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An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2015

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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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TABLE OF CONTENTS

ABSTRACT

Resource status was evaluated throughout Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 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. Data availability varied among divisions and between inshore and offshore areas within divisions. Trap and trawl surveys indicate that overall the exploitable biomass has recently declined to its lowest observed level, and Div. 3L now accounts for most of the biomass. Overall, recruitment has declined in recent years and is expected to decline further in the short term (2-3 years). The emergence of a pulse of small crabs, associated with cooling oceanographic conditions in the past three years, suggest a modest increase in recruitment within some NAFO divisions in about 5 to 7 years. However, a warm oceanographic regime coupled with relatively low abundance of young crabs for the past decade suggests overall weak recruitment in the long term. 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 2015

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 effectuée par des observateurs en mer, 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. La disponibilité des données varie en fonction des divisions ainsi qu'en fonction des zones côtières et extracôtières à l'intérieur des divisions. Les relevés au casier et au chalut indiquent que, dans l'ensemble, la biomasse exploitable a récemment atteint son plus bas niveau observé et que la division 3L représente maintenant la majorité de la biomasse. Dans l'ensemble, le recrutement a diminué au cours des dernières années et devrait continuer à diminuer à court terme (de deux à trois ans). L'émergence d'un grand nombre de petits crabes, associée au refroidissement des conditions océaniques au cours des trois dernières années, laisse supposer que certaines divisions de l'OPANO ont connu une légère augmentation du recrutement pendant environ cinq à sept ans. Toutefois, un régime océanographique chaud combiné à une abondance relativement faible des jeunes crabes au cours de la dernière décennie indiquent un faible recrutement général à long terme. 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 Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 2HJ3KLNOP4R. The information presented follows from a formal scientific assessment conducted during late February and early March 2016, focused upon determining changes in the exploitable biomass of crabs available to the 2015 fishery (commencing in April 2016), 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; Mullowney et al. 2016). 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 in the fishery is 95 mm carapace width (CW). This regulation excludes females from the fishery and ensures a portion of adult males remain available for reproduction.

Snow Crab in NL 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 (Figs. 1-2) with inshore and offshore portions of divisions separated where applicable, while in some areas divisions are combined. The approach partially conforms with Crab Management Areas (CMAs, Fig. 2), the spatial scale at which quotas are allocated, while accommodating different types and amounts of available information.

The NL Snow Crab fishery began in 1967 and was limited to NAFO Divs. 3KL until the mid-1980s. It expanded throughout Divs. 2HJ3KLNOP4R from the 1970s to 2000s, especially following groundfish stock collapses in the early 1990s, and is now prosecuted by several offshore and inshore fleet sectors. Management of the increasingly diverse fishery during the expansion years led to the development of the many quota-controlled areas, with about 3,500 active licence holders participating in the fishery in the mid-2000s. Resource declines and rationalization measures have led to reduced participation in recent years, with about 2,600 licence holders under enterprise allocation in 2015. 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 (Fig. 3), conducted during fall in Divs. 2HJ3KLNO and spring in Divs. 3LNOPs, 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 2016 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. The multi-species trawl surveys indicate the overall exploitable biomass has been lower since 2000 than it had been during the 1990s. Recently, it has declined since 2013 to its lowest observed level.

Trap and trawl surveys, as well as fishery logbooks, indicate that Divs. 3LNO has accounted for most of the biomass in recent years with the densest broad-scale aggregations of large Snow Crab occurring along the northern Grand Bank in the Downing Basin (Fig. 1). This cold area represents the most expansive area of high population productivity along the NL shelves.

Survey data also indicate that overall, recruitment is expected to decline in the short term (2-3 years), with the pre-recruit biomass index at its lowest level in all divisions in 2015. Although a pulse of small crabs emerged during 2013-14, which could contribute to modest improvements in recruitment in some divisions in about 5 to 7 years, a warm oceanographic regime coupled with relatively low abundance of young crabs for the past decade suggests overall weak recruitment in the long term. Declines in the exploitable biomass and fishery have recently occurred in the northernmost (Divs. 2HJ3K) and southernmost (Subdiv. 3Ps) divisions, although some recovery occurred in Div. 2J in 2015. Most recently, notable signs of decline occurred in the most productive Divs. 3LNO in 2015. Overall, resource declines are expected to continue in the forthcoming years.

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 Divs. 2HJ3KLNO and spring in Divs. 3LNOPs. The trawl used in these 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 1996-99, bi-annually from 2004-08, and annually from 2010-14. Snow Crab sampling during spring Divs. 3LNOPs surveys did not begin until 1996. 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. 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. The 2004 and 2014 Divs. 3LNO fall survey, and the 2006 Subdiv. 3Ps spring survey, were incomplete and have been omitted from analyses.

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 shell condition. Shell condition was assigned one of four categories:

- soft-shelled – these crabs had recently molted, have a high water content and are not retained in the fishery;
- 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;
- intermediate-shelled – these crabs last molted in the previous year and are fully recruited to the fishery throughout the current fishing season; and

- old-shelled – these crabs have been available to the fishery for at least two 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-shelled and subsequently old-shelled males.

Biomass and abundance estimates from trawl surveys were computed using an updated version of the ogive mapping technique of Evans (2000). A nonparametric estimate was made of the probability distribution for trawl catch (biomass or numbers) at any point in the area to be assessed. Total biomass or numbers were computed as the integral over the area of the mean value of the distribution. Confidence bounds were computed by bootstrap resampling from the distribution field. Biomass and abundance estimates were calculated for the total abundance of crabs, the abundance of small (< 40 mm CW) crabs, exploitable and pre-recruit biomasses for males, and the abundance of mature females. For spring surveys, the indices represent abundances or biomasses for the immediately upcoming (or on-going) fishery, whereas for 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 year, but would be fully recruited to the fishery in the following year.

The pre-recruit biomass index was calculated based on all adolescent (small-clawed) males larger than 75 mm CW caught in the surveys. 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 ratio of the exploitable to pre-recruit biomass index for each division was interpreted as an index of recruitment potential and compared to fishery discard levels to infer potential for soft-shell wastage in the fishery. 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.

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), as well as diel cycle. 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, as were the distributions of mature females and small crabs (< 60 mm CW).

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 Divs. 2HJ3KLNOP were not included in calculating the ratios because those areas were not surveyed in all years. Total annual mortality rates (*A*) were calculated as a two period moving average of stage-specific biomass indices of exploitable crabs:

$$A = \sum_{p=2}^{\bar{x}} 1 - (R/(r^{y-1} + R^{y-1}))$$

where,

R = residual biomass (shell conditions intermediate, old, very old)

r = recruitment (shell conditions soft, new)

y-1 = denotes survey of previous year

p = period (two years)

An index of spatial concentration of the exploitable biomass was developed from this assessment. The index was developed by ranking survey catches (by weight) in ascending order and calculating the cumulative percentage of survey tows necessary to capture the cumulative percentage of the catch for each division. A high percentage of tows relating to a low percentage of the total catch is interpreted as an aggregated biomass.

To examine size composition of males, STRAP (Smith and Somerton 1981) was applied to trawl survey catches grouped by 3 mm CW intervals to reflect total population abundance indices. In Divs. 2HJ3KLNOP, each size interval was partitioned, based on chela allometry, between juveniles plus adolescents (small-clawed) versus adults (large-clawed). For females, size frequency distributions were constructed for STRAP-estimated abundance of 3 mm CW groupings of immature versus mature animals, which was determined based upon visual observation of the abdomen.

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, NL Region of DFO. The dataset is normally incomplete in the current year due to a time lag associated with compiling data from the most recent fishery (Fig. 4). Logbook catch per unit of effort (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 (i.e. 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.

Annual logbook CPUEs were mapped for 10’ x 10’ (nautical minutes) cells, encompassing the entire fishery distribution each year, and used to qualitatively assess spatial fishery performance within each division. Further, the spatial extent of annual fishing effort of each division was calculated from commercial logbooks by assigning co-ordinates to 5’ x 5’ cells. 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.

The number of trap hauls and total catch from logbooks was calculated for each management area within assessment divisions on a weekly basis and compared against cumulative catch to assess the performance of the fishery against the level of removals. Cumulative weekly totals of effort expenditure were also used to assess the temporal distribution of the fishery each year.

ECOSYSTEM INDICES

Thermal habitat indices in each division were correlated against logbook CPUE at lags of best-fit, to assess the effect of thermal regime during early life history on future fishery success. Fishery CPUE indices are correlated with exploitable biomass indices from the trawl surveys but provide longer time series, thus comparisons with the thermal habitat indices focused on CPUE as the index of biomass. The index of bottom temperature (Fig. 5) was a three year moving average of the areal extent of cold bottom water distribution. Bottom temperatures used to make the habitat indices were isolated to shallow strata in each division (< 200 m in Div. 2J and 4R, < 300 m in Div. 3K and < 100 m in Divs. 3LNOPs) because settlement of early benthic stages occurs primarily in shallow areas such as the inshore and tops of 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 Divs. 2J3K, < 0°C in Divs. 3LNO and < 1°C in Subdiv. 3Ps. No thermal habitat index was calculated for Div. 4R due to insufficiency of data. Thermal habitat indices for Divs. 2J3K were derived using data from fall surveys, whereas those from Divs. 3LNOPs were derived using data from spring surveys and year-round data from Station 27, a frequently sampled oceanographic station located on the approach to the harbour of St. John’s, NL.

Indices of predation on crab were introduced into this assessment. Estimates of crab consumed by predators were generated by combining three sources of information: biomass estimates for predators, estimations of total food consumption by unit of biomass for those predators, and fractionation of that consumption using diet compositions to define the proportion of crab in the diet. Each one of these steps involves a set of assumptions and generalizations and the resulting index is not absolute but intended to generate a plausible envelope for the order of magnitude for that consumption.

Among all fish species recorded in DFO RV surveys, only those belonging to the piscivores and large benthivores functional groups were considered predators of crab (due to gape limitation of smaller fishes), and hence used in the estimations of consumption. The total biomass of predators was approximated using DFO multi-species trawl survey biomass estimates; this approach assumes that surveys properly capture the relative composition of the fish community. However, as these estimates were not corrected for gear catchability they likely reflect minimal estimates of predator biomass.

Estimations of consumption rates per unit of biomass were derived using three different approaches:

1. a bioenergetic-allometric consumer-resource modelling framework, which is based on empirical allometric scaling relationships (Yodzis and Innes 1992),

a multivariate statistical model (Palomares and Pauly 1998) and

by assuming daily rations as a percent fraction of body weight. We assumed two daily ration scenarios of 1% and 2% based on typical literature reports (Macdonald and Waiwood 1987, Richter et al. 2004).

Strictly speaking, these approaches estimate food requirements, not actual food consumption. The implicit assumption here is that all predators actually achieve their food requirements. Using these alternative estimates of consumption rates together allows the development of an envelope for consumption that likely contains the actual consumption rates.

Data on diet composition is only available for few recent years and for a small subset of crab predators (American plaice, cod and turbot). The overall fraction of crab in their diets, as well as the relative contribution by these species to the overall biomass of the entire crab predators assemblage were used to approximate the fraction of crab consumed by all piscivore and large benthivore fishes. Since these predator species are a major component of the biomass of the corresponding fish functional groups, using their diets to represent the functional groups is a reasonably proxy, but the assumption of a constant diet composition in the earlier part of the time series (where we lack of diet composition information) is a less robust (but unavoidable) assumption. Point estimates of Snow Crab consumed by all piscivore and large benthivore fishes, as well as just by American plaice, cod and turbot were presented along with confidence intervals representing the full range of estimated consumption values. As consumption rates cover a large range of options, some estimates are likely above reality while others are likely below reality. Nonetheless, trends in predation of Snow Crab are likely reliable.

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 (1995-2015), but at-sea sampling data have only been collected since 1999. Levels of sampling are generally highest in offshore Divs. 3KLNO due to high observer coverage in those areas (Fig. 7). Sampling has been consistently low in inshore CMAs and virtually absent throughout Divs. 2H and 4R. For inclusion in the assessment, a minimum standard of 4 weeks non-consecutive coverage during the fishery was required in any given management area. 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 Divs. 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 (10 x 7 na. mi.) when the percentage of soft-shell crab reached 20%. This was reduced to 15% for offshore Divs. 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, NL of DFO. 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 (i.e. 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 (Divs. 3KLNOP4R).

INSHORE DFO TRAP SURVEYS

Data were available from inshore Div. 3K trap surveys that were carried out in White Bay (CMA 3B) and Green (CMA 3C) and Notre Dame Bays (CMA 3D) during 1994-2015 (Fig. 8). There were no surveys in either bay in 2001, and no survey was conducted in Notre Dame Bay in 2009 or 2011. The surveys have consistently occurred in late August to mid-September and occupy five of the inshore fall multi-species survey strata with set locations randomly distributed within each stratum, and stratum-specific set allocations weighted by area. Each set includes six traps, with crabs sampled from three large-mesh (commercial, 135 mm) and three small-mesh (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 (1979-2015) within Div. 3L (Bonavista and Conception Bays) and a trap survey within Subdiv. 3Ps (Fortune Bay, 2007-15) (Fig. 8). 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 historically the Bonavista and Conception Bay surveys covered only the deepest stratum in each bay where the commercial fishery was thought to concentrate. However, shallower strata have been occupied in the surveys in the past three years. Further, Trinity Bay (CMA 6A) has been occupied with trap surveys during August for each of the past three years. Data on the expanded areas of Bonavista and Conception Bays, as well as Trinity Bay, were not used in the present assessment due to short time series. All surveys utilized commercial (135 mm) and small-mesh (27 mm) traps in each set. 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.

COLLABORATIVE POST-SEASON TRAP SURVEY

Data were examined from industry-DFO Collaborative Post-Season (CPS) trap surveys in Divs. 2J3KLOPs4R (Figs. 9-11). 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. 1st 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. 9). At each station, six (inshore) or ten (offshore) commercial (135 mm mesh) crab traps are set in a fleet. 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-mesh traps are included at selected stations to collect information on pre-recruits and females (Fig. 11). Biological sampling of males from small-mesh 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-mesh 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. 9) 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. 9). The depth-based stratification scheme closely conforms to all stations occupied in inshore and offshore management areas of each division since 2004. The boundary of each stratum extended 5 na. mi. 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, 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), analogous 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 76-94 mm CW males from this survey was introduced in the previous assessment and was 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

BROAD-SCALE TRENDS: DIVISIONS 2HJ3KLNOPS4R

Fishery

The fishery began in Trinity Bay (CMA 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 Divs. 3KL (Figs. 1-2) 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 licence holder resided. During 1982-87, 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 scale of the fishery has been considerably increased in all divisions. 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 divisions.

Licences 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 licences in 2003 and exploratory licences in the offshore were converted to full-time licences in 2008. There are now several fleet sectors and about 2,600 licence holders under allocation, with several rationalization initiatives gradually reducing the number of active participants in recent years from about 3,500 in the mid-2000s. In the late 1980s, quota control was initiated in all management areas. All fleets have designated trap limits, quotas, trip limits, fishing areas within divisions, and differing seasons. Mandatory use of the electronic 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 (Divs. 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, but have not occurred in the past couple years.

Historically, most of the landings have been from Divs. 3KLNO. Landings for Divs. 2HJ3KLNOP4R (Table 1, Fig. 12) most recently peaked at 53,500 t in 2009 and have since gradually declined to 47,000 t in 2015. Divs. 3LNO has accounted for a steadily increasing percentage of the landings in recent years, from about half in 2009 to 80% in 2015.

Effort, as indicated by estimated trap hauls, approximately tripled throughout the 1990s as the fishery grew (Dawe et al. 2004). Spatially, the fishery distribution pattern has since remained broad-based, but there have been significant changes in some divisions in recent years (Fig. 13). In the north, effort in Div. 2H and the northernmost portion of Div. 2J has gradually dissipated since 2011, with Div. 2H virtually abandoned in the past three years. In Div. 3K, effort greatly expanded in 2009 and remained relatively intense until 2012, but has dissipated since then, particularly in the outer-most fishing grounds in the northeastern portion of the division. The effort distribution pattern in Div. 3LNO has been relatively fixed since 2010, while in Subdiv. 3Ps expansion in spatial coverage of the fishery has occurred in the southernmost fringes in recent years and effort distribution became greatly reduced in Fortune Bay (CMA 11E, Fig. 2) in 2015. In Div. 4R, effort had become increasingly contracted and highly aggregated throughout the 2000s, but the fishery has grown in recent years with heavier concentrations of effort occurring inside the restricted confines of the inshore management areas as well as in localized aggregations throughout the offshore since 2010.

The timing of the fishery has differed both across and within some divisions in recent years (Fig. 14). Delayed starts have occurred in Divs. 2HJ, 3K, and 4R in the past two years. These delays reflect heavy ice conditions, particularly in Divs. 2HJ and 3K. However, these delays have not resonated to prolonged seasons, with the bulk of effort expended by about the same time each year in each division for the past five years. Generally, the fishery begins in early April for all but Divs. 2HJ. It normally finishes earliest in Div. 4R (i.e. week 12 = early July), runs until about mid-July (i.e. week 14) in Divs. 3K, 3L Inshore, and Subdiv. 3Ps, and is completed by late July (i.e. week 16) in Divs. 2HJ and 3LNO Offshore.

Logbook CPUE has shown a great deal of variability both across and within divisions over the past twenty-five years (Fig. 15). In recent years there have been considerable spatial changes in fishery CPUE. In 2008-2010, catch rates were at relatively high levels in Divs. 2HJ, 3K, and Subdiv. 3Ps. All three divisions have undergone declines since then, with only Div. 2HJ experiencing a recovery in recent years. Conversely, catch rates have improved in Divs. 3L Inshore, 3LNO Offshore, and 4R3Pn since 2009 and been near all-time highs in the past three to four years.

The improvement in catch rates in Div. 2HJ in the past two years reflects increases in both the Cartwright and Hawke Channels (Fig. 1), the two dominant centres of fishing activity (Fig. 16). In Div. 3K, fishing has been especially poor at < 5 kg/trap in Green Bay (CMA 3C, Fig. 2) in the past two years, but few areas have experienced good catch rates. One exception to the poor fishing throughout Div. 3K in recent years is White Bay (CMA 3B, Fig. 2), where catch rates have been relatively strong with most areas of the bay experiencing CPUEs ranging from about 10-15 kg/trap in the past three years. Most of Divs. 3LNO has experienced very high catch rates, above 15 kg/trap, since 2012. However, some areas are beginning to show signs of decline. For example, catch rates along the Div. 3N slope edge have decreased markedly during the past two years and localized aggregations of effort in shallow portions of the western Grand Bank in CMA 8B (Fig. 2) have performed relatively poorly since 2010. In Subdiv. 3Ps, the decline in fishery CPUE has been both precipitous and broad-based since 2010. No areas have yielded even moderate catch rates in the past two years, with CPUE < 5 kg/trap everywhere. In Div. 4R, catch rates in the offshore (CMA OS8, Fig. 2) have been perpetually low, while all inshore bays have experienced improved catch rates, in the order of 5-15 kg/trap, during the past three years. Overall, with some minor exceptions, the pattern suggests the fishery remains strongest in Div. 3L, consistent with the CPS trap survey (Fig. 11).

Although catch rate estimates are preliminary from both VMS and logbook datasets, VMS and observer CPUE reflect and verify trends in logbook CPUE indices in offshore portions of all divisions (Fig. 17).

Trends in CPUE tend to relate negatively to spatial coverage of the fishery, which reflects the level of searching and prospecting of grounds undertaken by harvesters in any given year. The increase in CPUE in Div. 2J in the past few years has been associated with the typical reduction in spatial extent of the fishery (Fig. 18). With a very low level of about 8% of the potential grounds occupied by the fishery, the pattern suggests that the localized pockets of distribution characterizing the Div. 2J fishery are performing well. In Div. 3K, the expected negative relationship between CPUE and areal extent of the fishery has eroded in recent years, with spatial coverage declining while catch rates are low. This is a point of concern and is interpreted to reflect abandonment of poorly performing fishing grounds and potential contraction of the biomass. Such patterns do not exist in Div. 3L Inshore or Divs. 3LNO Offshore where the areal extent of the grounds fished has not changed over the past decade. Noteworthy is the particularly intense coverage in Div. 3L Inshore, where 50-70% of the potential grounds are covered by the fishery each year. In Subdiv. 3Ps, the areal extent of fishing had increased during 2010-14 as fishery catch rates declined. Like Div. 3K, the abrupt decrease in spatial coverage of the fishery in 2015 while catch rates declined to a historical low likely reflects abandonment of some poorly performing areas. In Div. 4R, the expected negative relationship between fishery catch rates and spatial coverage has never occurred. The positive relationship between the two indices reflects a ‘fishery of opportunity’, whereby interest in the fishery increases when catch rates are high and diminishes as catch rates decrease. With fishery catch rates generally improving in recent years, the areal extent of the fishery has also increased with about 10-12% of the potential grounds occupied since 2011.

Observer data indicate that the improvement in fishery CPUE in Div. 2J in 2015 was predominately due to an increase in recruitment into the exploitable biomass, as seen by a tripling of catch rates of new-shelled crabs (Fig. 19). Conversely, the low and declining catch rates in offshore portions of Div. 3K reflect declining and low levels of recruitment. In Divs. 3LNO Offshore, recruitment has been more steady-state and the residual biomass (old-shelled crabs) has been high in recent years. In Subdiv. 3Ps, both the recruitment and residual components of the biomass have decreased by more than half since 2011 to historical lows in 2015.

Biomass

The overall exploitable biomass has declined since 2013 to its lowest observed level. Trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-98, Fig. 20). It declined from 1998-2004 and varied without trend until 2013. However, both the trawl and CPS trap survey indices show that the exploitable biomass has declined further since 2013 (Fig. 20) and is presently at or near time series lows in all divisions.

Consistent with fishery data, the CPS trap survey indicates that the majority of the biomass is in Div. 3LNO, with over 80% of the estimated biomass occurring in Div. 3LNO in 2015.

Despite both surveys indicating the biomass had decreased in recent years, there are some spatial inconsistencies within the overall stock delineation. For example, the exploitable biomass indices did not agree in Div. 2HJ in 2015, with the trap survey increasing and the trawl survey decreasing to near its lowest level. Similarly, there was no change in the trap survey index in Div. 3LNO in 2015, while the trawl survey index declined by more than half to a very low level. The two indices have agreed throughout the time series in Div. 3K and Subdiv. 3Ps, although there was no trap survey in Subdiv. 3Ps in 2015.

The disagreement between indices in Divs. 2HJ and 3LNO reflects differences in spatial coverage of the two surveys. The restricted spatial coverage of the CPS trap survey essentially measures the exploitable biomass on primary fishing grounds and is an analog of fishery CPUE. It closely agrees with fishery CPUE in each division, reflecting the occupation of like grounds with like gear. The spatially all-encompassing trawl survey detects changes in the biomass prior to them being detected in the CPS trap survey (and/or fishery). This lag effect between measuring signals of change in the biomass likely reflects the inclusion of marginal grounds in the trawl survey. The extended CPUE time series is correlated against the trawl survey indices in forthcoming division-specific analyses of this document, demonstrating the lag effect between the two biomass indices. The lack of a trap survey in Subdiv. 3Ps in 2015 reflects poor resource status. The survey operates under a compensation scenario of ‘quota-for-survey’ whereby harvesters are allocated additional quota in the following season for conducting the survey. Resource shortages and the perception that additional quota would not be catchable led to abandonment of the survey in 2015.

The exploitable biomass has become highly concentrated into localized areas in all divisions. In 2015, unusually high percentages of 70-88% of trawl survey tows captured no exploitable crabs in Divs. 2HJ, 3K, and 3LNO (Fig. 22). In Subdiv. 3Ps, an unprecedented 95% of tows captured no exploitable crabs. In Div. 2HJ, the exploitable biomass has become near-exclusive to the Cartwright and Hawke Channels (Fig. 22), where fishery CPUE has improved in recent years (Fig. 16) and the CPS trap survey increased in 2015 (Fig. 9). Fringe areas are virtually void of exploitable crabs in recent years, unlike historically (i.e. see 2008-09 in Fig. 22). The same scenario occurs in Divs. 3LNO where the trawl survey captured a significant amount of exploitable crabs along the northern portion of the Grand Bank in 2015 (Fig. 22). However, fringe areas in the center of the bank and along the slope edges were virtually barren of exploitable crabs in the survey, contributing to a major decline in the overall exploitable biomass index. Meanwhile, fishery CPUE remains strong along the northern portion of the Grand Bank (Fig. 16) and the near-exclusivity of the CPS trap survey to that area (Fig. 11) is not allowing it to capture the signal of a declining biomass on the Grand Bank as a whole. In Div. 3K, exploitable crabs have become localized in a linear pattern along the western and central portions of the Funk Island Deep (Fig. 2) and furthest offshore areas were virtually void of crabs in the 2015 survey, consistent with the abandonment of the fishery from this area (Fig. 16). In Subdiv. 3Ps, the distribution of survey catches of exploitable crabs has declined precipitously since 2009 and the entire area was virtually void of exploitable crabs in the 2015 trawl survey (Fig. 23).

Recruitment

The multi-species trawl survey shows a broad-scale decline in recruitment in recent years, with overall recruitment at or near its lowest observed level in all divisions in 2015. This is evident by decreases in the biomass of new-shelled crab in survey catches in all divisions (Fig. 24). Reductions in the residual biomass, comprised of intermediate and old-shelled crabs, were less pronounced. The CPS trap survey also reflects declining levels of recruitment into the exploitable biomass in recent years (Fig. 25). With the exception of Divs. 3LNO, the catch rates of new-shelled crabs were at or near their lowest observed levels in all divisions in 2015. The residual biomass, on primary fishing grounds targeted by the survey, was relatively high in Div. 2J, Div. 3L Inshore, Divs. 3LNO Offshore, and Div. 4R, while it was at its lowest observed levels in Div. 3K and Subdiv. 3Ps. This broad-scale decline of recruitment into the exploitable biomass has been anticipated and reflects a lack of productivity in the stock since the early to mid-2000s, with further reductions anticipated in the coming years (Mullowney et al. 2014).

Modal progression in size frequency distributions from large-mesh traps in the CPS survey suggest a pulse of recruitment that was approaching legal-size in Div. 2J in 2012, with a mode centered at 89 mm CW, has subsequently entered the exploitable biomass and is now beginning to grow old, with large old-shelled crabs dominating the catch in 2015 (Fig. 26). Meanwhile, in Div. 3K, no such recruitment pulse has entered the exploitable biomass in recent years and the abundance of crabs of all sizes has steadily decreased since 2012 to a time series low in 2015 (Fig. 27). In Div. 3L Inshore, the CPS survey indicates little recruitment into the exploitable biomass since about 2011, with old-shelled crabs dominating the large-mesh size frequency distributions in recent years (Fig. 28). The abundance of all legal-sized crabs decreased in 2015 indicating mortality on these old-shelled populations may now be increasing. In Divs. 3LNO Offshore, the size frequency distributions from large-mesh pots in the CPS survey suggest that a slow moving recruitment pulse that approached and entered the exploitable biomass from about 2008-2013, evident by modal progression of new-shelled crabs, has now fully contributed to the exploitable biomass as large old-shelled crabs have dominated the population in the past two years (Fig. 29). Like Div. 3L Inshore, it appears catch rates of most size groups of legal-sized crabs have declined in the past two years, inferring mortality on the residual biomass may now be increasing. Meanwhile, in Subdiv. 3Ps, the CPS survey size frequency distributions show that there has been little recruitment into the exploitable biomass since 2012 and that the resource is severely depleted (Fig. 30). In Div. 4R, like most other divisions, the CPS survey size frequency distributions suggest little recruitment into the exploitable biomass in the past two years, with the population dominated by large old-shelled crabs (Fig. 31).

Recruitment is expected to decline further in the next 2-3 years, as the pre-recruit biomass index was at or near its lowest observed level in all divisions in 2015 (Fig. 32). This decline in the pre-recruit biomass is broad-scale, with few pre-recruit crabs captured anywhere in multi-species trawl surveys in the past three years (Figs. 33-34). The short-term prognosis for the fishery appears poor. The impacts of this declining recruitment have been most evident in the fisheries in Div. 3K and Subdiv. 3Ps (Figs. 16-17) in recent years, where there is relatively little residual biomass in the population (Figs. 27 and 30). However, more obvious impacts are expected to emerge in Divs. 3LNO (Inshore and Offshore) in the forthcoming years, where evidence of a decline in the residual biomass is beginning to emerge (Figs. 28-29), as well as a downturn in the fishery in some management areas both inshore and offshore (Figs. 23-24).

Overall, the abundance of Snow Crab in Divs. 2HJ3KLNO during fall trawl surveys was at its lowest observed level in 2015 (Fig. 35). This reflects a relatively low abundance of all sizes of crabs in the population (Fig. 36). A small pulse of young crabs emerged during 2013-14 which could contribute to modest improvements in recruitment in some divisions in about five to seven years (Fig. 36). However, a warm oceanographic regime (Colbourne et al. 2016) coupled with relatively low abundance of young crabs for the past decade (Fig. 36) suggests overall weak recruitment in the long term. The pulse of small crabs that emerged in the fall trawl surveys in 2013-14 was broad-scale throughout Divs. 2J3KL (Fig. 37) and remained prominent in Divs. 2J and 3L in 2015. Despite an incomplete trawl survey in the spring of 2015, the limited survey sets in Div. 3L suggest the crabs still remain prominent along the northern portion of the Grand Bank (Fig. 38). All indications are that this emergent mode of small crabs is spatially broad-based.

Reproduction

The management regime of the NL, and virtually all other commercially harvested, Snow Crab stocks, inherently protects the reproductive potential of populations by restricting all females and a large proportion of breeding males from exploitation. The fishery targets only largest males, which constitutes a small fraction of the overall resource. Although this could theoretically have implications for genetic selection, the strategy of maintaining a residual biomass of largest males, coupled with the ability of sub-legal-sized adolescent and adult males to successfully copulate and breed, appears to be successful in maintaining reproductive potential in this stock. Reproductive potential is further safeguarded by the ability of mature females to store sperm and produce multiple clutches of eggs from a single mating event (Sainte-Marie 1993).

The inherent reproductive resiliency is evident in the index of egg clutches of females from the multi-species trawl surveys. Data from both the fall and spring surveys throughout Divs. 2HJ3KLNOPs show that in nearly all years the vast majority (i.e. > 80%) of mature females are carrying full clutches of viable eggs in all divisions (Fig. 39). Fluctuations that have occurred in the exploitable biomass appear to have exerted little impact on mating success for females, at least to date. A few notable exceptions have occurred, such as low percentages of clutch fullness in Divs. 2HJ in 1999, 2006, and 2007, in Div. 3LNO and Subdiv. 3Ps spring surveys in the mid-2000s, and in two of the last three years in the Div. 3LNO fall survey (excepting the incomplete 2014 value). Nonetheless, the overall reproductive potential appears to have been maintained each year under current management and fishing practices.

This index of egg clutches may best form the cornerstone to defining ‘serious harm’ to the Snow Crab resource caused by fishing. With no prolonged periods of low clutch fullness, the evidence suggests that under current management practices the species maintains a high level of resiliency to fishing, with all levels of exploitable biomass observed to date, including the present overall low and declining levels, causing no serious harm to the reproductive potential of the stock. Current prevailing theory is that productivity and recruitment success is driven more by bottom-up climatic and inter-specific competition factors than top-down fishery or predation impacts (Windle et al. 2012; Dawe et al. 2012b; Mullowney et al. 2014). The scenario of low potential for serious harm induced by fishing and productivity being predominately environmentally-driven suggests conventional exploitation rate-based Precautionary Approach (PA) frameworks (i.e. DFO 2014a) may be inappropriate for this stock. At present, alternative PA frameworks are being pursued for this resource.

Following an initial high period in the late-1990s, the abundance of mature females has remained relatively low and highly annually variable in all divisions (Fig. 39). Such ‘cyclic’ pulses have been described in other areas, including the northern Gulf of St. Lawrence (i.e. Sainte-Marie 1993; Sainte-Marie et al. 1996). It is unknown what effect over production present levels will have in any given division. Historically, largest recruitment pulses have been born from periods of low mature female abundance. For example, the 20-30 mm CW crabs seen in the 2001-2002 surveys (Fig. 36) would be expected to be about 2-3 years of age (Sainte-Marie et al.1995) and been produced from the relatively low levels of abundance of mature females that occurred in 1998-2000. Similarly, the present pulse of small crabs of about the same size would have been produced from the low mature female abundance levels seen during recent years (i.e. 2011-12).

Although poorly captured by the multi-species trawl surveys, the observed shallow water pattern of distribution of mature females (Figs. 40-41) appears to more closely mirror that of small males than pre-recruit and/or exploitable crabs. The spatial distributions of all population components including mature females are examined in finer detail in forthcoming division-specific sections of the document.

Environment

Knowledge on the impacts of bottom temperature on Snow Crab population dynamics has recently advanced. It is becoming increasingly apparent that bottom temperatures act positively on size and negatively on abundance in regulating stock productivity and biomass. 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 during early ontogeny are associated with the production of strong year classes and subsequent strong recruitment (Boudreau et al. 2011; Marcello et al. 2012; Mullowney et al. 2014; Émond et al. 2015).

Recent and on-going work has linked the abundance of small crabs in the trawl surveys with bottom temperatures occurring in real time in NL (unpublished data). In other regions, such as the Southern Gulf of St. Lawrence, Eastern Bering Sea, and Northern Gulf of St. Lawrence (Marcello et al. 2012; Émond et al. 2015), climate data have been directly linked to survey-based indices of small crab abundance. In NL, the present emergence of a pulse of small crabs (Figs. 36-38) has been associated with cooling oceanographic conditions in the past three years (Figs. 5 and 42), with the areal coverage of cold bottom water increasing in all divisions since 2011-12 (Fig. 42).

Although a return to cooler conditions in the past three years is positive in that it appears to have promoted the emergence of a pulse of small crabs, expectations for the future should be tempered as climatic conditions are still relatively warm (i.e. Colbourne et al. 2016). 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. Present cold bottom conditions are not near as spatially or temporally expansive as they were in the late-1980s and early-1990s (Fig. 42), from which highest exploitable biomass levels in the mid-late-1990s likely originated (Fig. 20) (Mullowney et al. 2014). Nonetheless, cross-correlation analyses in Div. 3LNO would suggest that the present high level of fishery catch rates in that division are associated with the pulse of cold water that occurred from about 2000-2003 (Mullowney et al. 2016), and current thermal conditions are approaching that level.

Long-term abundance may heavily hinge on the extent to which the current cold conditions are sustained, although it is unknown how environmental, anthropogenic, or other factors will interfere with the survival and progression of the present emergent and future recruitment pulses throughout life. Consumption models developed for this assessment suggest predation pressure from large benthivores and piscivores has (Subdiv. 3Ps) or is (Divs. 2J3KLNO) increasing in recent years in most divisions (Fig. 6). These trends predominately reflect increasing abundances of predatory finfish. Although the impacts on the fishery in most areas would be expected to be minimal at present, with finfish predation predominately occurring on small Snow Crabs below about 40 mm CW (Chabot et al. 2008), increased top-down controls could become more important in regulating the resource and consequently impact the fishery in the coming years. However, at present, it is not known if current levels of predation constitute a major concern for Snow Crab recruitment prospects, particularly with overall finfish abundances still low relative to pre-collapse levels.

The pulse of cold water that occurred from about 2007-09 (Fig. 42), most prominently in Divs. 3LNO and Subdiv. 3Ps, appears to be largely unaccounted for with respect to the presence of small crabs in the trawl surveys (i.e. Fig. 36). There is only a weak signal in abundance of small crabs (i.e. 12-30 mm CW) in the surveys during 2010-11 (Fig. 36). However, a recent pulse of mid-sized crabs has begun to be tracked in the CPS survey small mesh traps in Div. 3LNO and Subdiv. 3Ps (Mullowney et al. 2016). This emergent pulse of mid-sized crabs appears localized to the Whale Deep, Green Bank, and St. Pierre Bank Areas (Fig. 1) (Mullowney et al. 2016), whereas the previous pulse occurred across more of the Grand Bank, including the spatially expansive management areas of the northern Grand Bank in Div. 3L. Accordingly, it does not appear that this recruitment pulse now approaching legal-size will yield as much biomass to the broader-scale fishery.

Mortality

Bitter Crab Disease (BCD) has been observed, based on macroscopic observations of crabs captured in the fall trawl surveys, at generally low levels throughout Divs. 2J3KL from 1995-2015 (Fig. 43). The prevalence and distribution of this parasitic disease throughout the NL 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).

The disease, which is fatal to crabs, occurs primarily in new-shelled crab of both sexes and appears to be acquired during molting (Dawe 2002). Although the macroscopic analyses used to classify crabs as infected are known to underestimate true prevalence, a recent study using advanced polymerase chain reaction (PCR) techniques on specimens collected since the mid-2000s to identify infections has shown trends to closely reflect the patterns seen throughout the offshore (unpublished data). BCD has been consistently low in fall trawl surveys in Div. 2J and, although it is normally most prevalent in Div. 3K, levels in that division have been lower since 2000 than previously occurred. BCD is normally not common in Divs. 3LNO, but a prolonged incidence pulse was observed in Div. 3L from about 2001-06, most prominent in 40-59 mm CW crabs. This likely reflected progression of the recruitment pulse detected in the trawl surveys as 20-30 mm CW crabs in 2000-03, and is presently contributing to high fishery catch rates in that division, through those sizes.

Overall, the relatively low level of BCD observed in recent years is positive in that it suggests this source of natural mortality is killing fewer crabs than historically. However, it is also negative in that it suggests a decreased density or abundance of mid-sized crabs, representing future fishery prospects, presently occurring along the major areas of the NL shelf. Spatially, the disease has tended to follow a pattern of being most prominent in shallow nearshore areas of the continental shelf with a virtual absence in deeper areas further offshore (Mullowney et al. 2016). At present, BCD is not thought to be exerting much of a regulatory effect on NL Snow Crab populations, but its importance could once again increase as the newly emergent recruitment pulses grow into sizes more commonly associated with disease prevalence over the next few years.

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).

Rates of mortality imposed on Snow Crab by discarding are unknown, but preliminary results from an ongoing study that were presented at the previous stock assessment showed that about 30% of even the hardiest crabs (not soft-shell) were either directly killed or rendered critically weak from being discarded (unpublished data). However, the analysis is biased by the re-hauling of crabs in the experiment, which would likely inflate mortality rates, and the experiment did not feature soft-shell samples in the analysis. Mortality rates on soft-shell crabs are thought to be especially high.

Discard levels in the fishery are negatively related to the relative strength of the exploitable biomass (Fig. 44). This likely reflects competition for baited pots, with the catchability of less competitive crabs (both under-sized and soft-shelled) increasing when the exploitable biomass is relatively low. In 2015, the ratio of the exploitable biomass to pre-recruit crabs in the multi-species trawl survey was relatively high in all divisions. As a result, overall discard levels were generally low to moderate. However, the coincident increase in both indices in Subdiv. 3Ps is a point of concern. The ratio of exploitable to pre-recruit crab abundance is a relative index; in absolute terms, the abundance of both components of the population is very low (i.e. Figs. 20 and 32) and thus by extension the increasing percentage of discards infers the fishery is capturing and discarding increased levels of under-sized crabs. These under-sized crabs are thought to be an important portion of the population that helps safeguard high insemination levels of females (Fig. 39), particularly while the exploitable biomass is very low (Fig. 32). Mortality on both soft-shelled and under-sized males can be minimized by maintaining a relatively high level of residual biomass and, for soft-shell crab in particular, may be further reduced by fishing early in the spring before they are capable of climbing into traps.

The soft-shell protocol was introduced in 2005 to protect soft-shelled immediate pre-recruits from handling mortality by closing localized areas (70 na. mi.^{2} grids) for the remainder of the season when a threshold level of 20% of the legal-sized catch is reached. It became evident during 2010-12 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 all the inferences possible from moderate-sized samples frequently resulted in failure to invoke the protocol even when it was clear that the level of soft-shelled crabs had exceeded the threshold. These shortcomings undermine the intent of the protocol. Although soft-shell incidence in the catch has been very low in all divisions for the past two years, consistent with diminishing recruitment prospects, measures should be taken to ensure representative observer coverage and analysis so as to better quantify prevalence of soft-shelled crabs in the fishery to afford better protection to recruitment if and when the situation improves. Further, with expected further declines in the exploitable and pre-recruit biomass, the capture and release of under-sized crabs could become more problematic in the forthcoming years, such as appears to be occurring in Subdiv. 3Ps. Measures should also be taken to reduce the level of capture and handling on these crabs toward safeguarding against declining female insemination rates and promoting serious harm to the resource through fishing.

Discarding has overall been consistently lowest in Divs. 3LNO (Fig. 45), and generally been less of a concern in the other three major divisions since the mid-2000s than prior. In Div. 2J, a high incidence of discarding and a low exploitable:pre-recruit biomass ratio in 2002-04 (Fig. 44) was associated with high catch rates of legal-sized soft-shell crabs (i.e. immediate pre-recruits) in the fishery (Fig. 45) and extremely high levels of pre-recruit mortality (Fig. 46). This pattern has somewhat repeated itself in recent years, with catch rates of legal-sized soft-shell crabs again relatively high from 2012-14 when the exploitable:pre-recruit biomass ratio was low (Fig. 44) and the pre-recruit fishing mortality index was high in two of the three years during that period.

However, the sharp increase in the exploitable:pre-recruit biomass ratio and the very low pre-recruit fishing mortality rate index in 2015 suggests greatly reduced wastage in the fishery.

In Div. 3K, compared to historical norms, relatively few legal-sized soft-shell crabs have been captured in the fishery since 2005 (Fig. 45). This signifies increasingly poor short-term recruitment prospects. The relatively high level in the exploitable:pre-recruit biomass ratio in 2013 (Fig. 44) indicated little potential for damage to the incoming recruits. However, the decrease in that ratio along with the pre-recruit fishing mortality index increasing since 2013 to a recent high (Fig. 46) suggests wastage in the fishery is once again increasing. Although the prolonged decline in the exploitable biomass and fishery catch rates experienced since the late 2000s appears to have overall been more a function of low recruitment than fishery wastage, with further recruitment reductions anticipated in forthcoming years it is advised to make further efforts to minimize wastage in the fishery.

In Divs. 3LNO, there has been a virtual absence of soft-shell and under-sized new-shell crabs in the fishery in the past three years, signifying the lowest short-term recruitment prospects observed to date (Fig. 45). The extremely high exploitable:pre-recruit biomass ratio indicates very low potential for damage to incoming recruits and wastage in the fishery (Fig. 44), associated with a level of fishing that already appears efficient and effective in avoiding pre-recruit wastage with the pre-recruit fishing mortality index remaining consistently low since 2008 (Fig. 46).

In Subdiv. 3Ps, there have been few soft-shell crabs captured in the fishery since 2005, with a steadily declining signal of under-sized new-shell crabs in the catch (Fig. 45). The very high levels of the pre-recruit fishing mortality index in the most recent years (Fig. 46), coupled with an increasing trend in the ratio of exploitable:pre-recruit biomass (Fig. 44), indicates that the rate of decline in pre-recruits has been higher than that of exploitable crabs in recent years. The decline in pre-recruits does not appear attributable to handling mortality, with virtually no soft-shell crabs seen in the fishery for ten consecutive years (Fig. 45). Observer discard data suggest Subdiv. 3Ps has experienced a decade long period of steadily declining recruitment into the exploitable biomass.

Trends in fishery-induced mortality on exploitable crabs have varied among divisions throughout the time series (Fig. 46). In Divs. 2HJ, the exploitation rate index peaked in 2012 but since decreased to about its lowest level in 2015. However, status quo removals in 2016 would once again increase the index to a level similar to recent norms. In Div. 3K, the exploitation rate index was about average during 2014 and 2015 and maintaining the current level of removals would increase the exploitation rate in all management areas in 2016 with the overall trawl survey exploitation rate index increasing to its highest level in a decade and second highest level in the time series. In Divs. 3LNO, the exploitation rate index changed little from 2010-14 and maintaining the current level of fishery removals would substantially increase the trawl survey exploitation rate index to a new high in 2016. In Div. 3L Inshore, the overall post-season trap survey-based exploitation rate index changed little from 2005-15 and maintaining the current level of fishery removals would increase the exploitation rate index in all areas in 2016. In Subdiv. 3Ps, the exploitation rate index has been at or near its highest observed levels during the past three years and maintaining the current level of fishery removals would result in a continued high exploitation rate in 2016. Finally, in Divs. 4R3Pn, the post-season trap survey-based exploitation rate index has varied since 2005 and was about average in 2015; maintaining the current level of fishery removals would result in little change to the exploitation rate index in 2016.

Total mortality rates on exploitable crabs have been annually variable in most divisions, including in recent years (Fig. 47). Divs. 2HJ and 3K have been similar and fluctuated around a two-year moving average of A=0.5-0.6 in most years throughout the time series. Divs. 3LNO has historically fluctuated at similar levels, but an increasing trend has emerged since 2009. Overall, total mortality rates have historically been lowest in Subdiv. 3Ps with fluctuations in the range of A=0.3-0.5. The lower level of total mortality on exploitable crabs in Subdiv. 3Ps is consistent with declining productivity and recruitment being a major determinant of the prolonged decrease in the exploitable biomass.

DIVISION 2HJ

Fishery

In relative terms, the Divs. 2HJ fishery is one of the smaller fisheries for Snow Crab in the Province. Landings have remained relatively low at less than 2,000 t since 2011 (Table 2, Fig. 48). The fishery occurs in offshore regions of central and southern Labrador in CMAs 1 and 2 (Fig. 49). The bathymetry is characterized by a series of shallow water offshore banks separated by deep channels. The Cartwright and Hawke Channels, the two dominant fishing grounds, extend to depths of up to 750 m, although the fishery tends to avoid the deepest portions of the 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 Div. 2J is longer, extending back into the early 1980s. For the division as a whole, effort has been substantially reduced and been at its lowest level during the past three years (Table 2, Fig. 48). The shortfalls in achieving the TAC in 2011-2013, and the subsequent taking of the TAC in 2014-2015, predominately reflect a poor performing and now improving fishery in the northernmost management area (CMA 1) (Fig. 50), dominated by removals from the Cartwright Channel (Fig. 49).

Logbook return rates in Div. 2HJ have historically been persistently low relative to other divisions, but the situation improved in 2015, with 65% of the logbook data available for the assessment. In 2014, less than half the logbooks from fishing trips were accounted for in the logbook dataset. Incomplete datasets create uncertainty in calculating and interpreting logbook CPUE. Adding to uncertainty in assessing fishery performance in this division is that the CPUE index derived from the typically incomplete logbook dataset is deemed the most reliable because observer coverage is routinely low and VMS is not required to be used by all fishing fleets. However, all three indices are consistent is showing that CPUE has increased throughout the division since 2012 (Table 2, Fig. 17). In both CMAs, it was about 10-11 kg/trap in 2015 (Fig. 51) and close to the long-term average.

Weekly CPUE trends are normally highest during the early portion of the season and tend to decline throughout the fishery (Fig. 52). This is interpreted as reflecting depletion of the resource. Despite a noticeable delay in beginning the 2015 fishery (Fig. 14), the typical pattern of reducing catch rates throughout the season did not occur in the northernmost CMA, with catch rates hovering about 8-12 kg/ trap throughout (Fig. 52). Depletion was, however, evident in the larger fishery in the southern portion of the division. Biggest improvements in catch rates over previous years were exclusive to the early portion of the season and by the end of the fishery, the 8 kg/trap occurring after 1,000 t of removals was typical of the five year time series (Fig. 52).

Spatially, there has been a substantial reduction in the areal coverage of the fishery since 2011 (Fig. 18), a phenomenon often associated with a fishery that is performing well. The reduction of spatial coverage reflects a continued contraction of the fishery into the Cartwright and Hawke Channels in recent years (Fig. 16). The northernmost fishing grounds of Div. 2H have been virtually abandoned and effort no longer extends into the furthest offshore areas and the slope edge. The reduction of effort in the northernmost areas likely reflects resource shortages, but could also be influenced by a regulation change after the 2012 fishery whereby vessels that had previously been restricted to Div. 2H were allowed access to the northern portion of the Cartwright Channel, inside Div. 2J, at the southernmost portions of CMA 1.

Size distributions from at-sea sampling by observers during the fishery (Fig. 53) suggest there have been two recent recruitment pulses fuel the exploitable biomass during 2007-09 and 2012-15. This can be seen by an increase in abundance of soft- and new-shell legal-sized crabs during those periods. It is unclear from the fishery data if the most recent pulse has fully or near-fully contributed to the fishery, as the overall shape of the size frequency distributions has been similar for the past four years with little evidence of modal progression. The reasons for the low magnitude of the 2014 distribution are unclear.

Improved harvester stewardship practices and management decisions in recent years appear to be benefitting the Divs. 2HJ fishery. Observer sampling throughout the season suggests that the recruitment pulse presently contributing to an improved exploitable biomass and fishery was allowed to enter legal-size with consistently reduced levels of potential perturbation and wastage from the fishery. For example, soft-shell crab incidence generally becomes most prominent in the latter weeks of the fishery here (Fig. 54). In the past three years, there has been minimal fishing occur after weeks when soft-shell crab incidence approached or exceeded the 20% closure threshold. The 2014 plot would suggest fishing during high soft-shell crab incidence was prolonged during weeks 16-18 in that year, but those weeks only accounted for about 5% of the total effort expenditure for the season (Fig. 14).

Surveys

The trawl and CPS trap survey-based exploitable biomass indices both increased sharply in 2014 (Table 3, Fig. 14). The trawl index returned to a relatively low level in 2015, but the CPS trap survey index suggests the biomass remains unchanged on primary fishing grounds. Consistent with this, the trawl survey catches of exploitable crabs have been near exclusive to the Cartwright and Hawke Channels in recent years (Fig. 55). Notably, the survey trawl has captured no exploitable crabs in Div. 2H (i.e. north of 55.33N) in the past three years.

Recruitment increased sharply to a recent high in 2014, but subsequently decreased to a relatively low level in both the trap and trawl surveys in 2015 (Fig. 24-25). Short-term recruitment prospects appear poor. With the exception of 2014, the pre-recruit biomass index has been relatively low in recent years and was at its lowest level in 2015 (Table 3, Fig. 32). Like exploitable crabs, survey catches of pre-recruits by the multi-species trawl survey have been near exclusive to the Cartwright and Hawke Channels in recent years (Fig. 56) and no large catches of pre-recruits occurred in the 2015 survey.

Size frequency distributions from both the trawl (Fig. 57) and trap (Fig. 26) surveys showed increased levels of exploitable and pre-recruit crabs from 2013 to 2014. The catch rate of exploitable crabs was unchanged in the CPS survey but decreased again in the trawl survey, while the signal of pre-recruits (i.e. new-shelled crabs in the CPS survey) was reduced in both surveys in 2015. Inter-annual variability both within and across surveys creates uncertainty in the status of the exploitable biomass, however both surveys are consistent in indicating a reduction of recruitment into the biomass in 2015. Uncertainties in the status of the exploitable biomass are further compounded by the spatial limitations of the CPS trap survey and whether the signal of biomass emerging from primary fishing grounds is indicative of resource status.

In the past three years long-term recruitment prospects appear to have improved, with the abundance of crabs < 40 mm CW higher than it has been for about a decade (Fig. 57). With a mode of 18-21 mm CW in 2015, these crabs would be expected to be about two years old. However, the 2013-14 distributions infer there could be a year-class or two in front of these not visible in the 2015 size distribution. The campelen trawl typically poorly captures sizes of about 30-75 mm CW. If these small crabs survive and progress through sizes at rates similar to those historically seen, they would be expected to begin to contribute the fishery in about 2019-20. Mid-term recruitment prospects are uncertain in large part due to the persistently low signal of crabs in the survey trawl index ranging from poorly captured sizes of about 30-75 mm CW. However, the lack of consistent strong signals of small crabs in the survey trawl from 2004-12, particularly from about 2009-12, suggest poor prospects before the presently emerging pulse of small crabs begin to contribute to the fishery.

Smallest crabs in the trawl survey have consistently been captured in shallow areas, on top of the Hamilton Bank and adjacent nearshore plateaus, and their abundance has increased markedly both in terms of spatial distribution and magnitude of catches in the past three years (Fig. 58). Similar to small crabs, mature females tend to be most commonly captured at shallow depths on top of the Hamilton Bank and along the nearshore plateaus (Fig. 40). Catches tend to be sporadic, which may relate to the typically hard substrates associated with such shallow areas. The abundance index of mature females has remained relatively low since 2010 (Fig. 39), while egg clutches have remained near 100% full.

Overall, key resource indicators suggest there has been a prolonged decline in the resource, with both the pre-recruit and exploitable biomass near their lowest observed levels in 2015. The exploitable biomass has been strongly correlated against fishery CPUE at a one year lag for two decades (r^2=0.81) (Fig. 59). If this pattern holds it is expected to decline within the next one to two years. Further, lagged correlations of the thermal habitat index with the exploitable biomass (r^2=0.70) and fishery CPUE (r^2=0.66) suggest further deterioration over the next 2-3 years. If all factors remain equal, short-term prospects appear poor and improvements in the exploitable biomass might be expected to occur in about 2019-20 (Fig. 59).

DIVISION 3K

Fishery

The Div. 3K fishery occurs off the northeast coast of Newfoundland predominately within a network of deep trenches located between nearshore shallow water plateaus and the Funk Island Bank in the offshore (i.e. St. Anthony Basin and Funk Island Deep, Figs. 1and 60). Within the division there are six Crab Management Areas (Fig. 60). The effort distribution in Green Bay (CMA 3C), Notre Dame Bay (CMA 3D), and the offshore (CMA 4) forms a continuum stretching from the shallow nearshore waters of Green Bay (i.e. 200-300 m) into the deeper trenches of Notre Dame Bay (i.e. 300-400 m) and the Funk Island Deep in the offshore (i.e. 400-500 m) (Fig. 13). White Bay (CMA 3B) is a deep (i.e. 400-500 m) fjord protected at the mouth by a shallow sill (i.e. 200-300 m) that forms the basis of a relatively discrete pocket of fishing effort (Fig. 13). There are two discrete pockets of effort in CMA 3A, one concentrated near the mouth of White Bay in the south and another in an easterly extension of the management area that stretches into the offshore at depths of about 200-300 m (Figs. 13 and 60). Finally, CMA 3BC is relatively shallow (i.e. 200-300 m) with bathymetric features similar to the offshore and southern portions of CMA 3A (Fig. 60), with effort within CMA 3BC essentially forming a western extension of the offshore fishery (Fig. 13).

Overall landings in the division declined by 52% since 2008 to 7,200 t in 2015, their lowest level in two decades (Table 3, Fig. 48). Meanwhile, effort has declined by 35% and been near its lowest level for the past three years (Table 3, Fig. 48). These overall trends are reflective of patterns in the offshore (CMA 4) and Notre Dame Bay (CMA 3D), the two largest CMAs in terms of fishery scale, where TACs, landings, and effort levels are all at or near their lowest levels in a decade (Fig. 61). The fishery in Green Bay (CMA 3C) has also experienced persistent reductions in TAC and landings over the past five years, while effort has oscillated. Meanwhile, TACs and landings have been relatively stable in CMAs 3A, 3B, and 3BC during the past five years, with effort oscillating about median levels in each area.

Overall CPUE declined by 55% from 2008 to 2011 and has since changed little (Table 3, Fig. 15), remaining near a historic low and reflecting trends throughout most of the division (Fig. 62). Exceptions to CPUE being at or near historical lows in recent years have occurred in CMA 3A and White Bay (CMA 3B). This ultimately reflects a difference in the success of fisheries associated with the discrete pocket of effort in White Bay in recent years, with virtually all areas of the bay yielding catch rates in the order of 10-15 kg/trap, including near the mouth of the bay where the CMA 3A fishery has capitalized on good fishing along the management line separating the two areas (Fig. 16). Nonetheless, with the exception of the segregated area of fishing in and adjacent to White Bay, the fishery has performed poorly throughout most of the division in recent years (Figs. 16 and 62). At about 3 kg/trap, the fishery in Green Bay (CMA 3C) was especially poor in 2015.

Despite recent fisheries in CMAs 3A and 3B performing strong relative to historical levels, signals emerged in 2015 that indicate a potential forthcoming decline in those areas. Specifically, there were signs of resource depletion, with fishery CPUE declining throughout the season in both areas in 2015 (Fig. 63). The decline in White Bay (CMA 3B) from about 12 kg/trap after 100 t of removals to 8 kg/trap at 200 t of removals was particularly noteworthy in countering the more stable trends in the fishery during 2014-15. All other CMAs in the division experienced catch rates at or near the five year time series' low for most of the season (Fig. 63). Depletion in the offshore appeared particularly strong, with a precipitous decline in catch rates from about 8 kg/trap at 500 t of removals to 2 kg/trap at 2,500 t of removals.

Spatially, there has been a substantial reduction in the area fished in the division in recent years, from about 35% of potential cells occupied by the fishery during 2009-12 to about 23% in 2015 (Fig. 18). This reduction has been most apparent in the extreme offshore, with little effort occurring north or east of the Funk Island Bank in recent years (Fig. 16). The coupling of a reduction in the spatial extent of the fishery with persistent low catch rates since 2011 (Fig. 18) is concerning, suggesting abandonment of poorly performing fishing grounds and, by extension, a depleted biomass.

