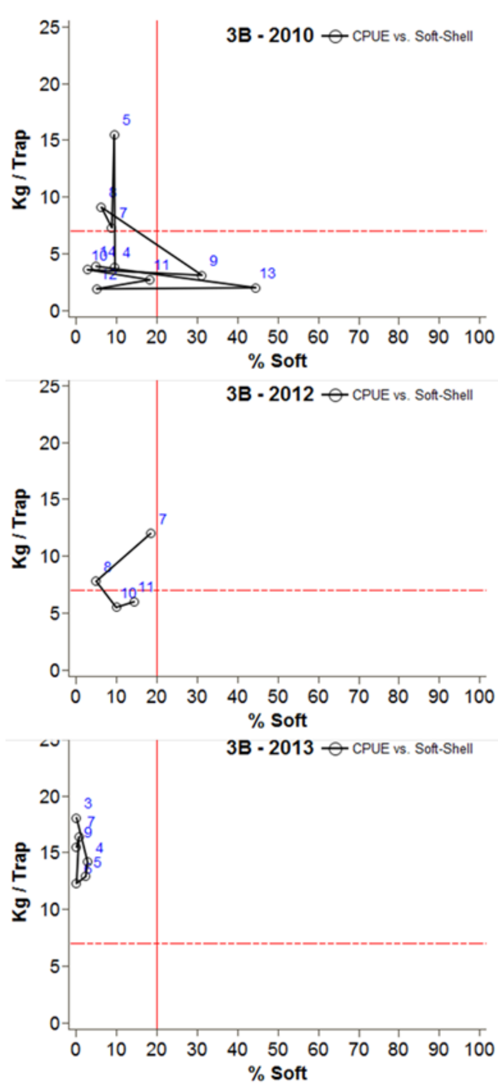

Figure 100: Trends in weekly percentages of kept vs. soft-shell crab in CMA 3B from at-sea sampling by observers.

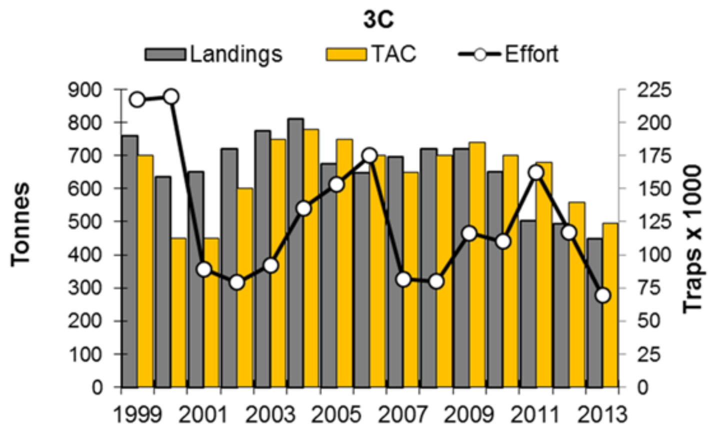

Figure 101: Trends in CMA 3C landings, TAC, and fishing effort. (2013 effort preliminary).

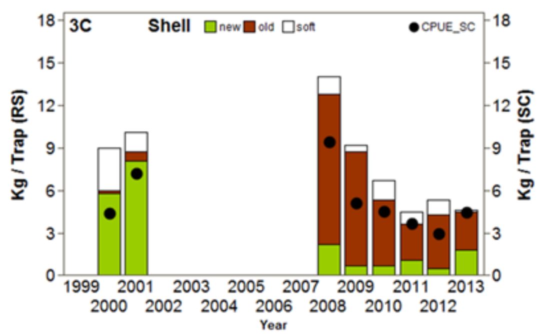

Figure 102: Trends in CMA 3C observer catch rates of exploitable-sized crabs by shell condition category from at-sea sampling.

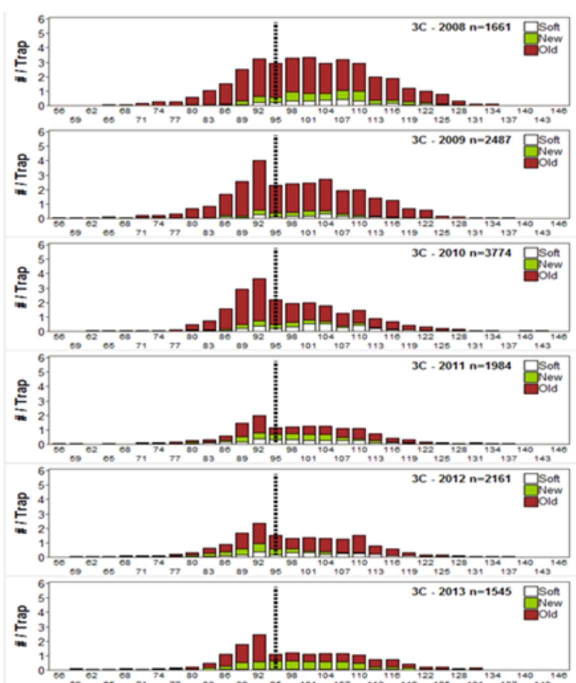

Figure 103: Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMA 3C. The vertical dashed line indicates the minimum legal size.

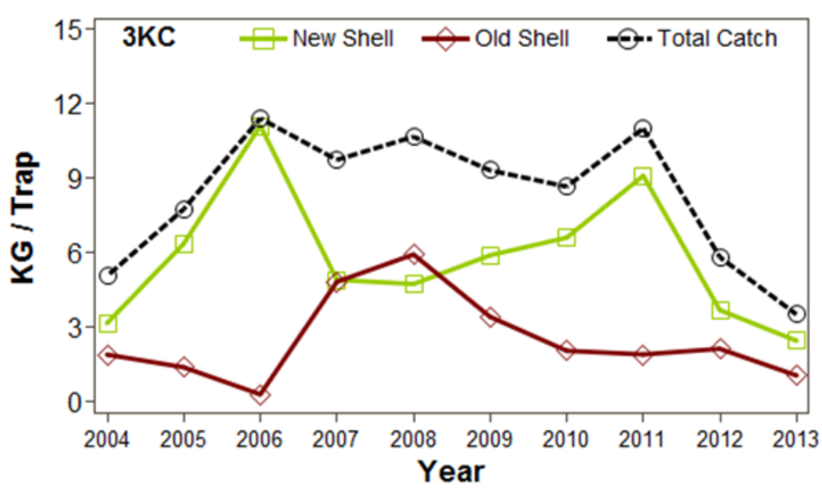

Figure 104: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 3C.

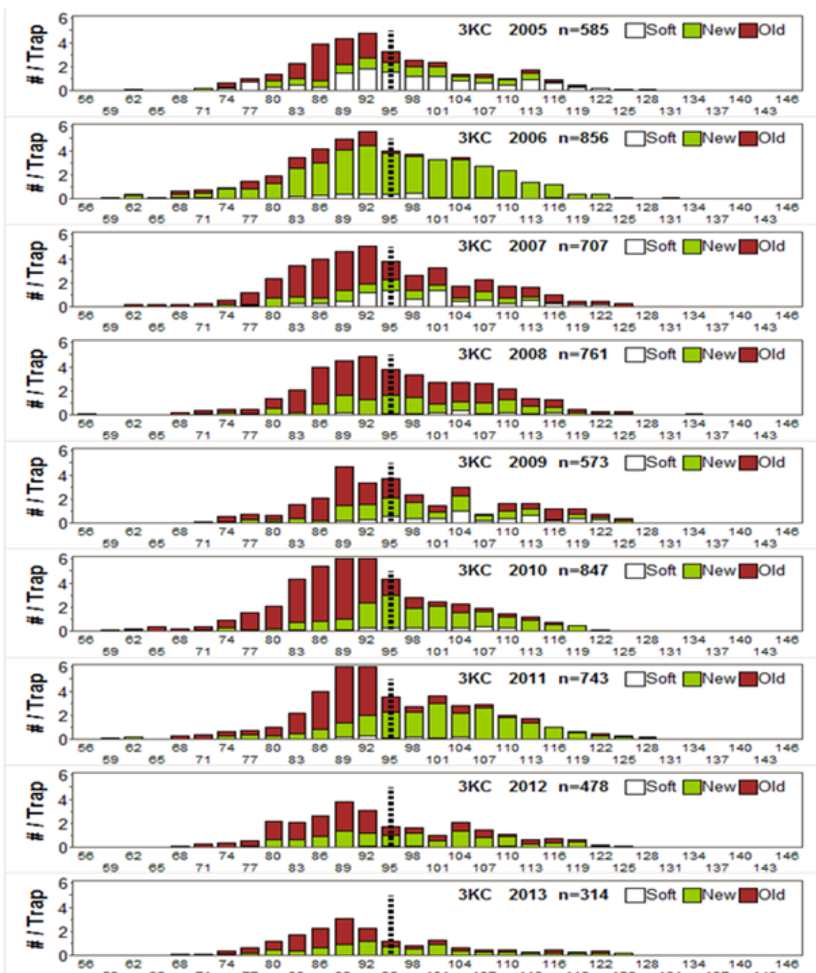

Figure 105: Trends in male carapace width distributions from core stations in CMA 3C from the CPS survey. The vertical dashed line indicates the minimum legal size.

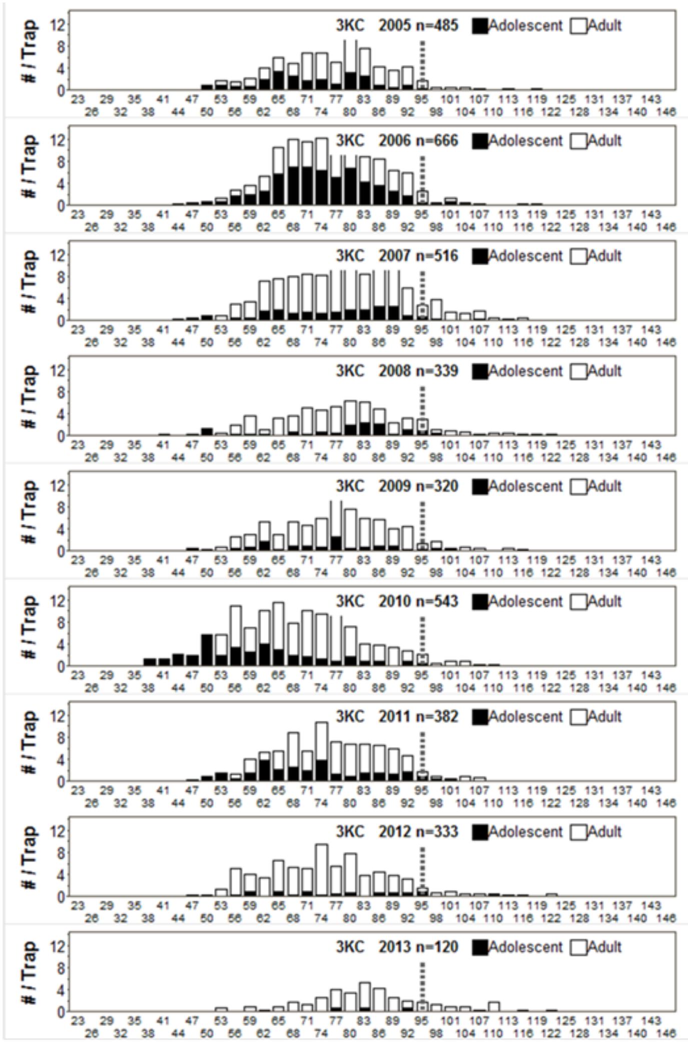

Figure 106: Trends in male carapace width distributions from small-mesh traps in CMA 3C from the CPS survey. The vertical dashed line indicates the minimum legal size.

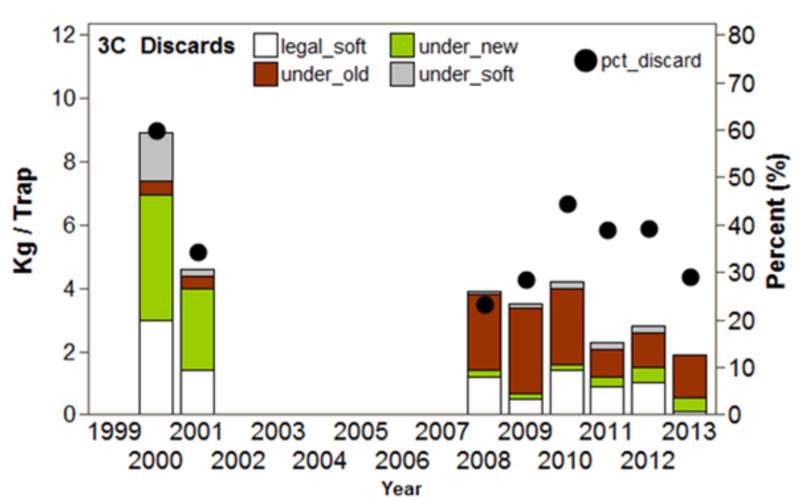

Figure 107: Trends in CMA 3C observer catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

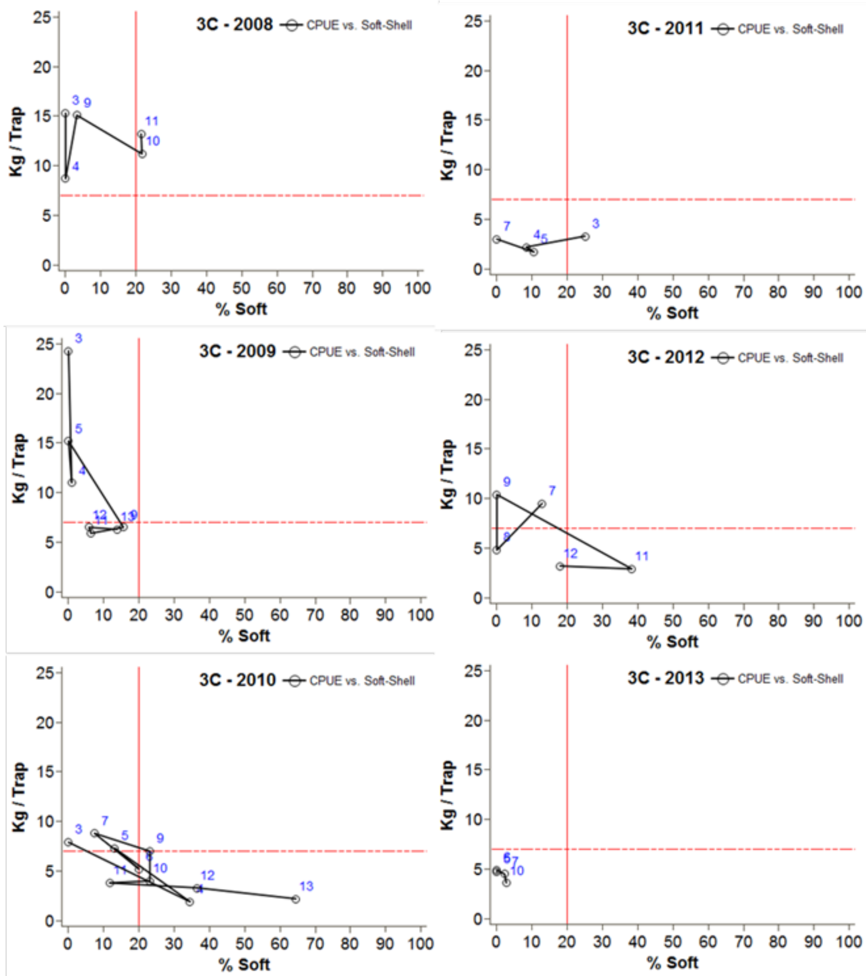

Figure 108: Trends in weekly percentages of kept vs. soft-shell crab in CMA 3C from at-sea sampling by observers.

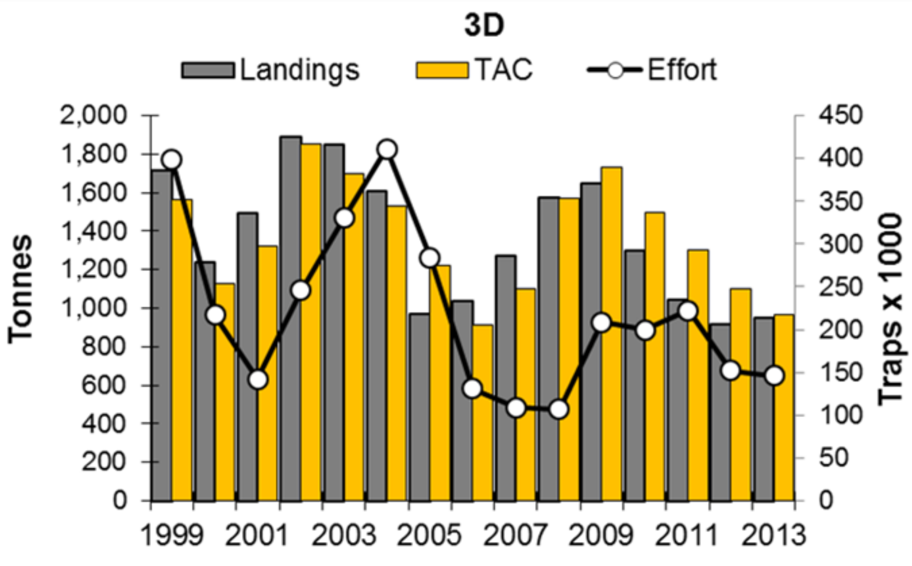

Figure 109: Trends in CMA 3D landings, TAC, and fishing effort. (2013 effort preliminary).

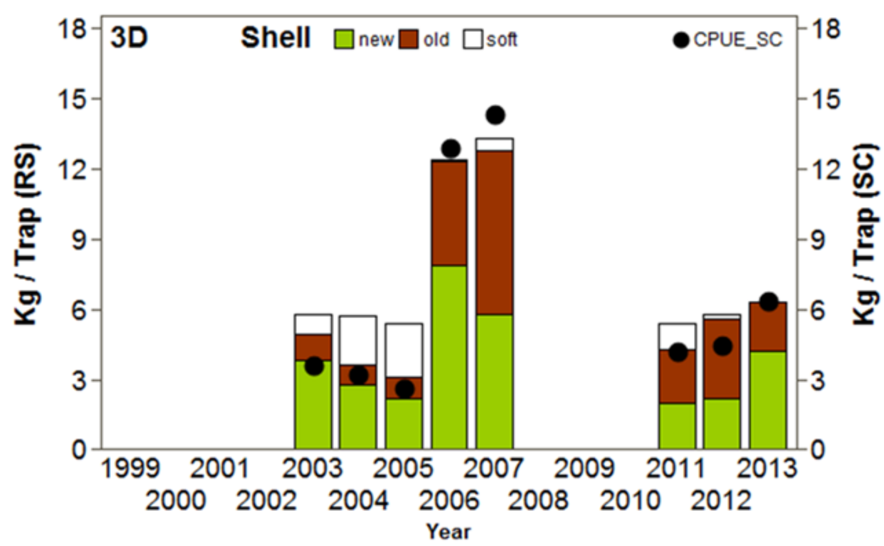

Figure 110: Trends in CMA 3D observer catch rates of exploitable-sized crabs by shell condition category from at-sea sampling.

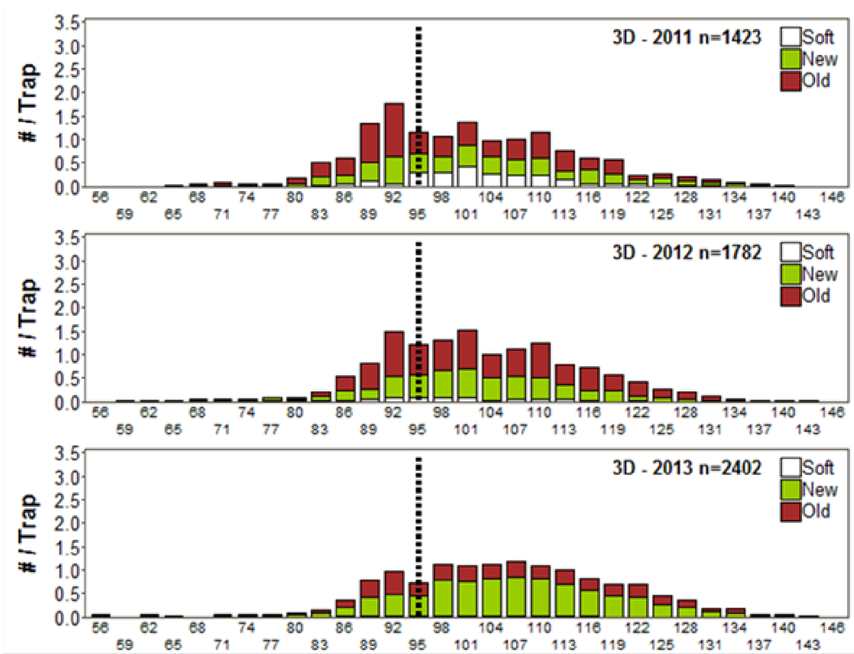

Figure 111: Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMA 3D. The vertical dashed line indicates the minimum legal size.

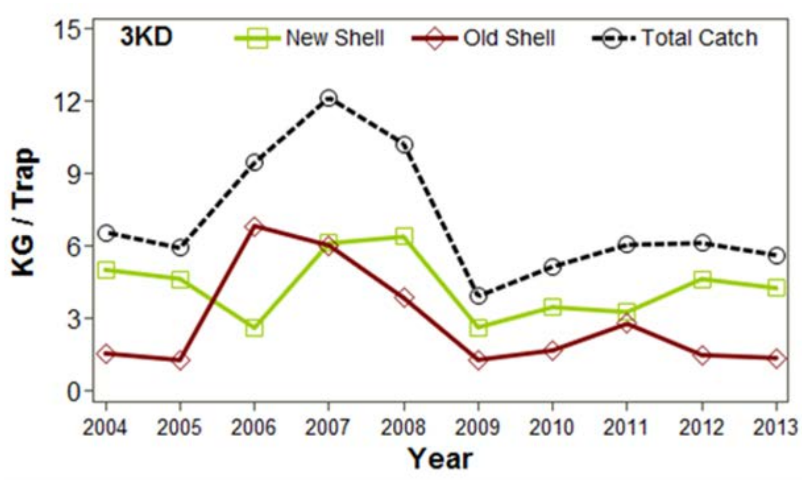

Figure 112: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 3D.

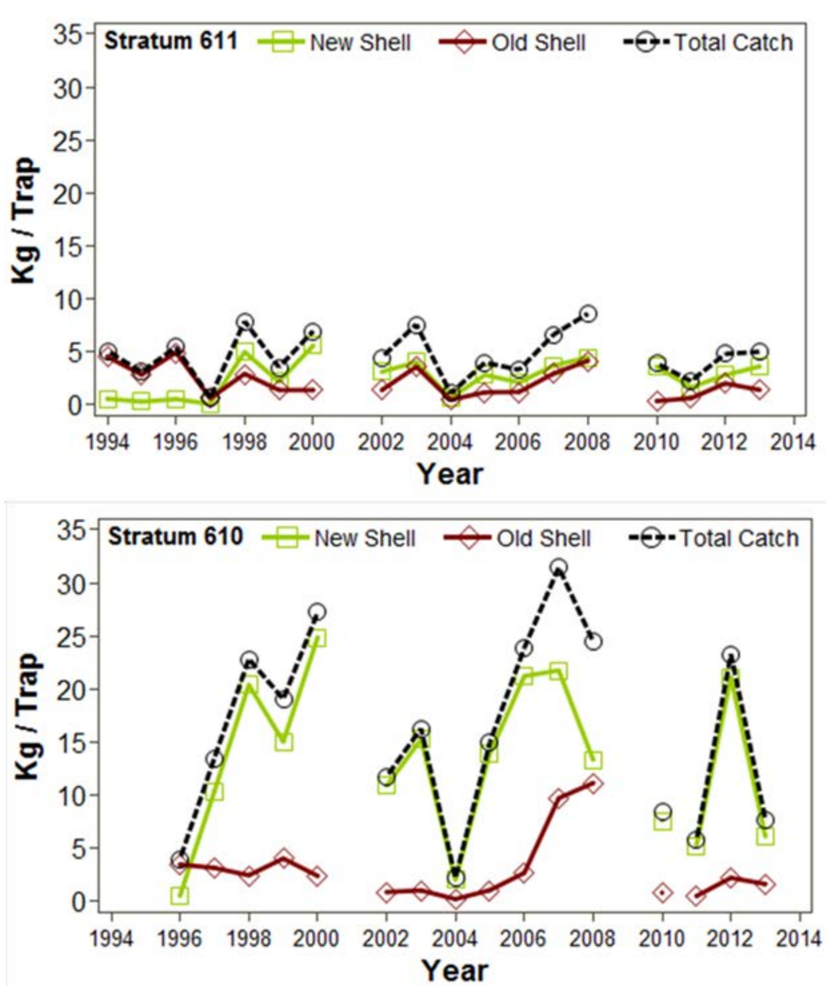

Figure 113: Trends in CPUE by shell condition for legal-sized crabs from strata occupied in the DFO trap survey in Notre Dame Bay. No surveys conducted in 2001 or 2009.

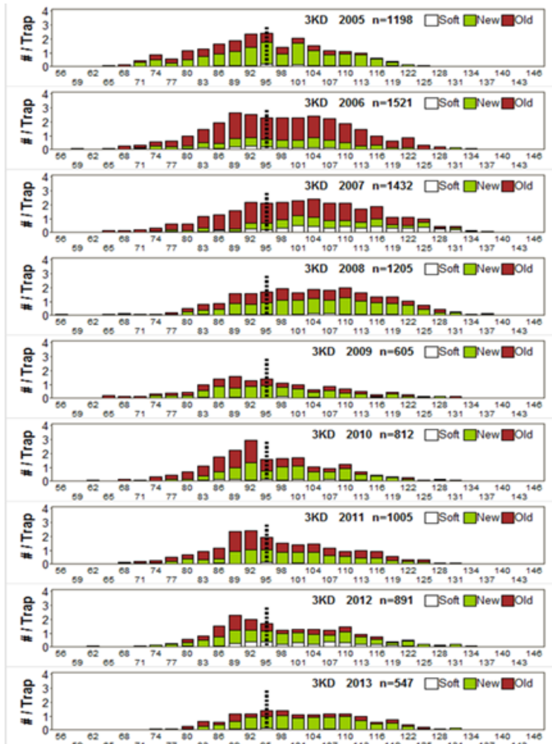

Figure 114: Trends in male carapace width distributions from large mesh traps at core stations in CMA 3D from the CPS survey. The vertical dashed line indicates the minimum legal size.

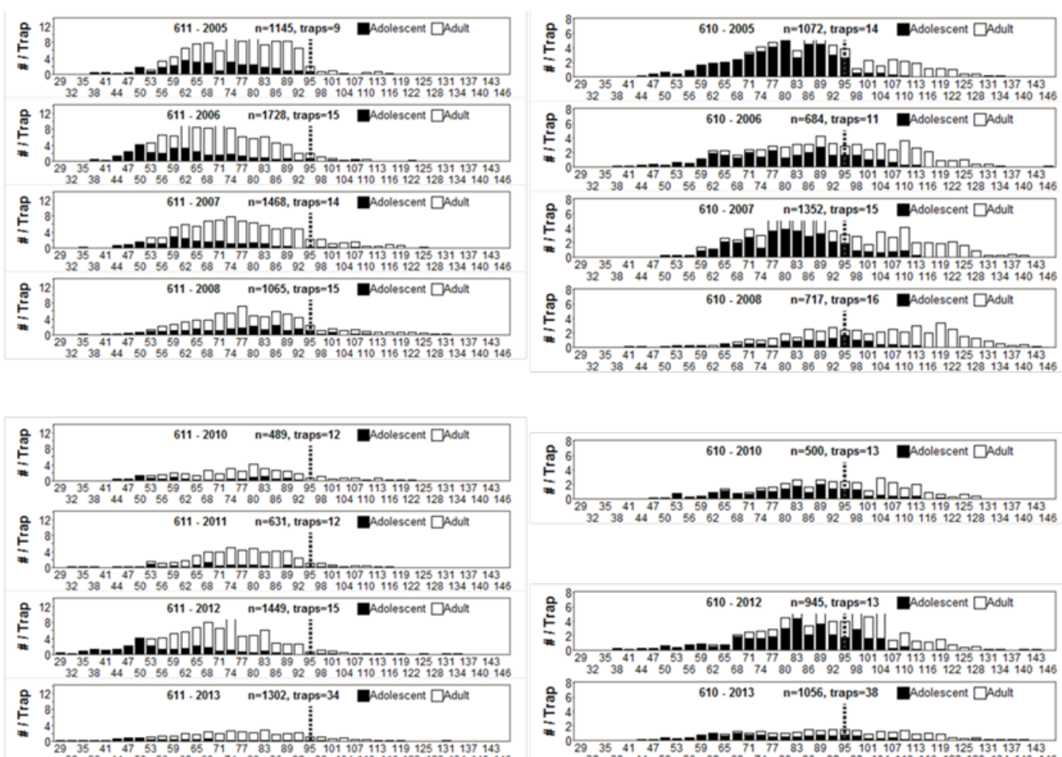

Figure 115: Small-claw (adolescent) vs. large-claw (adult) male catch rates by size from small-mesh traps in DFO trap survey in Notre Dame Bay. The vertical dashed line indicates the minimum legal size.

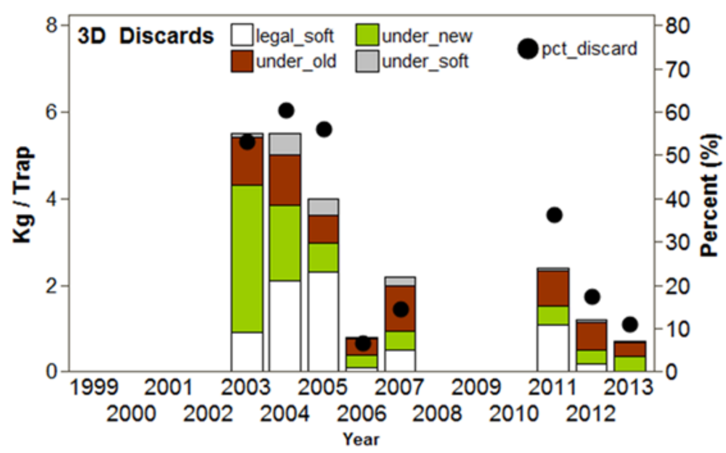

Figure 116: Trends in CMA 3D observer catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

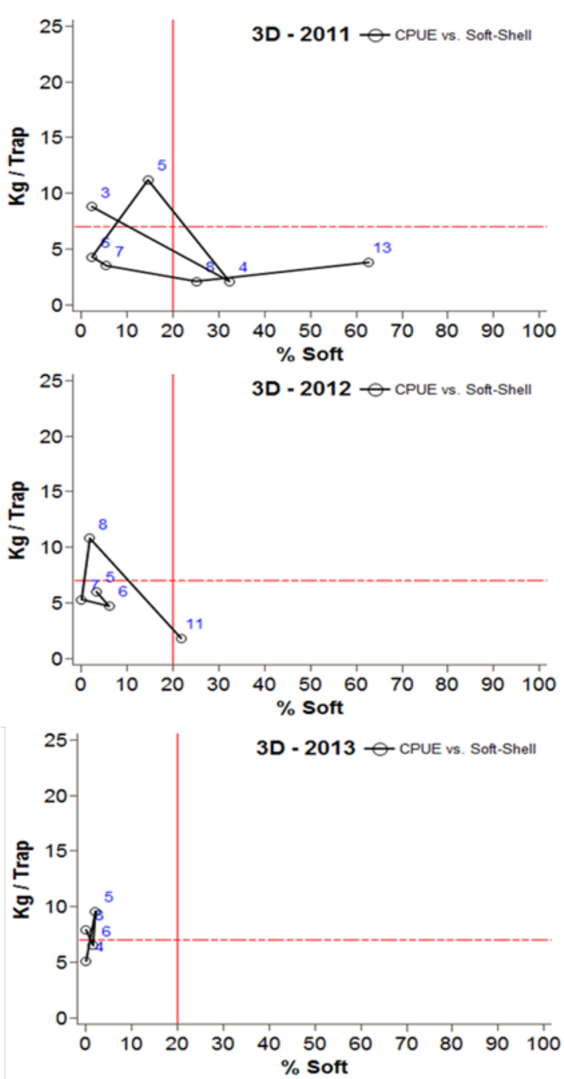

Figure 117: Trends in weekly percentages of soft-shell crab in CMA 3D from at-sea sampling by observers.

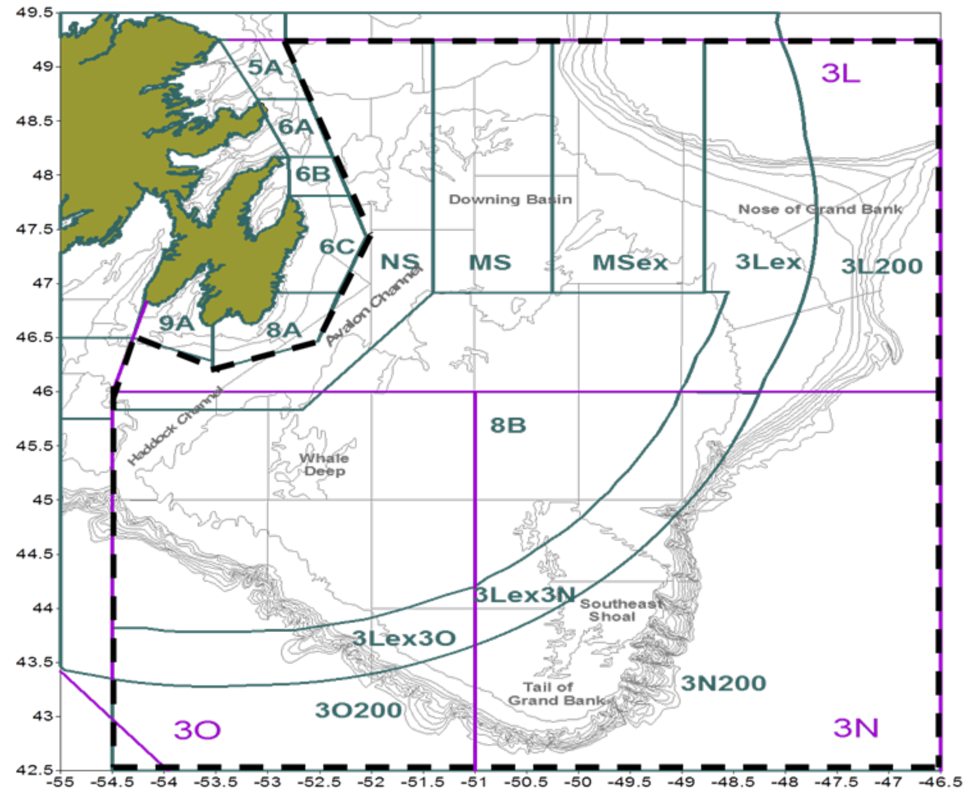

Figure 118: Map of Division 3LNO showing crab management areas and important bathymetric features. Dashed perimeter indicates offshore areas.

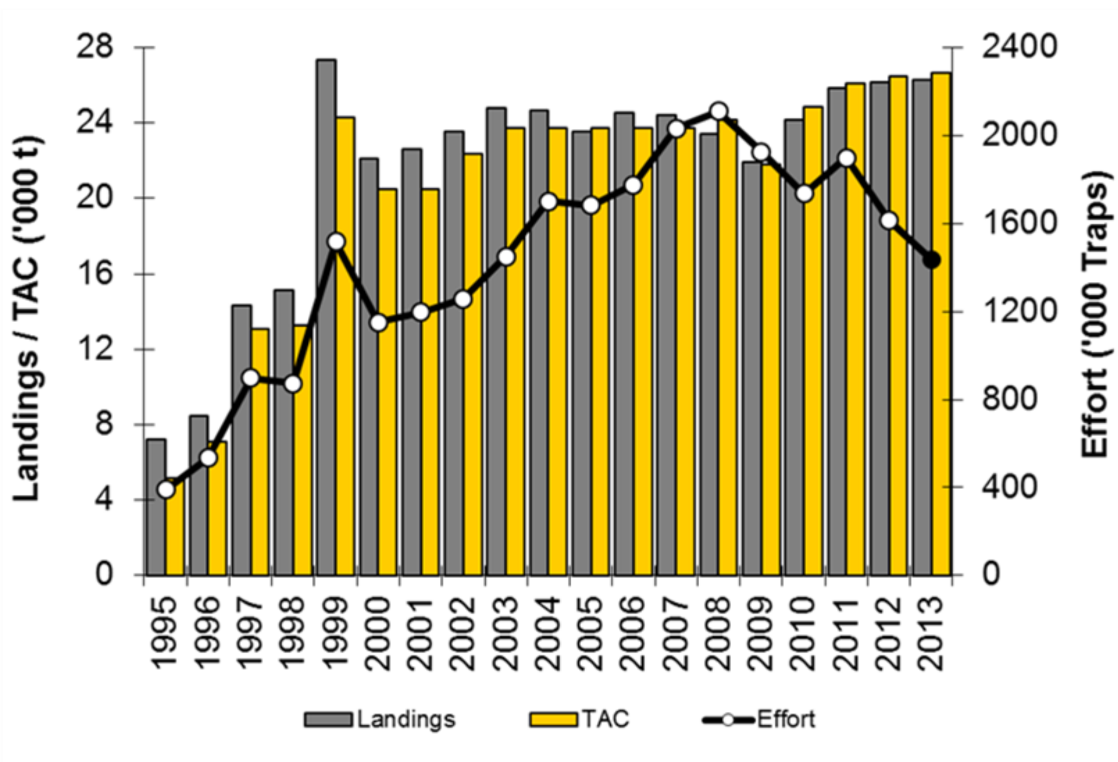

Figure 119: Trends in Div. 3LNO offshore landings, TAC, and fishing effort. (2013 effort preliminary).

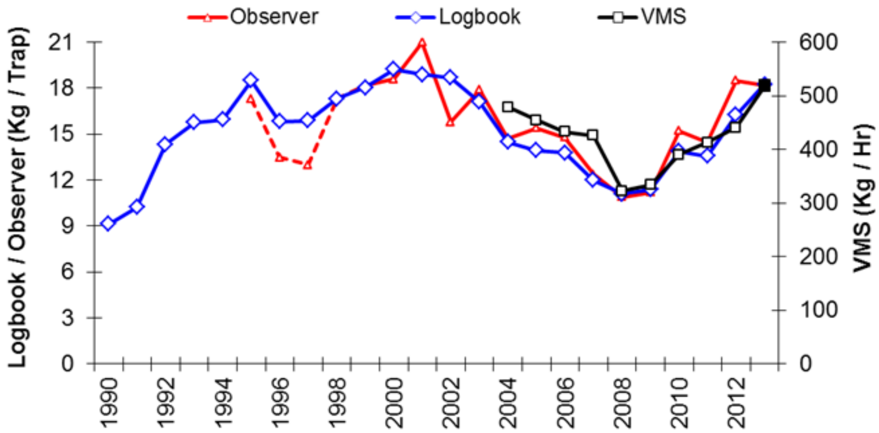

Figure 120: Trends in commercial logbook-based, observer-based, and VMS-based CPUE in the Div. 3LNO offshore fishery. (2013 logbook and VMS CPUE estimates preliminary).

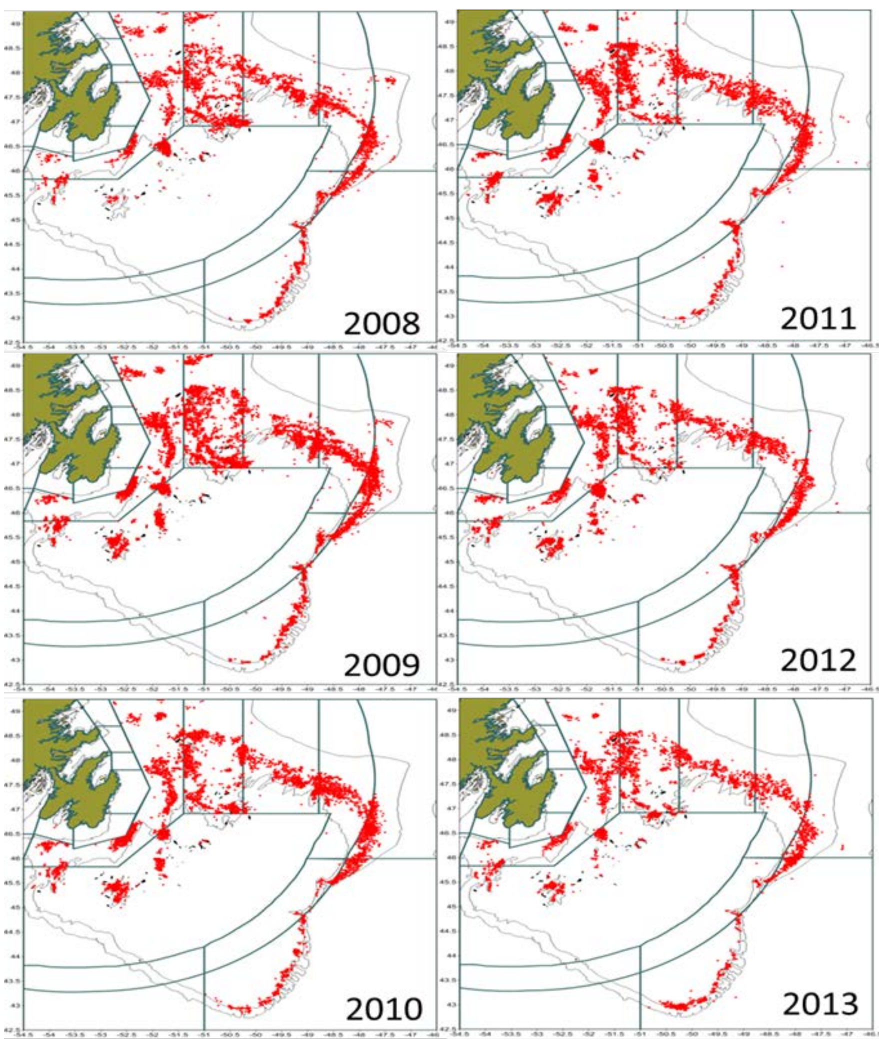

Figure 121: Spatial distribution of Div. 3LNO offshore fishing effort by year.

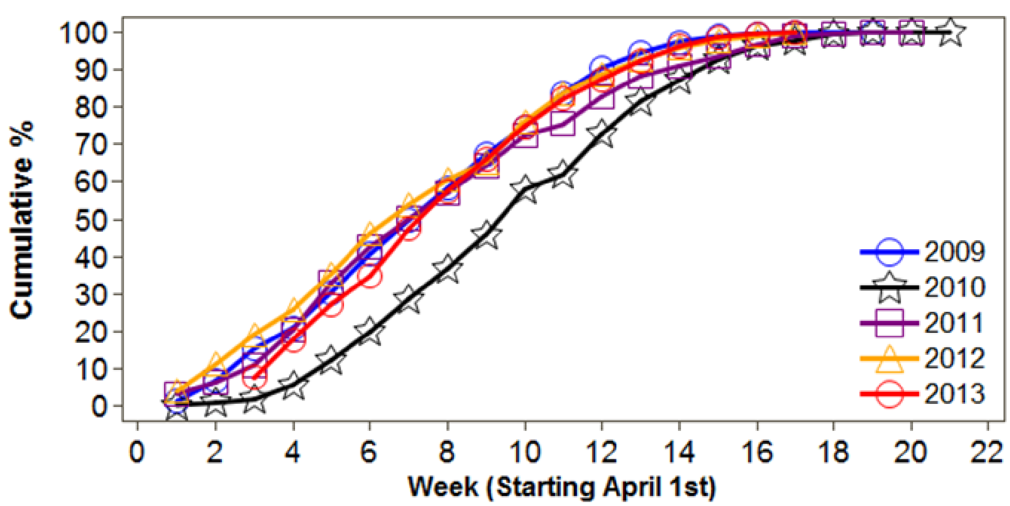

Figure 122: Seasonal trends in fishing effort for Div. 3LNO offshore.

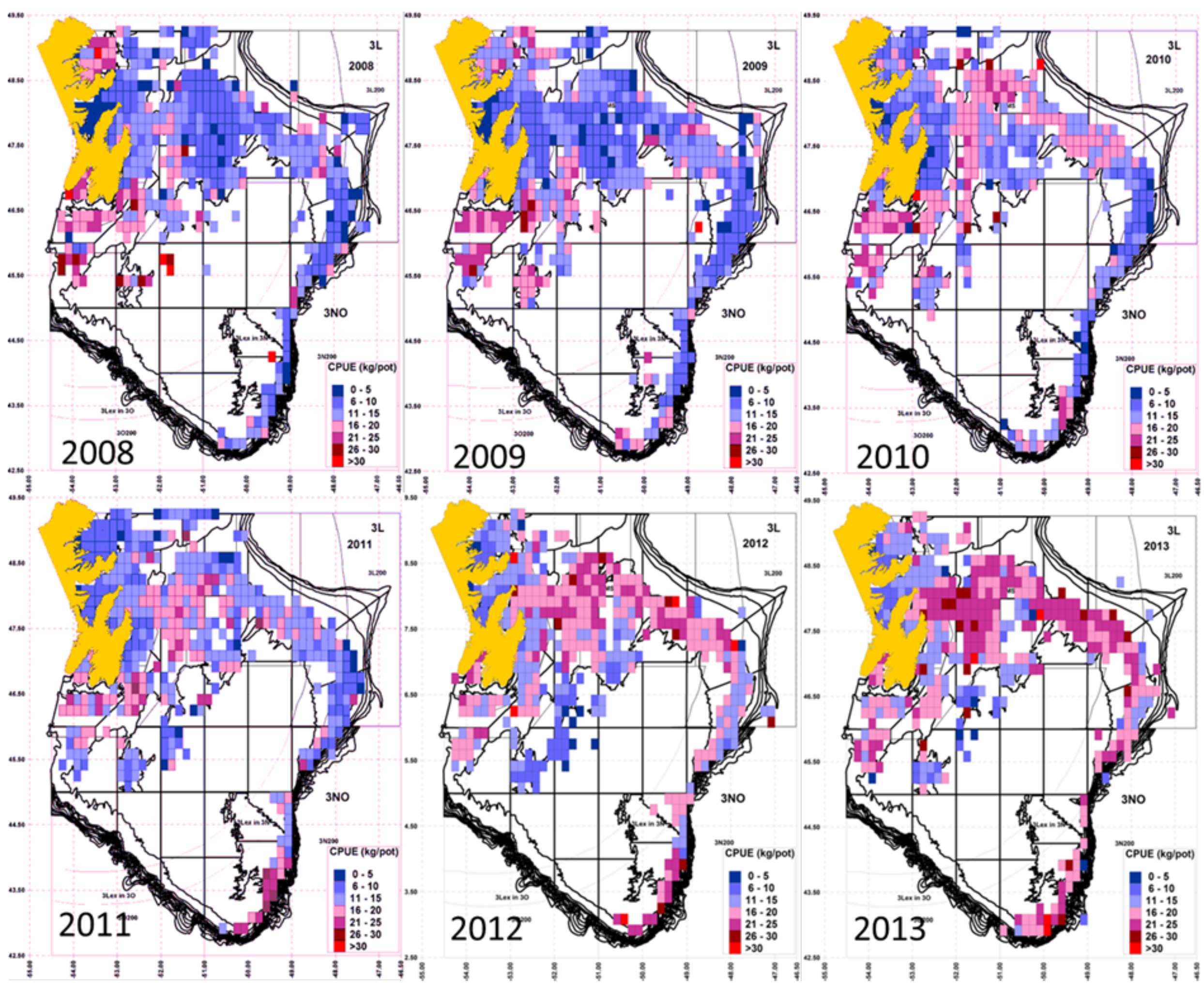

Figure 123: Spatial distribution of Div. 3LNO logbook CPUE by year.