Observer sampling during the fishery shows the population of crabs in White Bay (CMA 3B) to be consistently dominated by old-shelled animals, inferring a relatively strong residual biomass and relatively low exploitation rate. The higher contribution of new-shelled animals in the size frequency distribution in 2013 suggests recruitment into the fishery was strong in that year. The return to dominance of old-shelled crabs in the population in the past two years suggests those recruits are now present as residual crabs in the exploitable biomass (Fig. 64).

In Green Bay (CMA 3C), size frequency distributions from observer sampling during the fishery suggest a persistent high exploitation rate, evident by a sharp 'knife-edge' effect at legal-size for seven consecutive years (Fig. 64). With catch rates of most sizes of exploitable crabs hovering around or below 1 kg/ trap for five consecutive years, the population appears depleted. In Notre Dame Bay (CMA 3D), the overall magnitude of catch rates of most sizes of crabs has changed little in the past three years, but changes in the shape and shell compositions of size frequency distributions in the past three years suggests a small pulse of recruitment has been entering into the fishery, evident by a left-shift in the size composition and emergence of a mode at about legal-size in 2014 and a higher proportion of old-shelled animals at largest sizes in 2015 (Fig. 65). In the offshore (CMA 4 plus small contributions from CMAs 3A and 3BC), observer sampling shows a gradually dissipating exploitable biomass since 2009, with progressive depreciation in catch rates of legal-sized crabs and no evidence of any major recruitment pulses entering into the population (Fig. 65).

Observer sampling shows discarding has been a minor concern in White Bay (CMA 3B) in recent years, with discard percentages near or below 10% since 2013 (Fig. 66). Discarding has been more of a concern in all other areas, but especially so in Green Bay (CMA 3C), where discard percentages have been at or above 30% for seven consecutive years (Fig. 66). These data are consistent with the size frequency distributions (Fig. 64) in suggesting a high exploitation rate and depleted biomass. With a low level of exploitable crabs in the population, the fishery persistently captures and releases a high percentage of less competitive (i.e. under-sized and soft-shelled) crabs. With few soft-shelled crabs in the population in the past three years, discards have been dominated by under-sized crabs. This is a concern as high levels of mortality on these crabs could lead to a situation where there are very few male crabs capable of reproduction in the population. Measures should be taken to reduce the level of discards in Green Bay. In Notre Dame Bay (CMA 3D) and the offshore, discard percentages have been lower and tend to reflect the level of soft-shelled crab encountered each year. In most years, 10-20% of the crabs captured are discarded, but percentages can spike when soft-shelled incidence increases (Fig. 66). The overall low level of soft-shelled crabs in the catch in both areas since 2005 reflects a decade-long phenomenon of relatively low recruitment entering the exploitable biomass.

Overall, weekly percentages of soft-shelled crab in the fishery have been particularly low throughout the season in the past three years (Fig. 67). During 2008-12, late-season fishing consistently yielded soft-shelled incidences at or above the 20% grid closure threshold. The low incidence in the past three years, coupled with overall low catch rates in the fishery (Figs. 62 and 67), implies further deteriorating recruitment prospects beyond the already low levels recently occurring. If recruitment potential was strong, with such low catch rates, one would expect to see high percentages of soft-shelled crab in the catch, particularly in the late season. All inferences from in-fishery observer data are that despite six consecutive years of TAC reductions, overall, the resource in Div. 3K continues to deteriorate.

Handling mortality is not ascribed as the primary reason for the lack of recovery in the Div. 3K Snow Crab resource, a prolonged period of climate-induced low productivity is (Mullowney et al. 2014). However, there is little management or harvesters can do to control such bottom-up forces. All that can be controlled are impacts from the fishery. In times of resource shortages, an aim of maximizing fishing efficiency via reducing discards as much as possible is recommended as the best approach toward maximizing short-term economic gains, protecting resource production potential, and promoting some recovery of the exploitable biomass.

Surveys

The post-season trawl and trap survey exploitable biomass indices both declined since 2008 to their lowest observed levels (Table 3, Fig. 20). Both indices decreased by a third from 2014 to 2015, reflecting decreases throughout the division. Similar to Div. 2J, exploitable males here are found deep, predominately at fringe areas of the Funk Island Deep and St. Anthony Basin (Fig. 68). Catch rates in the multi-species trawl survey have been consistently deteriorating since about 2009, but have been particularly abysmal in the past two years. Few exploitable crabs have been captured in the furthest offshore portions of the division, with capture near-exclusive to the fringes of Funk Island Deep and St. Anthony Basin (Fig. 68). Consistent with this, the CPS trap survey shows that the biomass decreased substantially in all management areas in 2009 and has been reducing more gradually since, to its overall lowest observed level in 2015 (Fig. 69). Although the biomass indices in all but CMA 3BC were at a time series low in 2015, declines in the catch rates of exploitable crabs in the offshore (CMA 4) have been particularly precipitous (Fig. 70). The catch rates of old-shelled crabs (i.e. ‘residual’) were below 3 kg/trap in all but White Bay (CMA 3B) in 2015 (Fig. 70).

Recruitment is at or near time series’ lows throughout the division (Figs. 24 and 70). At less than 3 kg/trap, the catch rate of new-shelled legal-sized crabs in the CPS trap survey in 2015 was at its lowest observed level in all but CMA 3BC, although it decreased by half in that area in 2015 (Fig. 70). Recruitment is expected to decline further in the short term with all trawl (Table 3, Fig. 32) and trap (Fig. 71 and forthcoming) pre-recruit indices near historical lows during the past three years. The thermal habitat index suggests further deterioration of recruitment potential over the next 2-3 years (Fig. 42). Like exploitable crabs, the decline in survey catch rates of pre-recruits has been widespread throughout the division since about 2009 and few captures of pre-recruits have occurred in the offshore portions of the division in recent years (Figs. 71-72).

Size frequency distributions from both the trawl (Fig. 73) and trap (Fig. 27) surveys show low and generally reducing levels of adolescent pre-recruit-sized males and a consistently depleting exploitable biomass since about 2008. This reflects low resource productivity, with a low level of small crabs in the population from 2003-13 (Fig. 73). It is most likely that the strong signal of high small crab abundance (i.e. < 30 mm CW) from 2000-02 was associated with the most recent level of high exploitable biomass that occurred in 2007-08 (Fig. 20). Accordingly, there has been a relatively low level of stock productivity and associated recruitment potential for over a decade here. In 2014, a higher level of small crabs was captured in the survey than has occurred in the past eleven years, signifying some increased long-term recruitment prospects for the fishery. However, any increases in exploitable biomass to be gleaned from those crabs are a long way out. Nonetheless, it is important to monitor the extent to which this mode becomes established along with its progression through sizes to better understand the relative level of future improvements that may be expected. Notwithstanding, the lower magnitude of the abundance of small crabs in the 2014 survey relative to the early 2000s, inferences from increased levels of predation on these small crabs (Fig. 6), suggest less may be gleaned out of current recruitment pulses than in the past.

Small-mesh traps in the DFO survey in White Bay showed the emergence of a pulse of small crabs in the mid-2000s that has since progressed into the exploitable biomass (Fig. 74). The signal of small adolescent crabs (i.e. mode of 40-50 mm CW) in the shallow waters of stratum 615 (200-300 m) gradually progressed toward intermediate- and large-sized adolescents and ultimately exploitable crabs in the deeper waters of stratum 614 (400-500 m) and 613 (> 400 m) from 2007-13, reflecting a down-slope ontogenetic movement of crabs in the bay. Such down-slope progression of crabs through sizes has been tracked in previous recruitment events in this bay and the emergence of a mode of small adolescents (i.e. 40-50 mm CW) in 2014-15 in shallow stratum 615 is consistent with the signal of small crabs in the multi-species trawl survey in 2014 (Fig. 73). However, as elaborated previously, caution is warranted on the expectation of yield from this emergent recruitment pulse and its potential to benefit the fishery in the long-run.

There is spatiotemporal inconsistency across signals from small-mesh traps in various surveys that create uncertainty in recruitment prospects for Green Bay, Notre Dame Bay, and the offshore, over the next few years. In Green Bay (CMA 3C), small-mesh traps in the CPS survey give no indication of imminent recruitment prospects, with very few adolescent crabs captured in the past four years (Fig. 75). However, the DFO trap survey in stratum 611 (200-300 m, Figs. 8 and 75), which covers most of Green Bay and portions of Notre Dame Bay (CMA 3D), showed a broad pulse of adolescents ranging from about 40-70 mm CW in 2015. The capture of adolescent pulses in this survey has been sporadic over the time series (Fig. 75), thus it will be imperative to monitor their presence and/or magnitude in the surveys of the next few years to determine if some increased recruitment above the present low levels can be expected.

Interestingly, small-mesh traps in the deeper waters of the DFO survey in Green and Notre Dame Bays showed the presence of adolescents of about the same size in 2014-15 (stratum 610, 301-400 m, Figs. 8 and 76), while small-mesh traps in the CPS survey in the offshore showed a pulse of adolescent males ranging from about 40-70 mm CW in 2015 (Fig. 76).

Like Div. 2J, small crabs here (i.e. < 60 mm CW) tend to aggregate in shallow waters near to shore as well as on top or along the perimeter of offshore banks (Fig. 77). However, occasionally the survey captures high abundances of small crabs in deep areas such as in 2014 when numerous tows with 20 or more crabs < 60 mm CW occurred in the Funk Island Deep, contributing to a broad-based signal throughout the division (Fig. 77).

Trends in Bitter Crab Disease from the DFO trap survey in White Bay have served as a good indicator of recruitment potential over the past two decades. For example, a rapid increase in prevalence in stratum 615 during 2004 was followed by a large increase in prevalence in stratum 614 during 2006 and subsequently by a spike in prevalence in stratum 613 during 2007 (Fig. 78). These patterns mirrored the emergence and progression of the pulse of adolescent crabs through sizes and depth ranges during that period (Fig. 74). White Bay serves as a clear example of the density-dependent nature of this disease (Mullowney et al. 2011). The increase in disease prevalence in stratum 615 in 2014 and subsequently a large spike in prevalence in stratum 614 in 2015 (Fig. 78) is consistent with the emergence of another recruitment pulse of small crabs in the population during the past two years (Fig. 74). In Green and Notre Dame Bays, disease prevalence in both depth strata have coincided within year rather than at successive lags (Fig. 78). The increasing prevalence in the past two years would suggest that the abundance of small and intermediate-sized adolescents in the population has increased. Despite inferring overall positive signs on long-term recruitment prospects, with prevalence ranging 10-20% in most strata in 2015, the trap survey data indicate BCD is a major contributor to mortality in these bays. Akin to increased predation pressure (Fig. 6), the exact extent to which this disease will moderate recruitment moving forward remains unknown.

For 2016, survey data for White Bay (and the associated CMA 3A fishery at the mouth of the bay) are suggesting that the exploitable biomass is down considerably from 2014 and at a level closer to historical norms (Figs. 79-80). Most crabs in the exploitable portion of the population appear to be old-shelled (Figs. 79 and 81). Moving forward, it appears the biomass may be maintained at this lower level or decline further in the next few years, with the pre-recruit biomass index from small-mesh traps in the DFO survey at a low, but unchanged level for the past three years (Fig. 80). Overall, gains from the 2011-12 spike in the pre-recruit index appear to have now been realized in the fishery. There is an emergent pulse of small crabs in the population which, if they progress through sizes at the same rate as the last pulse, could contribute to the fishery in about 5 to 7 years. The abundance of mature females has been variable over the past decade, with the 2015 level about average.

For Green and Notre Dame Bays, for 2016, survey data suggest the exploitable biomass appears to be similar to or slightly below levels of the past two years (Figs. 79 and 82). Both the CPS and DFO trap surveys suggest the exploitation rate is especially high in Green Bay (i.e. Fig. 81) and the population of crabs is depleted. The DFO survey is consistent with the CPS survey in suggesting a mix of shell conditions in the exploitable population in Green Bay (Figs. 79 and 81), while there is inconsistency in Notre Dame Bay with the DFO survey suggesting the population is dominated by new-shelled crabs (Fig. 79) and the CPS survey showing an even mix of shell conditions (Fig. 83). Although recruitment potential has been steadily declining over the past decade and is relatively low, recruitment into the fishery in 2016 is likely to be similar to the level of recent years with little change in the pre-recruit biomass index from the DFO survey for the past three years (Fig. 82). Trap surveys in these bays have not detected a strong signal of small crabs in the population in recent years, but broader scale trawl and trap surveys are suggesting the potential for some improved prospects beyond the short-term. The abundance of mature females has been variable over the past decade, with the 2015 level about average.

For the offshore, prospects for the 2016 fishery appear poor. The abundance of legal-sized crabs has steadily eroded since about 2008 (Fig. 83), the exploitable and pre-recruit biomass indices are at their lowest observed levels, and the thermal habitat index is suggesting further deterioration of fishery prospects in the short-term (Fig. 84). There is an emergent pulse of small crabs in the population which, if they progress through sizes at the same rate as the last emergent pulse of similar size, could begin to contribute to the biomass and fishery during about 2018-20.

Collectively, the fishery and survey data are beginning to reflect a situation whereby management area boundaries in Div. 3K do not conform well to the biology of Snow Crab. It is emerging that resource components in Green and Notre Dame Bays are tightly connected not only with one another, but also to the broader-scale offshore. The deep-water channel extending out of Green Bay through Notre Dame Bay and into the offshore likely provides similar habitat and promotes an apparent high level of connectivity between areas. Trends in the fishery data reflect this, with catch rates in all these areas similarly peaking in 2008, declining precipitously to 2011, and either improving slightly or being variable at a low level since (Fig. 62). However, catch rates in Green Bay are generally lower than in the other areas and exploitation rates appear exceptionally high there.

Although most aspects of spatial connectivity, such as migration routes, are not understood, of potential concern is that the shallow waters of Green Bay could serve to source recruitment into the deeper adjacent channels of Notre Dame Bay and the offshore. If this is the case, excessive exploitation in such shallow areas could exert direct or indirect impacts on adjacent areas. Spatial segregation by size is evident in crab populations in the northern portions of the NL shelf, including Div. 3K (Dawe and Colbourne, 2002). Large-scale ontogenetic migrations occur in both the Eastern Bering Sea (McBride 1982; Orensanz et al. 2004; Ernst et al. 2005) and Barents Sea (Ivan Zagorsky, VNIRO – Russia, pers.comms.), with crabs undertaking down-slope movements over the course of life. This is consistent with the spatial segregation patterns seen in Divs. 2HJ and 3K. In the case of the Eastern Bering Sea, these movements have been shown to follow warm temperature fields (Orensanz et al. 2004; Ernst et al. 2005; Parada et al. 2010), which is also consistent with the physical attributes of Divs. 2HJ and 3K whereby deeper waters are warmer (Fig. 5), and crabs may seek these warmer waters as they age to undertake more molts and achieve larger sizes (Dawe et al. 2012a).

The population of crabs in the shallow waters of Green Bay tends to be dominated by small terminally molted males (Fig. 75), which promotes a high incidence of under-sized crabs in the catch and an associated high level of discards in the fishery. The generally smaller sizes of crabs in the population in Green Bay is associated with colder conditions there than in the adjacent deep water troughs of Notre Dame Bay and the offshore (Mullowney et al. 2011). Based on the biology and behaviour of the species, it is suspected that crabs that do not undertake their terminal molt in the cold, shallow confines of Green Bay migrate out of it into the deeper warmer confines of Notre Dame Bay and the offshore and achieve larger sizes (i.e. Figs. 64-65). This is similar to how crabs in White Bay appear to move from shallow cold stratum 615 into the deeper and warmer waters of strata 614 and 613, and how crabs in Div. 2J appear to move from shallow nearshore plateaus and tops of banks into adjacent deep-water channels (i.e. Figs. 55 and 58). Further efforts to understand the connectivity of resource components in Div. 3K are necessary, but management is advised to consider broad-scale resource trends in decision making processes that affect exploitation of the stock at the small spatial scales of CMAs.

DIVISION 3LNO OFFSHORE

Fishery

The Div. 3LNO offshore fishery occurs on and surrounding the Grand Bank off Newfoundland's southeast coast (Fig. 85). It is a massive, shallow, cold, and productive environment for Snow Crab that encompasses Crab Management Areas Nearshore (NS), Midshore (MS), Midshore Extended (MSex), 3L Extended (3Lex), 3L Extended in 3N (3Lex3N), 3L Extended in 3O (3Lex3O), 8B, 3L Outside 200 Miles (3L200), 3N Outside 200 Miles (3N200), and 3O Outside 200 Miles (3O200). The numerous management areas have no biological basis and serve to differentiate fishing grounds among a large number of vessels in several fleet sectors that prosecute the fishery here. Since the late 1990s there have been an estimated 1.2-2.2 million trap hauls per annum (Fig. 48). This area alone has accounted for a steadily increasing proportion of the landings from the NL Region, from 30% of the total in 1998 to 60% in 2015 (Tables 1 and 5). The fishing pattern normally forms a continuum extending from inshore bays of eastern Newfoundland into dense masses of effort in the NS and MS (Figs. 2 and 14) before further extending east in a thin band along the northern Grand Bank from the MSex to 3L200. The continuum ends after wrapping around the deep slope edge of Div. 3N in CMA 3N200 (Fig. 13). Discrete pockets of effort also occur in small bathymetric intrusions on the shallow northwestern portion of the Grand Bank in CMA 8B (Figs. 2 and 13).

Overall, landings increased gradually since 2009 to a historic high of 28,750 t in 2015 (Fig. 48, Table 5). Effort declined considerably from 2011-2013, but increased slightly in the past two years (Fig. 48, Table 5). These overall patterns reflect stability in TACs and removals at or near historic highs since 2009 in the MS, MSex, and 3Lex management areas. Meanwhile, removals in the NS and 3N200 have been increasing since 2009 to historic highs. Converse to these positive patterns in most CMAs, removals in 3L200 and 8B have been relatively low or decreasing since 2009. The TAC has not been taken in CMA 8B in five of the past six years. Effort has been stable or decreasing while removals have been stable or increasing at high levels since 2009 in CMAs NS, MS, MSex, and 3Lex (Fig. 86). Meanwhile, effort has increased in the outermost areas of 3L200 and 3N200 in the past two years and has fluctuated between about 200-250 thousand trap hauls each year since 2009 in CMA 8B while landings have declined.

Overall, the fishery has been performing well. CPUE most recently peaked in 2013 (Table 5, Fig. 15). It declined slightly in the past two years, but remains high. This overall picture reflects CPUEs that have been increasing to or stable near historical highs in CMAs NS, MS, MSex, and 3Lex in the past three years (Fig. 87). Meanwhile, CPUE in the outermost areas of 3L200 and 3N200 has declined sharply in the past two years to be near decadal lows, while CPUE in CMA 8B has precipitously declined since 2009 from about 17 kg/trap during 2007-09 to 10 kg/trap in the past two years. Spatially, the fishery data are reflecting a situation where fishing remains strong along the northern Grand Bank but has begun to depreciate in fringe areas of the deep slope edges and in the discrete patches of effort in the central and western portions of the Bank (Fig. 16). More generally, the fishery along the northern portion of the Grand Bank in Div. 3L is one of the few areas yet to be impacted by a broad scale decline in productivity and recruitment in the NL Snow Crab stock (Fig. 32, Mullowney et al. 2016).

There has been no evidence of resource depletion from the fishery in management areas along the northern Grand Bank (CMAs NS, MS, MSex, 3Lex) in the past three years (Fig. 88). All these areas have maintained catch rates in the order of 18-25 kg/trap throughout the fishing seasons. Meanwhile, a pattern of annual stepwise decreases in CPUE has occurred in CMAs 3L200, 3N200, and 8B in recent years, where there has been little evidence of declining

CPUE throughout each season, but fisheries have performed successively poorer throughout each of the past three (3L200, 3N200) or four (8B) years.

Spatially, there have been subtle changes in the area fished while fishery CPUE has oscillated since the late 1990s (Fig. 18). The relatively minor level of change in spatial expansion and contraction of fishing effort is likely a function of the numerous management areas, which force effort to be broadly distributed. Nonetheless, there has been a reduction in area fished from about 23% of the grounds in 2009 to 18% in 2015 while CPUE has improved, consistent with an overall minor element of searching necessary to find suitable aggregations of crab in the fishery.

Size distributions from at-sea sampling by observers reflected a primary mode at a large size of 110 mm CW in 2006-07 (Fig. 89), when CPUE was low or in decline in most management areas (Fig. 87). Coincidentally, the population was predominately comprised of old-shelled crabs. However, the shape, magnitude, and shell composition of the population distribution changed considerably from 2008-14. The mode of the size distributions abruptly shifted left to about 92-98 mm CW in 2008-09, followed by a marked increase in the magnitude of new-shelled crabs in the population during 2010-12 while the primary mode gradually returned to larger sizes. Since then, the overall magnitude of the distributions has been gradually decreasing due in large part to diminishing contributions for new-shelled crabs, and the primary mode has returned to 110 mm CW in 2015. These observer data clearly depict a prolonged period of strong recruitment contributing to the exploitable biomass from about 2008-12 and subsequently a resource not being renewed at a high rate and gradually being eroded. This pattern is consistent with the high pre-recruit biomass index from the multi-species trawl survey during 2008-10 that has since declined to a historical low (Fig. 32). Accordingly, the renewal rate and magnitude of the exploitable biomass is expected to decline further in the forthcoming years as gains from the strong recruitment period dissipate.

Observer discard data depict the pattern of declining recruitment prospects as the percentage of the catch discarded in the past three years has been low, at about 10% (Fig. 45). This reflects a near absence of soft-shelled and under-sized new-shelled crabs in the catch (Fig. 45), two components of the population that contribute to immediate recruitment into the fishery. The fishery here is generally very efficient in extracting the resource, with soft-shelled crab incidence rarely a concern. This has been especially clear in the past three years (Fig. 90), with virtually no soft-shell in the observed catch. Comparatively, any reductions of recruitment into the exploitable biomass here are less prone to top-down fishery interferences than in most other divisions and more clearly reflect bottom-up productivity factors. It is noteworthy that even in the latest stages of the fisheries of the past three years, soft-shell crab incidence did not approach 15% as it did from 2010-12. This further implies that the recent prolonged recruitment pulse has now near-fully contributed to the exploitable biomass and that recruitment prospects have substantially diminished.

Surveys

The trawl survey of exploitable biomass shows the resource has become increasingly localized into portions of Div. 3L (Fig. 91), with the biomass index at its lowest observed level in 2015 (Table 5, Fig. 20). The CPS trap survey index suggests the density of exploitable crabs remains unchanged on the primary fishing grounds (Figs. 20 and 92). The distribution of exploitable crabs became unusually concentrated in 2015, with few crabs captured outside the northern portion of the Grand Bank (Fig. 91). About 85% of the survey tows captured no exploitable crabs in 2015 (Fig. 21); this index has ranged from about 45-72% in all other survey years. Of particular note is the virtual disappearance of exploitable crabs in the survey along the Divs. 3L, 3N, and southern 3O slope edges in 2015 as well as a lack of large catches in the northwestern portion of the Grand Bank in CMA NS (Fig. 91). Essentially, the trawl survey indicates the exploitable biomass has become substantially reduced in fringe and marginal areas. Conversely, the CPS trap survey, which does not cover such fringe and marginal areas and intensively targets the MS and particularly the MSex management areas (Fig. 9), where trawl survey catch rates remain relatively strong (Fig. 91) and fishery catch rates are the highest in the province (Fig. 16), showed no change in the exploitable biomass index in 2015 (Fig. 92). The spatial differences in coverage of the two surveys largely account for differences in trend in the exploitable biomass indices derived from the two surveys and highlight deficiencies in the CPS survey design with respect to its ability to detect changes in the resource.

Overall recruitment has declined since 2012 to be near its lowest level, reflecting trends throughout most of the division. This is evident in the substantially reduced biomass of new-shelled exploitable crabs in the multi-species trawl survey in 2015 (Fig. 24), as well as reduced catch rates of new-shelled legal-sized crabs in the CPS survey in the past two years (Fig. 25). This reduction in abundance of recently recruited crabs in the CPS survey reflects a decline in all surveyed areas with the exception of CMA MSex to be near 0 kg/trap in the past two years (Fig. 93). The resource has become dominated by old-shelled crabs, which are increasing in abundance in key management areas of the MS, MSex, and 3Lex (Fig. 93) where a relatively strong residual biomass has been established, while most other areas of the Grand Bank are in decline.

Recruitment is expected to decline further in the short term (2-3 years). The trawl survey pre-recruit biomass index has steadily declined since 2009 to a historic low (Fig. 32), while the CPS trap survey index is at or near its lowest observed level in most surveyed areas (Fig. 94). The decline in pre-recruit crabs is widespread, with a steadily depreciating signal of catches of all magnitudes in the trawl survey throughout the division since 2009 to a nearly barren state in 2015 (Fig. 95). The reduction in abundance of all components of the population since 2009-10 is obvious in trawl survey size frequency distributions (Fig. 96). The strong pulse of pre-recruits seen in the survey from 2008-10 (Fig. 32) most likely emerged from the relatively strong pulse of small crabs (i.e. 15-30 mm CW) captured in the survey during 2001-03 (Fig. 96). The lack of any sustained strong pulses of small crabs in the survey since the early 2000s is a major point of concern and strongly suggests the Divs. 3LNO Offshore exploitable biomass will decline further in the forthcoming years.

Despite a strong inference of a widespread decline in recruitment in the next few years, small-mesh traps in the CPS survey have been tracking a pulse of approaching recruits centered at about 53-65 mm CW in 2015 (Fig. 97). This approaching recruitment pulse appears localized to small-mesh traps deployed in the Whale Deep area of Div. 3O (Fig. 6 [45.5N/-52.5W]). The leading tail of this pulse would be expected to begin contributing to the pre-recruit biomass index (i.e. > 75 mm CW adolescents) in 2016. Small-mesh traps deployed in the CPS survey in other portions of Divs. 3LNO are consistent with the broader-scale trawl survey pre-recruit index in showing poor recruitment prospects over the next few years. In particular, the mode of adolescents tracked in small-mesh traps from 2007-13 in CMA MSex appears to have now fully contributed to the exploitable biomass (Fig. 97).

In CMA NS, a small pulse of young crabs ranging from about 35 -50 mm CW was detected in small-mesh traps from the CPS survey in 2015. It is not known if this reflects another emerging recruitment pulse, as the fall multi-species trawl survey has not captured elevated levels of small crabs in recent years (Figs. 96-98). However, in contrast to this, the spring multi-species trawl survey captured an unusually high abundance of small crabs in Divs. 3LN in 2014 (Fig. 38), which appears consistent with the coincidental emergence of a recruitment pulse in Divs. 2HJ (Fig. 57) and 3K (Fig. 73). Further, this broad-scale emergence of small crabs coincides with a return to cooler bottom temperatures along the NL shelf since 2012 (Fig. 42). Collectively, several pieces of evidence are suggesting small crab survival could be improving, thus it will be imperative to monitor for their presence in both the CPS and multi-species trawl surveys over the next few years.

Large-mesh traps in the CPS survey clearly show that the overall biomass is dominated by residual crabs. In CMAs NS, MS, and 3Lex there have been few new-shelled crabs in the population in the past two years (Fig. 99). Moreover, the size frequency distributions indicate that the pulse of recruitment that has recently benefitted CMA MSex has now near-fully made its contribution to the exploitable biomass, evident by advancement of the primary mode from 95 mm CW in 2012 to 110 mm CW in 2014-15 and an increasing proportion of old-shelled crabs in the population. Collectively, this, coupled with a greatly reduced abundance of crabs in CMAs 3L200 and 8B, depict a population of crabs on the Grand Bank suffering from a lack of recruitment and in decline.

Management and harvesters are advised to carefully consider the rate at which crabs are to be extracted from this area over the next few years. Most crabs in the population are old and natural mortality rates are likely to increase over the next few years. Chronologically, although they have not been aged, the crabs of 15-30 mm CW seen in the 2001-03 trawl surveys (Fig. 96) would most likely be about 2-3 years of age (Sainte-Marie et al. 1995) and would thus be about 14-17 years of age in 2015. This is old for Snow Crab and maximum longevity is not expected far beyond these ages. In Div. 3LNO, crabs likely recruit to the fishery at about 9-12 years of age. This is based on best fit lags of about 9 (Fig. 100) or 10 years (Mullowney et al. 2016) between the thermal habitat index and fishery CPUE and the assumption that temperature strongly affects early-life survival at 0-2 years of age. Recruitment into the exploitable biomass occurs earlier, with lags of 2-3 years between trends in the exploitable biomass and CPUE (Fig. 100). Accordingly, a reasonable guess on age of recruitment into the exploitable biomass is about 7-10 years of age; although seven years is not likely typical in these cold waters where skip-molting is common and ages-at-recruitment older than 10 are possible. Nonetheless, with maximum longevity following terminal molt being in the order of 7 to 8 years (Fonseca and Sainte-Marie 2008), one would not expect crabs to live to ages of more than about 14-18 years. Divs. 3LNO Offshore is the only area covered by multi-species trawl surveys where there has been an increasing trend in total mortality rates in recent years (Fig. 47). With the exploitation rate index held relatively constant since 2009 (Fig. 46), this suggests that natural mortality rates are increasing. A fishing strategy of extracting the crabs before natural mortality kills them could be employed; however, on the other hand, there are very poor short-term recruitment prospects and a strategy of slowly extracting the available biomass to prolong gains from the resource over a longer-term could also be advisable.

In summary, despite the fishery currently performing at a very high level along northern portions of the Grand Bank, all available information suggests recruitment into the exploitable biomass has been low in recent years and short-term recruitment prospects are poor. The exploitable biomass and fishery CPUE have begun to decline in marginal and fringe areas of the Grand Bank and further declines are expected throughout the division in forthcoming years. Natural mortality is likely to become a more important regulator of the resource in the next few years and the thermal habitat index suggests no major improvements in renewal rate are expected until at least 2020 (Fig. 100). An anticipated decline of the Snow Crab resource on the Grand Bank will have a large impact on the overall biomass available to the NL Snow Crab fishery.

DIVISION 3L INSHORE

Fishery

The Div. 3L inshore fishery occurs in coastal bays and near-shore regions within 25 nm of headlands off the east coast of Newfoundland (Fig. 101). It incorporates Bonavista Bay

(CMA 5A), Trinity Bay (CMA 6A), Conception Bay (CMA 6B), Northeast Avalon (CMA 6C), Southern Avalon (CMA 8A), and St. Mary's Bay (CMA 9A). All but CMAs 6C and 8A are further sub-divided into inner and outer management areas, but those finer-scale areas are not considered in the assessment. All the bays feature deep holes in their central interior portions. Bonavista and Trinity Bays are open at their mouths, thus the deep water inner portions are continuous with the offshore bathymetry, whereas Conception and especially St. Mary's Bays feature shallow sills at their mouths. The bathymetry in the areas east of the Avalon Peninsula encompassing CMAs 6C and 8A is dominated by the Avalon Channel, a deepwater trough through which the southerly flowing cold inner branch of the Labrador Current passes. Overall, the bottom water here is cold (Fig. 5), particularly in the south, and most of the area is characterized by productive Snow Crab grounds.

Overall landings increased gradually since 2010 to a historical high of 8,400 t in 2015 while effort changed little (Fig. 48). The recent overall high in landings reflects highs in all management areas except Bonavista Bay (CMA 5A) (Fig. 102). For effort, levels have been similar to historical norms in Bonavista and Trinity Bays, below average in Conception Bay and the Northeast Avalon, and at historical highs in the Southern Avalon and St. Mary's Bay (Fig. 102) in recent years.

Overall CPUE has been near its highest level for the past four years (Fig. 15). This reflects trends in CMAs 6A, 6B, and 6C, while other CMAs have been declining during the past two years (Fig. 103). There is a spatial trichotomy occurring in the pattern of fishing performance. In the northernmost Bonavista Bay (CMA 5A), fishery CPUE is overall lowest and trends over the past two decades have more closely reflected those of Div. 3K, particularly in Notre Dame Bay (CMA 3D) and the offshore (CMA 4) (Fig. 62). In 2015, at 8 kg/trap, CPUE in Bonavista Bay was near historic lows. In the central management areas of Div. 3L Inshore (CMAs 6A, 6B, 6C), recent positive trends in CPUE closely reflect not only one another, but the broader scale offshore portion of the northern Grand Bank (Figs. 16 and 87). CPUEs are at or near historic highs in all three CMAs and at over 20 kg/trap have been exceptionally high in Conception Bay in the past two years. Finally, in the south, the recent declining trends in CPUE in CMAs 8A and 9A are similar to CMA 8B on the western Grand Bank (Fig. 87). Delineating proper assessment boundaries for resource assessment is difficult here as bathymetric features of the numerous bays appear to promote discrete populations of crab, yet there is clearly connectivity both among bays and with broader-scale areas, including across NAFO divisions.

Observer coverage has been thinly distributed among the various management areas (Fig. 7) and no area has consistently achieved the minimum standard of four non-consecutive weeks of sampling in recent years for inclusion in the assessment. No observer data were used in the stock assessment of Div. 3L Inshore in 2015.

Depletion of the resource during the fishery was evident in all areas but Trinity (CMA 6A) and Conception (CMA 6B) Bays in 2015 (Fig. 104). In Bonavista Bay (CMA 5A), fishery CPUE declined throughout the season from 2013 to 2014. In 2015, it remained near the 2014 level until about 600 t of removals, after which it steadily declined from about 10 kg/trap at 600 t to 5 kg/trap at 800 t of removals. In Trinity Bay, CPUE has been consistent at 10-15 kg/trap during all parts of the past four seasons. In Conception Bay, fishing performance increased substantially during all parts of the season from 2011-14 and has been very strong at 20-25 kg/trap during all portions of the past two seasons. In CMA 6C, there was consistency in the pattern of CPUE from 2012-14 with it holding near 18-20 kg/trap until about 600 t of removals before gradually decreasing thereafter. However, in 2015 CPUE began to decline earlier, at about 500 t of removals. In both CMAs 8A and 9A, depletion of the resource by the fishery has become increasingly evident since 2013 and a notable drop in CPUE occurred after early portions of the 2015 fishery.

The overall high catch rates of recent years have been associated with a gradual decline in area fished (Fig. 18). This likely reflects the relative strength of strongly performing fisheries such as Conception Bay in influencing the overall divisional analysis. Of note in Div. 3L Inshore is the intensity of the fishery. With 50-70% of potential grounds occupied each year since 2002, the fishing pattern here is particularly dense relative to other divisions. Despite this, CPUE has remained relatively stable over the past two decades on these productive Snow Crab grounds.

Surveys

The overall post-season trap survey exploitable biomass index steadily increased from 2011-2014 to its highest level in the time series (Fig. 105). However, it decreased in all areas in 2015 and returned to the 2011 level. Most management areas experienced increases in biomass from 2011-2014, but a notable exception was Bonavista Bay (CMA 5A) where the exploitable biomass index has steadily declined since 2012 to its lowest level in the time series.

Overall recruitment has declined gradually since 2010 to its lowest observed level. At the management area level, the declining biomass in Bonavista Bay (CMA 5A) since 2012 is primarily due to declining recruitment. There was a sharp reduction of new-shelled legal-sized crabs in the catch from about 12 kg/trap in 2012 to 6 kg/trap in 2013 and the index has remained at that lower level since (Fig. 106). The exploitable biomass in Bonavista Bay has been comprised of an equal mixture of new-shelled recruits and old-shelled residual crabs for the past three years. In Trinity Bay (CMA 6A), recruitment has been variable throughout the time series, but the abundance of new-shelled legal-sized crabs plummeted in 2015 to about 1 kg/trap. Meanwhile, the residual component of the exploitable biomass increased. This is similar to many areas of the adjacent offshore (Fig. 93) as well as Conception Bay (CMA 6B), where legal-sized new-shelled crab abundance was at a time series low in 2015 while residual crab abundance was near a historic high of 18 kg/trap (Fig. 106). In the Northeast Avalon (CMA 6C) and Southern Shore (CMA 8A), the recruitment index of new-shelled legal-sized crabs has fluctuated at 3-6 kg/trap since 2011. Both areas experienced relatively strong catch rates of residual (old-shelled) crabs at about 7-9 kg/trap during 2013-14, but the catch rate dropped substantially in the Southern Shore in 2015 while it remained strong in the Northeast Avalon. Finally, St. Mary’s Bay (CMA 9A) has been experiencing a prolonged and steady decline in catch rates of recently recruited crabs since 2010 and the index of new-shelled legal-sized crabs was at a time series low in 2015. The catch rates of old-shelled legal-sized crabs increased steadily from 2011 to 2014 to counter the declining recruitment. However, in 2015 the catch rates of residual crabs decreased by nearly half, driving a substantial decrease in the exploitable biomass index.

Recruitment is expected to decline further in the short-term (2-3 years). Pre-recruit biomass surveys from CPS and DFO trap surveys throughout the division have been at or near their lowest levels in a decade during the past two years. In the broader scale CPS survey, declines in the pre-recruit biomass index have been measured in Trinity (CMA 6A) and Conception (CMA 6B) Bays, the Northeast Avalon (CMA 6C), and especially St. Mary’s Bay (CMA 9A) since 2012-13 (Fig. 107). This is consistent with a broad-scale decline in pre-recruit biomass to very low levels in the adjacent offshore as well as throughout Newfoundland and Labrador (Fig. 32). Small-mesh trap size frequency distributions from CPS and DFO surveys throughout the division (Fig. 108) show very poor short-term recruitment prospects in all areas but Bonavista Bay (CMA 5A). With the exception of Bonavista Bay, virtually no adolescent crabs larger than 75 mm CW were captured in 2015. Approaching pulses of adolescents were clearly tracked in Trinity (CMA 6A) and St. Mary’s Bays (CMA 9A) during the 2007-13 period. Moreover, trawl surveys in Conception Bay show that a pulse of large adolescent crabs that approached legal-size in 2012 has since contributed to the exploitable biomass and no such signal has been detected in the past three years (Fig. 109). Finally, the incidence of bitter crab disease, which provides a signal of the relative strength of the density of small and intermediate-sized crabs and subsequent recruitment prospects, has been nil in Conception Bay for three consecutive years (Fig. 110). All data are suggesting a broad-scale decline of recruitment into the exploitable biomass in Div. 3L in the short-term, and there are currently no inferences of any emerging pulses of smallest crabs in the population.

DFO trap surveys in both Bonavista (CMA 5A) and Conception (CMA 6B) Bays are consistent with the CPS trap surveys in showing reduced levels of recruitment into the exploitable biomass in recent years which have been countered by a relatively low level of residual biomass in Bonavista Bay and an exceptionally high level of residual biomass in Conception Bay (Fig. 111). Both surveys have shown pulses in recruitment to consistently be followed by pulses in residual biomass over the past twenty years, but contrasting temporal trends across areas depict differences in how Snow Crab populations tend to operate in warm versus cold areas. Recruitment pulses oscillate more quickly in Bonavista Bay, similar to Divs. 2J and 3K. However, in Conception Bay, the process of recruitment into the exploitable biomass is prolonged and drawn out over many years, similar to the Grand Bank (Divs. 3LNO Offshore). This reflects a higher incidence of skip-molting in crabs inhabiting colder water areas (Dawe et al. 2012a) and manifests itself in temporal differences between thermal changes in the environment and impacts on the fishery, with relatively short lags in warm areas (i.e. Divs. 2J [Fig. 59] and 3K [Fig. 84]) and long lags in cold areas (i.e. Divs. 3LNO Offshore [Fig. 100]). Moreover, it explains, at least in part, why recent and present impacts of a broad-scale decline in recruitment stemming from prolonged warming (Fig. 42) are last to be felt by the Divs. 3LNO Offshore and Div. 3L Inshore fisheries. In these divisions, the most recent increase and subsequent decline of the pre-recruit biomass index (2007-11) has been delayed relative to Div. 3K (2006-2010) as were/are changes in the exploitable biomass (Fig. 20) and fishery performance (Fig. 22) indices. The Snow Crab resource is strongly driven by bottom-up (thermal) processes in all areas, but the rate of changes induced by temperature shifts differs substantially.

The biomass indices from the DFO and CPS trap surveys in Bonavista Bay differ greatly in magnitude, likely reflecting the broader spatial distribution of the CPS survey, but both are consistent in trend, indicating a greatly reduced biomass in the past four years (Fig. 112). This can be seen in size frequency distributions in the CPS survey, which show erosion in the abundance of all sizes of legal crabs since 2012 (Fig. 113). The size frequency distributions show a large pulse of incoming recruitment into the exploitable population in Bonavista Bay in 2011, consistent with the DFO survey (Fig. 111). In Conception Bay (CMA 6B), both the DFO and CPS surveys again show a similar trend, but considerable difference in magnitude in the exploitable biomass (Fig. 114) which likely reflects the broader spatial distribution of the CPS survey. Collectively the two surveys show that the biomass in Conception Bay is clearly very high. However, like pre-recruit biomass indices throughout the division (Fig. 11), the DFO pre-recruit biomass index in Conception Bay has been very low during the past three years (Fig. 114). Little inference can be drawn from the abundance of smallest crabs or mature females in the population from small-mesh traps in the DFO survey in Conception Bay as catches have been sporadic and/or highly variable (Fig. 114). Like the DFO survey data, size frequencies from the CPS survey in Conception Bay show an abundant population of old-shelled males inhabiting the bay (Fig. 113). A similar dominance of old-shelled crabs in the population has also been seen in Trinity Bay (CMA 6A), the Northeast Avalon (CMA 6C) and St. Mary's Bay (CMA 9A) in the most recent years, while the size frequency distributions show a depleted biomass along the Southern Shore (CMA 8A).

Overall fisheries-induced mortality in the division has been consistent for the past decade. The overall post-season trap survey-based exploitation rate index changed little from 2005-15 (Fig. 115). There had been considerable variability among management areas from about 2005-11, but exploitation rates converged in most management areas during the past four years, with CMA-specific indices ranging from about 10-30%. In 2015, the exploitation rate index was lowest in Trinity Bay (CMA 6C) and highest in Bonavista Bay (CMA 5A). With a decrease in exploitable biomass in all management areas in 2015 (Fig. 105), maintaining the current level of fishery removals would increase the exploitation rate in all management areas in 2016. Bonavista Bay, St. Mary's Bay, and the Southern Shore management areas in particular would increase their exploitation rates to relatively high levels.

Like Divs. 3LNO Offshore, harvesters and managers are advised to give careful consideration into short-term removal levels in Div. 3L Inshore. The exploitable biomass in most areas is dominated by old crabs and it is likely that natural mortality will become a more important determinant of population abundance in the forthcoming years. However, recruitment prospects also appear very poor in most areas. A strategy of aggressive resource extraction in the short-term to minimize loss to natural causes could be employed, and conversely, an approach of lightly extracting the resource in the short-term could be deemed the best approach in prolonging the yield from the current biomass which is not expected to renew itself to any appreciable level in the foreseeable future.

SUBDIVISION 3PS

Fishery

The Subdiv. 3Ps fishery occurs off the south coast of Newfoundland (Fig. 116). In the Inshore, it predominately occurs within the confines of two major bays, Fortune Bay (CMA 11E) and Placentia Bay (CMA 10A). While the land and bathymetrical features partition Fortune Bay as relatively discrete from the remainder of the Subdivision, Placentia Bay forms a continuum with the expansive offshore. Historically, most major aggregations of Snow Crab have been found in a deep-water trough (i.e. maximum 275 m depth) extending out of Placentia Bay and into the Halibut Channel in CMA 10BCD. In terms of scale, the fisheries in all other management areas of the Subdivision are small compared to CMAs 10A and 10BCD. Like other divisions, there is little scientific basis for the numerous Crab Management Areas of Subdiv. 3Ps, with fishery and resource trends among CMAs often synchronous.

Relative to other divisions along the Newfoundland and Labrador continental shelves, Subdiv. 3Ps is shallow. The tops of the two major offshore banks, the St. Pierre Bank in the west and the Green Bank in the east (Fig. 116), are both shallower than 100 m depth and the intersecting Halibut Channel is less than 200 m depth throughout. These shallow areas of the Subdivision, where virtually the entire fishery occurs (Fig. 13), are cold, but temperatures increase abruptly at the slope edges. In spring of 2015, the distribution of bottom water was typical, with virtually the entire shallow water plateau of the continental shelf comprised of water < 1°C, little areal extent of 1-3°C bottom water, and temperatures exceeding 6°C along the slope edges to the west and south (Fig. 5).

Overall landings declined from a recent peak of 6,700 t in 2011 to 2,500 t in 2015 (Table 6, Fig. 48). Effort reached a historical high in 2014 and decreased slightly in 2015, when only 60% of the TAC was taken (Table 6, Fig. 48). These overall trends in removals and effort reflect the patterns in the two major CMAs (10A and 10BCD), as well as the smaller scale fisheries of CMAs 10X and 11S (Fig. 117). In the remaining CMAs 11E and 11W, similar to the rest of the Subdivision landings have been decreasing and TACs not taken in recent years, but effort levels have remained relatively consistent for about the past five years.

Overall CPUE has steadily declined since 2009 to a record low in 2015, reflecting declines throughout the division (Table 6, Figs. 15, 17 and 122). With the exception of CMA 11W, all management areas were below 5 kg/trap in 2015 (Fig. 118). The declines in CMAs 10A and 10BCD, from about 15-16 kg/trap in 2009-10 to 4 kg/trap in 2015, have been particularly large and precipitous. In 2015, the fishery in all management areas began at about 5 kg/trap (Fig. 119). In all but CMA 11W it declined thereafter to about 1-3 kg/trap over very low levels of removals (Fig. 119) ranging from 45 t in CMA 11E to 600 t in CMA 10BCD. The broad-scale and rapid decline in CPUE is striking relative to other divisions. Since 2011, no other division has undergone such large change in CPUE (Fig. 16).

In-season data from observer sampling are consistent with the logbook data in depicting a poorly performing fishery. In Placentia Bay, the magnitude of legal-sized crabs of all sizes has dropped considerably since 2012 (Fig. 120). This drop has been coincident with the virtual disappearance of new-shelled crabs in the population. The decline in overall abundance of crabs since 2012 has also occurred in the offshore (CMAs 10BCD, 10X, 11S), but a substantial reduction in the abundance of new-shelled crabs did not occur until 2015. Nonetheless, observer data suggest dissipating recruitment into the exploitable biomass in recent years and a population dominated by small old-shelled crabs throughout the Subdivision in recent years. The sharp ‘knife-edge’ appearance at legal-size in the size frequency distributions is suggestive of a high exploitation rate by the fishery.

Discard data from observers further exemplify the decline in recruitment that has been occurring in Subdiv. 3Ps, with continually dwindling catch rates of under-sized soft- or new-shelled crabs since 2005 (Fig. 45). In the past four years the majority of discards have been under-sized old-shelled crabs, a high proportion of which are likely terminally molted adults. The coupling of low fishery catch rates and low percentages of soft-shelled crabs in the catch, such has occurred in Placentia Bay (CMA 10A) and the offshore in most recent years (Fig. 121), is indicative of further poor forthcoming recruitment prospects. In the offshore in 2015, soft-shell crab incidence rose to relatively high levels above the 20% closure threshold in two of the latter weeks of the fishery. It is unknown if this is a positive signal for 2016 recruitment prospects as this occurred under minimal levels of fishing, with 90% of the seasonal effort expended by week 12 (Fig. 14). Further, the brief emergence of a high incidence of soft-shell crabs in the catch would not infer a high biomass of pre-recruit crabs in the population in absolute terms with the exploitable biomass at such a low level (Fig. 20), but could merely reflect a severely depleted residual biomass.

Overall, the fishery data show that the exploitable biomass is currently very low throughout Subdiv. 3Ps and that the recent decline in fishery performance is largely due to a decline of recruitment into the fishery. The catch in 2015 was comprised predominately of old-shelled crabs and with poor renewal prospects the situation is likely to be similar in 2016 as the fishery and natural mortality continue to erode the remaining residual biomass.

Surveys

The trawl survey exploitable biomass index declined by 78% since 2009 to a time series low in 2015 (Table 6, Fig. 20). The CPS trap survey was not conducted in most areas in 2015 (Fig. 11) due to poor resource status, thus no biomass index is available from that survey. The decline in the exploitable biomass reflects poor recruitment. Overall recruitment has declined since 2009 to its lowest observed level (Fig. 24) with virtually no new-shelled legal-sized crabs captured in the spring trawl survey (Fig. 24) or fall CPS trap survey (Fig. 25) in the past three years. The residual biomass, represented by intermediate- to old-shelled legal-sized crabs, began to decline after 2010 (Figs. 24-25). The trawl survey has not captured any large catches of exploitable crabs anywhere in the Subdivision since 2011 (Fig. 122). In the past three years an increasingly high percentage of survey tows have captured very few or no exploitable crabs (Fig. 122), with 97% of the tows capturing no exploitable crabs in 2016 (Fig. 21). The CPS survey is consistent with this broad-scale decline in the resource, showing substantial declines in catch rates of legal-sized old-shelled crabs in all CMAs in recent years, to 0-1 kg/trap in all CMAs occupied by the survey in 2015 (Fig. 123). The residual biomass is severely depleted.

Recruitment has recently been declining (Figs. 24 and 25) and is expected to remain low in the short-term (2-3 years) as the trawl survey pre-recruit biomass index has been at its lowest level for three consecutive years (Table 6, Fig. 32). Like exploitable crabs, the trawl survey has captured very few pre-recruits anywhere in the Subdivision for the past three years (Fig. 124). Moreover, long-term recruitment prospects appear poor with few small crabs (i.e. < 30 mm CW) captured in the spring trawl survey in the past three years (Fig. 125).

The recent low recruitment with poor prospects for the foreseeable future is inconsistent with the presence of a relatively large mode of 15-30 mm CW crabs in the trawl survey from 2009-11 that would be expected to have already or presently be contributing to the pre-recruit and/or exploitable biomass. The last major prolonged pulse of crabs of this size occurred from 2003-2005. Subsequently, the pre-recruit biomass index increased to a very high level in 2009 (Fig. 32), a lag period of 4-6 years from detection of small crabs in the survey, and the exploitable biomass index was high from 2009-11 (Fig. 20). However, the pre-recruit biomass index has been at its lowest level for three consecutive years and there is little to no suggestion of any forthcoming improvements from the 2009-11 pulse of small crabs in the population. Consistent with the trawl survey size frequency distributions, a pulse of adolescent crabs ranging about 44-68 mm CW was detected in small-mesh traps in a localized portion of the offshore in the 2014 CPS survey. However, no survey was conducted in 2015, thus further progression could not be tracked. Nonetheless, the leading tail of this distribution would be expected to have contributed to the pre-recruit biomass index in 2015. Based primarily on the broad-scale trawl survey, with the possibility of some localized improvements, it appears that overall yield from this recruitment pulse will be low.

Several factors may have contributed to dampening the lack of yield from the emergent 2009-2011 recruitment pulse. First, spring bottom temperatures in Subdiv. 3Ps in 2014 and 2015 were relatively cold (Fig. 42). Such cold conditions promote terminal molt at small sizes (Dawe et al. 2012a). Accordingly, it is possible that high proportions of crabs have terminally molted as under-sized adults here in recent years. Although it is typical to see a high percentage of old-shelled animals in the catch of sub-legal-sized crabs in the fishery in Subdiv. 3Ps, there is a suggestion of a very high proportion of old-shelled animals in that component of the population in the past two years (Fig. 120). Second, natural mortality on mid-sized crabs in the population may have increased in recent years, specifically in the form of increased predation. The index of total consumption of Snow Crab by large benthivores and piscivores in 3Ps increased sharply in 2010 and varied between 200,000-250,000 t for five consecutive years, an atypical temporal pattern of consistently high consumption rates (Fig. 6). Finally, fisheries-induced mortality could have contributed to a low yield from any crabs from that recruitment pulse that have approached or entered pre-recruit size (i.e. > 75 mm CW), with the pre-recruit fishing mortality index very high in the past three years (Fig. 46).

Expanding upon the trawl survey indices of abundance that suggest a poor long-term outlook, small-mesh traps from the DFO survey in Fortune Bay have captured virtually no adolescent crabs of any size for the past four years (Fig. 126), with the few crabs captured being small terminally molted adults. Spatially, the capture of small adolescent crabs by the trawl survey has occurred throughout the division since 2010, but their reduction has been most severe in the furthest offshore areas (Fig. 127).

With respect to short-term prospects in specific CMAs, total catch rates of exploitable crabs in all three depth strata of the DFO trap survey in Fortune Bay (CMA 11E) have been at time series lows in the past two years (Fig. 128). This translates into an overall exploitable biomass index at time series lows (Fig. 129). Regarding recruitment prospects, the pre-recruit biomass index from that survey has been very low for the past four years, suggesting little change in the short-term. Moreover, the abundance of small crabs (< 50 mm CW) captured in the survey has been zero for three consecutive years, suggesting poor long-term prospects. Finally, there has been a marked reduction in the abundance of mature females in the past three years. The survey shows all components of the Snow Crab population have declined in recent years in CMA 11E. Large-mesh trap size frequency distributions are consistent with this, showing a depleted population of crabs comprised predominately of under-sized old-shelled crabs (Fig. 130). The situation is similar in Placentia Bay (CMA 10A), and although there is a higher proportion of new-shelled crabs in the area, the resource in CMA 11SX in the offshore is also clearly depleted (Fig. 130).

Key summary indices from Subdiv. 3Ps yield conflicting information. Both the pre-recruit and exploitable biomass indices are presently very low (Fig. 131), yet their within-year correspondence suggests year effects in the catchability of the survey trawl are common and compromises the reliability of predictions for the pre-recruit index. However, the exploitable biomass index serves as a good predictor of fishery CPUE in the following year (r^2=0.48) and suggests fishery performance is likely to decline further in 2016. However, in opposition to this, the lagged habitat index would suggest that both the exploitable biomass and fishery CPUE should now be improving or begin to improve in 2016. This would be consistent with the emergence of the pulse of small crabs detected in the trawl survey in 2009-11 (Fig. 125), but there is little to no sign of increasing recruitment potential in recent survey or fishery data. The scenario suggests that the reliability of the thermal habitat index as a predictor of long-term productivity and recruitment potential may be diminishing. This is thought to reflect a current shift in trophic control in the ecosystem and on this resource. In the absence of high abundances of finfish for the past two and a half decades, this resource has been predominately under bottom-up control. However, survey data from Subdiv. 3Ps (DFO 2015) and the broader-scale Newfoundland and Labrador Shelf (DFO 2014b) are suggesting finfish abundances have recently been increasing in association with prolonged warming and top-down predation controls are becoming more important regulators of not only the Snow Crab resource, but also of northern shrimp (*Pandalus borealis*). Northern shrimp is another cold-water crustacean that benefitted from cold water and release of predation controls (DFO 2014b) following the collapse of finfish stocks in the early 1990s, but is presently in decline in the transitioning ecosystem. The overall scenario suggests that along with poor short- and mid-term recruitment prospects, the long-term outlook for Subdiv. 3Ps Snow Crab is poor.

DIVISION 4R3PN

Fishery

The Divs. 4R3Pn fishery occurs along the west and southwest coasts of Newfoundland (Fig. 132). The area encompasses nine CMAs. The offshore CMA OS8 is separated from the numerous inshore CMAs by a line at eight nautical miles from headlands of the shoreline. There is little fishing activity in the southwestern CMAs 12A and 12B and the largest scale fishery occurs in Bay St. George (CMA 12C). The bathymetry off the west coast is characterized by a shallow water nearshore plateau that borders the deep Esquiman Channel (Figs. 1 and 132). 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 assessment division are the warmest along the NL shelf, and it is comparatively unproductive for Snow Crab. Fishery

CPUE is consistently low compared to other divisions and the fishery has historically tended to be opportunistic in nature, with harvesters choosing to prosecute it when commercial quantities of crab are believed to be present.

Overall landings increased from a historic low of 190 t in 2010 to between 750-900 t since 2012 (Table 7, Fig. 48). Effort has been relatively unchanged since 2012 (Table 7, Fig. 48). These overall trends in landings and effort reflect patterns in most CMAs (Fig. 133). In all areas, removals increased from 2011-13. They have been unchanged or increased slightly since in Bay St. George (CMA 12C), the Inner and Outer Bay of Islands (CMAs 12F and 12E), and Bonne Bay (CMA 12G), but have declined once again off Port aux Port (CMA 12D) and Port au Choix (CMA 12H), as well as in the offshore (CMA OS8).

The overall increase in removals in recent years has been associated with improved fishery catch rates. Overall CPUE has remained near its highest observed level in the past four years (Table 7, Fig. 15), but there is considerable variability among management areas (Fig. 134). All major areas experienced CPUE increases from 2011-13 to levels at or close to historic highs. Most areas have since declined, but remain near average or higher levels. The Inner Bay of Islands (CMA 12F) and Bonne Bay (CMA 12G) have maintained catch rates near historic highs during the past two years. The offshore fishery has been patchily distributed for the past six years, with pockets of effort occurring along adjacent management area lines (Fig. 16). It has performed consistently poor relative to the inner areas (Fig. 16).

The broad-scale improvements in CPUE in all areas during 2011-13 occurred not only across years, but in the presence of successively higher levels of removals in most CMAs (Fig. 135). However, since 2013 there appears to have been higher levels of resource depletion by fisheries in most CMAs. A clear exception to this is Bonne Bay (CMA 12G), where the 2015 fishery was very quick (only three weeks of fishing data present) and catch rates remained high at about 12-14 kg/trap. Nonetheless, the depletion plots give an overall suggestion of fisheries now in decline.

Surveys

Trends in the fishery data coincide with trends in the CPS trap survey data. The post-season trap survey biomass index increased substantially in 2011 and 2012, but decreased once again in 2013 and has been unchanged for the past four years (Fig. 136). This pattern is reflected in most surveyed areas. The abrupt 2011 increase in the exploitable biomass index in 2011 was associated with sharp increases in recruitment (new-shelled legal-sized crabs) in Bay St. George (CMA 12C), and the Inner and Outer Bay of Islands (CMAs 12F and 12E), and an increasing trend in Bonne Bay (CMA 12G). However, overall recruitment has since declined and has been low for the past two years (Fig. 25). This reflects decreases to low levels in all CMAs (Fig. 137). Meanwhile, the residual biomass (old-shelled legal-sized crabs) has increased or remained relatively high in most CMAs in the past two years (Fig. 137). An exception to this overall broad-scale increase in recruitment that has now decreased in strength and produced an increased residual biomass is the offshore (CMA OS8), where survey catch rates have remained relatively poor throughout the time series.

Recruitment prospects appear relatively weak for the next 2-3 years. The CPS trap survey pre-recruit index has been relatively low since 2012 (Fig. 138). This reflects lows levels of pre-recruits in the population in the three CMAs where small-mesh traps are used in the survey. The substantial increase and high level in the index seen from 2010-12 was associated at a one year lag with trends in the exploitable biomass index (Fig. 138), and the index appears to be a strong predictor of forthcoming recruitment prospects. The entry of a broad-scale recruitment pulse into the exploitable biomass from about 2010/11 to 2013 was apparent in large-mesh size frequency distributions in all surveyed CMAs (Fig. 139), as is the subsequent deterioration of the population. These recruitment pulses were clearly tracked in small-mesh size frequency distributions in preceding years (Fig. 140). Unfortunately, there is little suggestion of any major recruitment pulses of small crabs burgeoning in recent years. The fishery is not ascribed as the primary cause of the resource decline; a lack of productivity and diminishing recruitment into the fishery is. The post-season exploitation rate index has varied since 2005 and was about average in 2015 (Fig. 141). Maintaining the current level of fishery removals would result in little change to the exploitation rate index in 2016, but like most other divisions, all indications are that the Snow Crab resource will decline further in Divs. 4R3Pn in the forthcoming years.

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TABLES

Table 1. Annual TAC, landings, and estimated effort for Divs. 2HJ3KLNOP4R, as well as the exploitable EBI and PBI from the fall multi-species trawl surveys in Divs. 2HJ3KLNO.

Year	TAC (t)	Landings (t)	EBI (t x 1000	PBI (t x 1000)
1995	27,875	31,451	46.1	17.4
1996	34,864	36,702	60.0	29.3
1997	42,015	43,345	48.2	21.3
1998	49,225	50,467	66.4	20.6
1999	61,806	68,700	37.3	10.5
2000	51,159	55,151	32.9	13.5
2001	52,267	56,470	40.4	13.5
2002	56,981	58,735	30.5	8.3
2003	56,250	58,330	23.1	8.5
2004	53,590	55,609	20.3	7.1
2005	49,978	43,982	27.1	7.0
2006	46,233	47,257	18.0	8.0
2007	47,663	50,205	26.5	8.1
2008	54,338	52,734	30.2	13.9
2009	54,110	53,440	31.7	15.1
2010	56,087	52,199	23.9	14.9
2011	55,559	52,903	20.1	7.8
2012	52,990	50,474	25.1	7.8
2013	52,122	50,741	24.6	4.6
2014	51,611	49,847	19.8	3.3
2015	50,106	47,250	9.41	1.53

Note – effort estimated as the amount of traps necessary to take the reported landings using the calculated unstandardized CPUE in each division each year.

Table 2. Annual TAC, landings, estimated effort, and standardized CPUE for Divs. 2HJ, as well as the EBI and PBI from the fall multi-species trawl survey.

Year	TAC (t)	Landings (t)	Effort (trap hauls)	CPUE (kg/trap)	EBI (t x 1000)	PBI (t x 1000)
1995	3,050	3,189	398,625	8.0	5.98	2.19
1996	2,800	3,102	333,548	9.3	5.85	1.56
1997	2,800	3,183	286,757	11.1	8.97	1.79
1998	3,500	4,098	286,573	14.3	11.70	1.65
1999	4,655	5,416	410,303	13.2	6.96	0.66
2000	3,411	3,682	304,298	12.1	4.78	1.97
2001	3,340	3,754	431,494	8.7	4.02	1.02
2002	3,381	3,520	577,049	6.1	2.12	1.29
2003	2,185	2,530	575,000	4.4	1.79	1.28
2004	1,780	1,925	534,722	3.6	1.90	2.14
2005	1,425	1,576	297,358	5.3	4.96	1.65
2006	1,425	2,139	257,711	8.3	3.27	1.34
2007	1,570	2,523	274,239	9.2	4.57	0.97
2008	2,466	2,530	245,631	10.3	2.63	0.84
2009	2,466	2,389	298,625	8.0	3.06	1.41
2010	2,227	2,131	280,395	7.6	1.58	0.60
2011	2,197	1,933	371,731	5.2	1.09	0.78
2012	1,952	1,606	281,754	5.7	1.54	0.95
2013	1,765	1,392	156,404	8.9	1.49	0.46
2014	1,765	1,736	209,157	8.3	3.64	1.28
2015	1,765	1,769	170,096	10.4	1.62	0.23

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

Table 3. Annual TAC, landings, estimated effort, and standardized CPUE for Div. 3K, as well as the EBI and PBI from the fall multi-species trawl survey.

Year	TAC (t)	Landings (t)	Effort (trap hauls)	CPUE (kg/trap)	EBI (t x 1000)	PBI (t x 1000)
1995	11,450	12,326	1,035,798	11.9	12.10	4.70
1996	12,950	14,210	1,268,750	11.2	16.70	5.65
1997	14,300	14,796	1,395,849	10.6	12.90	4.93
1998	15,390	16,685	1,390,417	12.0	12.60	3.55
1999	17,842	20,980	2,119,192	9.9	7.62	1.68
2000	13,228	15,140	1,663,736	9.1	6.67	3.05
2001	13,428	15,029	1,549,381	9.7	6.77	3.09
2002	14,683	15,671	1,551,584	10.1	5.77	2.69
2003	15,608	16,509	1,737,789	9.5	3.52	1.93
2004	15,593	16,463	2,318,732	7.1	3.86	2.28
2005	12,860	8,693	1,402,097	6.2	5.24	2.54
2006	10,430	10,744	1,063,762	10.1	6.97	4.05
2007	11,750	12,270	908,889	13.5	9.11	2.17
2008	15,075	15,071	991,513	15.2	10.60	3.48
2009	16,475	16,184	1,602,376	10.1	5.32	2.69
2010	14,440	12,425	1,479,167	8.4	4.36	1.94
2011	12,053	10,744	1,580,000	6.8	3.84	1.86
2012	9,438	8,390	1,252,239	6.7	3.34	1.40
2013	8,449	8,519	1,038,902	8.2	5.74	1.15
2014	7,980	7,828	1,030,000	7.6	3.73	1.04
2015	7,294	7,182	1,040,870	6.9	2.40	0.64

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

Table 4. Annual TAC, landings, estimated effort, and standardized CPUE for Div. 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	677,094	11.7
1997	5,850	6,398	639,800	10.0
1998	7,225	6,882	609,027	11.3
1999	5,350	5,453	478,333	11.4
2000	4,633	4,731	404,359	11.7
2001	5,615	5,543	522,925	10.6
2002	6,540	6,524	567,304	11.5
2003	6,774	6,817	802,000	8.5
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	520,753	14.6
2014	8,170	7,969	577,464	13.8
2015	8,522	8,391	621,556	13.5

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

Table 5. Annual TAC, landings, estimated effort, and standardized CPUE for Divs. 3LNO offshore, as well as the EBI and PBI from the fall multi-species trawl survey.

Year	TAC (t)	Landings (t)	Effort (trap hauls)	CPUE (kg/trap)	EBI (t x 1000)	PBI (t x 1000)
1995	5,175	7,212	394,098	18.3	28.50	9.91
1996	7,100	8,494	541,019	15.7	35.90	20.50
1997	13,075	14,293	898,931	15.9	26.90	15.00
1998	13,250	15,111	873,468	17.3	41.40	15.80
1999	24,275	27,329	1,518,278	18.0	23.80	8.42
2000	20,502	22,083	1,144,197	19.3	20.50	8.56
2001	20,465	22,630	1,184,817	19.1	29.00	9.59
2002	22,333	23,528	1,244,868	18.9	21.20	5.33
2003	23,703	24,818	1,442,907	17.2	16.90	5.96
2004	23,703	24,656	1,688,767	14.6	14.60	3.30
2005	23,703	23,571	1,695,755	13.9	16.60	2.82
2006	23,703	24,526	1,751,857	14.0	7.07	2.88
2007	23,703	24,406	2,017,025	12.1	11.10	4.64
2008	24,148	23,421	2,110,000	11.1	15.10	9.14
2009	21,769	21,946	1,925,088	11.4	22.90	10.70
2010	24,835	24,136	1,736,403	13.9	17.60	11.70
2011	26,100	25,845	1,900,368	13.6	15.10	5.12
2012	26,490	26,141	1,613,642	16.2	19.50	5.29
2013	26,643	26,289	1,436,557	18.3	16.90	3.05
2014	27,023	26,530	1,607,879	16.5	12.20	0.86
2015	29,651	28,768	1,798,000	16.0	5.37	0.65

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

Table 6. Annual TAC, landings, estimated effort, and standardized CPUE for Subdiv. 3Ps, as well as the EBI and PBI from the spring multi-species trawl survey.

Year	TAC (t)	Landings (t)	Effort (trap hauls)	CPUE (kg/trap)	EBI (t x 1000)	PBI (t x 1000)
1995	1725	1929	163,475	11.8		
1996	3,050	2,974	178,084	16.7	3.06	0.91
1997	4,600	4,675	292,188	16.0	0.84	0.18
1998	6,200	6,624	424,615	15.6	1.31	0.34
1999	7,999	7,905	513,312	15.4	2.22	0.60
2000	7,700	7,887	551,538	14.3	1.13	0.39
2001	7,600	7,839	515,724	15.2	0.93	0.29
2002	7,600	7,637	748,725	10.2	0.80	0.26
2003	6,085	6,118	826,757	7.4	0.70	0.24
2004	4,395	4,720	749,206	6.3	0.87	0.40
2005	4,100	3,172	598,491	5.3	0.94	0.30
2006	3,045	3,105	477,692	6.5	0.52	0.10
2007	3,245	3,963	535,541	7.4	0.68	0.43
2008	4,358	4,524	443,529	10.2	0.58	0.43
2009	5,280	5,559	441,190	12.6	1.28	1.04
2010	6,205	6,035	490,650	12.3	1.06	0.35
2011	7,027	6,716	633,585	10.6	0.97	0.54
2012	6,467	6,225	604,369	10.3	0.58	0.18
2013	6,467	6,047	711,412	8.5	0.48	0.07
2014	5,577	4,904	860,351	5.7	0.51	0.05
2015	4,299	2,540	705,556	3.6	0.28	0.06

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

Table 7. Annual TAC, landings, estimated effort, and CPUE for Divs. 4R3Pn.

Year	TAC (t)	Landings (t)	Effort (trap hauls)	CPUE (kg/trap)
1998	1,310	1,067	248,140	4.3
1999	1335	1617	330,000	4.9
2000	1430	1628	339,167	4.8
2001	1544	1,675	372,222	4.5
2002	1749	1855	276,866	6.7
2003	1,817	1538	290,189	5.3
2004	1,836	1425	331,395	4.3
2005	1,817	856	203,810	4.2
2006	1535	514	138,919	3.7
2007	1290	558	206,667	2.7
2008	1240	365	104,286	3.5
2009	901	268	83,750	3.2
2010	900	188	53,714	3.5
2011	1029	596	152,821	3.9
2012	1059	742	125,763	5.9
2013	1059	891	135,000	6.6
2014	1059	850	146,552	5.8
2015	1059	776	143,704	5.4

Note – effort estimated as the amount of traps necessary to take the reported landings using unstandardized CPUE. 2015 effort preliminary.

FIGURES

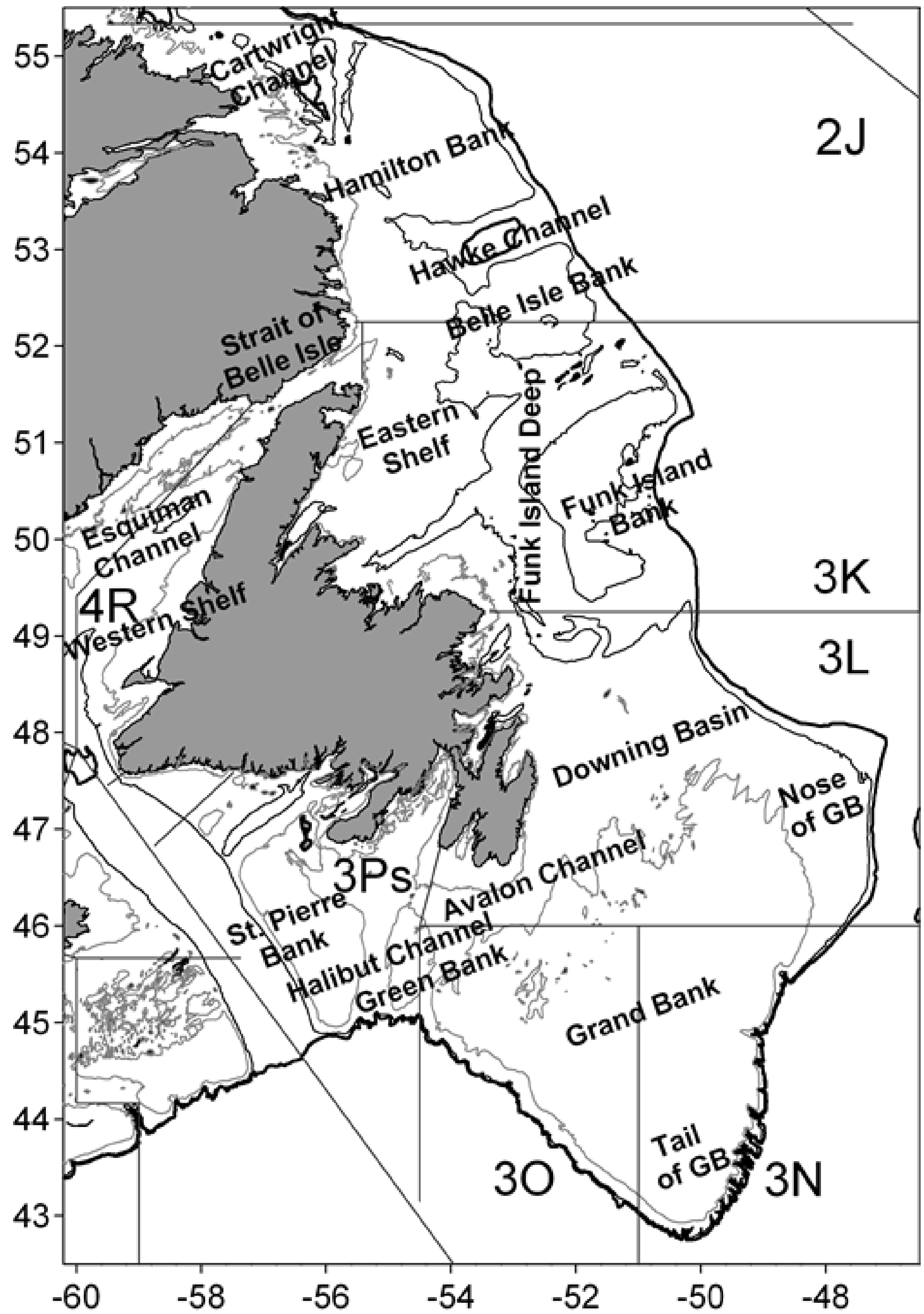

Figure 1. Map of the NL Continental Shelf showing place names, bathymetrical features, and NAFO divisions.

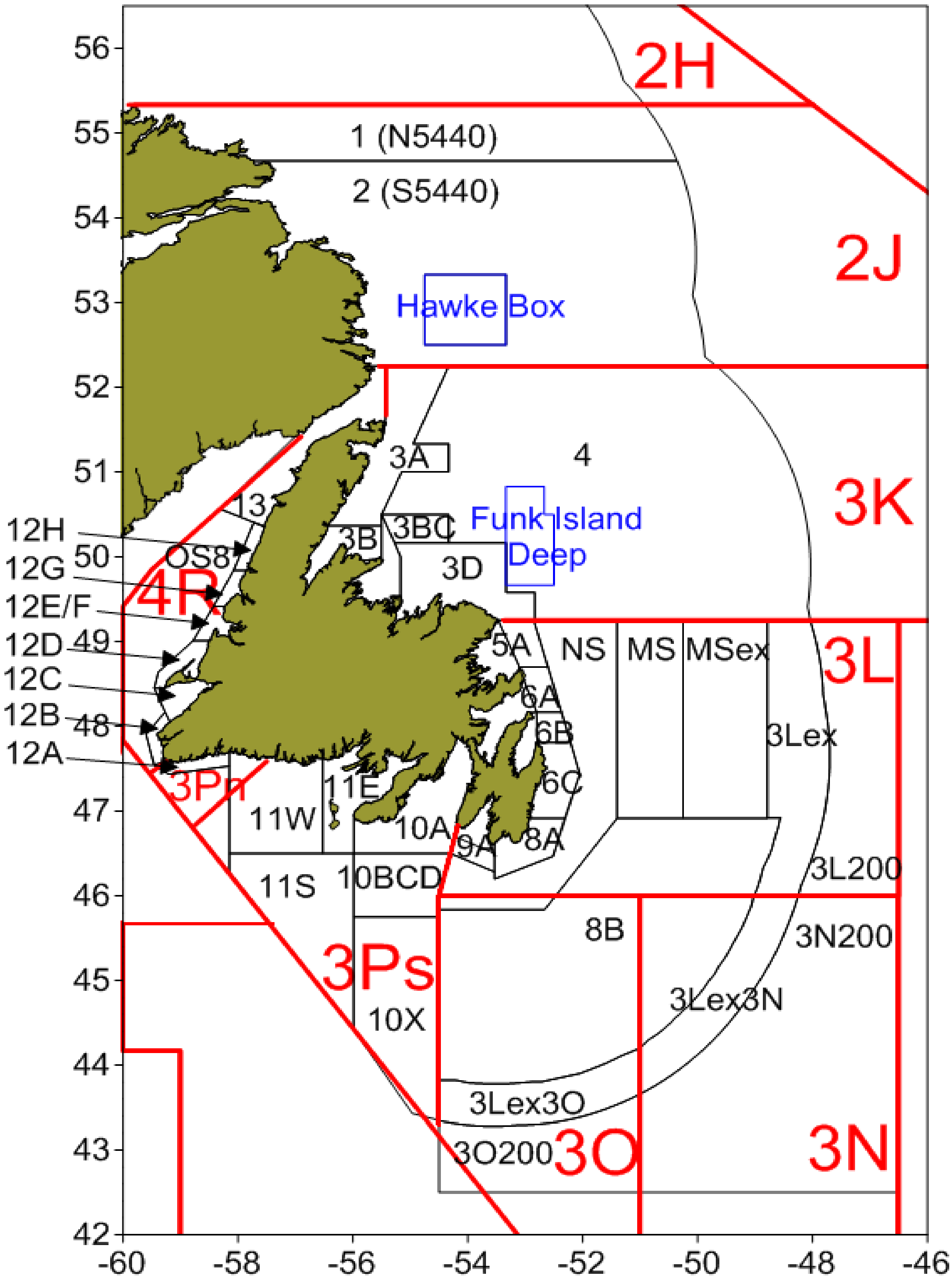

Figure 2. NAFO divisions (red lines), NL Snow Crab Management Areas (black lines), and trawling and gillnetting closures (blue boxes).

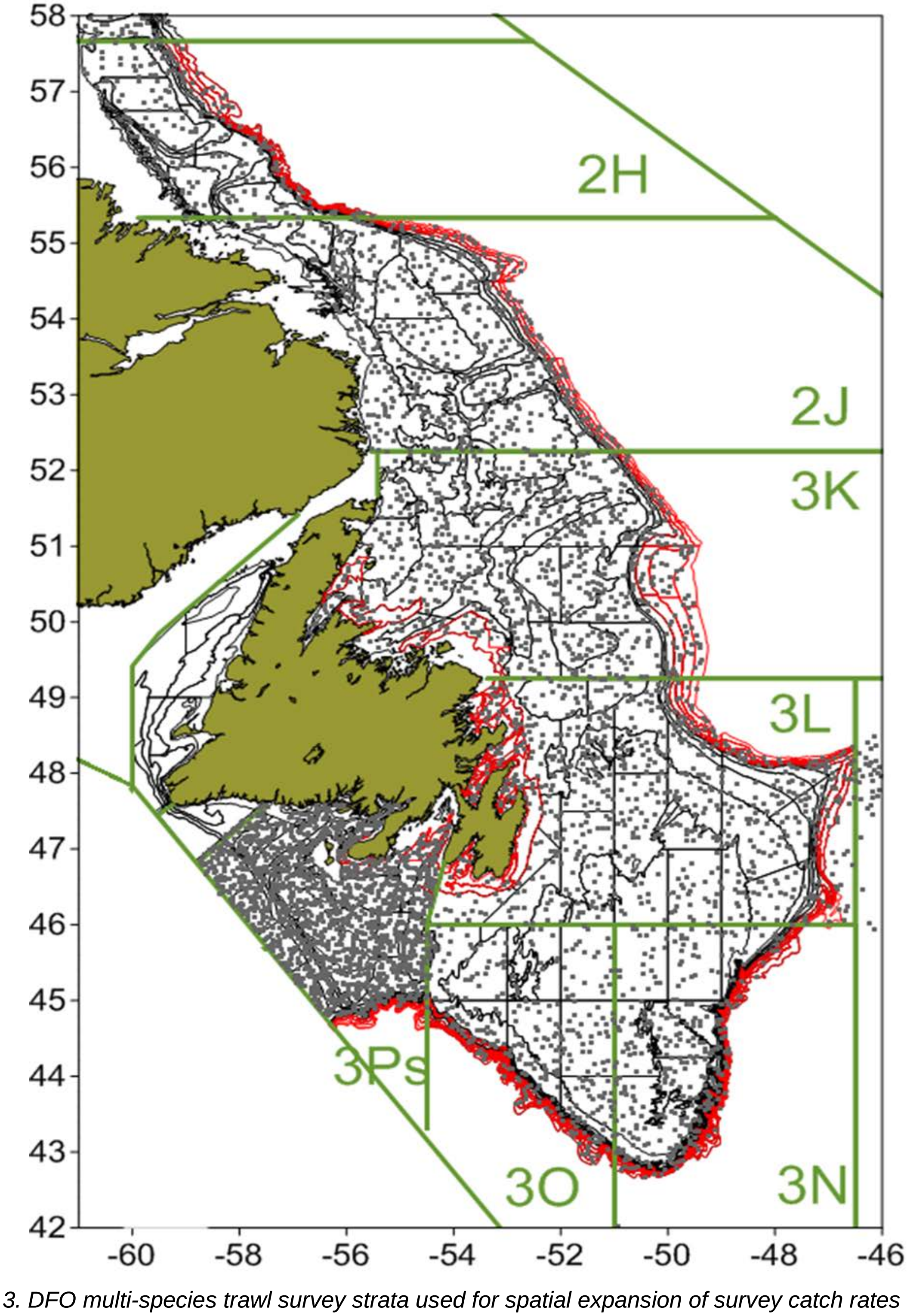

Figure 3. DFO multi-species trawl survey strata used for spatial expansion of survey catch rates (black) and omitted strata (red). Ogmap vertex positions (grey dots).

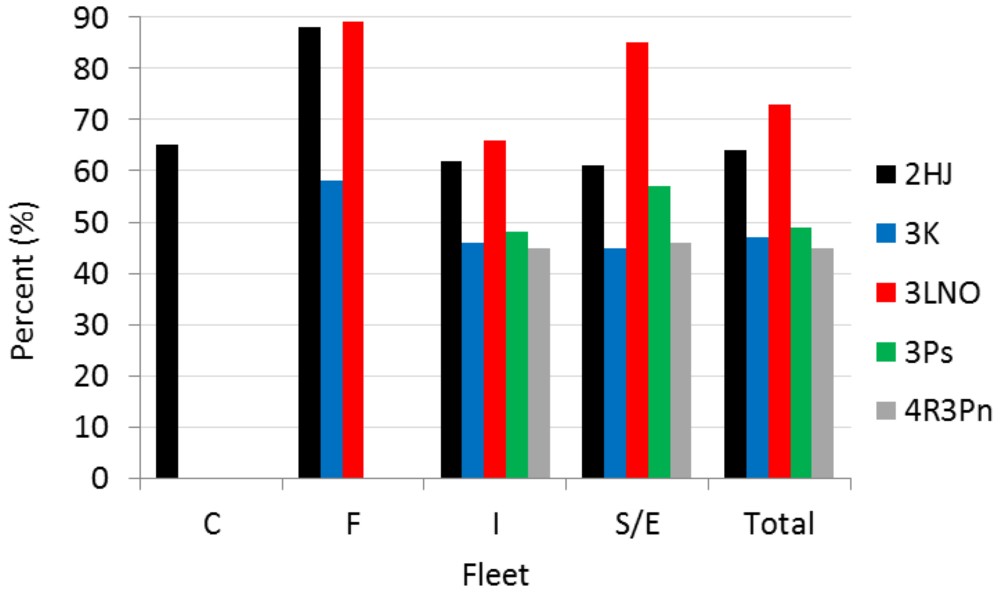

Figure 4. Percentage of logbooks contained in the database for the 2015 assessment by fleet sector and division. Note – 60% of logbooks present overall. Fleets are Communal (C), Full-time (F), Inshore (I), Supplementary (S), and Exploratory (E).

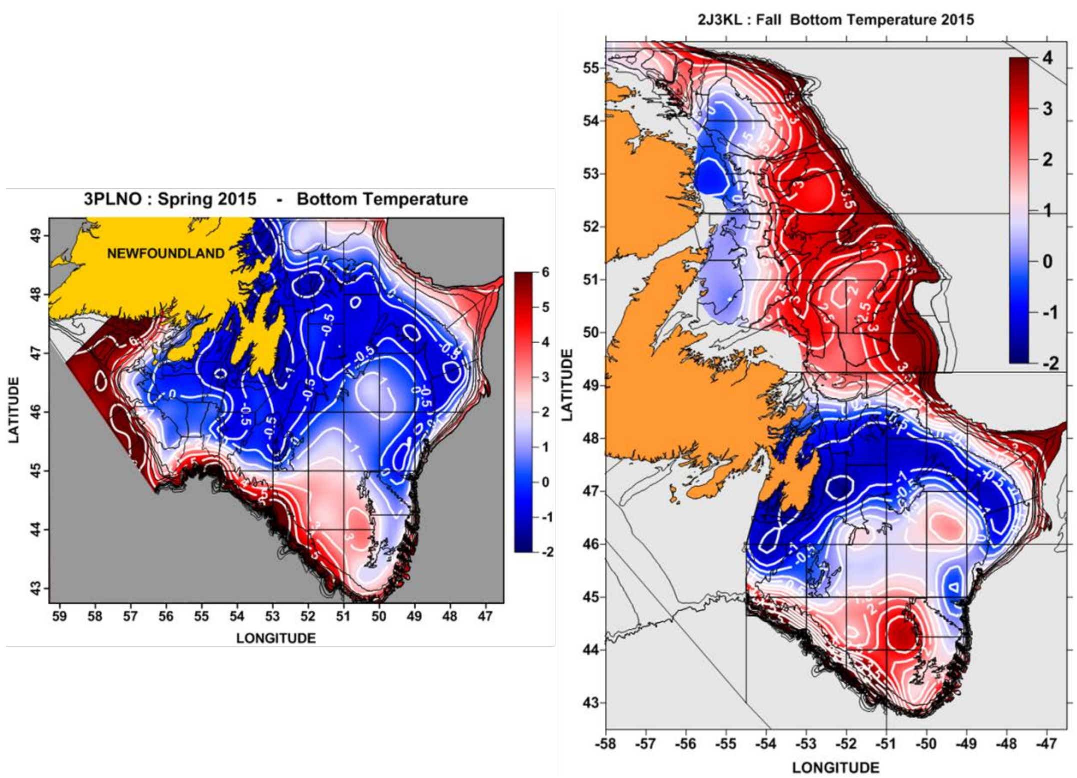

Figure 5. Maps of bottom temperatures along the NL shelf during spring (left map) and fall (right map) from multi-species trawl surveys in 2015.

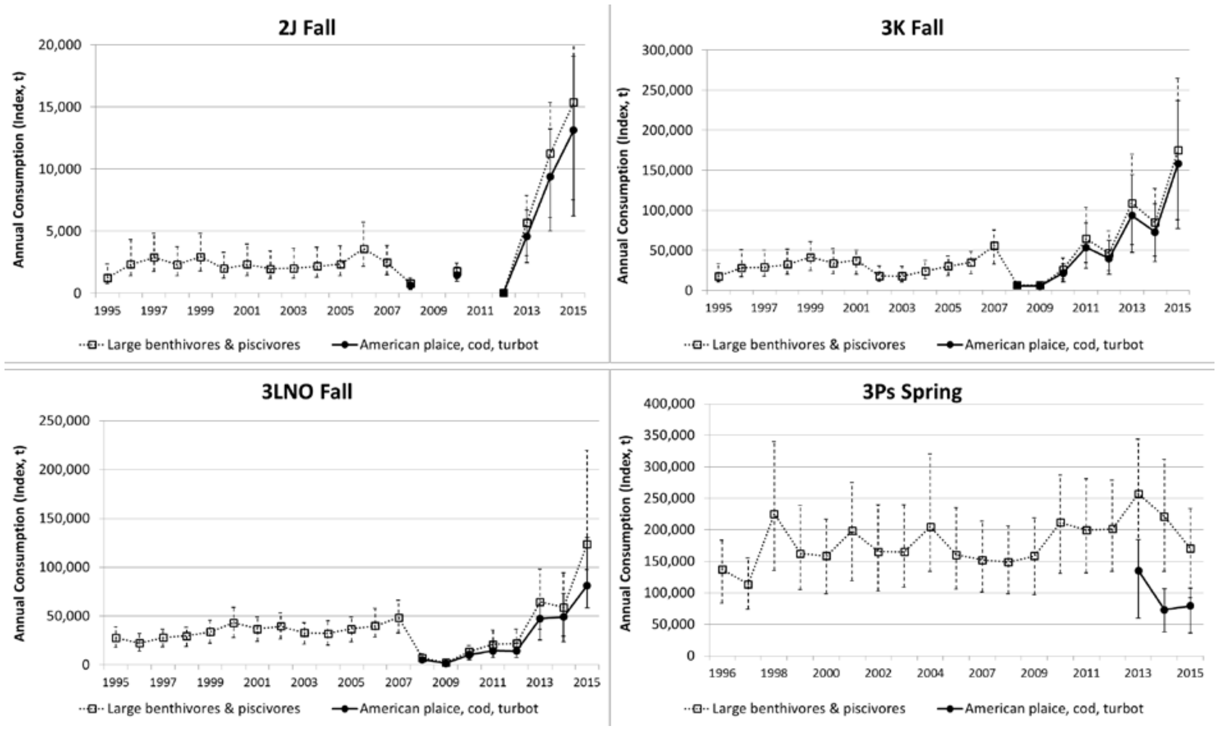

Figure 6. Indices of consumption of snow crab by predators by assessment division.

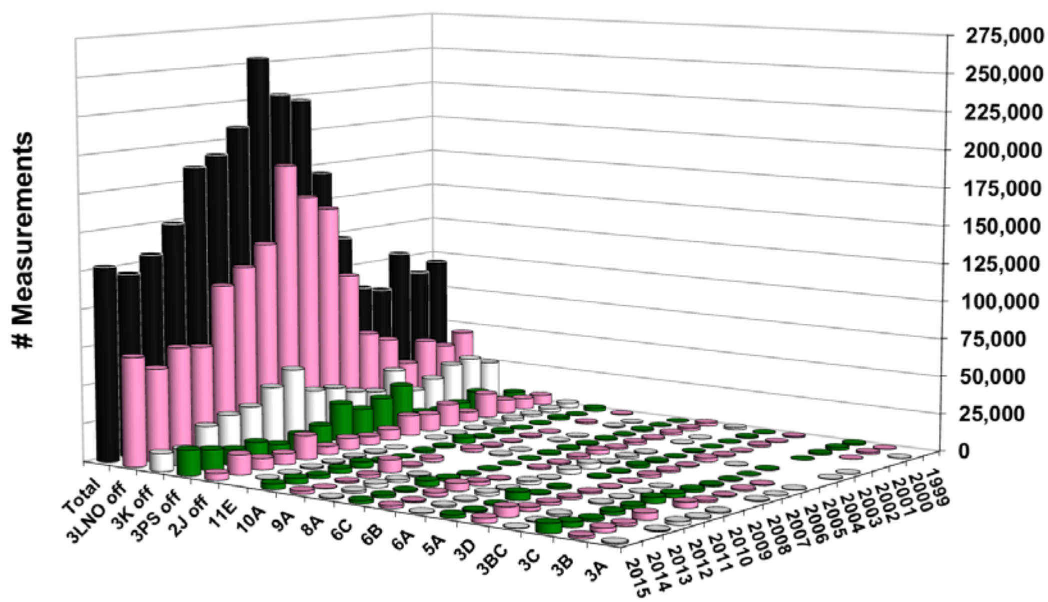

Figure 7. Observer sampling by CMA and year. Data pooled for offshore CMAs in each division.

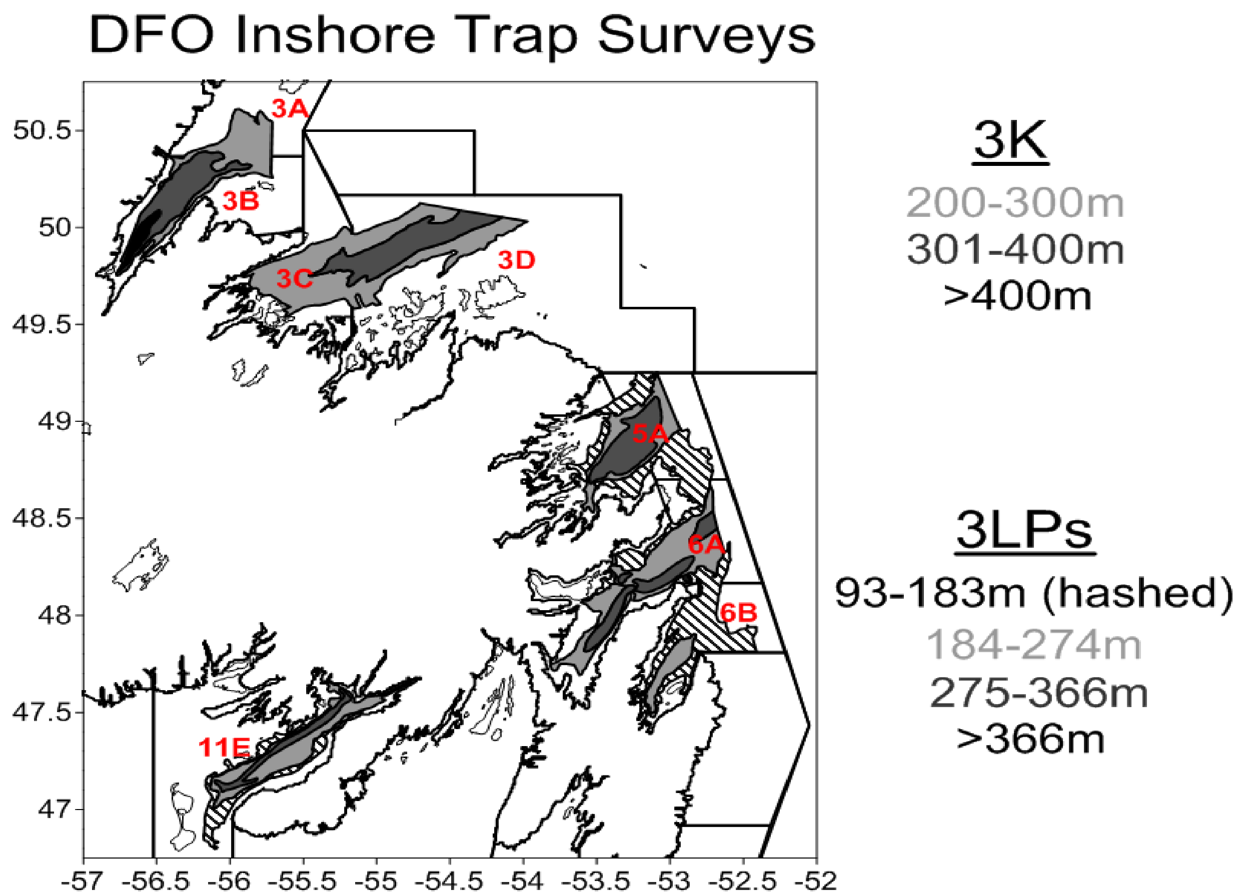

Figure 8. Strata occupied during DFO inshore trap and trawl surveys. Note - St. Mary's Bay covered in past two years. Trawling exclusive to deepest strata of Bonavista (CMA 5A) and Conception (CMA 6B) Bays.

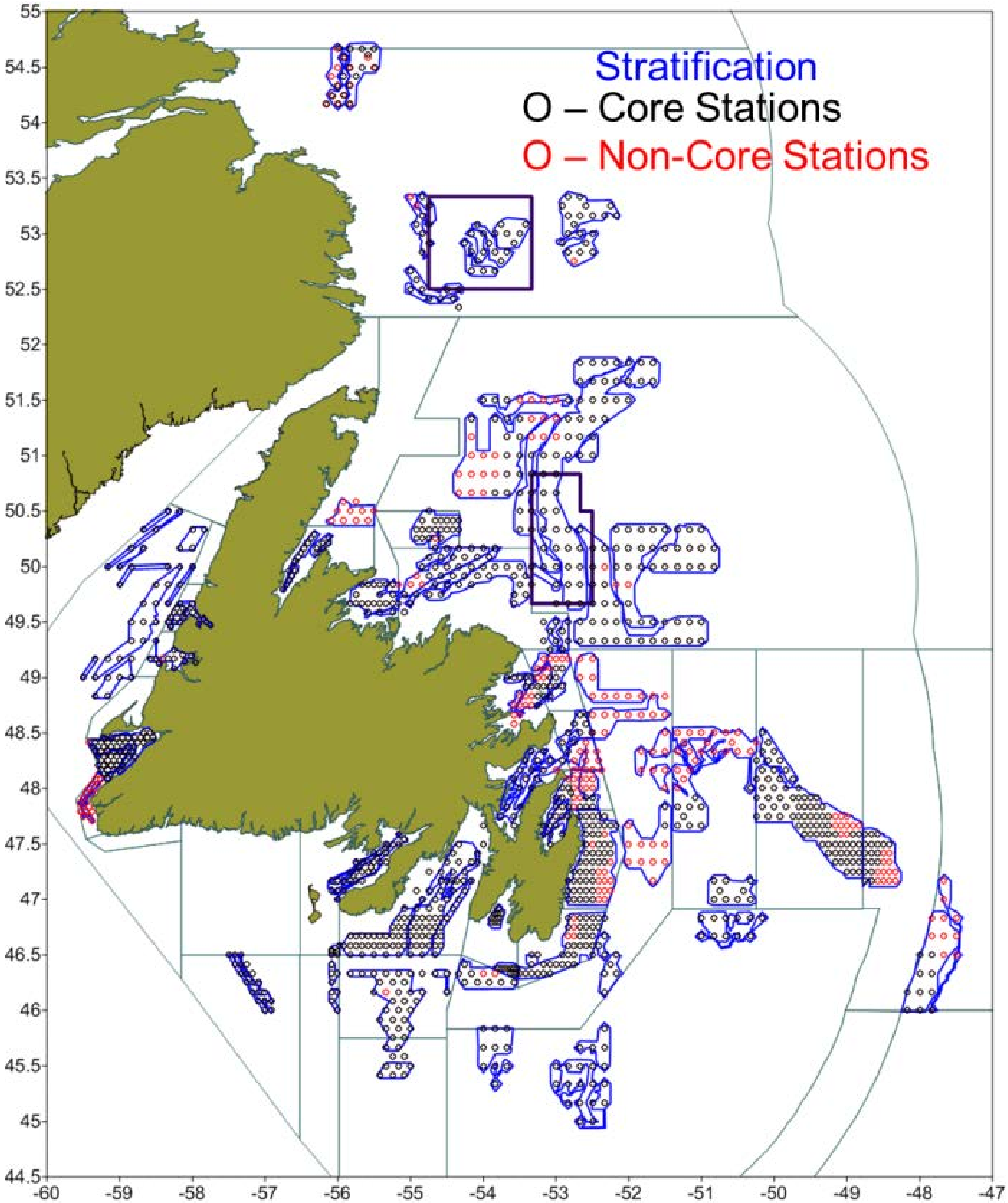

Figure 9. CPS trap survey map showing occupied and core stations as well as stratification scheme used for data analyses.

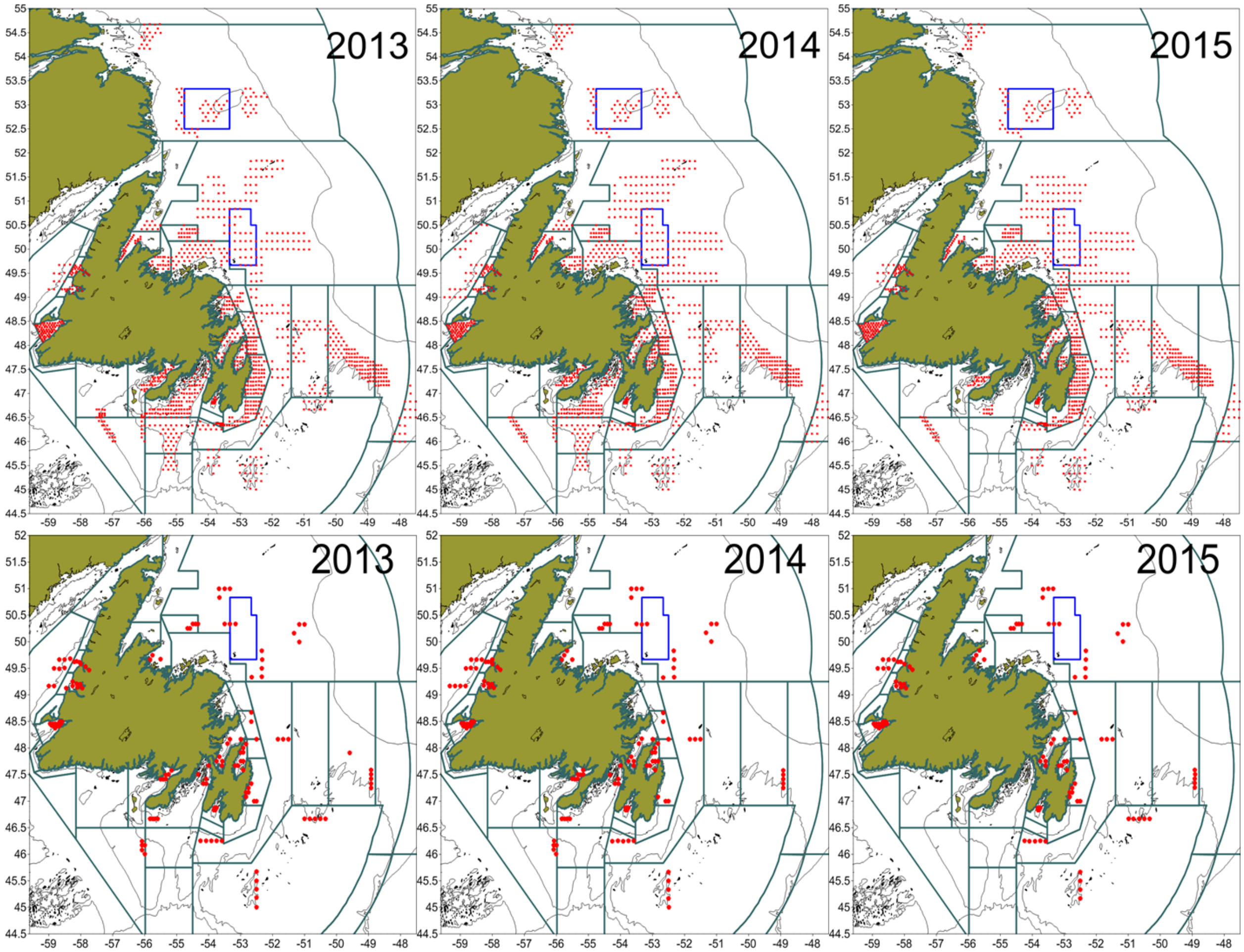

Figure 10. CPS trap survey locations of large-mesh (top panels) and small-mesh (bottom panels) traps from 2013-15. Note omission of most of Subdiv. 3Ps in 2015.

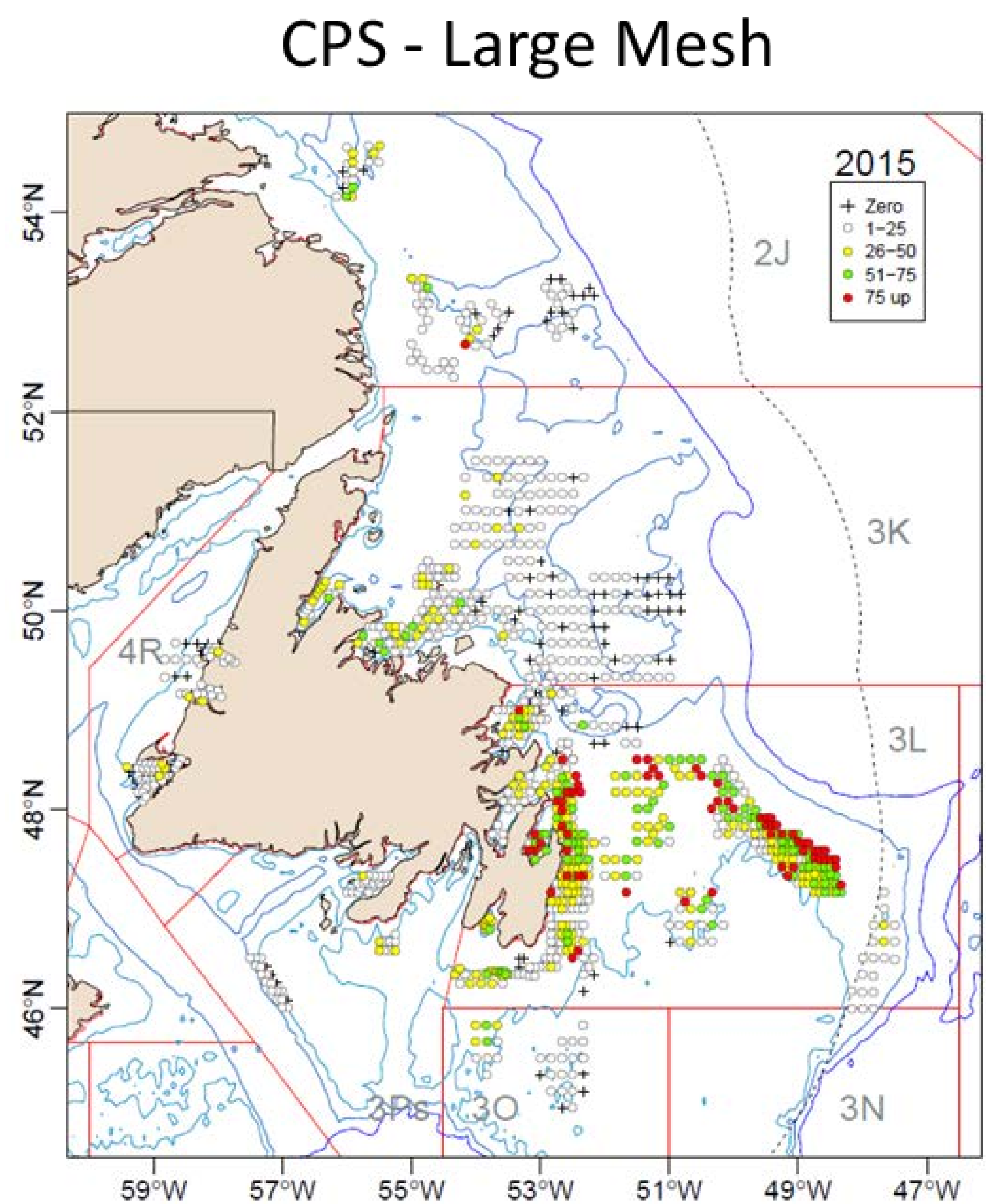

Figure 11. CPS trap survey catch rates (#/trap) of legal-sized crabs in large-mesh traps during 2015.

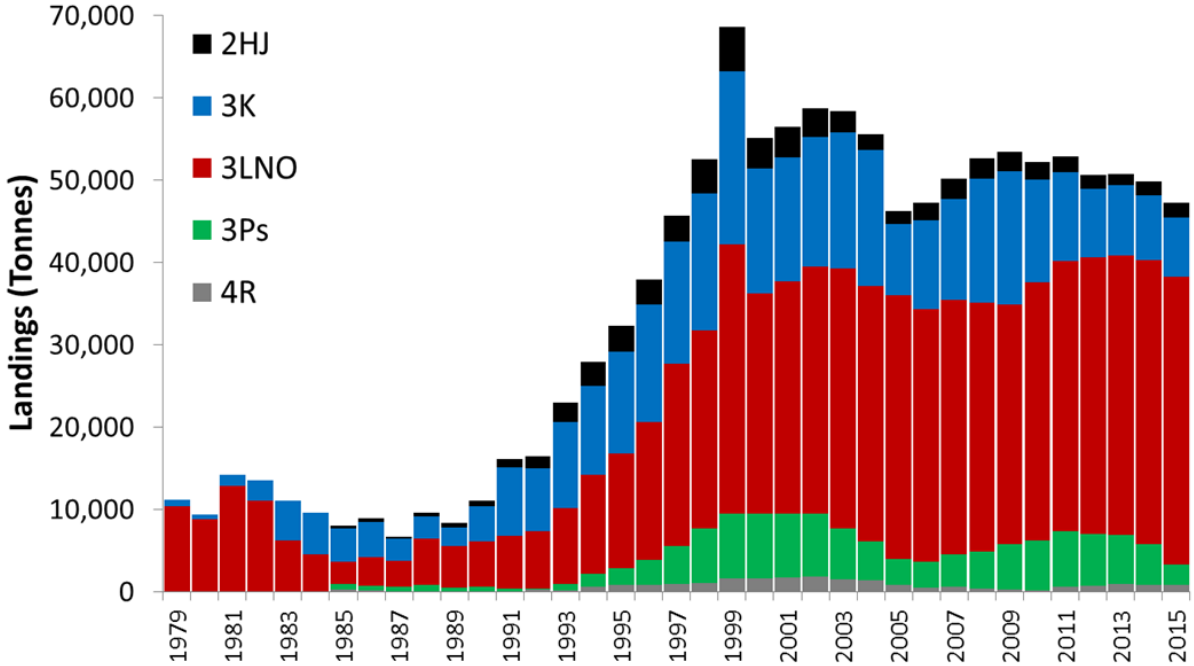

Figure 12. Annual landings by NAFO Division.

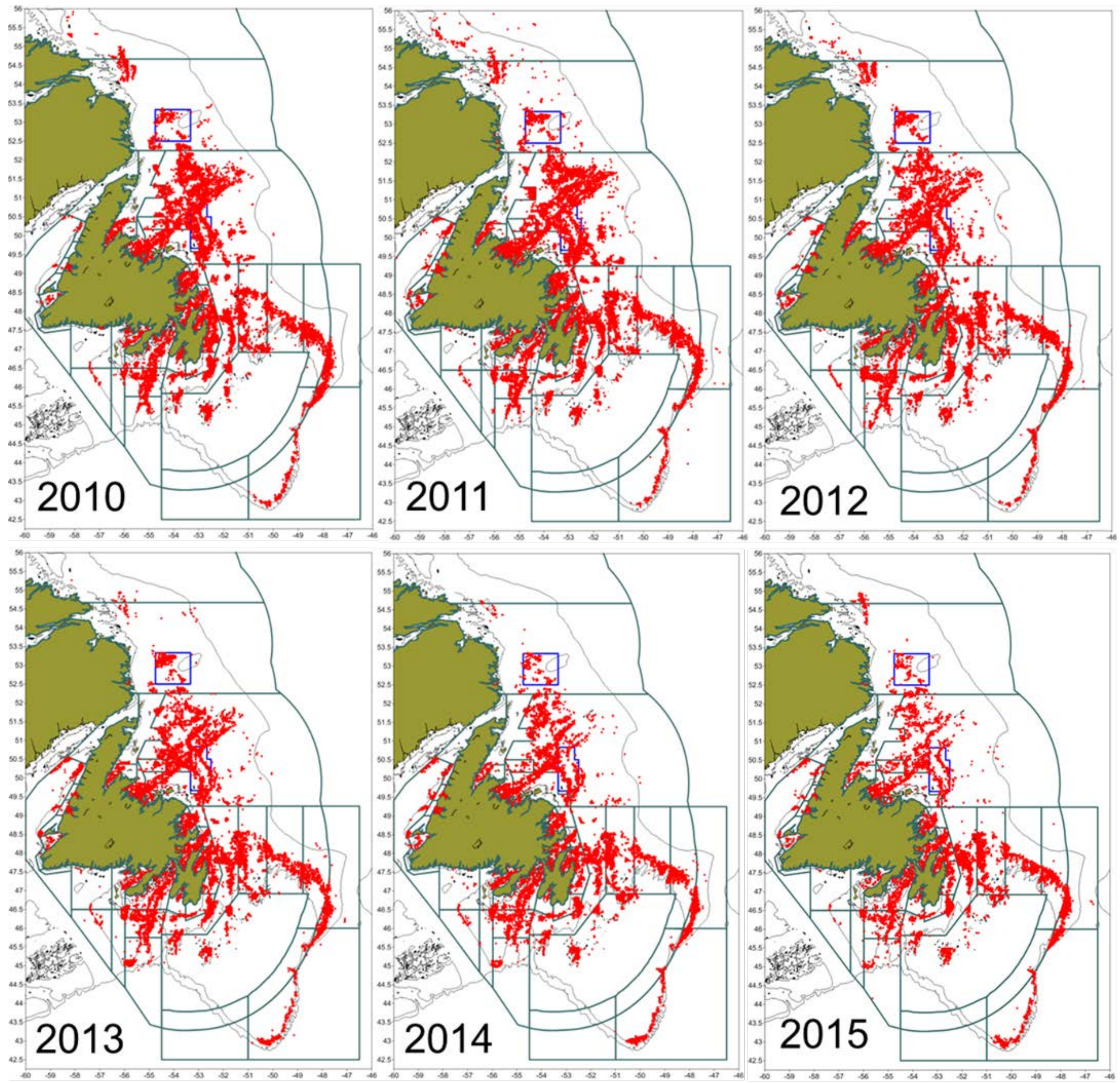

Figure 13. Distribution of logbook fishing effort from 2010-15.