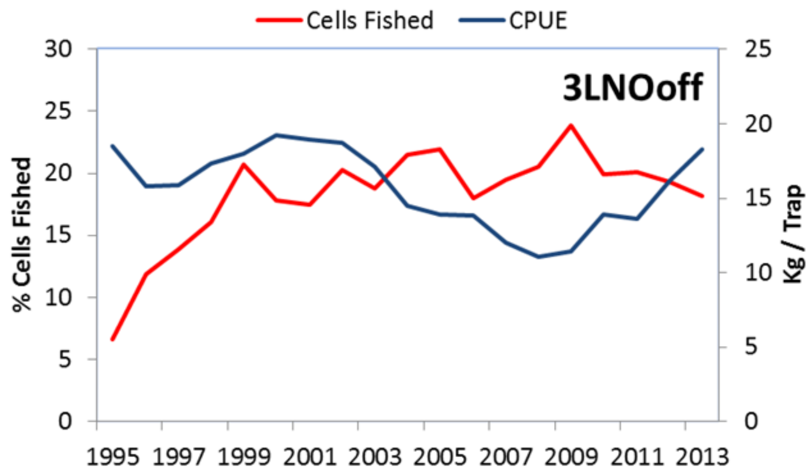

Figure 124: Trends in Div. 3LNO offshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

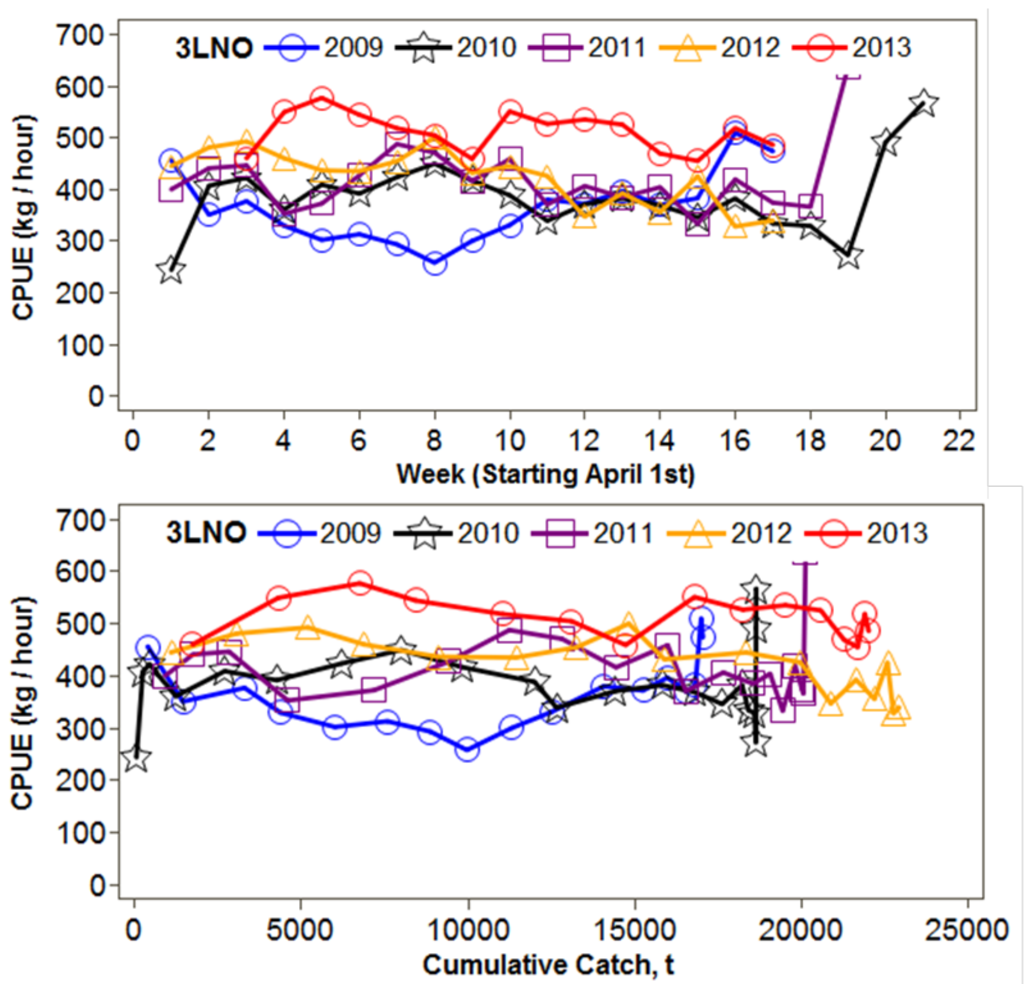

Figure 125: Seasonal trends in VMS-based CPUE for Div. 3LNO offshore; by week (top), and in relation to cumulative catch (bottom).

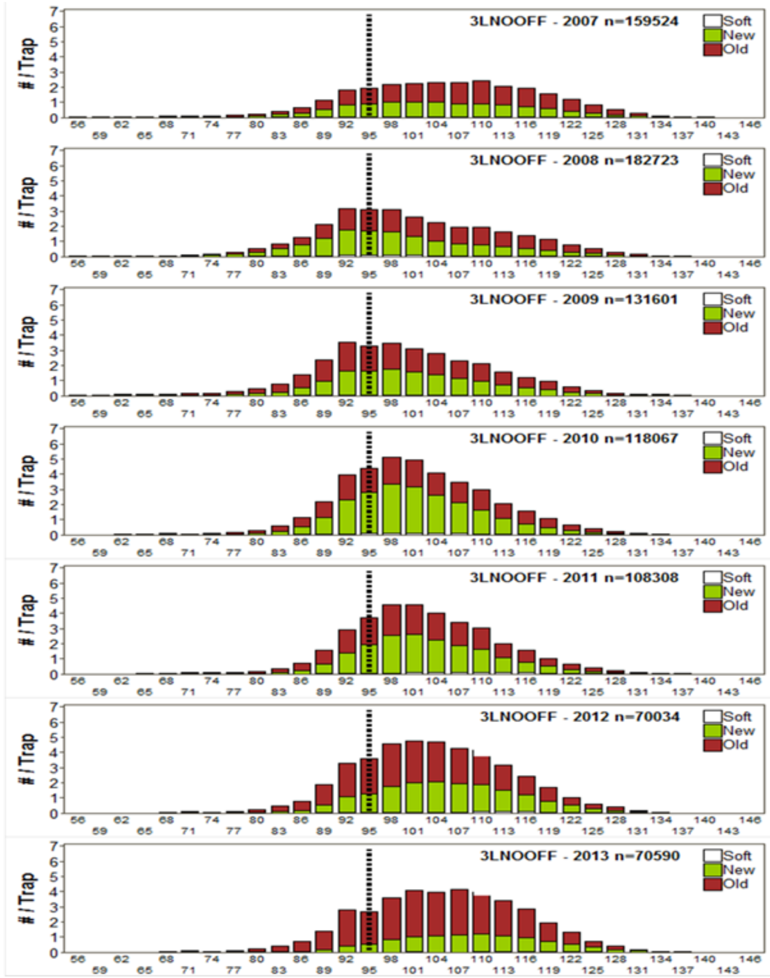

Figure 126: Trends in male carapace width distributions by shell condition from observer at-sea sampling for Div. 3LNO offshore. The vertical dashed line indicates the minimum legal size.

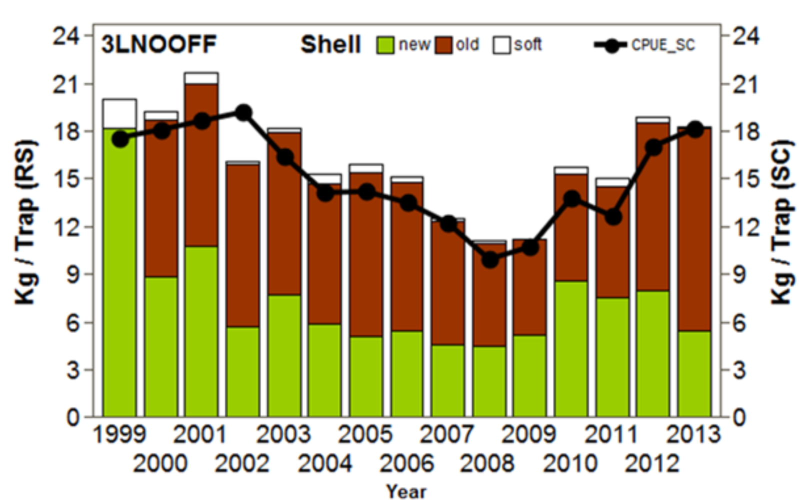

Figure 127: Trends in Division 3LNO offshore observer catch rates of exploitable crabs by shell condition category from at-sea sampling.

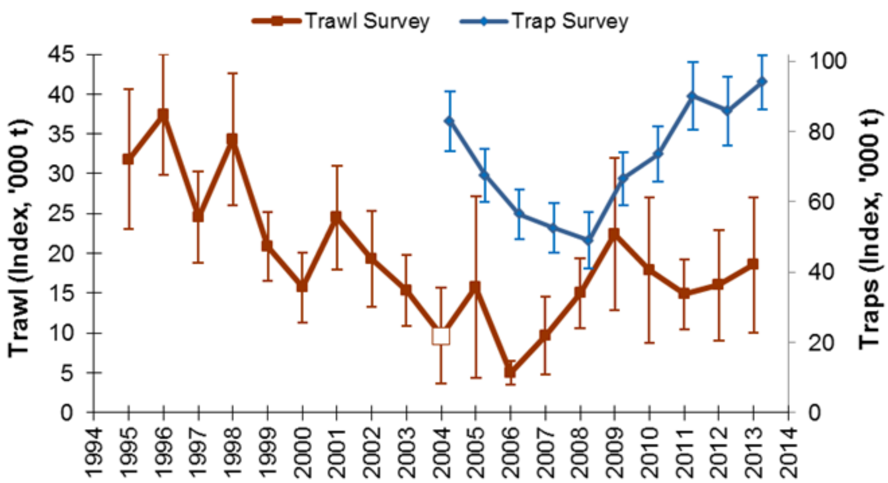

Figure 128: Trends in the Div. 3LNO offshore fall trawl survey exploitable biomass index and the CPS trap survey biomass index. The trawl survey was incomplete in 2004.

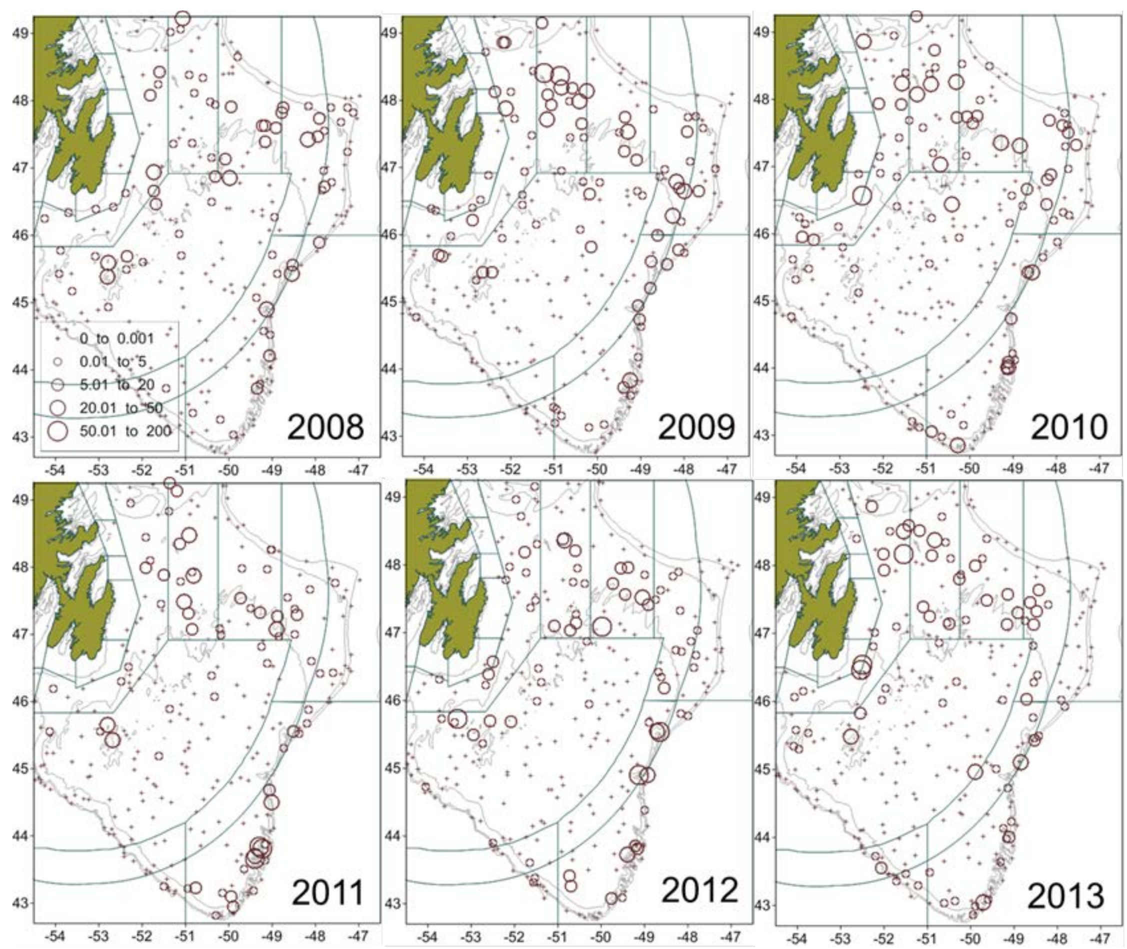

Figure 129. Spatial distribution of catches (number / set) of exploitable snow crab in the Div. 3LNO offshore trawl survey.

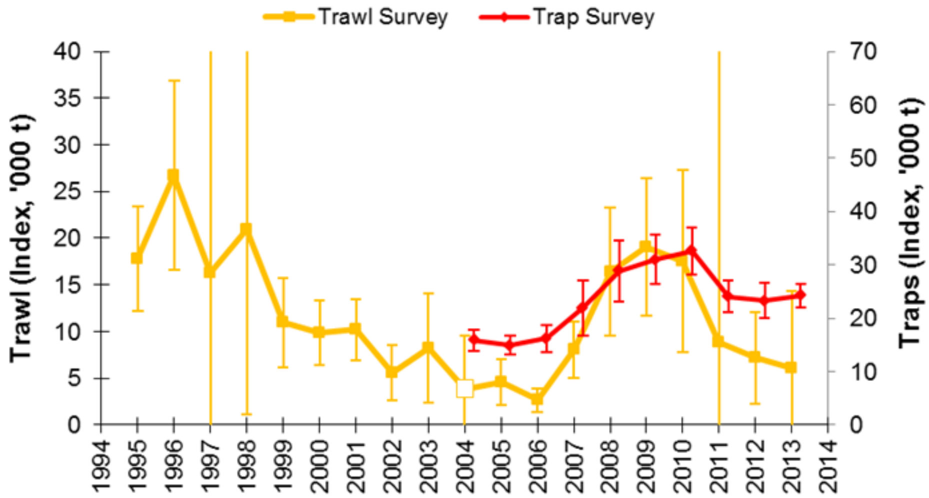

Figure 130: Trends in the Div. 3LNO offshore fall trawl survey pre-recruit biomass index and the CPS trap survey biomass index. The trawl survey was incomplete in 2004.

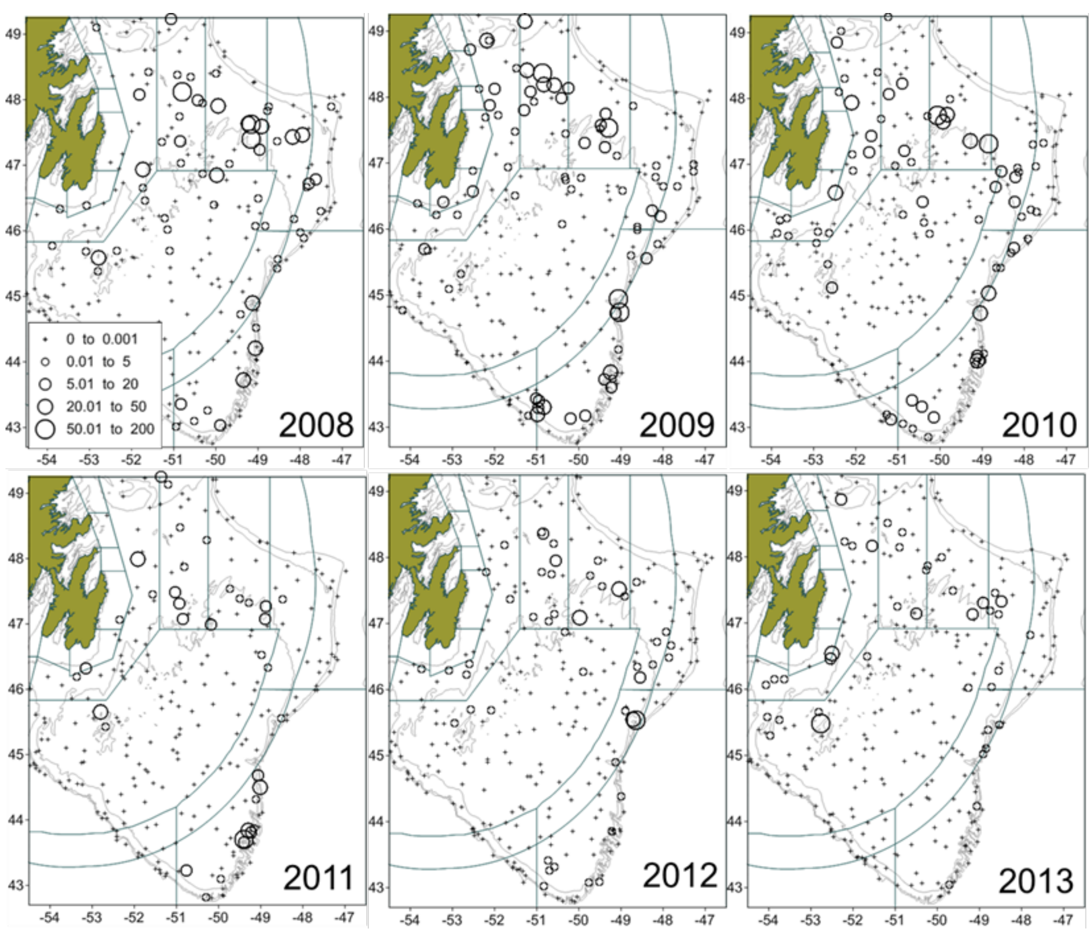

Figure 131. Spatial distribution of catches (number / set) of pre-recruit snow crab in the Div. 3LNO offshore trawl survey.

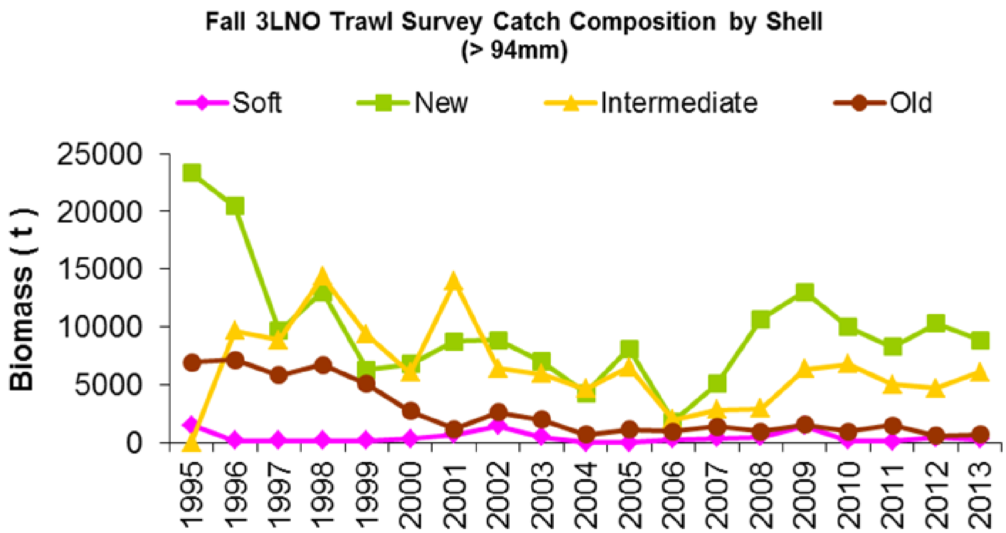

Figure 132: Trends, by shell condition, in biomass of legal-sized males for Div. 3LNO offshore from fall trawl surveys.

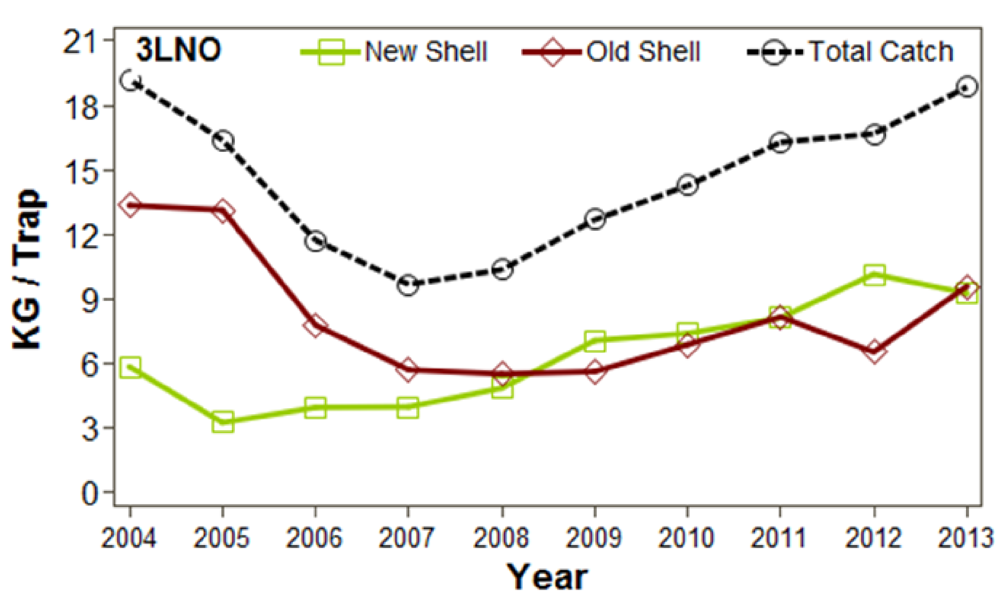

Figure 133: Trends in CPUE by shell condition for legal-sized crabs from core stations in the Div. 3LNO offshore CPS trap survey.

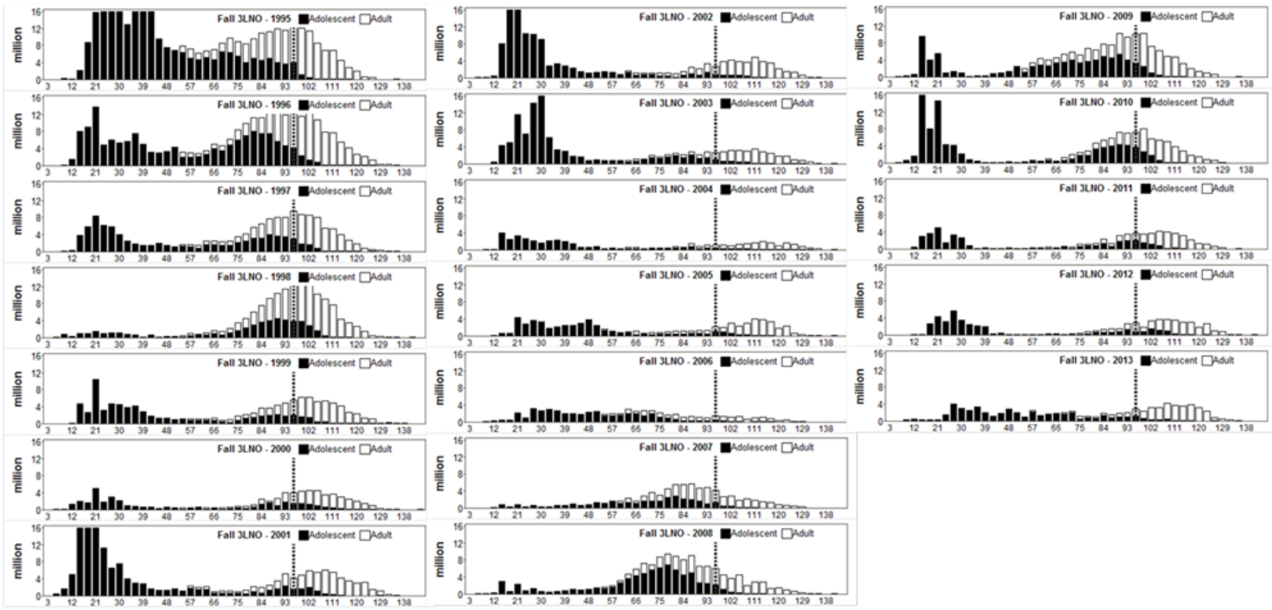

Figure 134: Abundance indices by carapace width for Div. 3LNO juveniles plus adolescents (dark bars) versus adults (open bars) from fall trawl surveys.

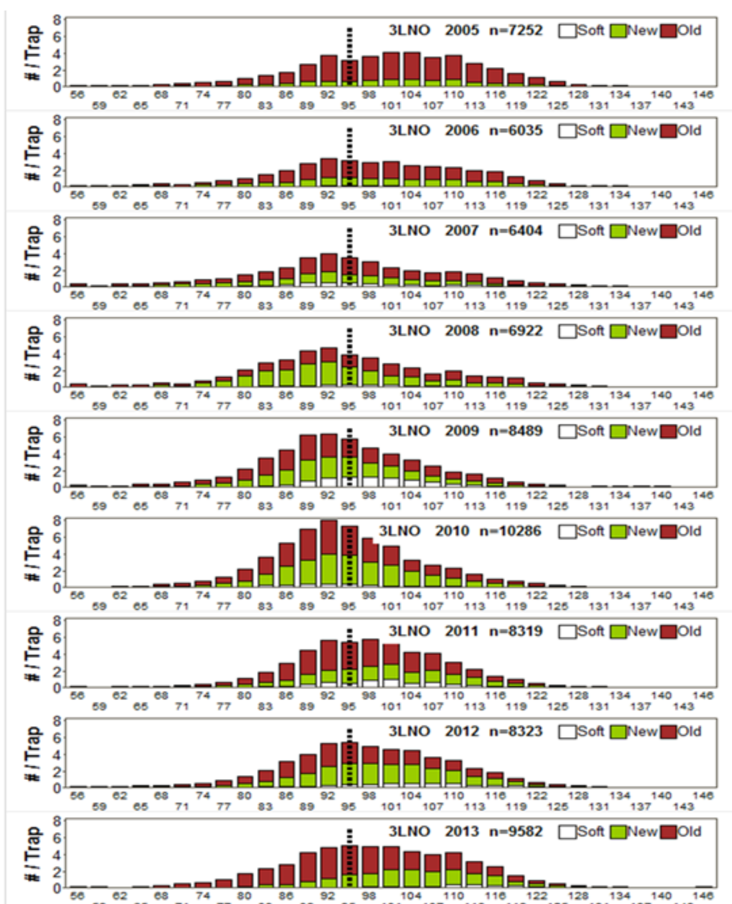

Figure 135: Trends in male carapace width distributions from large mesh traps at core stations in the Div. 3LNO offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

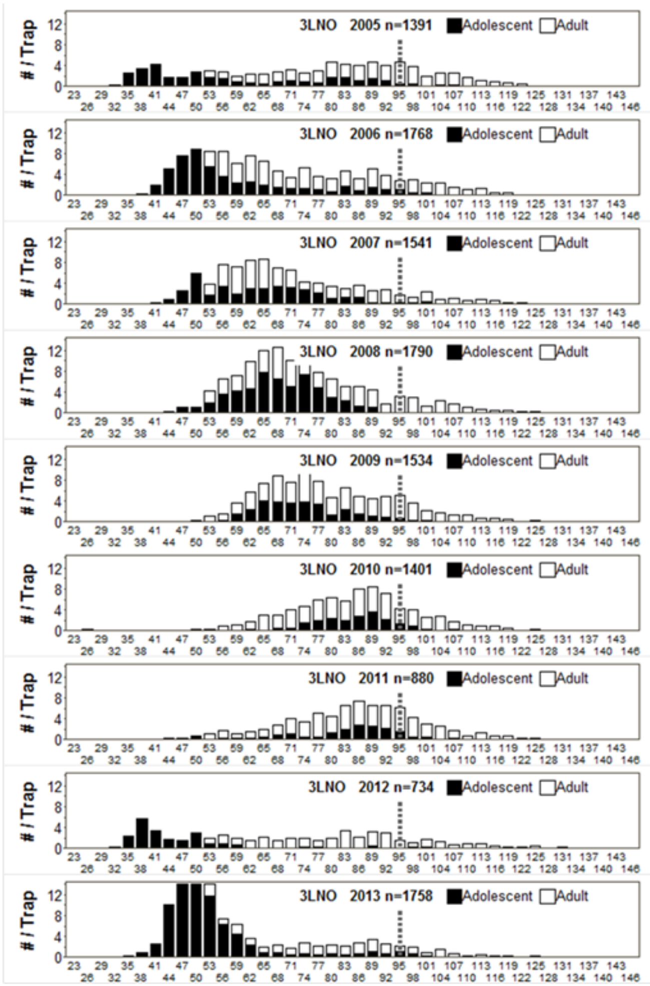

Figure 136: Trends in male carapace width distributions from small-mesh traps in the Div. 3LNO offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

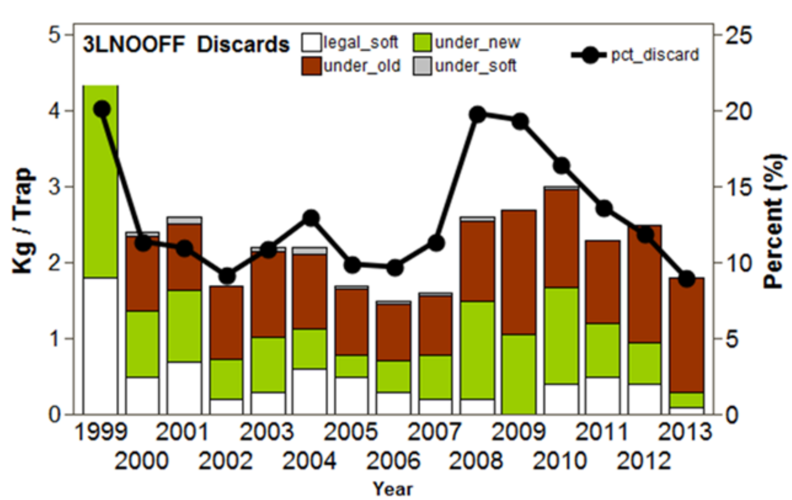

Figure 137: Trends in Division 3LNO offshore observer catch rates of total discards, under-sized discards, and legal-sized discards, as well as the percentage of the catch discarded.

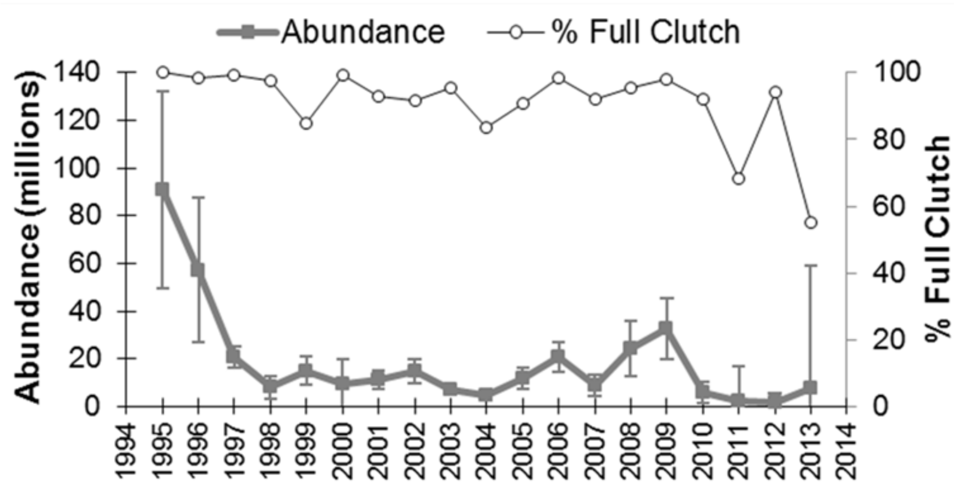

Figure 138: Trends in percent of mature females as well as the percentage of mature females bearing full clutches of viable eggs in Div. 3LNO from fall multi-species surveys.

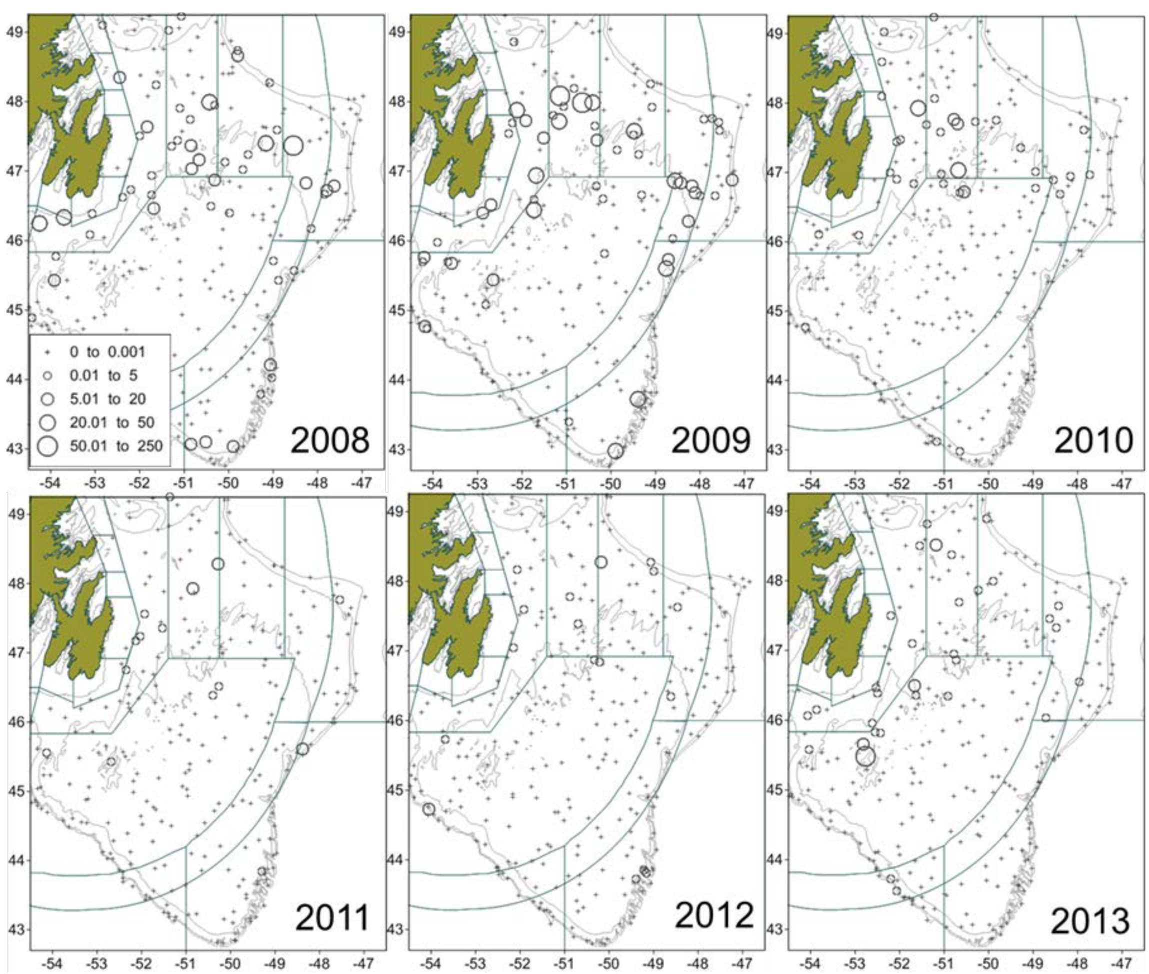

Figure 139: Spatial distribution of catches (number/set) of mature females in the Div. 3LNO fall trawl survey.

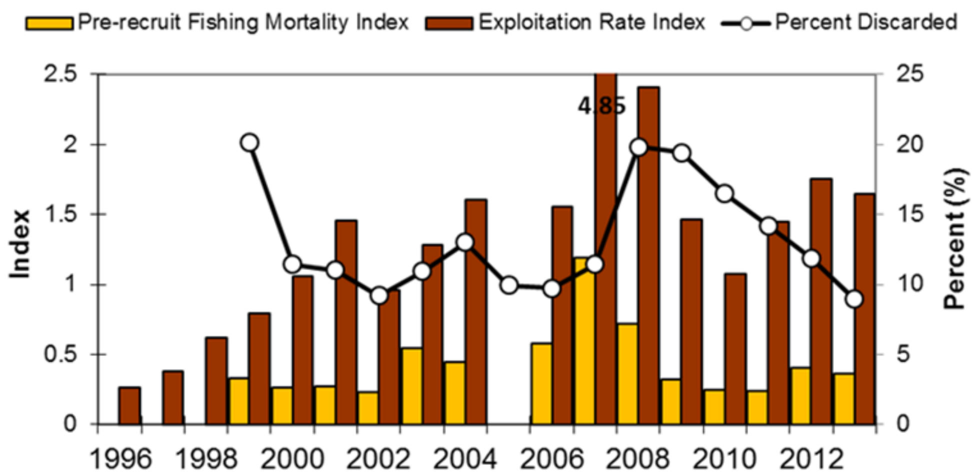

Figure 140: Trends in Div. 3LNO offshore mortality indices (the exploitation rate index and the pre-recruit fishing mortality rate index) and in the percentage of the catch discarded in the fishery (no 2005 exploitation rate or pre-recruit fishing mortality indices because of incomplete 2004 survey).

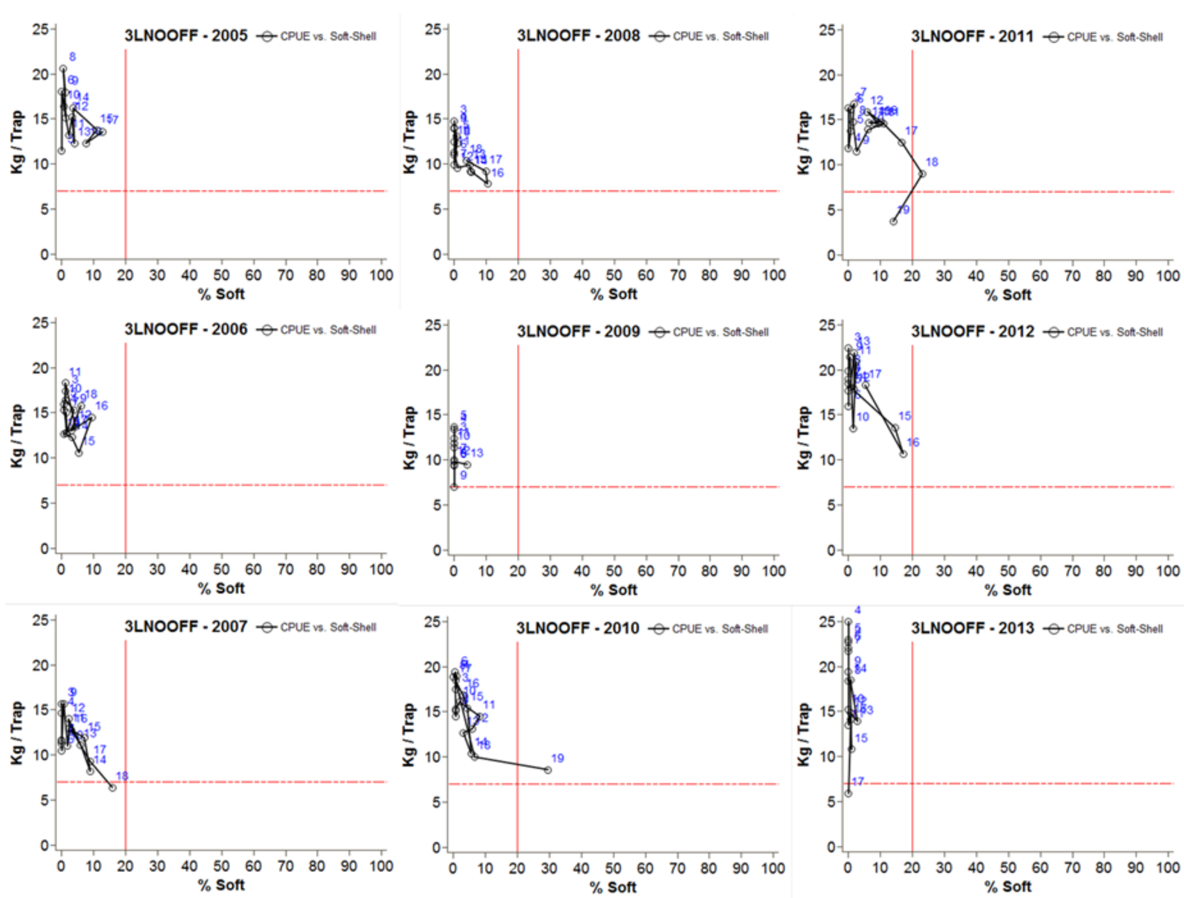

Figure 141: Trends in weekly percentages of kept vs. soft-shell crab in Div. 3LNO from at-sea sampling by observers.

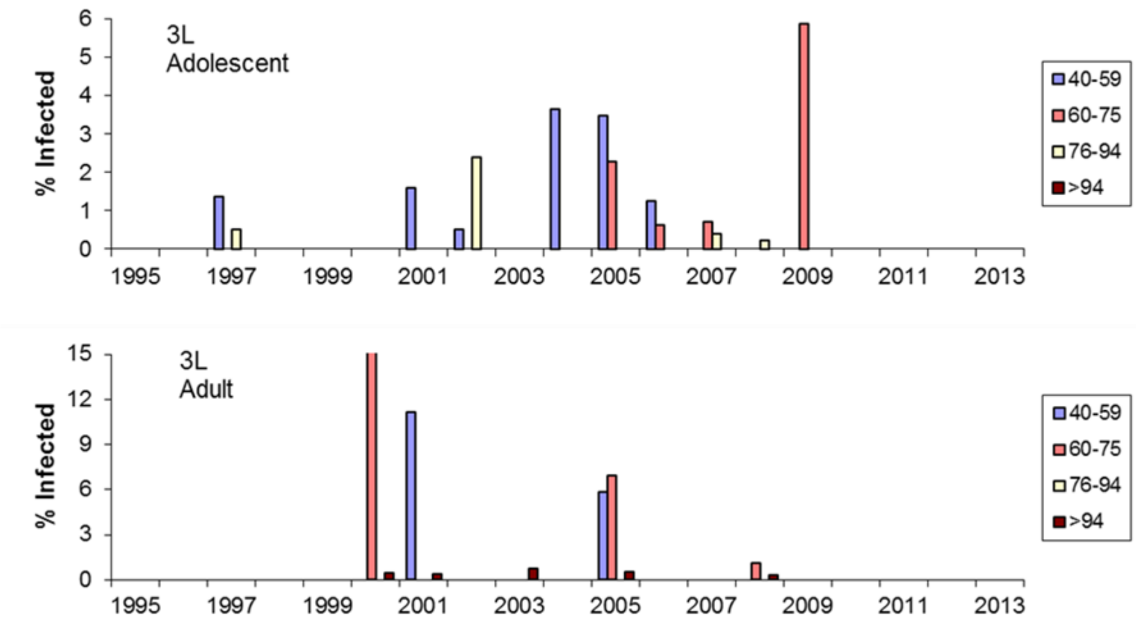

Figure 142: Annual trends in prevalence of BCD in new-shelled adolescent (above) and adult (below) males by size group from Div. 3L fall trawl surveys.

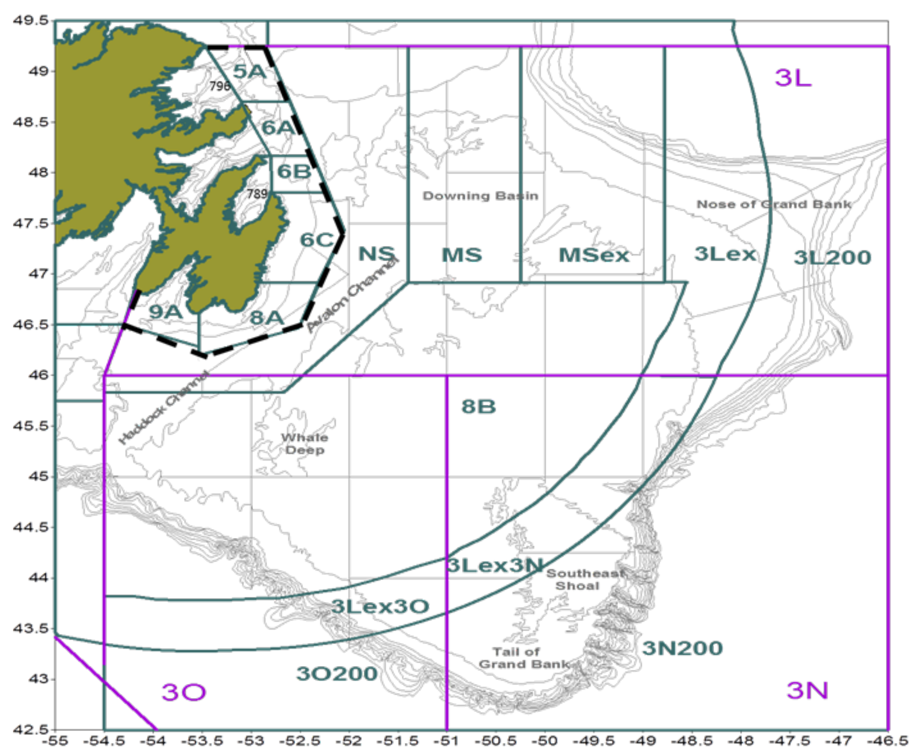

Figure 143: Map of Division 3LNO showing crab management areas and important bathymetric features. Dashed perimeter indicates Div. 3L inshore areas.

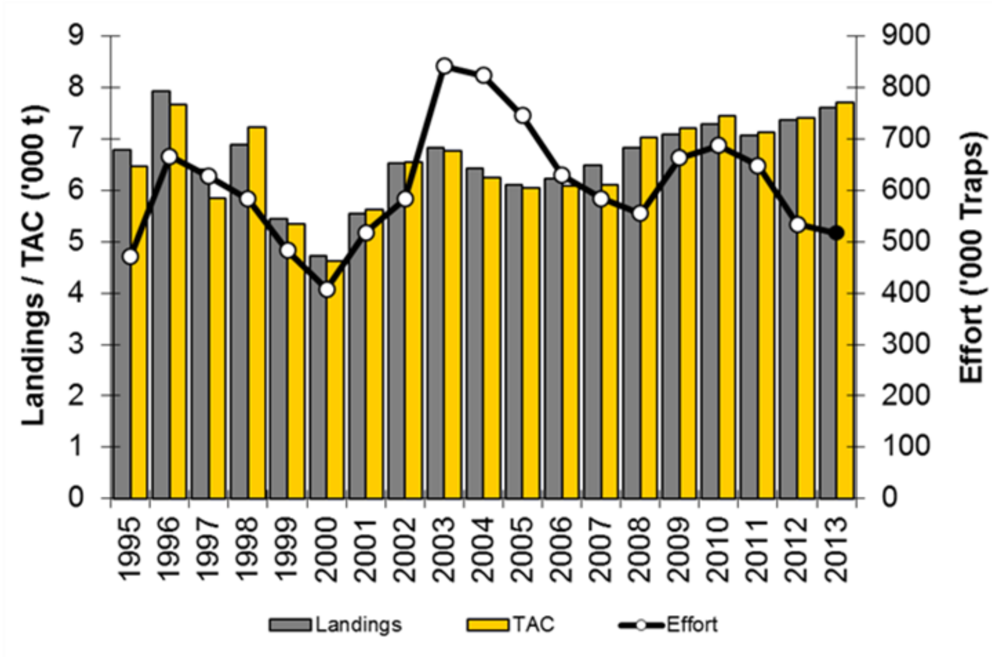

Figure 144: Trends in Div. 3L inshore landings, TAC, and fishing effort. (2013 effort preliminary).

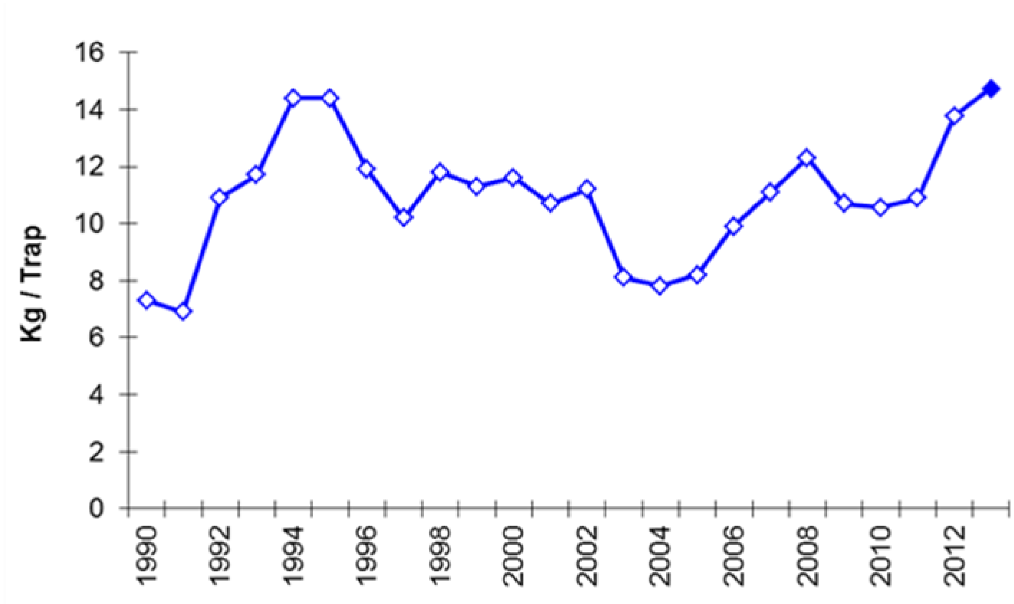

Figure 145: Trends in commercial logbook-based CPUE in the Div. 3L inshore fishery. (2013 estimate preliminary).