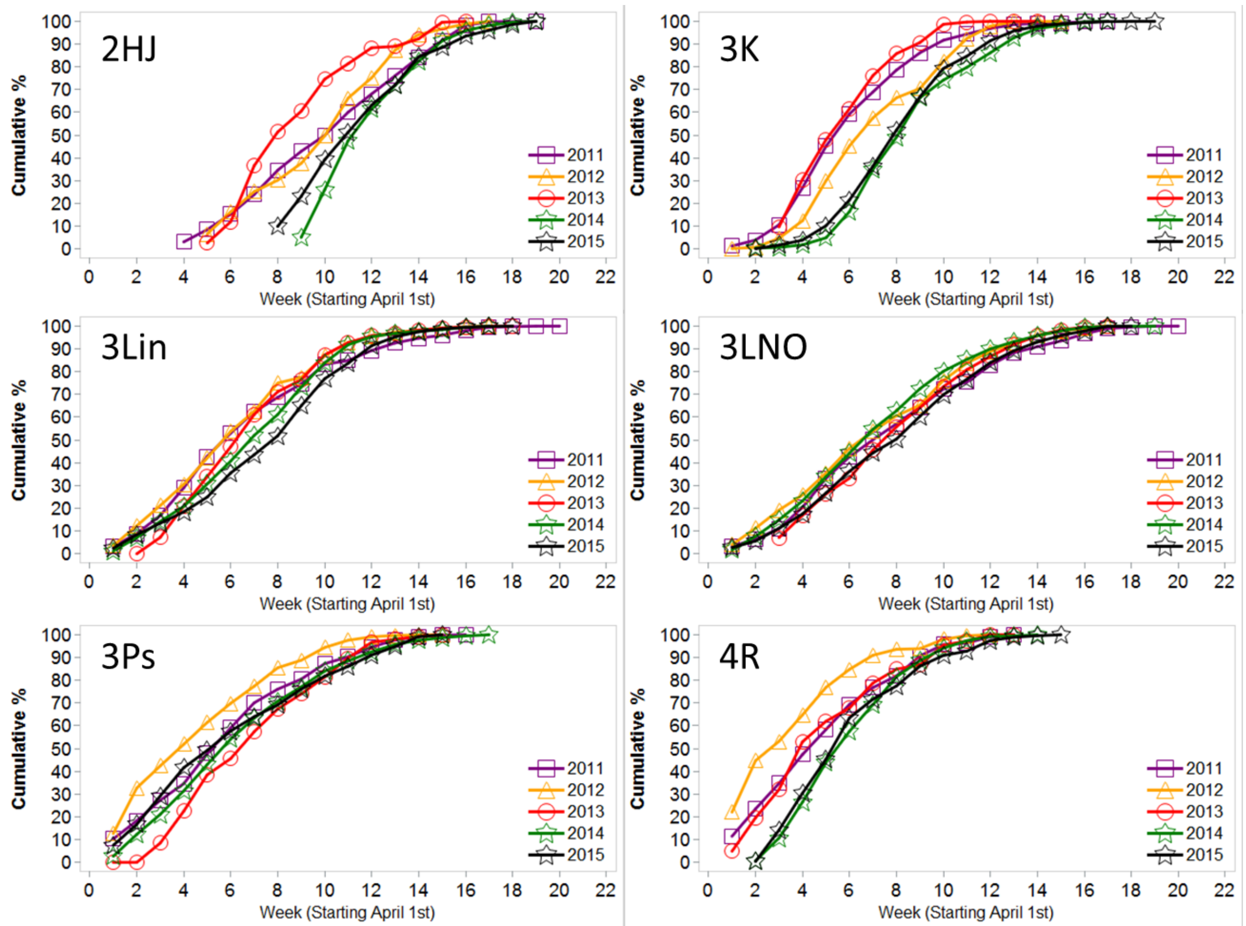

Figure 14. Seasonal trends in weekly fishing effort by assessment division from 2011-15.

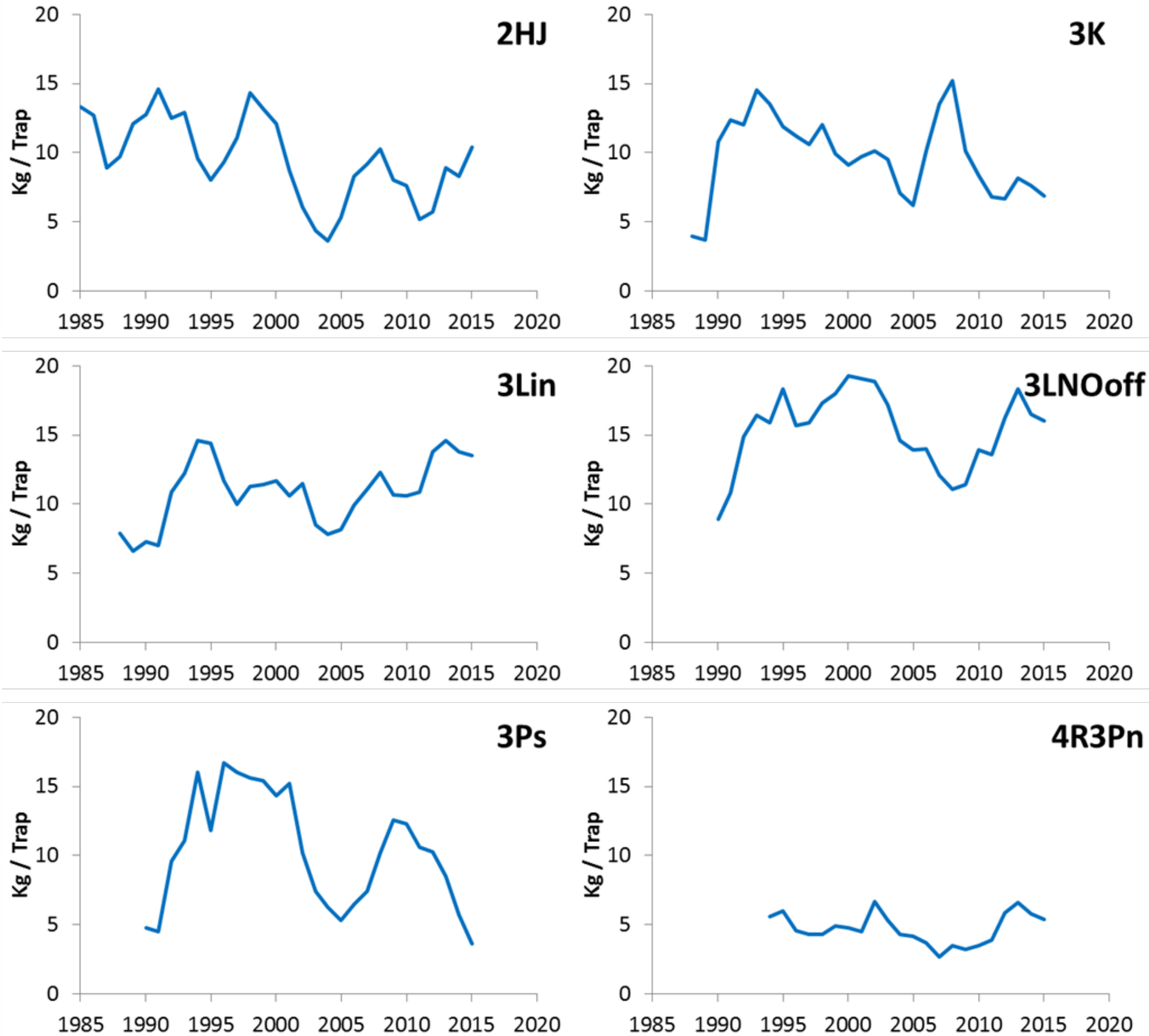

Figure 15. Unstandardized CPUE by assessment division from 1985-2015.

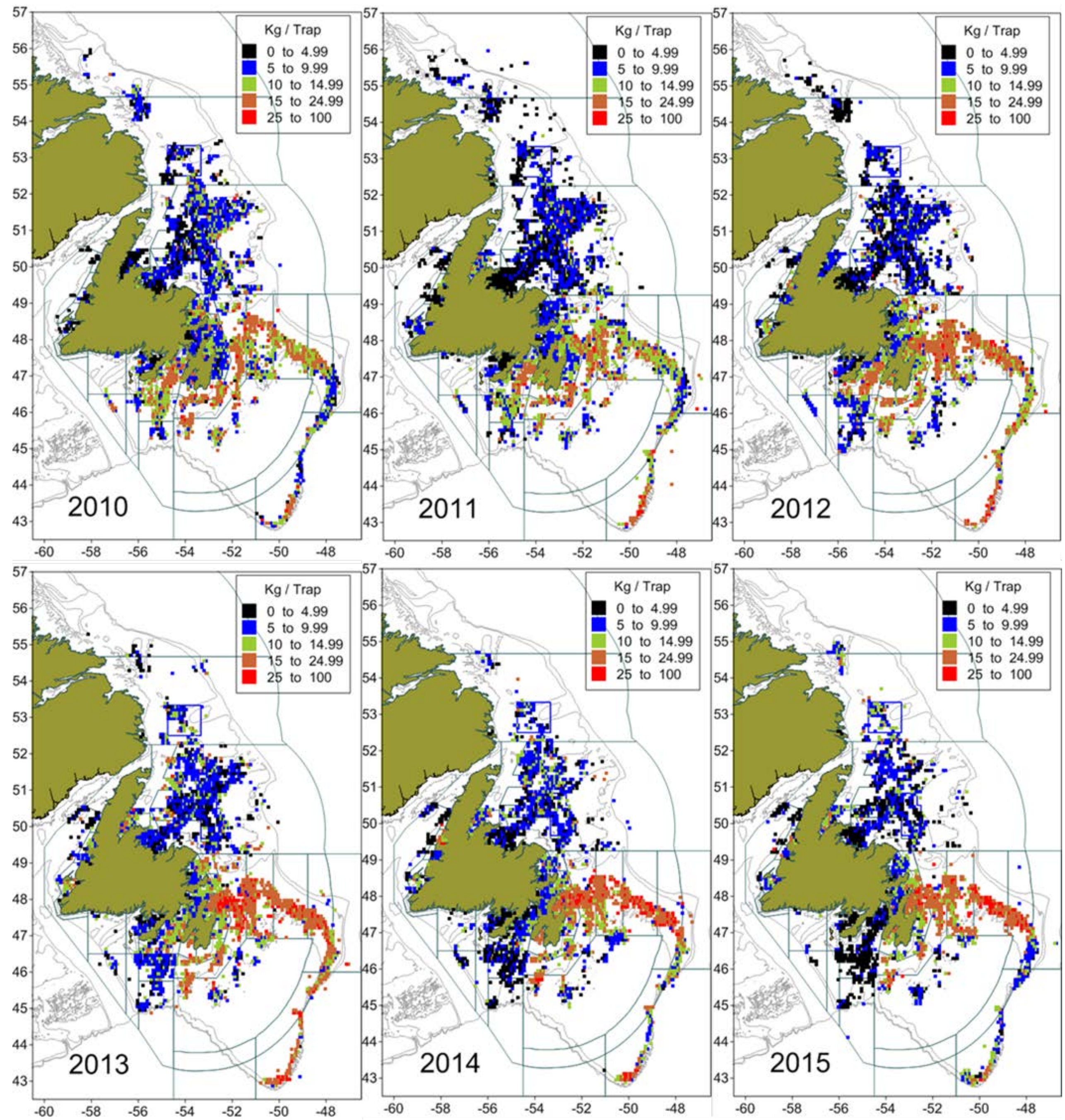

Figure 16. Spatial distribution of unstandardized logbook CPUE by year.

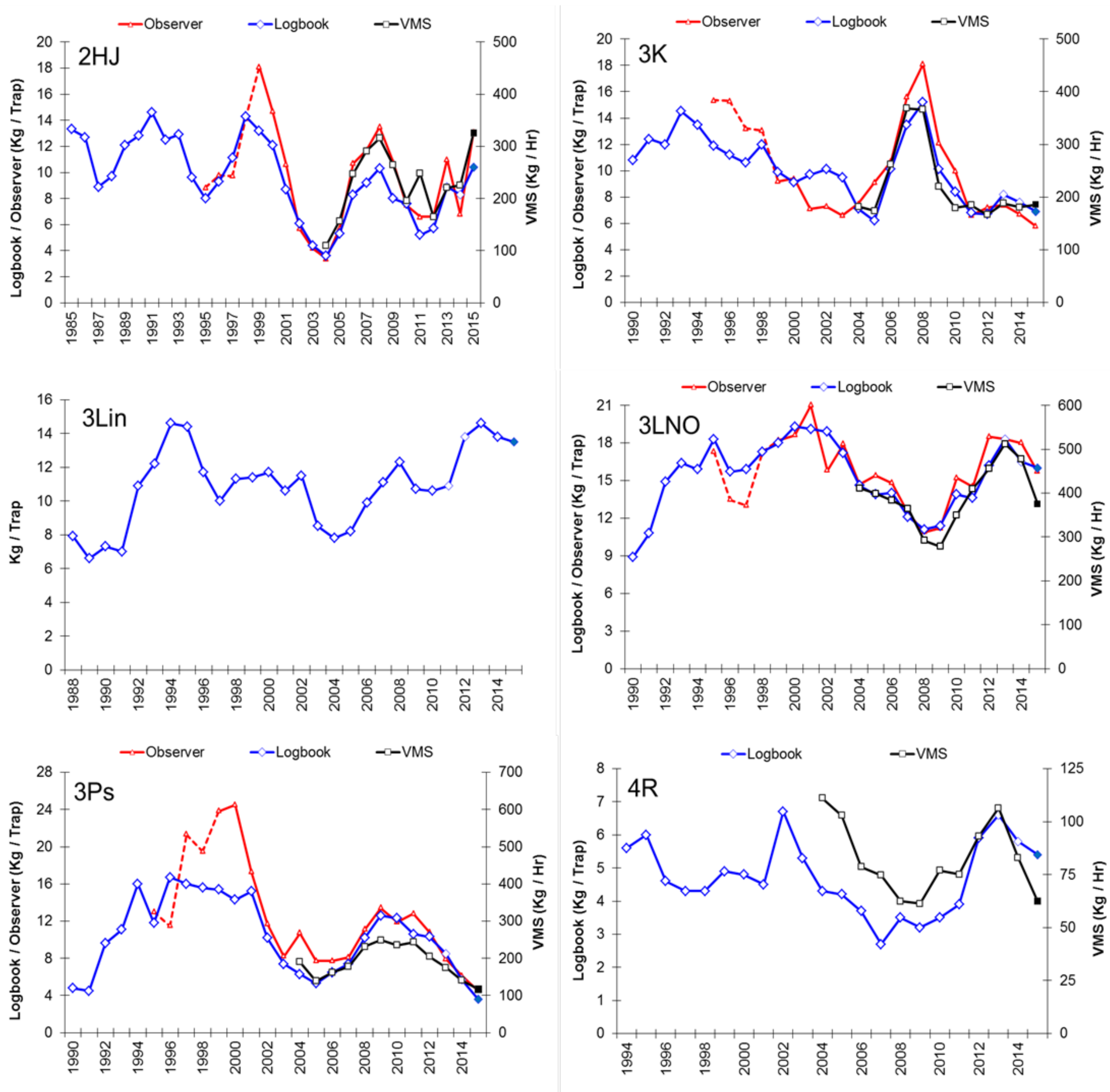

Figure 17. Offshore CPUEs by division. Comparison of standardized logbooks with unstandardized VMS and observer trends.

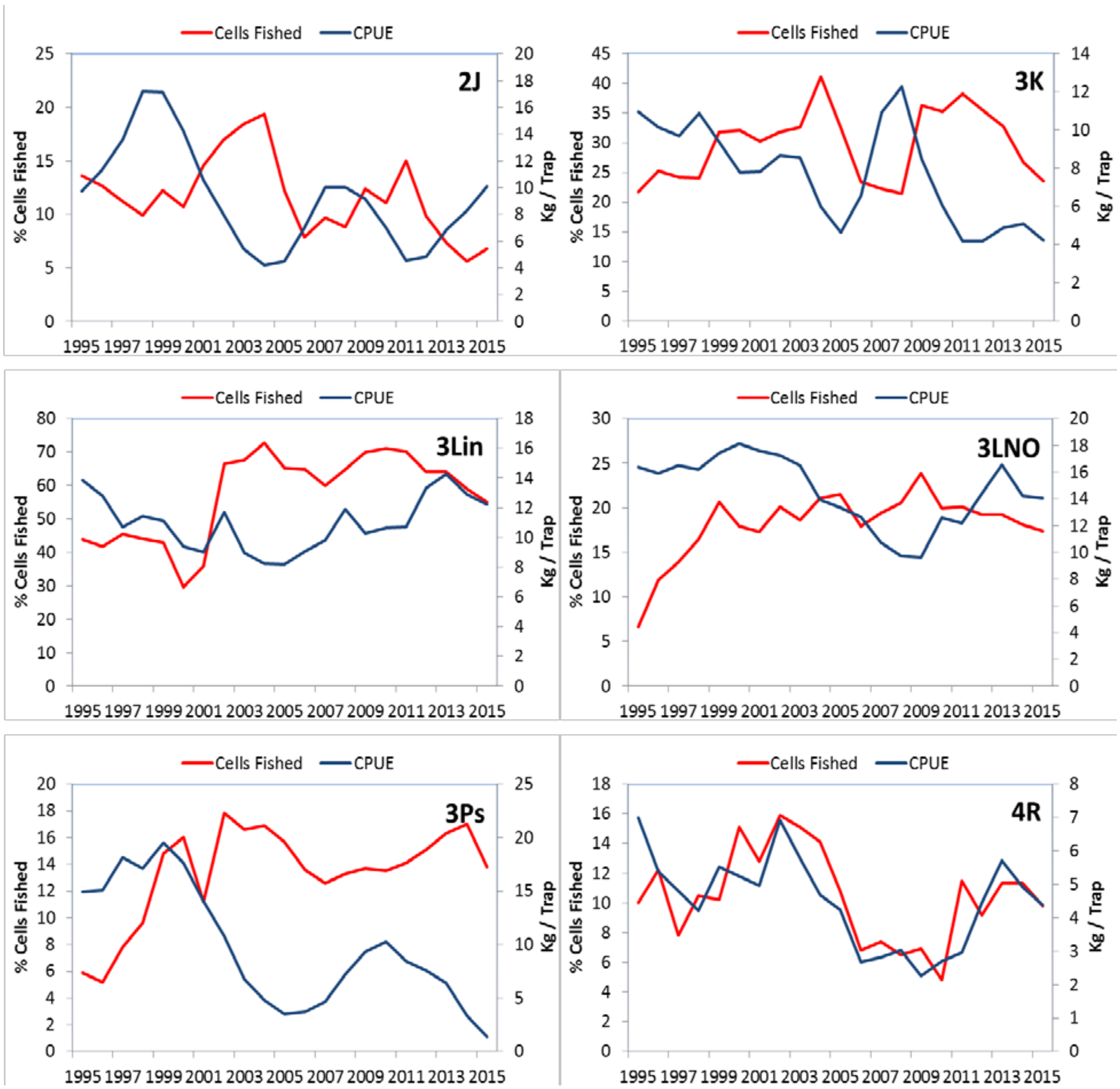

Figure 18. Trends in standardized CPUE vs. the percentage of 5' x 5' cells fished in each assessment division.

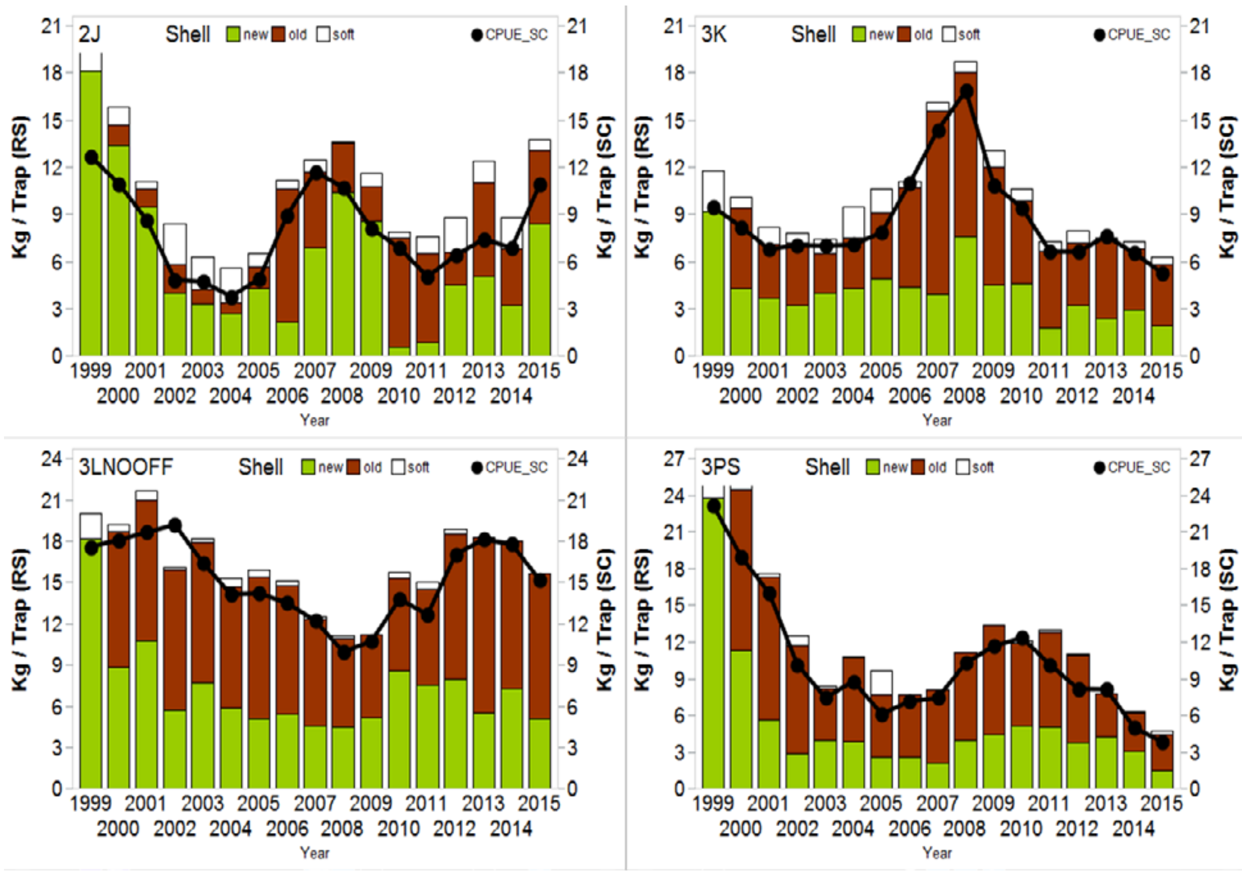

Figure 19. Trends in catch rates of legal-sized crabs by shell condition from observer at-sea sampling as well as crabs kept based on set and catch records (sc) for offshore portions of assessment divisions.

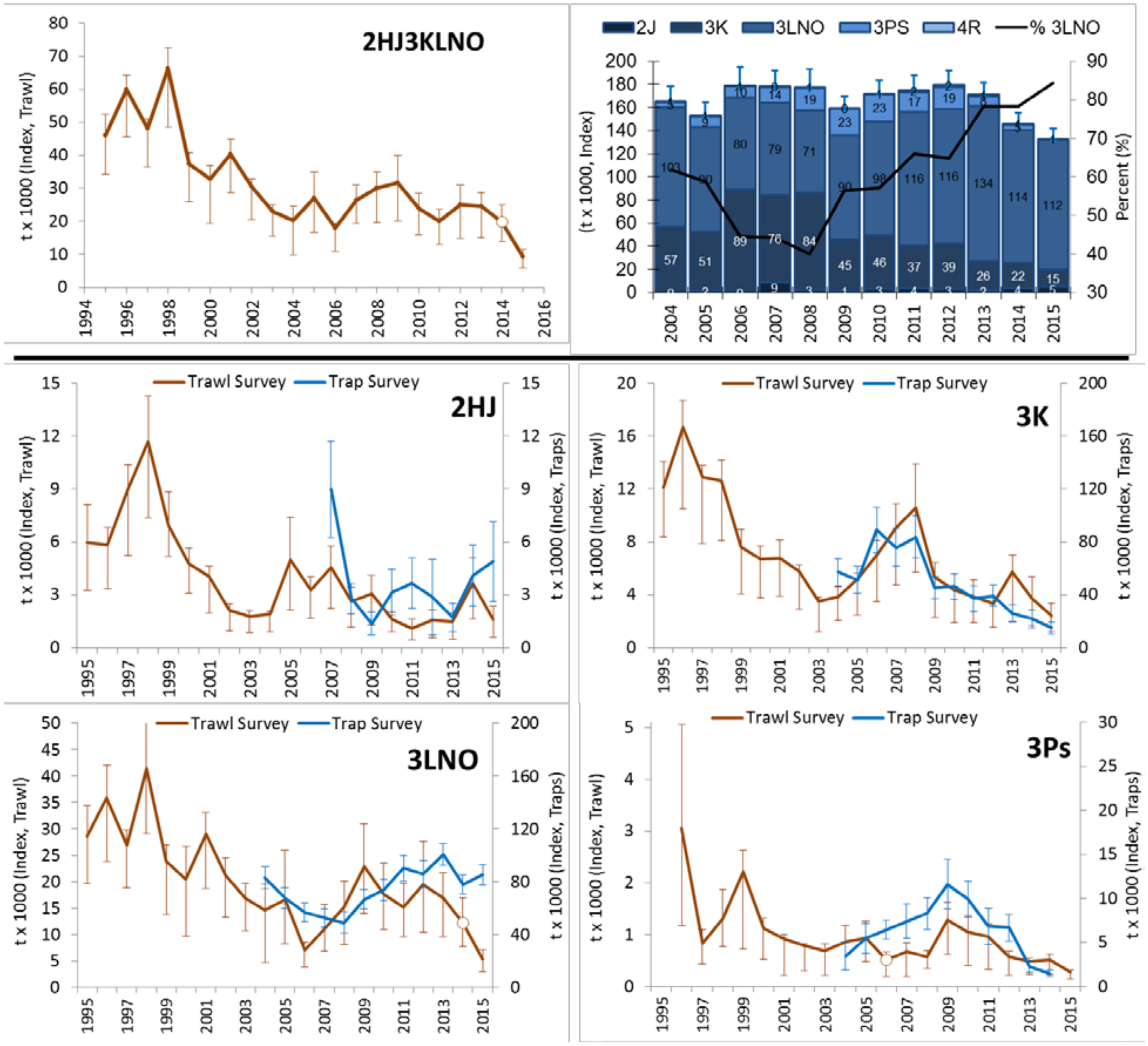

Figure 20. Trends in trawl survey exploitable biomass indices and the CPS trap survey exploitable biomass indices by division. Open symbols on the trawl abundance indices depict incomplete surveys. Note - no trap survey in Subdiv. 3Ps in 2015.

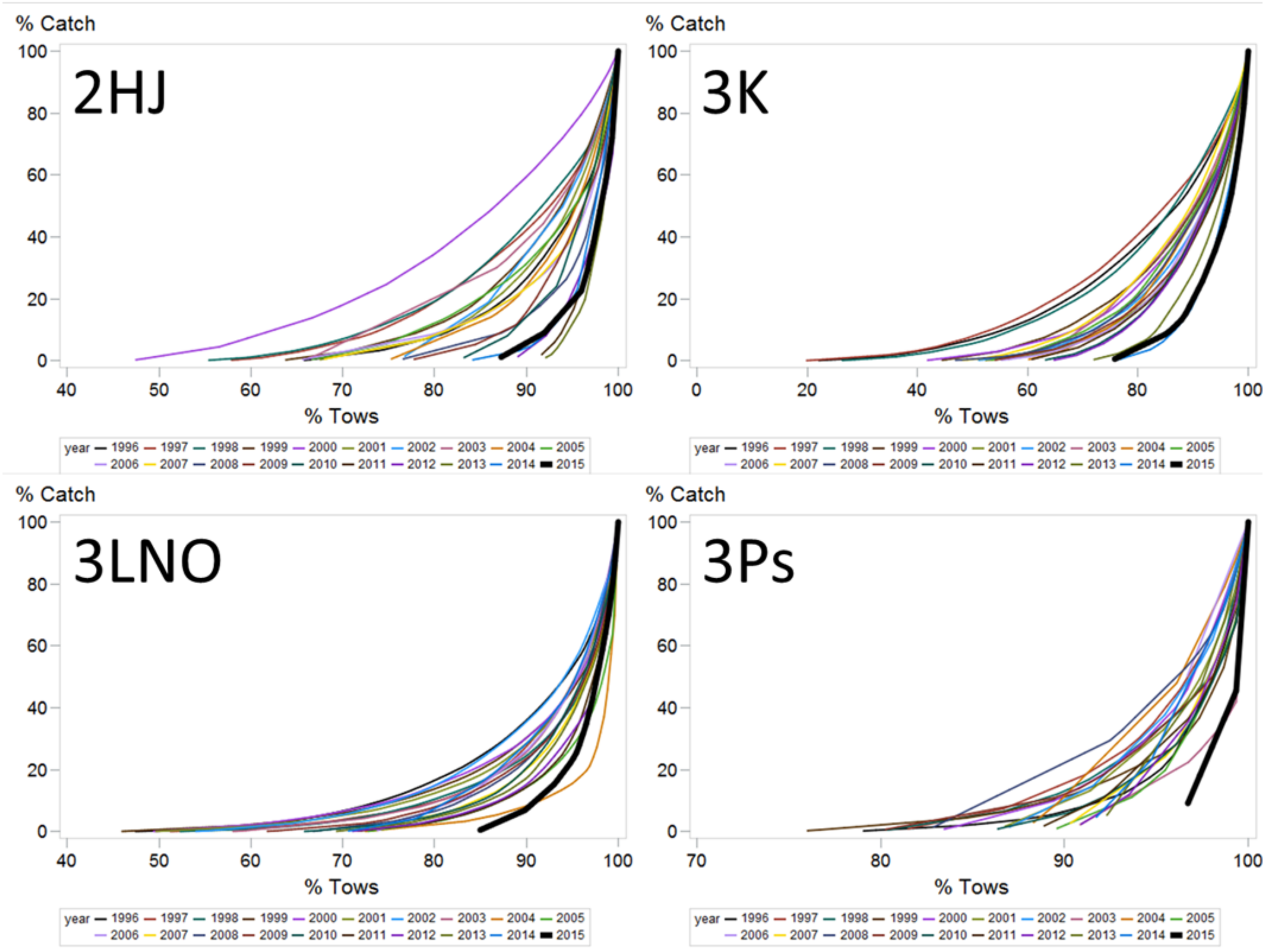

Figure 21. Relationships of cumulative percentage of the catch of exploitable crabs versus the cumulative percentage of multi-species trawl survey tows capturing exploitable crabs, by division and year. 2015 depicted by thick dark lines.

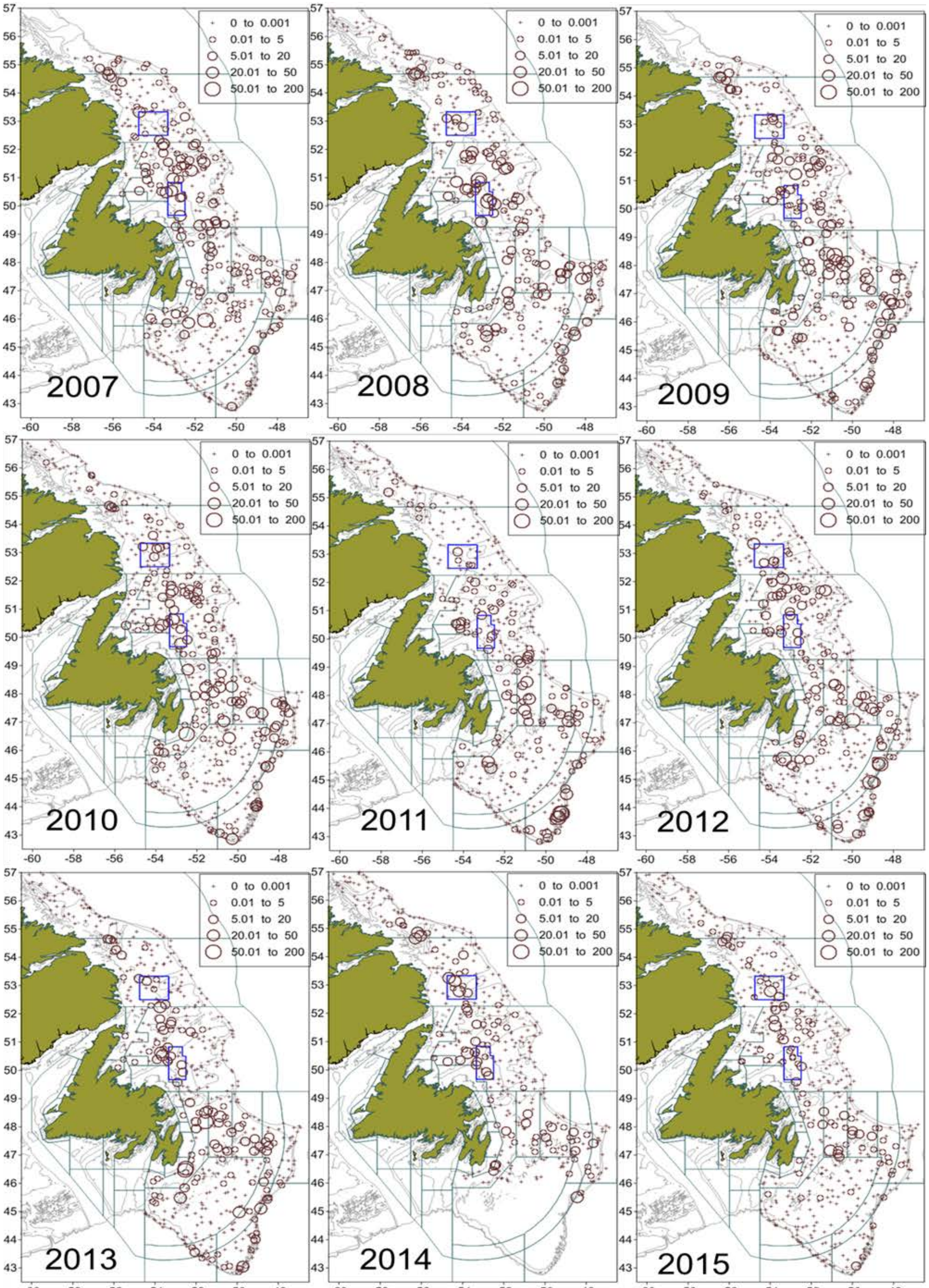

Figure 22. Distribution of exploitable males (#/tow) from Divs. 2HJ3KLNO fall bottom trawl surveys from 2007-15.

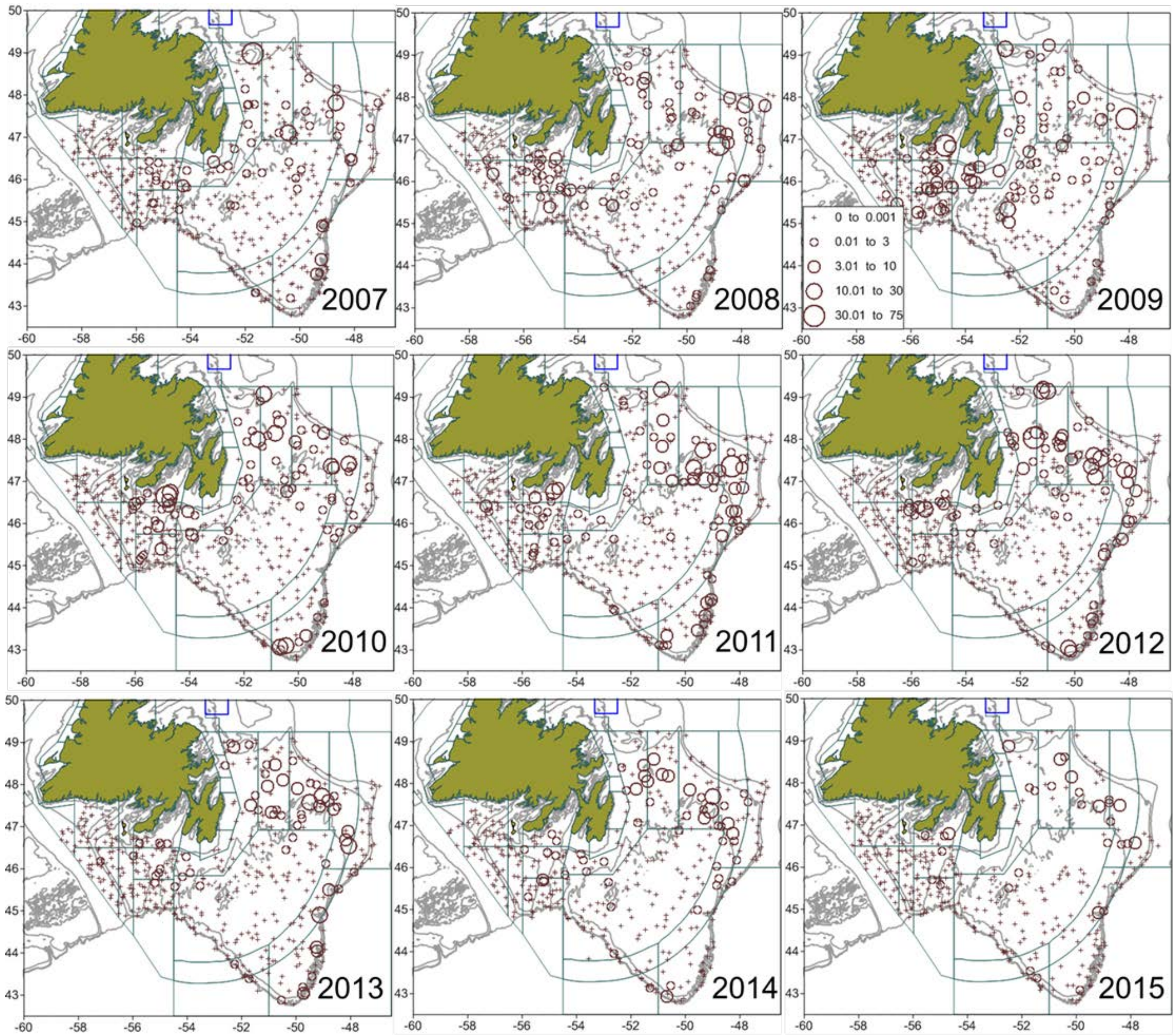

Figure 23. Distribution of exploitable males (#/tow) from Divs. 3LNOPs spring bottom trawl surveys from 2007-15.

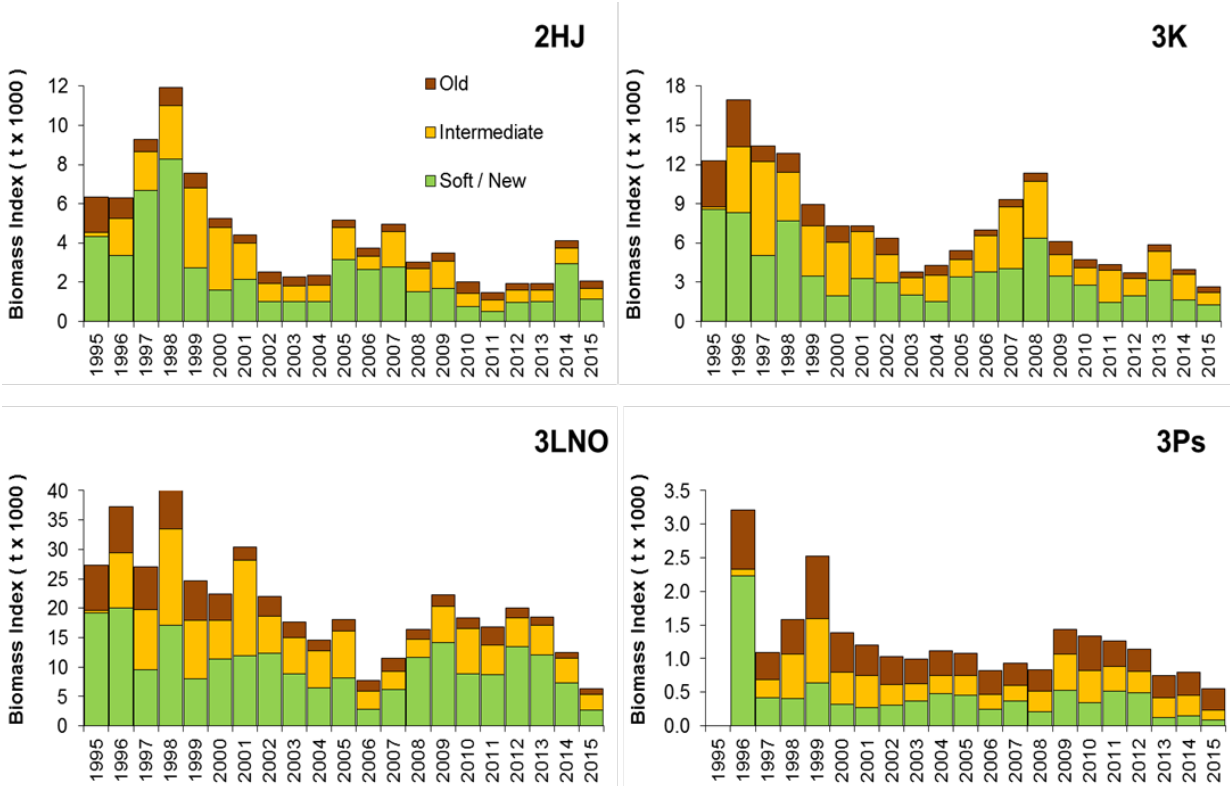

Figure 24. Trends in trawl survey exploitable biomass indices by shell condition by assessment division.

Figure 25. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey by assessment division.

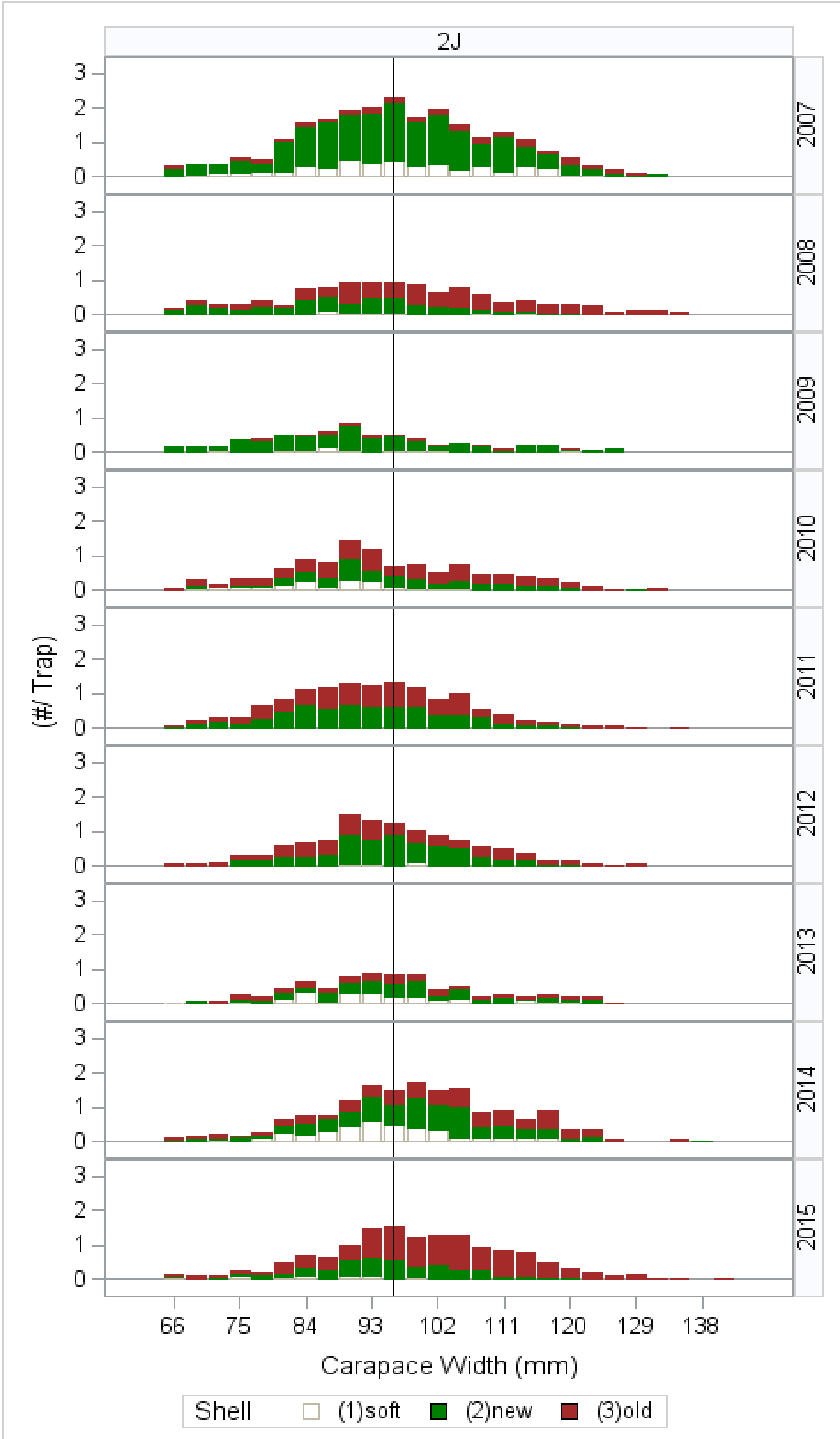

Figure 26. Trends in male carapace width distributions from large-mesh traps at core stations in the Div. 2J offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

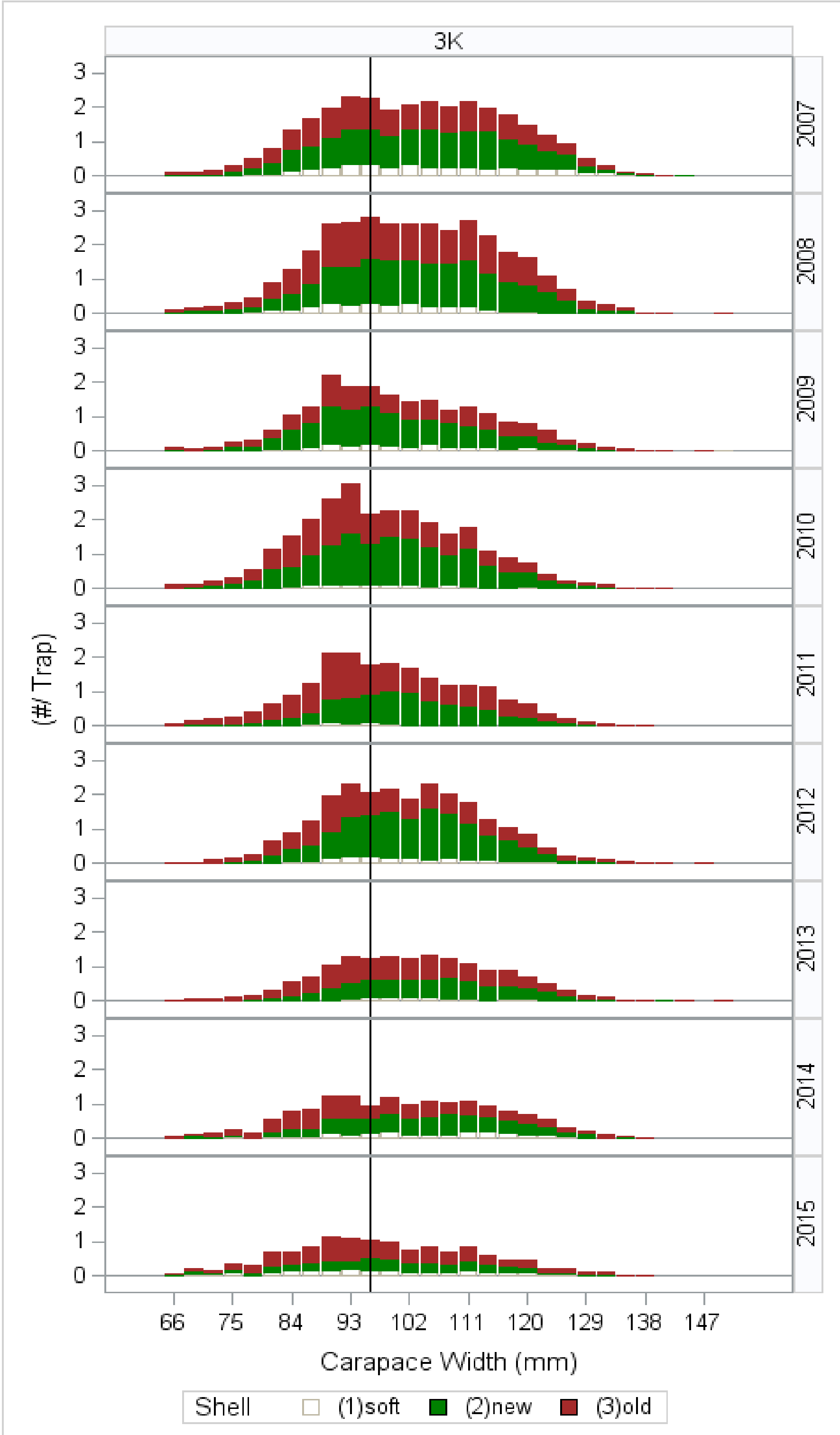

Figure 27. Trends in male carapace width distributions from large-mesh traps at core stations in the Div. 3K CPS trap survey. The vertical dashed line indicates the minimum legal size.

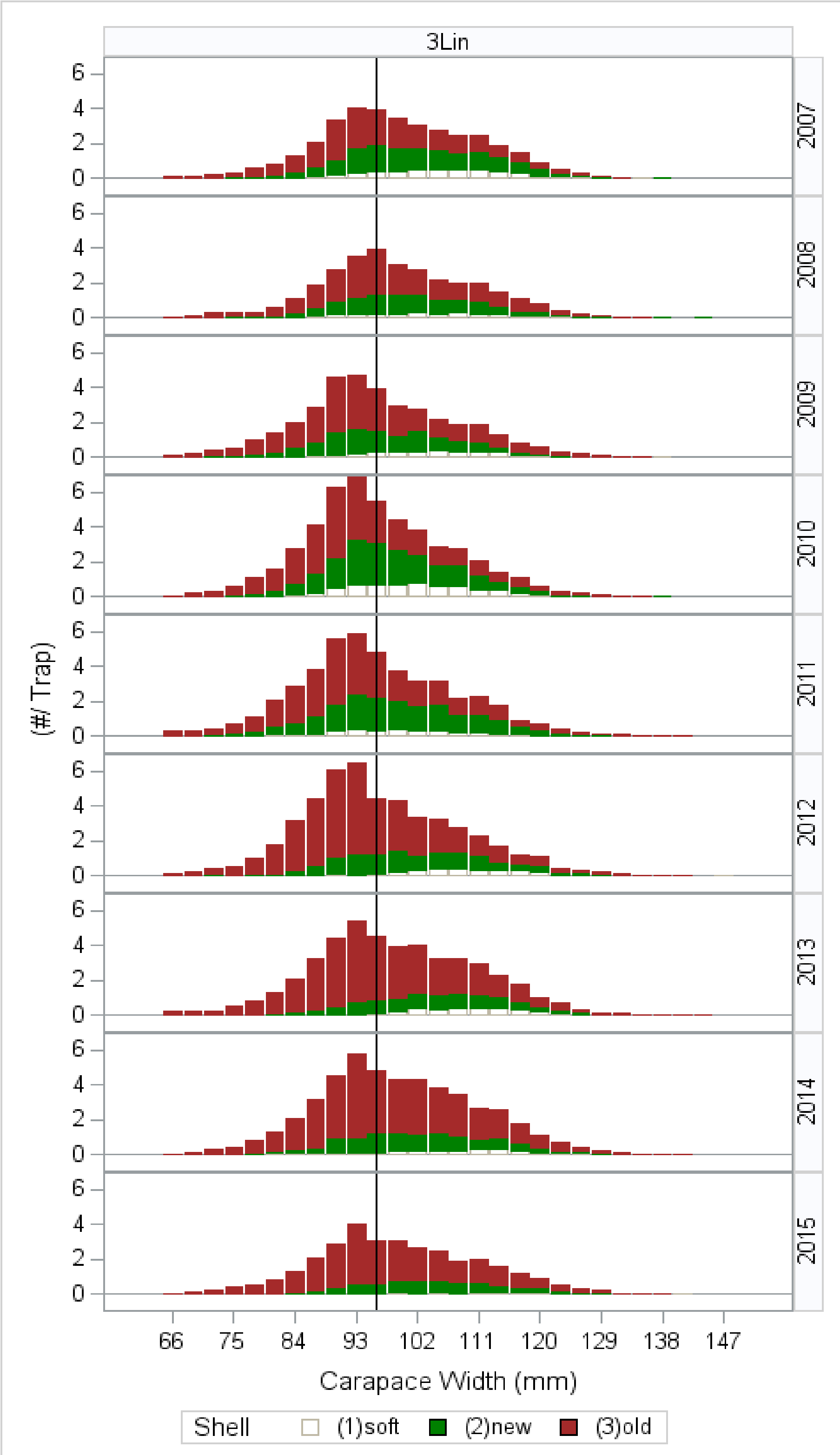

Figure 28. Trends in male carapace width distributions from large-mesh traps at core stations in the Div. 3L Inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

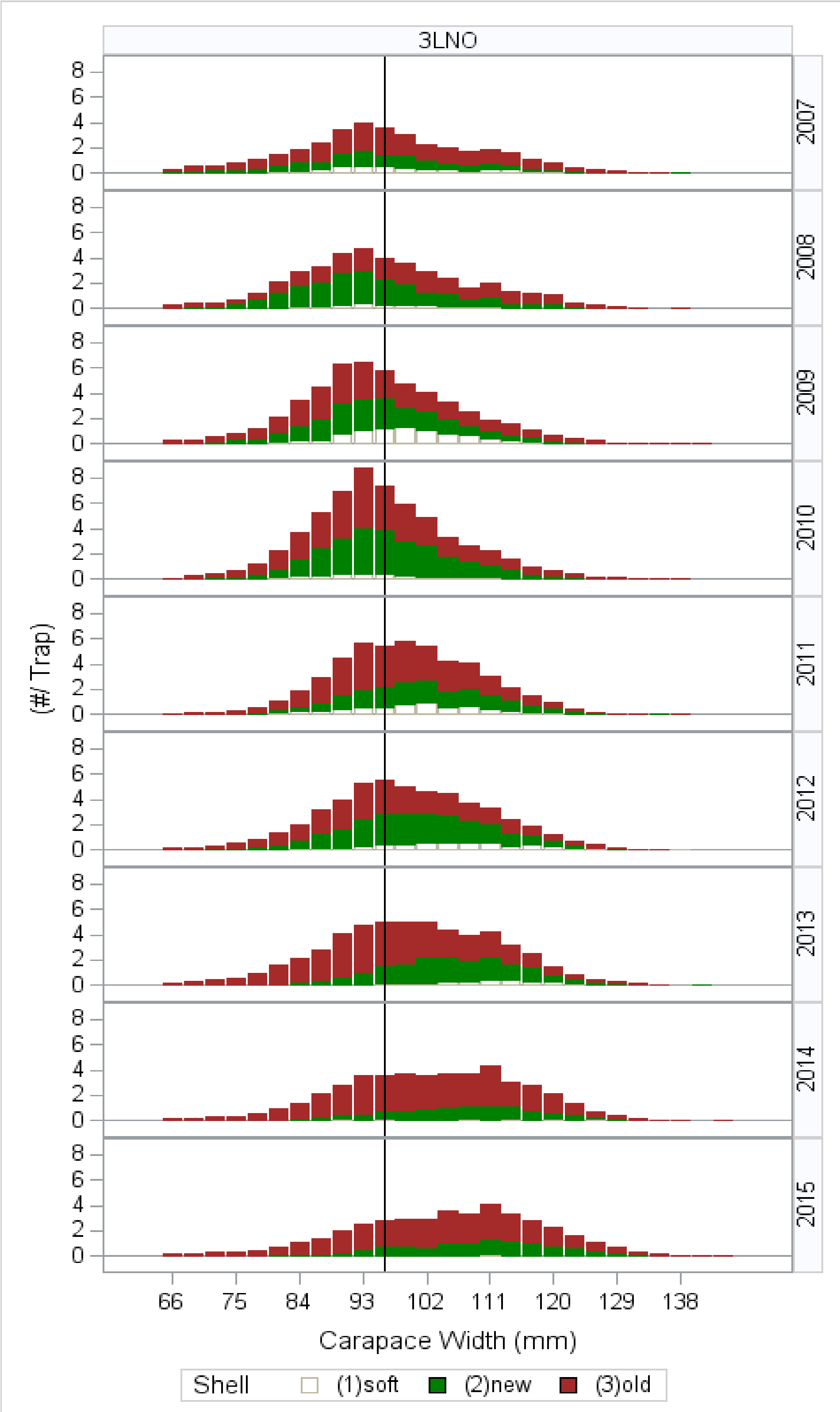

Figure 29. Trends in male carapace width distributions from large-mesh traps at core stations in the Divs. 3LNO offshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

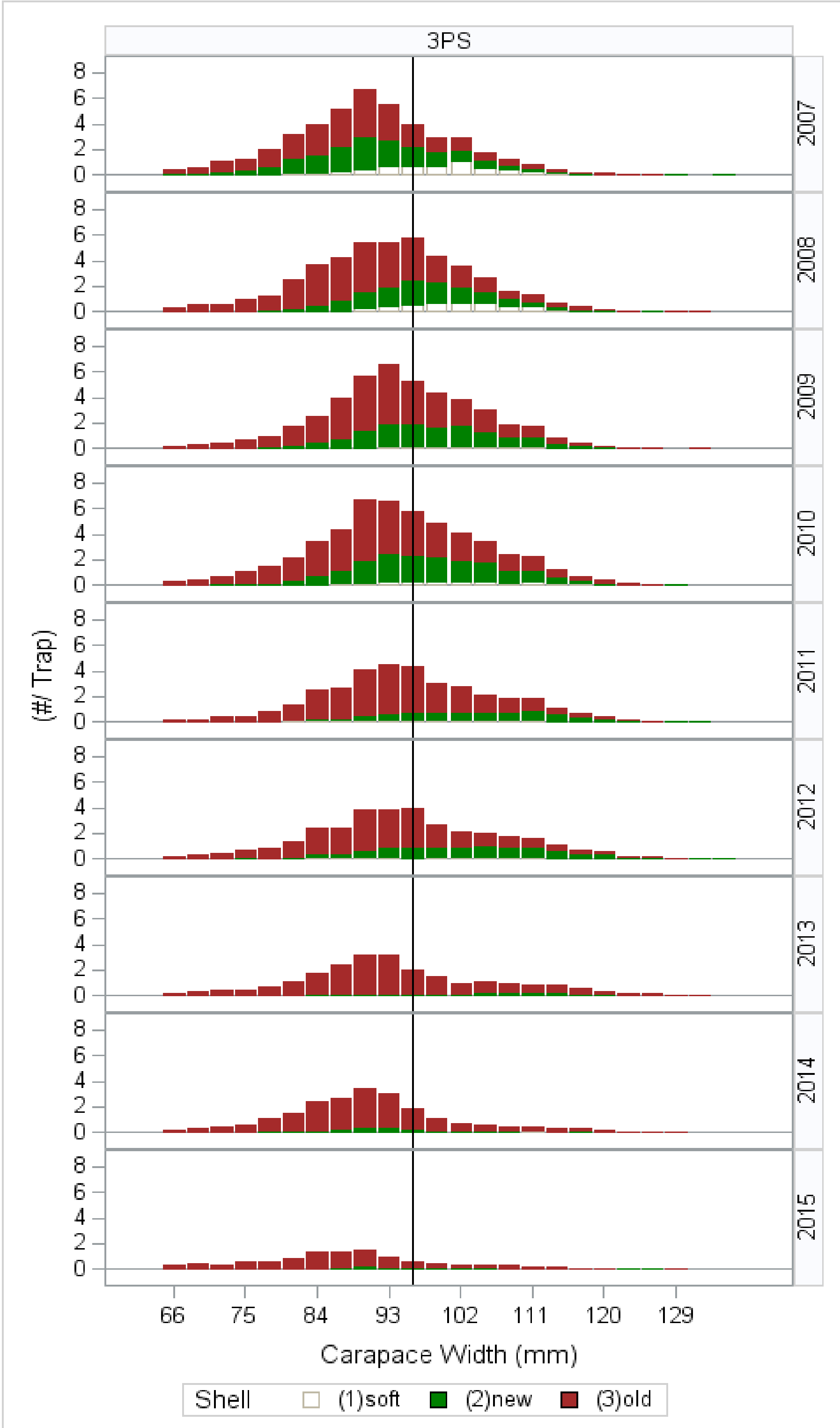

Figure 30. Trends in male carapace width distributions from large-mesh traps at core stations in the Subdiv. 3Ps CPS trap survey. The vertical dashed line indicates the minimum legal size. The 2015 survey was incomplete.

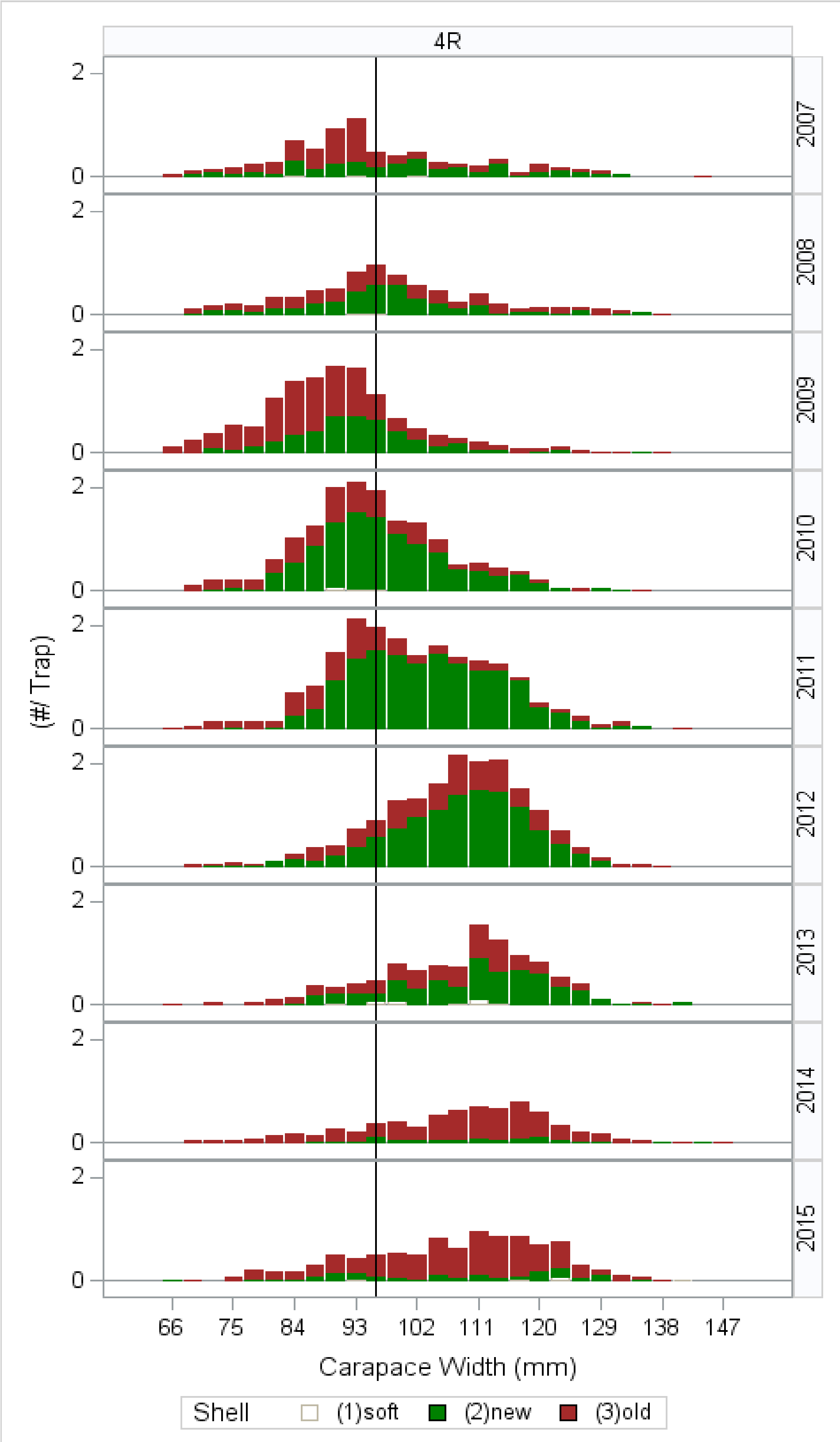

Figure 31. Trends in male carapace width distributions from large-mesh traps at core stations in the Div. 4R CPS trap survey. The vertical dashed line indicates the minimum legal size.

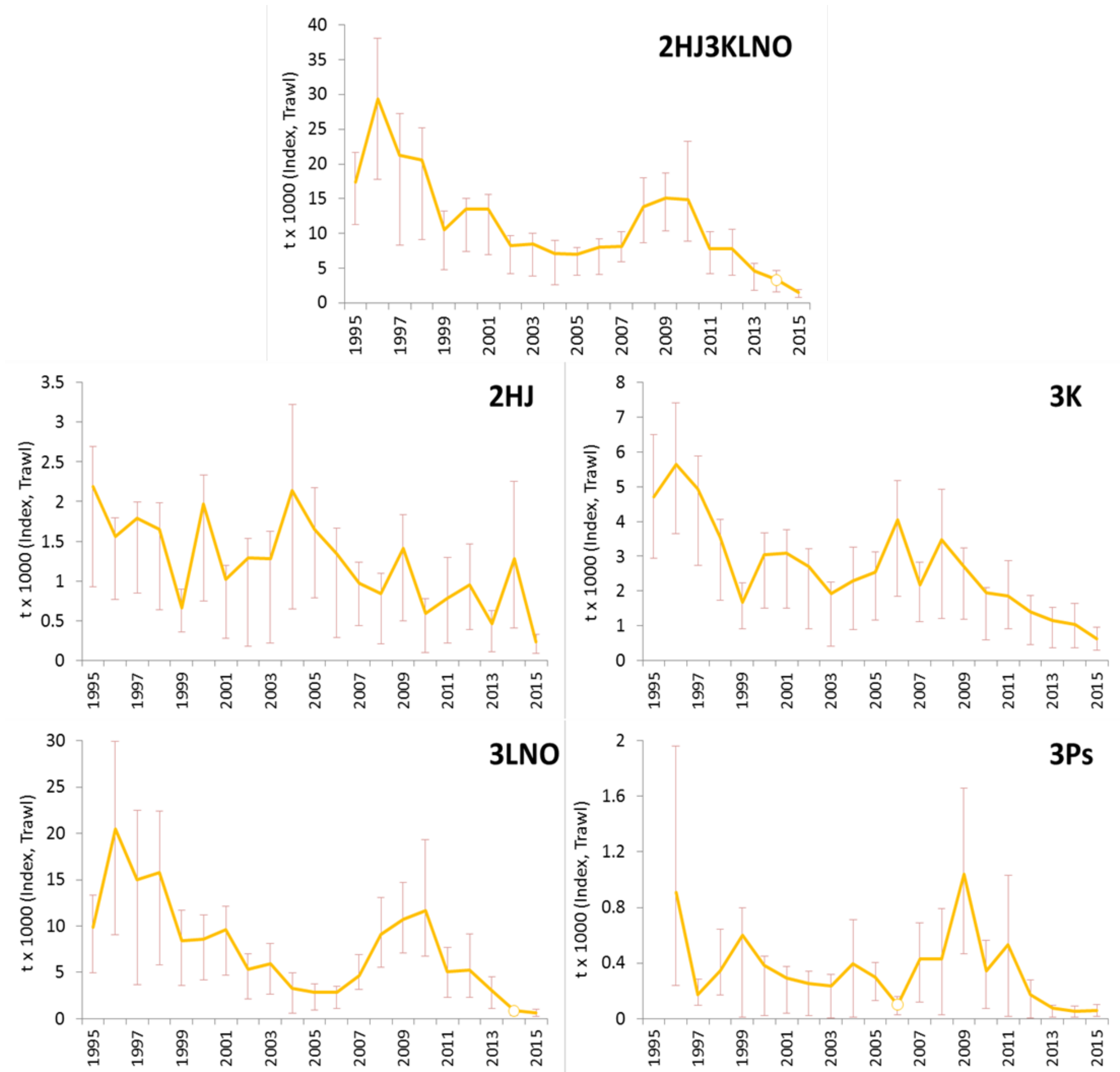

Figure 32. Trends in trawl survey pre-recruit biomass indices by division. Open symbols on the biomass index depict incomplete surveys.

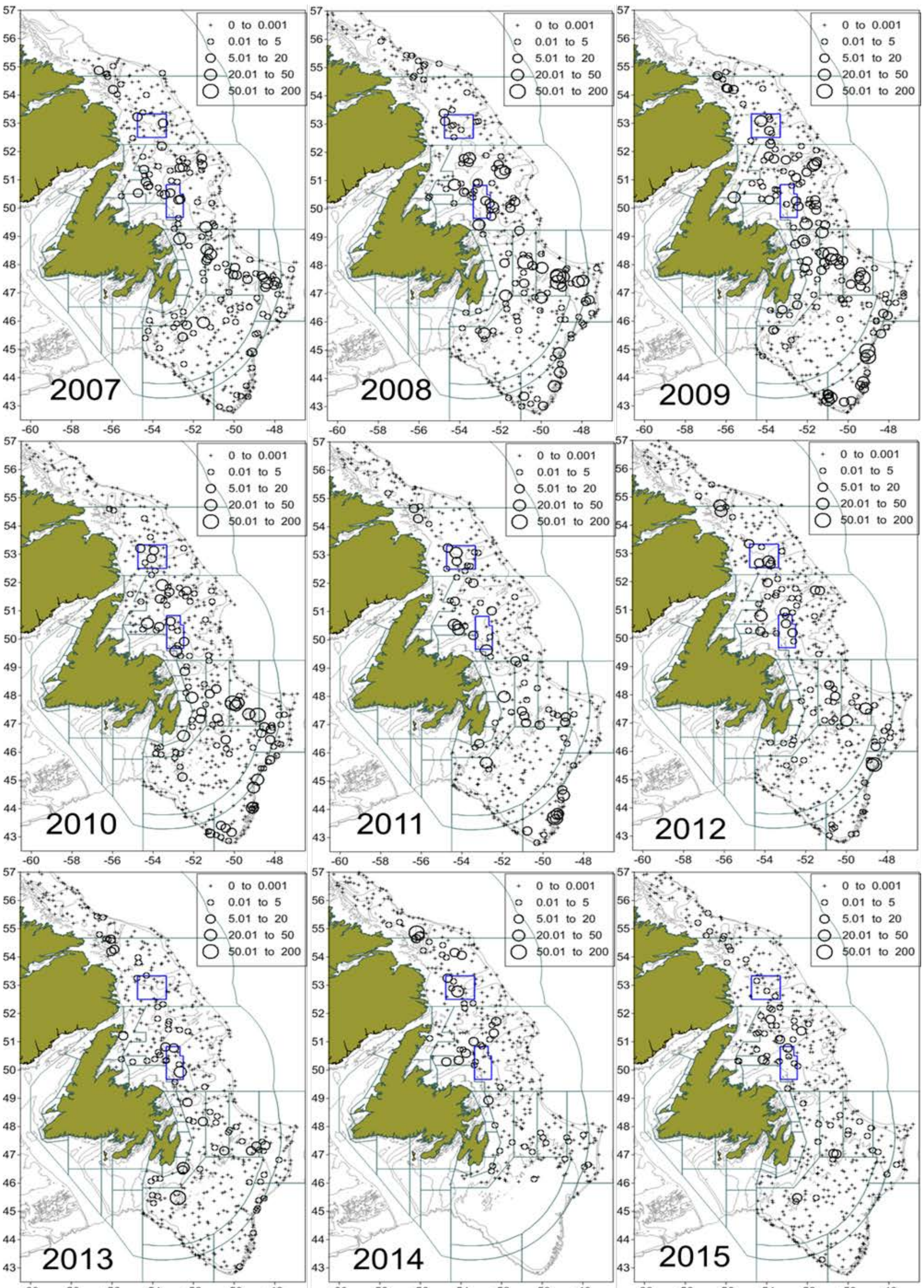

Figure 33. Distribution of pre-recruit males (#/tow) from Divs. 2HJ3KLNO fall bottom trawl surveys from 2007-15.

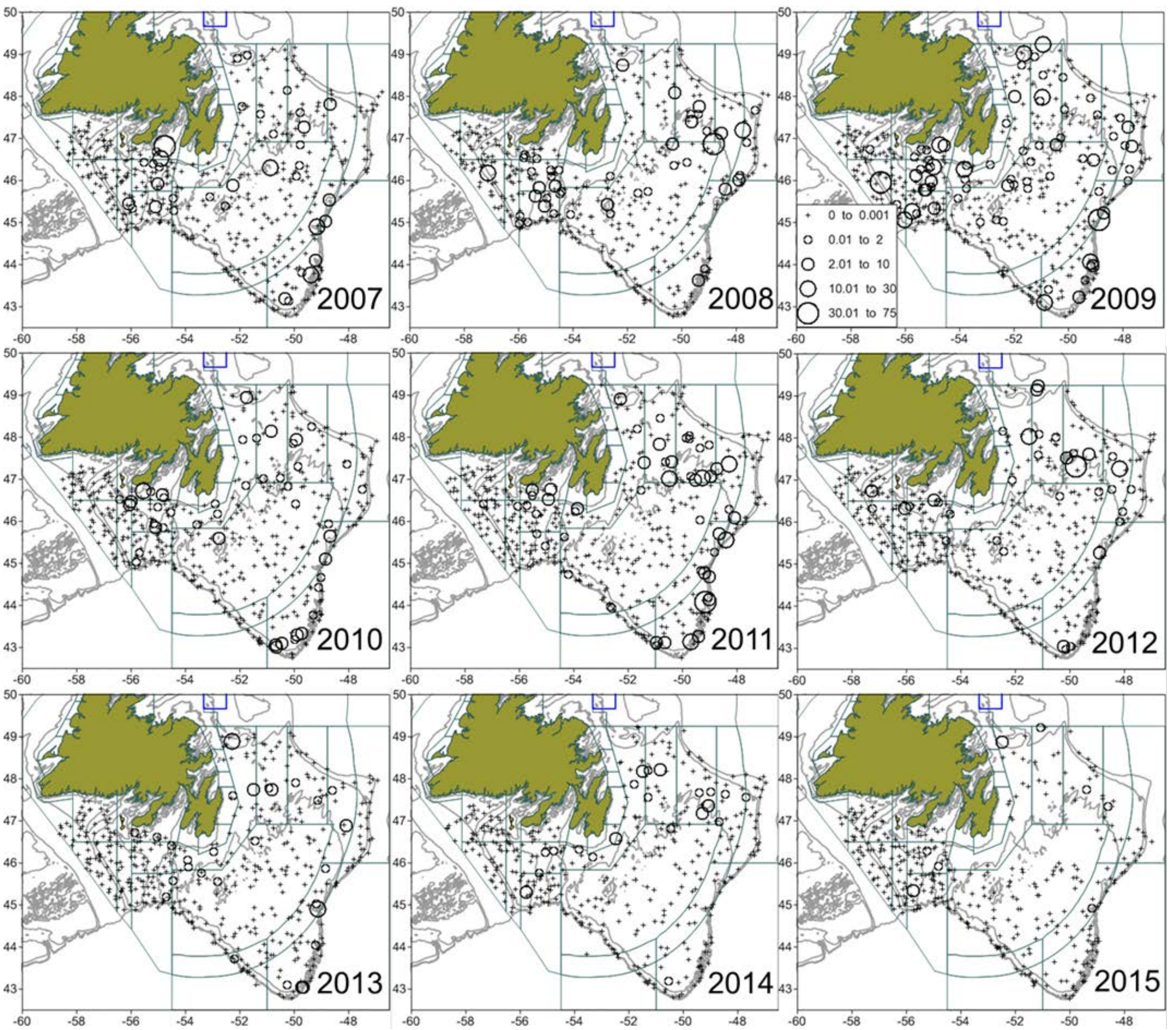

Figure 34. Distribution of pre-recruit males (#/tow) from Divs. 3LNOPs spring bottom trawl surveys from 2007-15.

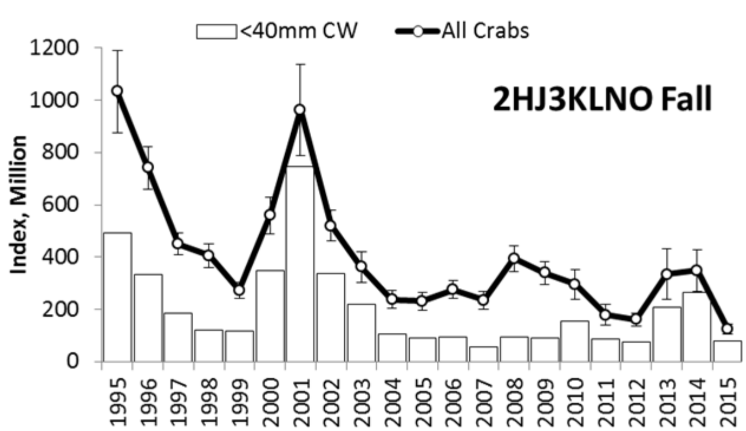

Figure 35. Trends in abundance of all crabs as well as small (< 40 mm CW) crabs captured in fall Divs. 2J3KLNO trawl surveys. Analysis done with STRAP.

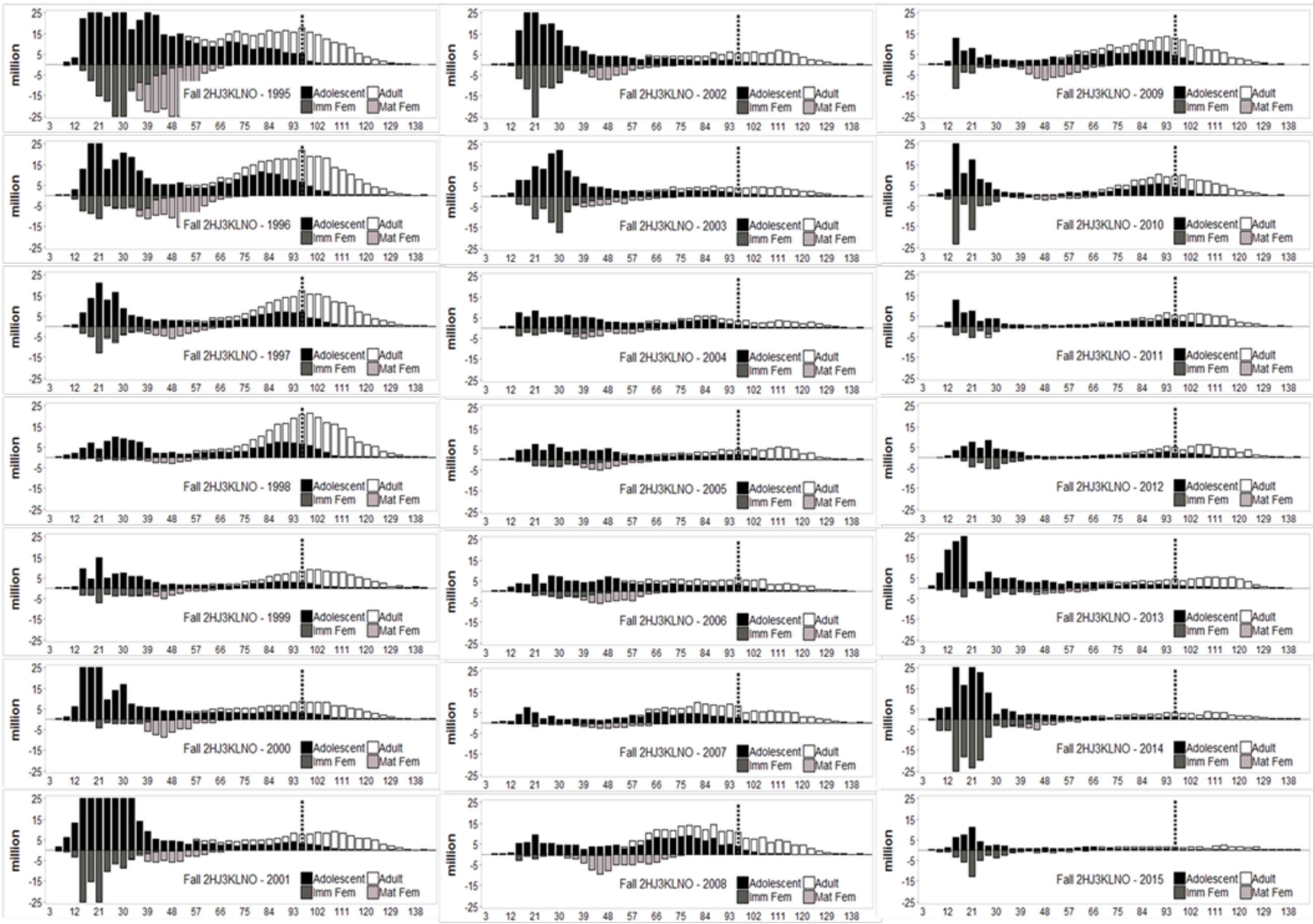

Figure 36. Annual abundance indices by carapace width for Divs. 2HJ3KLNO juveniles plus adolescent males (dark bars), adult males (white bars), immature females (dark grey bars), and mature females (light grey bars) from fall trawl surveys. Abundance is truncated for smallest crabs (< 50 mm CW). The minimum legal size is indicated by a vertical dashed line.

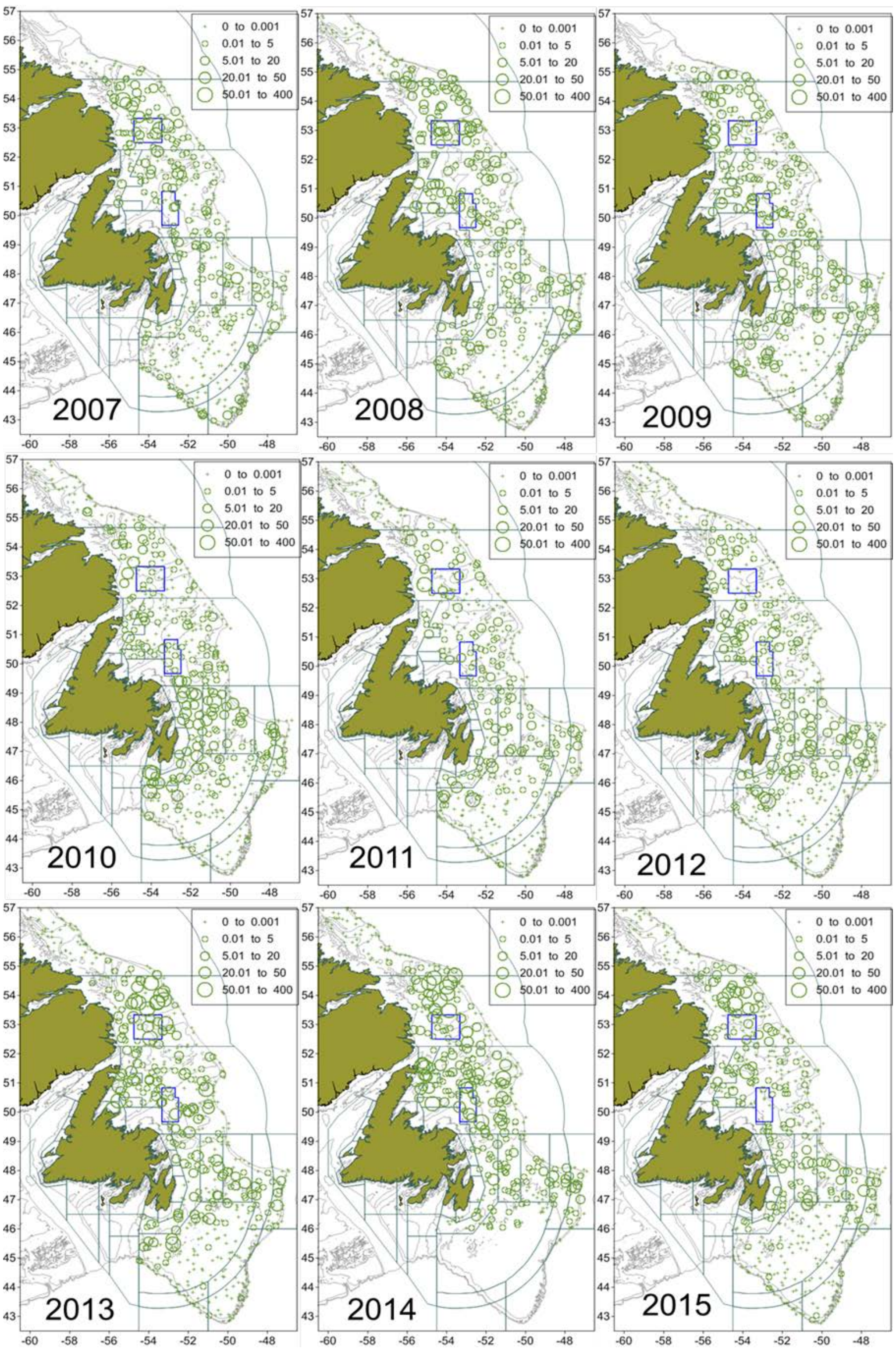

Figure 37. Distribution of small (< 60 mm CW adolescents) males (#/tow) from Divs. 2HJ3KLNO fall bottom trawl surveys from 2007-15.

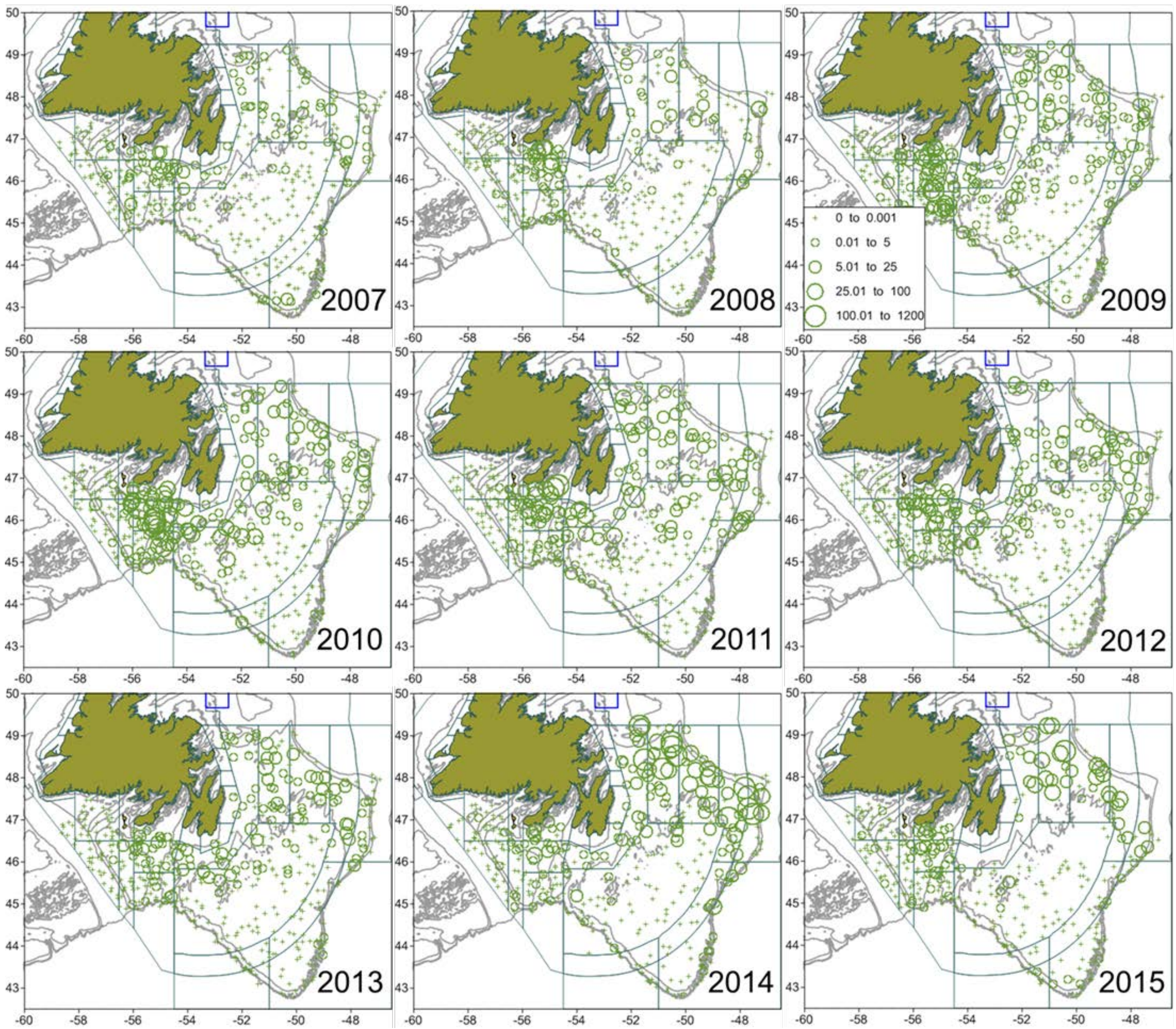

Figure 38. Distribution of small (< 60 mm CW adolescents) males (#/tow) from Divs. 3LNOPs spring bottom trawl surveys from 2007-15.

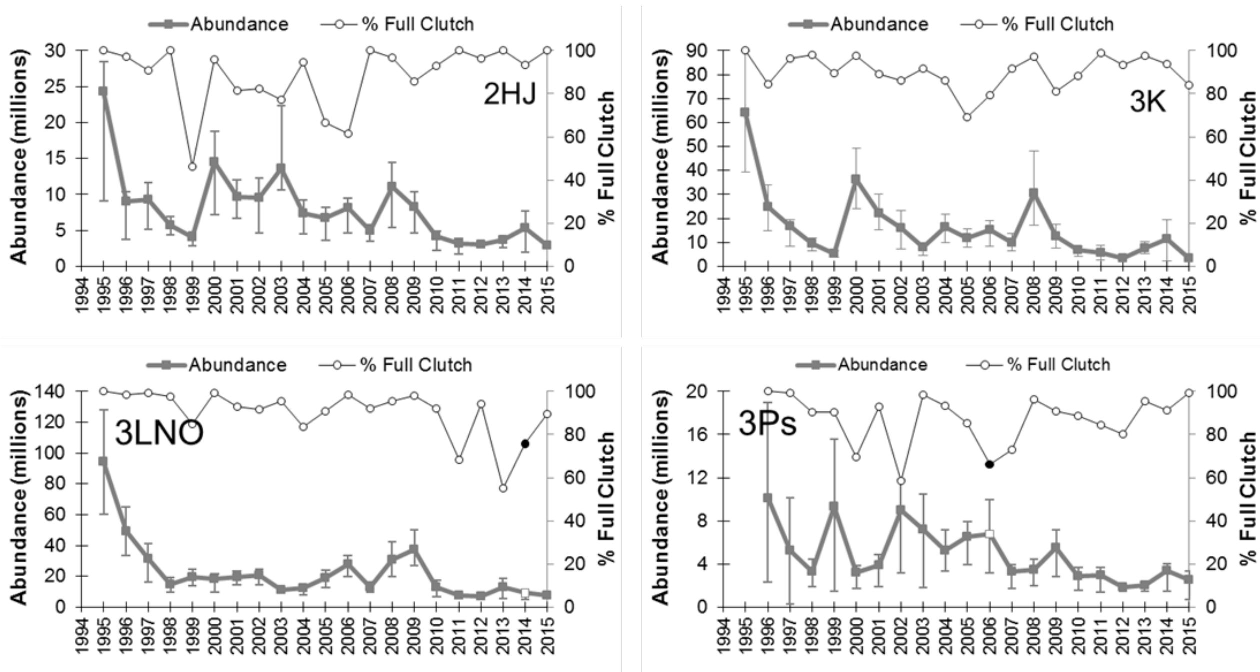

Figure 39. Trends in mature female abundance and percentage of mature females bearing full clutches of viable eggs in fall and spring trawl surveys for portions of offshore assessment divisions. Filled symbols on the abundance index and solid symbols on the egg clutch index depict incomplete surveys.

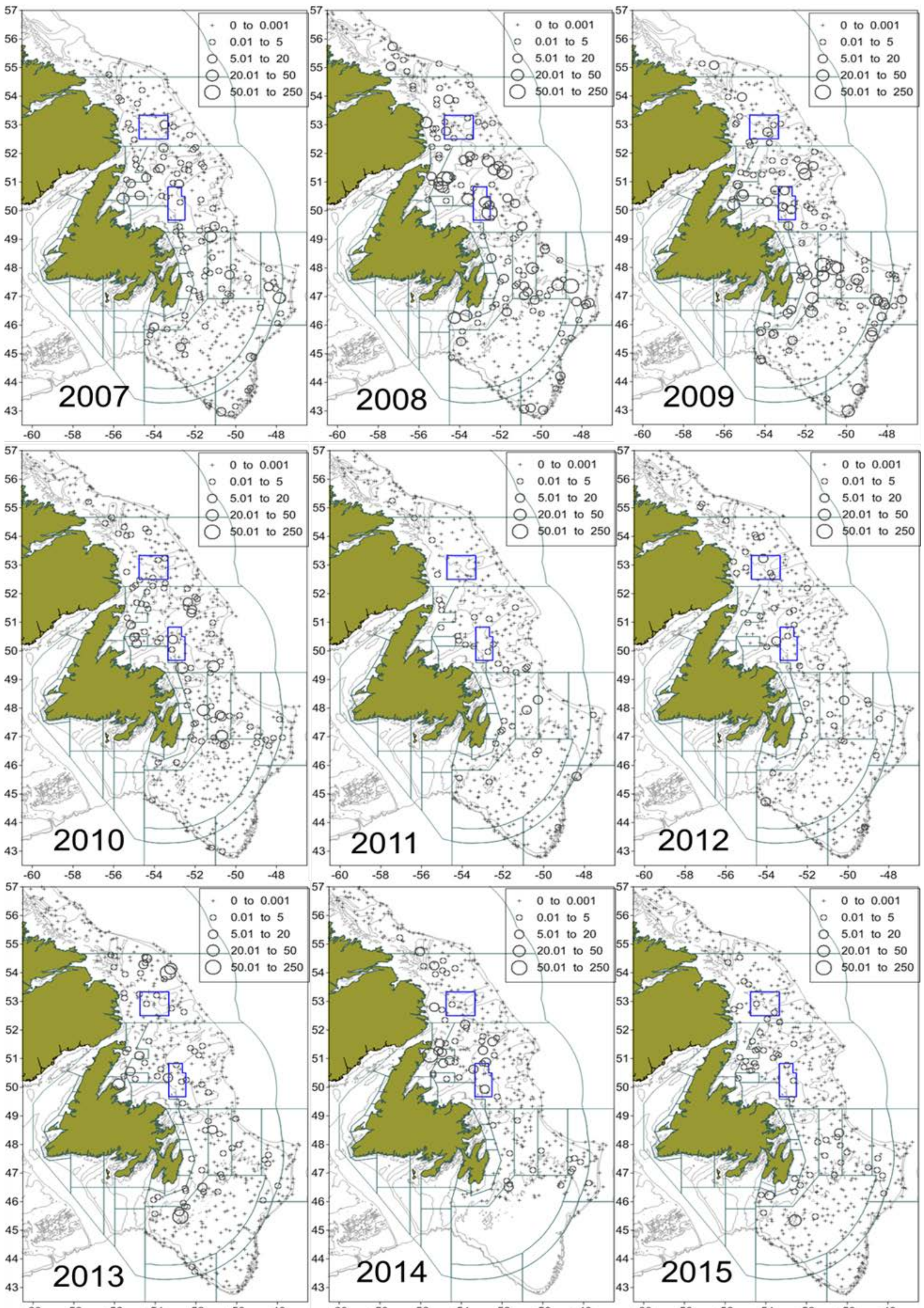

Figure 40. Distribution of mature females (#/tow) from Divs. 2HJ3KLNO fall bottom trawl surveys from 2007-15.

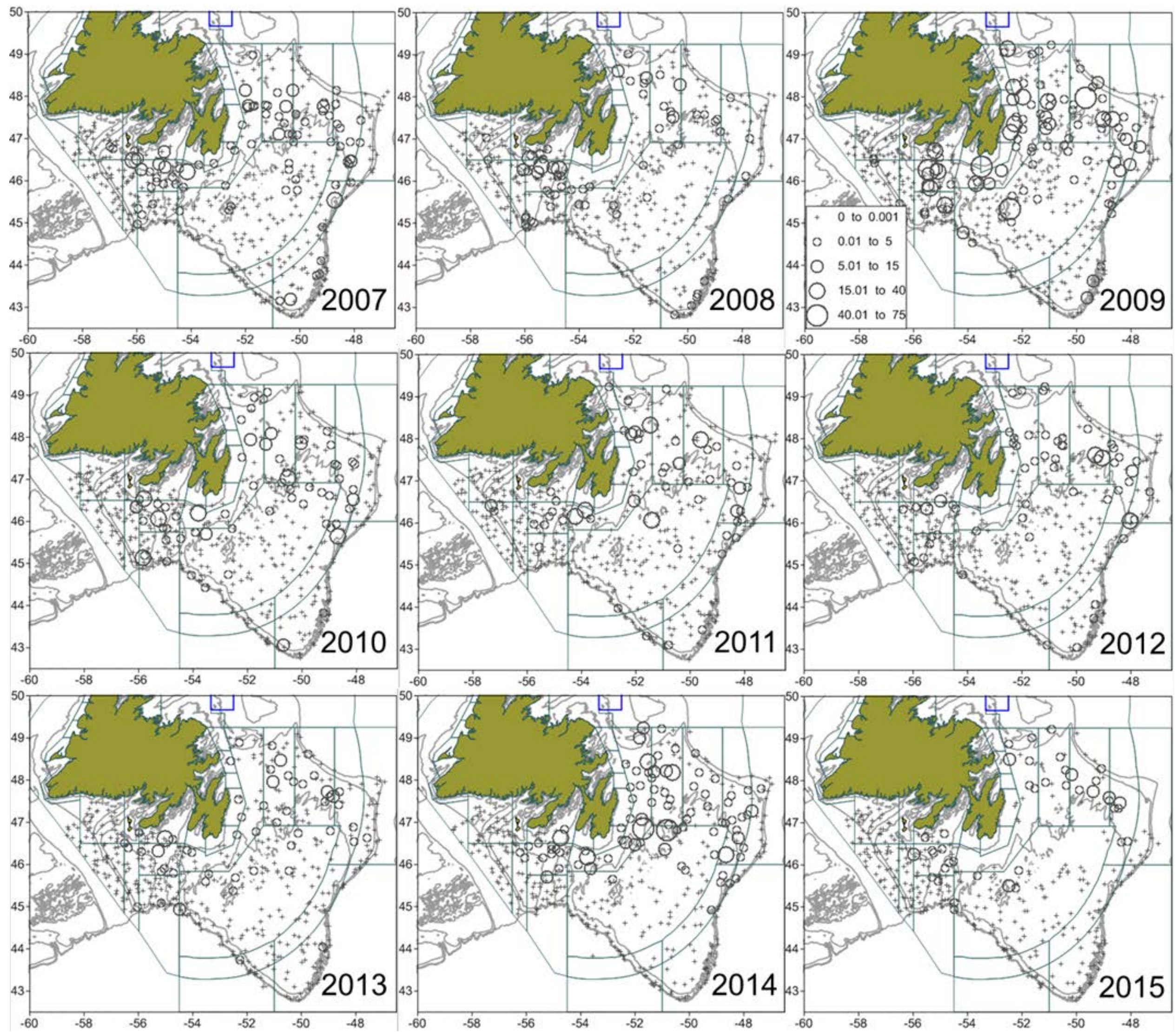

Figure 41. Distribution of mature females (#/tow) from Divs. 3LNOPs spring bottom trawl surveys from 2007-15.

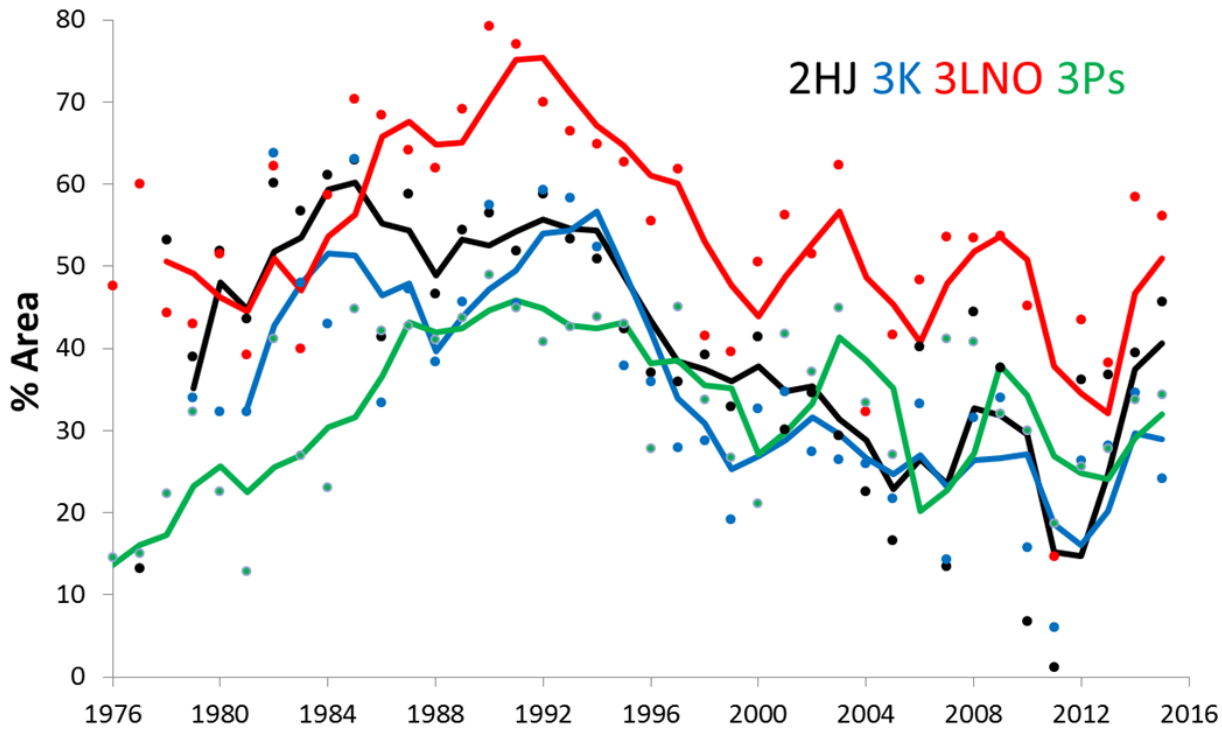

Figure 42. Snow crab thermal habitat indices by division. Dots show annual estimates and thick lines show three-year running averages. Divs. 2HJ and 3K indices defined as areal extent of < 2°C bottom water during fall and Divs. 3LNO and 3Ps indices defined as < 1°C bottom water during spring.

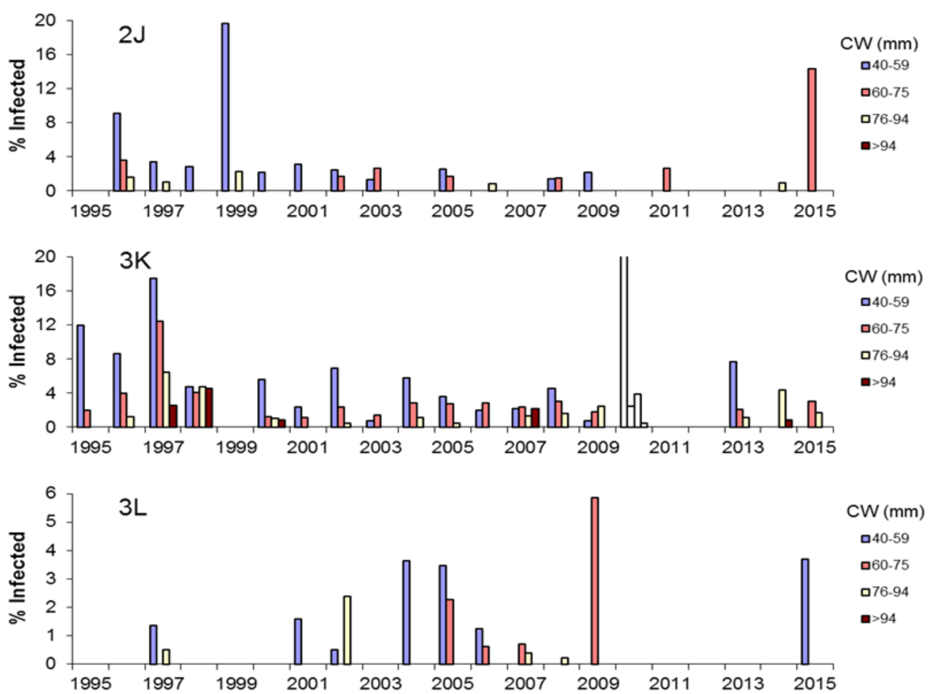

Figure 43. Annual trends in incidence of BCD from macroscopic observations in adolescent male crabs in fall multi-species trawl surveys, by division, year, and carapace width.

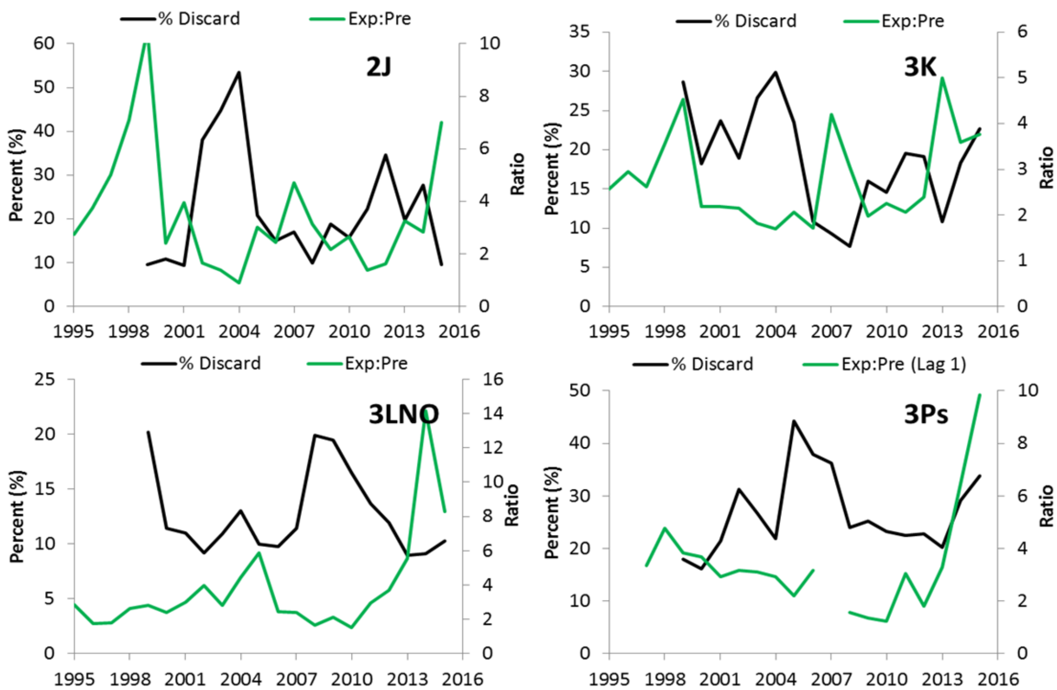

Figure 44. Trends in the ratio of exploitable to pre-recruit biomass indices from trawl surveys in relation to the observed percentage of the catch discarded in the fishery in offshore portions of assessment divisions. The multi-species index in Subdiv. 3Ps (Exp:Pre) is lagged by one year due to it occurring in the spring.

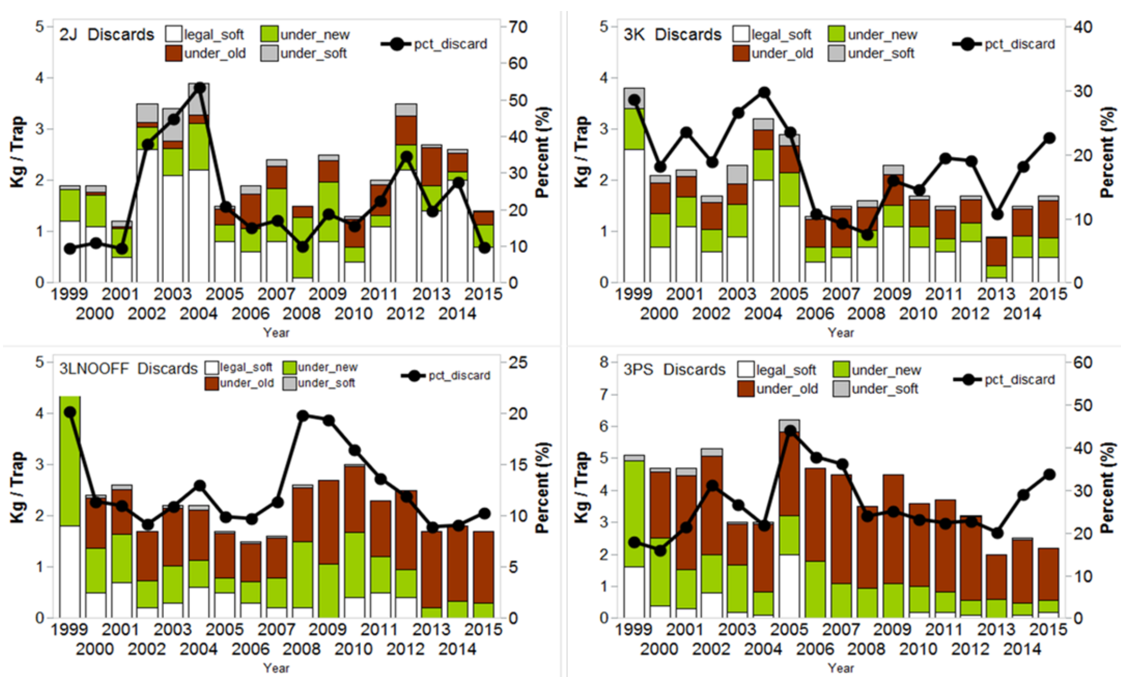

Figure 45. Trends in observed catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded, in offshore portions of assessment divisions.

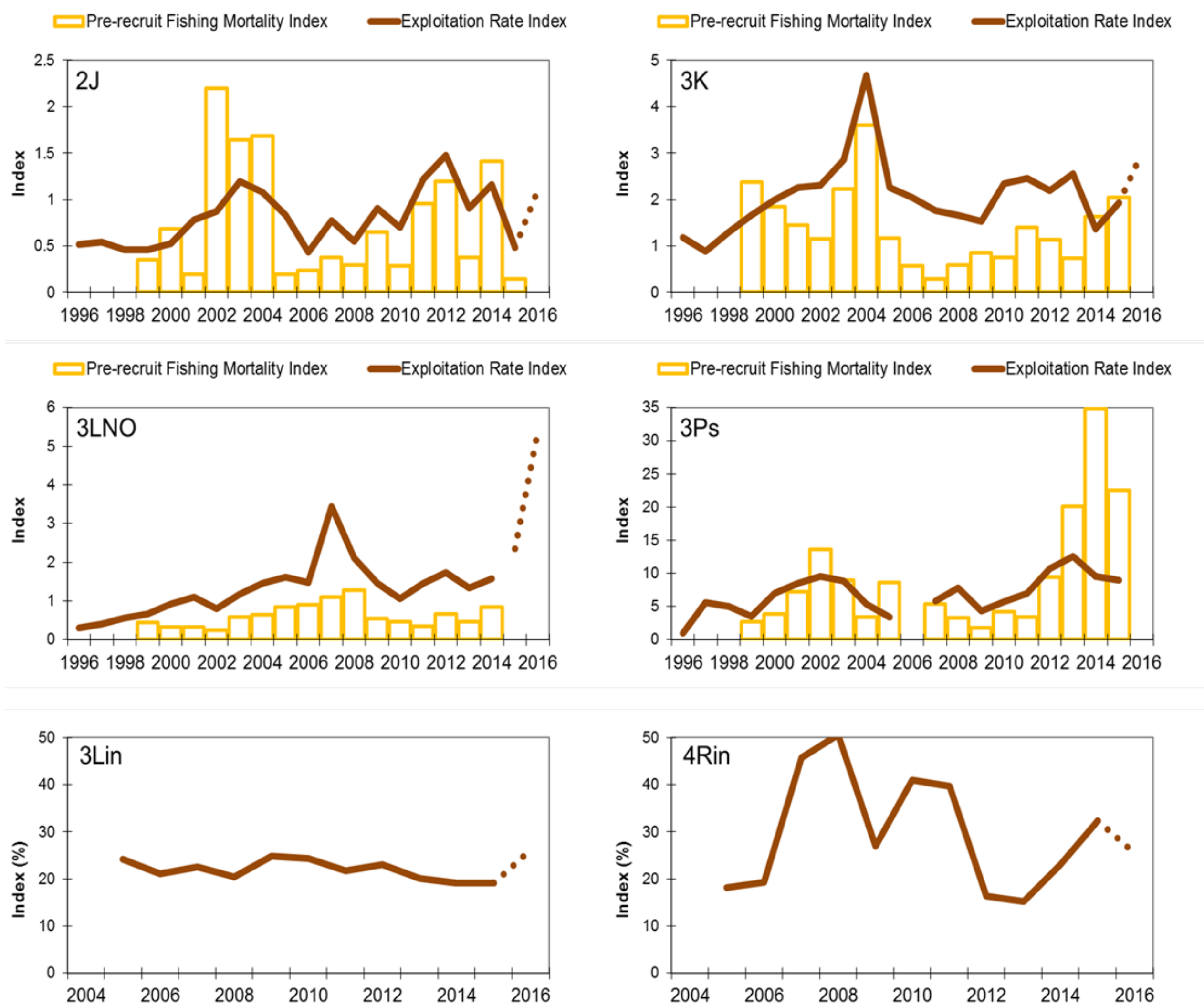

Figure 46. Trends in mortality indices (the exploitation rate index and the pre-recruit fishing mortality rate index for offshore assessment divisions based on trawl data and the exploitation rate index for inshore assessment divisions based on CPS trap data). Dashed brown lines depict projected 2016 exploitation rate indices based on status quo landings.