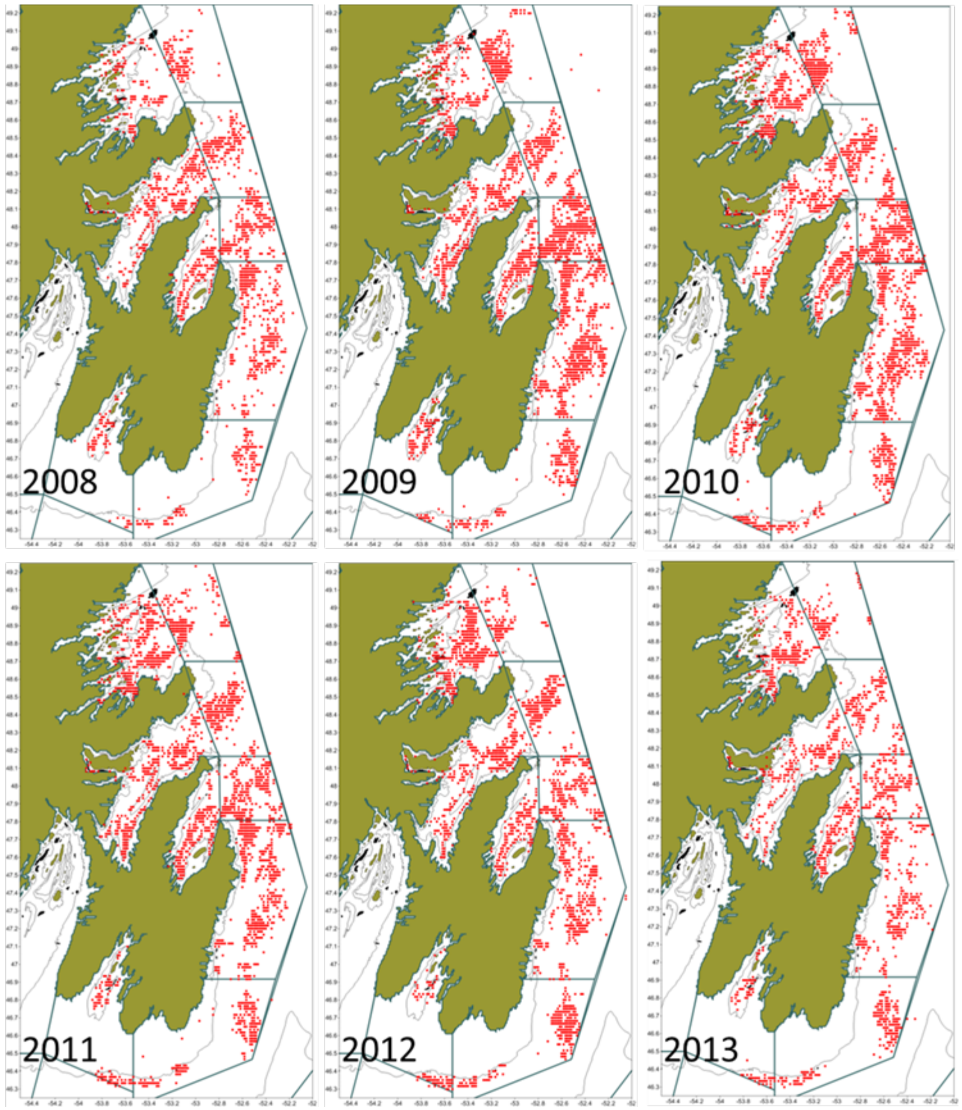

Figure 146: Spatial distribution of Div. 3L inshore fishing effort by year.

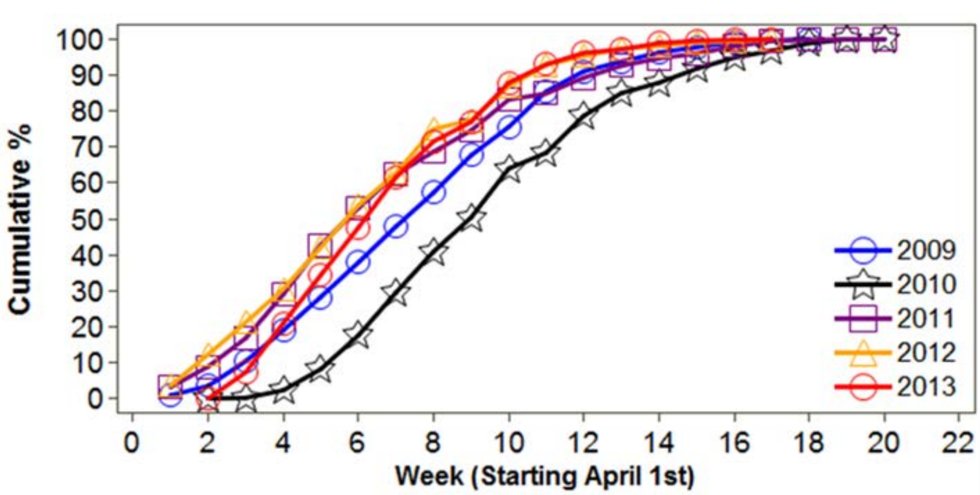

Figure 147: Seasonal trends in weekly fishing effort for Div. 3L inshore.

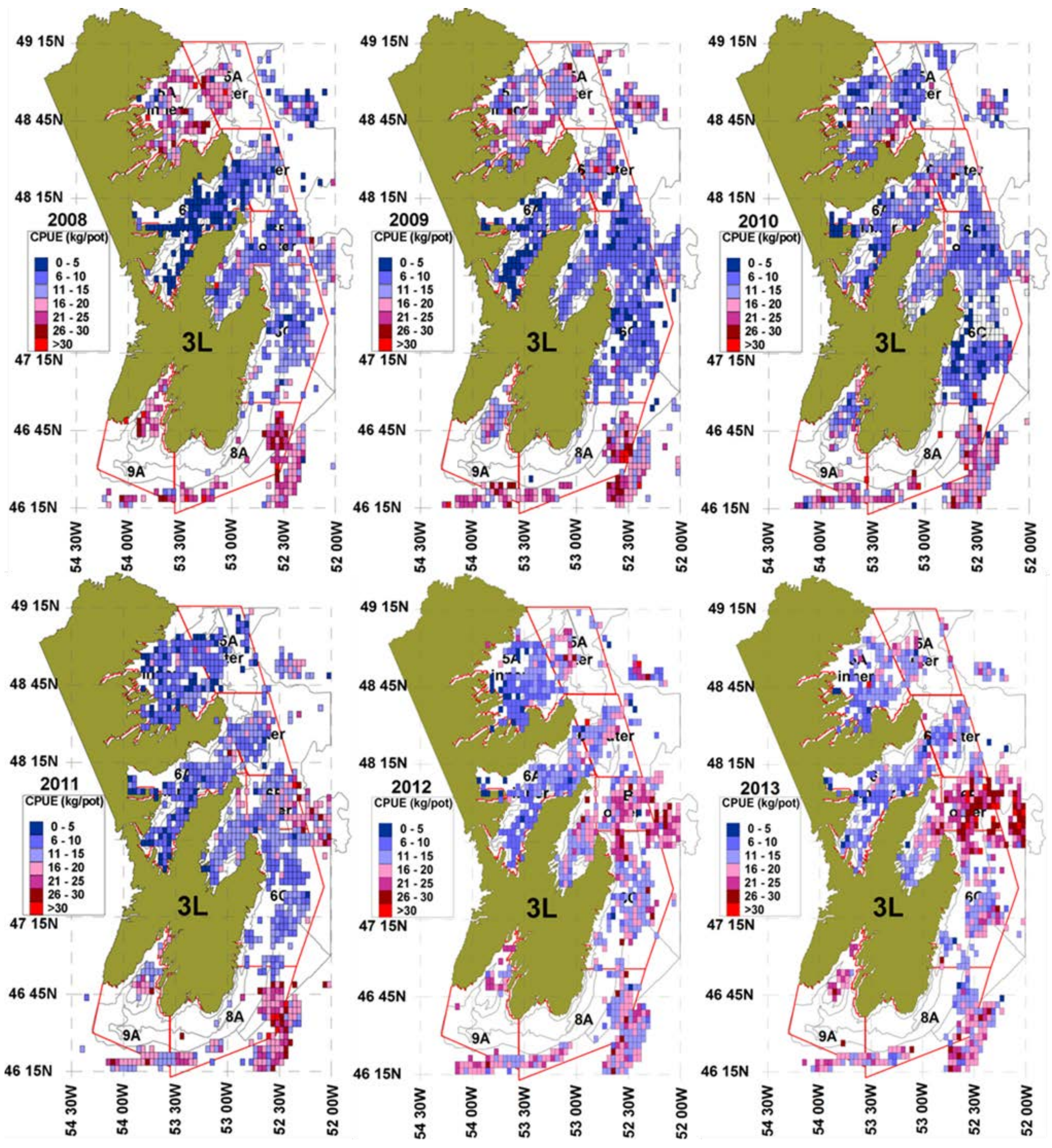

Figure 148: Spatial distribution of Div. 3L inshore logbook CPUE by year.

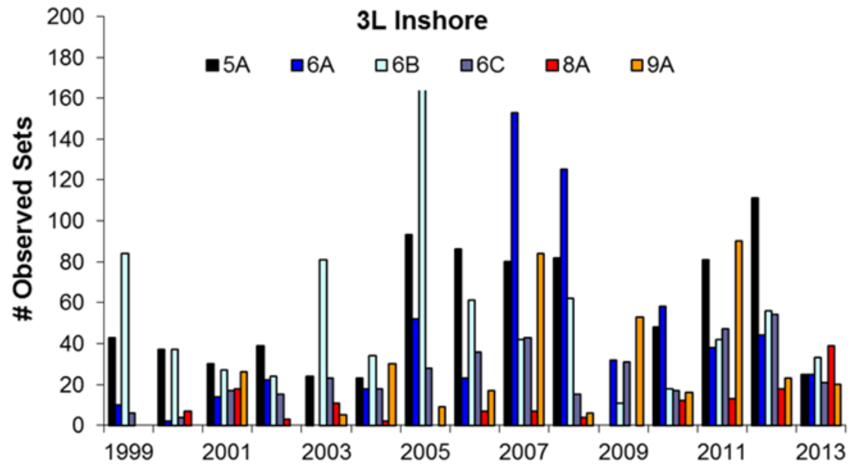

Figure 149: Trends in number of observed sets by Crab Management Areas and year in Division 3L inshore.

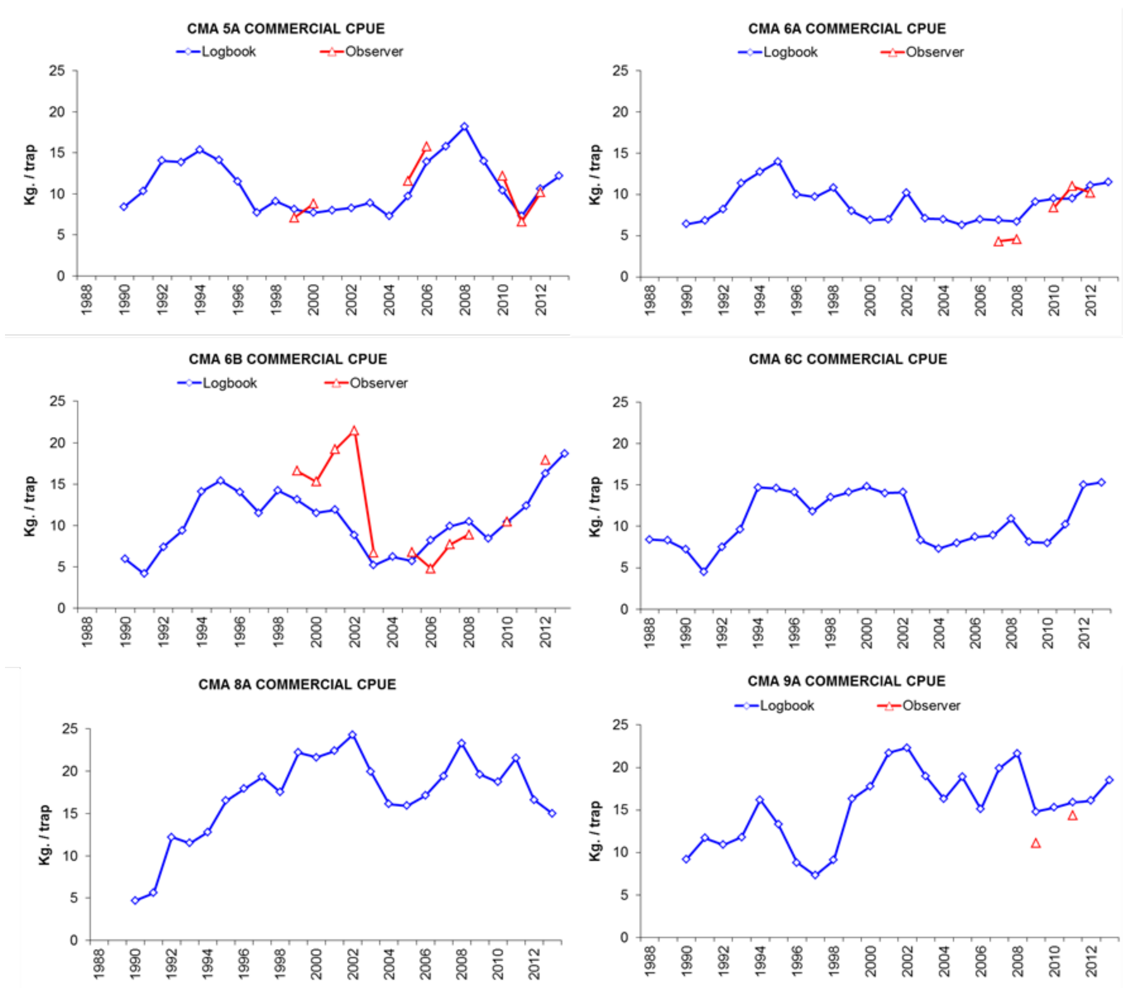

Figure 150: Trends in Division 3L inshore logbook CPUE and observer CPUE by Crab Management Area. (2013 logbook CPUE preliminary).

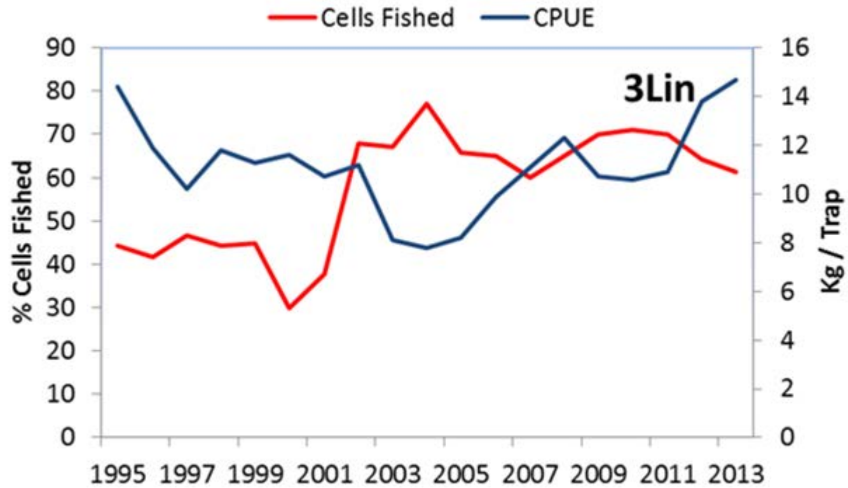

Figure 151: Trends in Div. 3L inshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

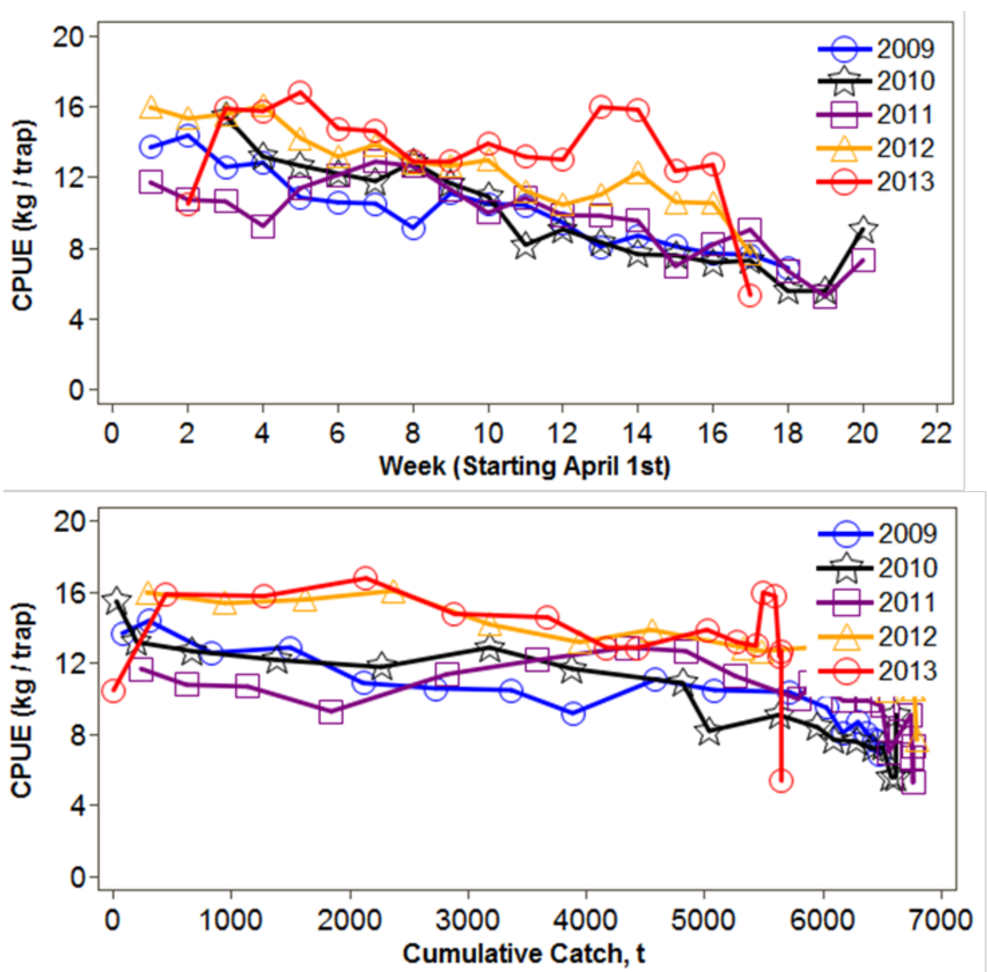

Figure 152: Seasonal trends in logbook-based CPUE for Div. 3L inshore; by week, (top) and in relation to cumulative catch (bottom).

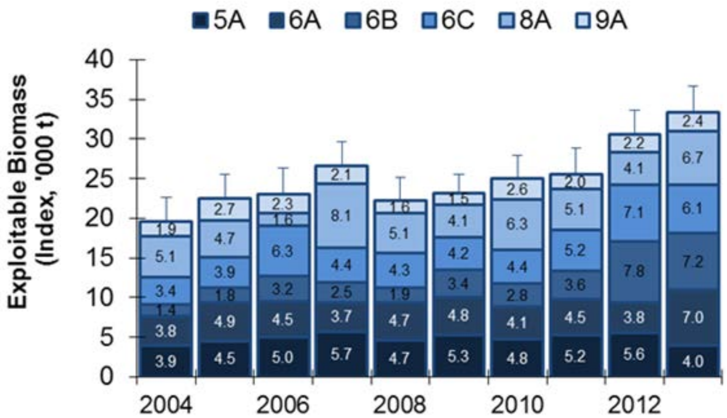

Figure 153: Exploitable biomass indices by crab management area from the CPS trap survey in Division 3L inshore.

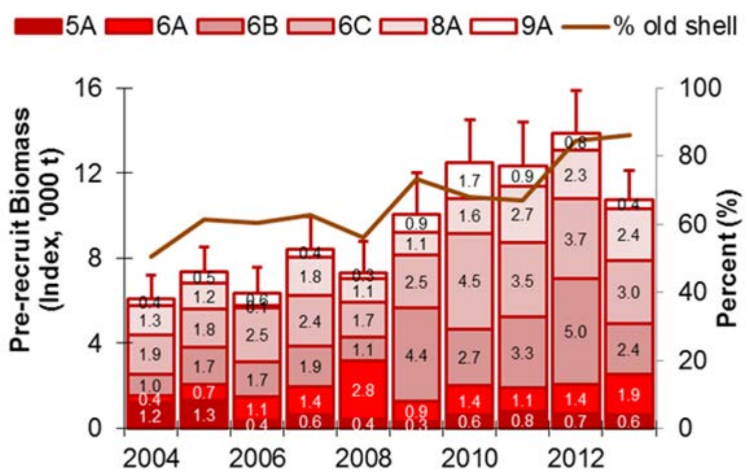

Figure 154: Pre-recruit biomass indices by crab management area from the CPS trap survey in Division 3L inshore.

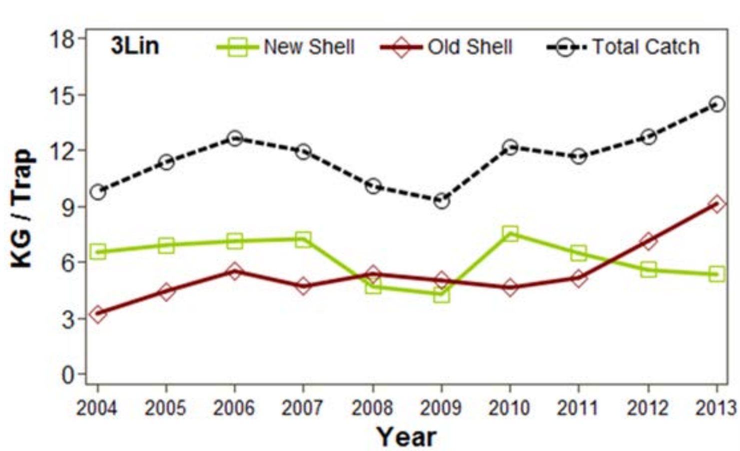

Figure 155: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in Div. 3L inshore.

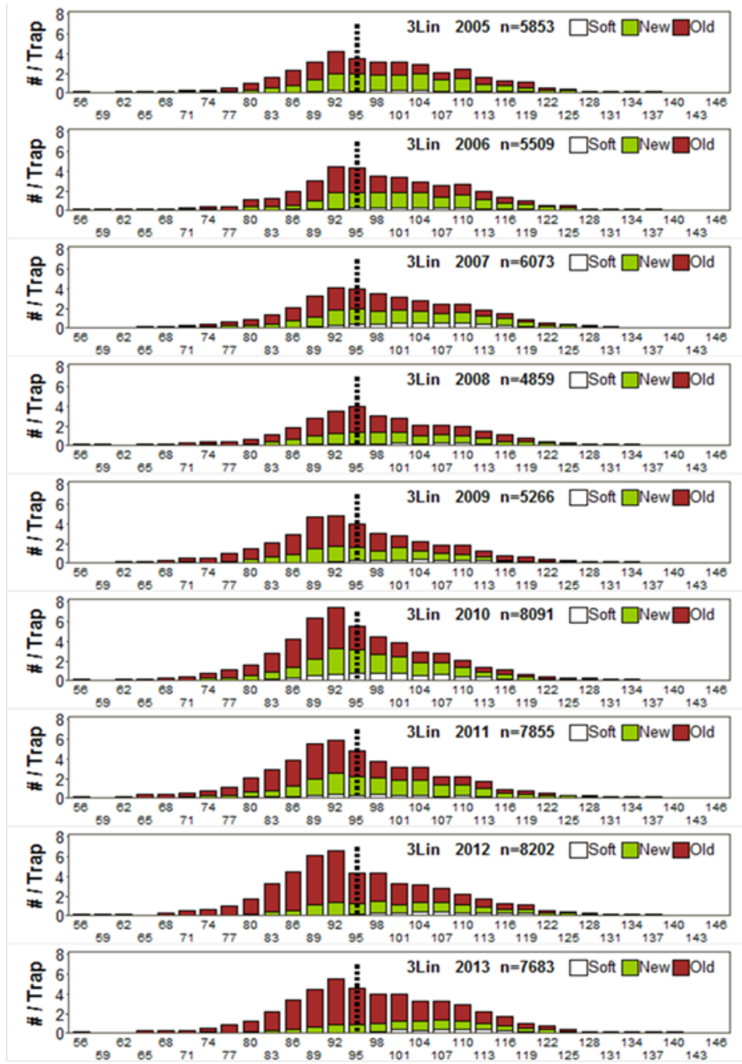

Figure 156: Trends in male carapace width distributions from large mesh traps at core stations in the Div. 3L inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

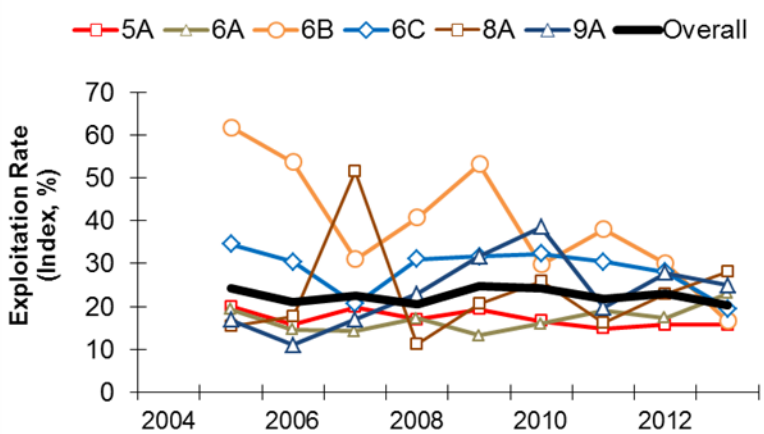

Figure 157: Exploitation rate indices by crab management area as well as overall for Div. 3L inshore based on the CPS trap survey.

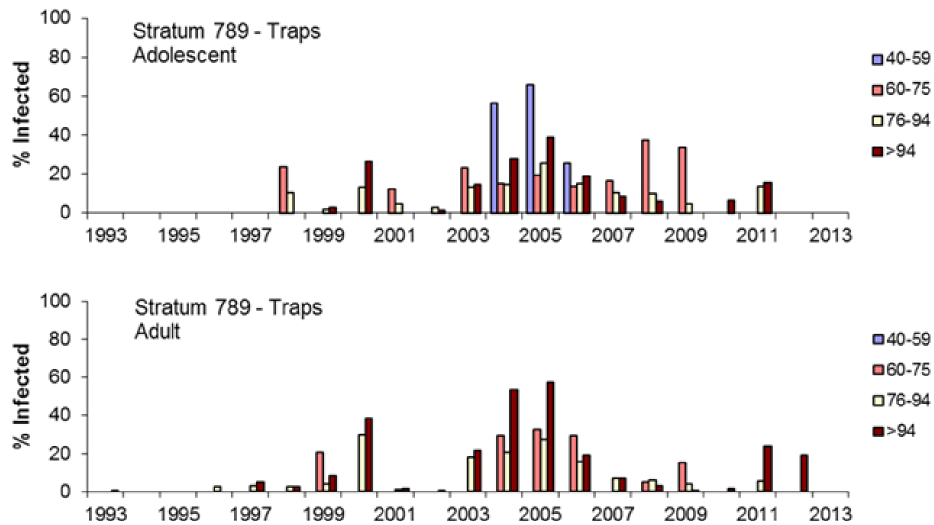

Fig. 158: Trends in prevalence of BCD in new-shelled males by year and size group in stratum 789 from DFO trap surveys in Conception Bay; adolescents (top) and adults (bottom).

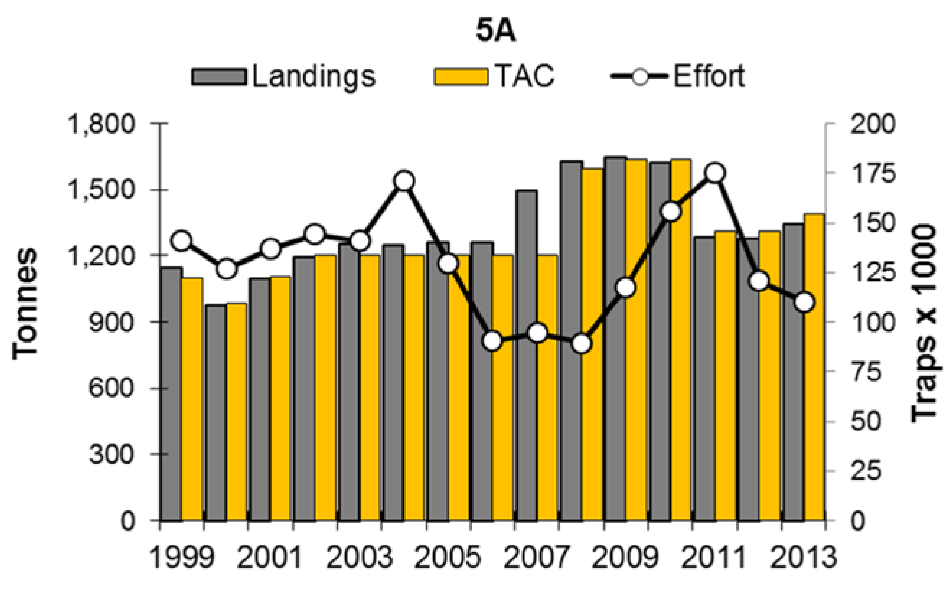

Figure 159: Trends in CMA 5A landings, TAC, and fishing effort. (2013 effort preliminary).

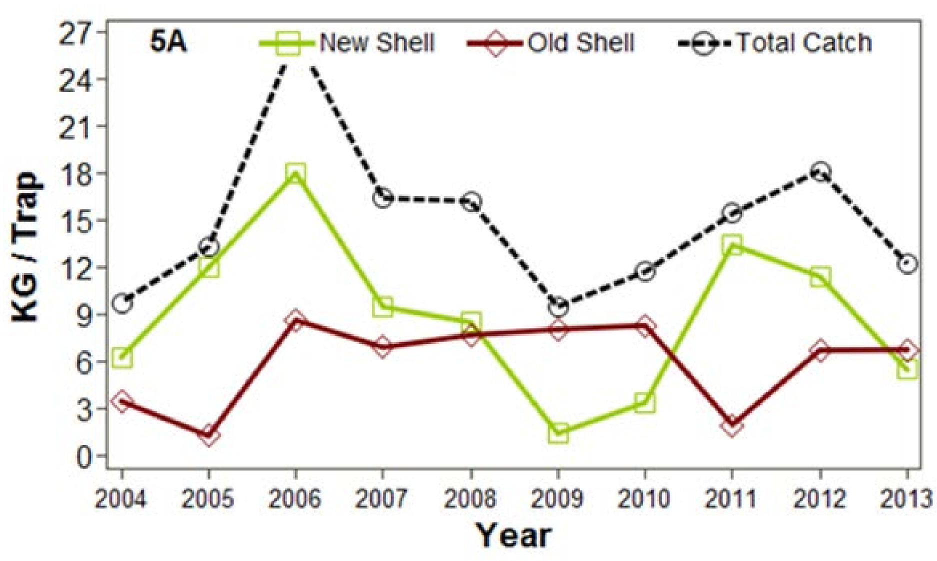

Figure 160: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 5A.

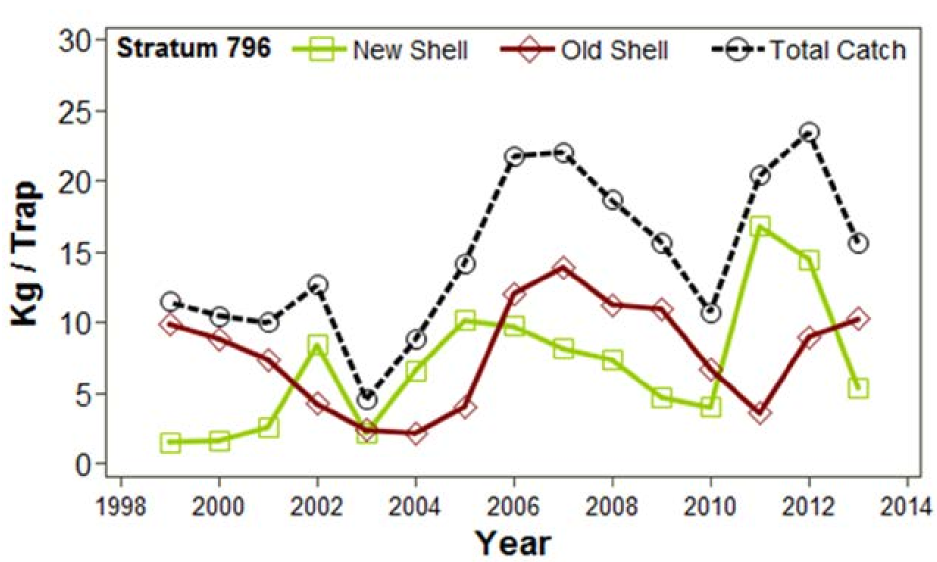

Figure 161: Trends in CPUE by shell condition for legal-sized crabs from the stratum occupied in the DFO trap survey in Bonavista Bay.

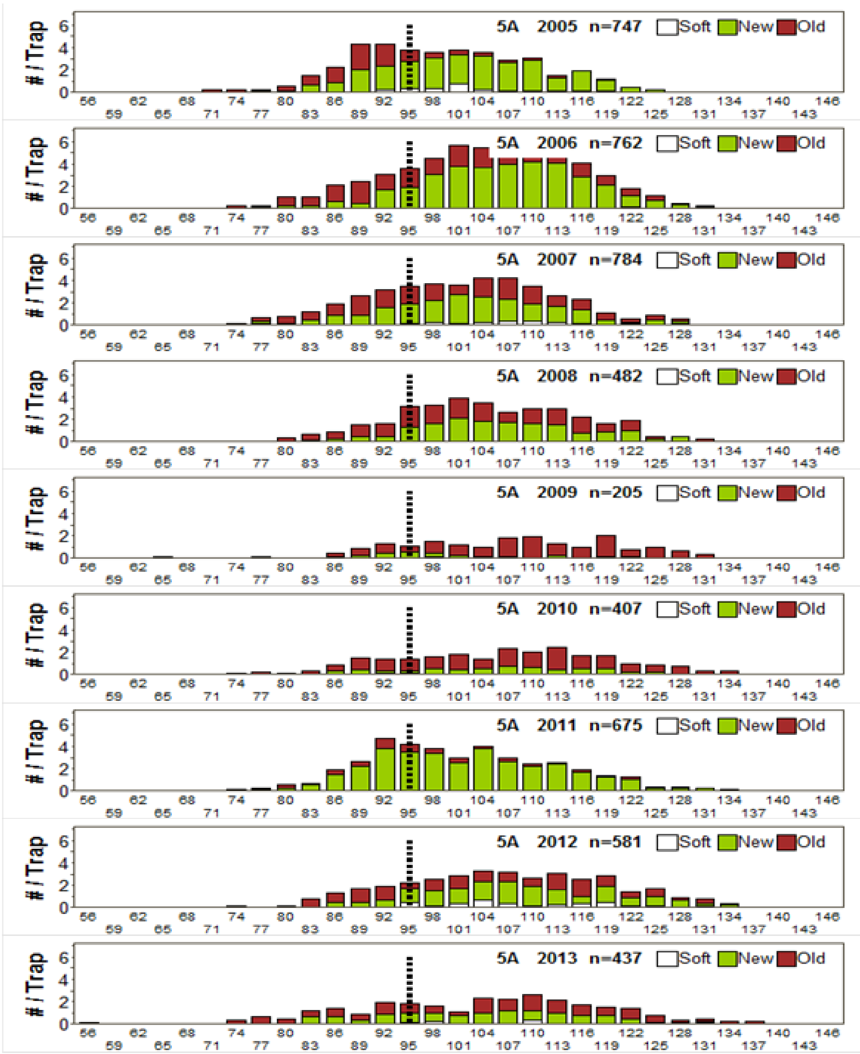

Figure 162: Trends in male carapace width distributions from large mesh traps at core stations in CMA 5A from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

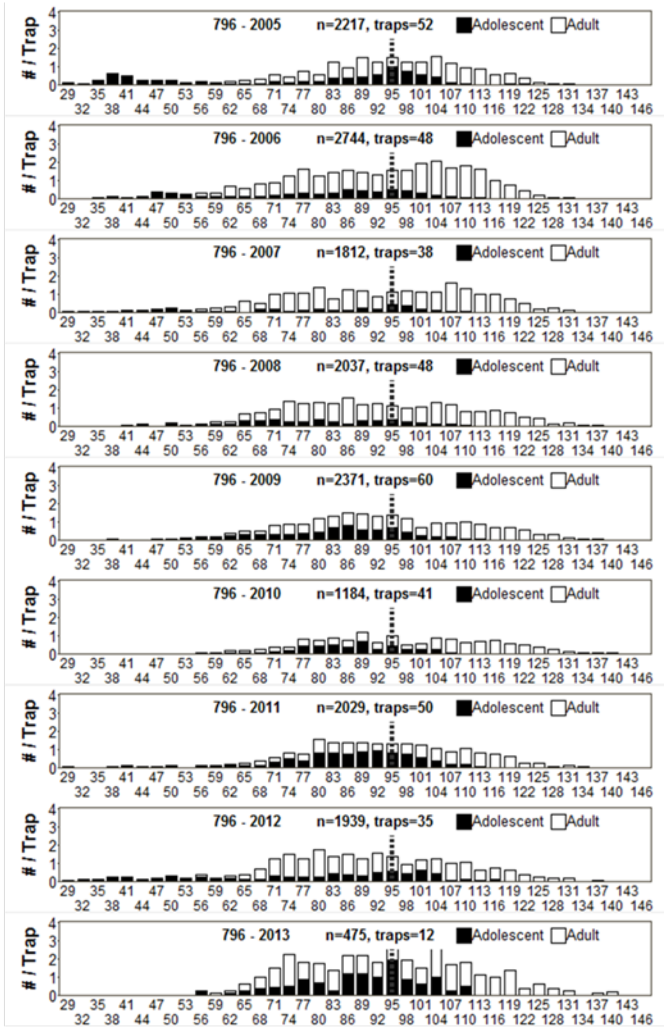

Figure 163: Small-claw (adolescent) vs. large-claw (adult) male catch rates by size from small-meshed traps in the DFO trap survey in Bonavista Bay. The vertical dashed line indicates the minimum legal size.

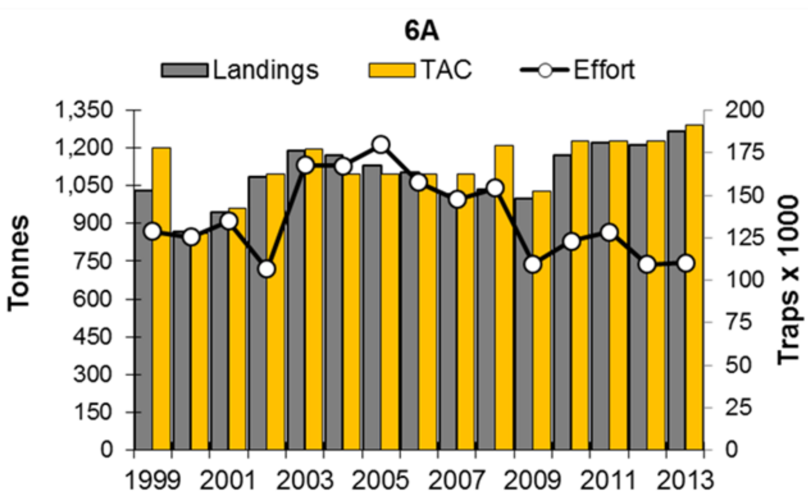

Figure 164: Trends in CMA 6A landings, TAC, and fishing effort. (2013 effort preliminary).

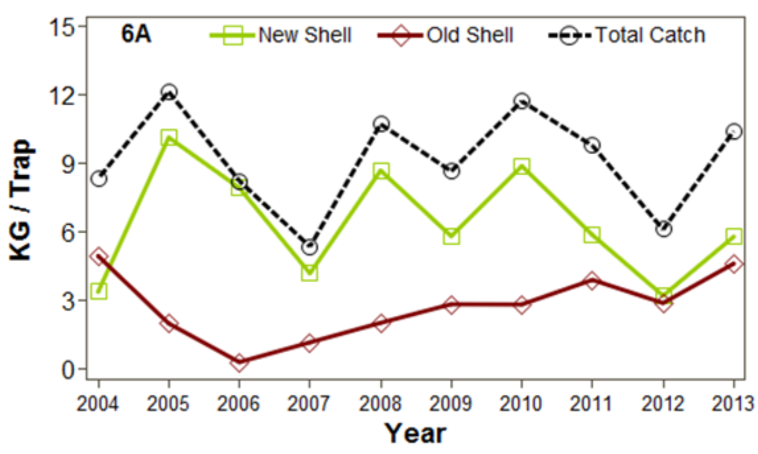

Figure 165: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 6A.

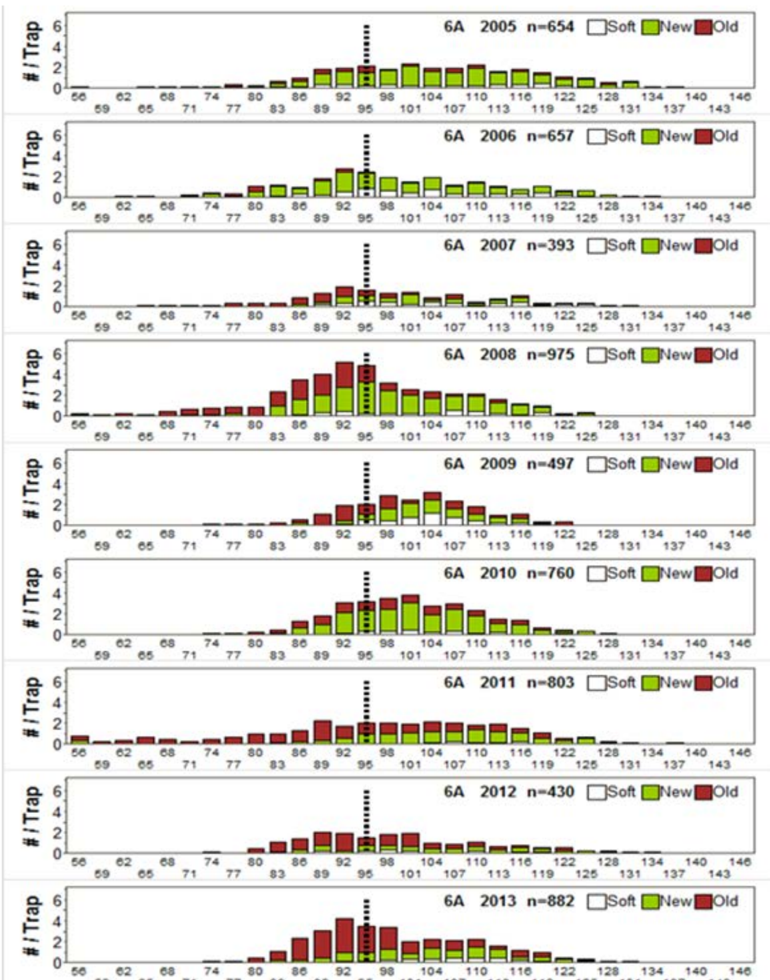

Figure 166: Trends in CPUE by shell condition for legal-sized crabs from large mesh traps at core stations in the CPS trap survey in CMA 6A. The vertical dashed line indicates the minimum legal size.

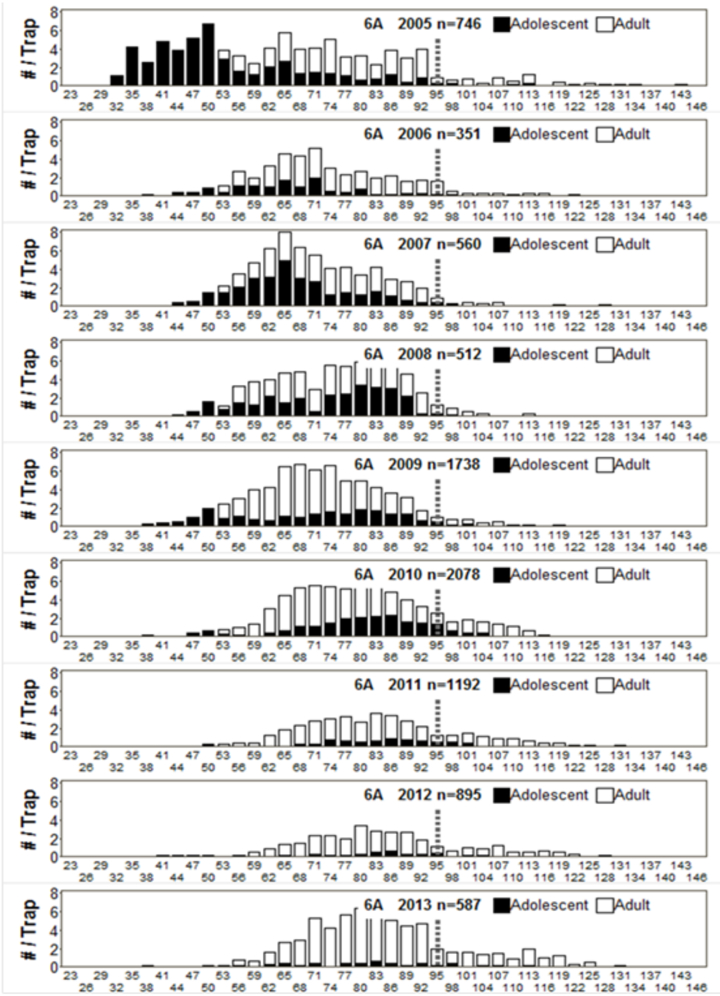

Figure 167: Trends in male carapace width distributions from small-mesh traps in CMA 6A from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

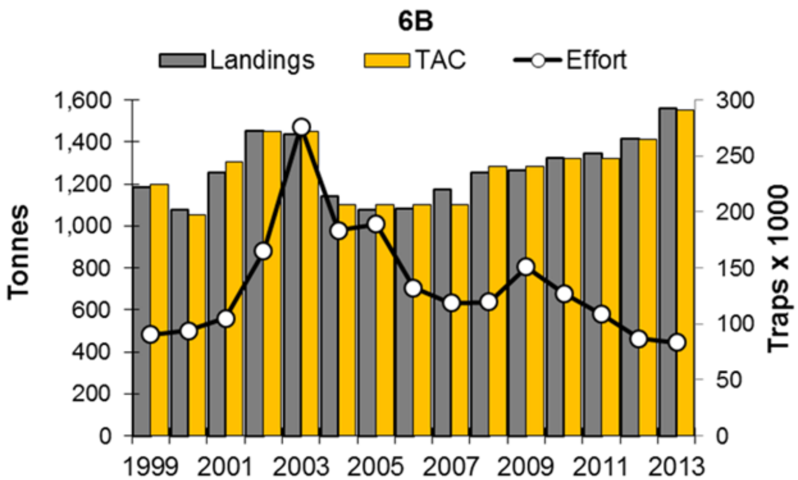

Figure 168: Trends in CMA 6B landings, TAC, and fishing effort. (2013 effort preliminary).

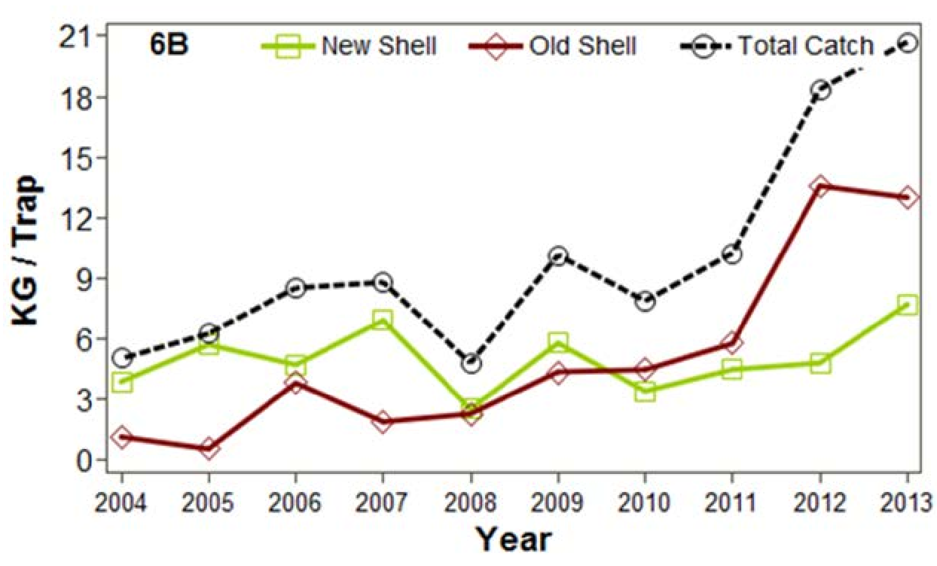

Figure 169: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 6B.