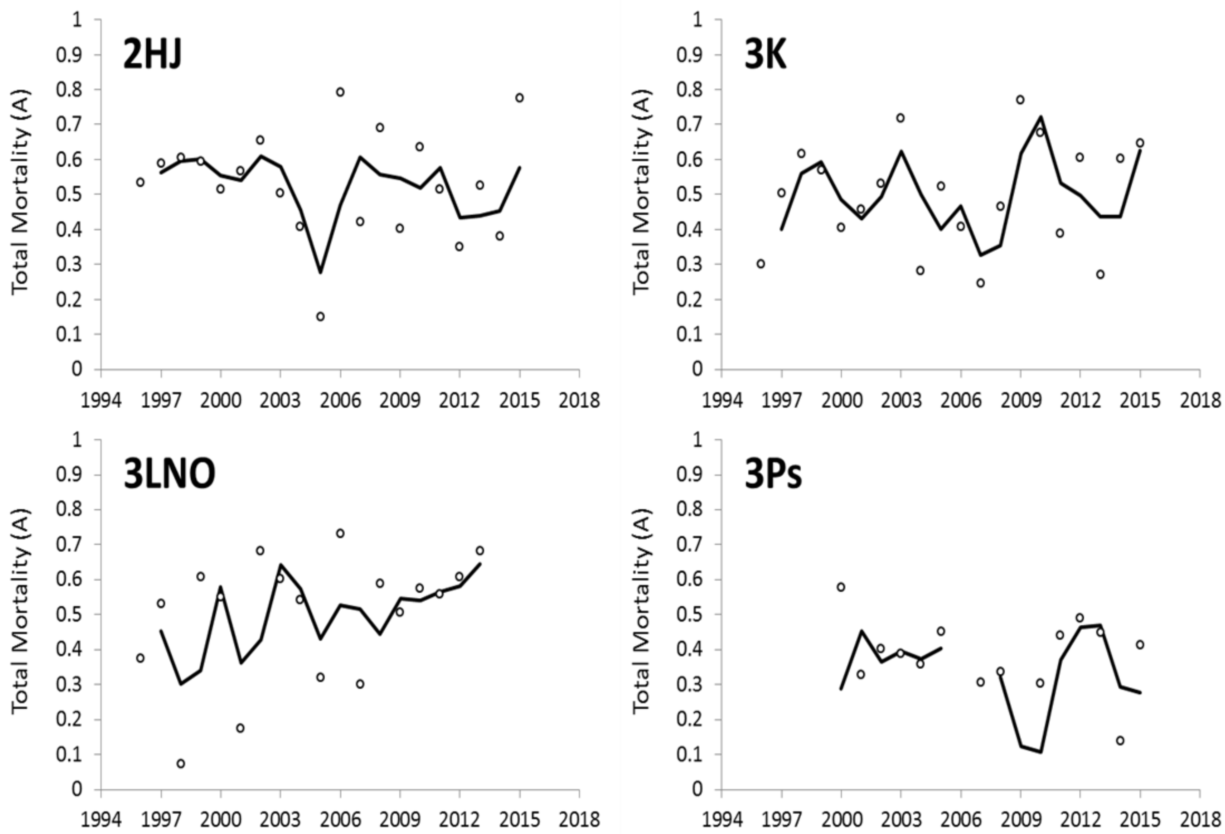

Figure 47. Trawl survey shell condition-based index of annual mortality of exploitable crabs, by division. Annual point estimates (open circles) versus two period moving averages (black lines).

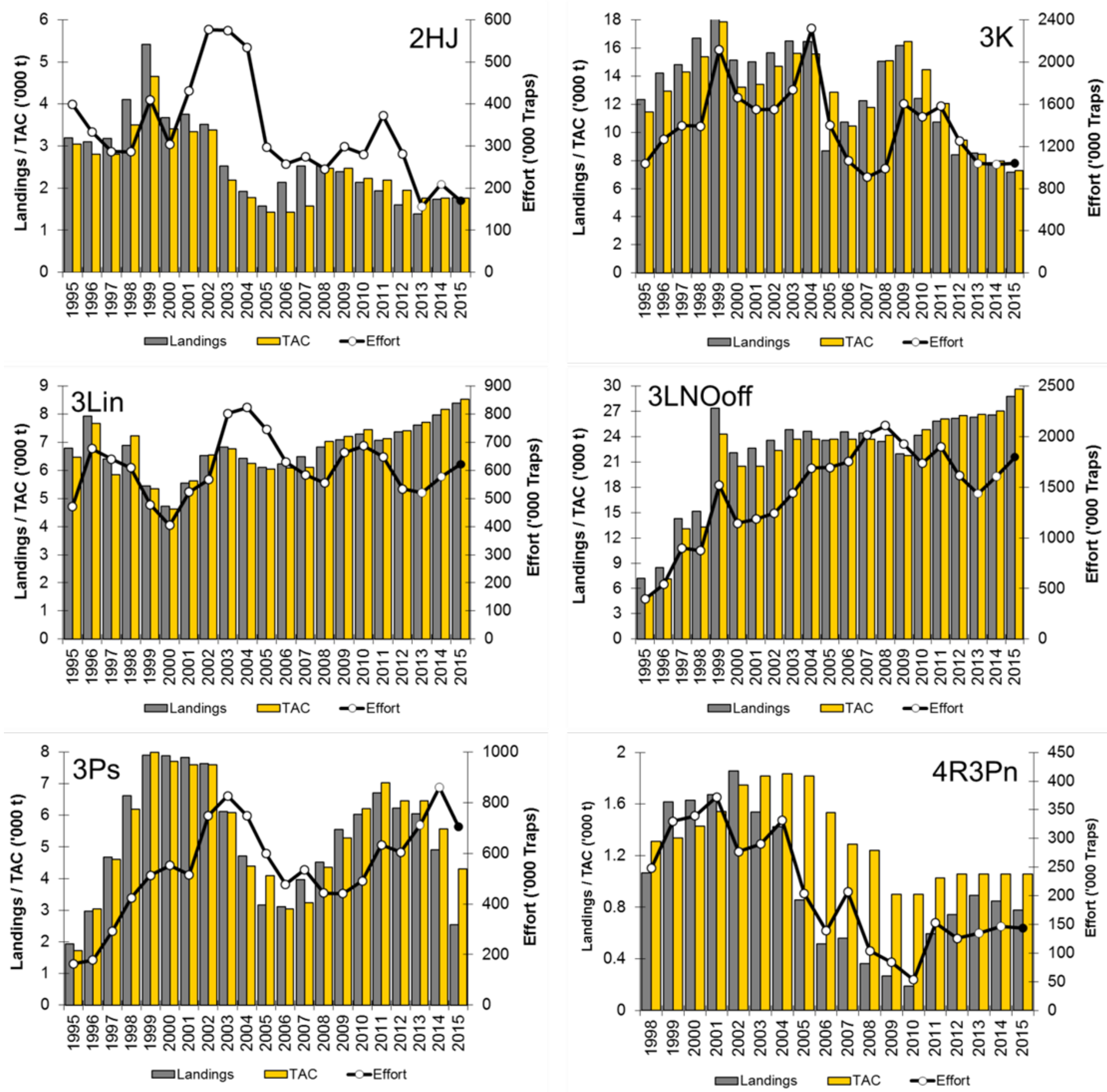

Figure 48. Annual landings, TAC, and estimated effort by assessment division.

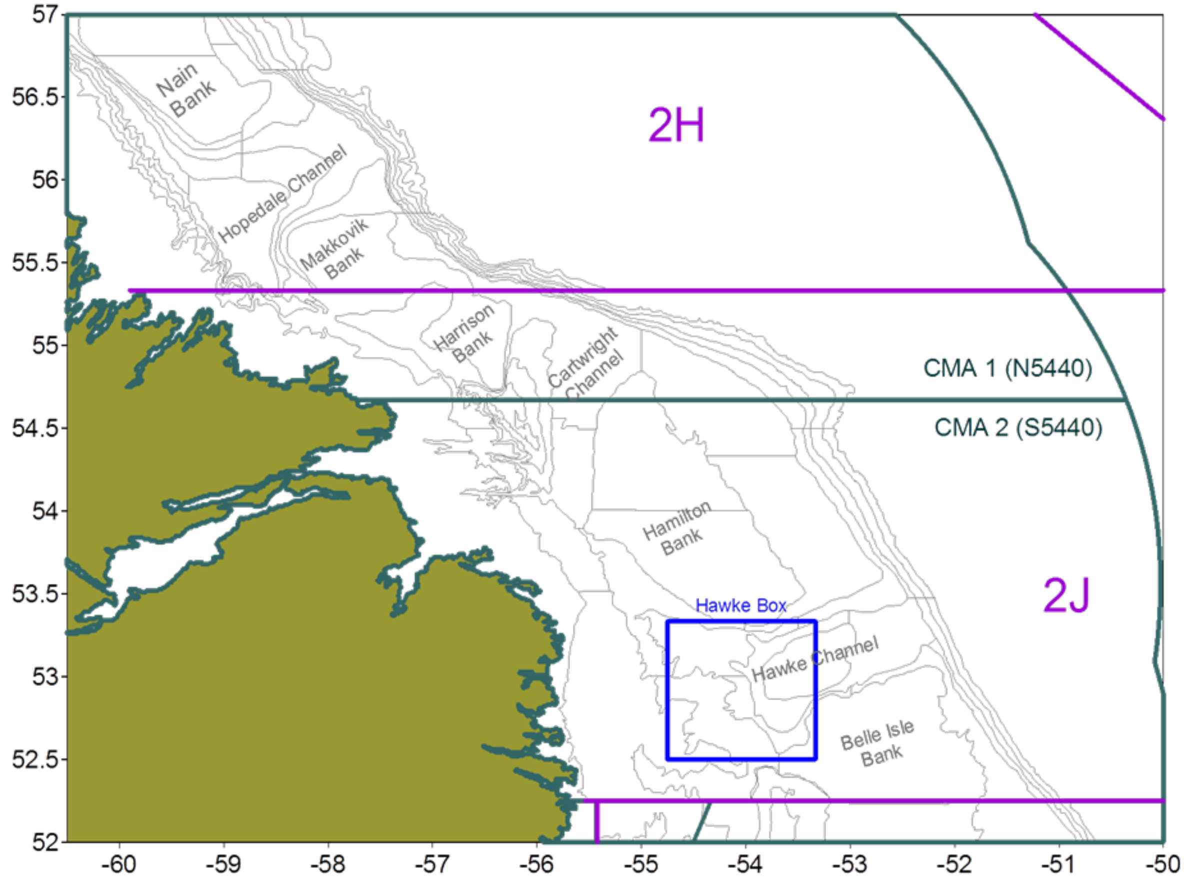

Figure 49. Map of Divs. 2HJ showing important bathymetric features, CMAs, and the Hawke Channel closure area.

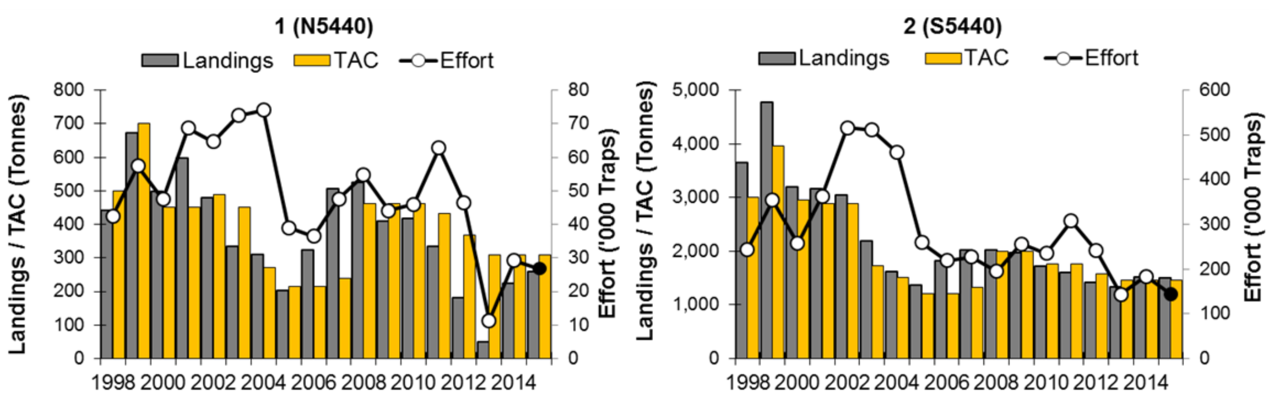

Figure 50. TAC, landings, and estimated effort for CMAs in Divs. 2HJ. 2015 effort preliminary.

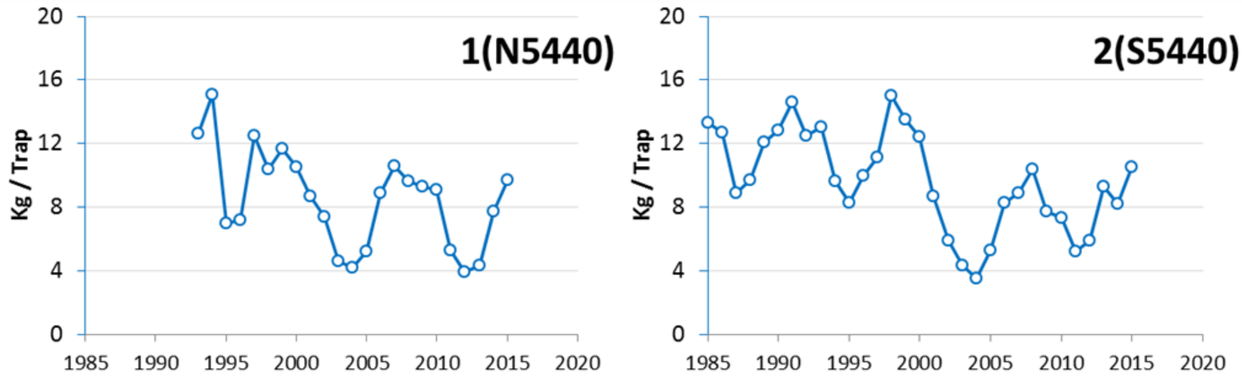

Figure 51. Trends in unstandardized CPUE by CMA for Divs. 2HJ.

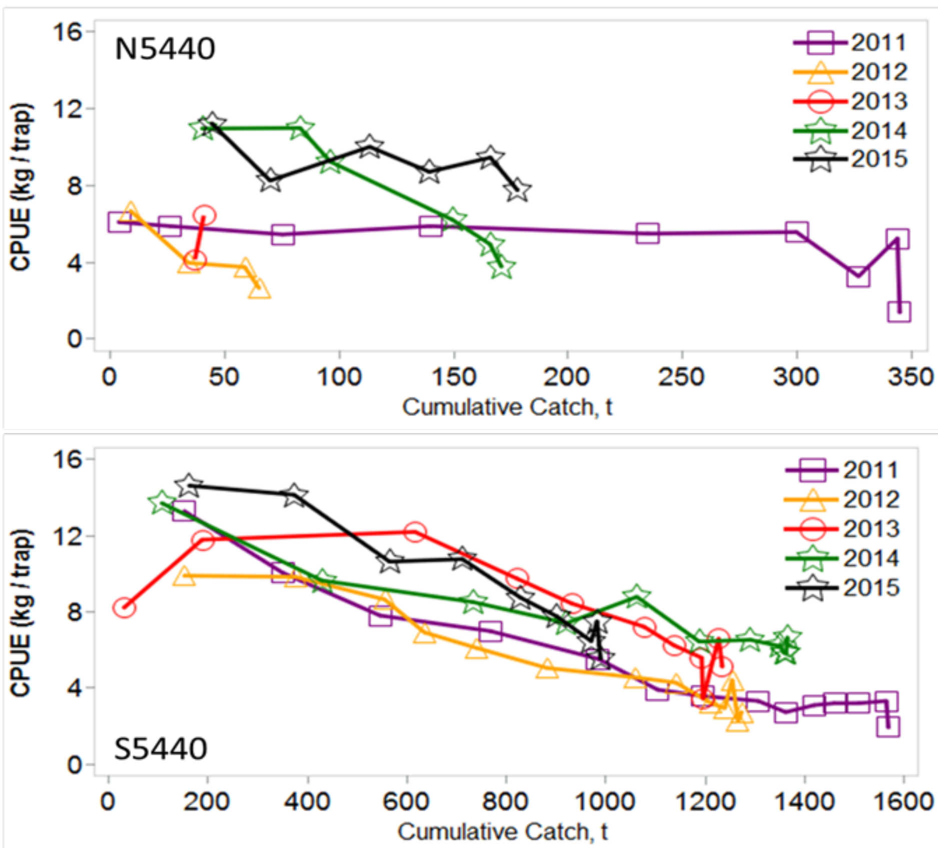

Figure 52. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Divs. 2HJ.

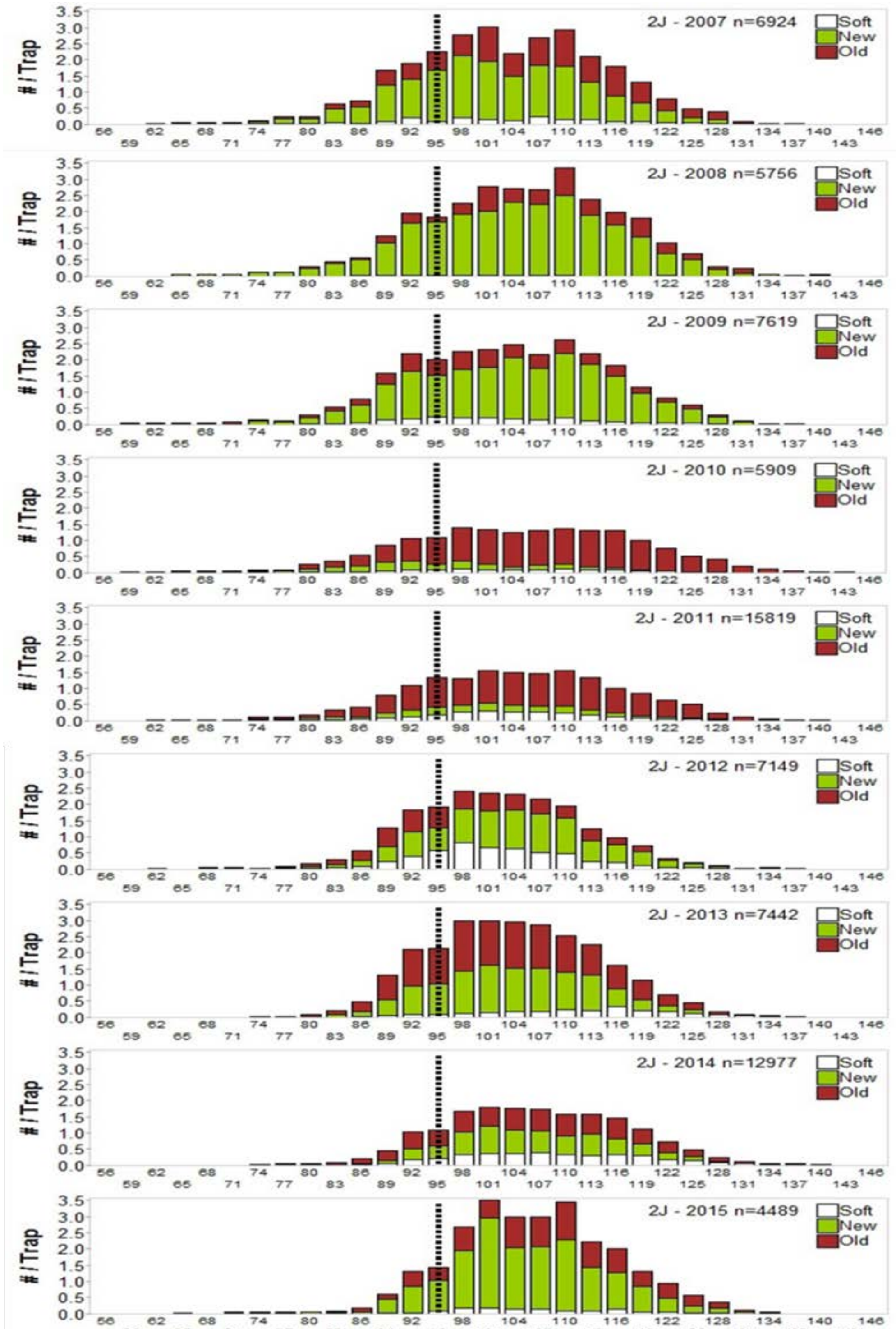

Figure 53. Trends in male CW distributions by shell condition from observer at-sea sampling for Div. 2J. The vertical dashed line indicates the minimum legal size.

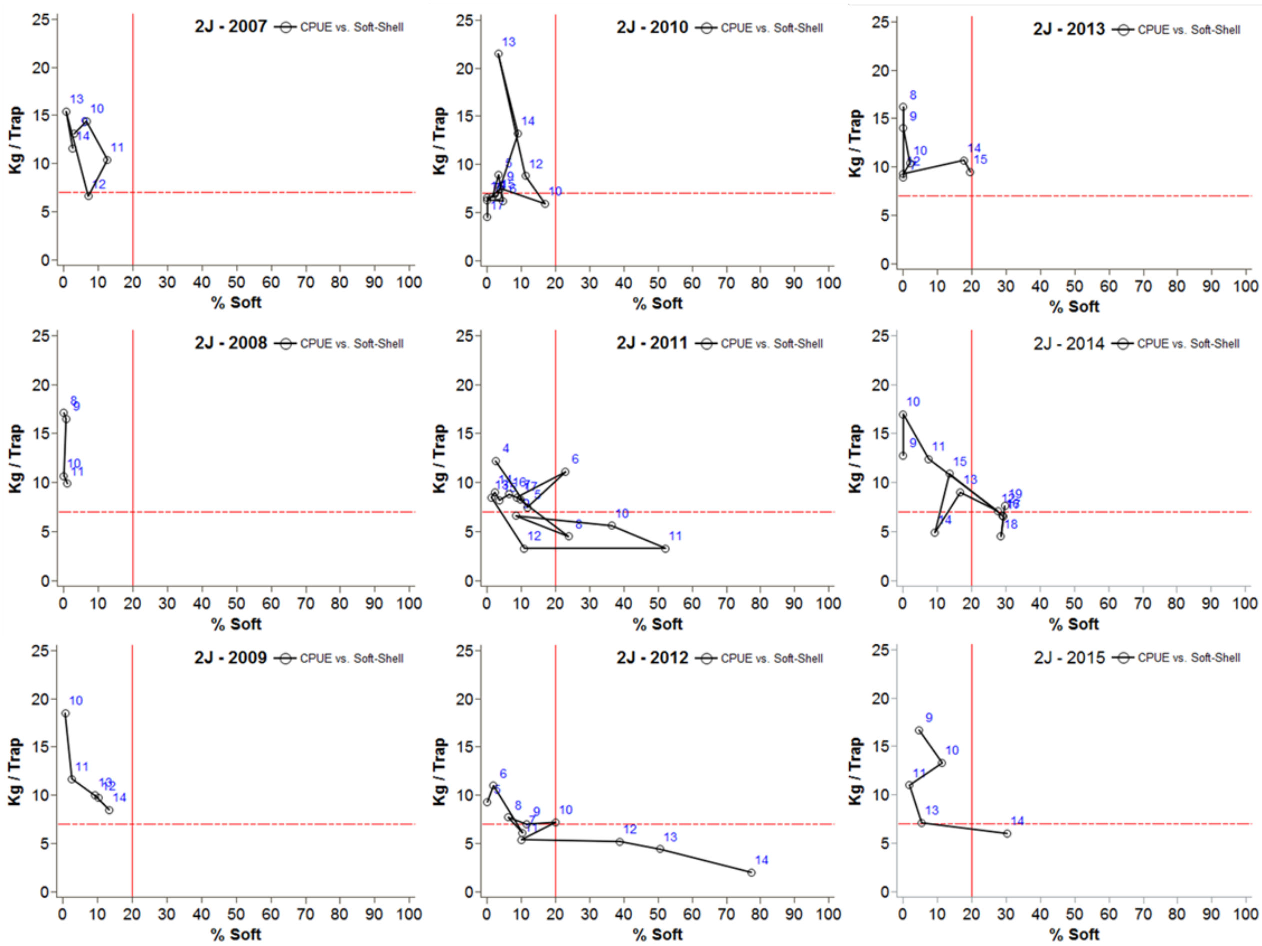

Figure 54. Trends in observed weekly catch rates versus the percentage of soft-shell crab in the catch in Div. 2J.

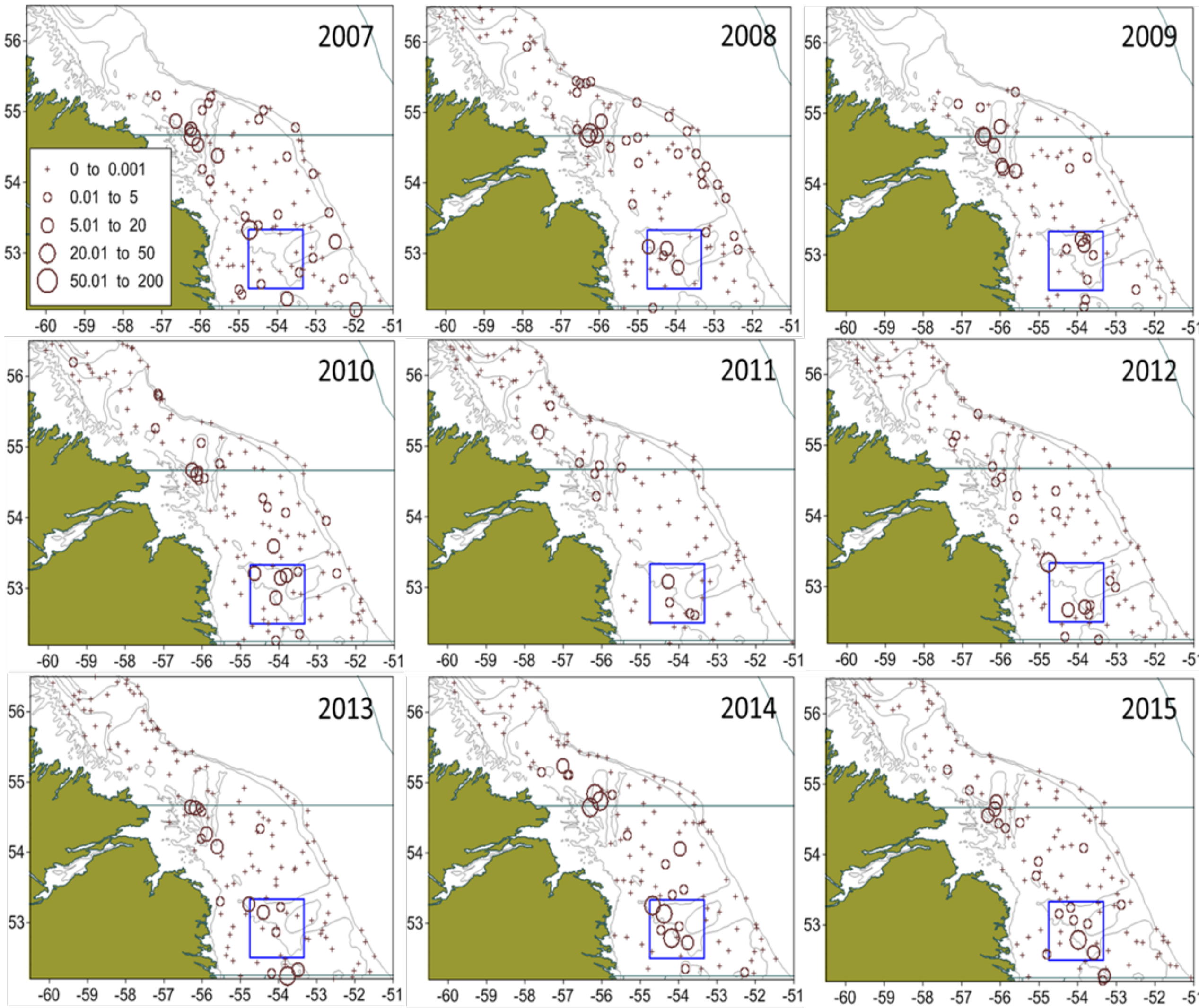

Figure 55. Distribution (#/tow) of exploitable males (> 94 mm CW adults) from Divs. 2HJ fall bottom trawl surveys from 2007-15.

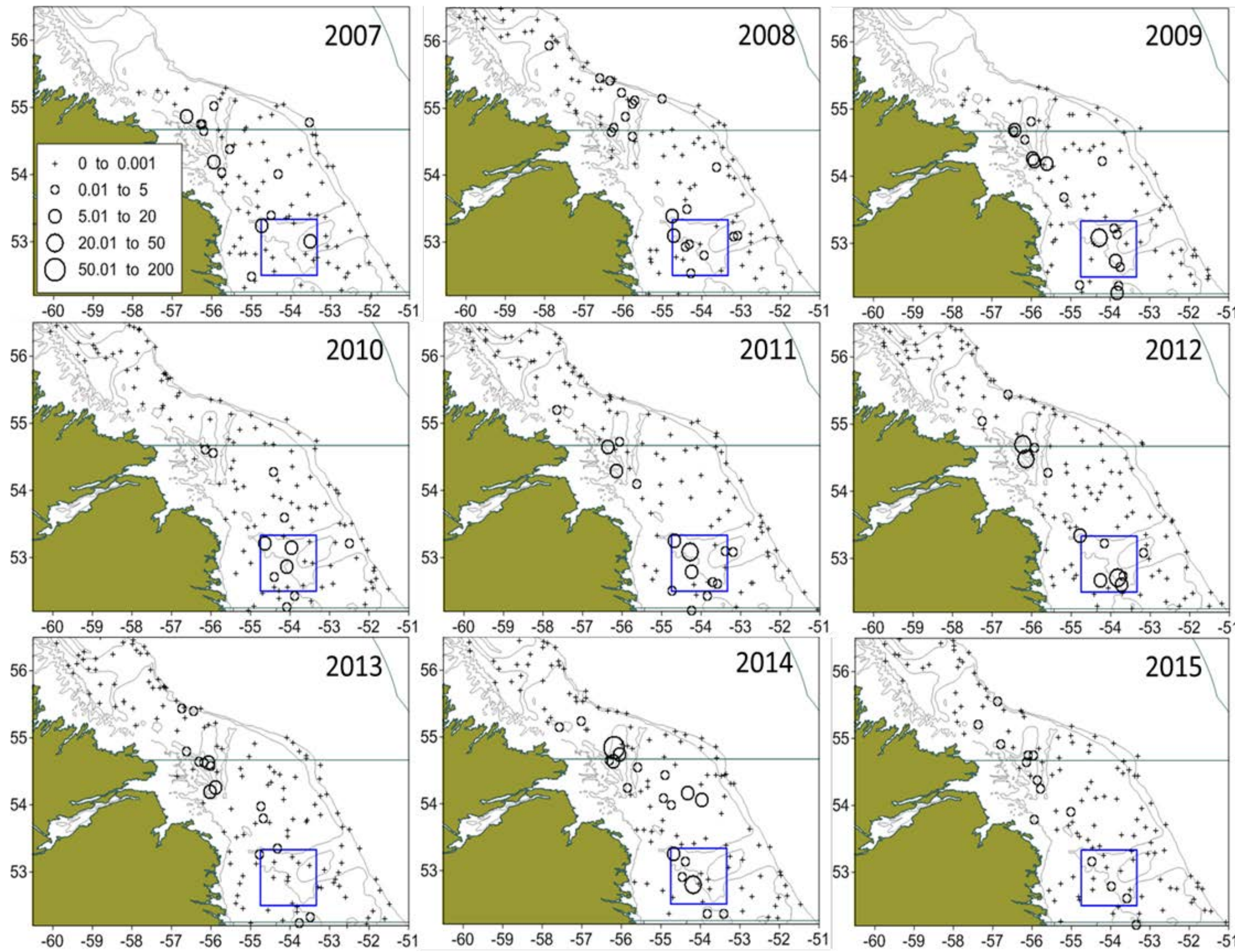

Figure 56. Distribution (#/tow) of pre-recruit males (> 75 mm CW adolescent) from Divs. 2HJ fall bottom trawl surveys from 2007-15.

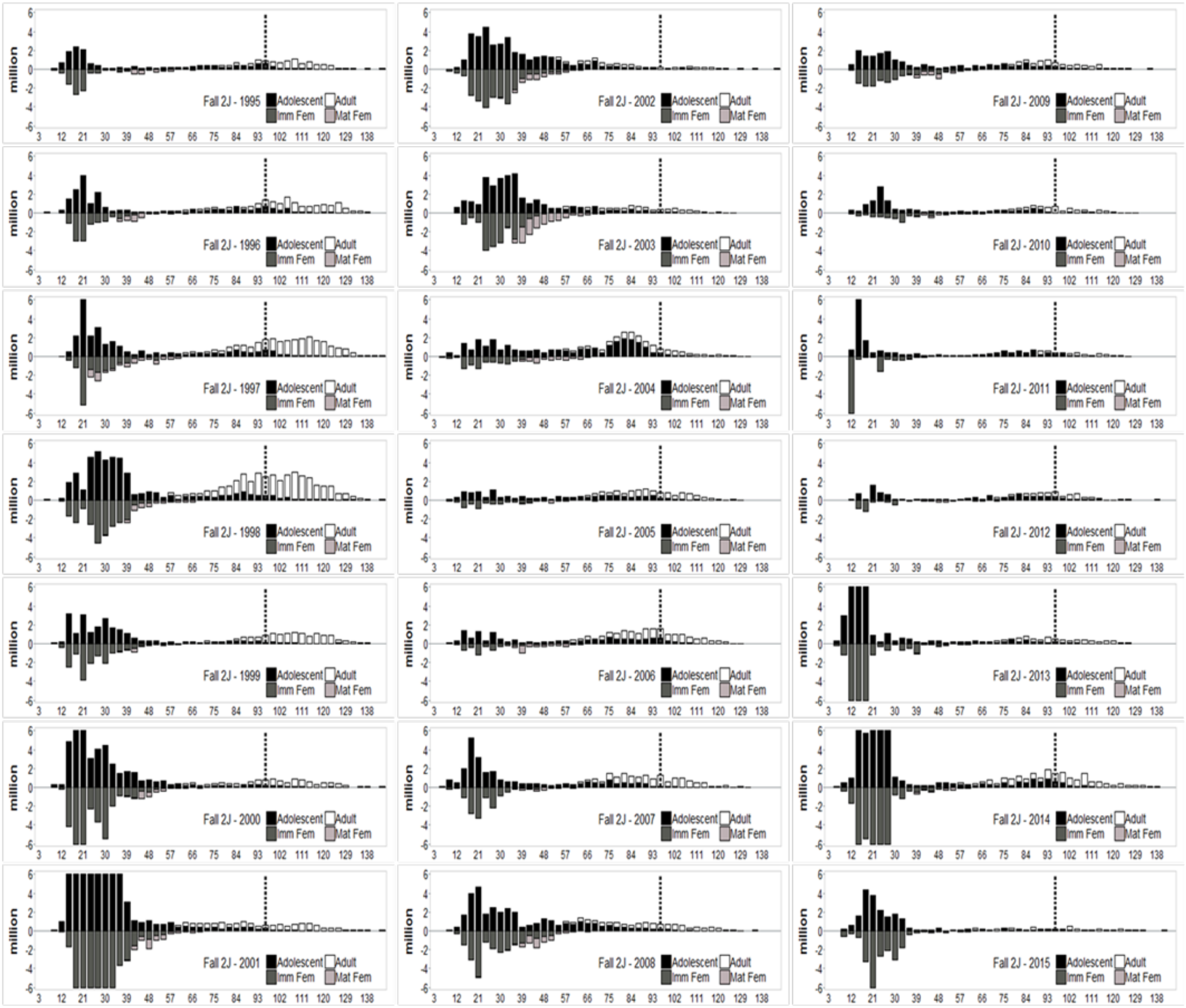

Figure 57. Abundance indices by carapace width for Divs. 2HJ juveniles plus adolescent males (dark bars), adult males (white bars), immature females (dark grey bars), and mature females (light grey bars) from fall trawl surveys.

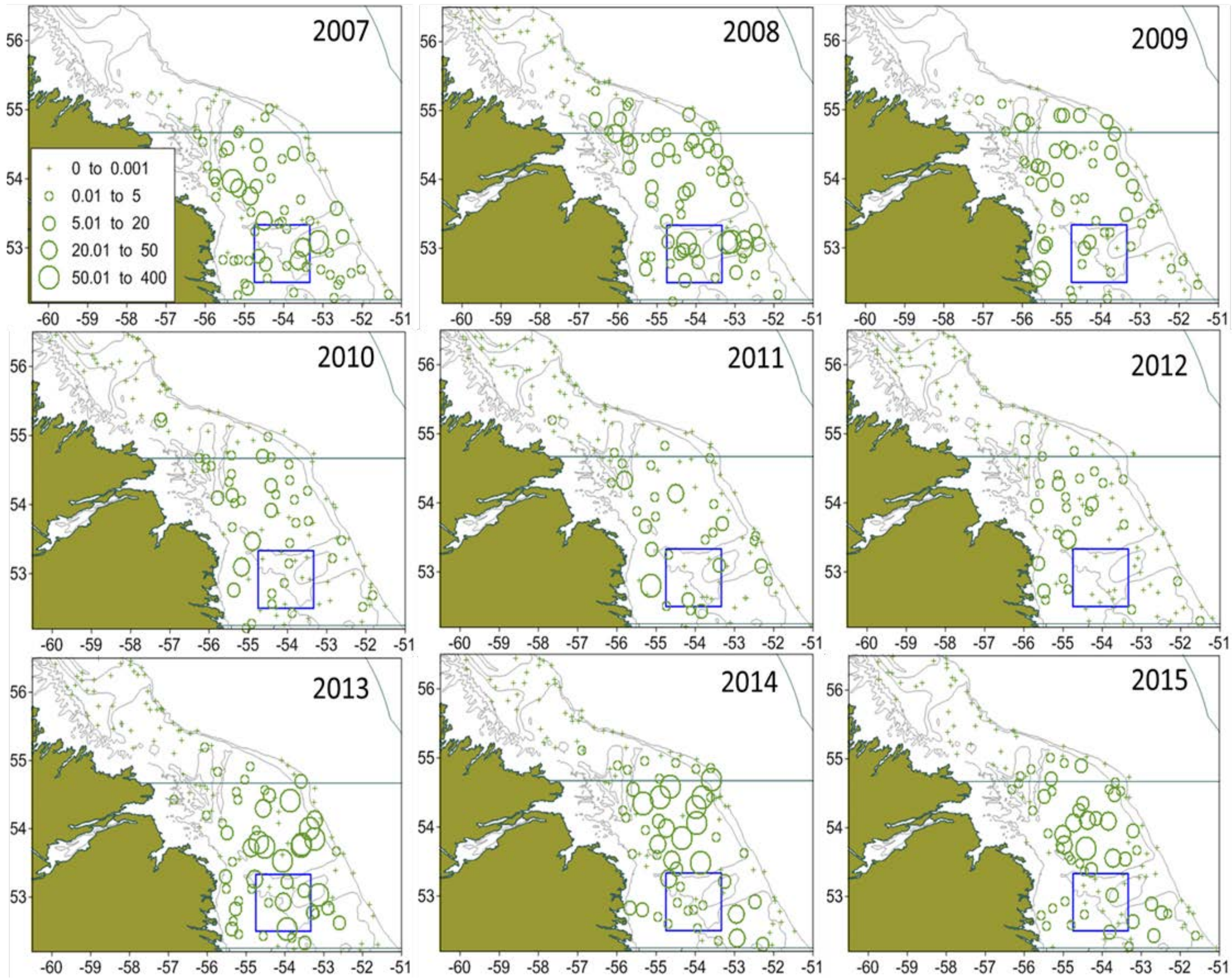

Figure 58. Distribution (#/tow) of small males (< 60 mm CW adolescents) in the Divs. 2HJ fall bottom trawl surveys from 2007-15.

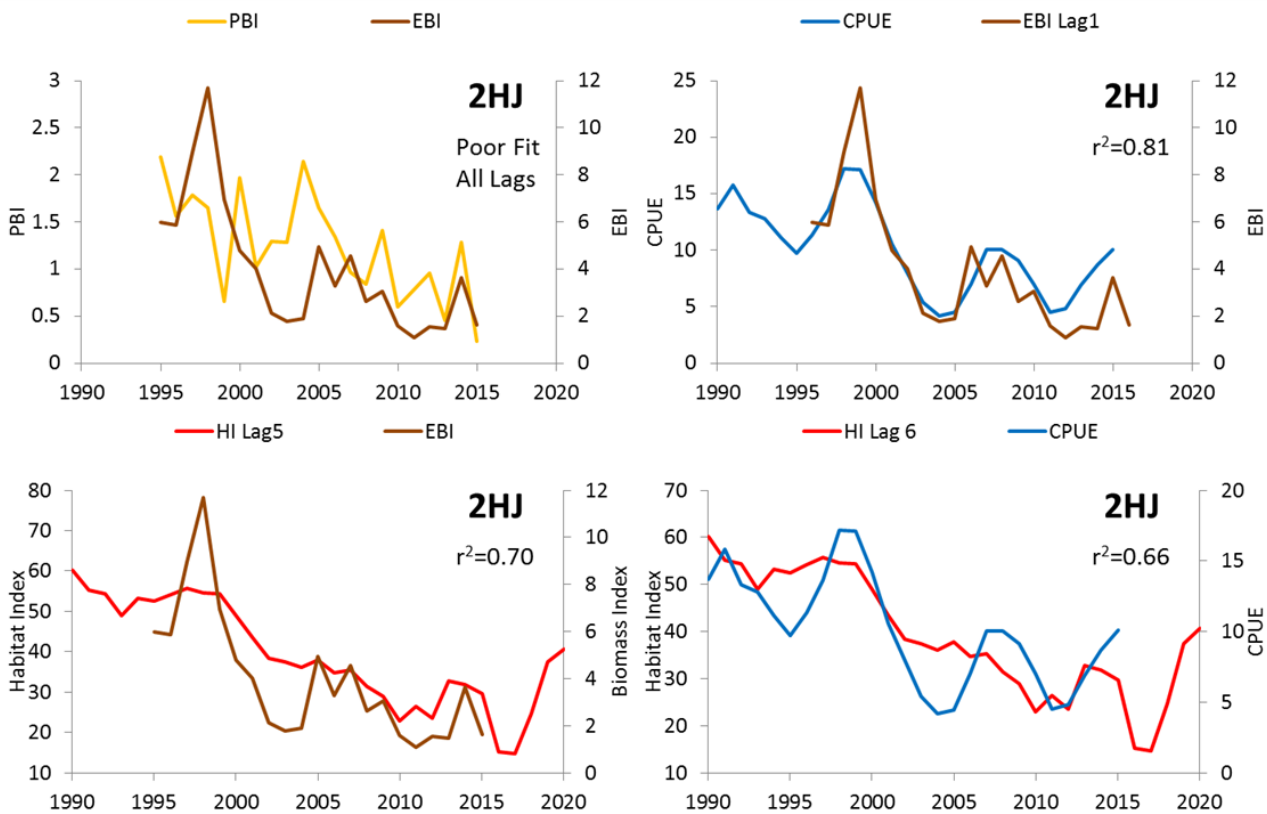

Figure 59. Summary of temporal relationships among key indices of resource status in Divs. 2HJ. Best fit correlation lags shown. PBI is pre-recruit biomass index, EBI is exploitable biomass index, CPUE is fishery catch per unit of effort, and HI is habitat index.

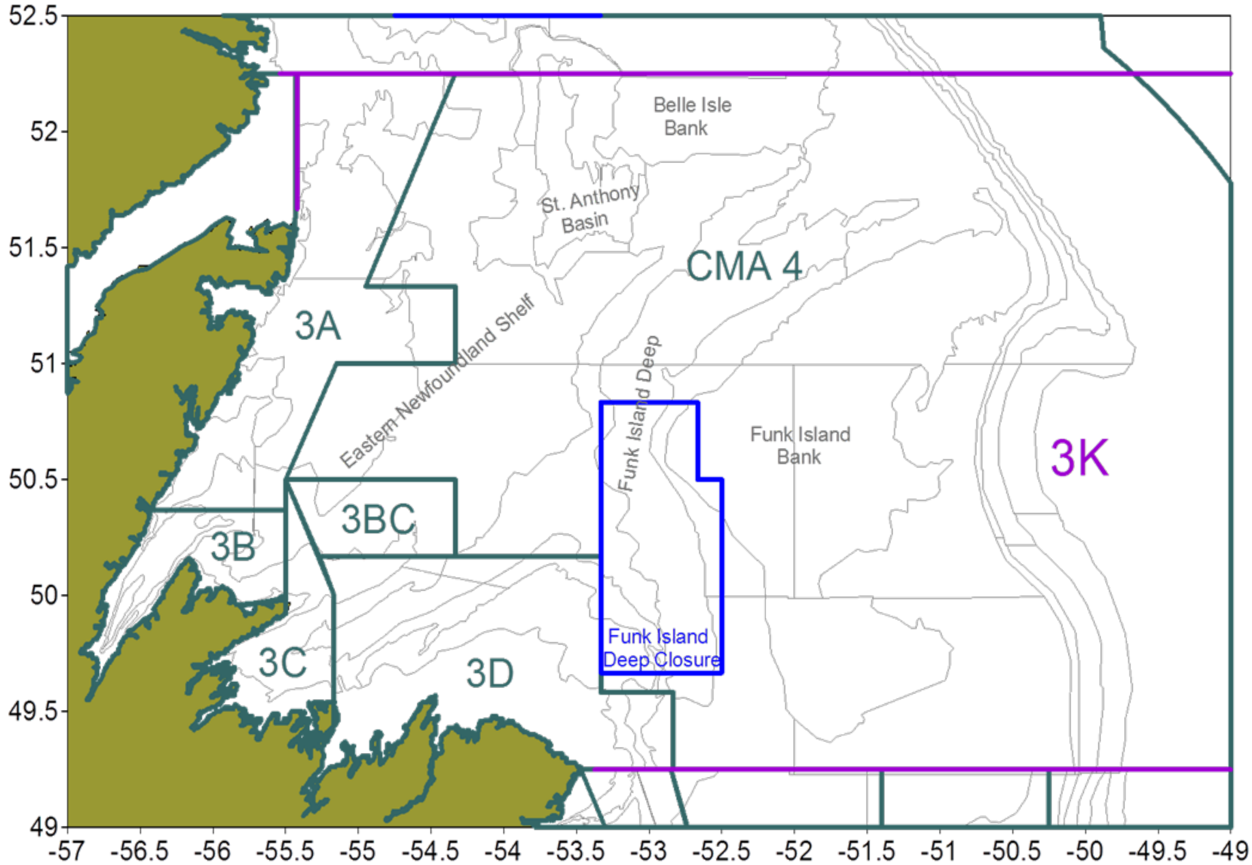

Figure 60. Map of Div. 3K showing important bathymetric features, CMAs, and the Funk Island Deep closure area.

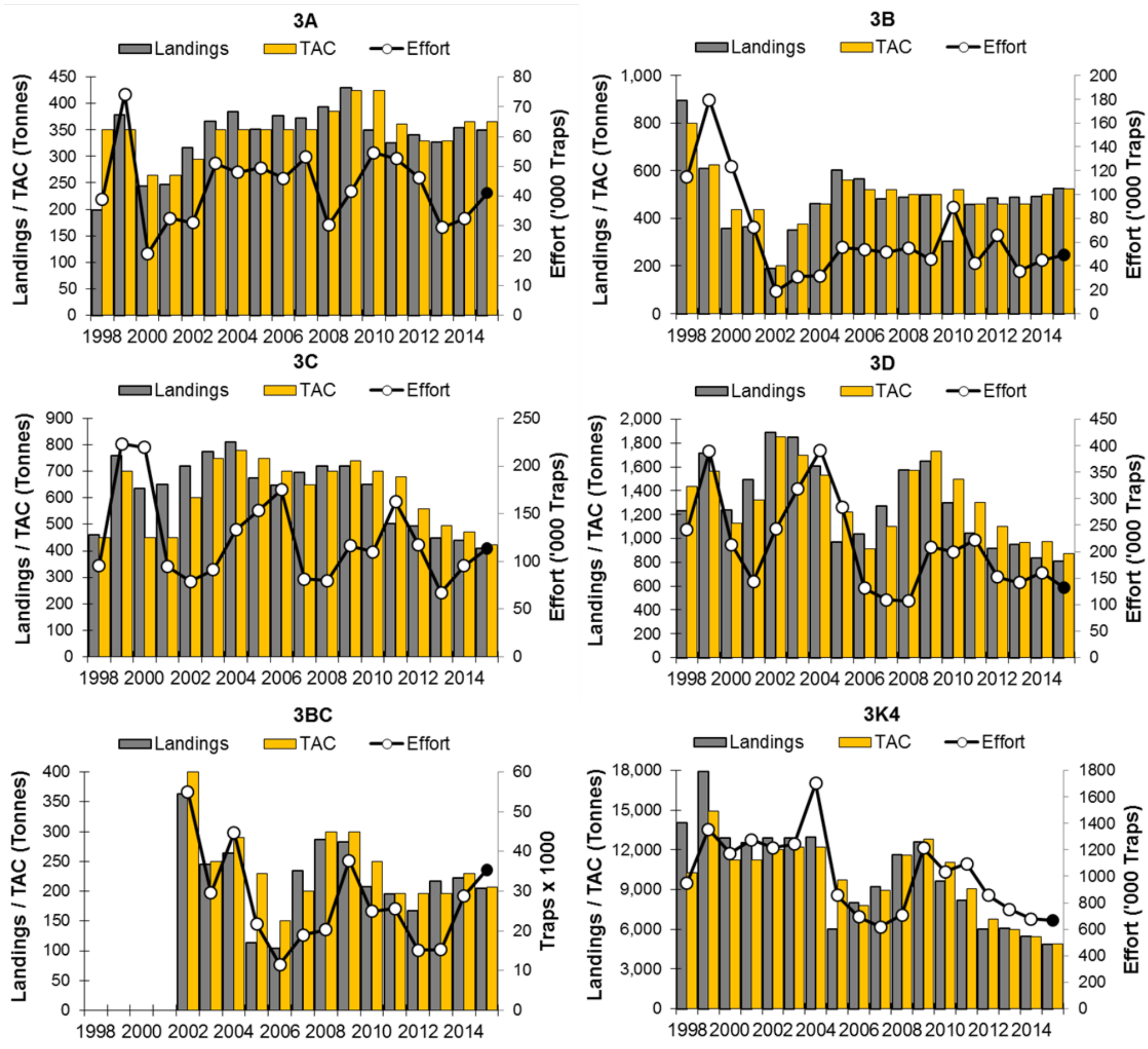

Figure 61. TAC, landings, and estimated effort for CMAs in Div. 3K. 2015 effort preliminary.

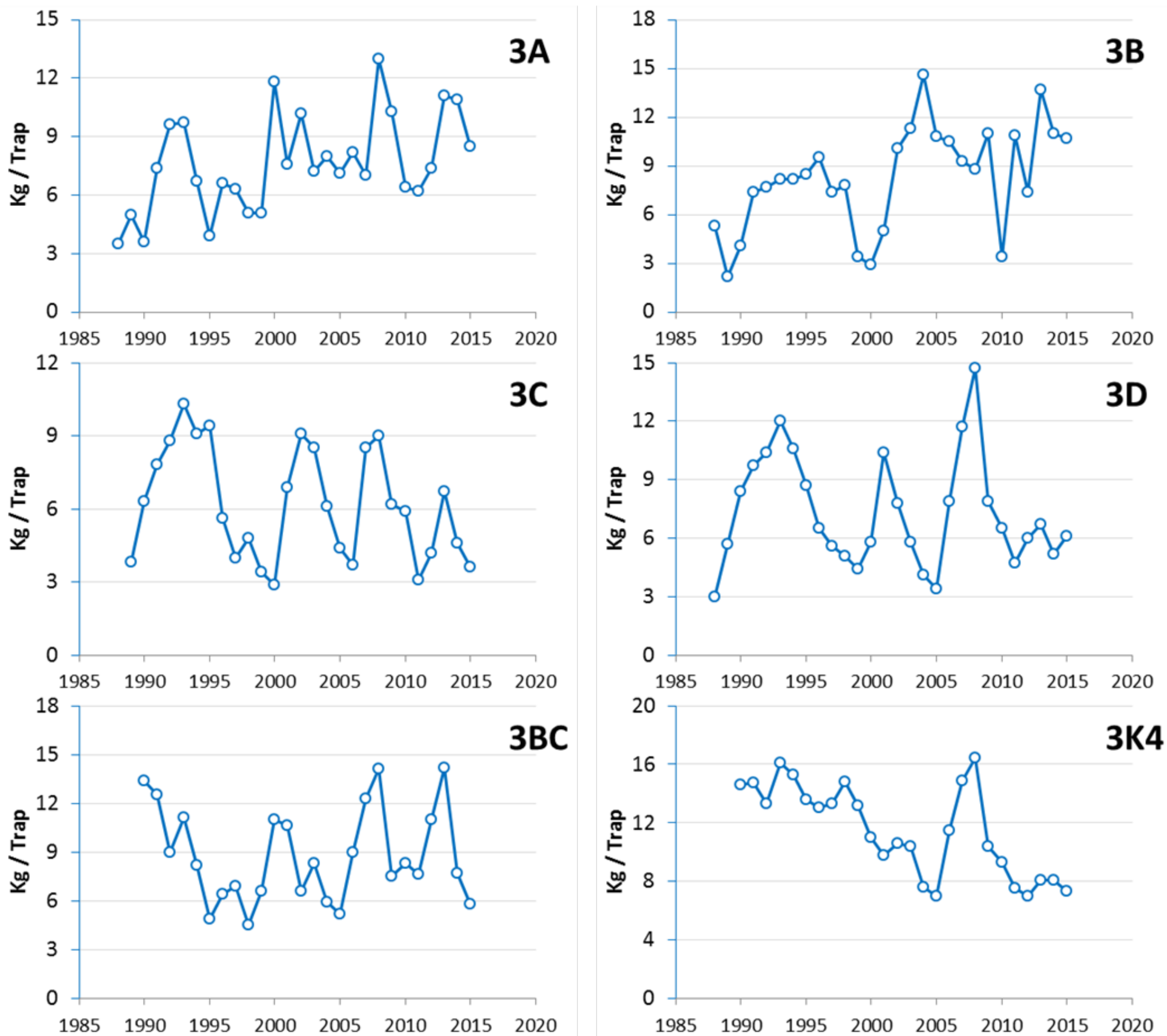

Figure 62. Trends in unstandardized CPUE by CMA for Div. 3K.

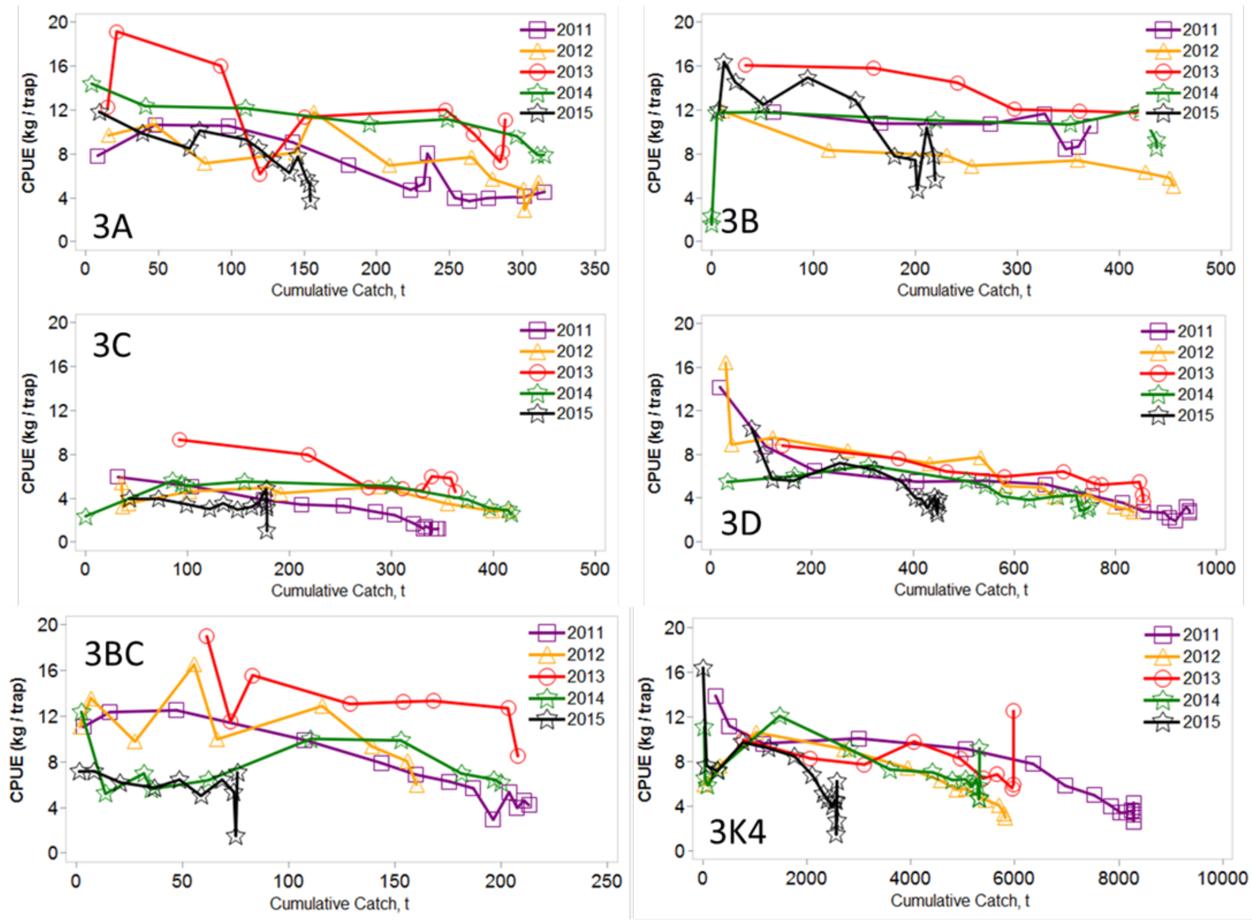

Figure 63. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Div. 3K.