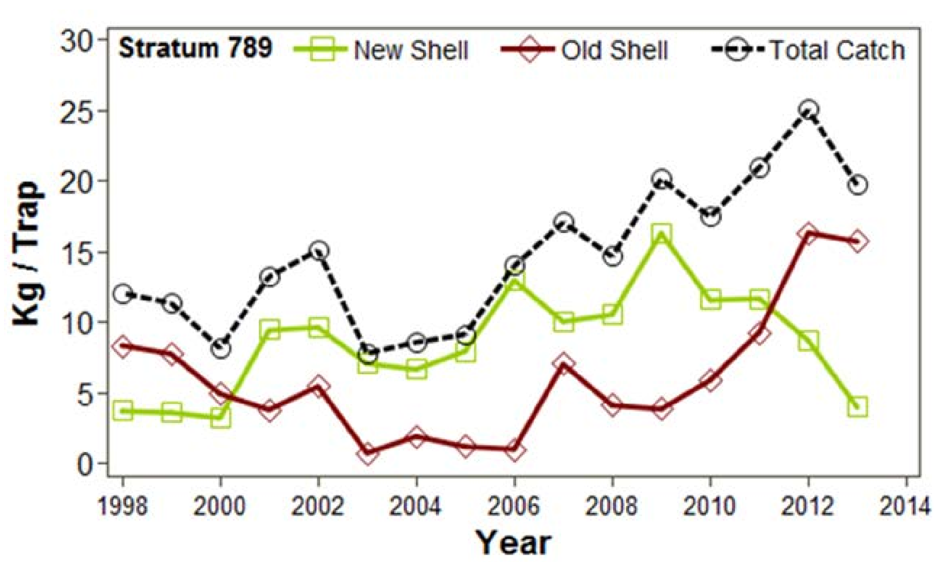

Figure 170: Trends in CPUE by shell condition for legal-sized crabs from the stratum occupied in the DFO trap survey in Conception Bay.

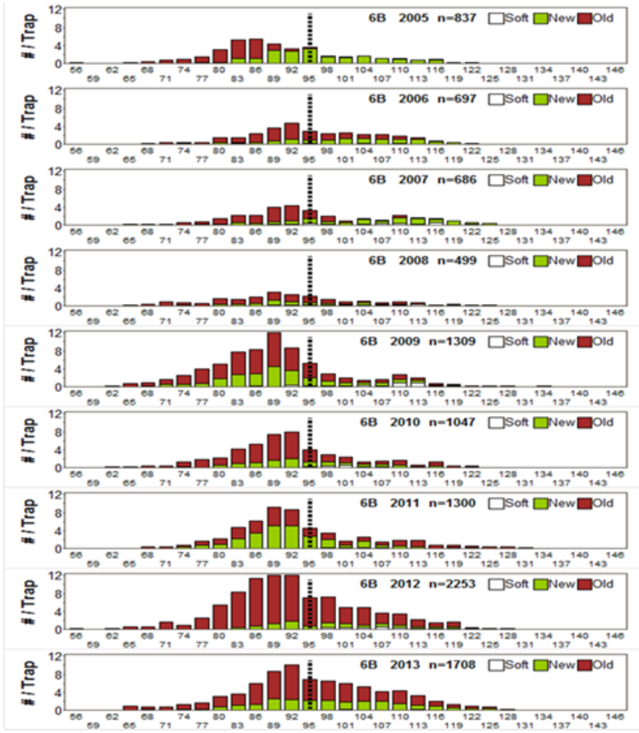

Figure 171: Trends in male carapace width distributions from large mesh traps at core stations in CMA 6B from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

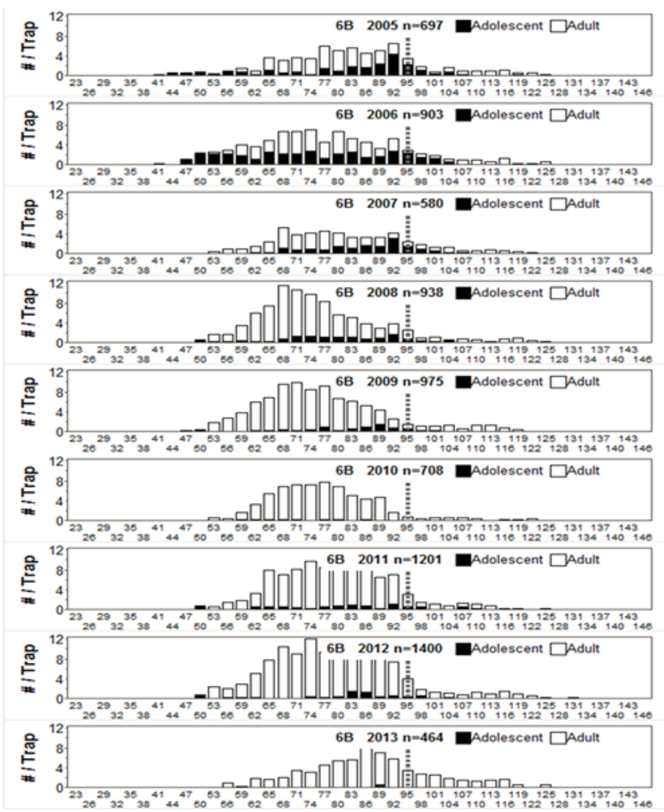

Figure 172: Trends in male carapace width distributions from small-mesh traps in CMA 6B from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

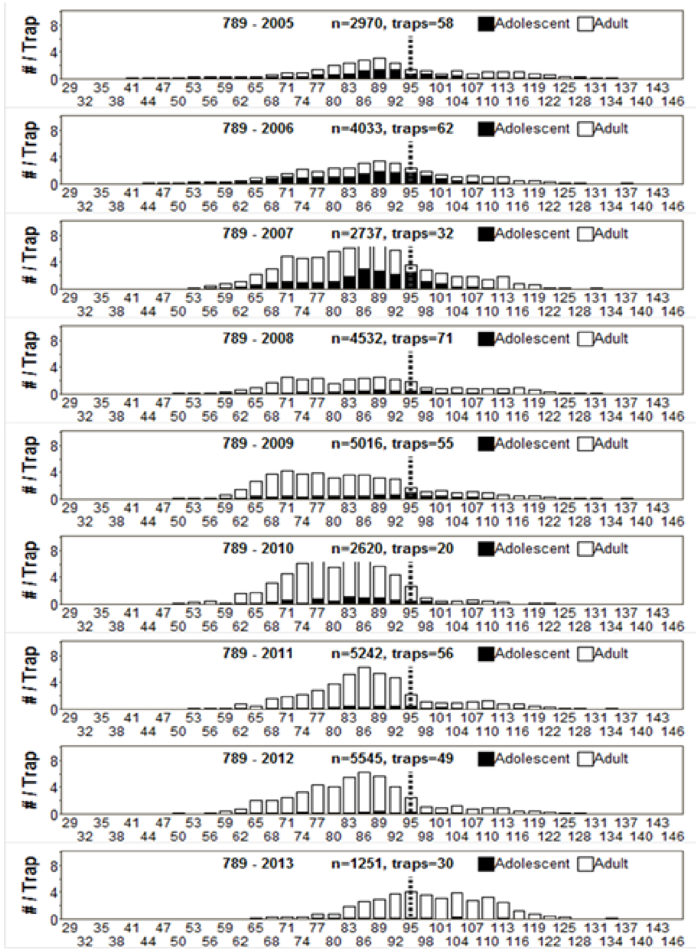

Figure 173: Small-claw (adolescent) vs. large-claw (adult) male catch rates by size from small-mesh traps in the DFO trap survey in Conception Bay.

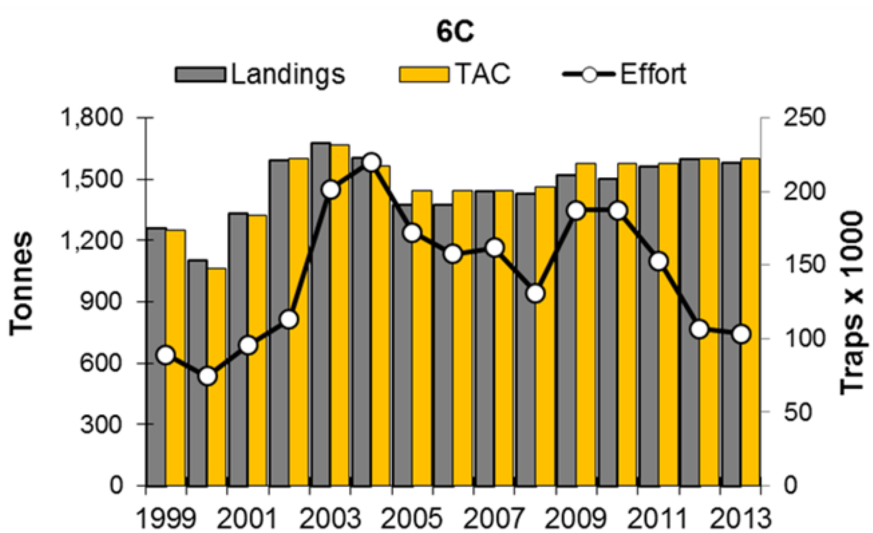

Figure 174: Trends in CMA 6C landings, TAC, and fishing effort. (2013 effort preliminary).

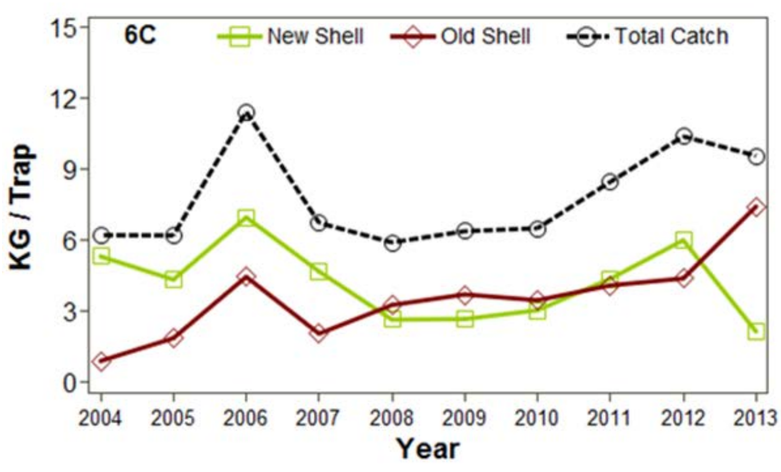

Figure 175: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 6C.

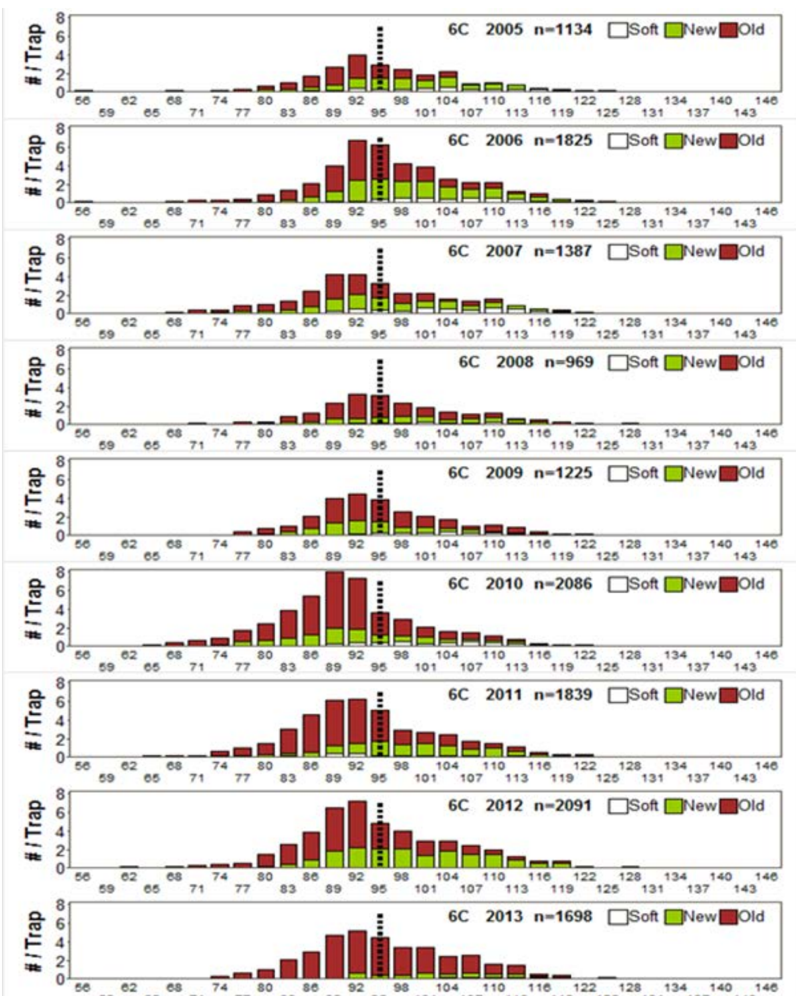

Figure 176: Trends in male carapace width distributions from large mesh traps at core stations in CMA 6C from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

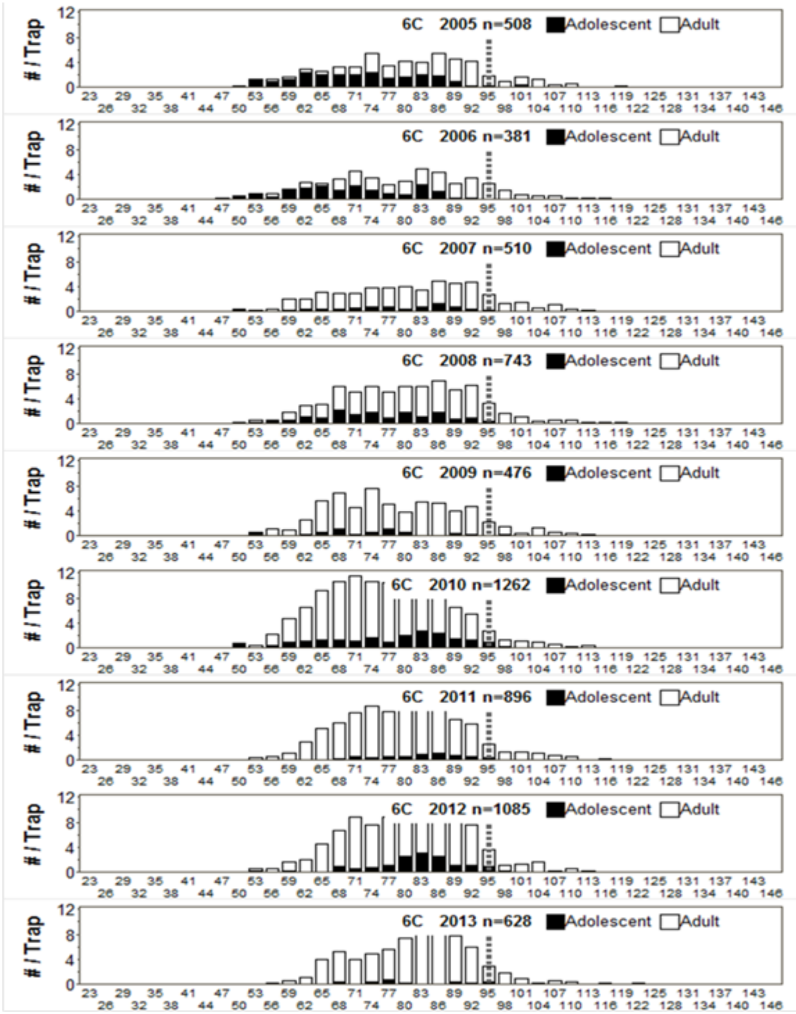

Figure 177: Trends in male carapace width distributions from small-mesh traps in CMA 6C from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

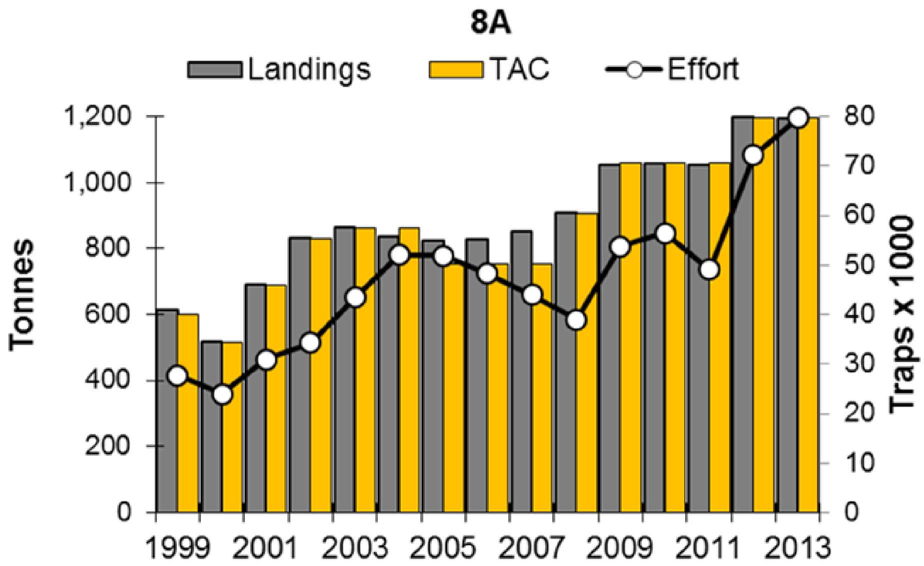

Figure 178: Trends in CMA 8A landings, TAC, and fishing effort. (2013 effort preliminary).

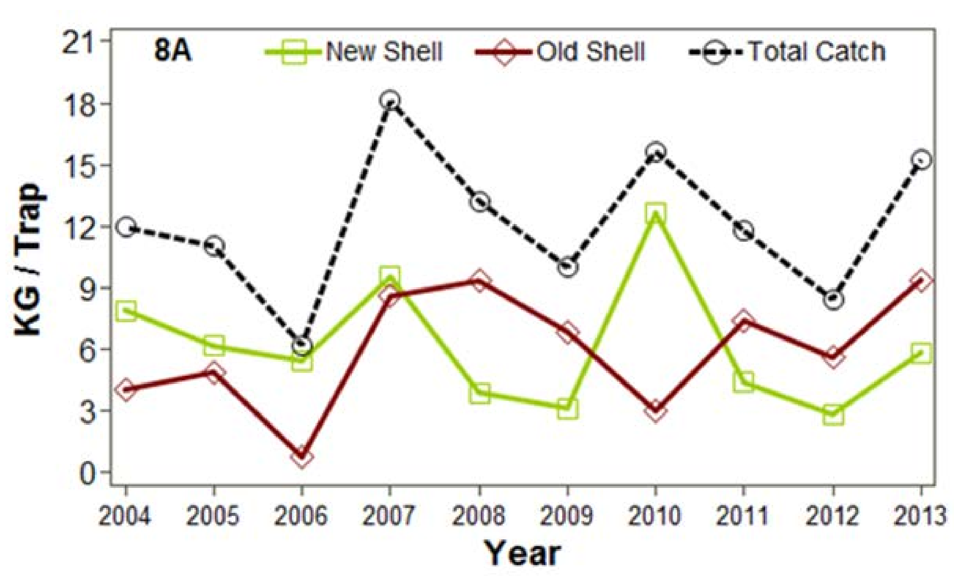

Figure 179: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 8A.

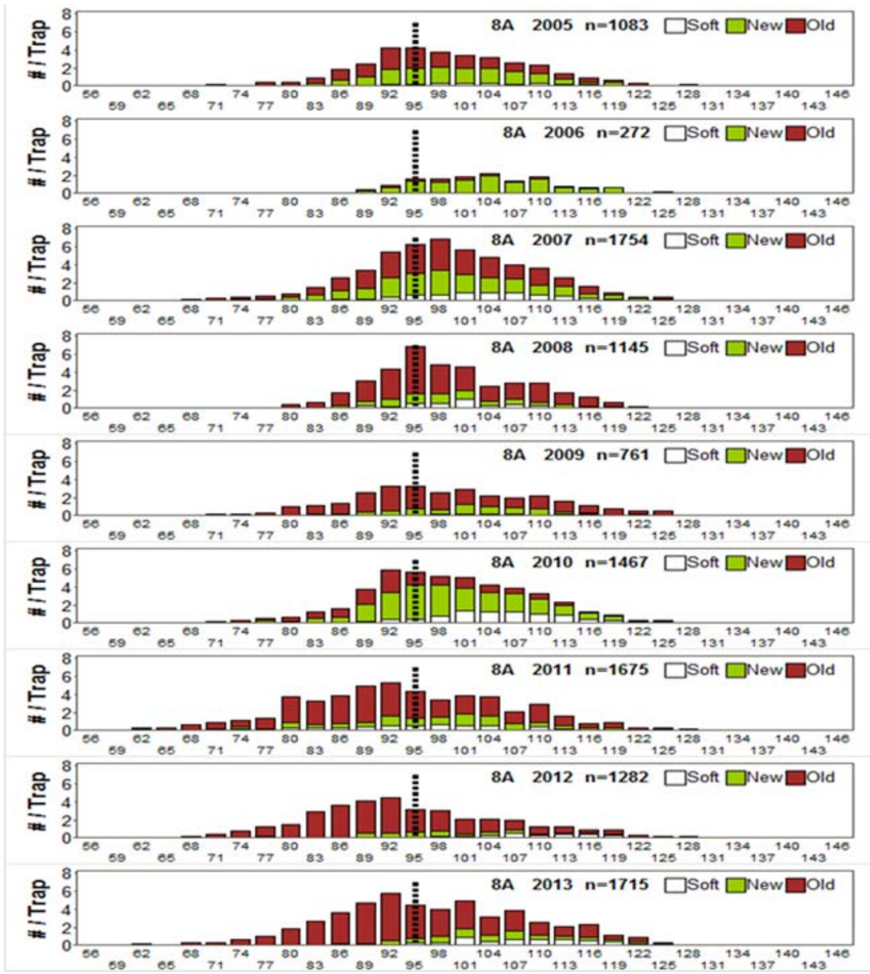

Figure 180: Trends in male carapace width distributions from large mesh traps at core stations in CMA 8A from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

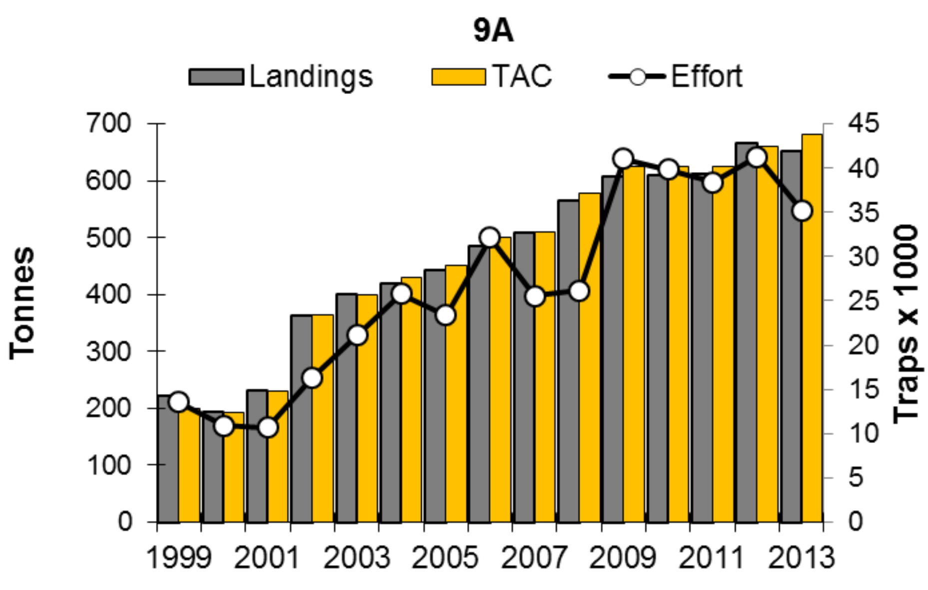

Figure 181: Trends in CMA 9A landings, TAC, and fishing effort. (2013 effort preliminary).

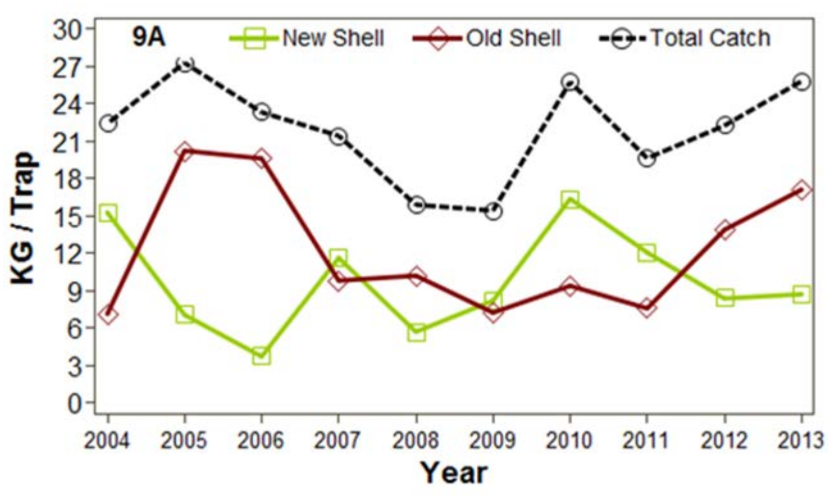

Figure 182: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 9A.

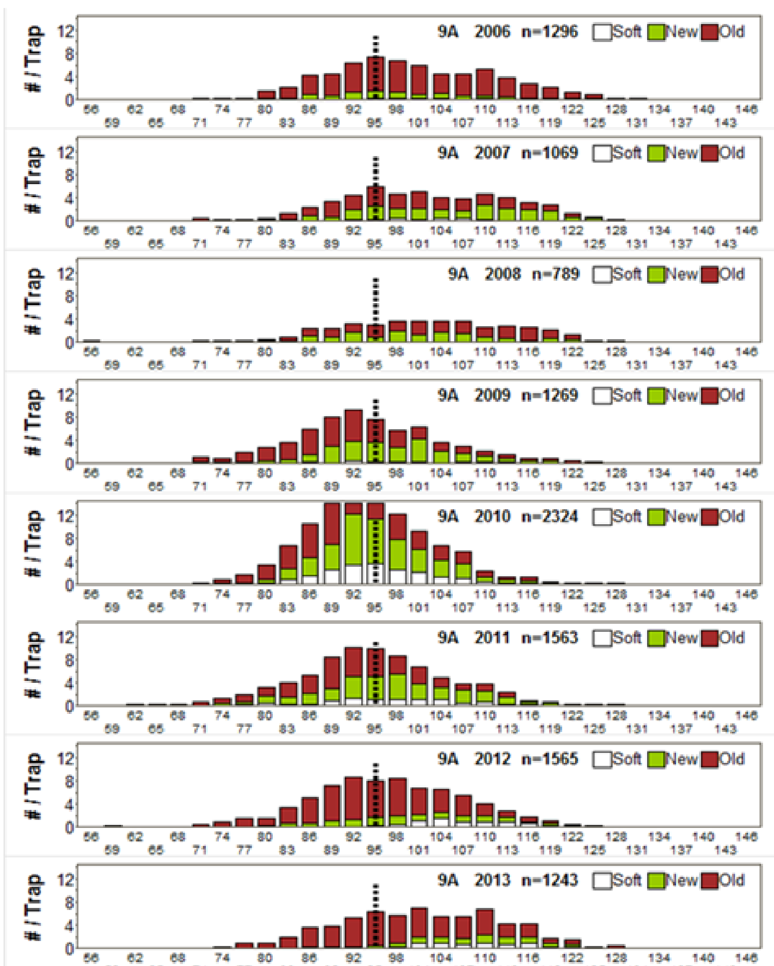

Figure 183: Trends in CPUE by shell condition for legal-sized crabs from large mesh traps at core stations in the CPS trap survey in CMA 9A.

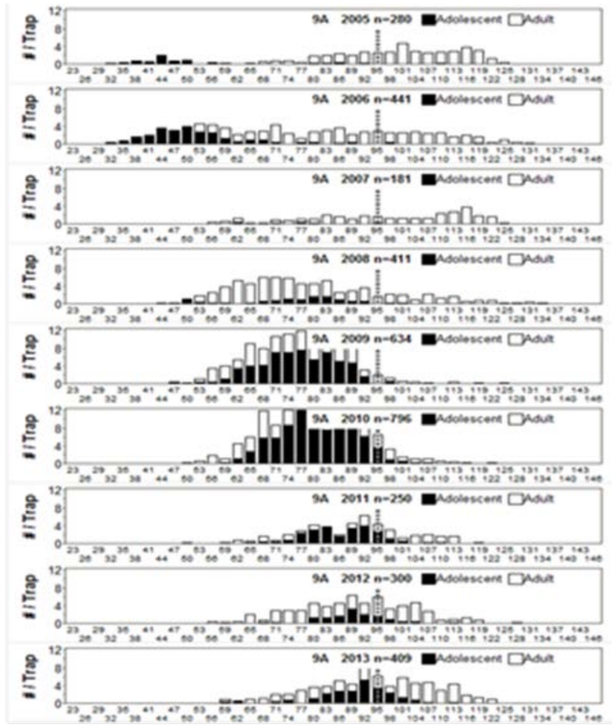

Figure 184: Trends in male carapace width distributions from small-mesh traps in CMA 9A from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

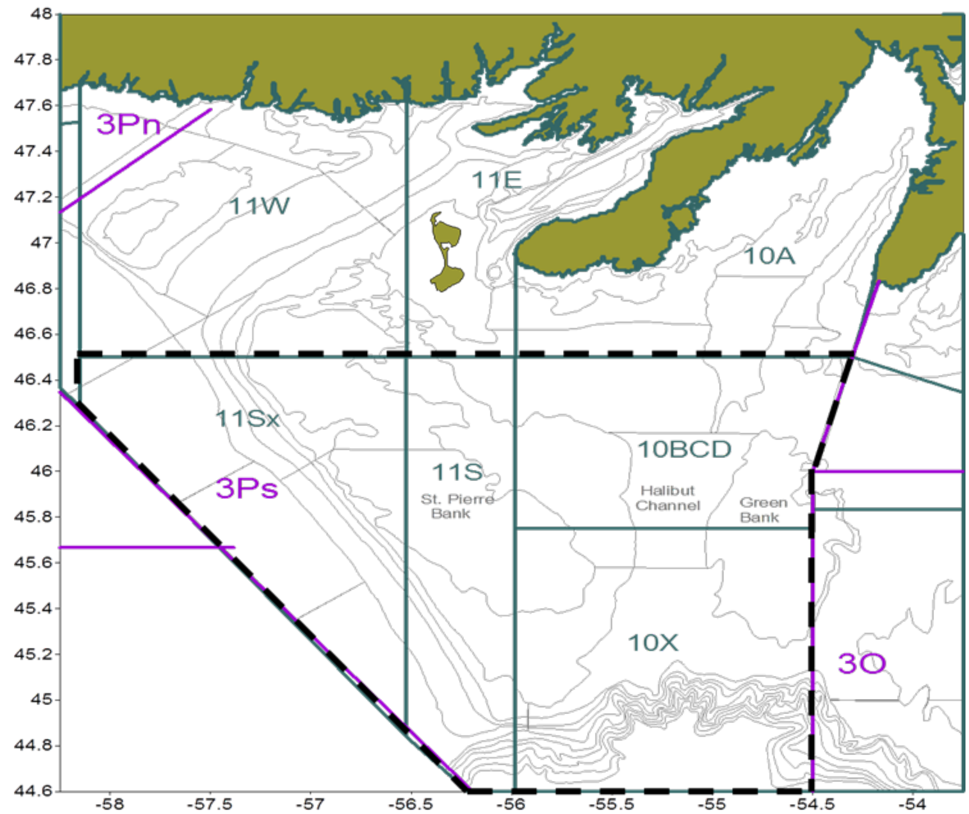

Figure 185: Map of Subdivision 3Ps showing crab management areas and important bathymetric features. Dashed perimeter indicates offshore areas.

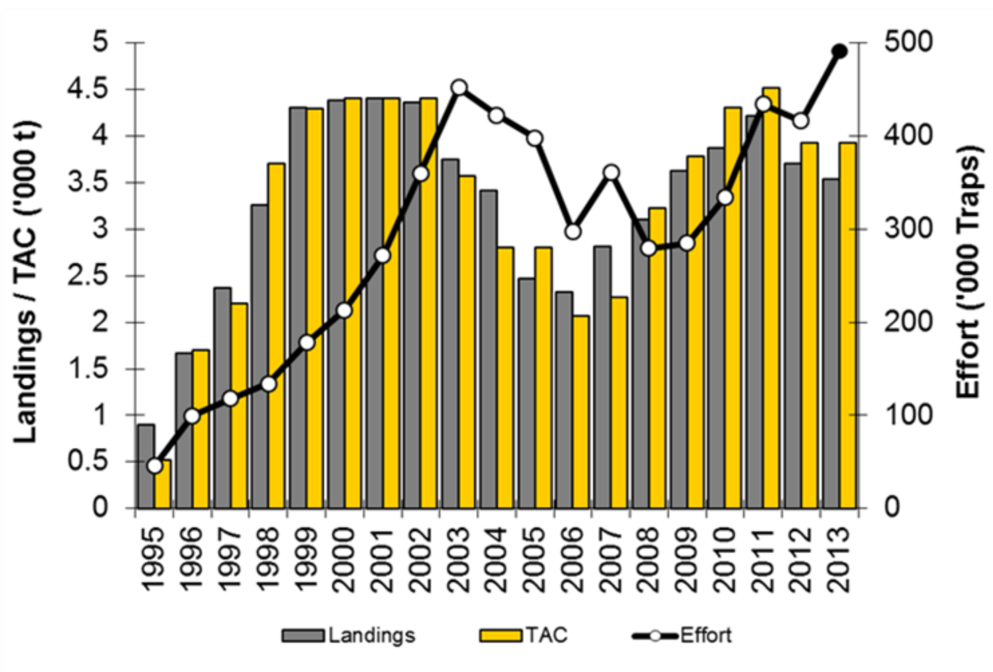

Figure 186: Trends in Subdiv. 3Ps offshore landings, TAC, and fishing effort. (2013 effort preliminary).

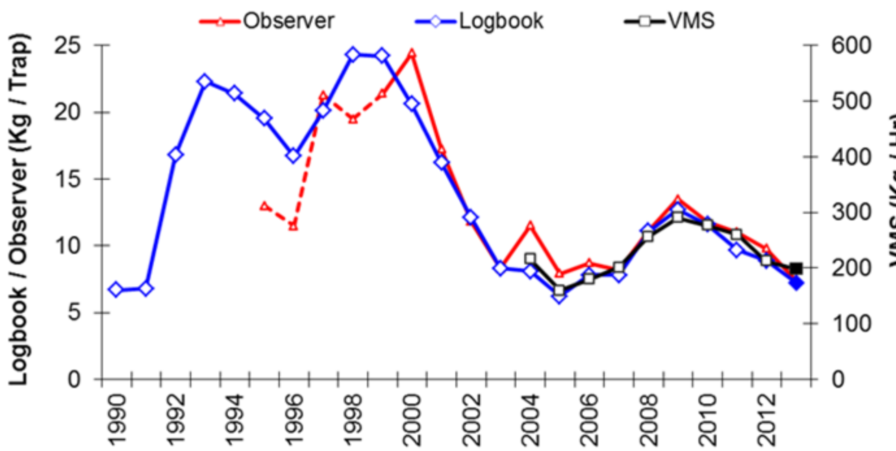

Figure 187: Trends in commercial logbook-based, observer-based, and VMS-based CPUE in the Subdiv. 3Ps offshore fishery. (2013 logbook and VMS CPUE estimates preliminary).

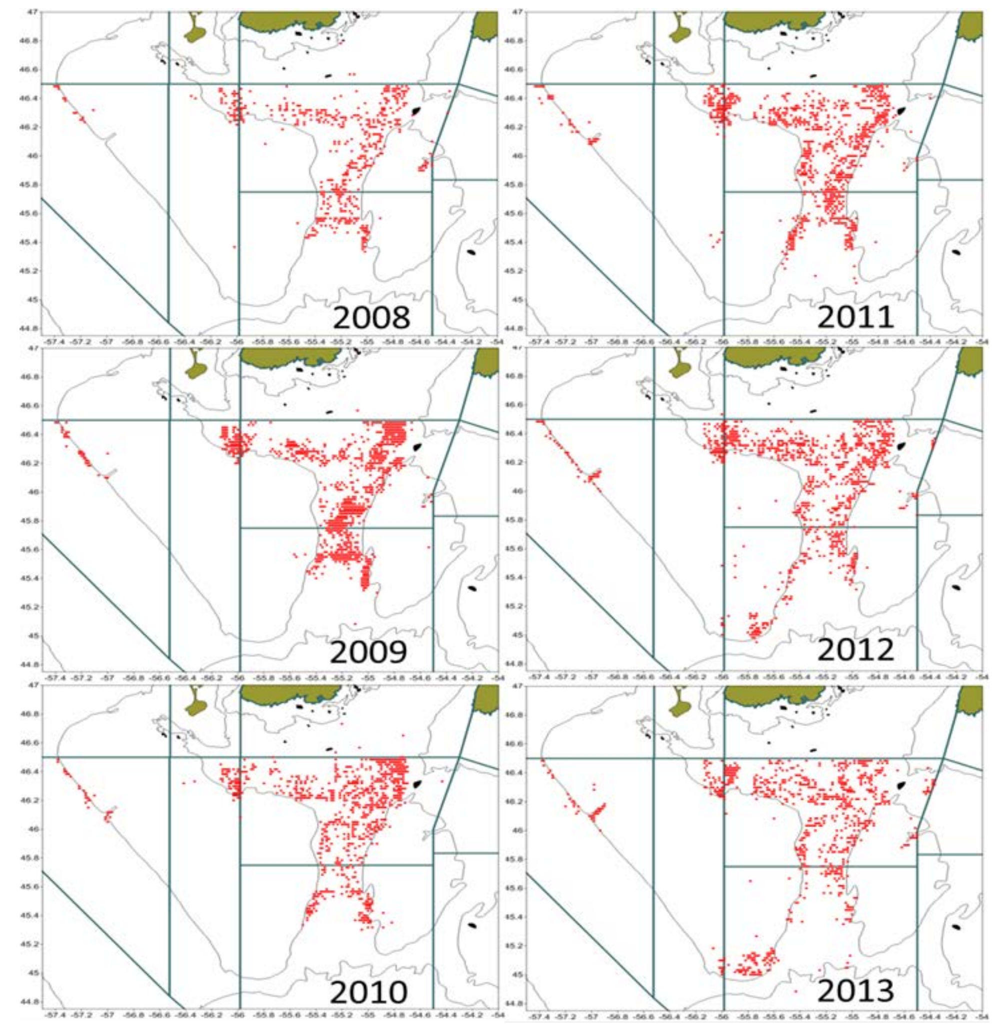

Figure 188: Spatial distribution of Subdiv. 3Ps fishing effort by year.

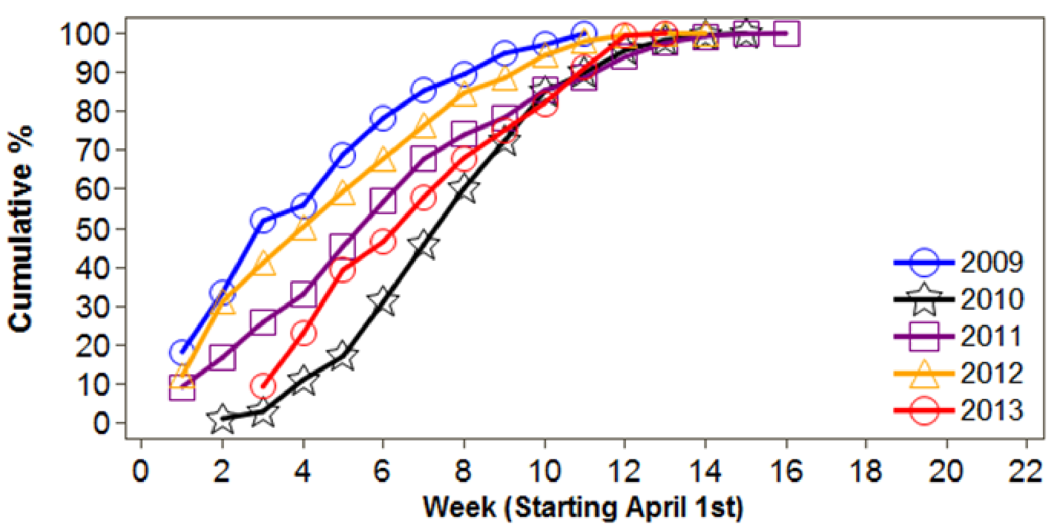

Figure 189: Seasonal trends in fishing effort for Subdiv. 3Ps offshore.

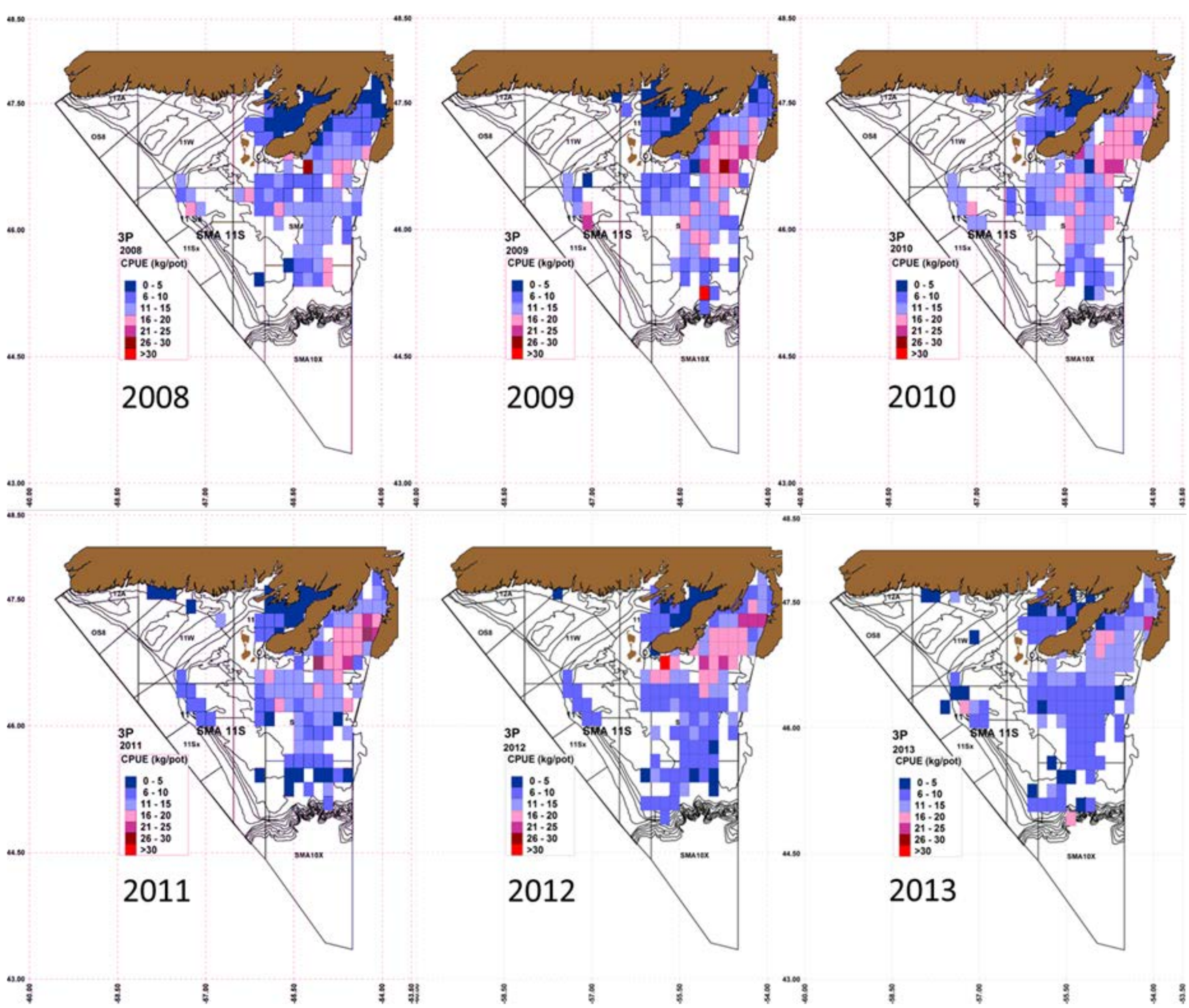

Figure 190: Spatial distribution of Subdiv. 3Ps offshore logbook CPUE by year.

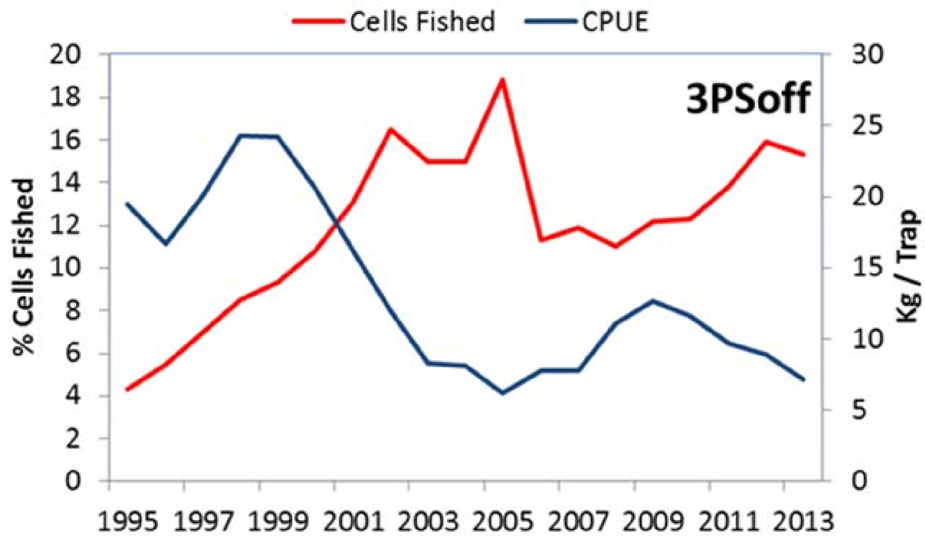

Figure 191: Trends in Subdiv. 3Ps offshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

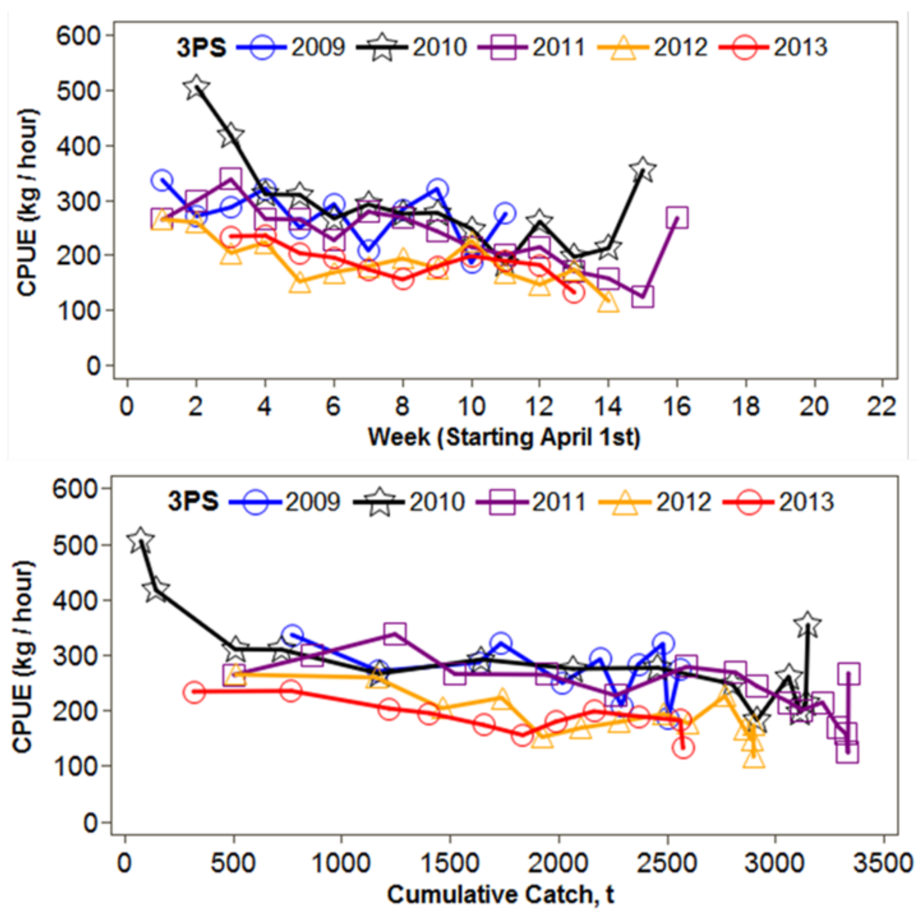

Figure 192: Seasonal trends in VMS-based CPUE for Subdiv. 3Ps offshore; by week (top), and in relation to cumulative catch (bottom).

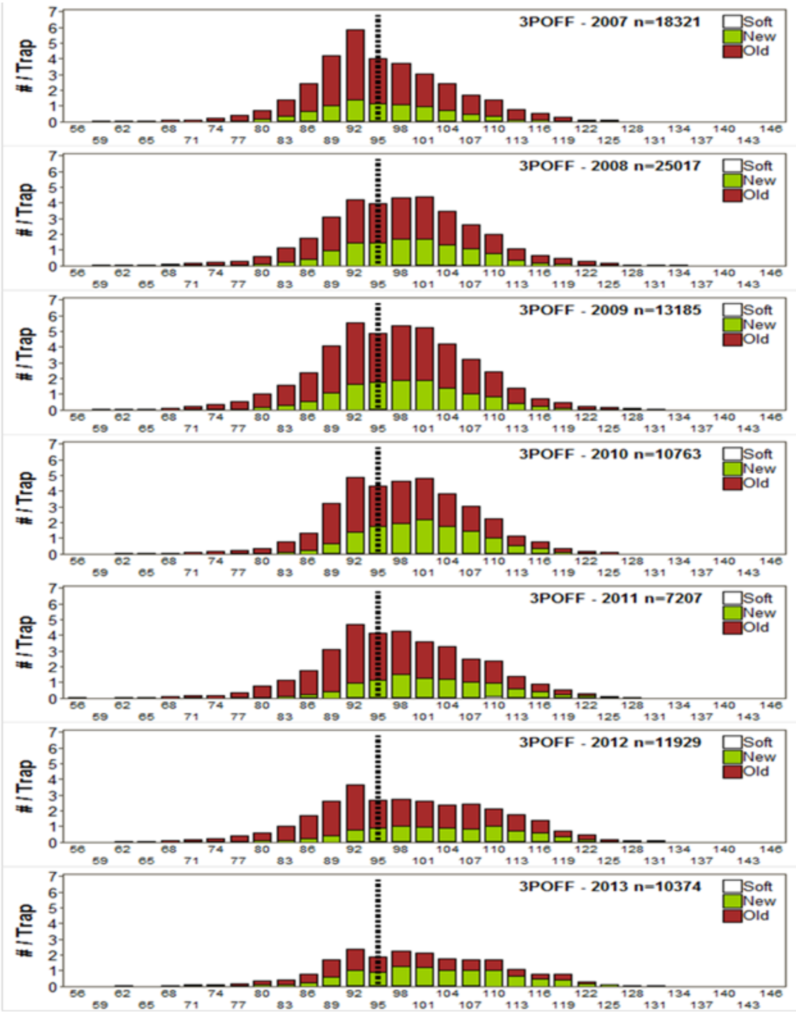

Figure 193: Trends in male carapace width distributions by shell condition from observer at-sea sampling for Subdiv. 3Ps offshore. The vertical dashed line indicates the minimum legal size.

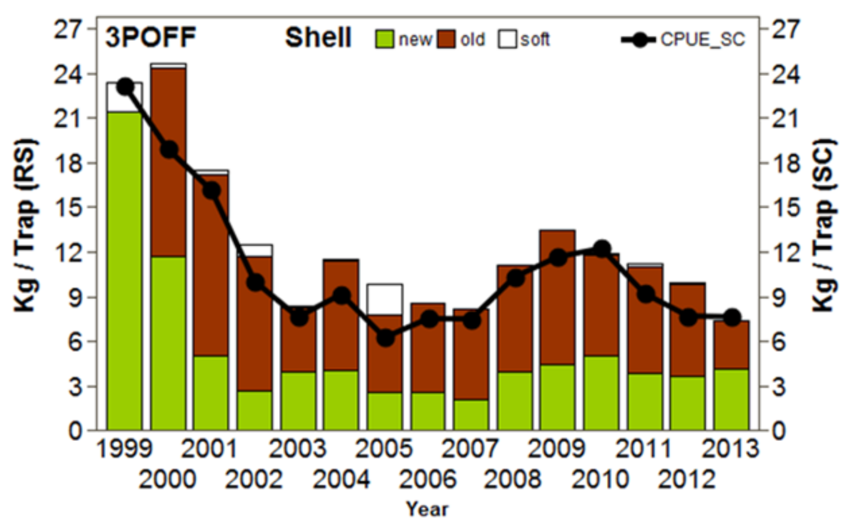

Figure 194: Trends in Subdiv. 3Ps offshore observer catch rates of exploitable crabs by shell condition from at-sea sampling.

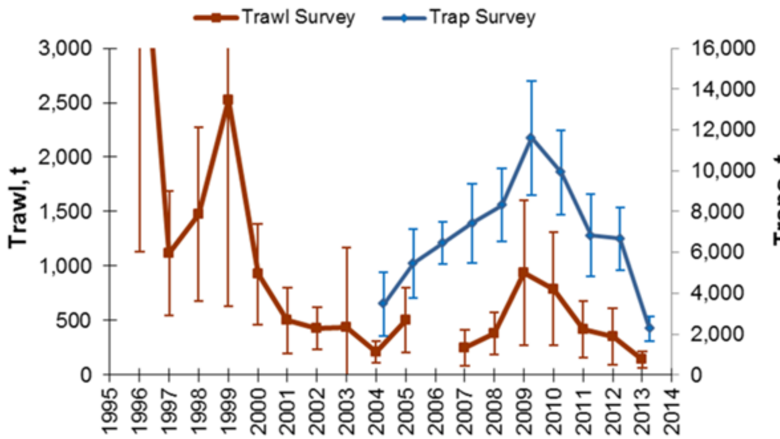

Figure 195: Trends in the Subdiv. 3Ps offshore spring trawl survey exploitable biomass index and the CPS trap survey biomass index. The trawl survey was incomplete in 2006.

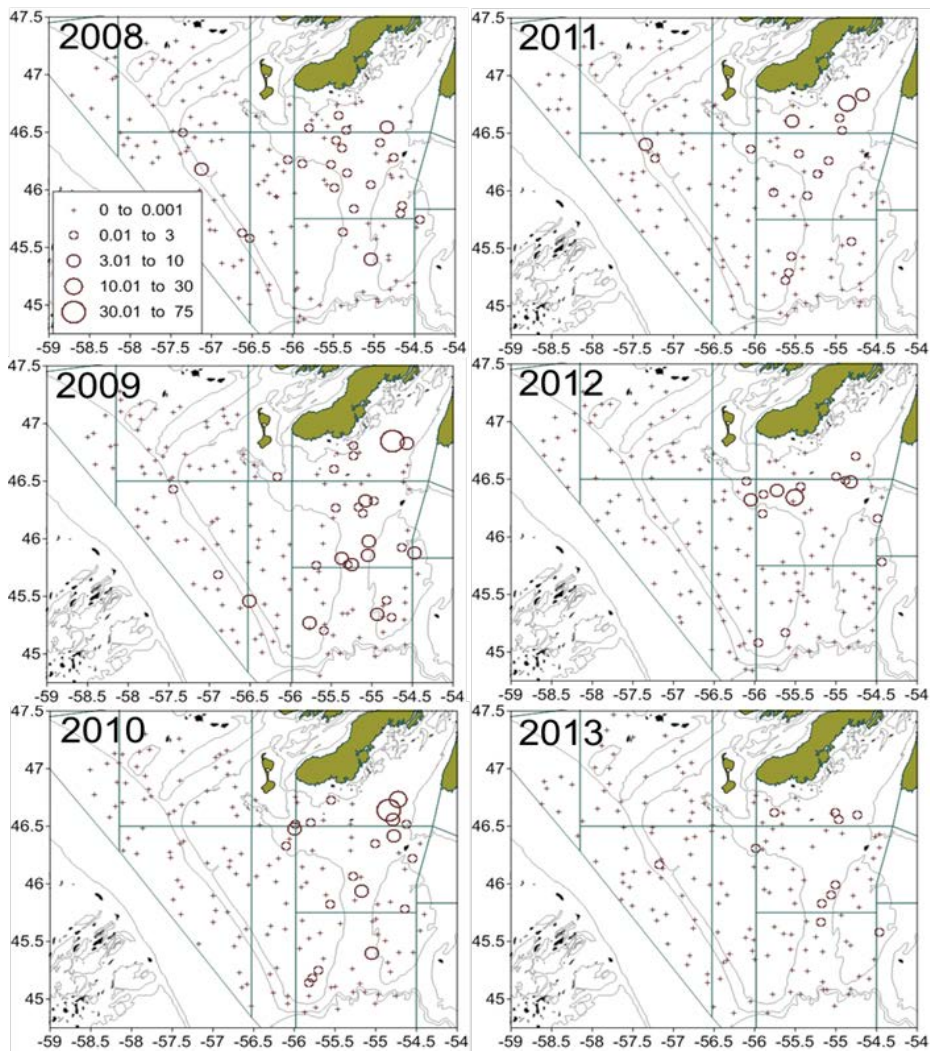

Figure 196: Spatial distribution of catches (number/set) of exploitable crab in the Subdiv. 3Ps offshore trawl survey.

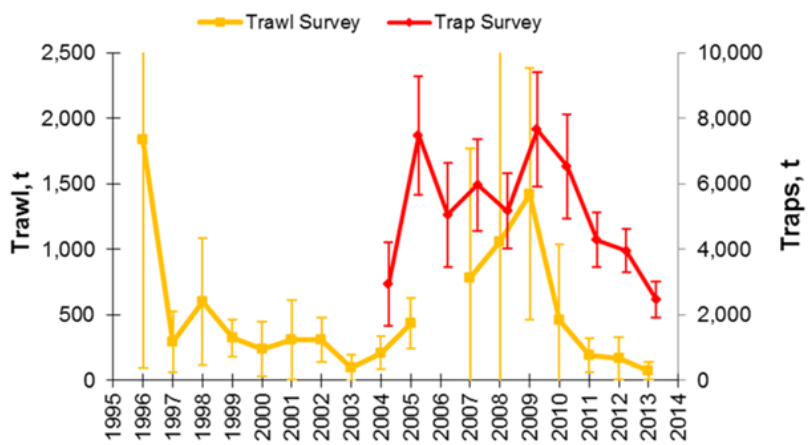

Figure 197: Trends in the Subdiv. 3Ps offshore spring trawl survey pre-recruit biomass index and the CPS trap survey biomass index. The trawl survey was incomplete in 2006.

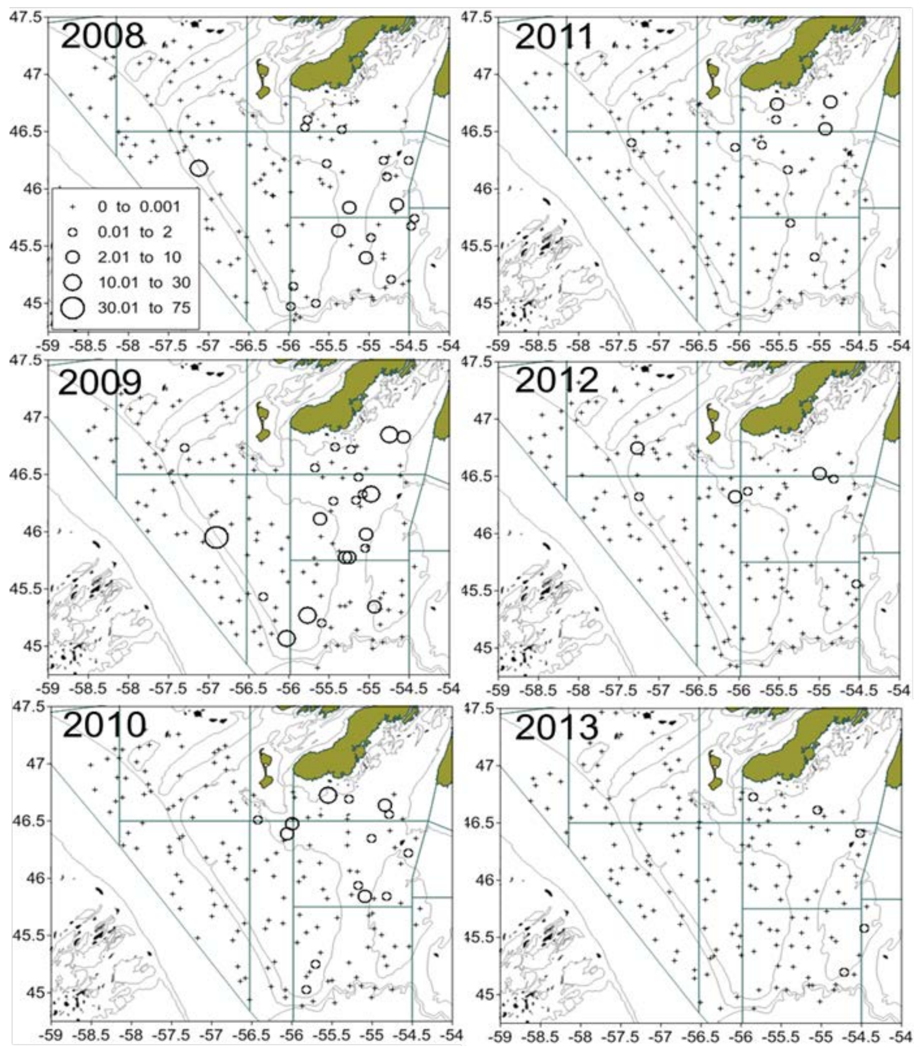

Figure 198: Spatial distribution of catches (number/set) of pre-recruit crab in the Subdiv. 3Ps offshore trawl survey.

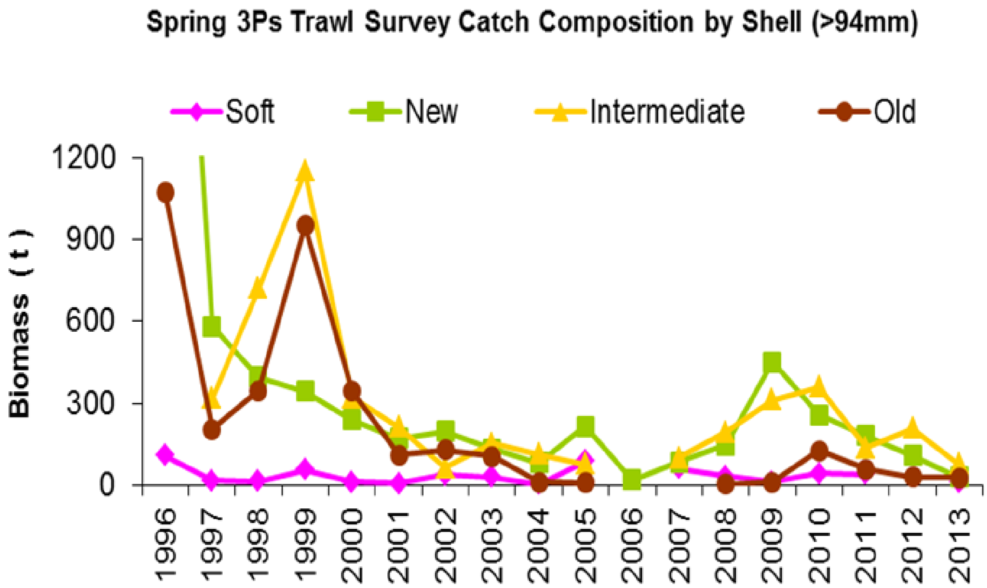

Figure 199: Trends, by shell condition, in legal-sized males for Subdiv. 3Ps offshore from spring trawl surveys.

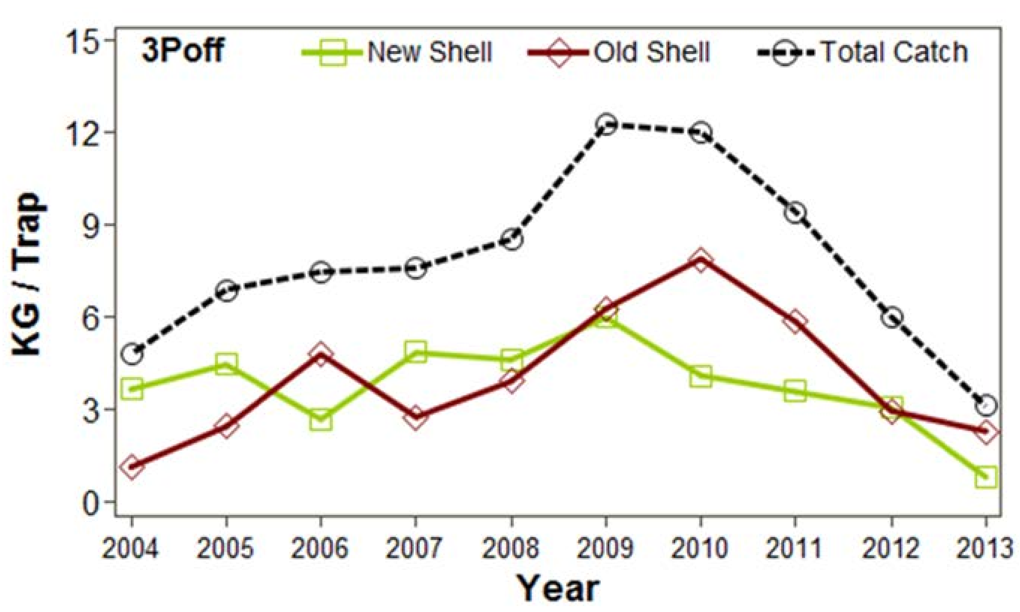

Figure 200: Trends in CPUE by shell condition for legal-sized crabs from core stations in the Subdiv. 3Ps offshore CPS trap survey.

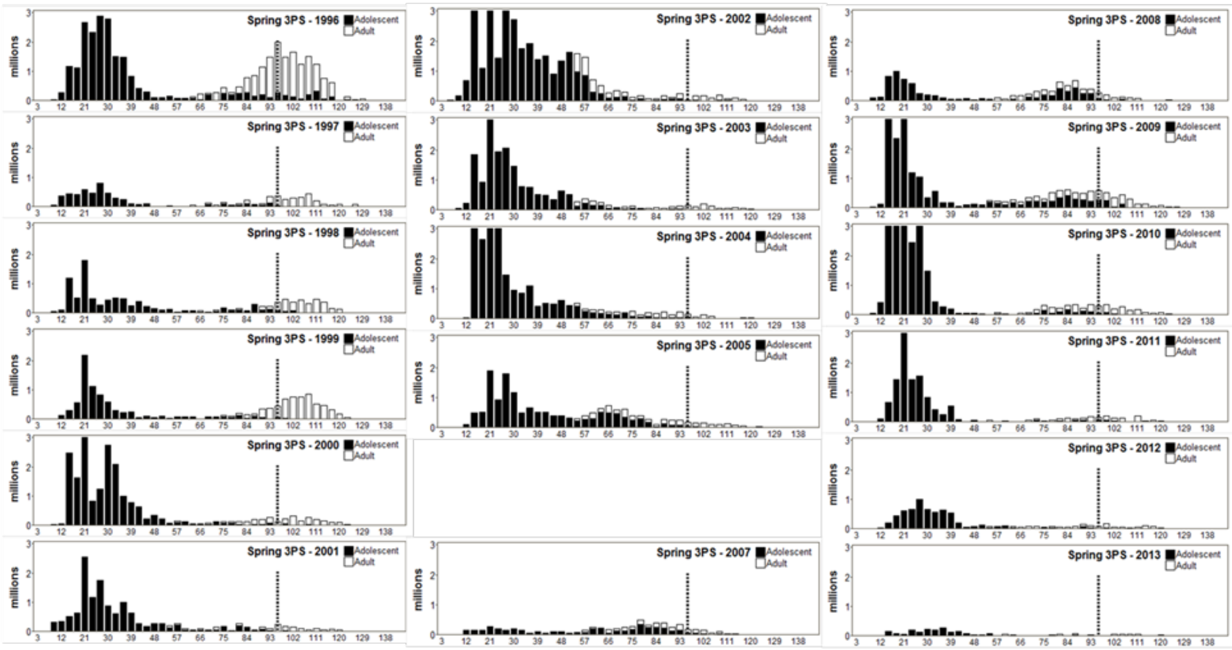

Figure 201: Abundance indices by carapace width for Subdiv. 3Ps juveniles plus adolescents (dark bars) versus adults (open bars) from spring trawl surveys.

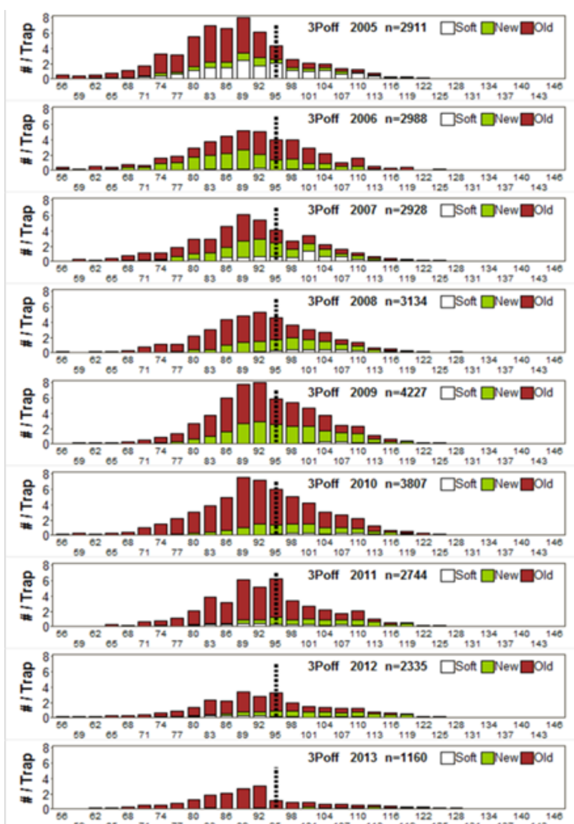

Figure 202: Trends in male carapace width distributions from large mesh traps at core stations in the Subdiv. 3Ps offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

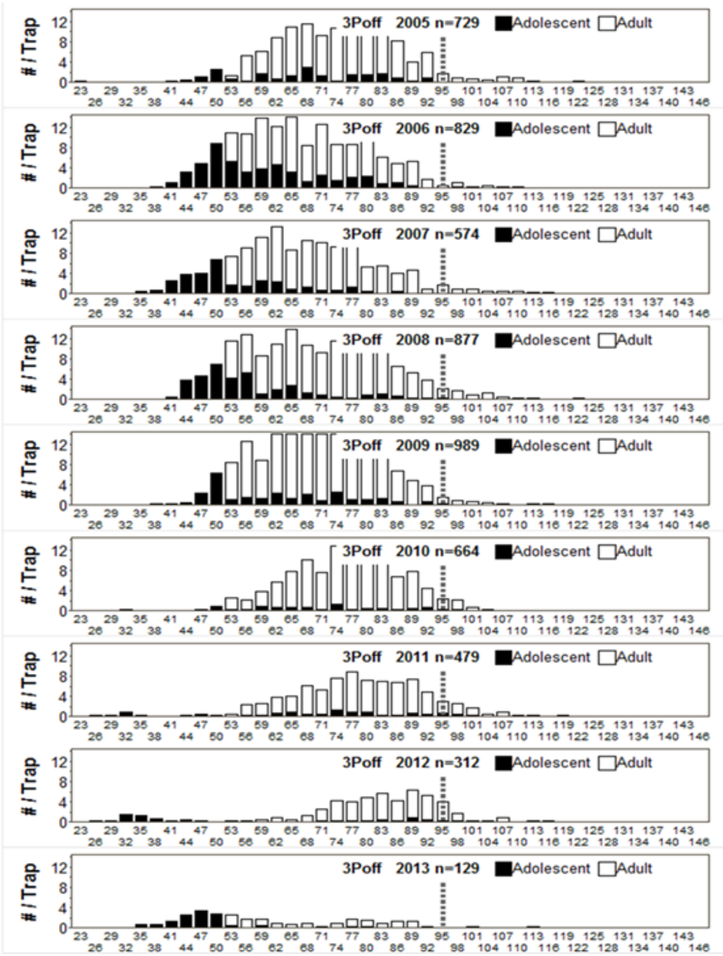

Figure 203: Trends in male carapace width distributions from small-mesh traps in the Subdiv. 3Ps offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

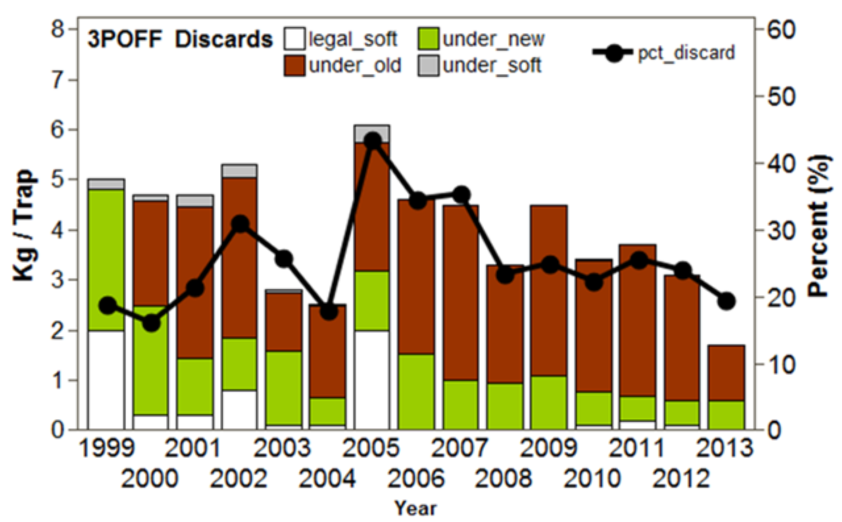

Figure 204: Trends in Subdiv. 3Ps offshore observer catch rates of total discards, under-sized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded.

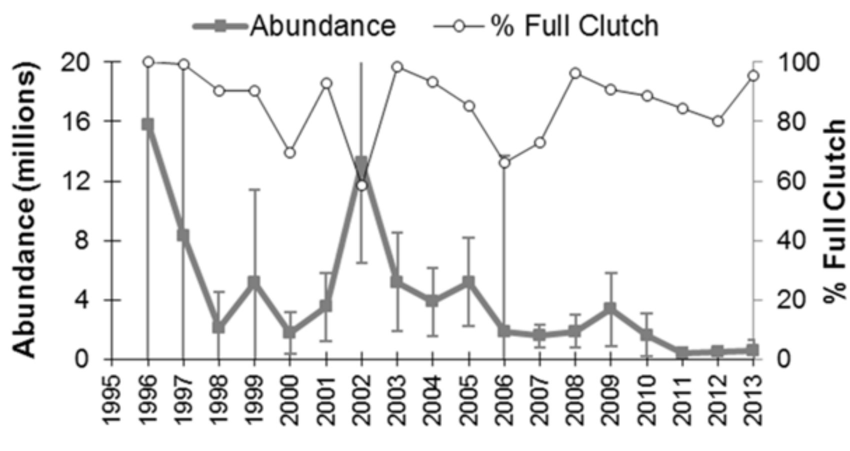

Figure 205: Trends in percent of mature females as well as the percentage of mature females bearing full clutches of viable eggs in Subdiv. 3Ps from spring multi-species surveys.

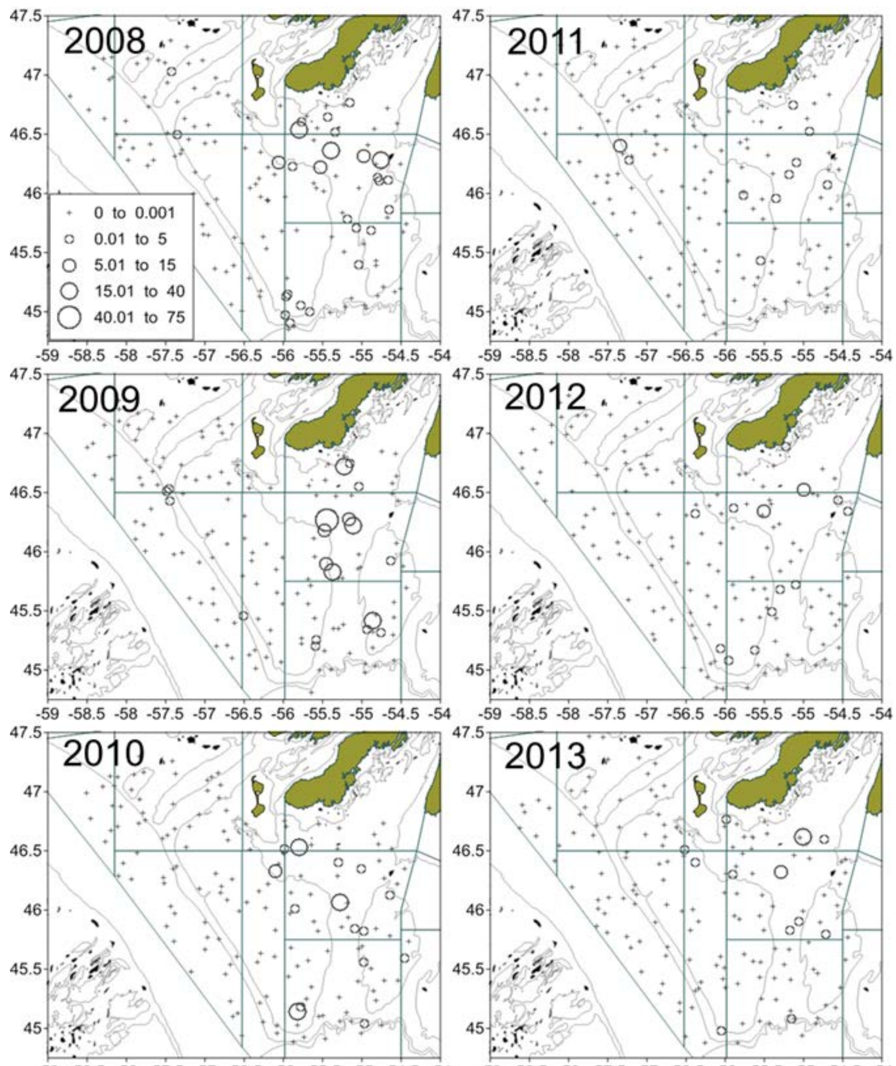

Figure 206: Spatial distribution of catches (number/set) of mature females in the Subdiv. 3Ps offshore trawl survey.

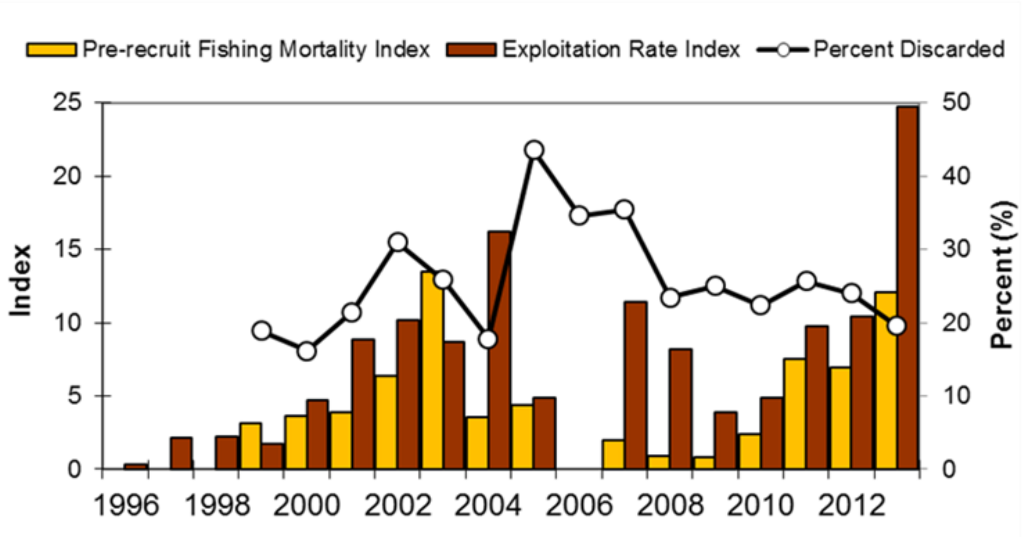

Figure 207: Trends in Subdiv. 3Ps offshore mortality indices (the exploitation rate index and the pre-recruit fishing mortality index) and in the percentage of the catch discarded in the fishery. (No 2006 exploitation rate or pre-recruit fishing mortality indices because of an incomplete 2006 survey).

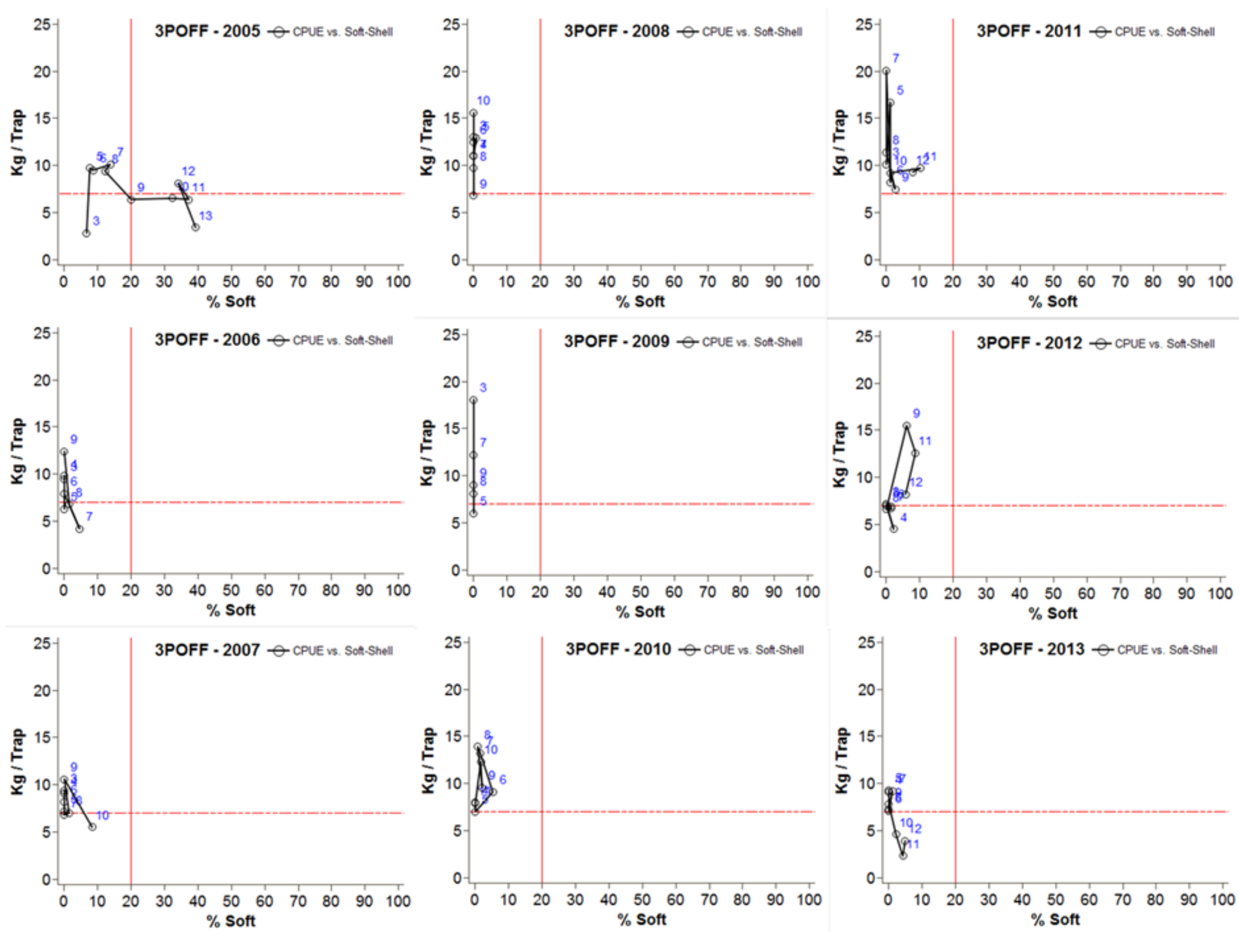

Figure 208: Trends in weekly percentages of kept vs. soft-shell crab in Subdiv. 3Ps offshore from at-sea sampling by observers.

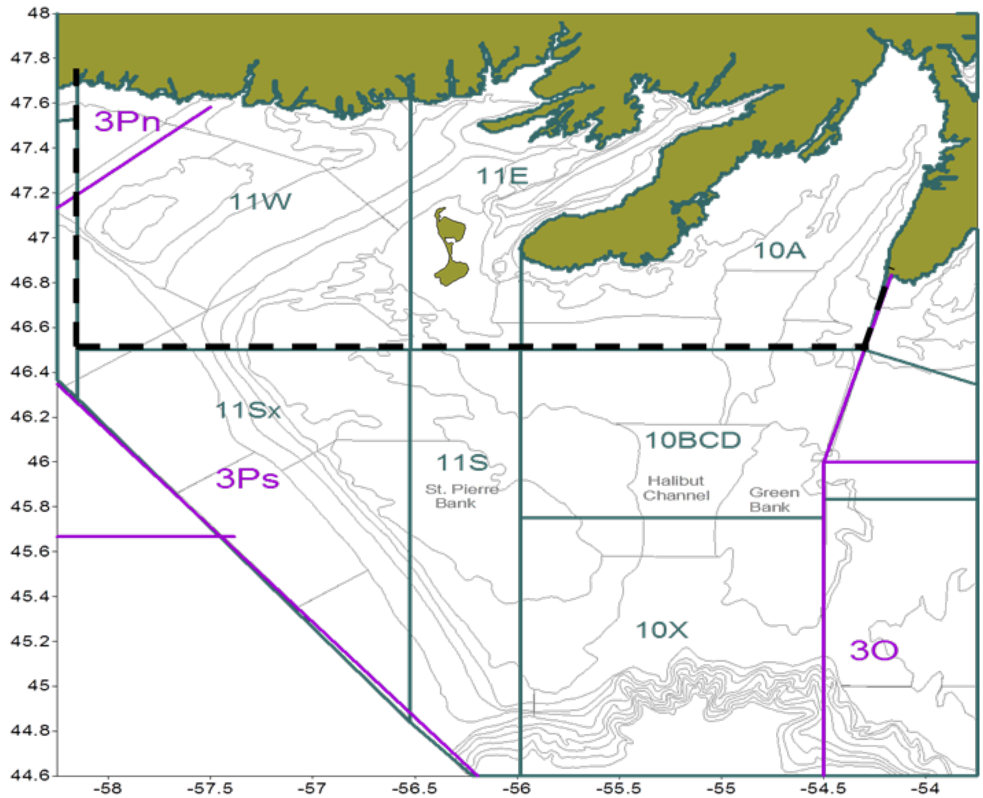

Figure 209: Map of Subdivision 3Ps showing crab management areas and important bathymetric features. Dashed perimeter indicates inshore areas.

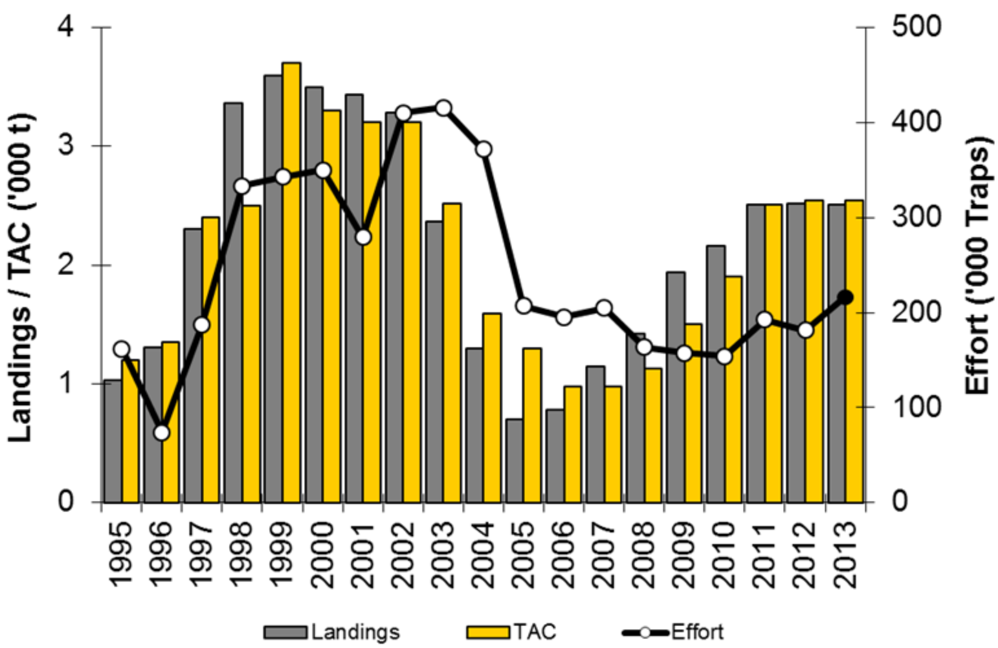

Figure 210: Trends in Subdiv. 3Ps inshore landings, TAC, and fishing effort. (2013 effort preliminary).

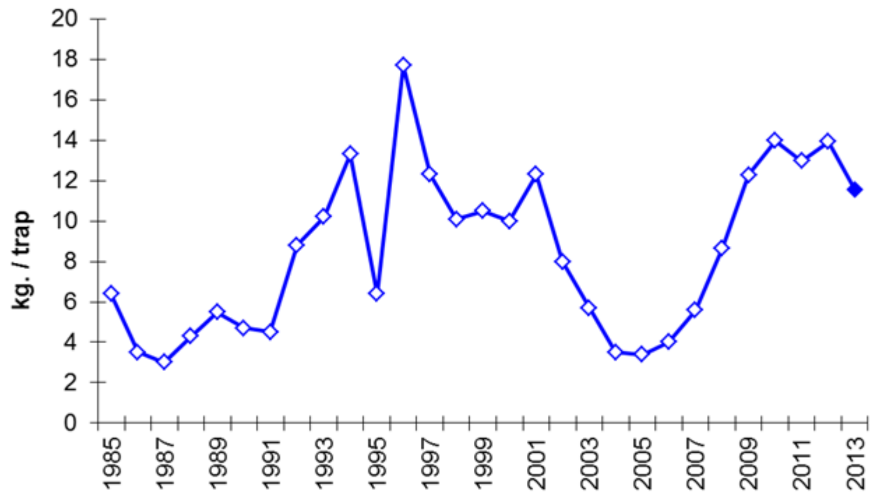

Figure 211: Trends in commercial logbook-based CPUE in the Subdiv. 3Ps inshore fishery. (2013 estimate preliminary).

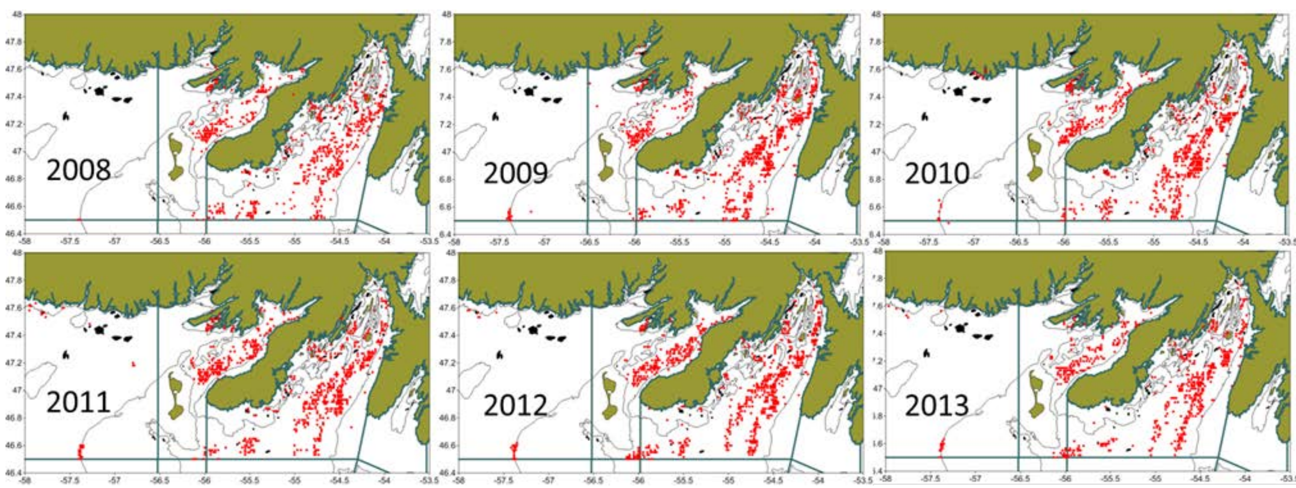

Figure 212: Spatial distribution of Subdiv. 3Ps inshore fishing effort by year.

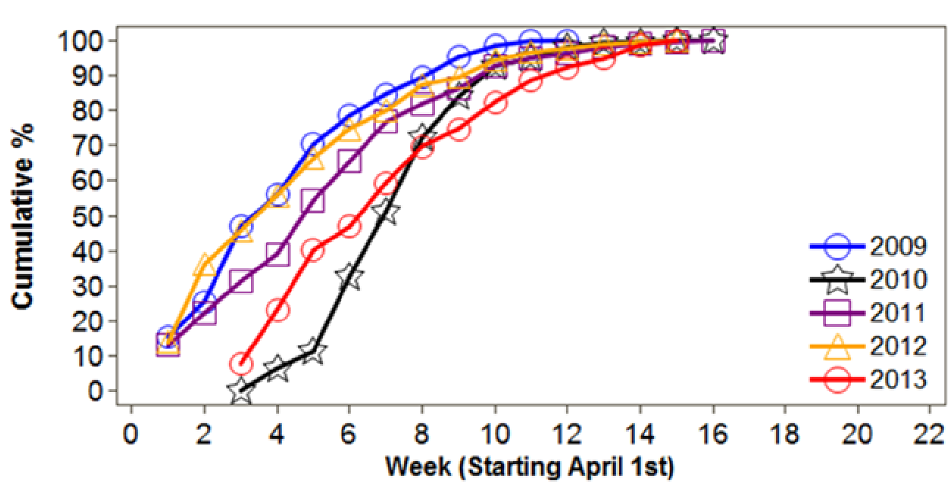

Figure 213: Seasonal trends in weekly fishing effort for Subdiv. 3Ps inshore.

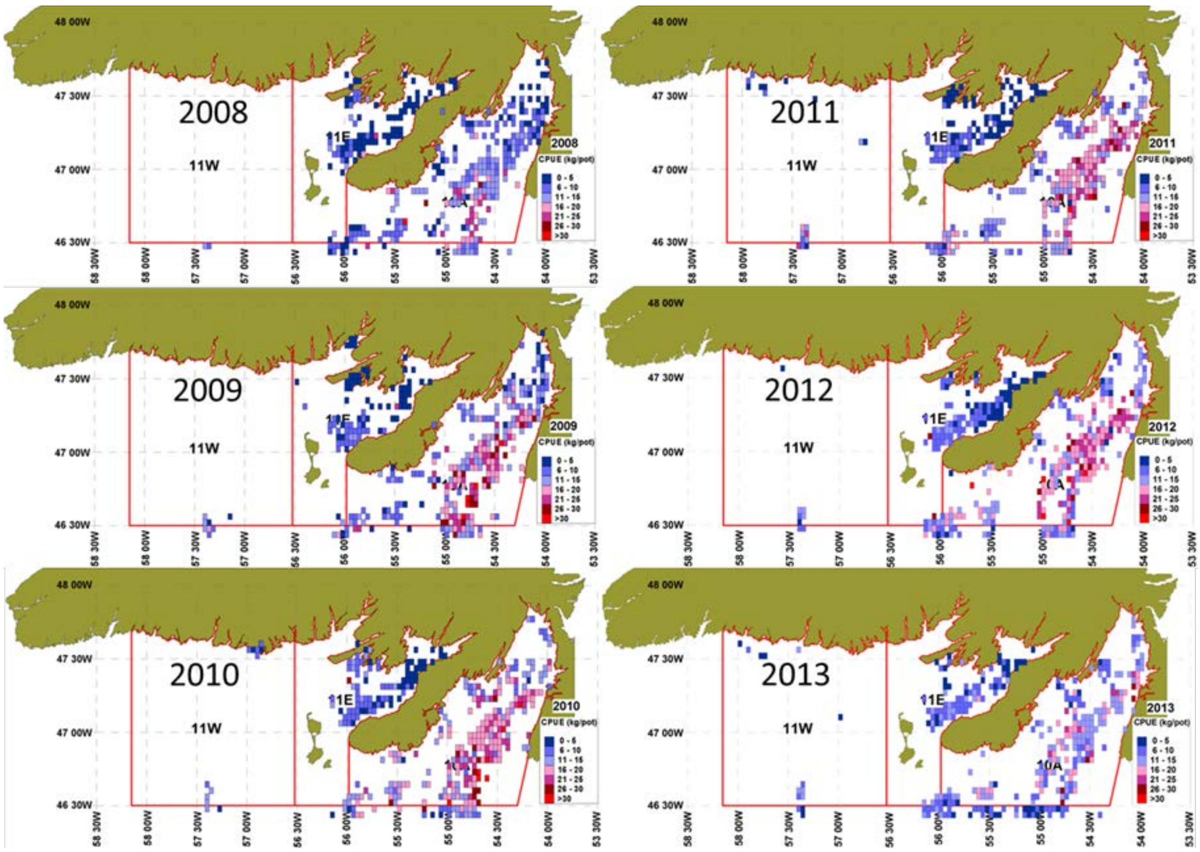

Figure 214: Spatial distribution of Subdiv. 3Ps inshore logbook CPUE by year.