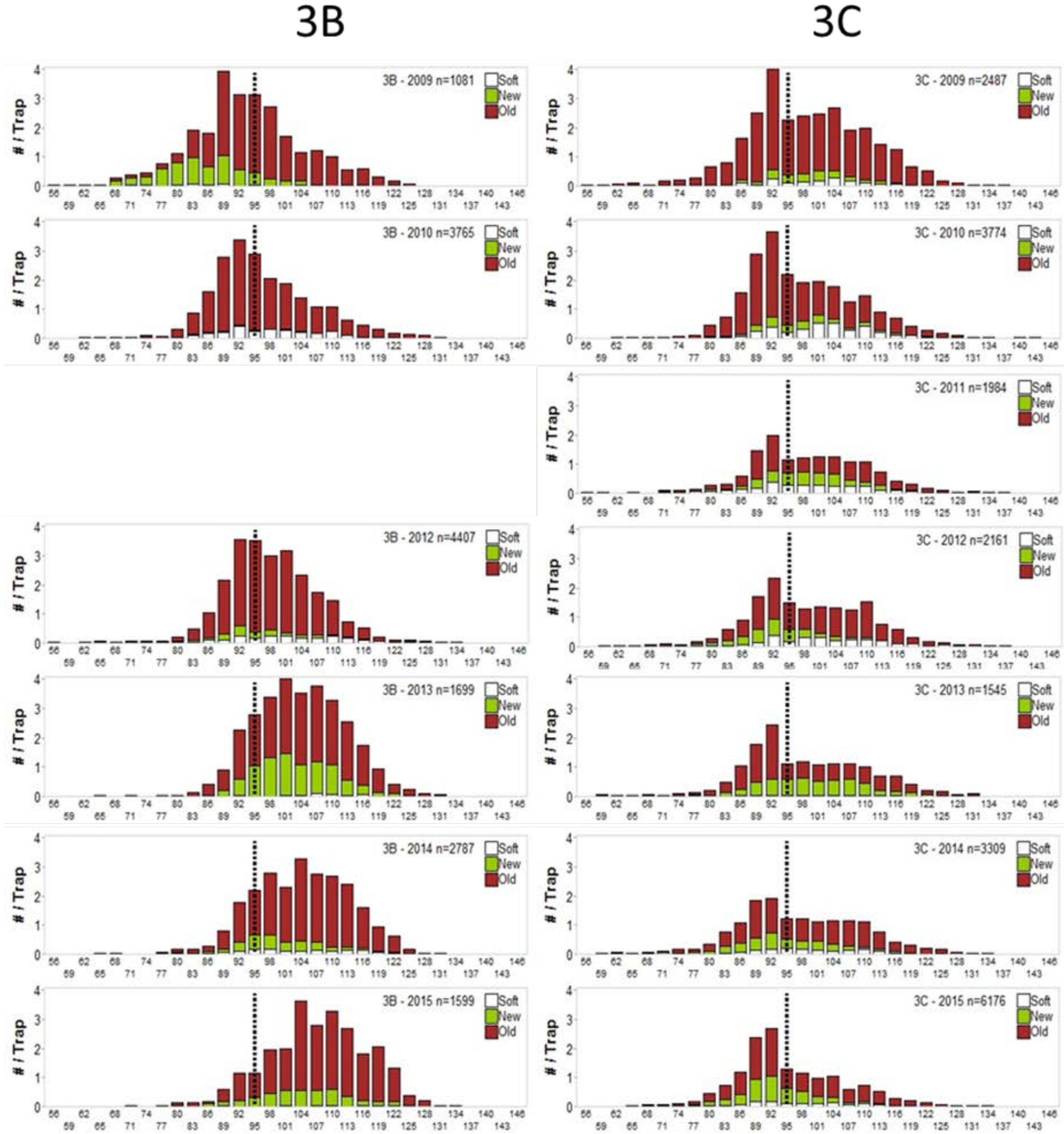

Figure 64. Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMAs in Div. 3K. The vertical dashed line indicates the minimum legal size.

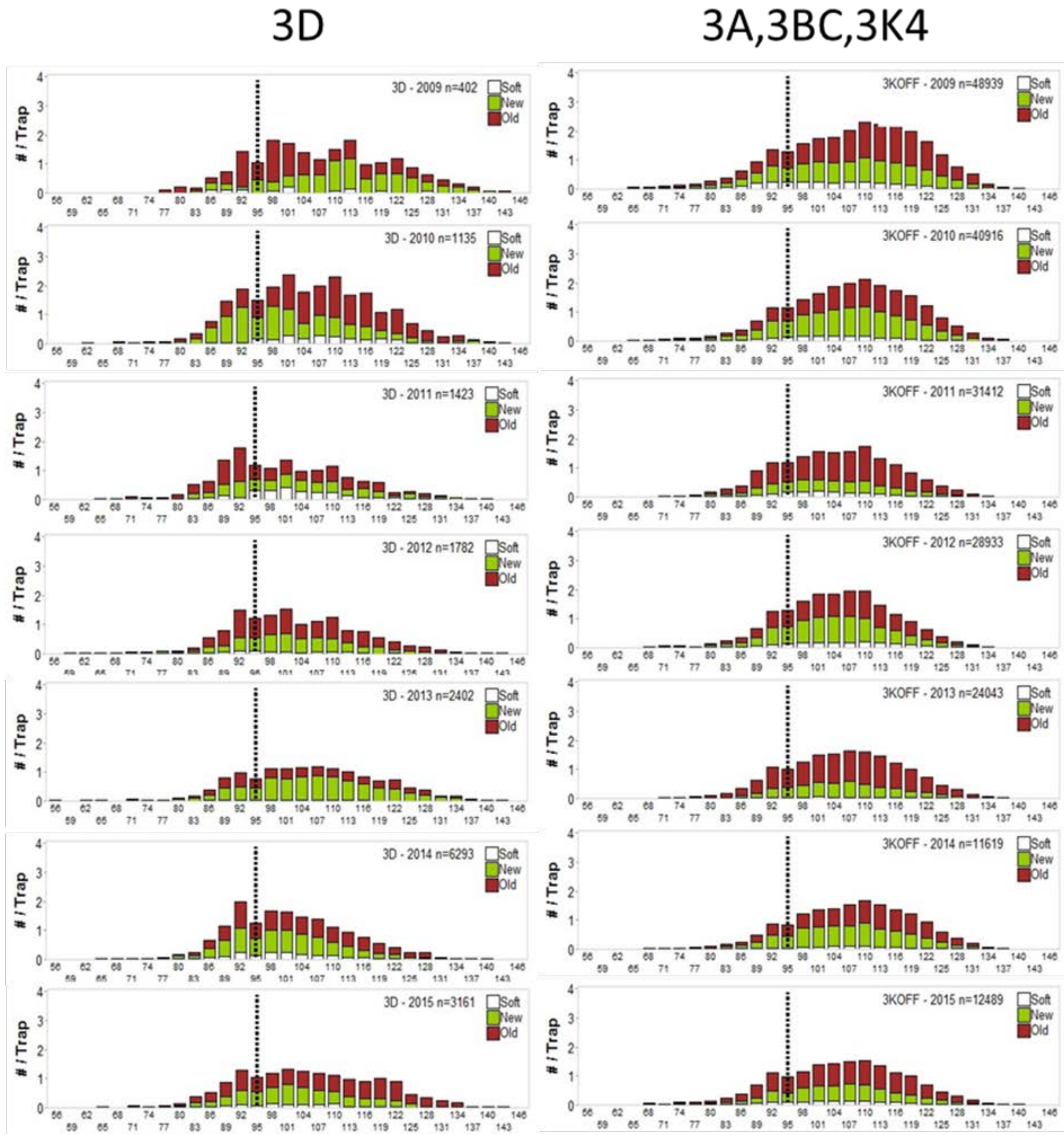

Figure 65. Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMAs in Div. 3K. The vertical dashed line indicates the minimum legal size.

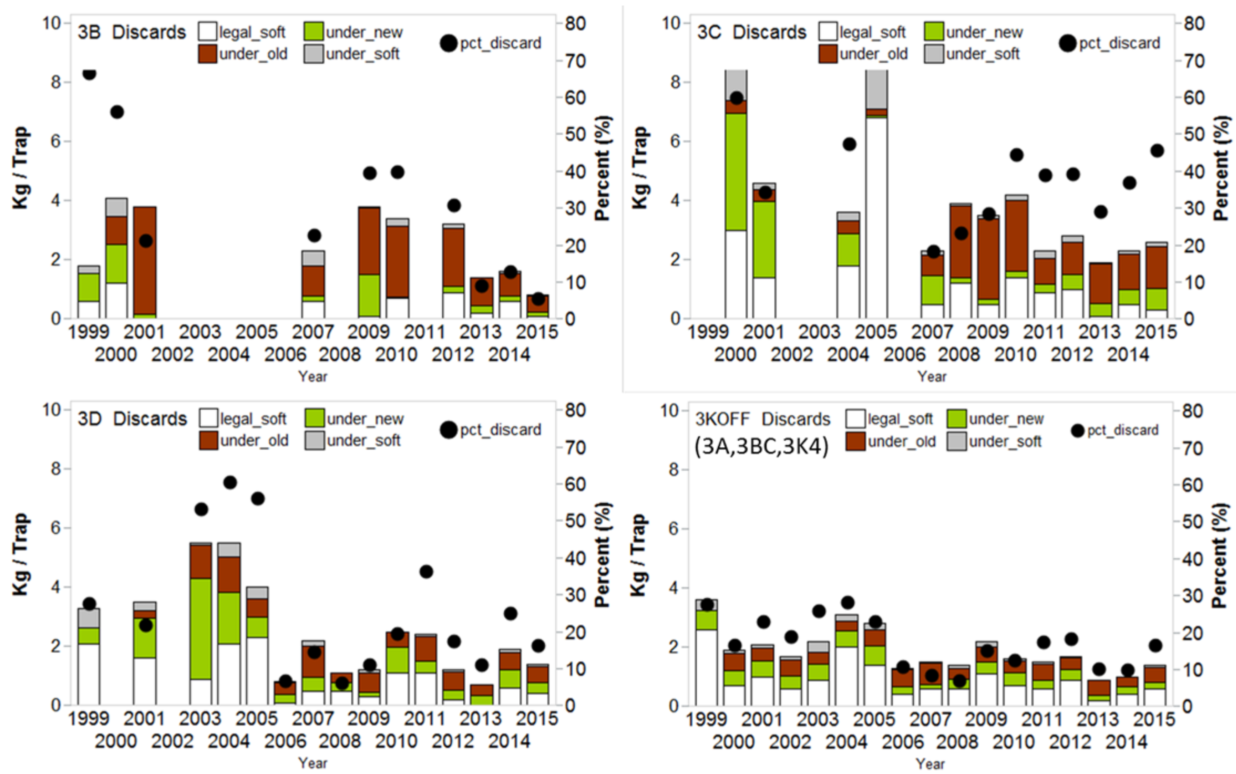

Figure 66. Trends in observed catch rates of total discards, undersized discards, and legal-sized soft-shelled discards, as well as the percentage of the catch discarded, in Div. 3K CMAs.

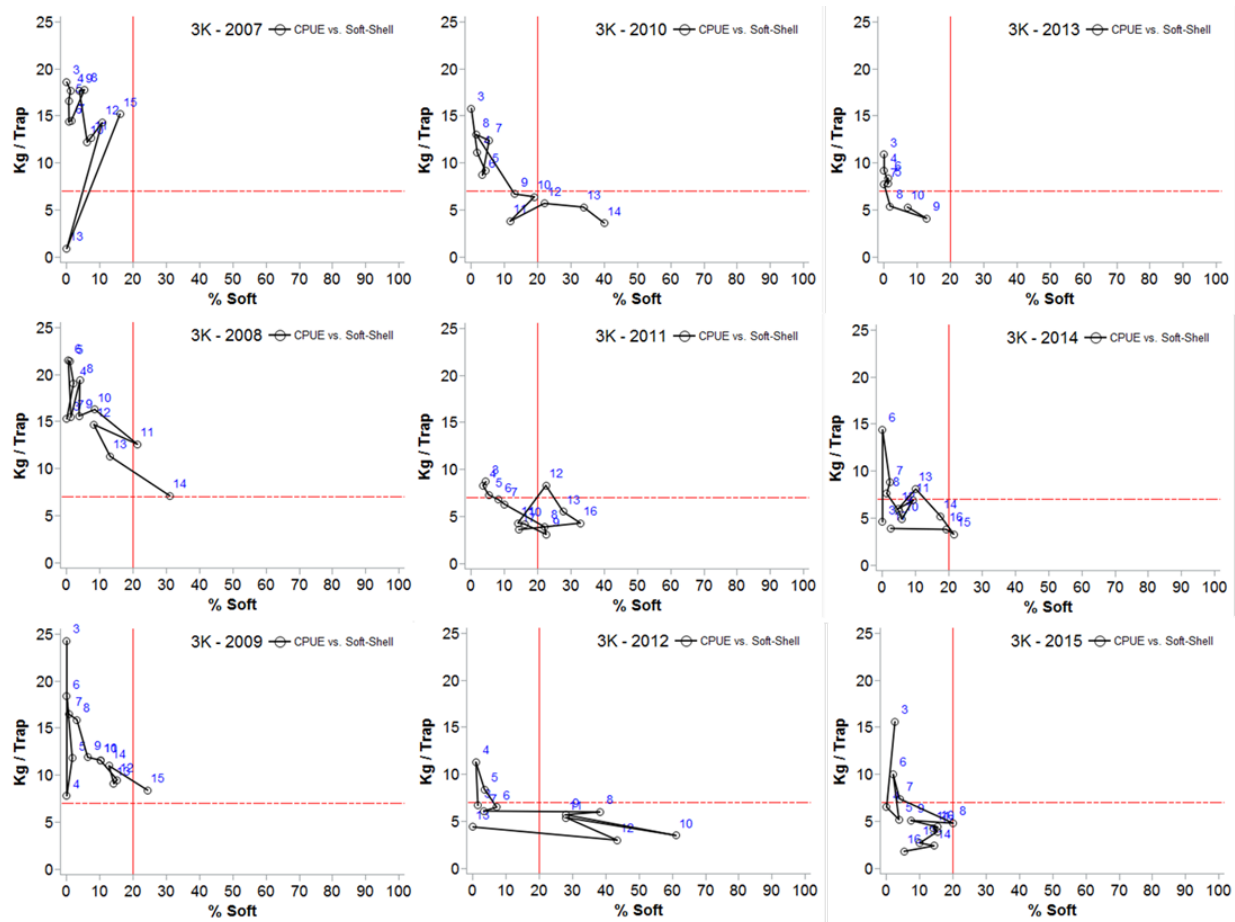

Figure 67. Trends in observed weekly catch rates versus the percentage of soft-shell crab in the catch in offshore portions of Div. 3K.

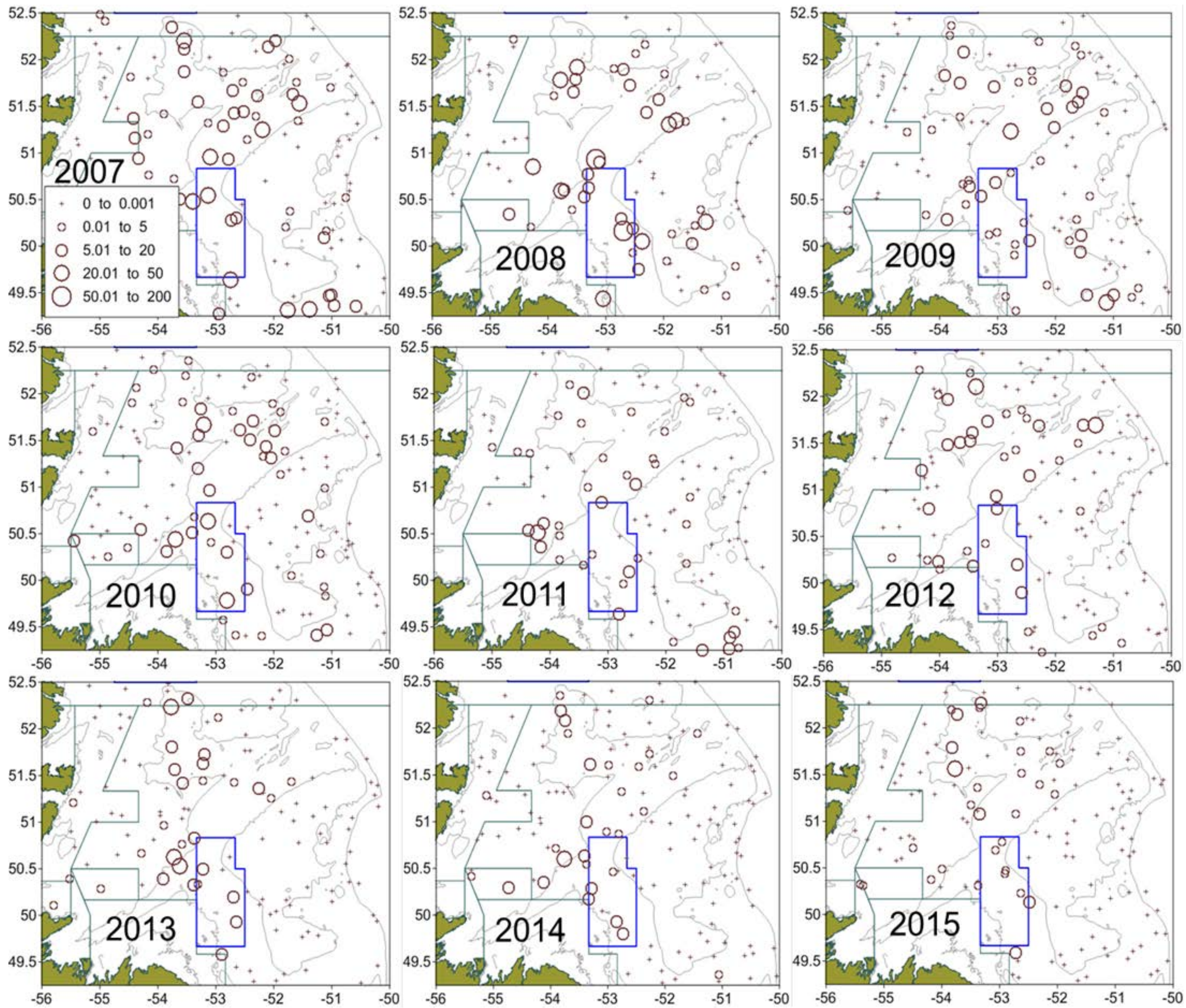

Figure 68. Distribution (#/tow) of exploitable males (> 94 mm CW adults) from Div. 3K fall bottom trawl surveys from 2007-15.

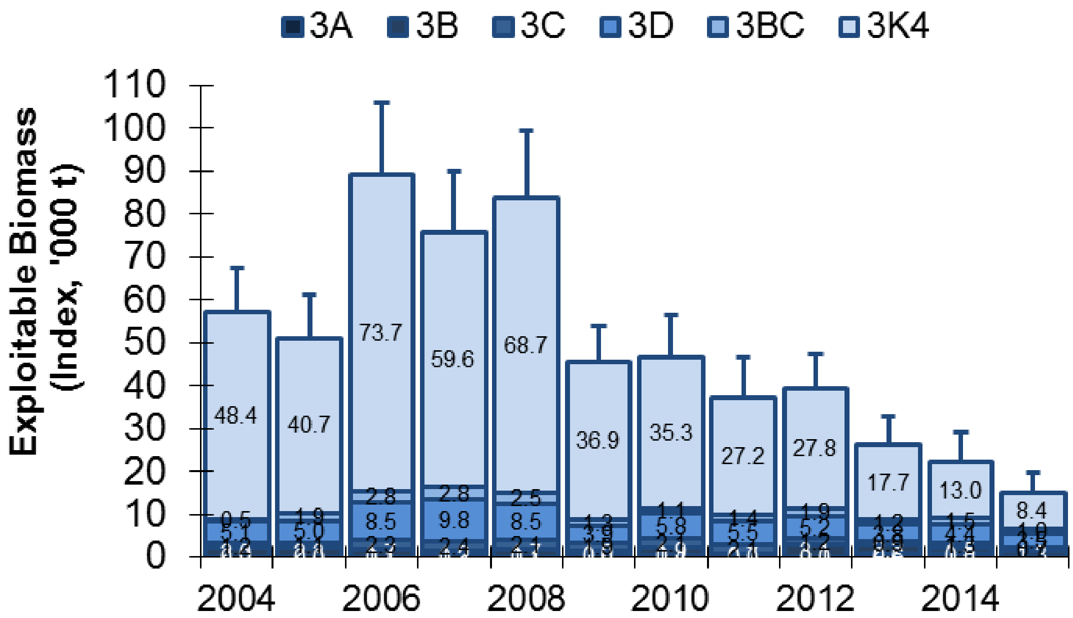

Figure 69. CPS trap survey exploitable biomass index from large-mesh traps for CMAs in Div. 3K.

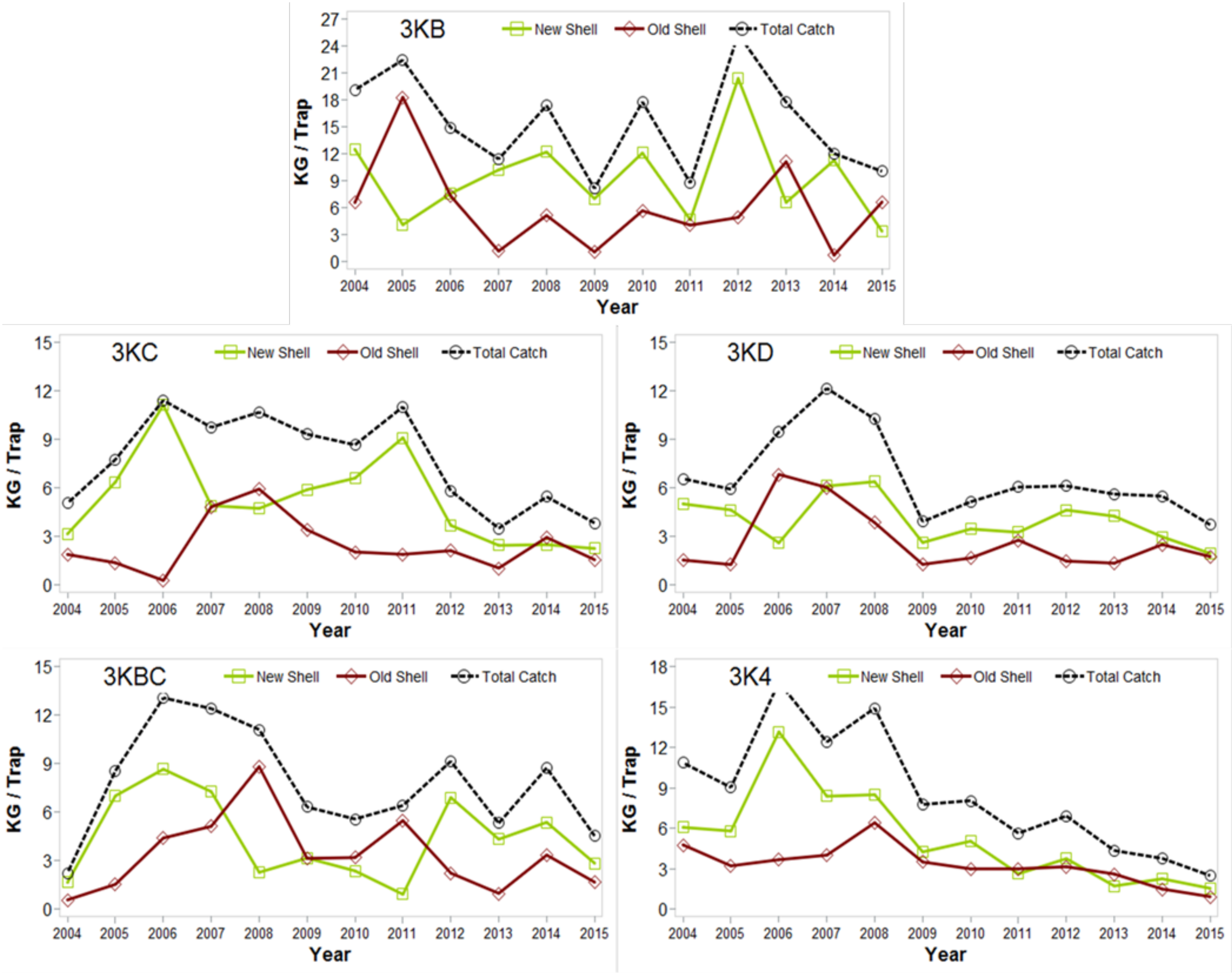

Figure 70. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMAs in Div. 3K.

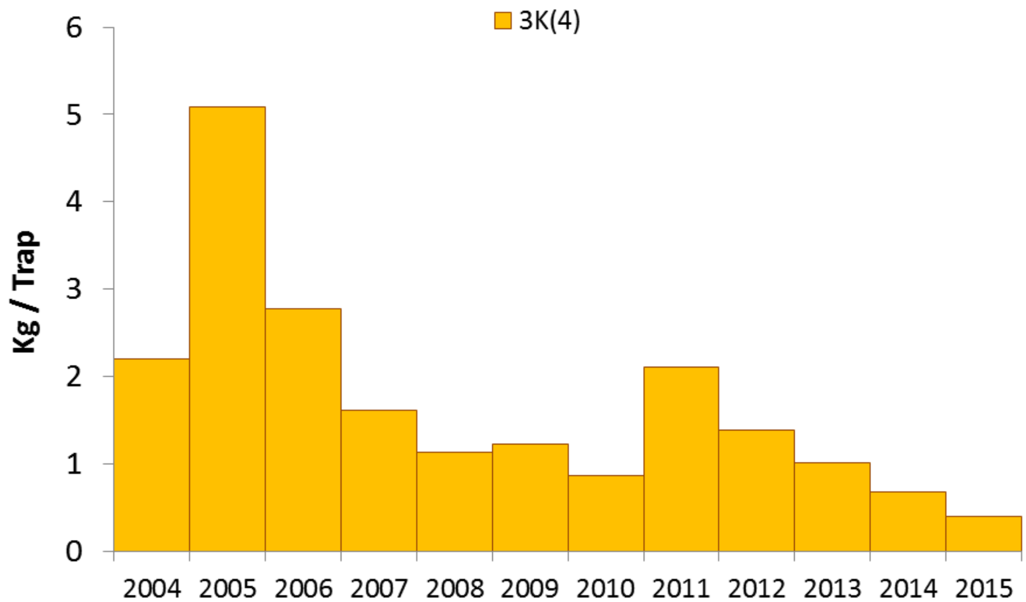

Figure 71. CPS trap survey pre-recruit biomass index from small-mesh traps for CMAs in Div. 3K. Index calculated as > 75 mm CW adolescent males.

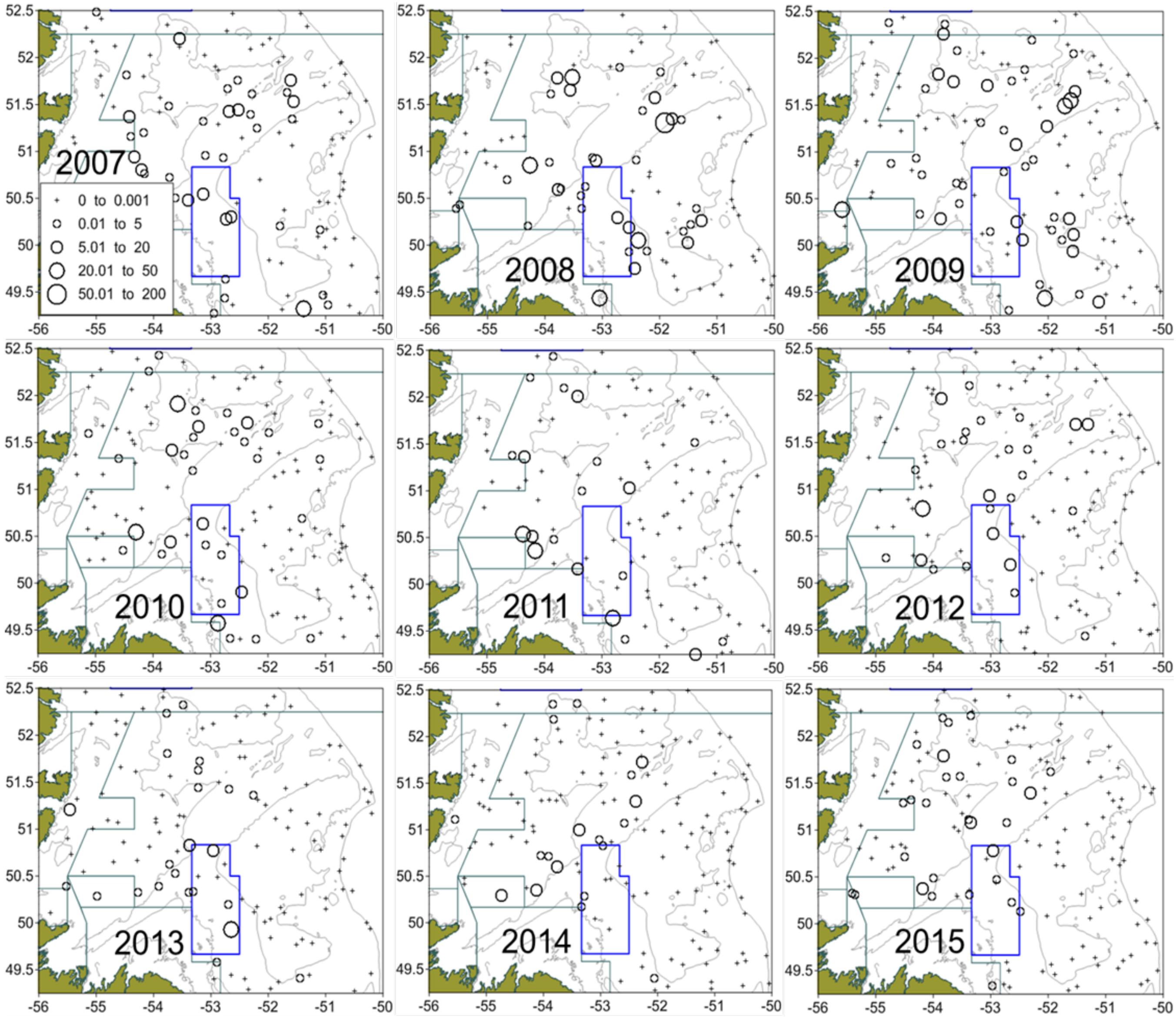

Figure 72. Distribution (#/tow) of pre-recruit males (> 75 mm CW adolescent) from Div. 3K fall bottom trawl surveys from 2007-15.

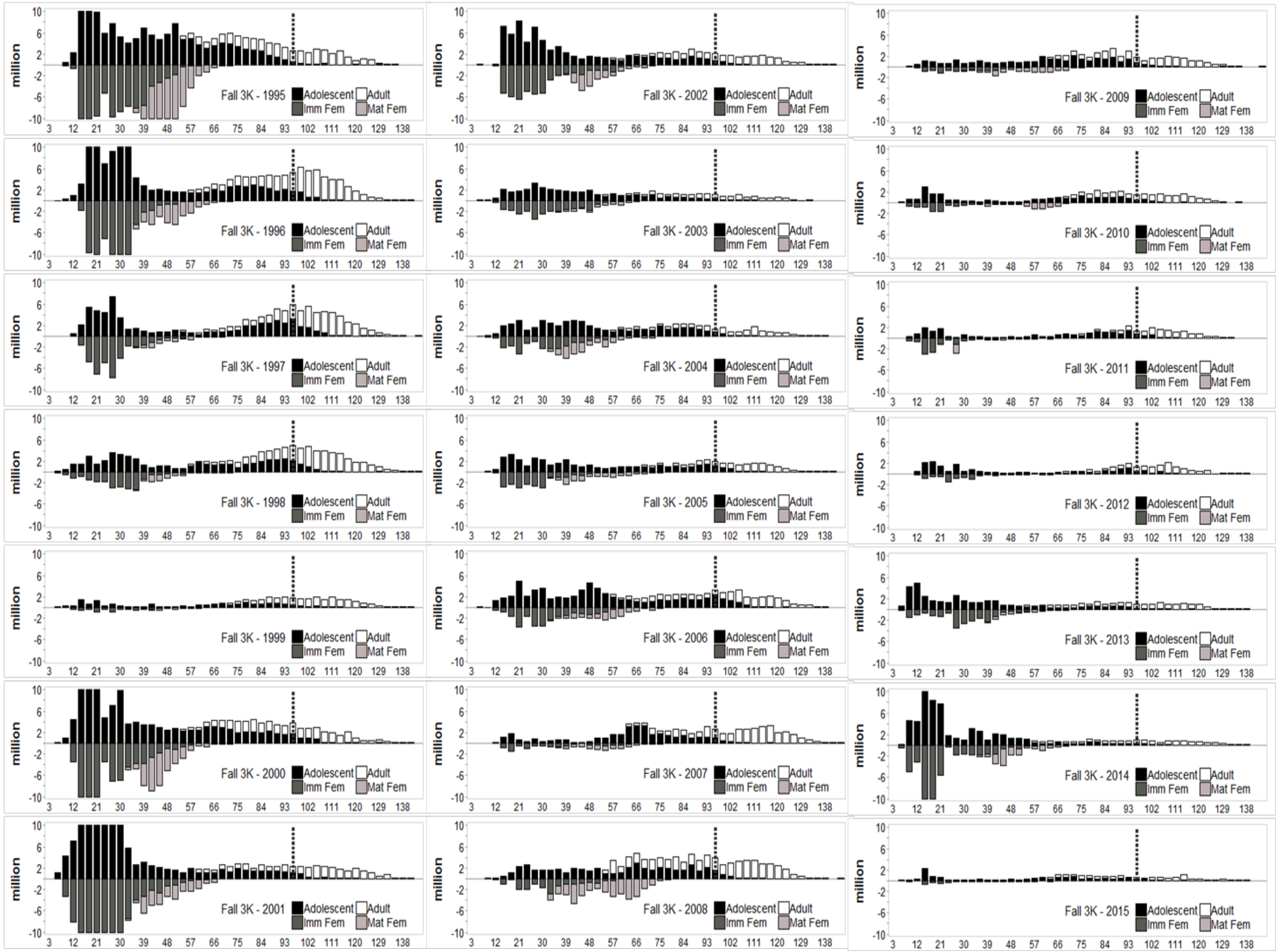

Figure 73. Abundance indices by carapace width for Div. 3K juveniles plus adolescent males (dark bars), adult males (white bars), immature females (dark grey bars), and mature females (light grey bars) from fall trawl surveys.

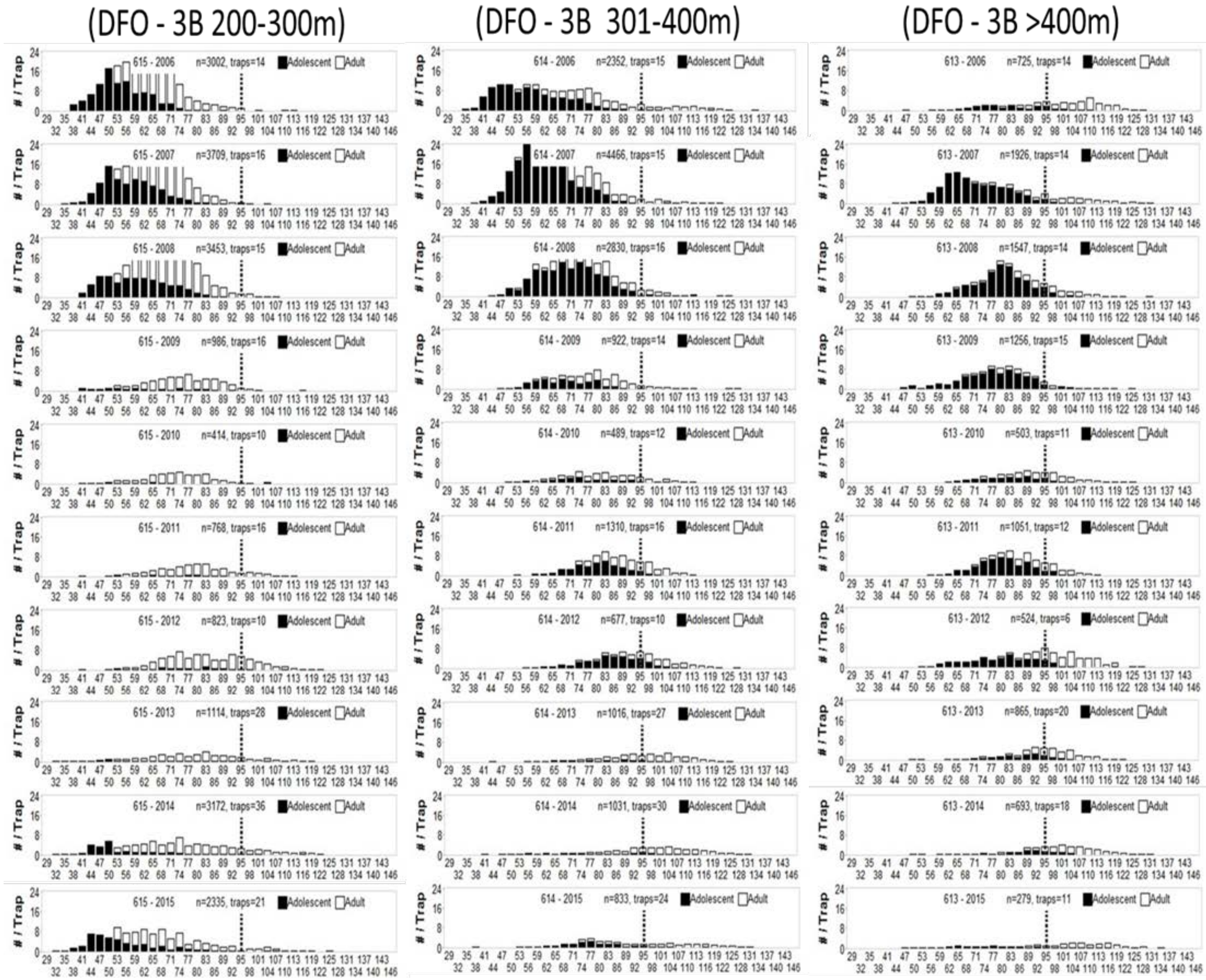

Figure 74. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Div. 3K CPS and DFO trap surveys. The vertical dashed line indicates the minimum legal size.

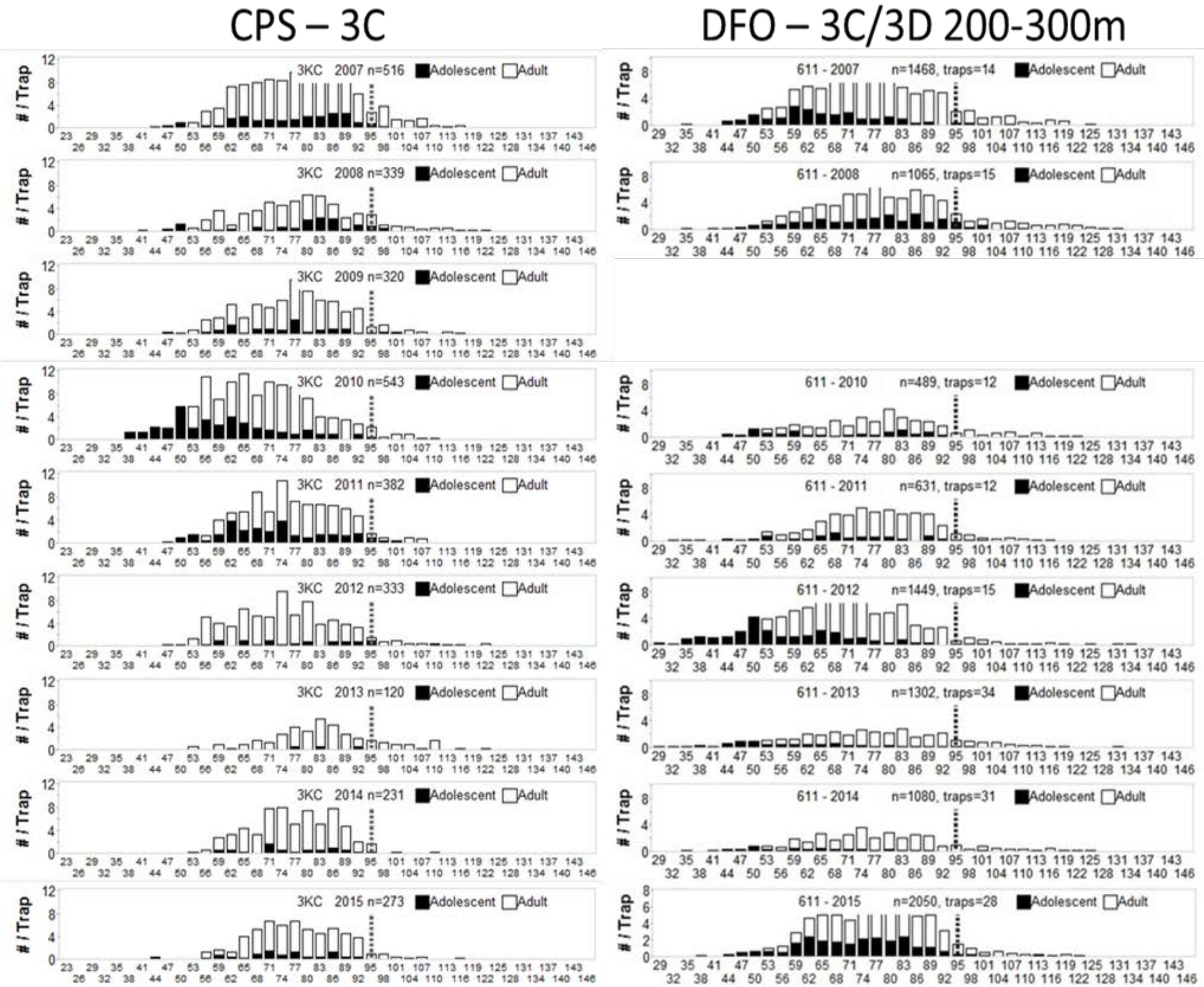

Figure 75. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Div. 3K CPS and DFO trap surveys. The vertical dashed line indicates the minimum legal size.

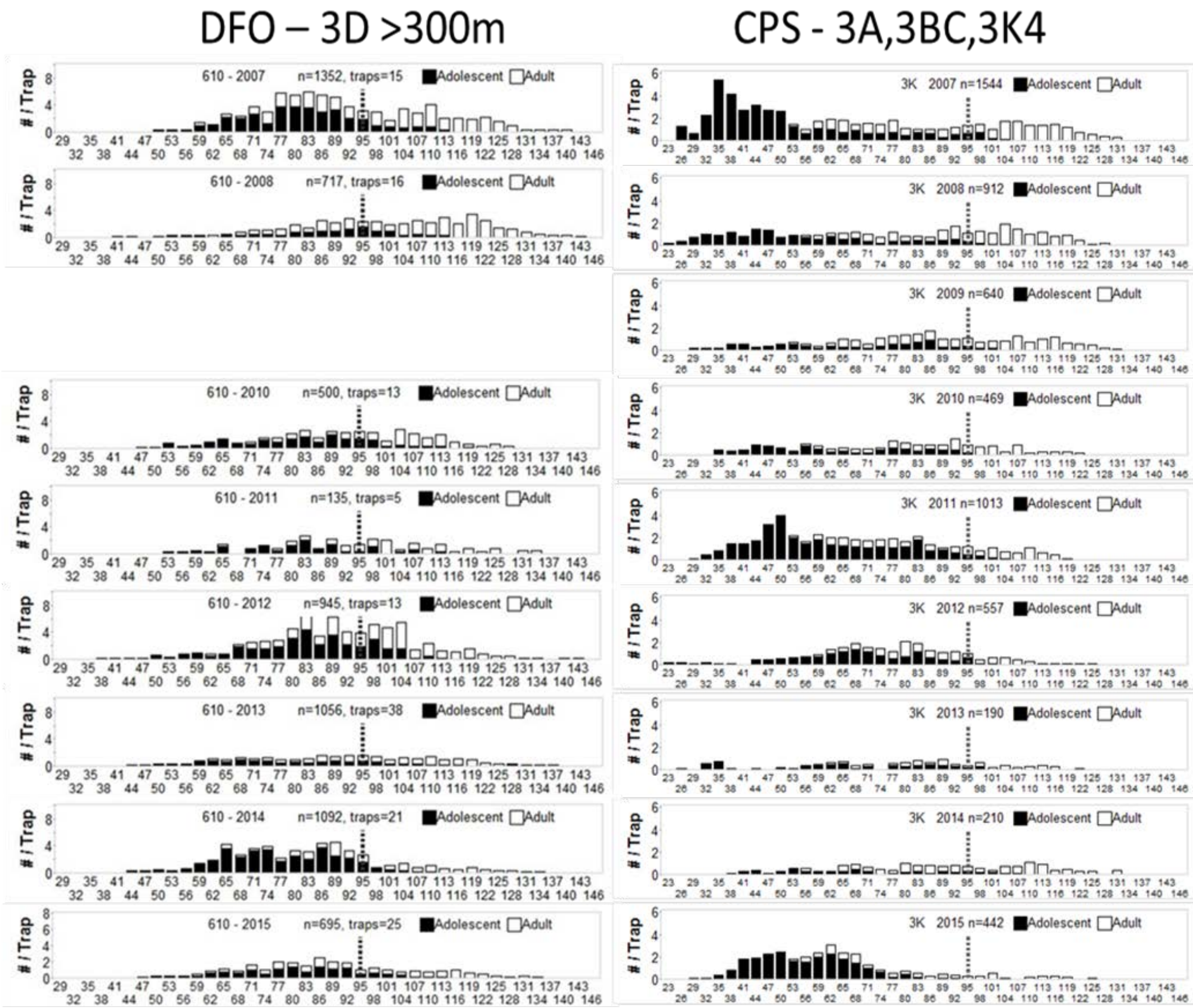

Figure 76. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Div. 3K CPS and DFO trap surveys. The vertical dashed line indicates the minimum legal size.

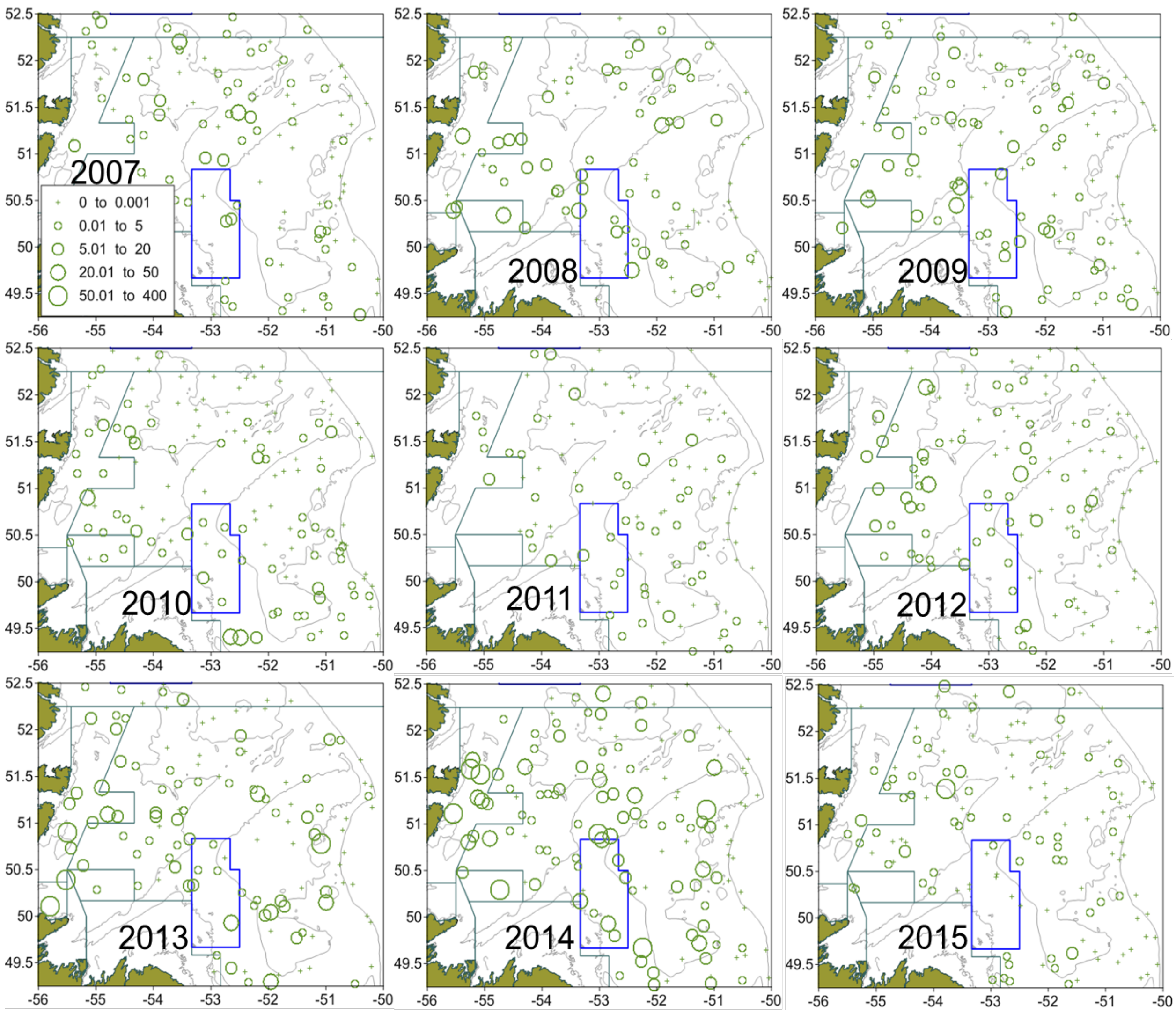

Figure 77. Distribution (#/tow) of small males (< 60 mm CW adolescents) in the Div. 3K fall bottom trawl surveys from 2007-15.

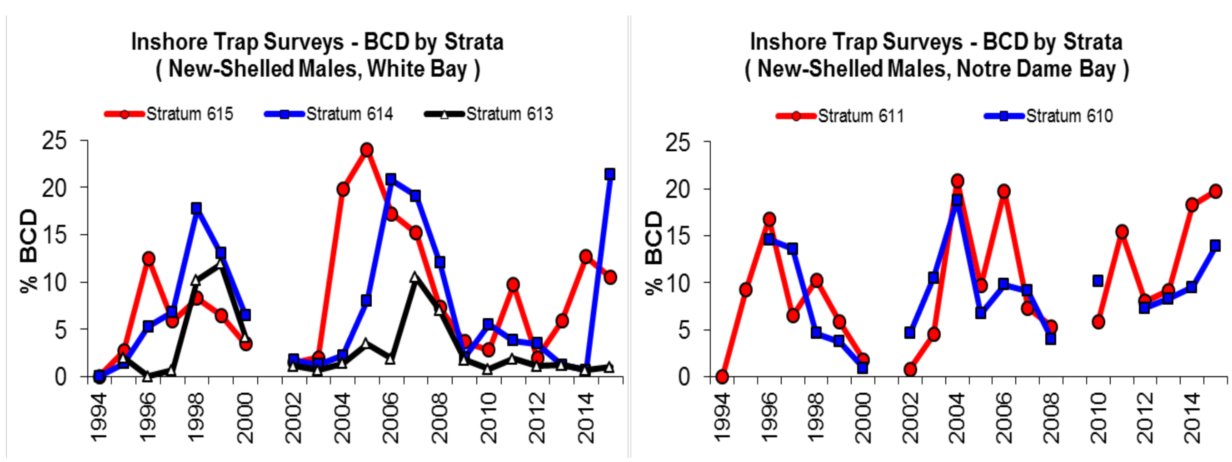

Figure 78. Prevalence of BCD in new-shelled males from Div. 3K DFO inshore trap surveys by stratum in White Bay (CMA 3B) and Notre Dame Bay (CMA 3D).

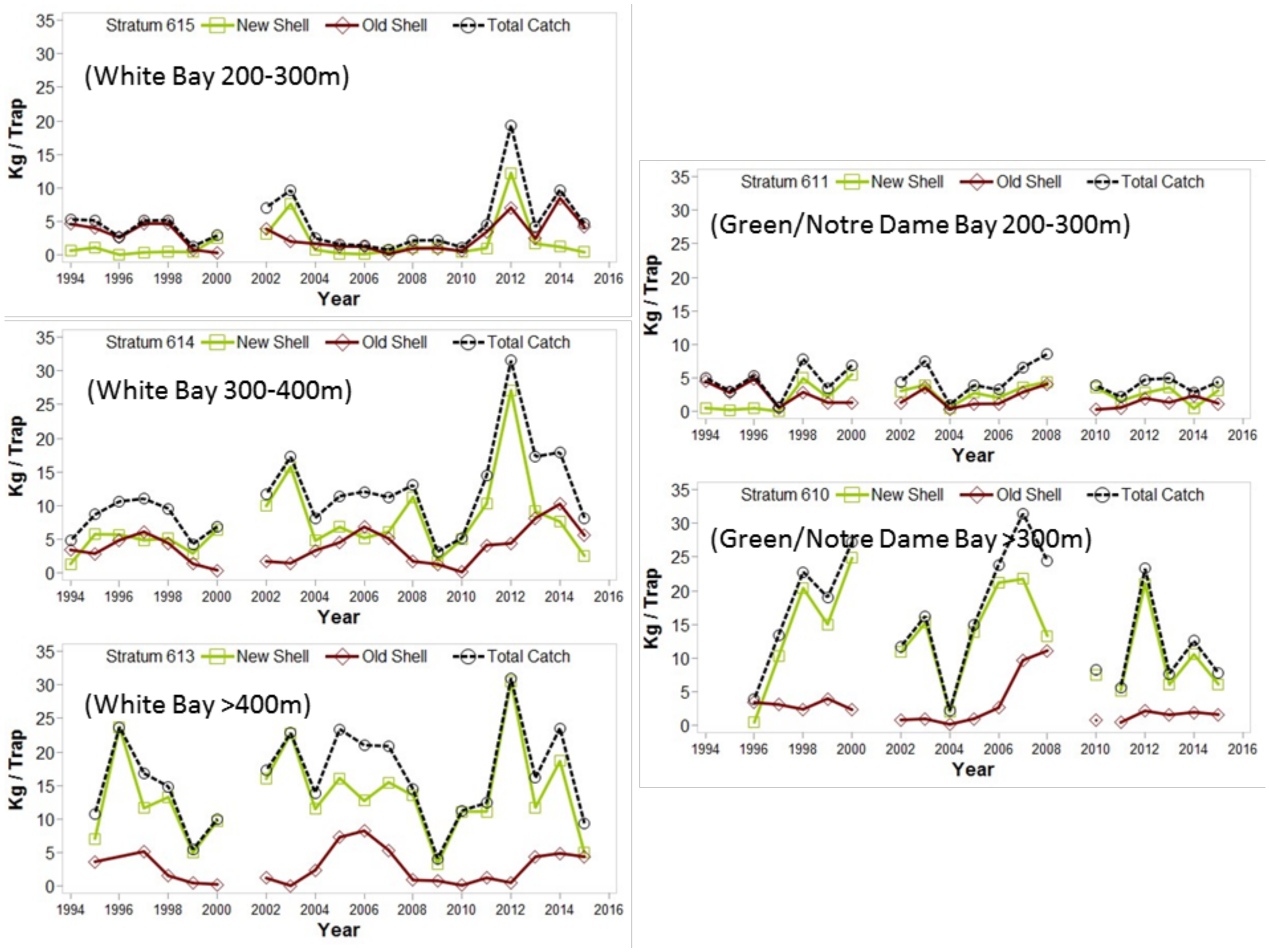

Figure 79. Trends in CPUE by shell condition for legal-sized crabs from the DFO trap survey in CMAs in Div. 3K. Data stratified by depth.