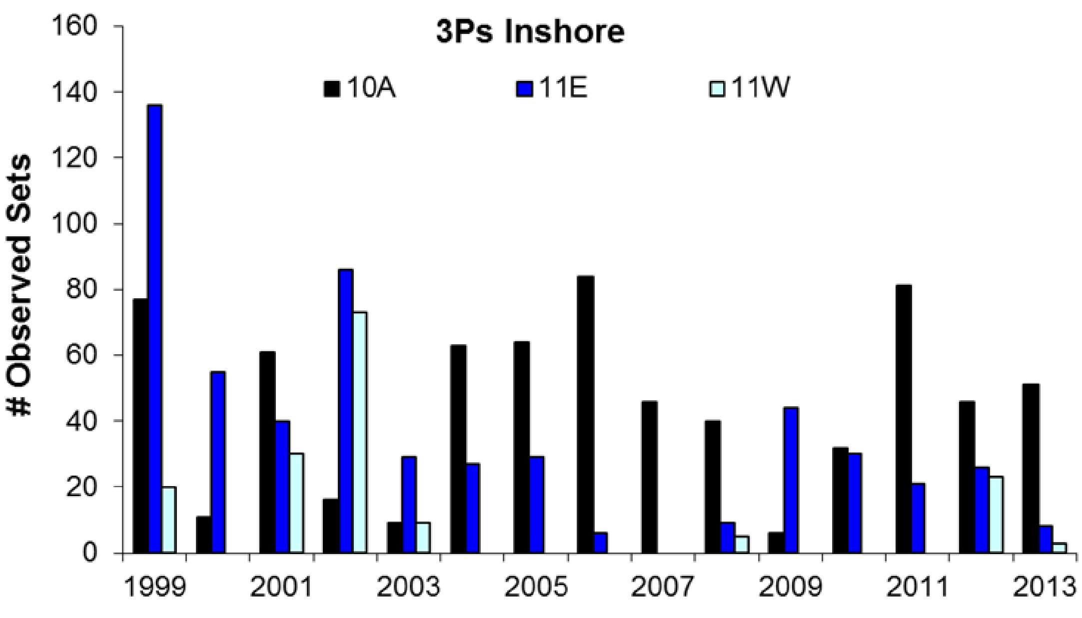

Figure 215: Trends in number of observed sets by Crab Management Areas and year in Subdiv. 3Ps inshore.

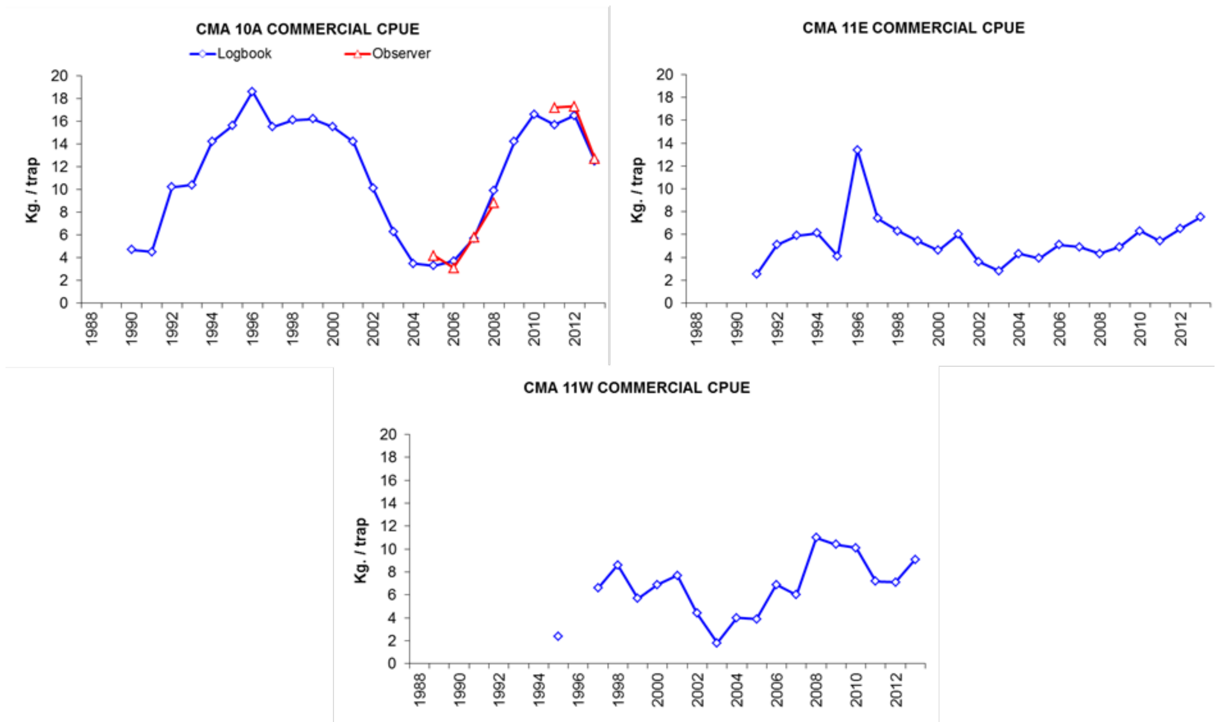

Figure 216: Trends in Subdiv. 3Ps inshore logbook CPUE and observer CPUE by Crab Management Area.

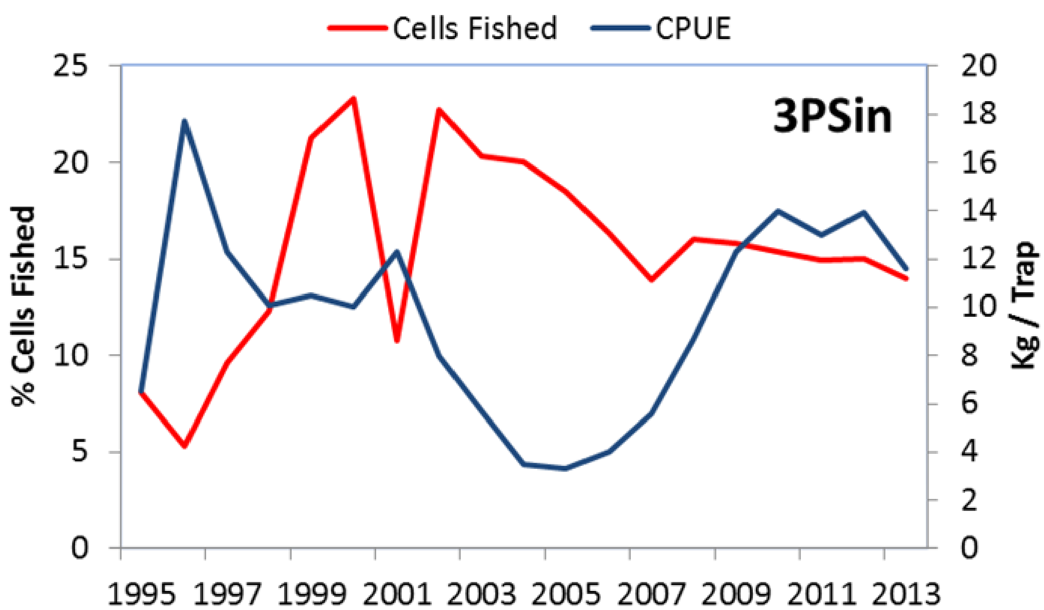

Figure 217: Trends in Subdivision 3Ps inshore logbook CPUE vs. the percentage of 5' x 5' cells fished.

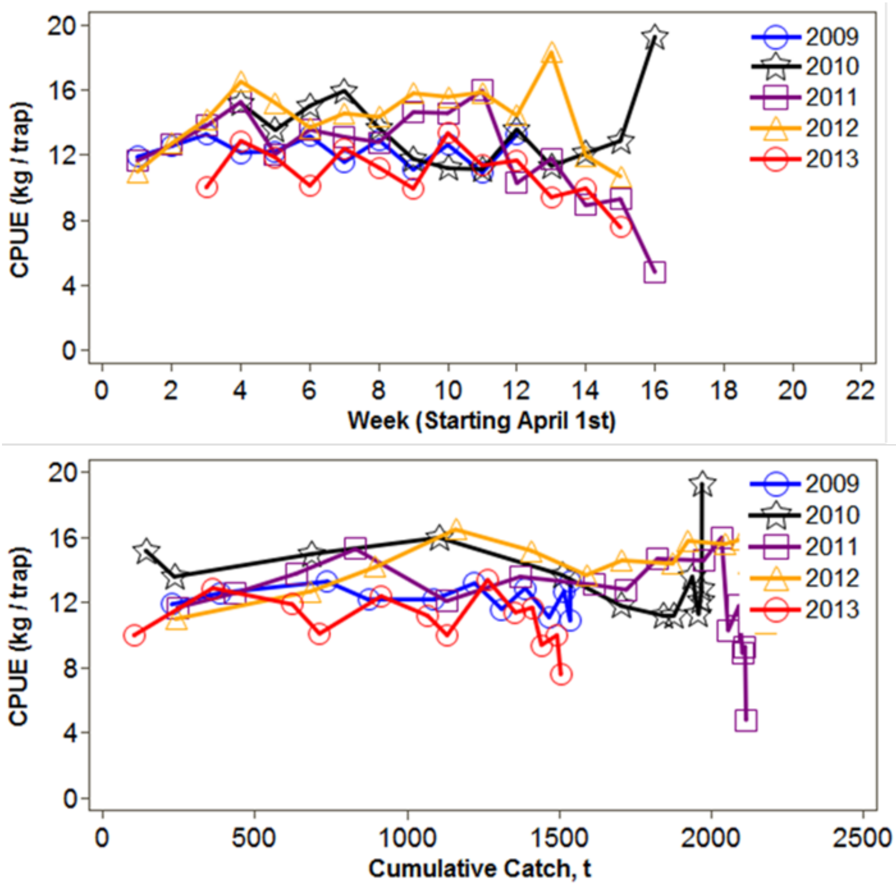

Figure 218: Seasonal trends in logbook-based CPUE for Subdiv. 3Ps inshore; by week (top), and in relation to cumulative catch (bottom).

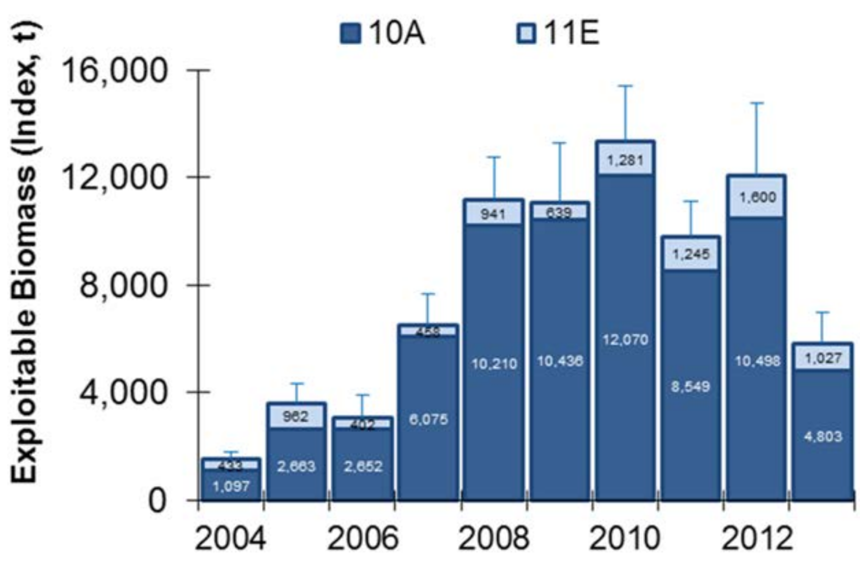

Figure 219: Trends in the exploitable biomass index from the CPS trap survey in Subdivision 3Ps inshore.

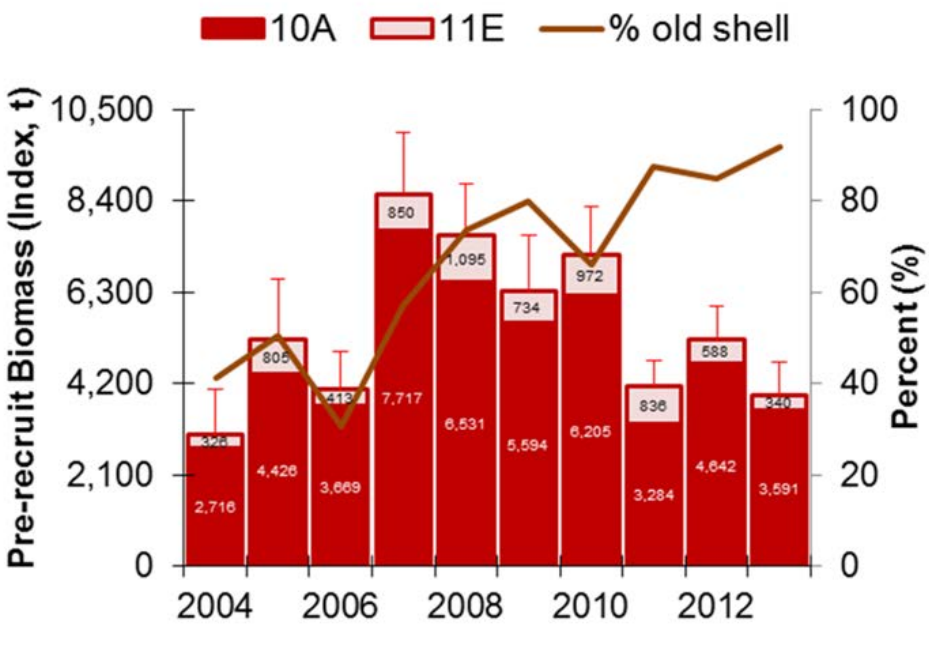

Figure 220: Trends in the exploitable biomass index from the CPS trap survey in Subdivision 3Ps inshore.

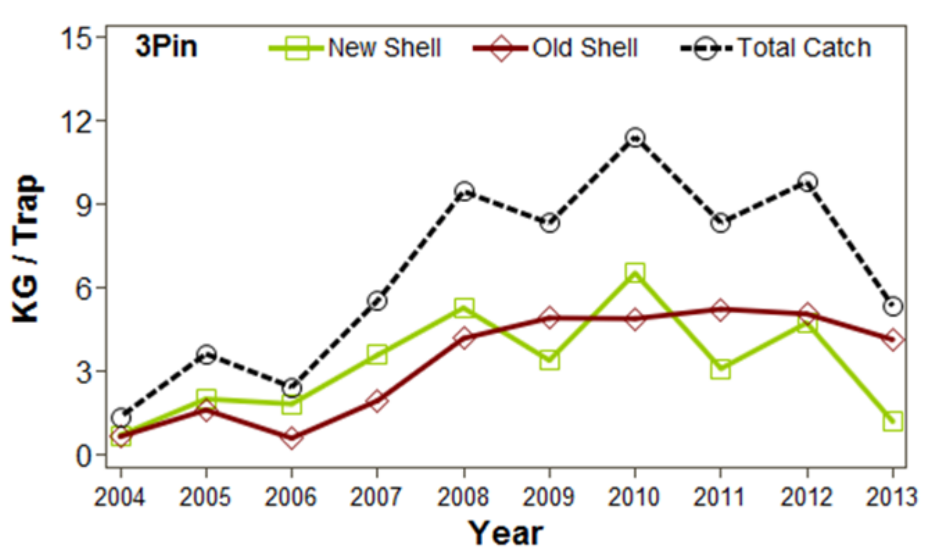

Figure 221: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in Subdiv. 3Ps inshore.

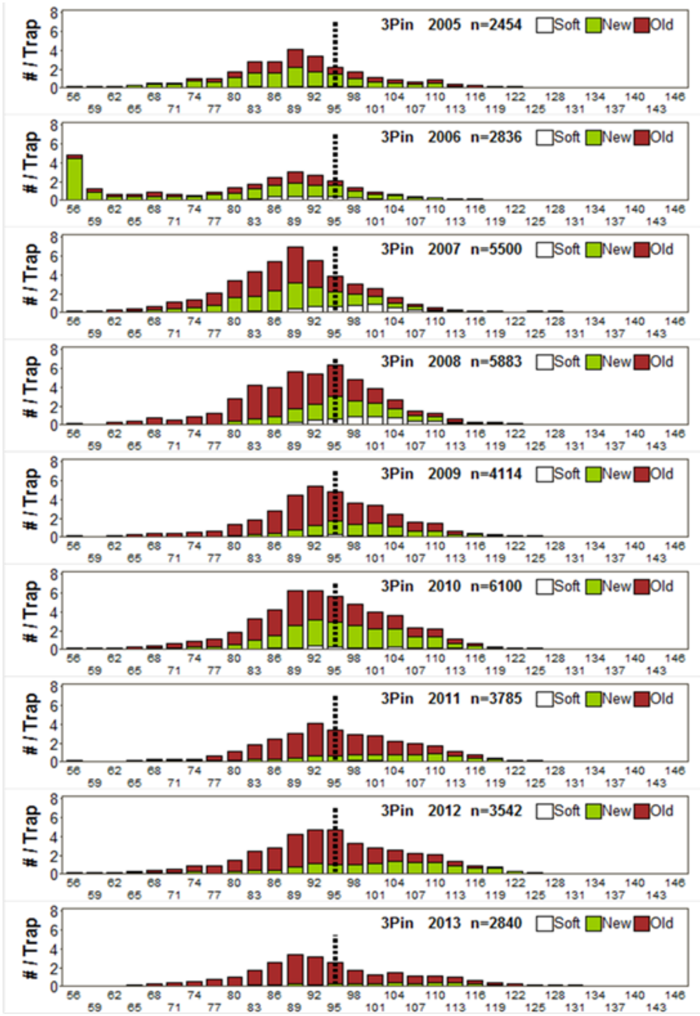

Figure 222: Trends in male carapace width distributions from large mesh traps at core stations in the Subdiv. 3Ps inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

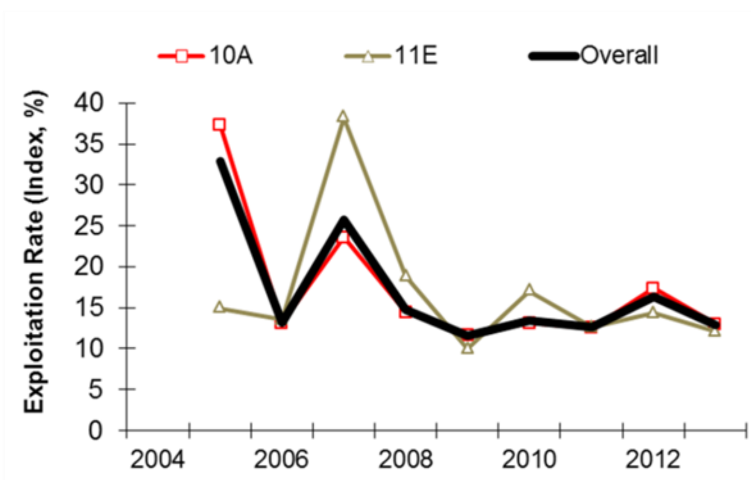

Figure 223: Exploitation rate indices by crab management area as well as overall for Subdiv. 3Ps inshore based on the CPS trap survey.

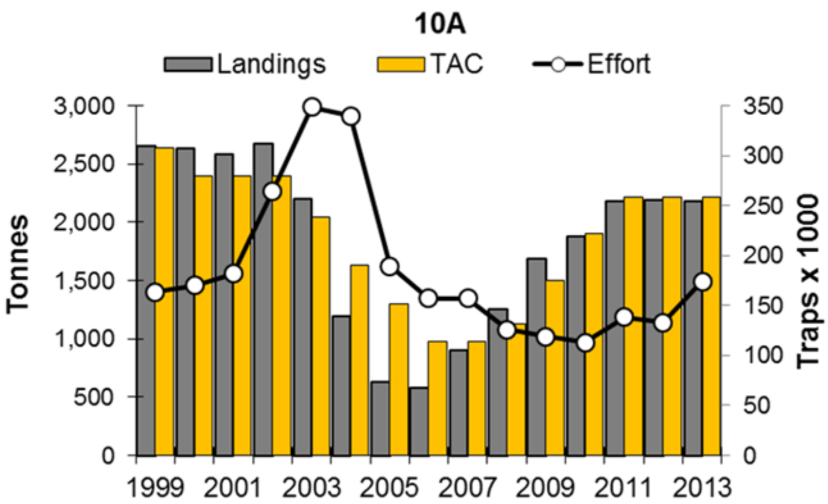

Figure 224: Trends in CMA 10A landings, TAC, and fishing effort. (2013 effort preliminary).

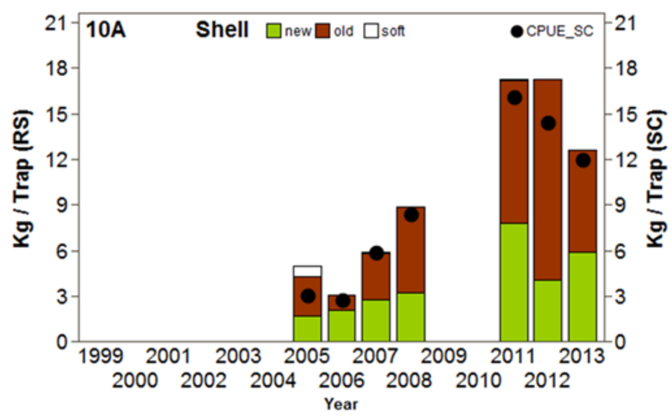

Figure 225: Trends in CMA 10A observer catch rates of exploitable-sized crabs by shell condition category from at-sea sampling.

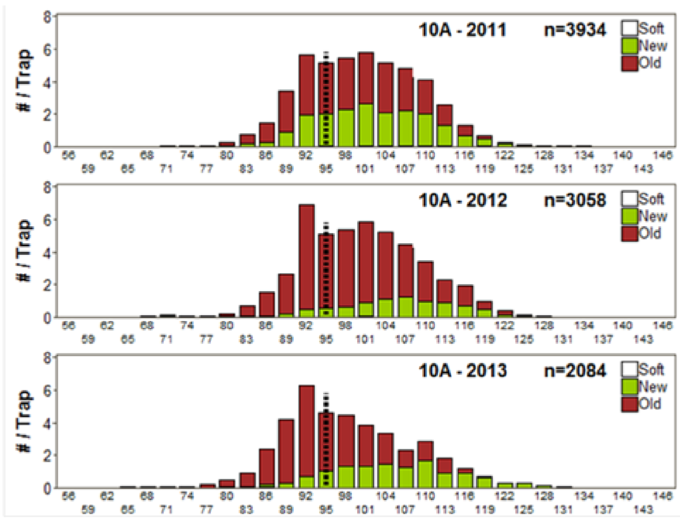

Figure 226: Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMA 10A. The vertical dashed line indicates the minimum legal size.

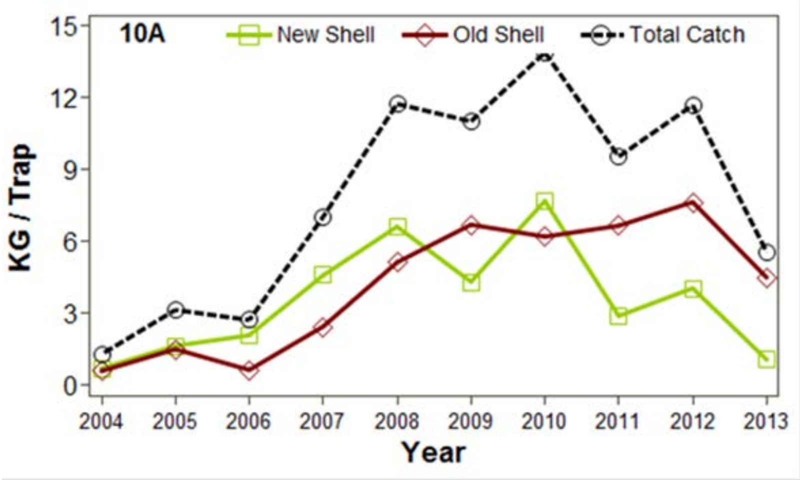

Figure 227: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 10A.

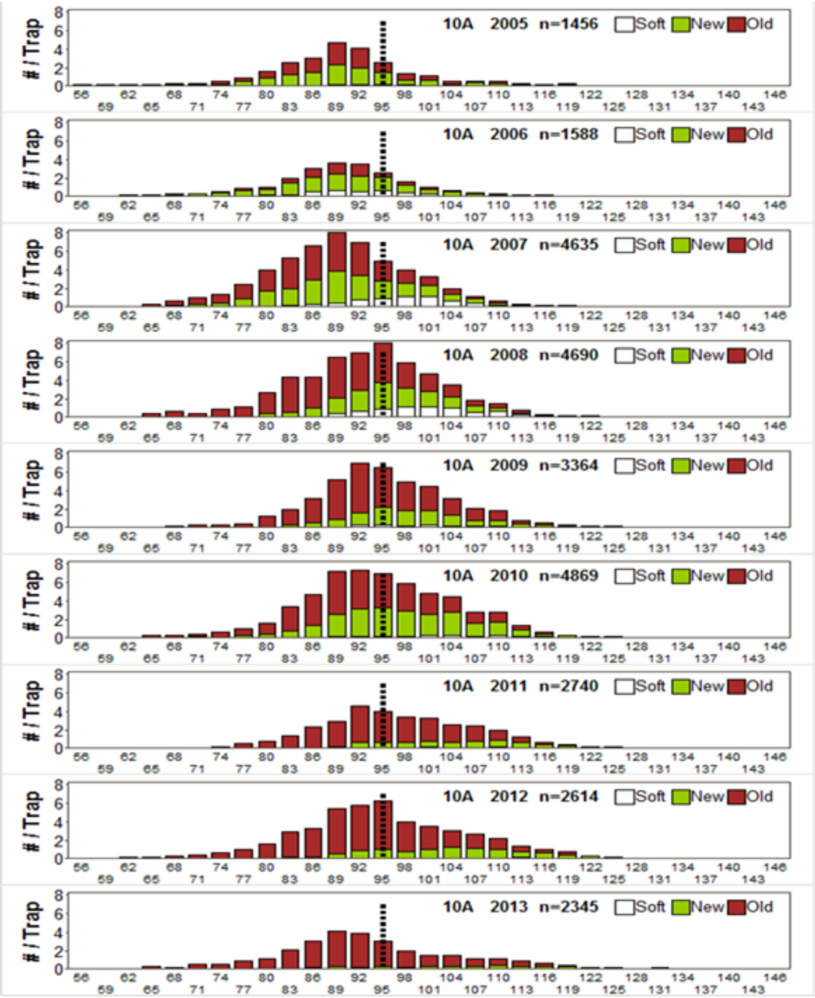

Figure 228: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 10A CPS trap survey. The vertical dashed line indicates the minimum legal size.

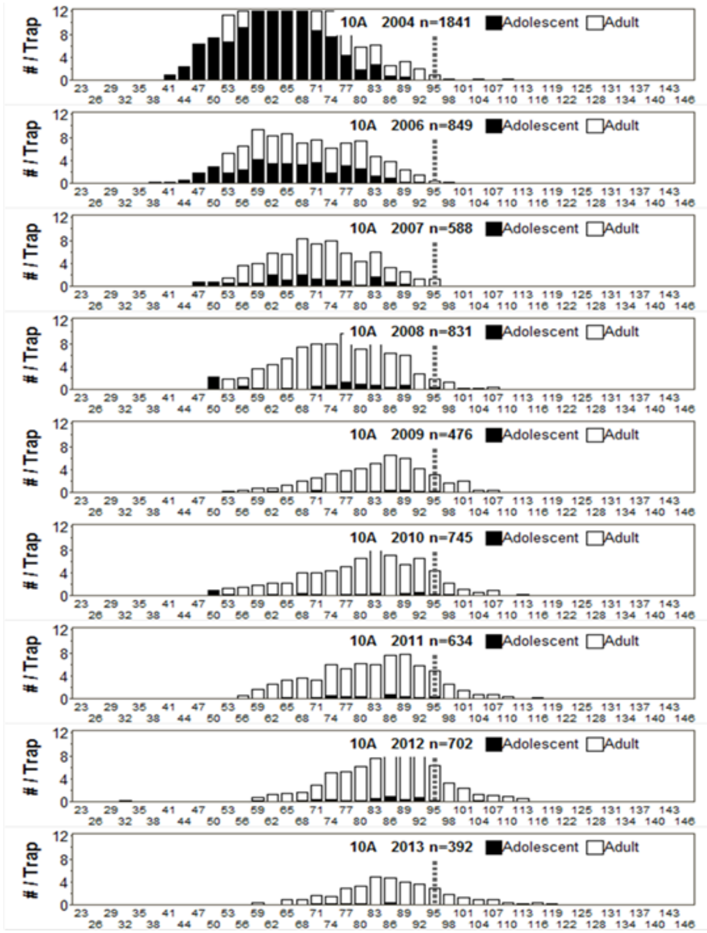

Figure 229: Trends in males carapace width distributions from small-mesh traps in CMA 10A from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

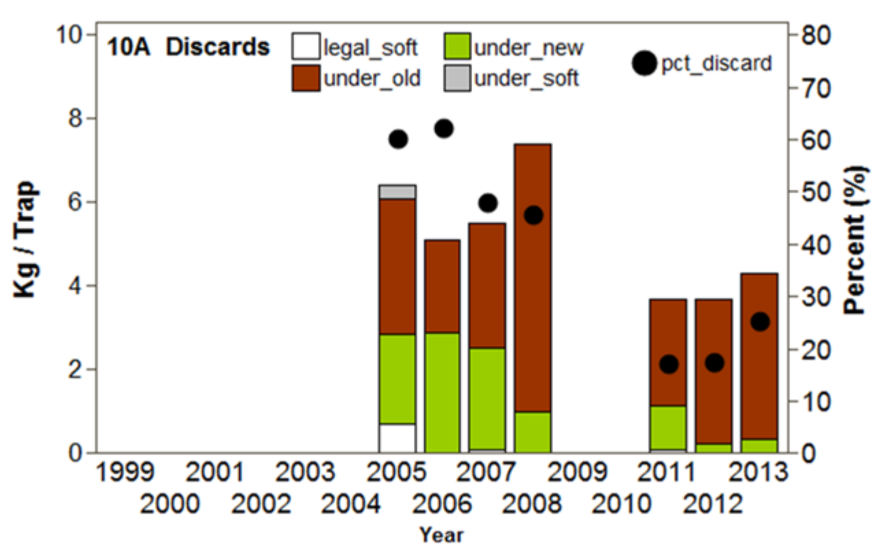

Figure 230: Trends in CMA 10A observer catch rates of total discards, undersized discards, and legal-sized discards, as well as the percentage of the catch discarded.

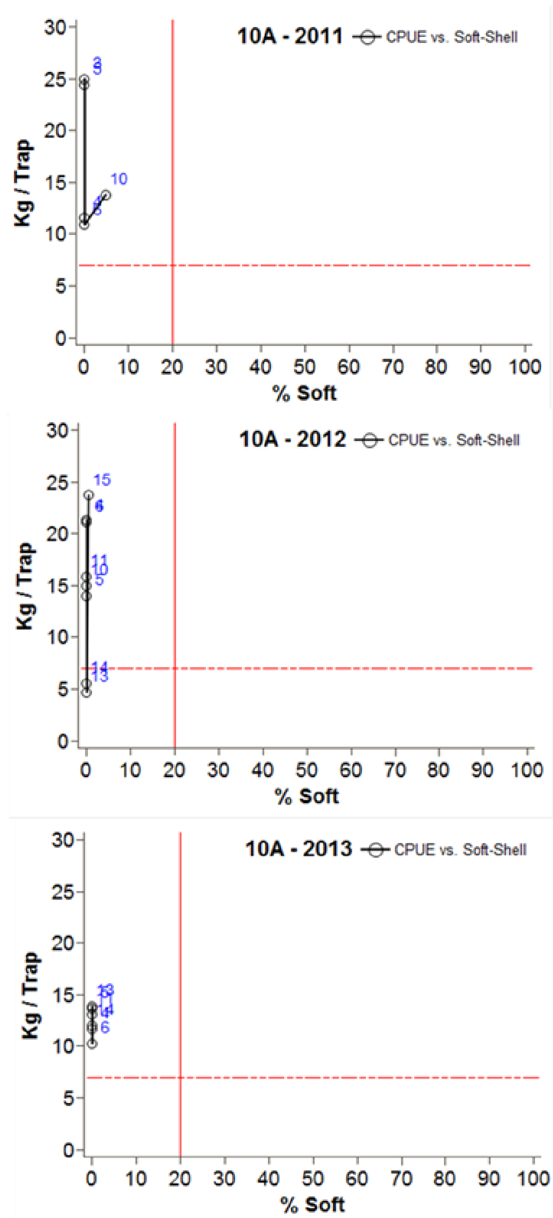

Figure 231: Trends in weekly percentages of kept vs. soft-shell crab in CMA 10A from at-sea sampling by observers.

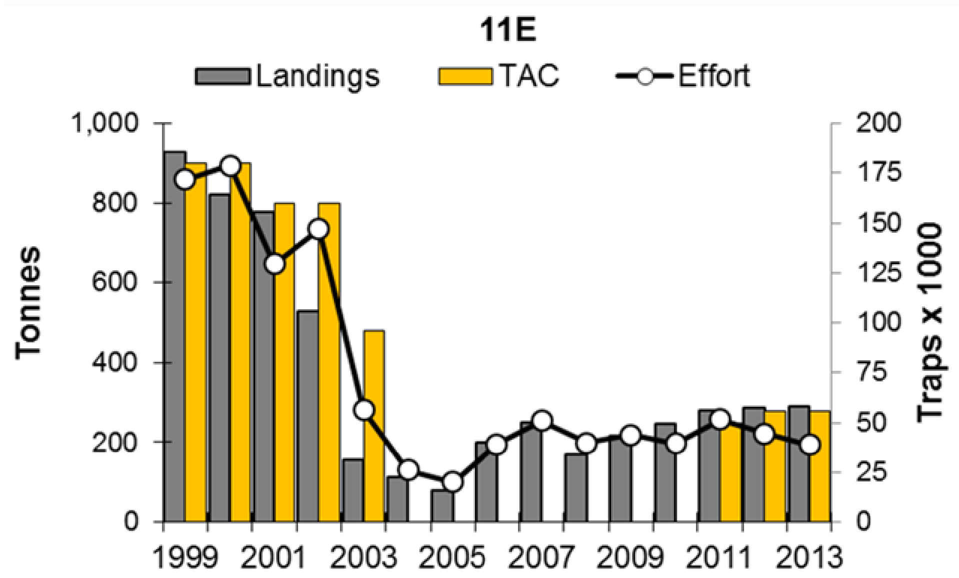

Figure 232: Trends in CMA 11E landings, TAC, and fishing effort. (2013 effort preliminary).

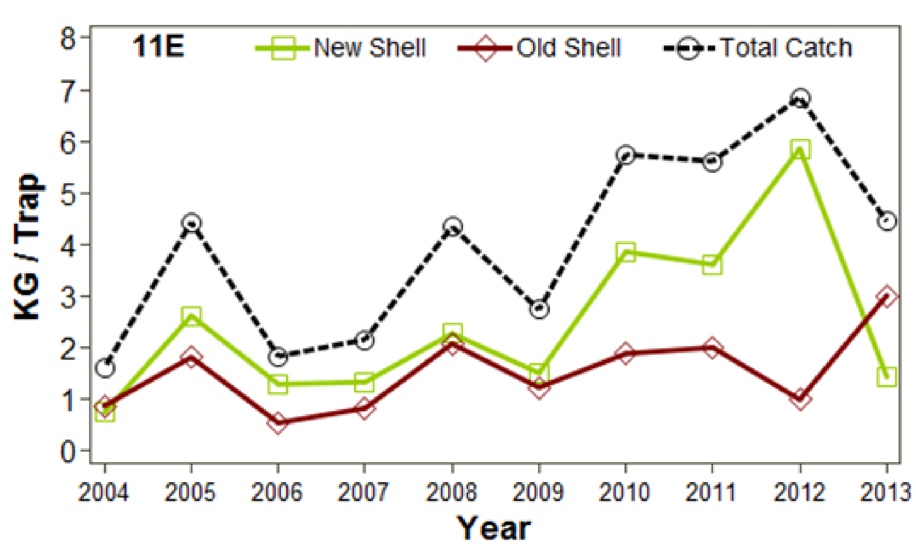

Figure 233: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 11E.

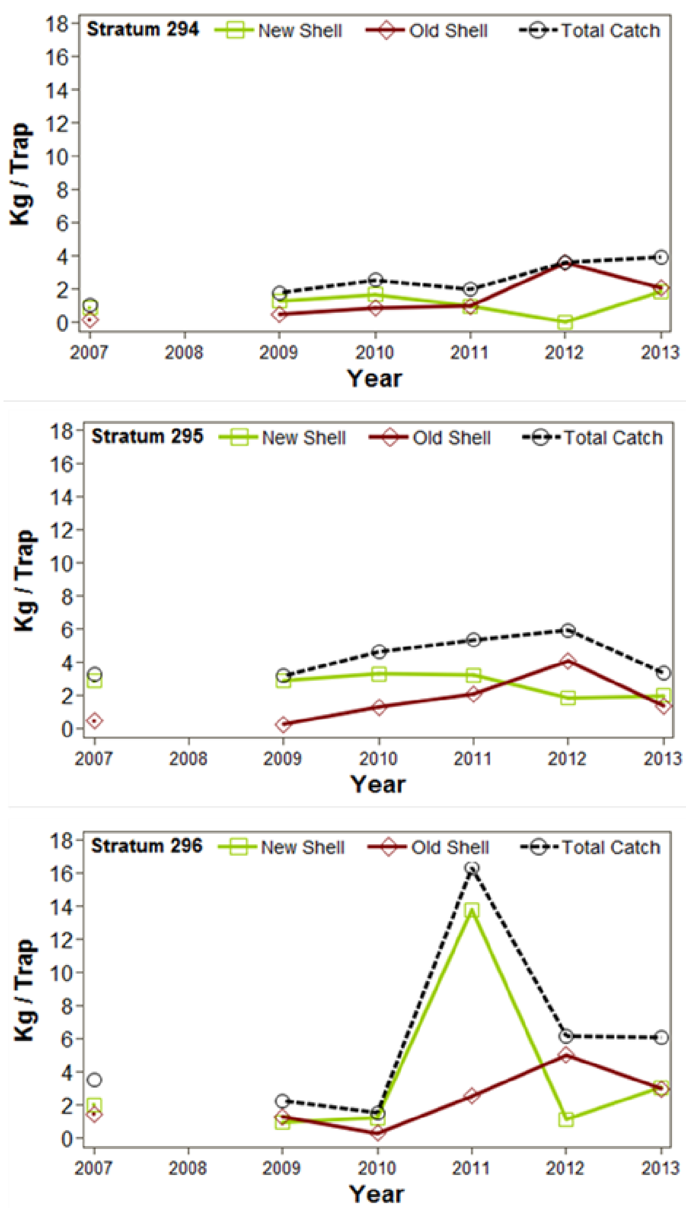

Figure 234: Trends in CPUE by shell condition for legal-sized crabs from strata occupied in the DFO trap survey in Fortune Bay.

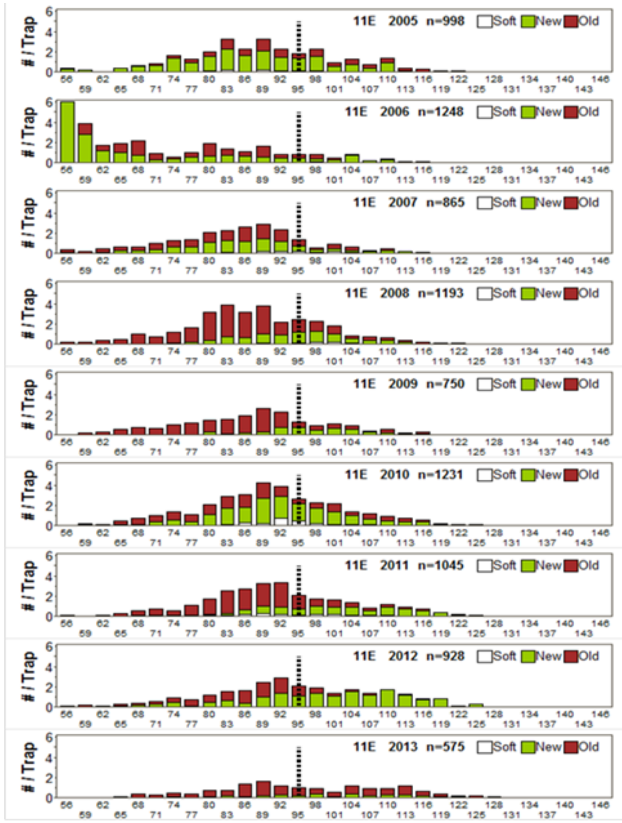

Figure 235: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 11E CPS trap survey. The vertical dashed line indicates the minimum legal size.

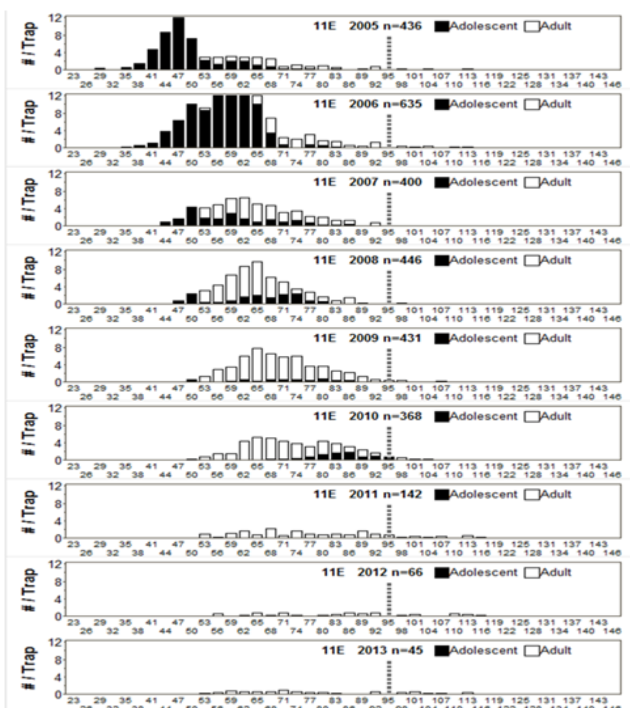

Figure 236: Trends in males carapace width distributions from small-mesh traps in CMA 11E from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

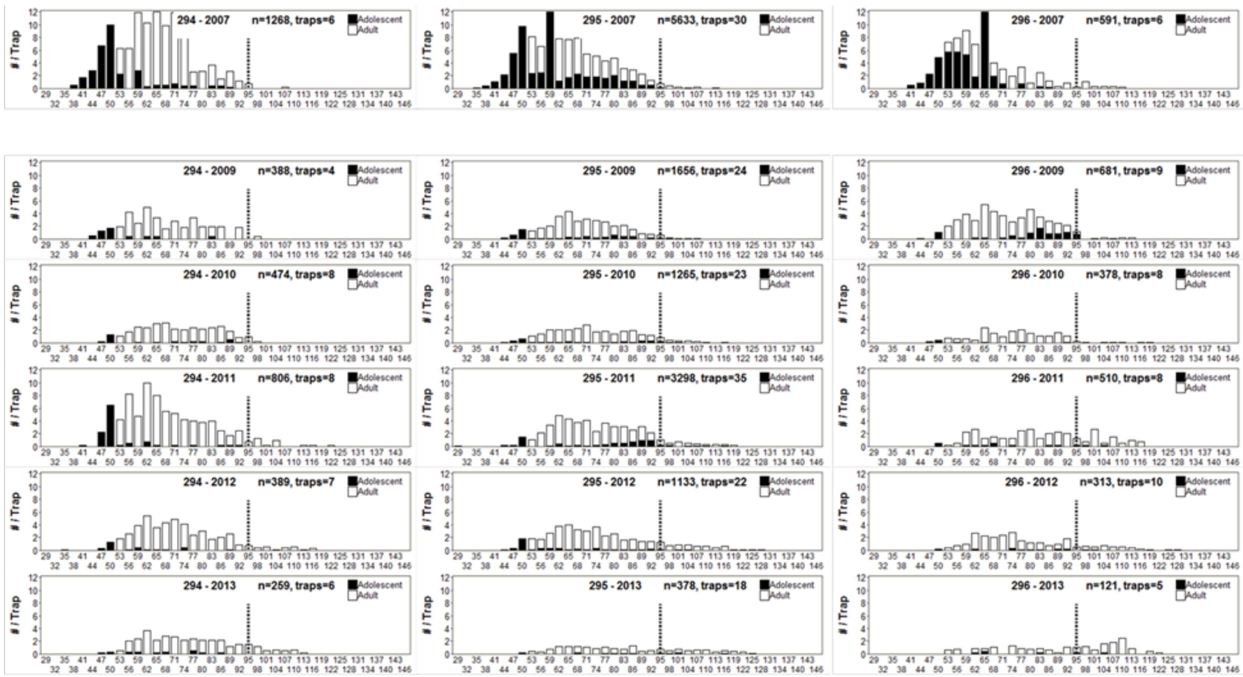

Figure 237: Small-claw (adolescent) vs. large-claw (adult) male catch rates by size from small-mesh traps in DFO trap survey in Fortune Bay. The vertical dashed line indicates the minimum legal size.

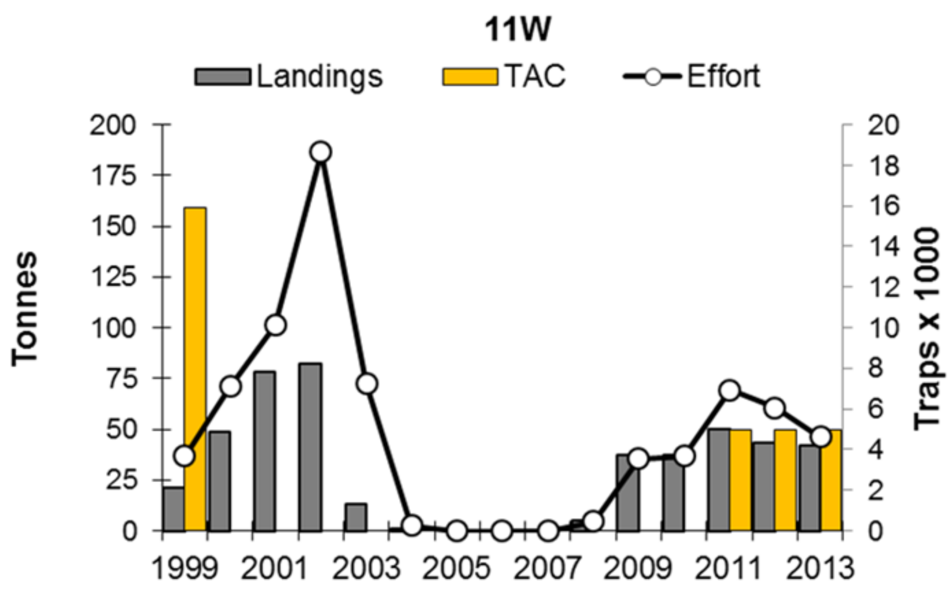

Figure 238: Trends in CMA 11W landings, TAC, and fishing effort. (2013 effort preliminary).

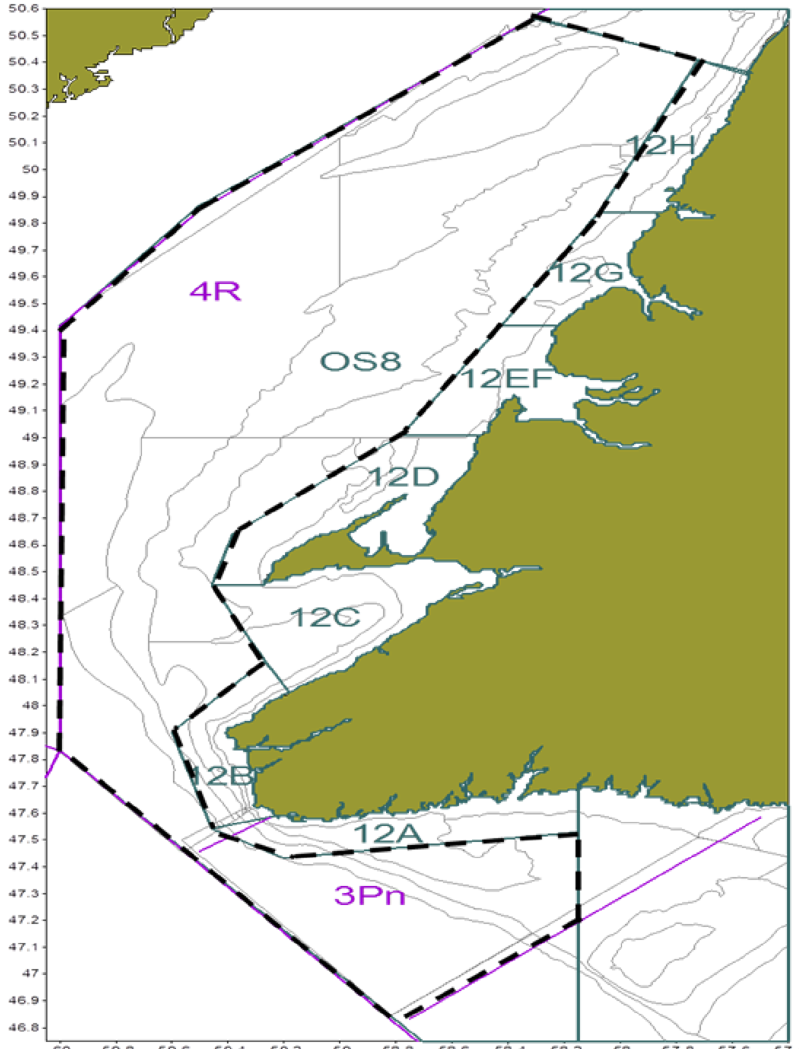

Figure 239: Map of Division 4R3Pn showing crab management areas and important bathymetric features. Dashed perimeter indicates offshore areas.

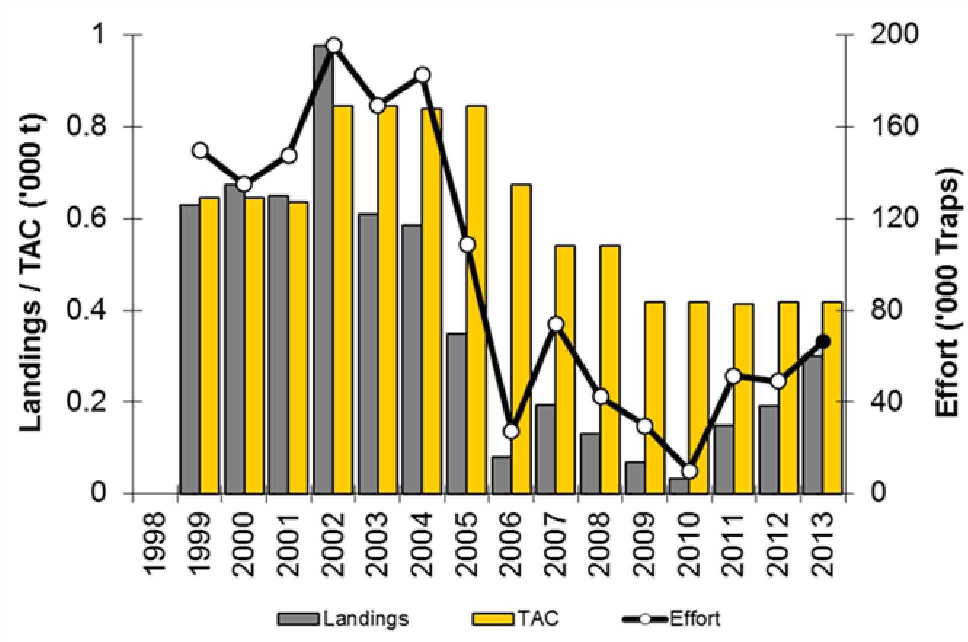

Figure 240: Trends in Div. 4R3Pn offshore landings, TAC, and fishing effort. (2013 effort preliminary).

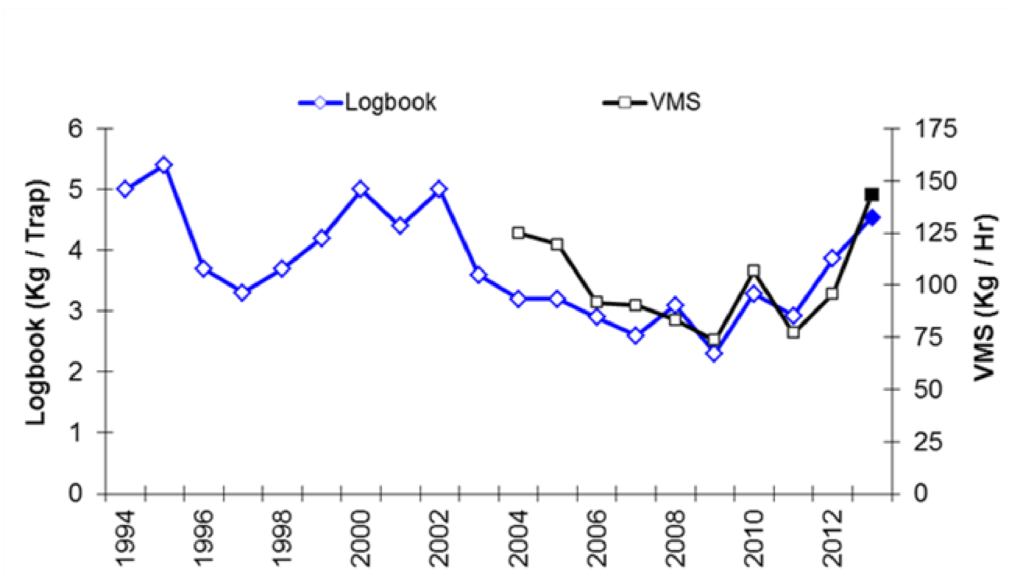

Figure 241: Trends in commercial logbook-based and VMS-based CPUE in the Division 4R offshore fishery. (2013 estimates preliminary).

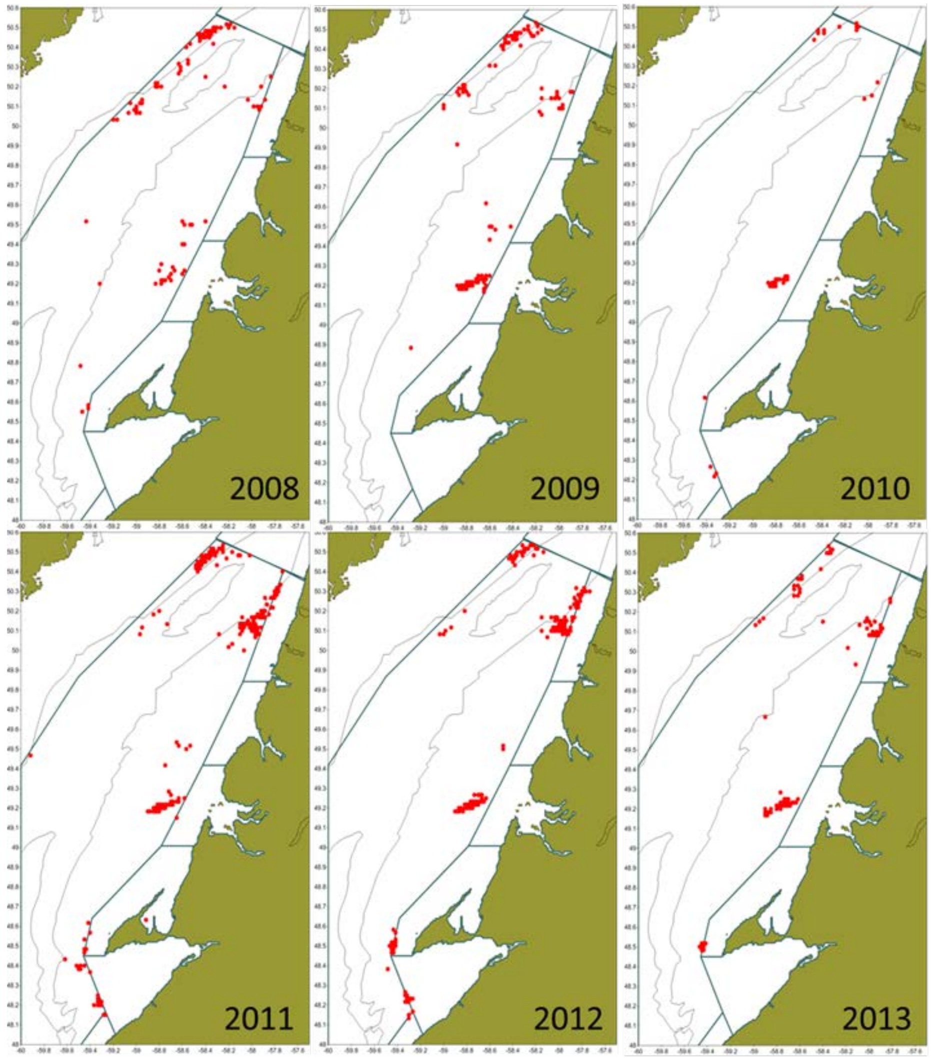

Figure 242: Spatial distribution of Div. 4R3Pn offshore fishing effort by year.

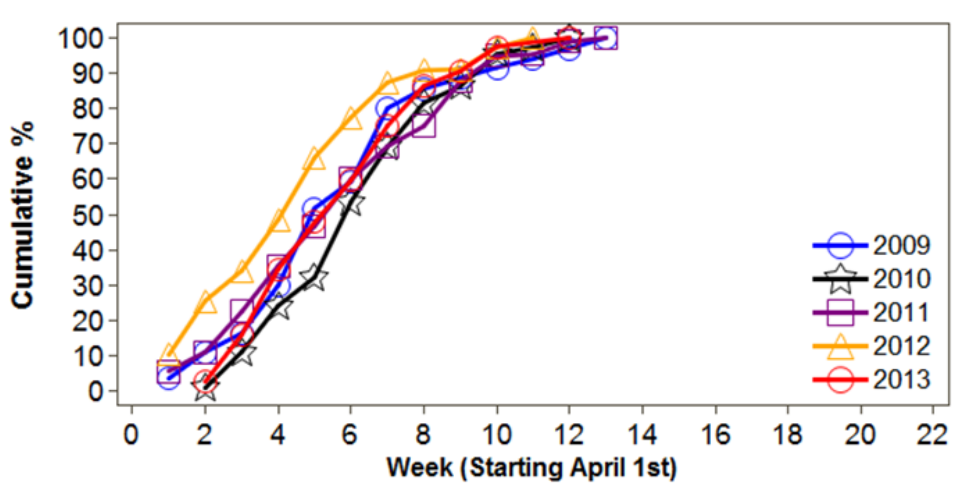

Figure 243: Seasonal trends in weekly fishing effort for Div. 4R3Pn offshore.

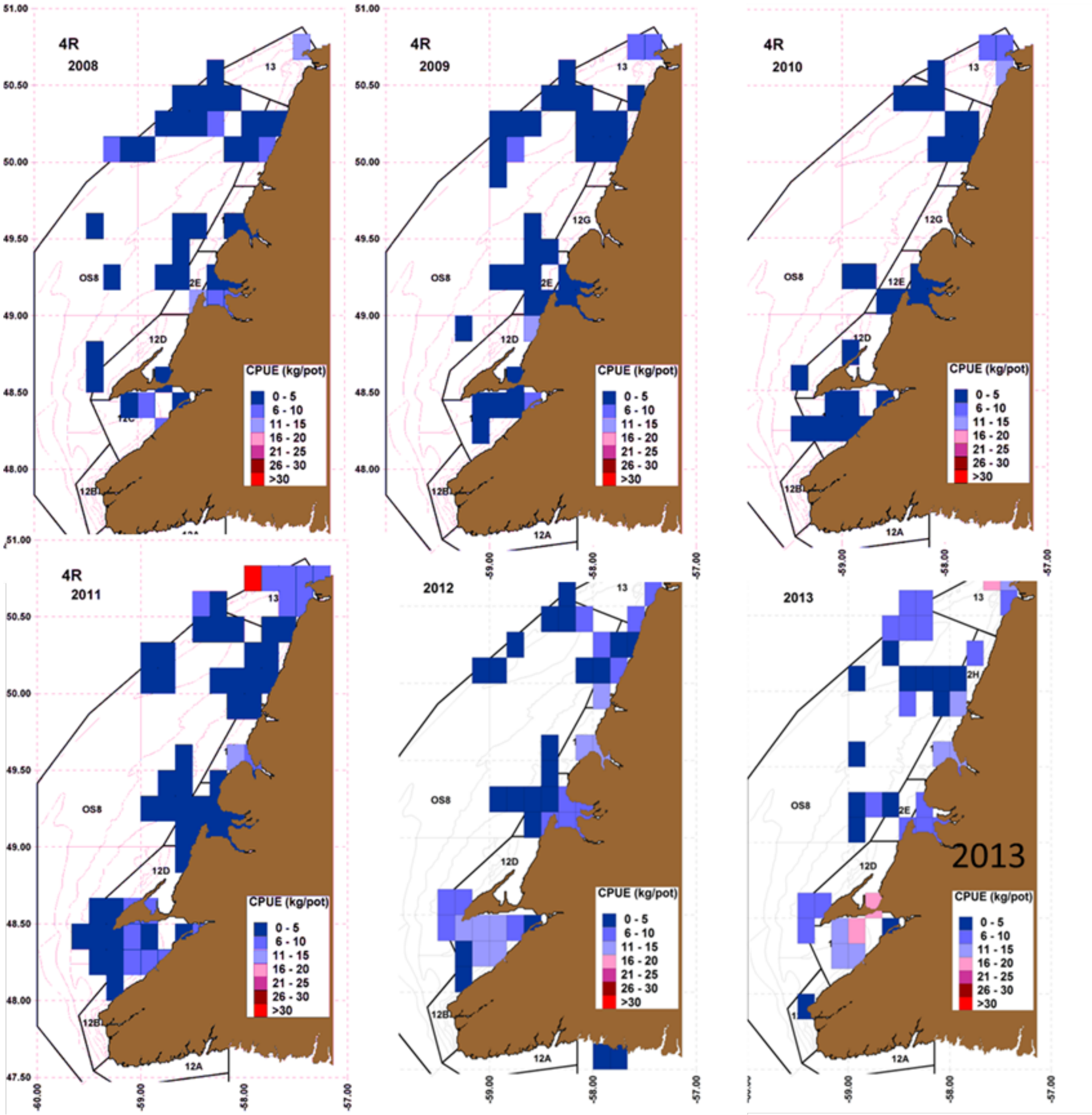

Figure 244: Spatial distribution of Div. 4R3Pn offshore logbook CPUE by year.

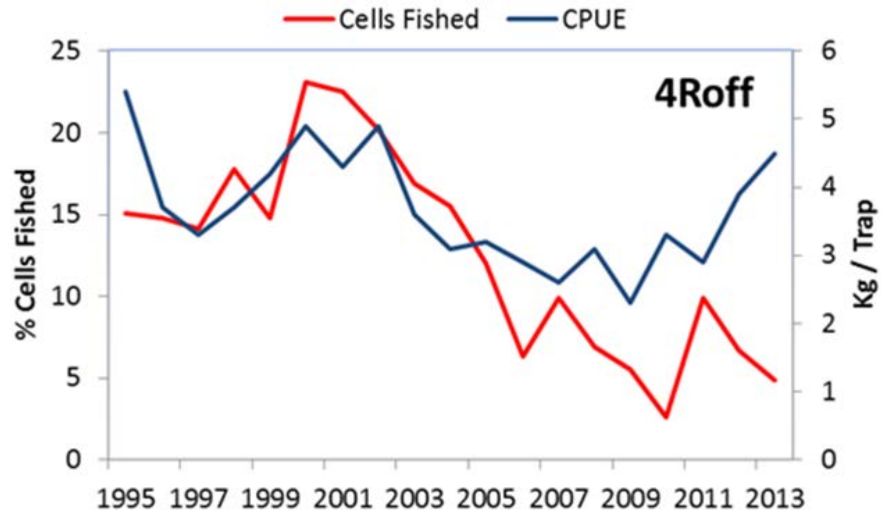

Figure 245: Trends in Div. 4R3Pn offshore commercial CPUE vs. the percentage of 5' x 5' cells fished.

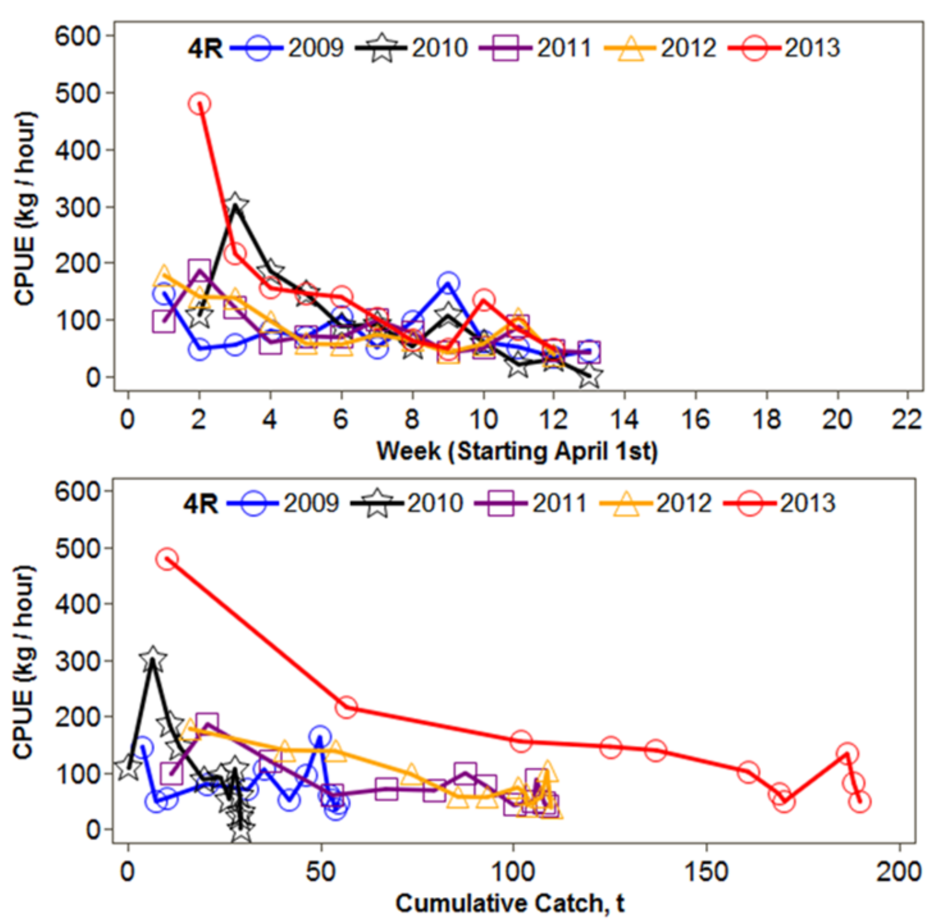

Figure 246: Seasonal trends in VMS-based CPUE for Div. 4R3Pn offshore; by week (top), and in relation to cumulative catch (bottom).

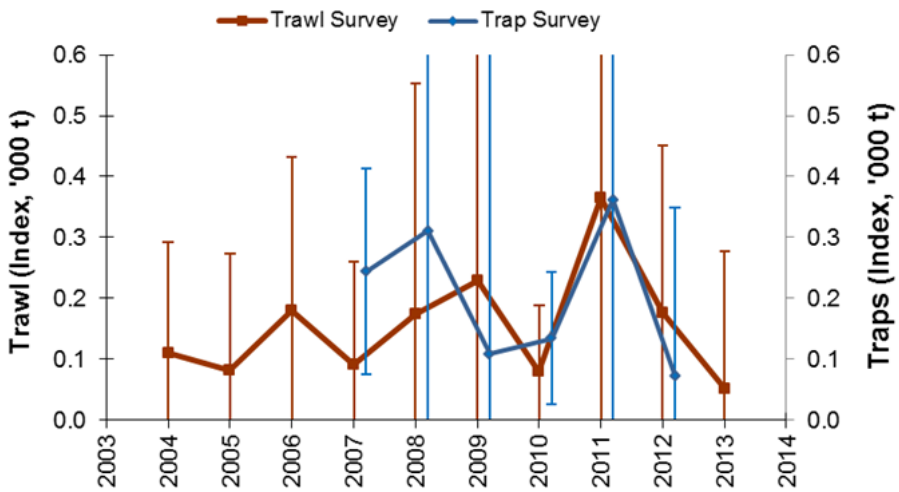

Figure 247: Trends in Div. 4R3Pn offshore summer trawl survey exploitable biomass index and the CPS trap survey exploitable biomass index.

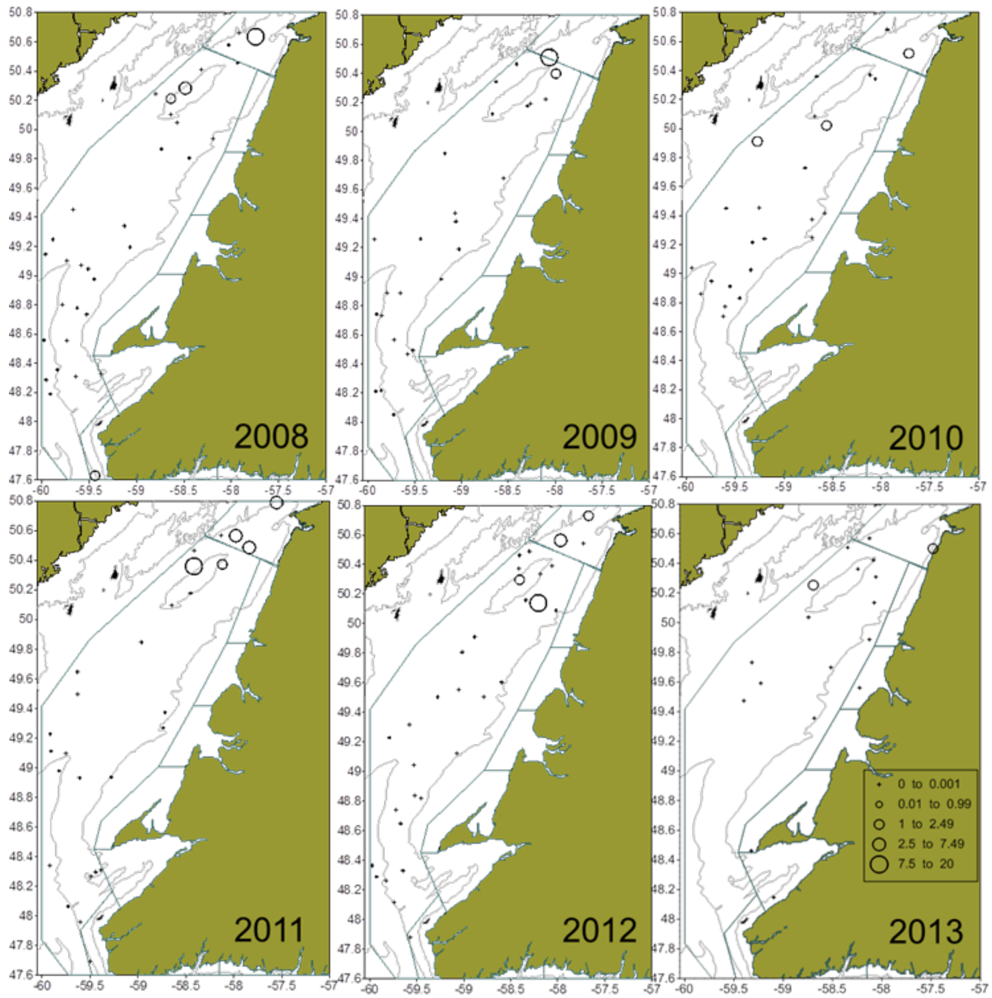

Figure 248: Spatial distribution of catches (number/set) of exploitable crab in the Div. 4R summer trawl survey.

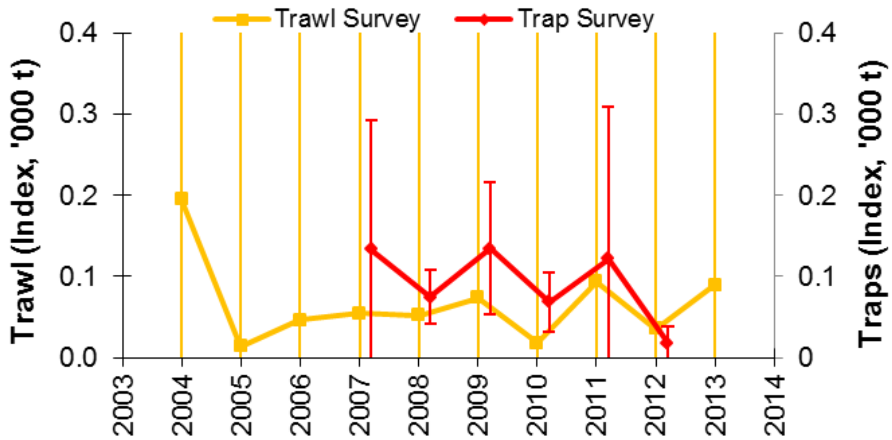

Figure 249: Trends in Div. 4R3Pn offshore summer trawl survey pre-recruit biomass index and the CPS trap survey pre-recruit biomass index.

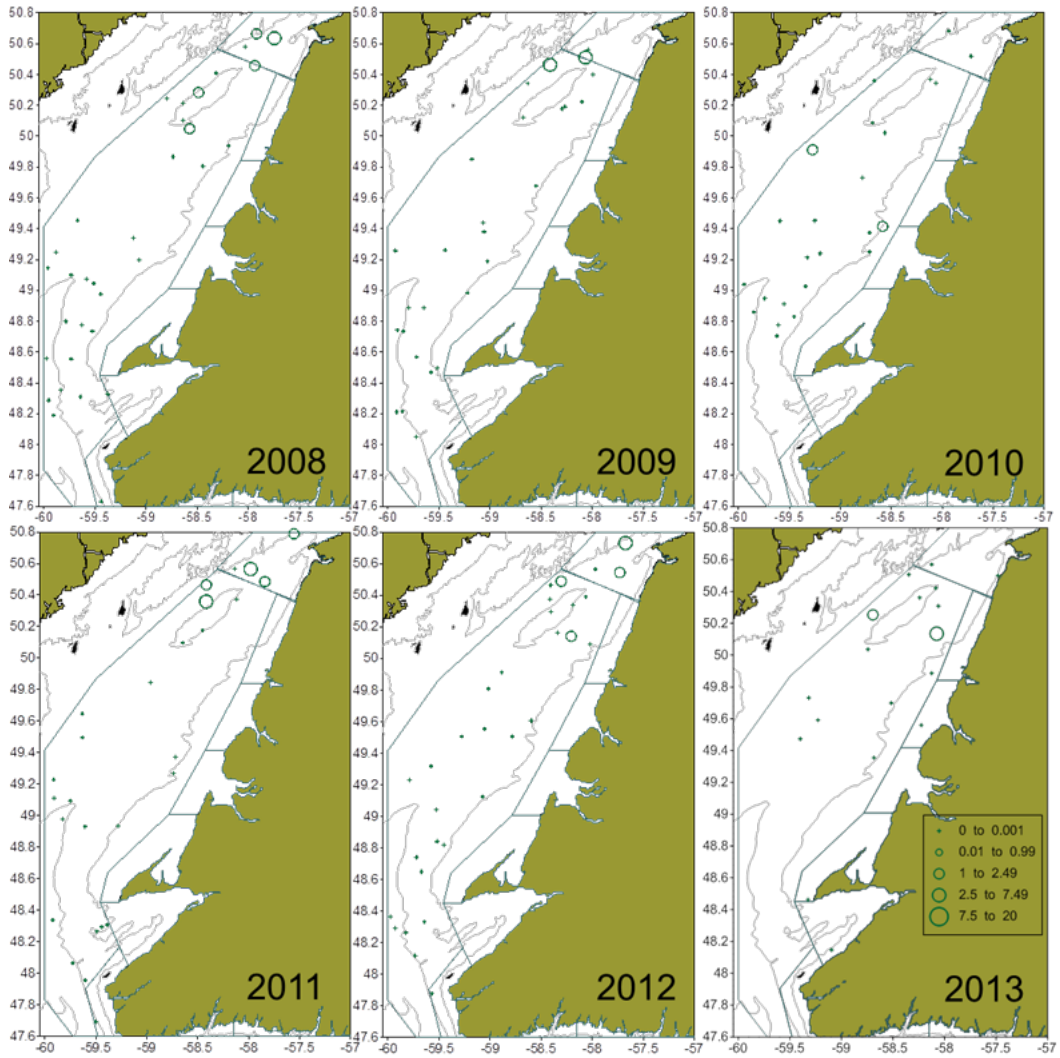

Figure 250: Spatial distribution of catches (number/set) of pre-recruit crab in the Div. 4R3Pn summer trawl survey.

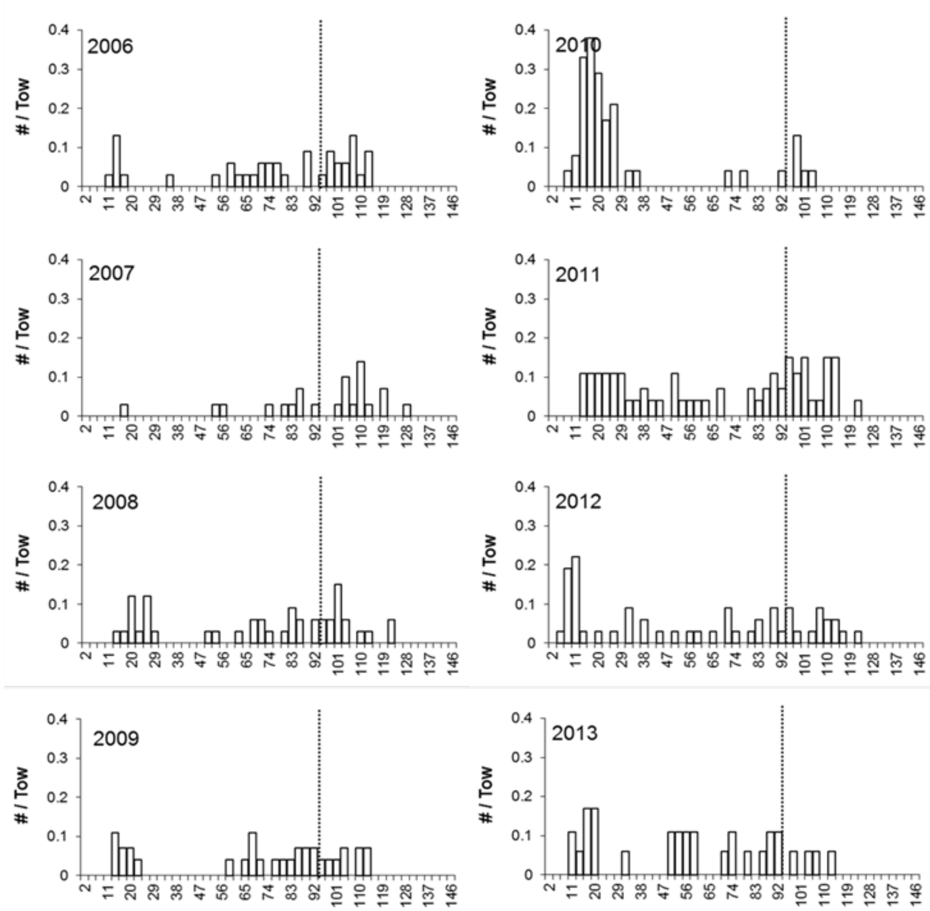

Figure 251: Abundance indices by carapace width for Div. 4R3Pn offshore male crabs from summer trawl suveys. The vertical dashed line indicates the minimum legal size.

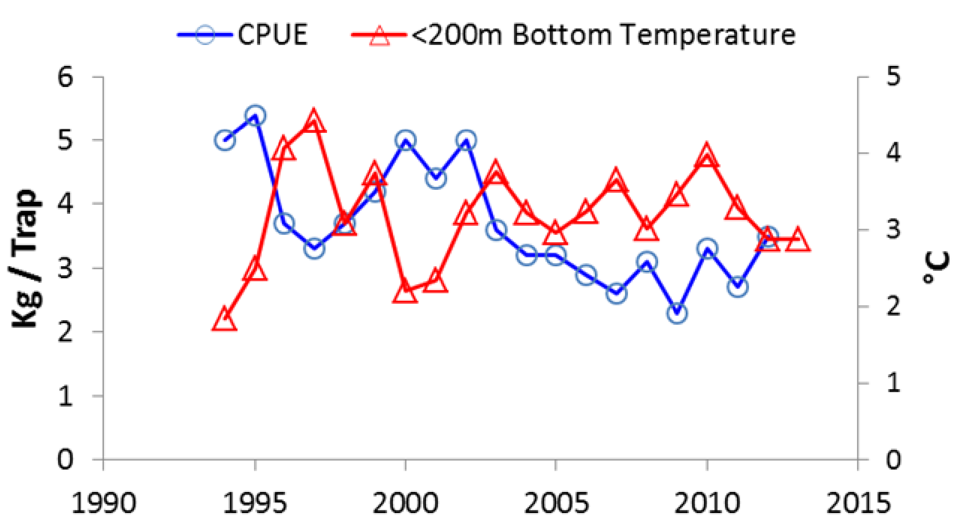

Figure 252: Trends in the Div. 4R3Pn offshore CPUE vs. bottom temperature at a five year lag.

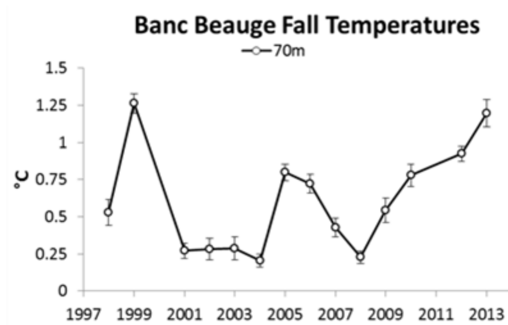

Figure 253: Trend in Banc Beauge fall bottom temperature.

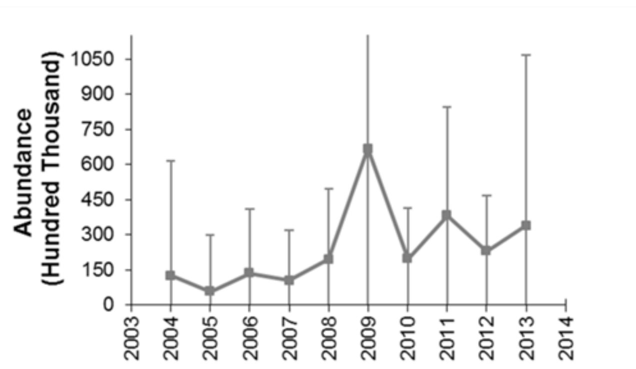

Figure 254: Trends in abundance of large females in Division 4R3Pn from summer multi-species surveys.

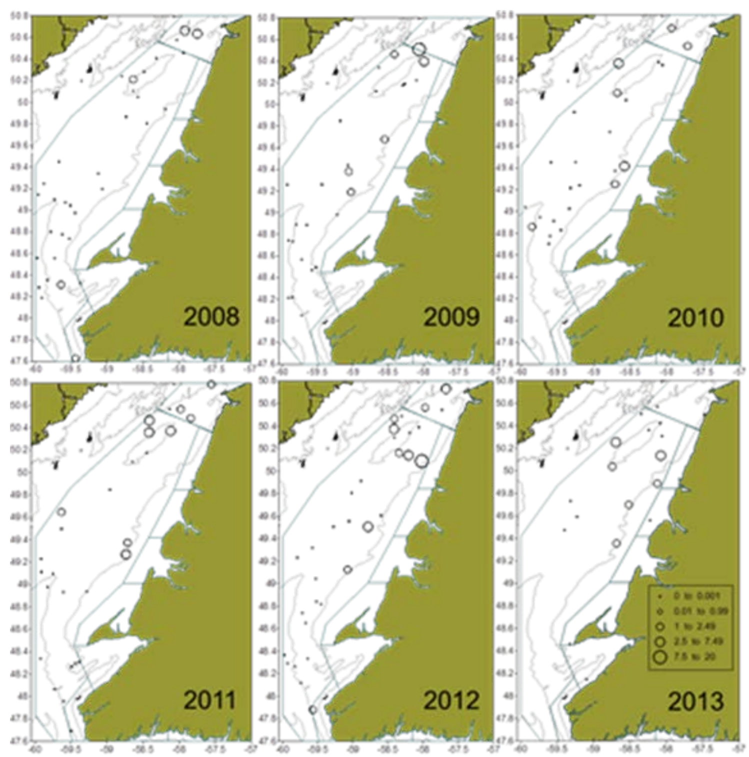

Figure 255: Spatial distribution of catches (number/set) of large female crab in the Div. 4R3Pn summer trawl survey.

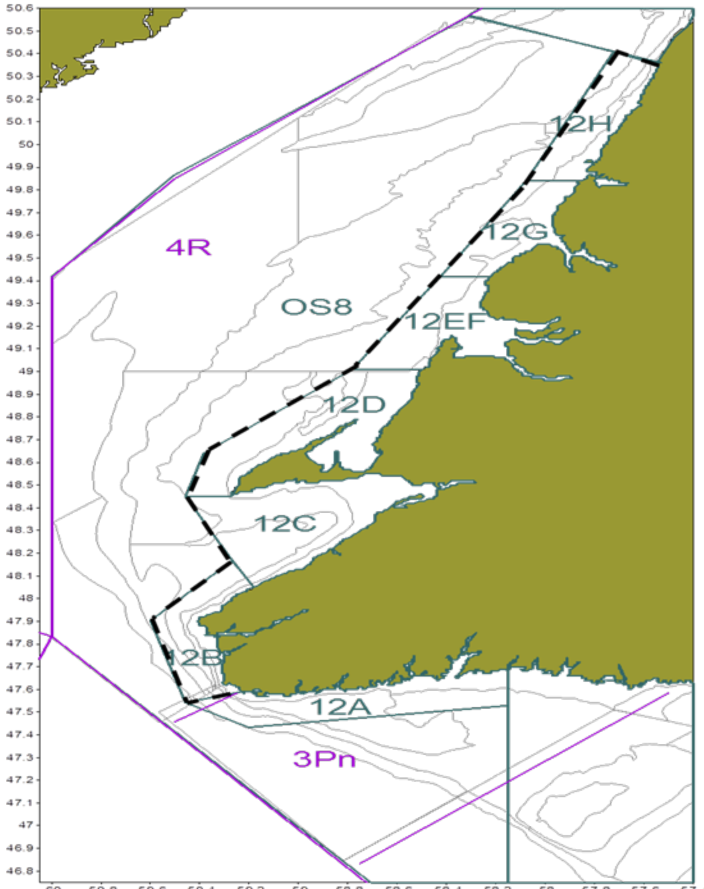

Figure 256: Map of Division 4R showing crab management areas and important bathymetric features. Dashed perimeter indicates inshore areas.

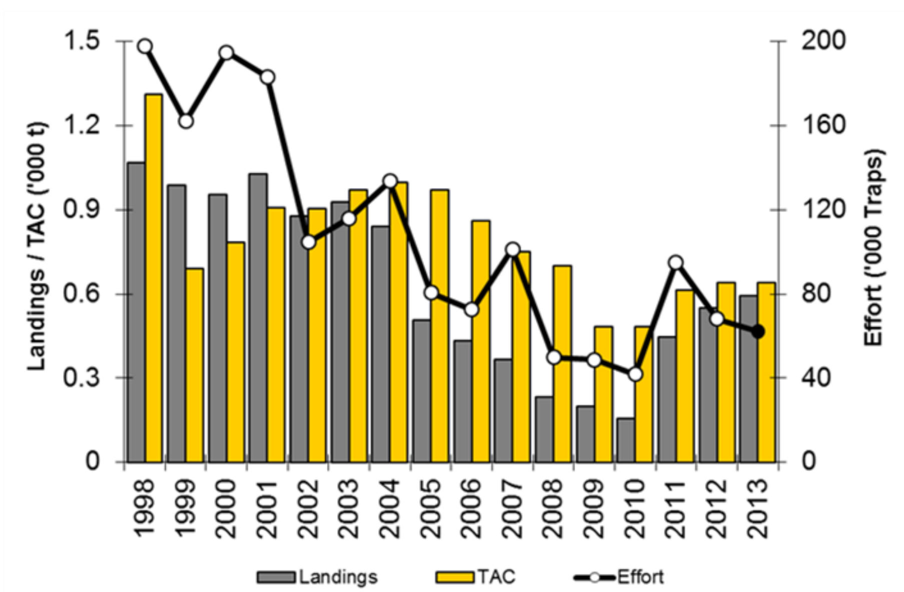

Figure 257: Trends in Div. 4R inshore landings, TAC, and fishing effort. (2013 effort preliminary).

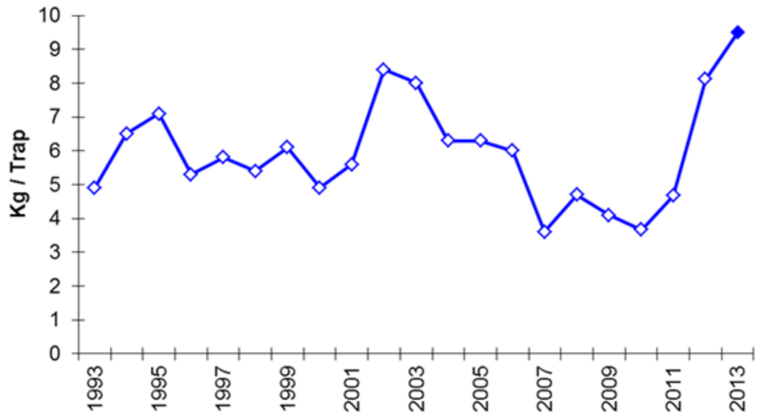

Figure 258: Trend in commercial logbook CPUE in the Div. 4R inshore fishery. (2013 estimate preliminary).

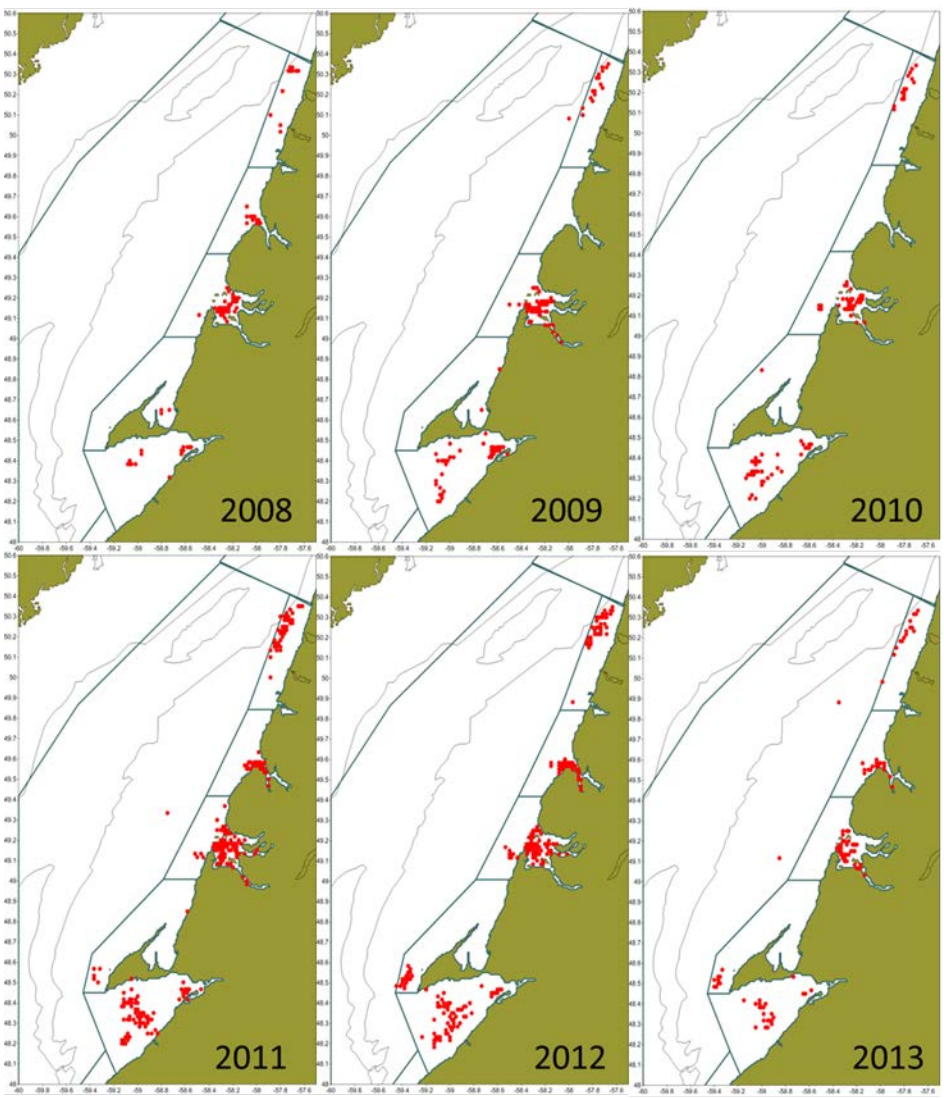

Figure 259: Spatial distribution of the Div. 4R inshore fishing effort by year.

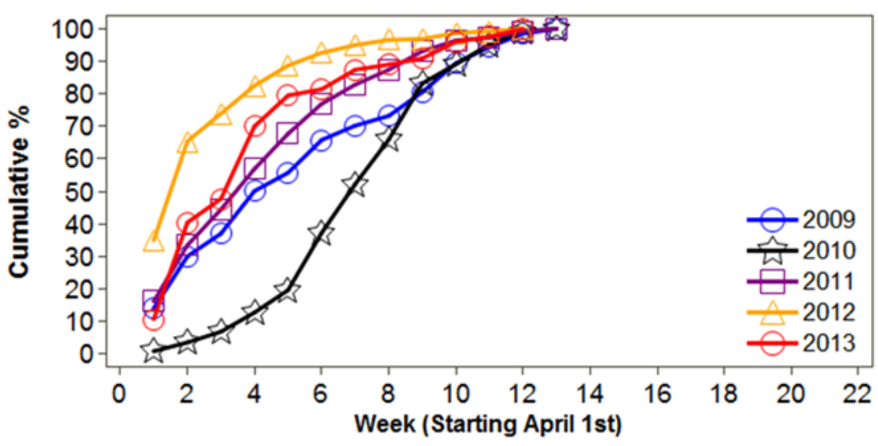

Figure 260: Seasonal trends in weekly fishing effort for Div. 4R inshore.

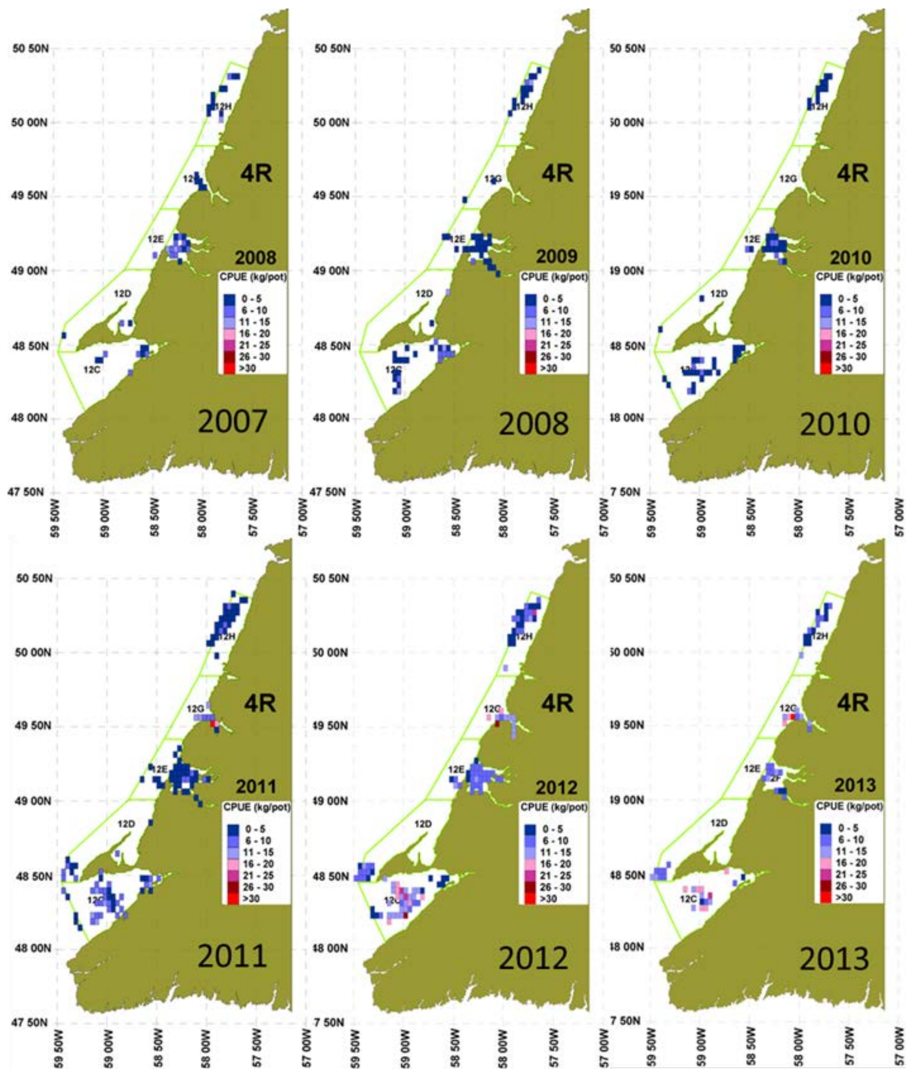

Figure 261: Spatial distribution of Div. 4R inshore logbook CPUE by year. (2013 estimates preliminary).

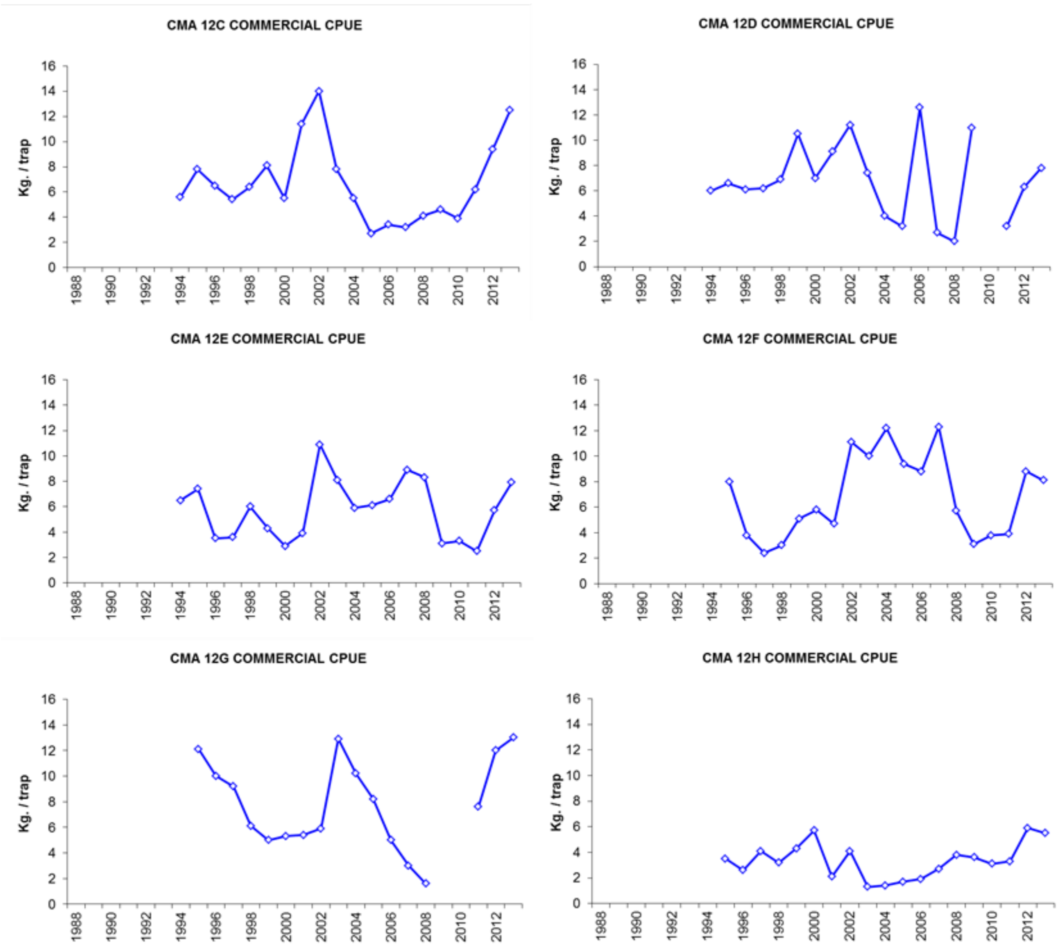

Figure 262: Trends in Division 4R inshore logbook CPUE by Crab Management Area. (2013 estimates preliminary).

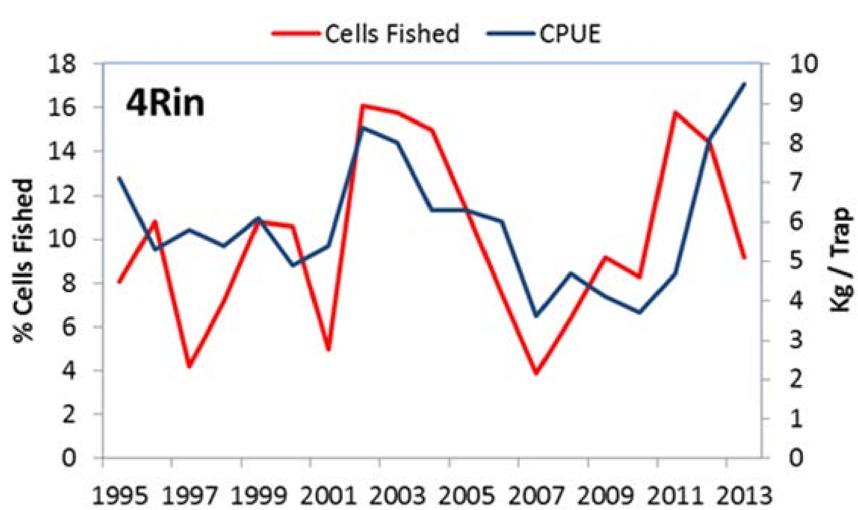

Figure 263: Trends in Division 4R inshore logbook CPUE vs. the percentage of 5' x 5' cells fished.

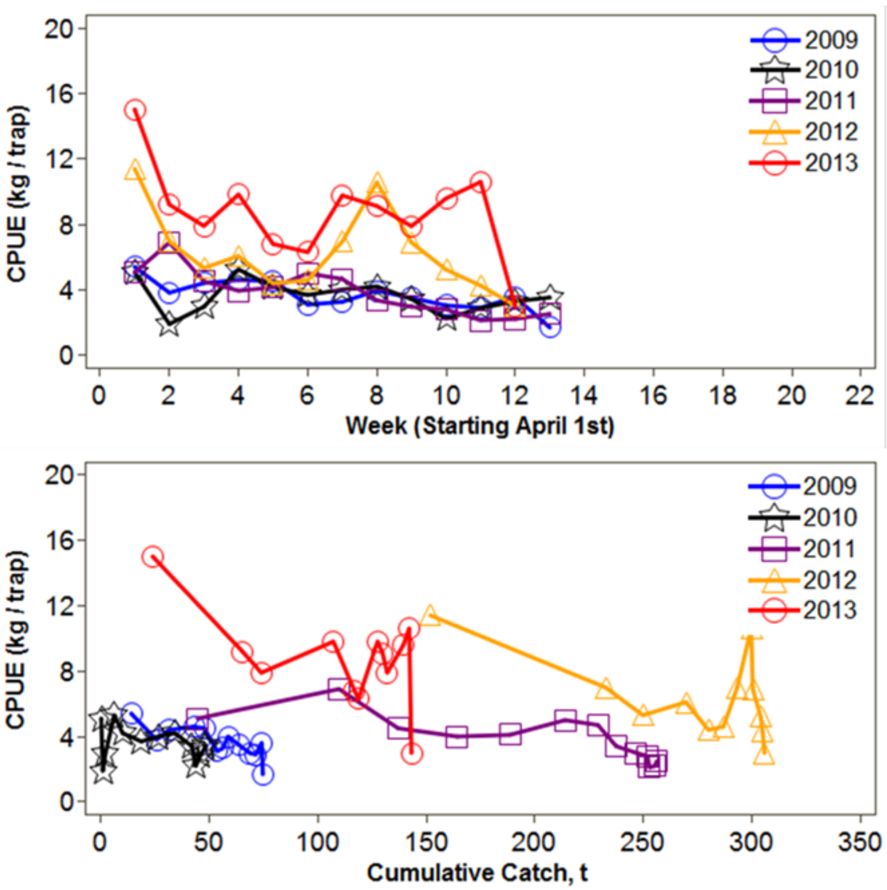

Figure 264: Seasonal trends in logbook-based CPUE for Division 4R inshore; by week (top), and in relation to cumulative catch (bottom).

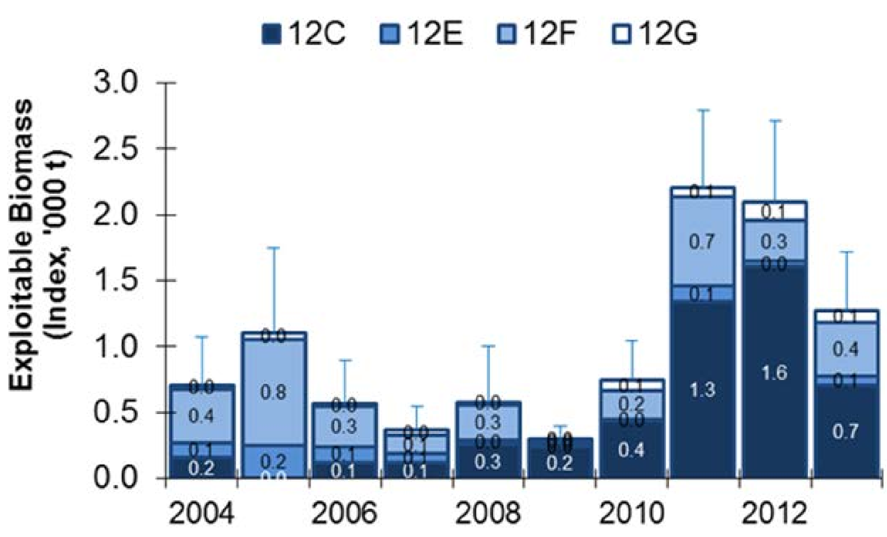

Figure 265: Exploitable biomass indices by management area from the CPS trap survey in Division 4R inshore.

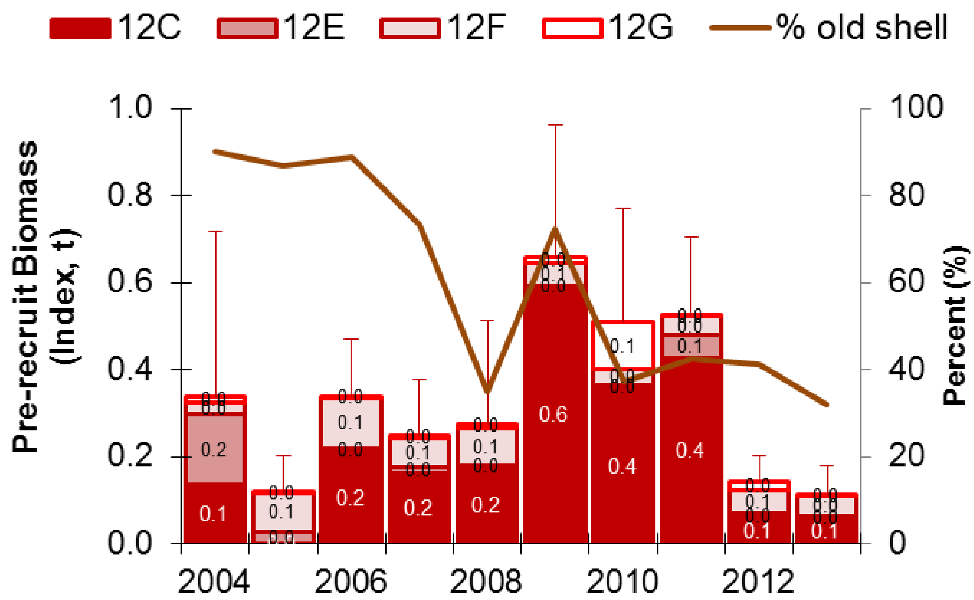

Figure 266: Pre-recruit biomass indices by management area from the CPS trap survey in Division 4R inshore.

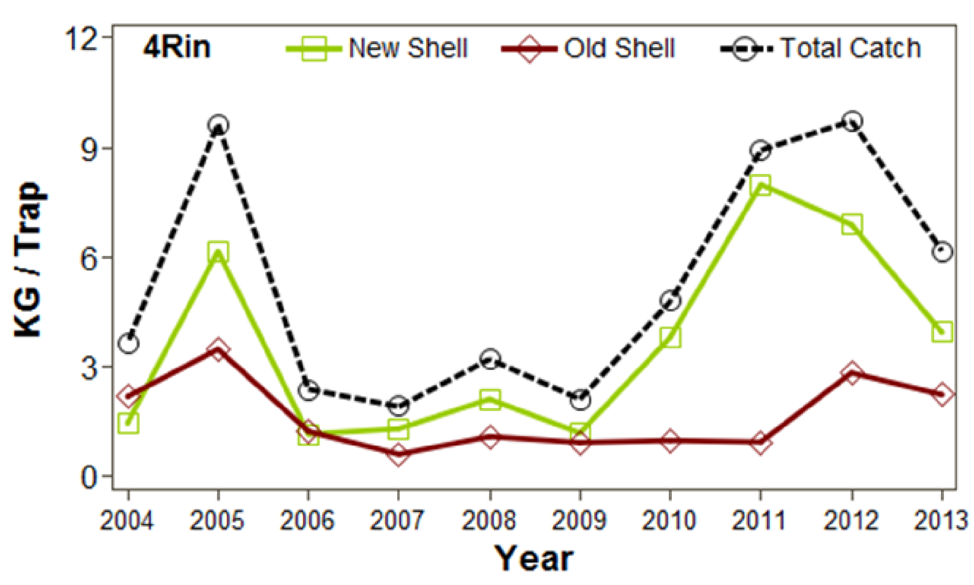

Figure 267: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in Division 4R inshore.

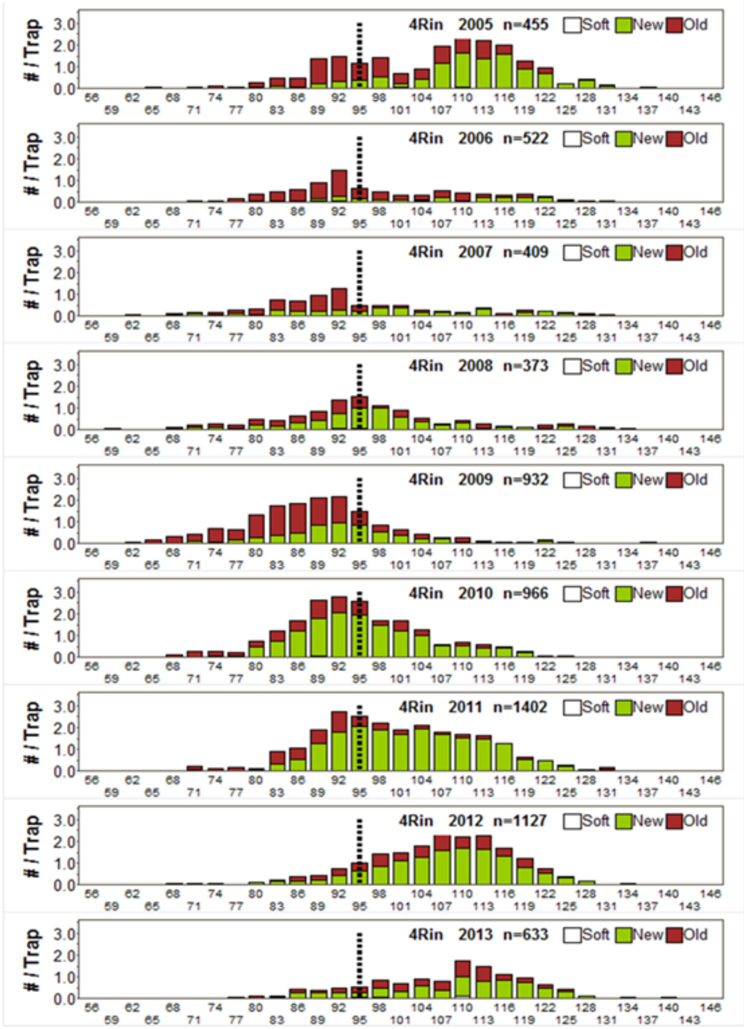

Figure 268: Trends in male carapace width distributions from large mesh traps at core stations in the Division 4R inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

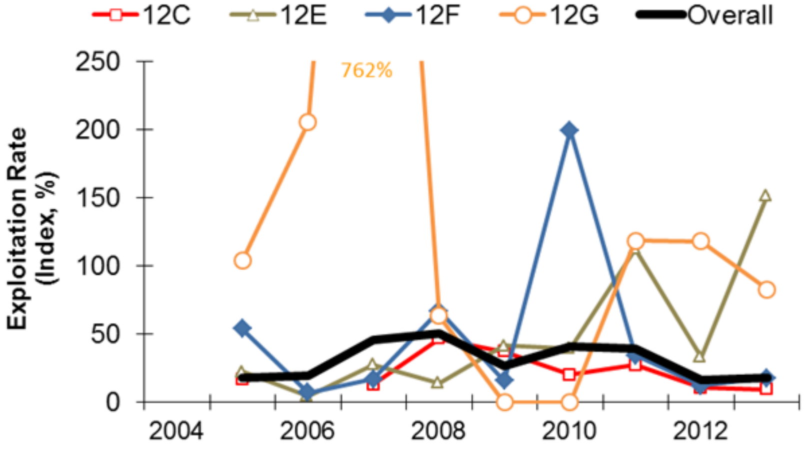

Figure 269: Exploitation rate indices by crab management area as well as overall for Div. 4R inshore based on the CPS trap survey.

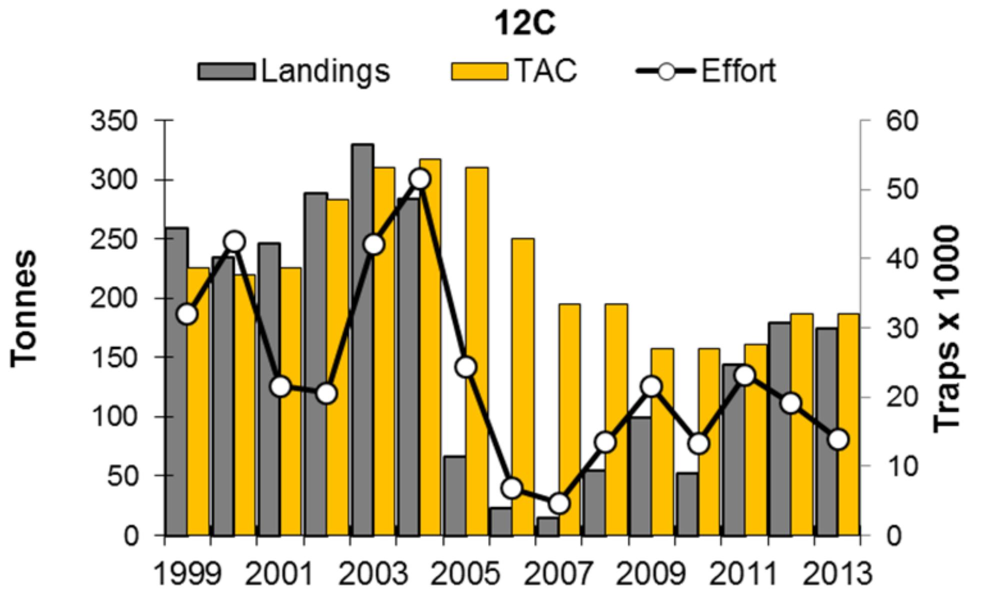

Figure 270: Trends in CMA 12C landings, TAC, and fishing effort. (2013 effort preliminary).

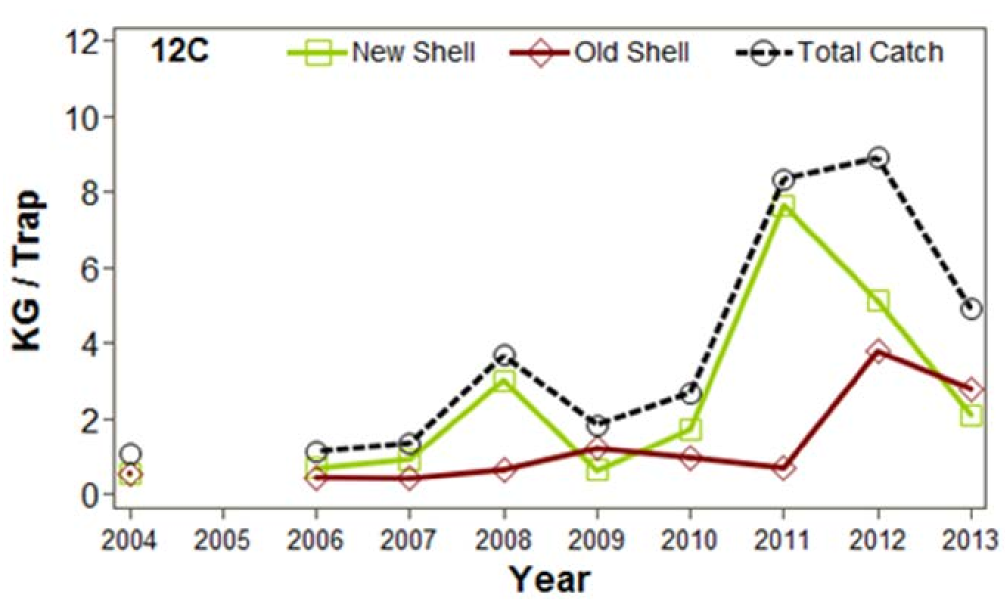

Figure 271: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 12C.

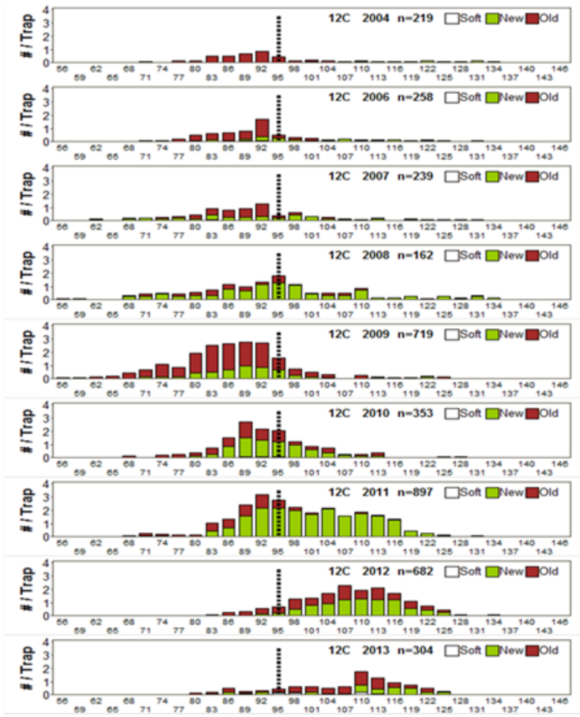

Figure 272: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 12C inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

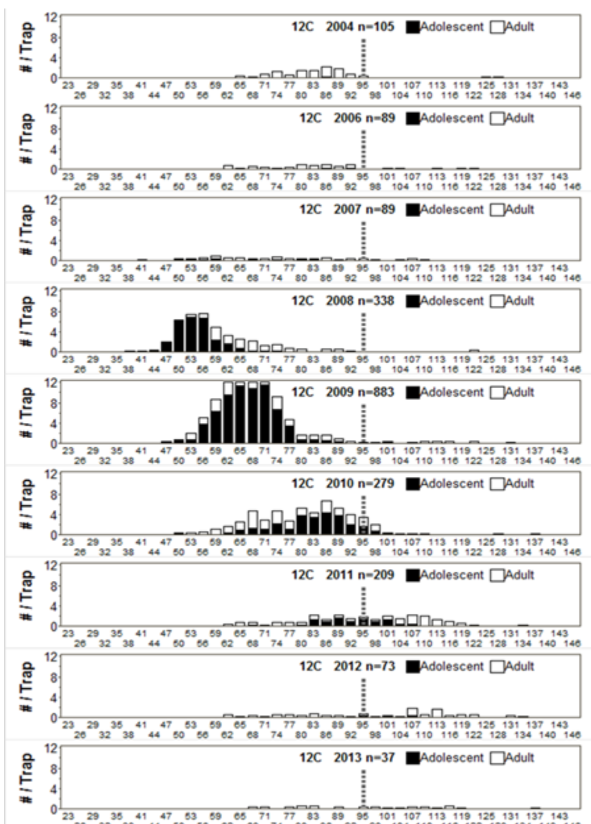

Figure 273: Trends in male carapace width distributions from small-mesh traps in CMA 12C from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

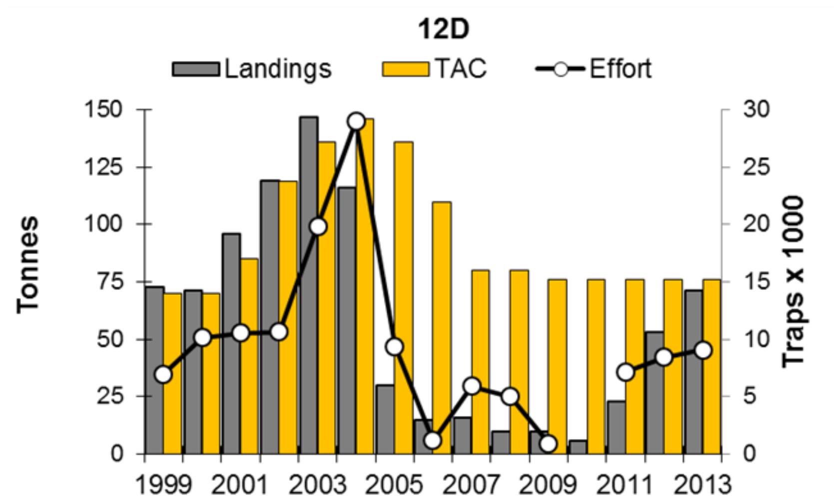

Figure 274: Trends in CMA 12D landings, TAC, and fishing effort. (2013 effort preliminary).

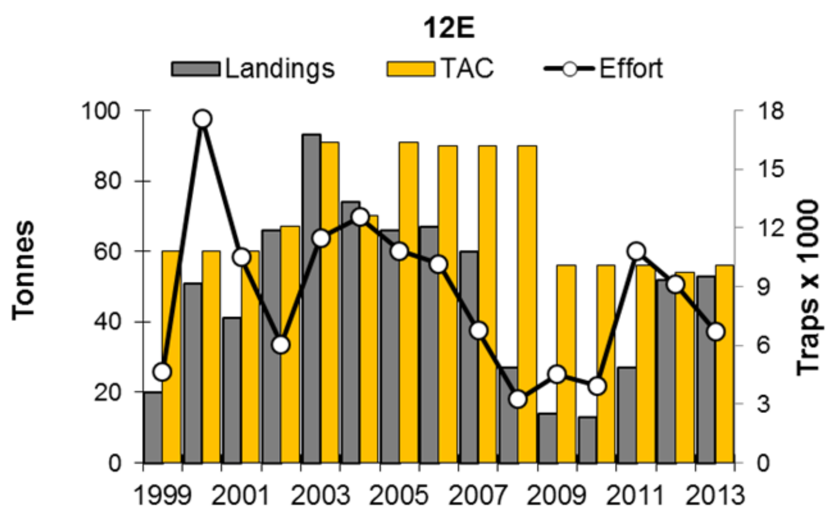

Figure 275: Trends in CMA 12E landings, TAC, and fishing effort. (2013 effort preliminary).

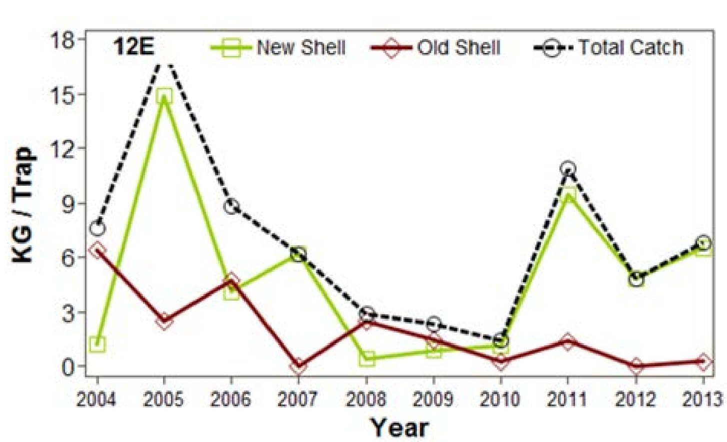

Figure 276: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 12E.

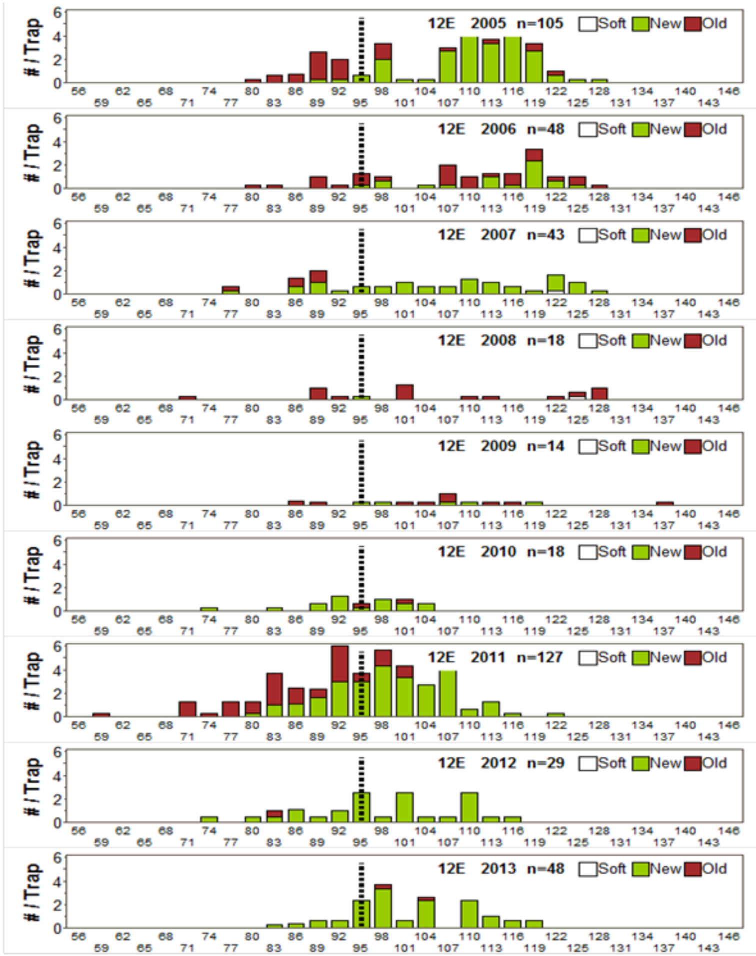

Figure 277: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 12E CPS trap survey. The vertical dashed line indicates the minimum legal size.

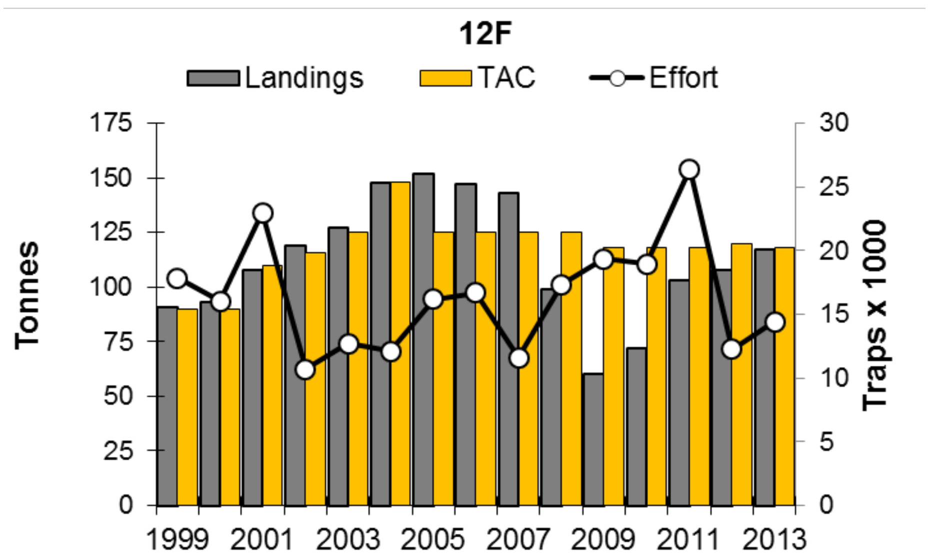

Figure 278: Trends in CMA 12F landings, TAC, and fishing effort. (2013 effort preliminary).

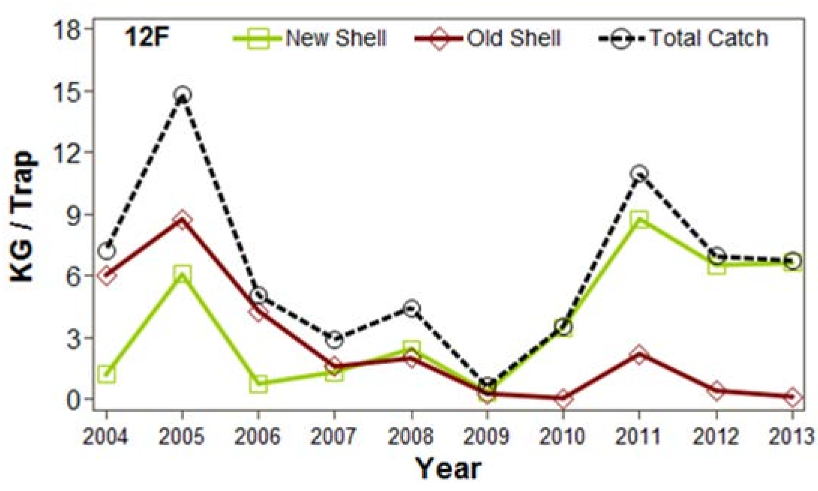

Figure 279: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 12F.

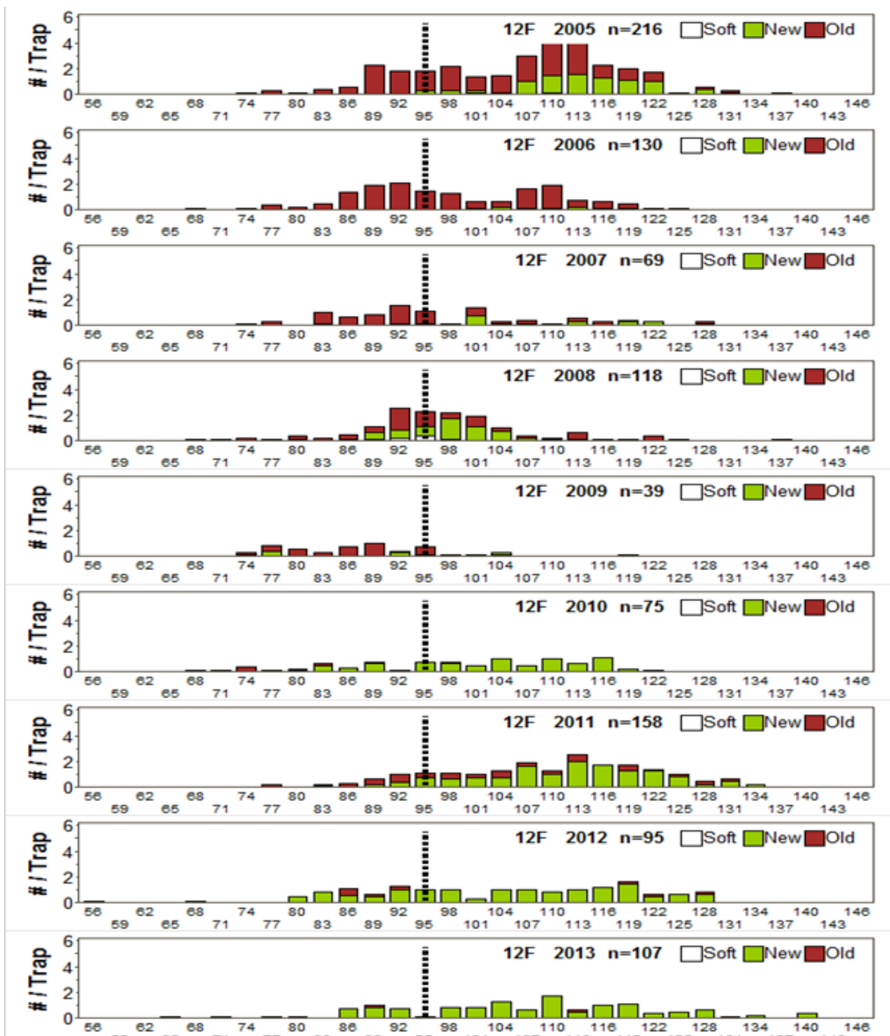

Figure 280: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 12E CPS trap survey. The vertical dashed line indicates the minimum legal size.

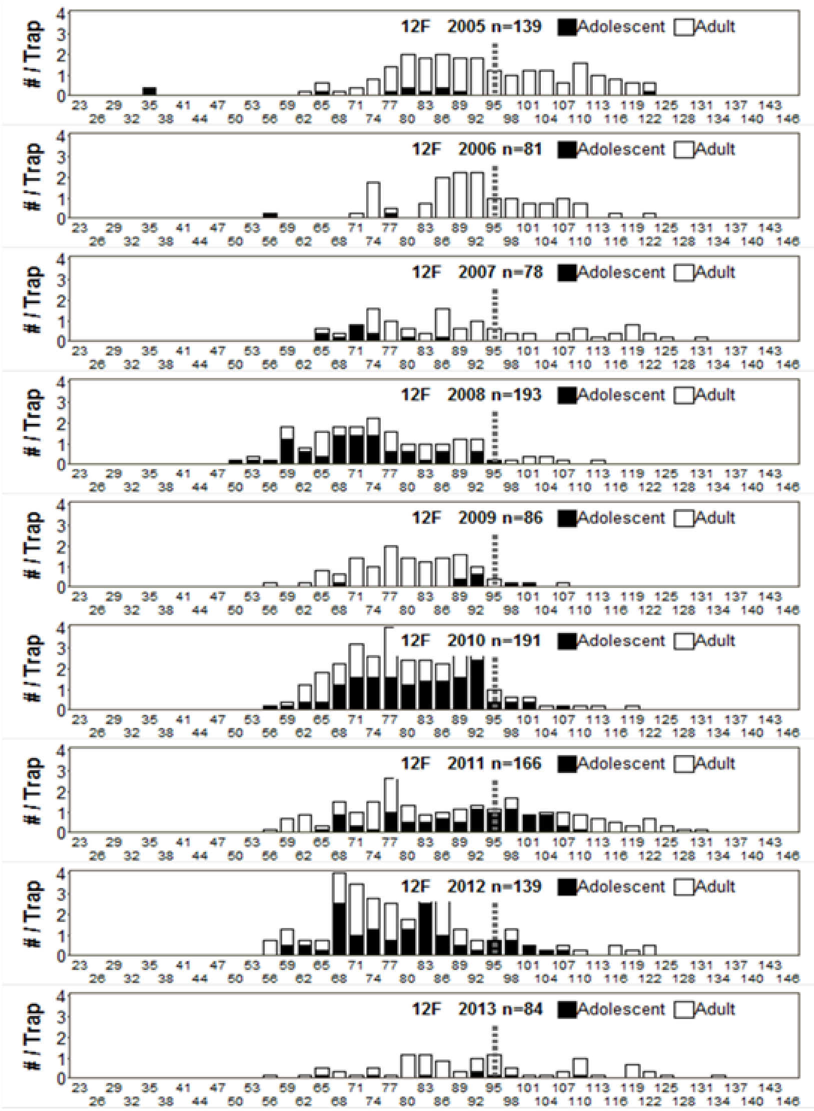

Figure 281: Trends in male carapace width distributions from small-mesh traps in CMA 12F from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

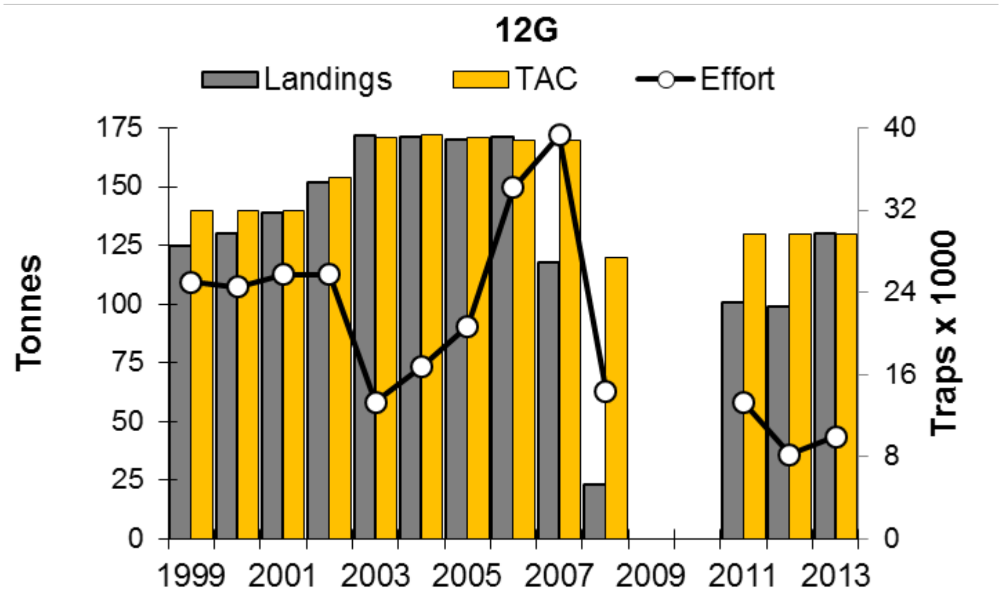

Figure 282: Trends in CMA 12G landings, TAC, and fishing effort. (2013 effort preliminary).

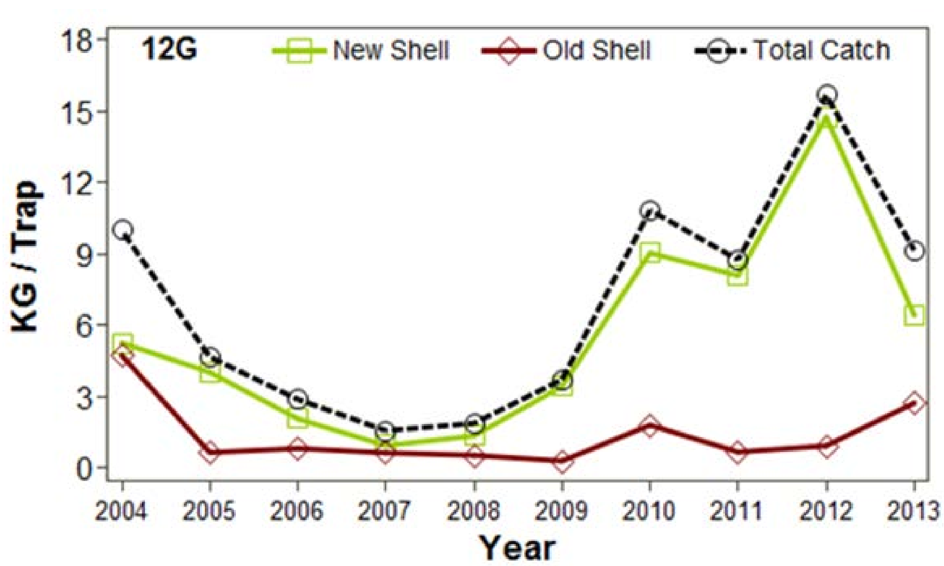

Figure 283: Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMA 12G.

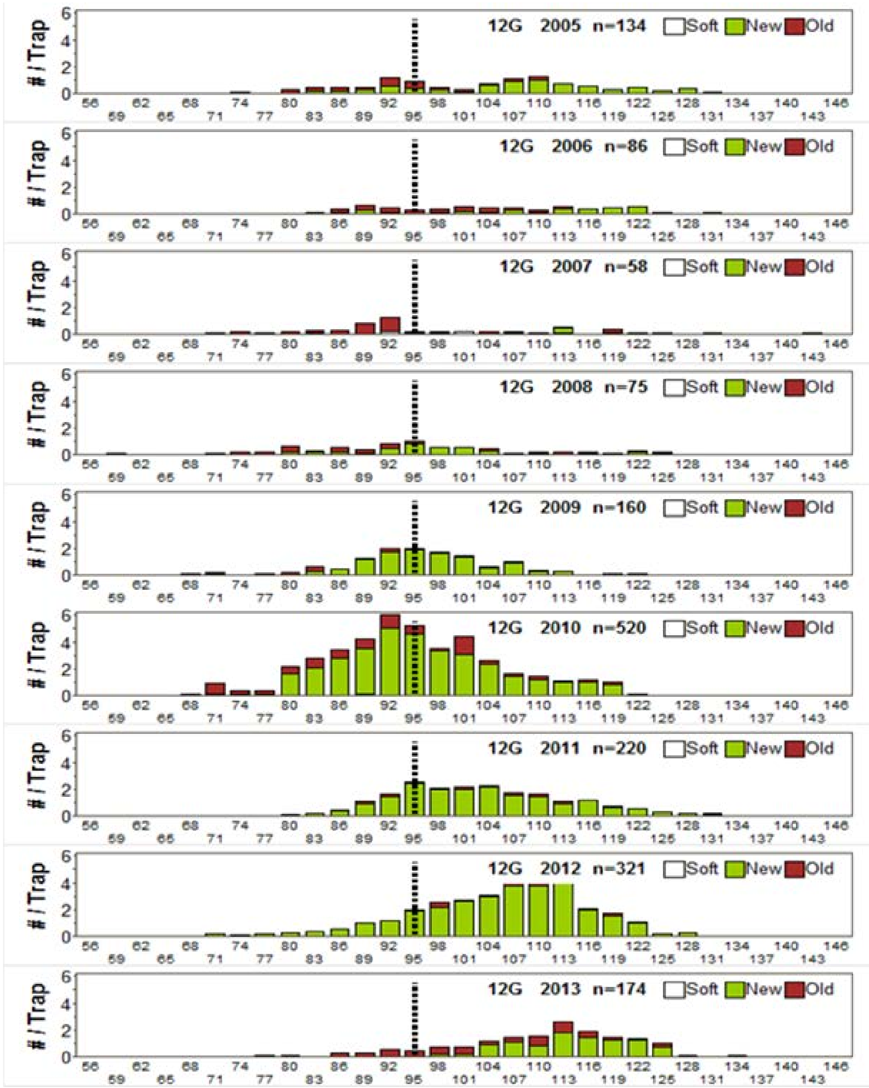

Figure 284: Trends in male carapace width distributions from large mesh traps at core stations in the CMA 12G CPS trap survey. The vertical dashed line indicates the minimum legal size.

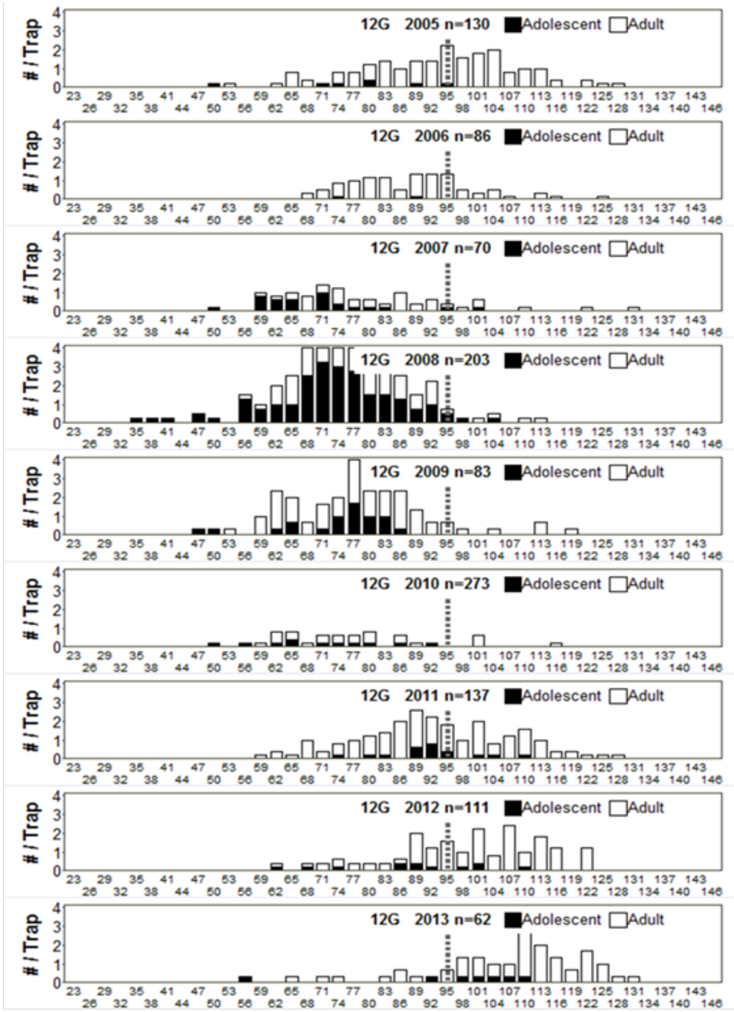

Figure 285: Trends in male carapace width distributions from small-mesh traps in CMA 12G from the CPS trap survey. The vertical dashed line indicates the minimum legal size.

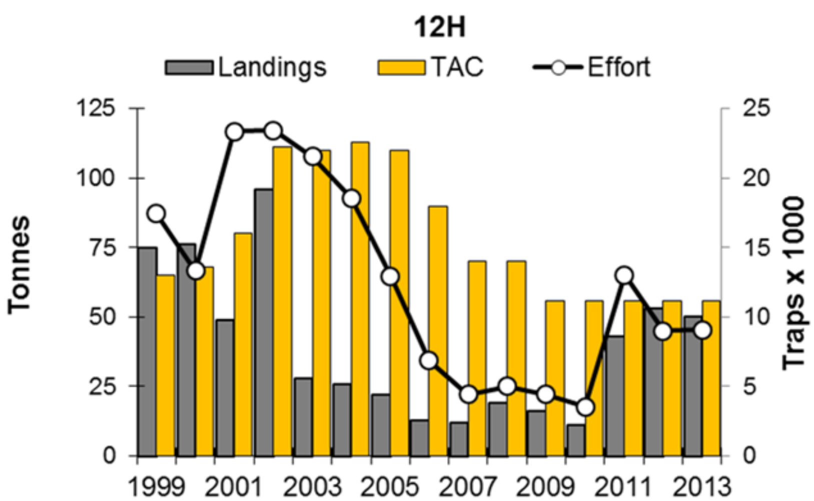

Figure 286: Trends in CMA 12H landings, TAC, and fishing effort.