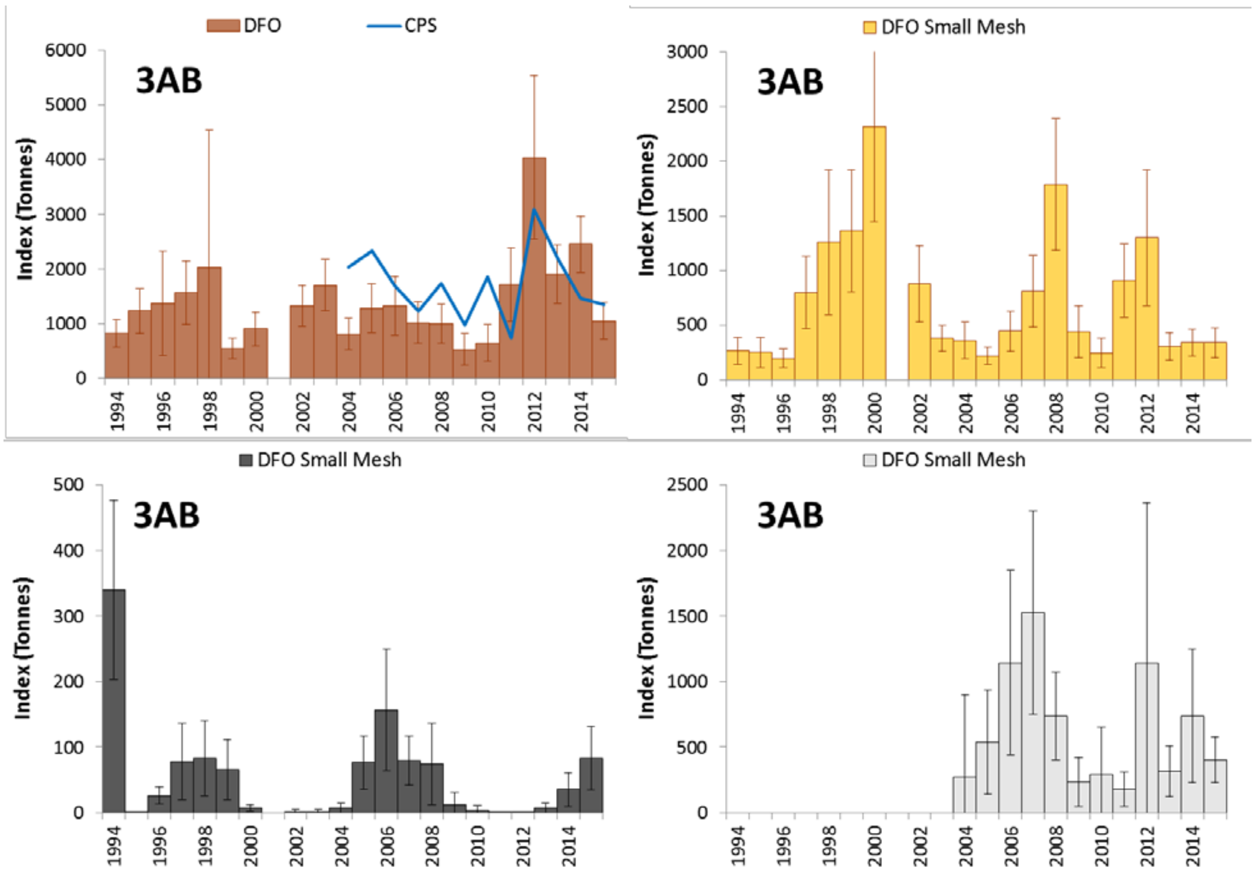

Figure 80. Indices from the DFO trap survey in CMAs 3A and 3B. Exploitable biomass index from large-mesh traps (top left), pre-recruit biomass index from small-mesh traps (top right), < 50 mm CW crab biomass index from small-mesh traps (bottom left), and mature female biomass index from small-mesh traps (bottom right). All indices derived with STRAP.

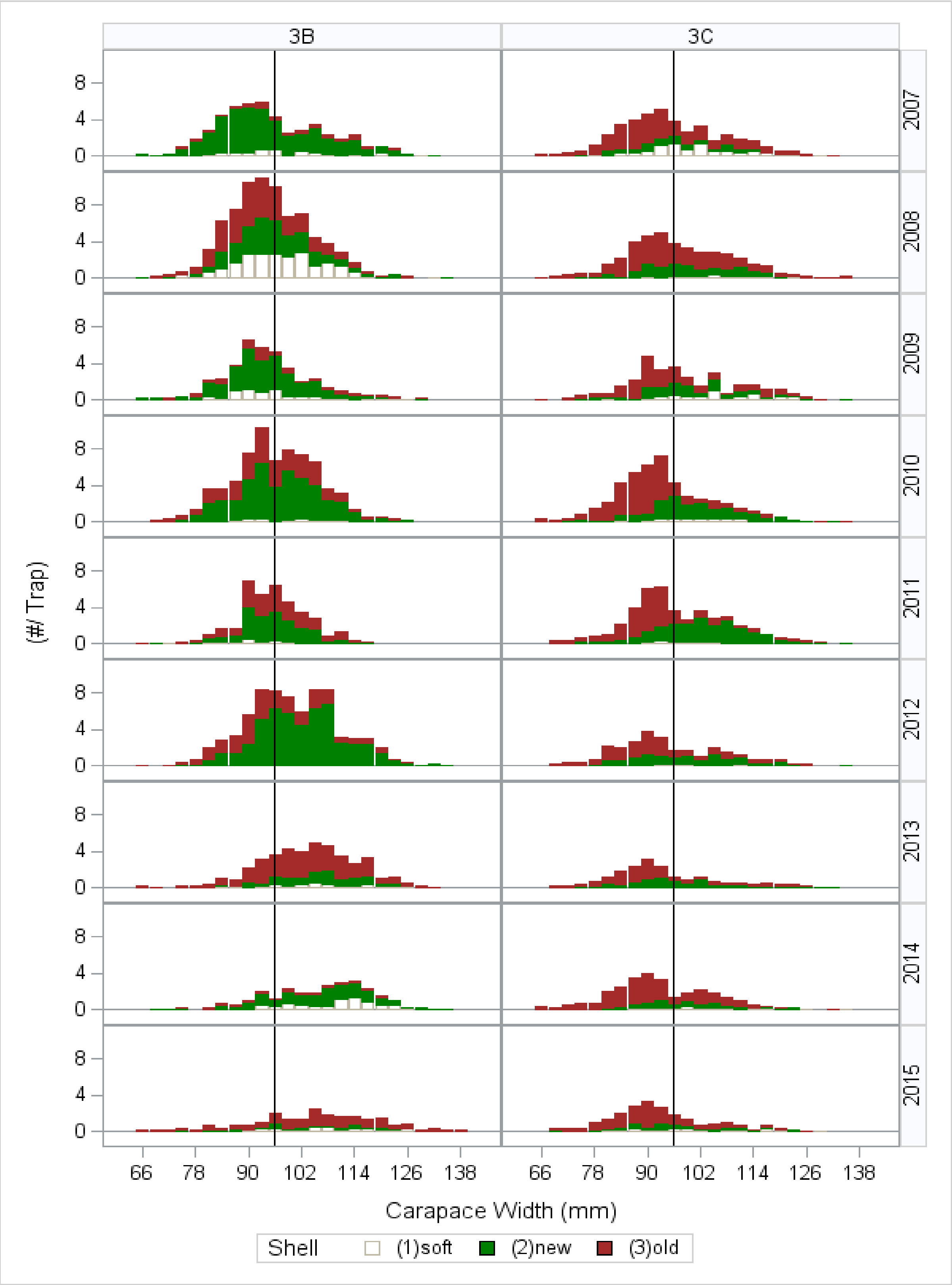

Figure 81. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Div. 3K CPS trap survey. The vertical dashed line indicates the minimum legal size.

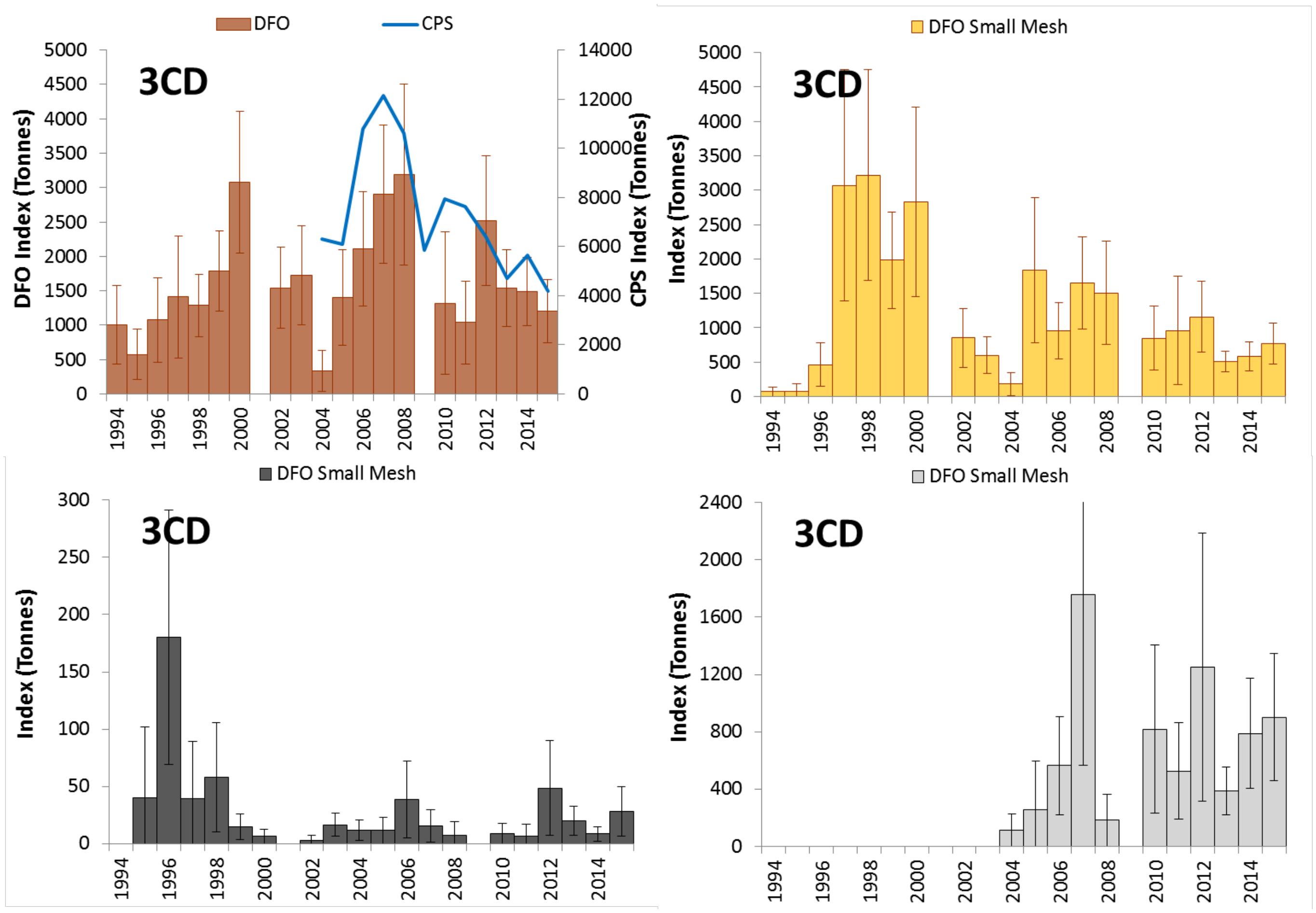

Figure 82. Indices from the DFO trap survey in CMAs 3A and 3B. Exploitable biomass index from large-mesh traps (top left), pre-recruit biomass index from small-mesh traps (top right), < 50 mm CW crab biomass index from small-mesh traps (bottom left), and mature female biomass index from small-mesh traps (bottom right). All indices derived with STRAP.

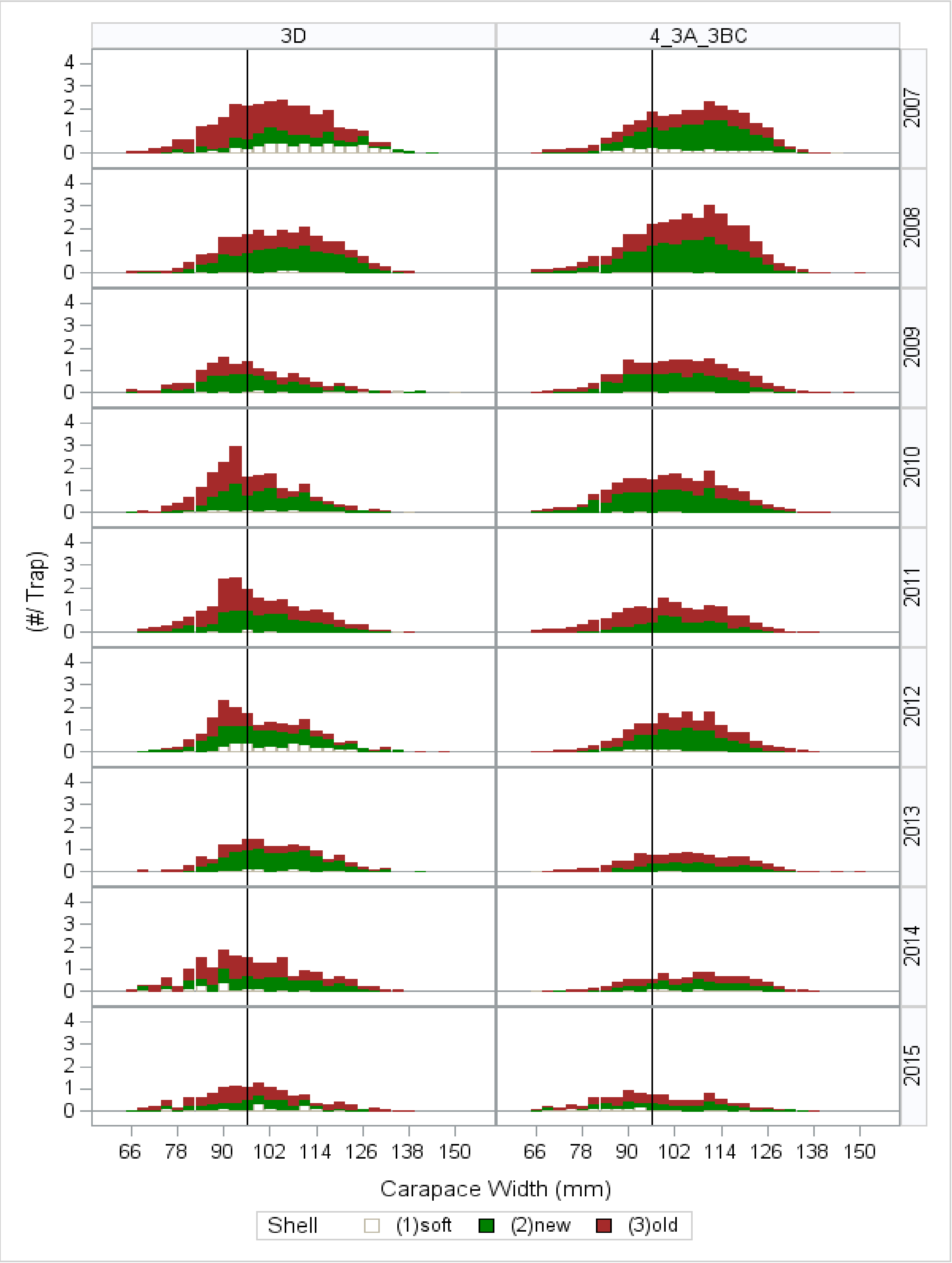

Figure 83. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Div. 3K CPS trap survey. The vertical dashed line indicates the minimum legal size.

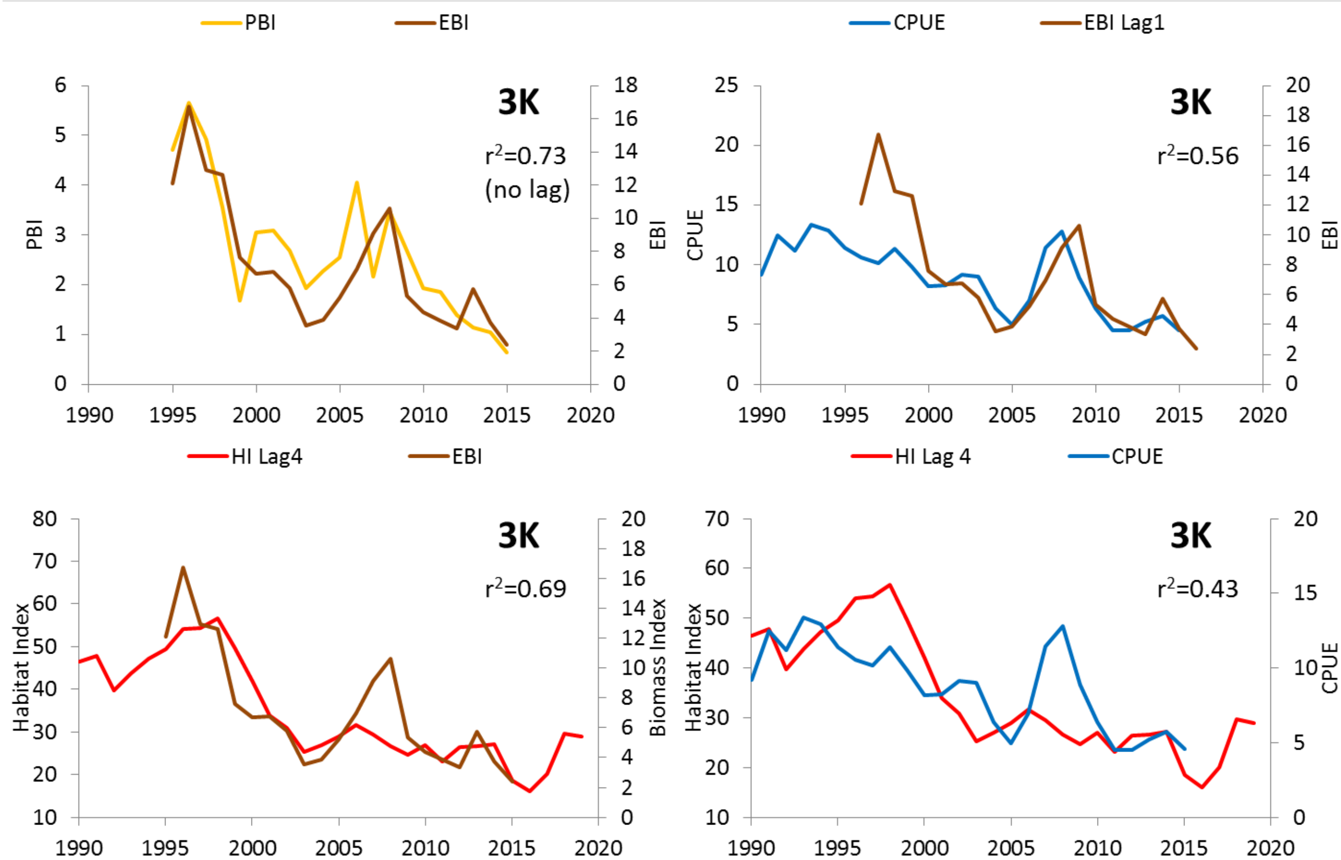

Figure 84. Summary of temporal relationships among key indices of resource status in Div. 3K. Best fit correlation lags shown. PBI is pre-recruit biomass index, EBI is exploitable biomass index, CPUE is fishery catch per unit of effort, and HI is habitat index.

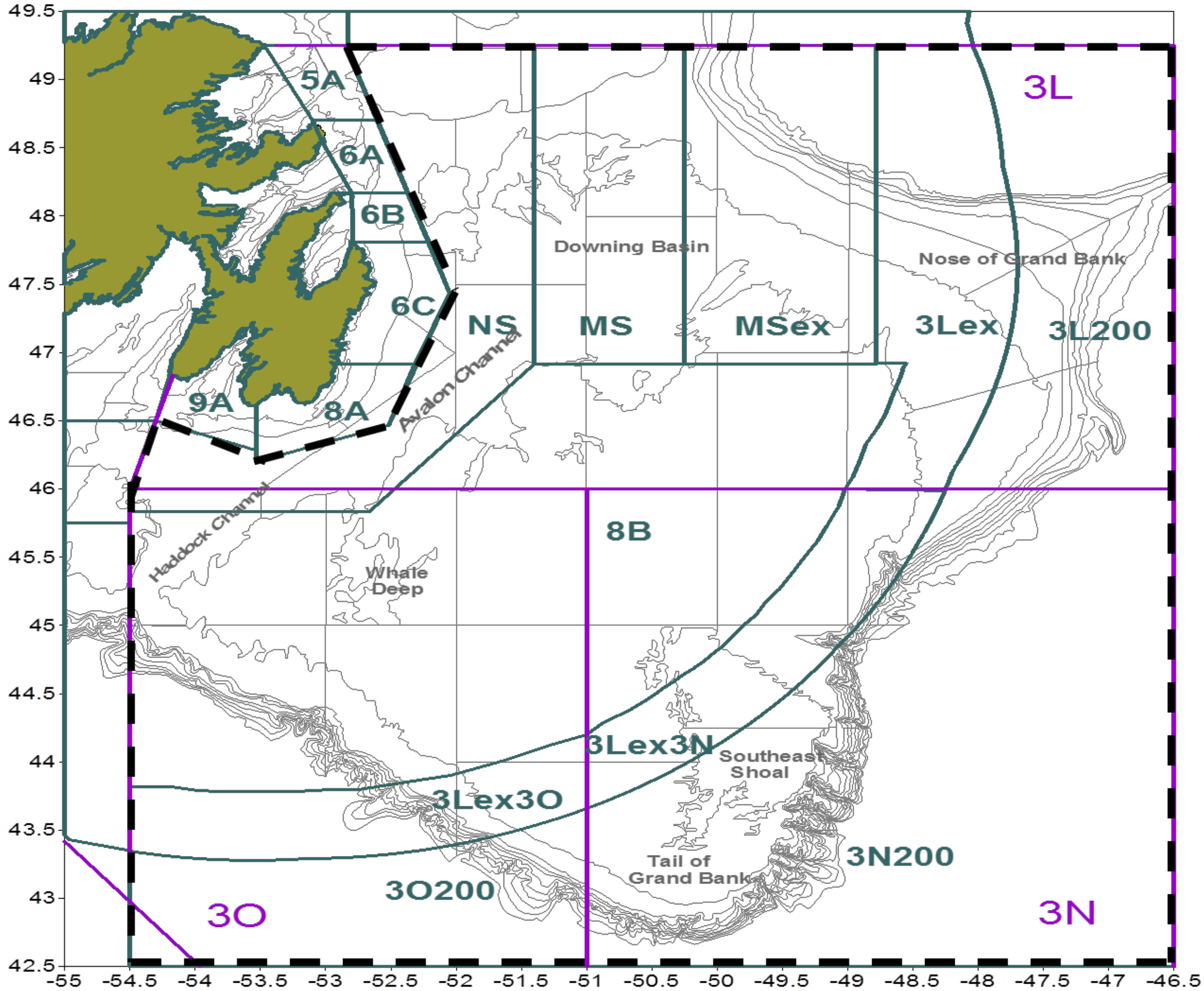

Figure 85. Map of Divs. 3LNO showing CMAs and important bathymetric features. Dashed perimeter indicates offshore areas.

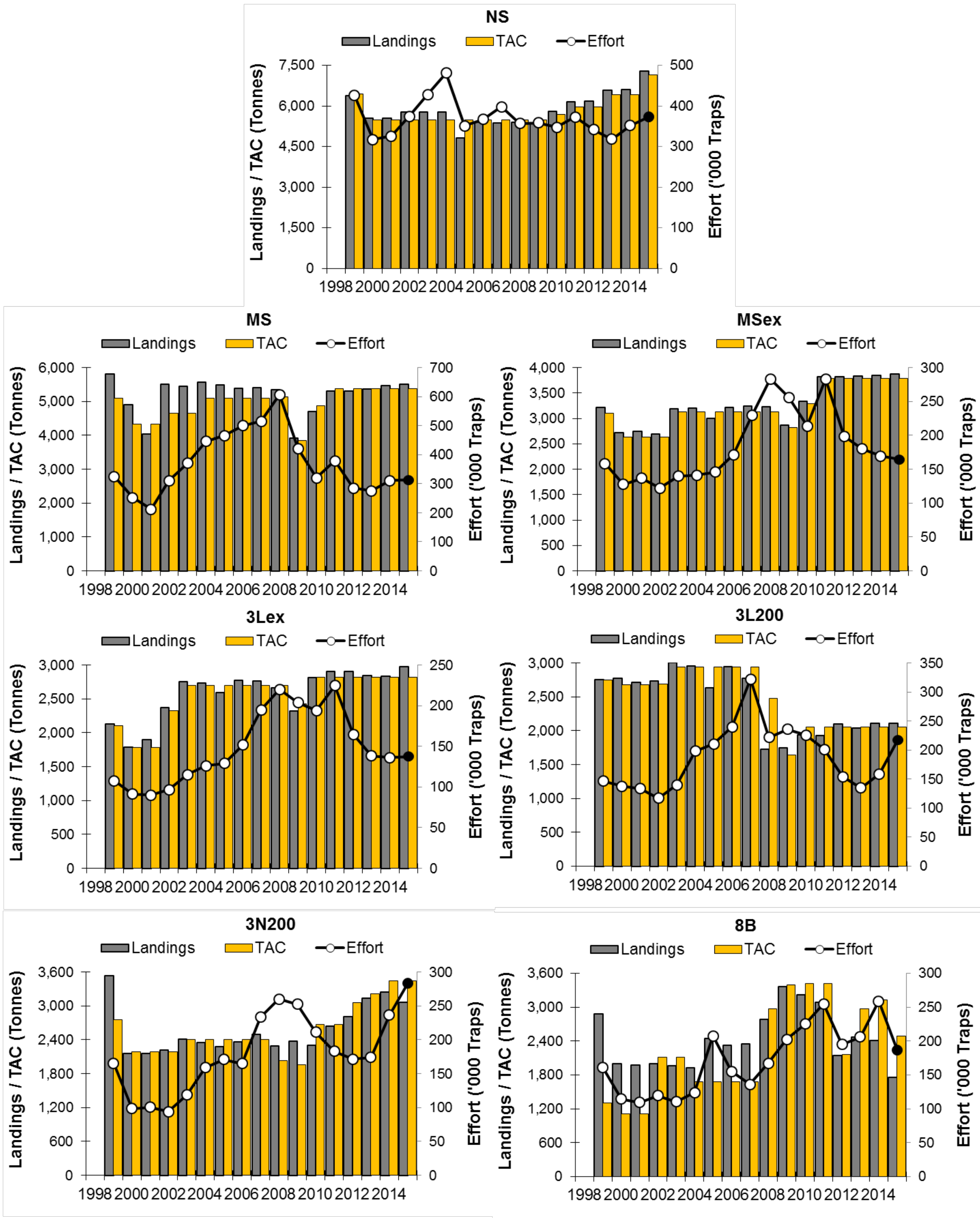

Figure 86. TAC, landings, and estimated effort for CMAs in Divs. 3LNO. 2015 effort preliminary.

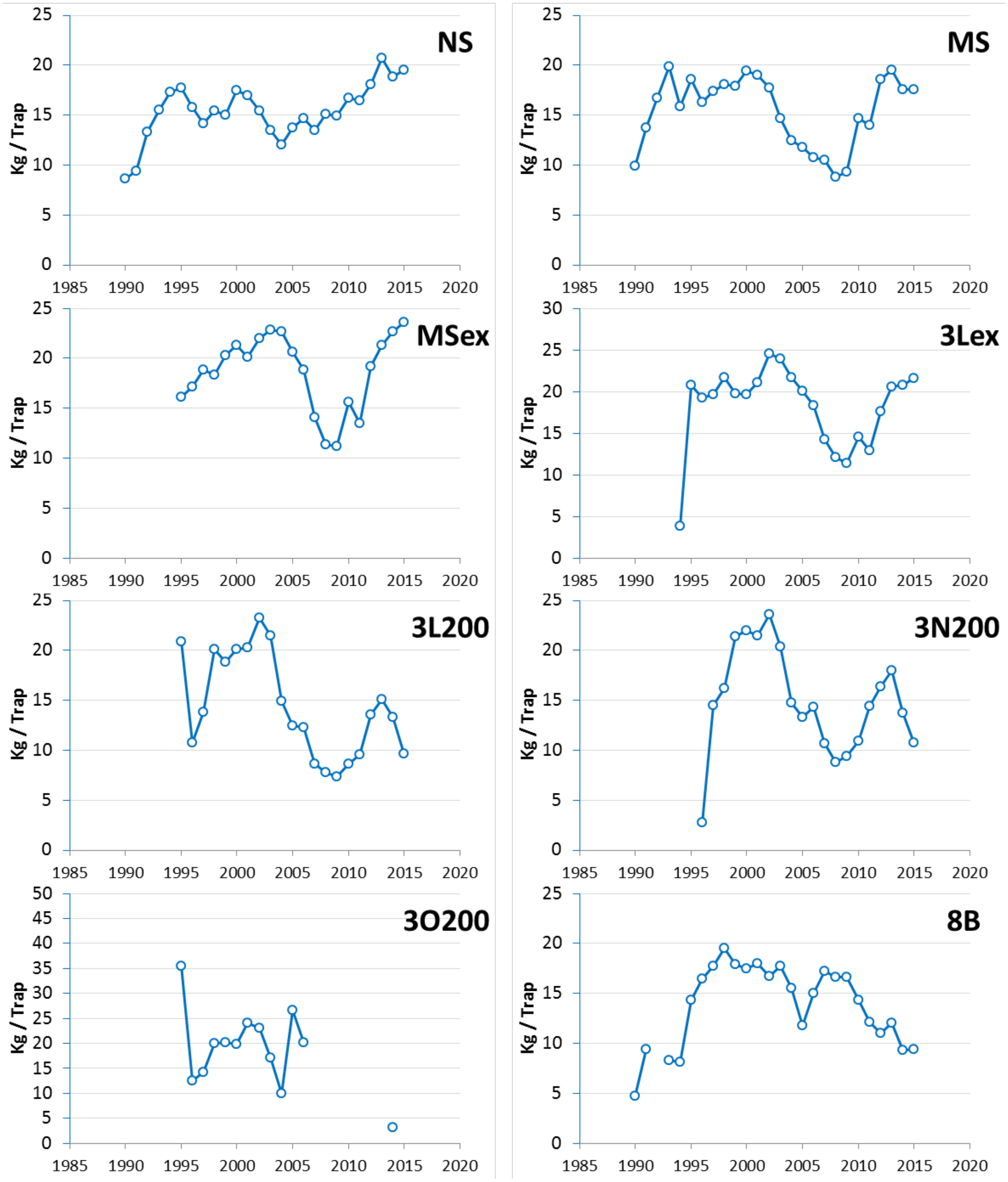

Figure 87. Trends in unstandardized CPUE by CMA for Divs. 3LNO Offshore.

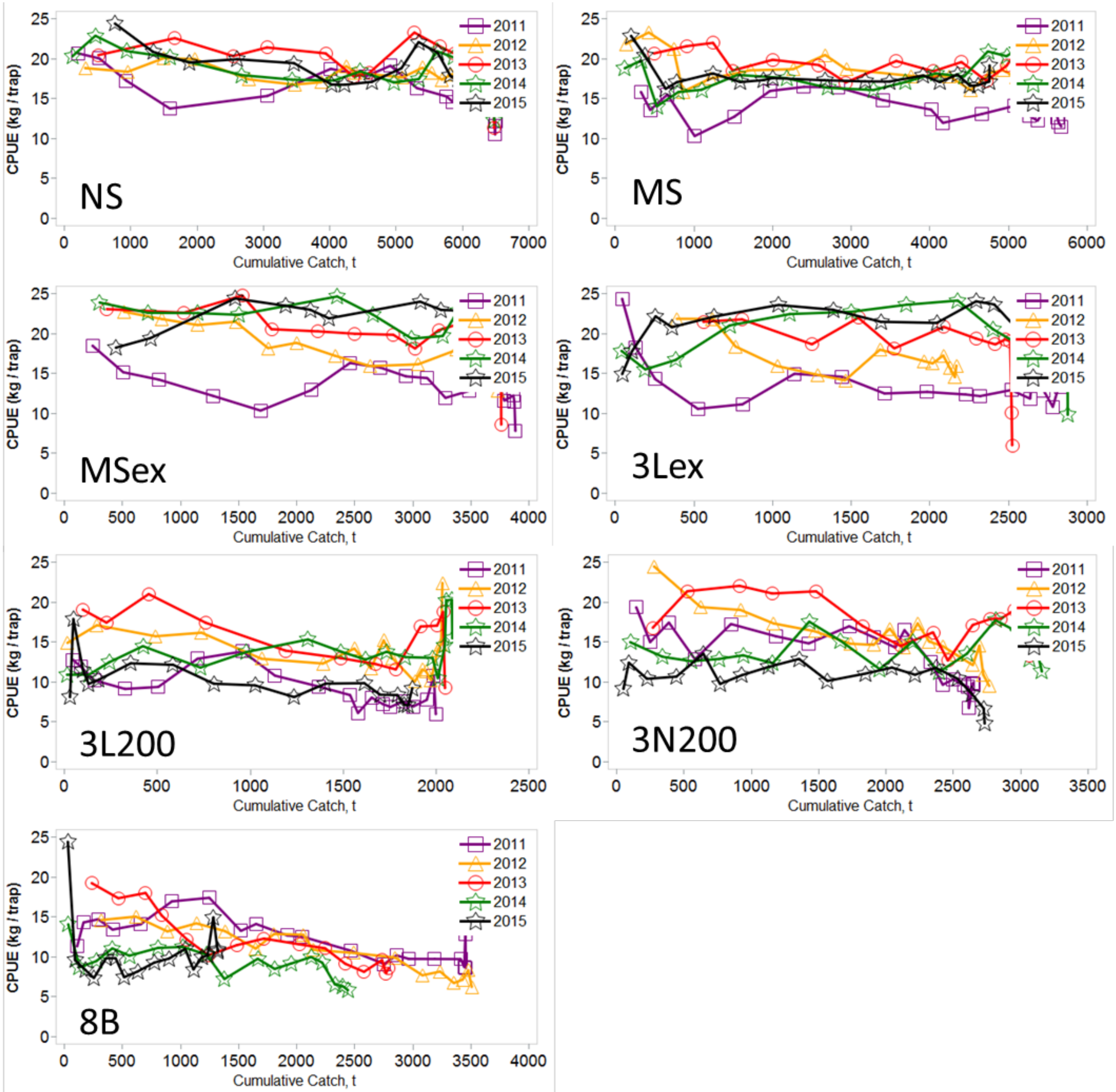

Figure 88. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Divs. 3LNO.

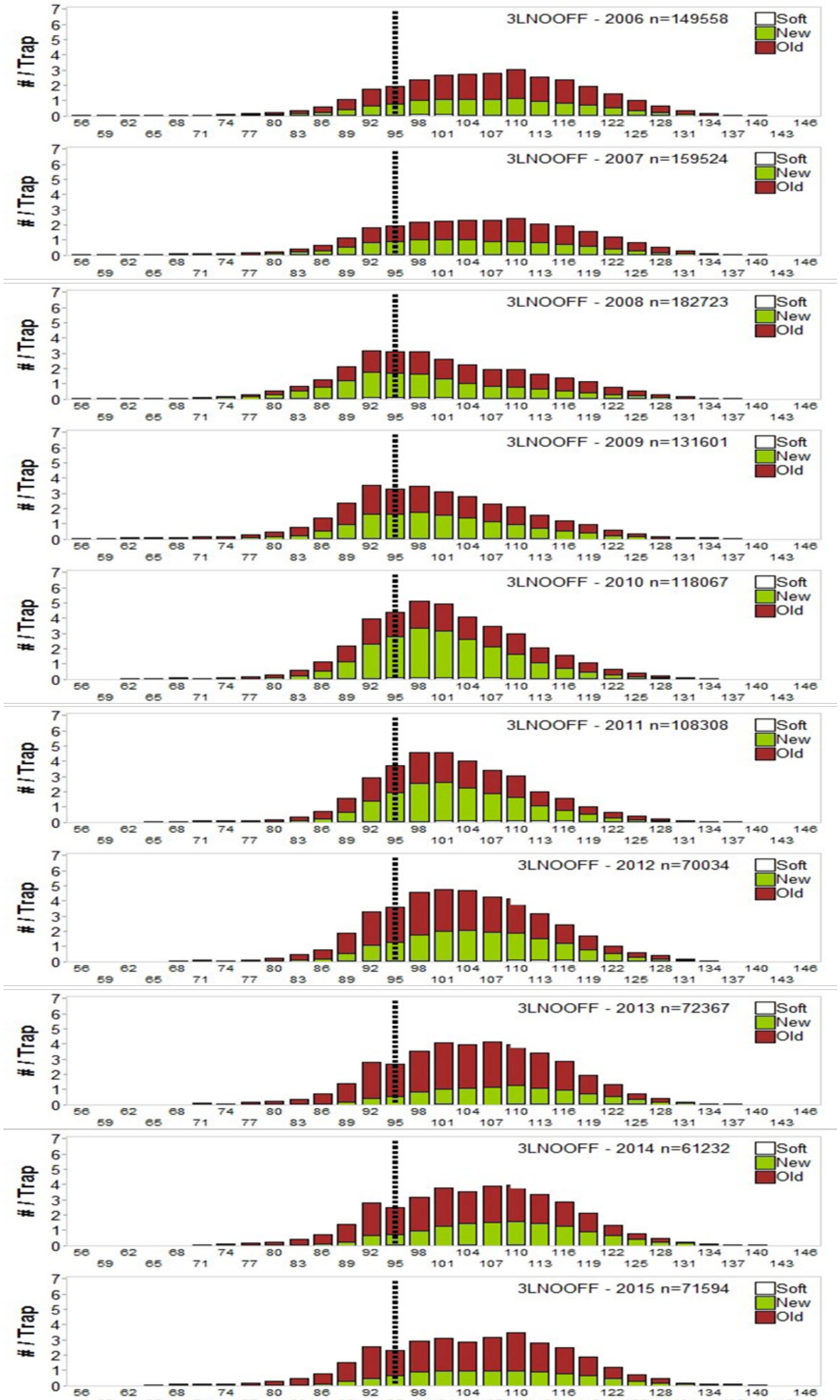

Figure 89. Trends in male carapace width distributions by shell condition from observer at-sea sampling in Divs. 3LNO. The vertical dashed line indicates the minimum legal size.

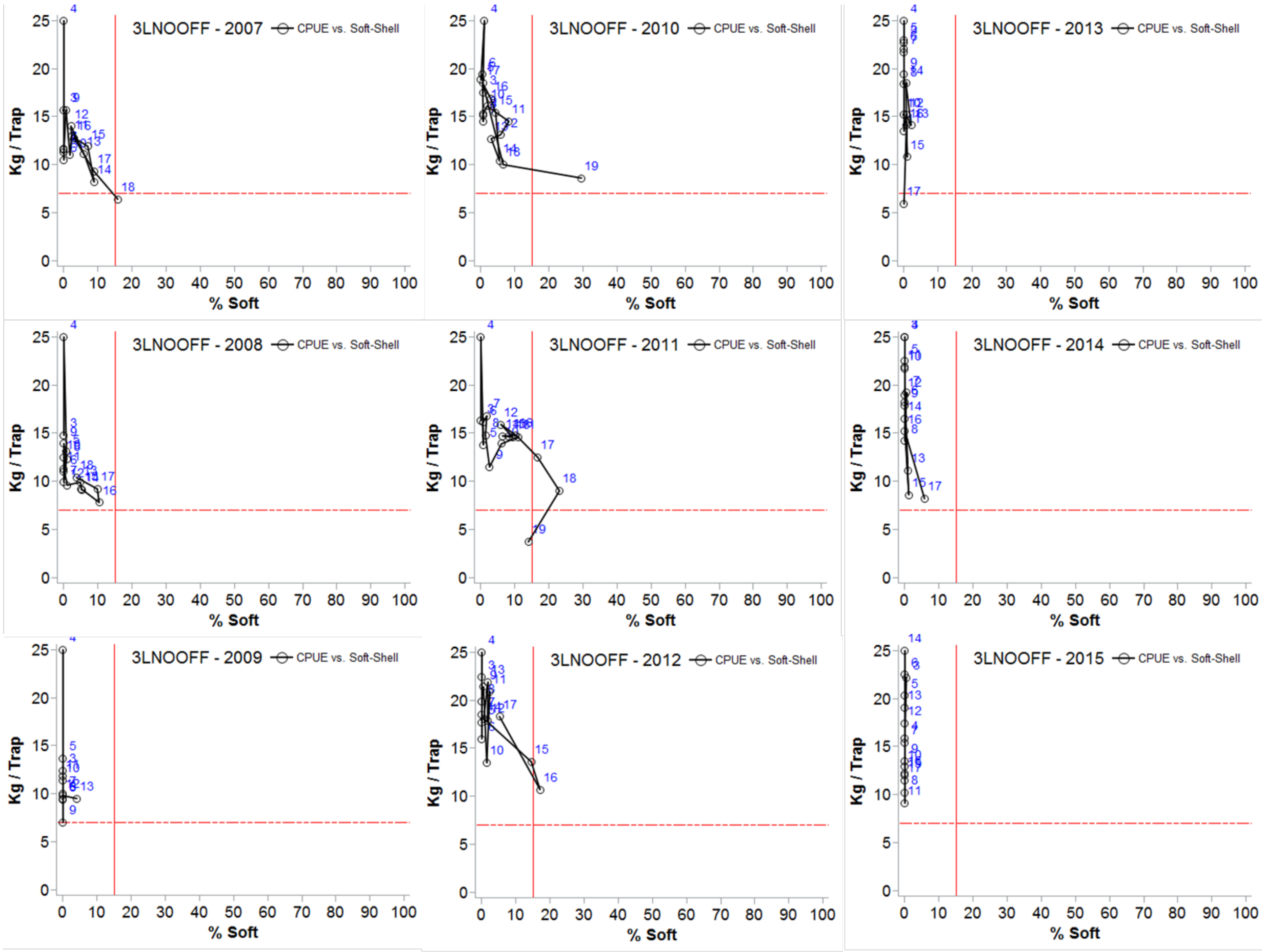

Figure 90. Trends in observed weekly catch rates versus the percentage of soft-shell crab in the catch in Divs. 3LNO.

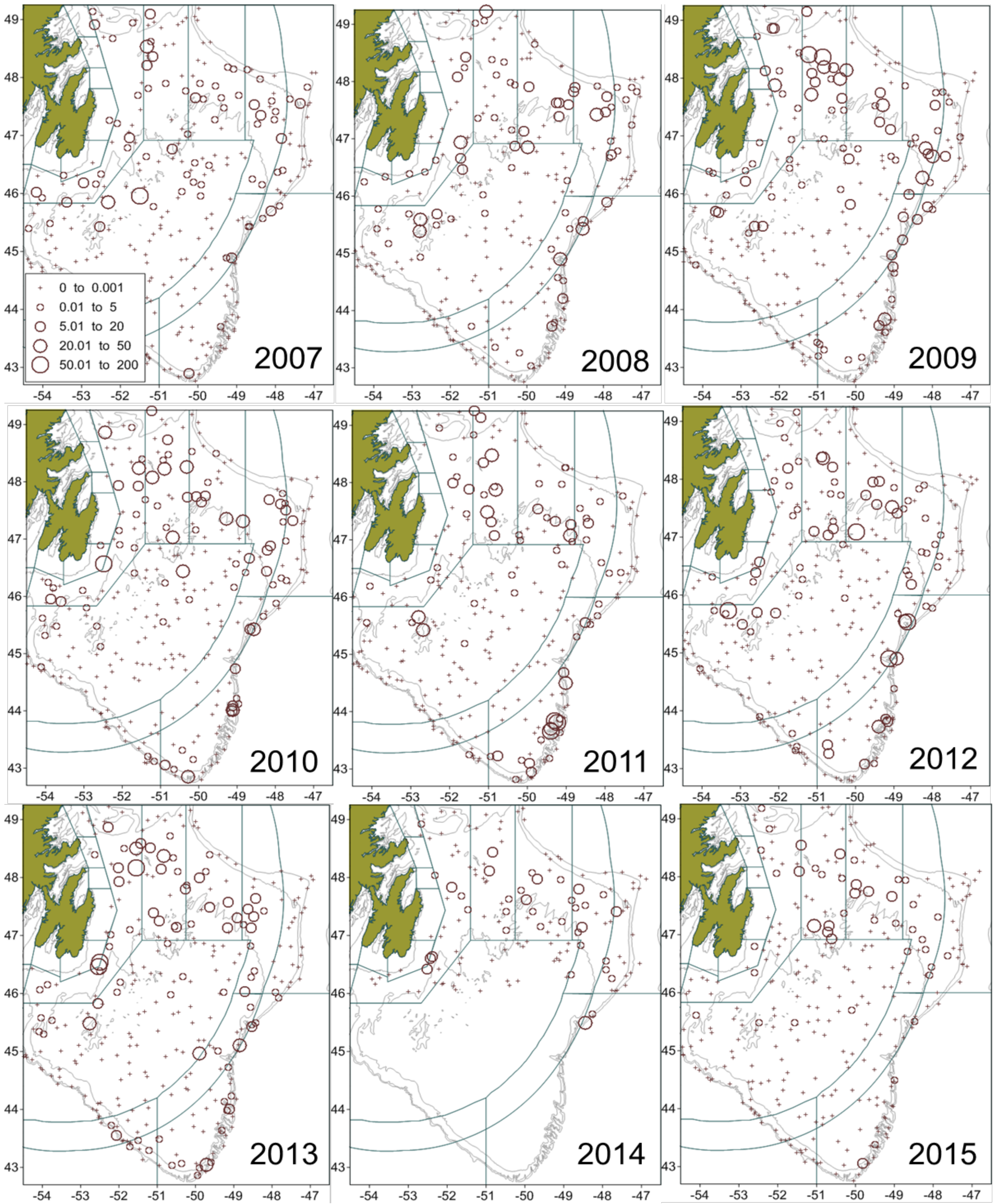

Figure 91. Distribution (#/tow) of exploitable males (> 94 mm CW adults) from Divs. 3LNO fall bottom trawl surveys from 2007-15.

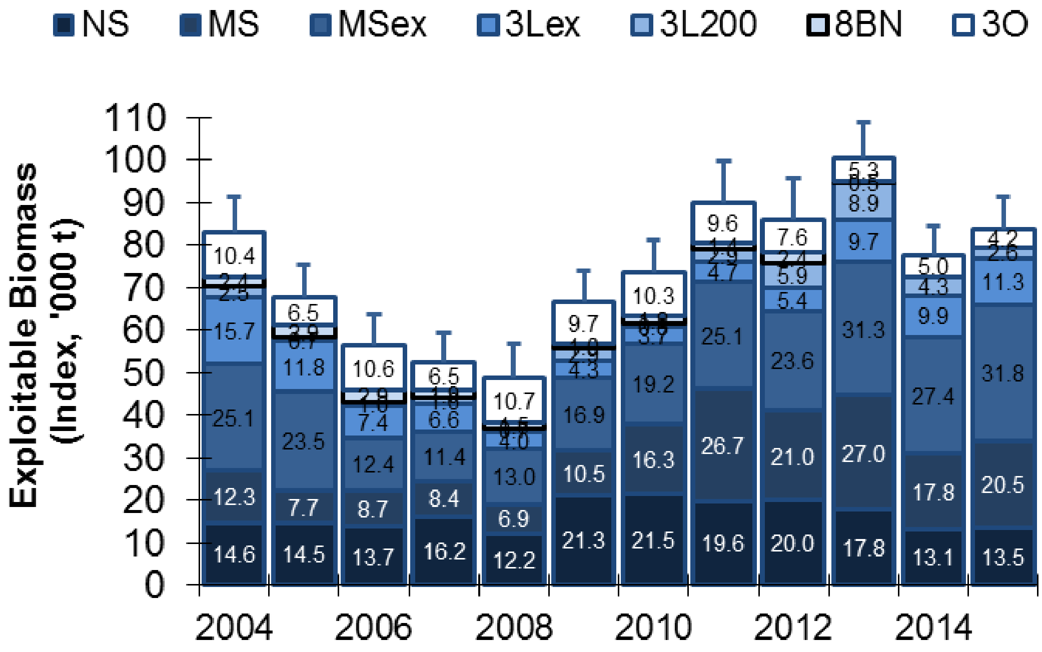

Figure 92. CPS trap survey exploitable biomass index from large-mesh traps for CMAs in Divs. 3LNO.

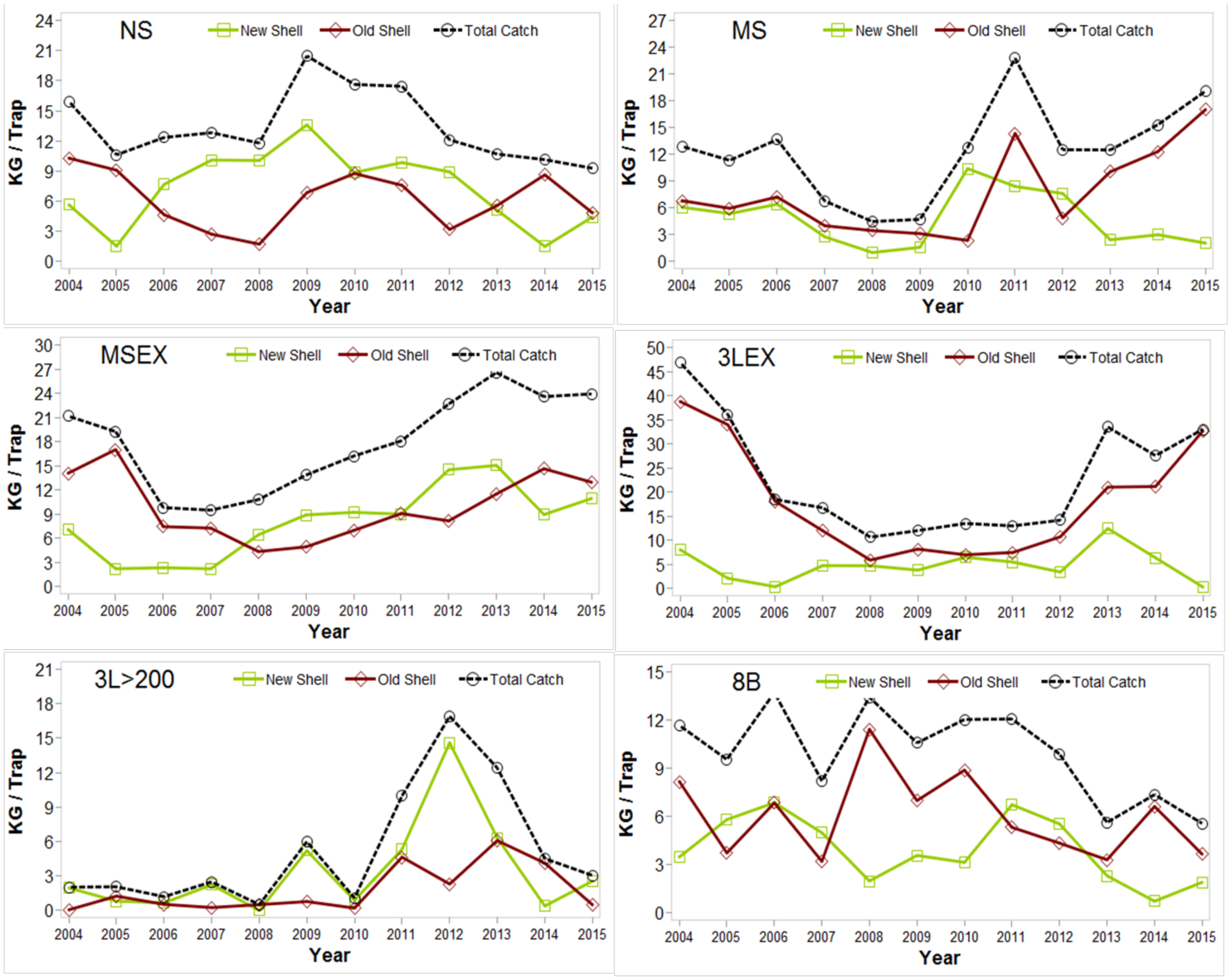

Figure 93. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMAs in Divs. 3LNO.

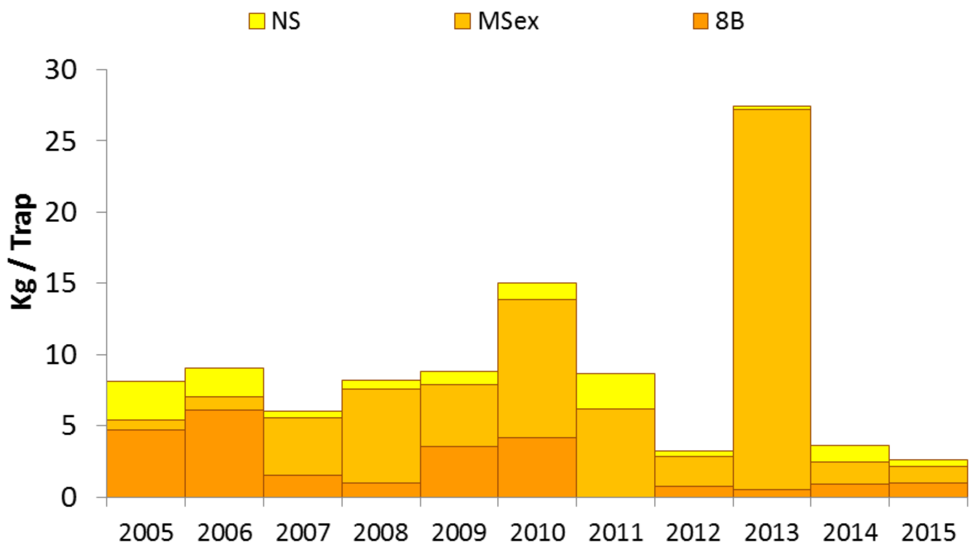

Figure 94. CPS trap survey pre-recruit biomass index from small-mesh traps for CMAs in Divs. 3LNO. Index calculated as > 75 mm CW adolescent males.

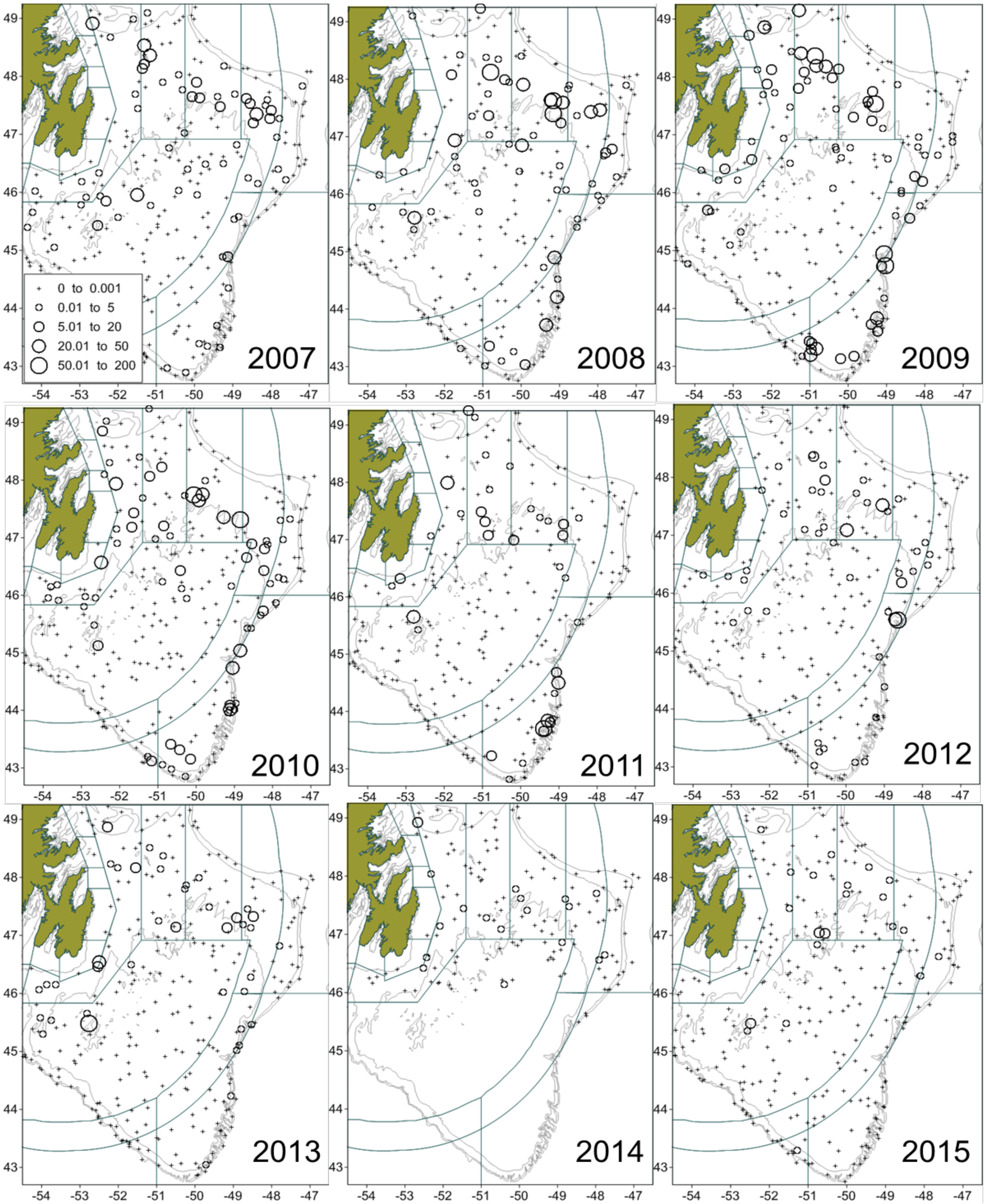

Figure 95. Distribution (#/tow) of pre-recruit males (> 75 mm CW adolescent) from Divs. 3LNO fall bottom trawl surveys from 2007-15.

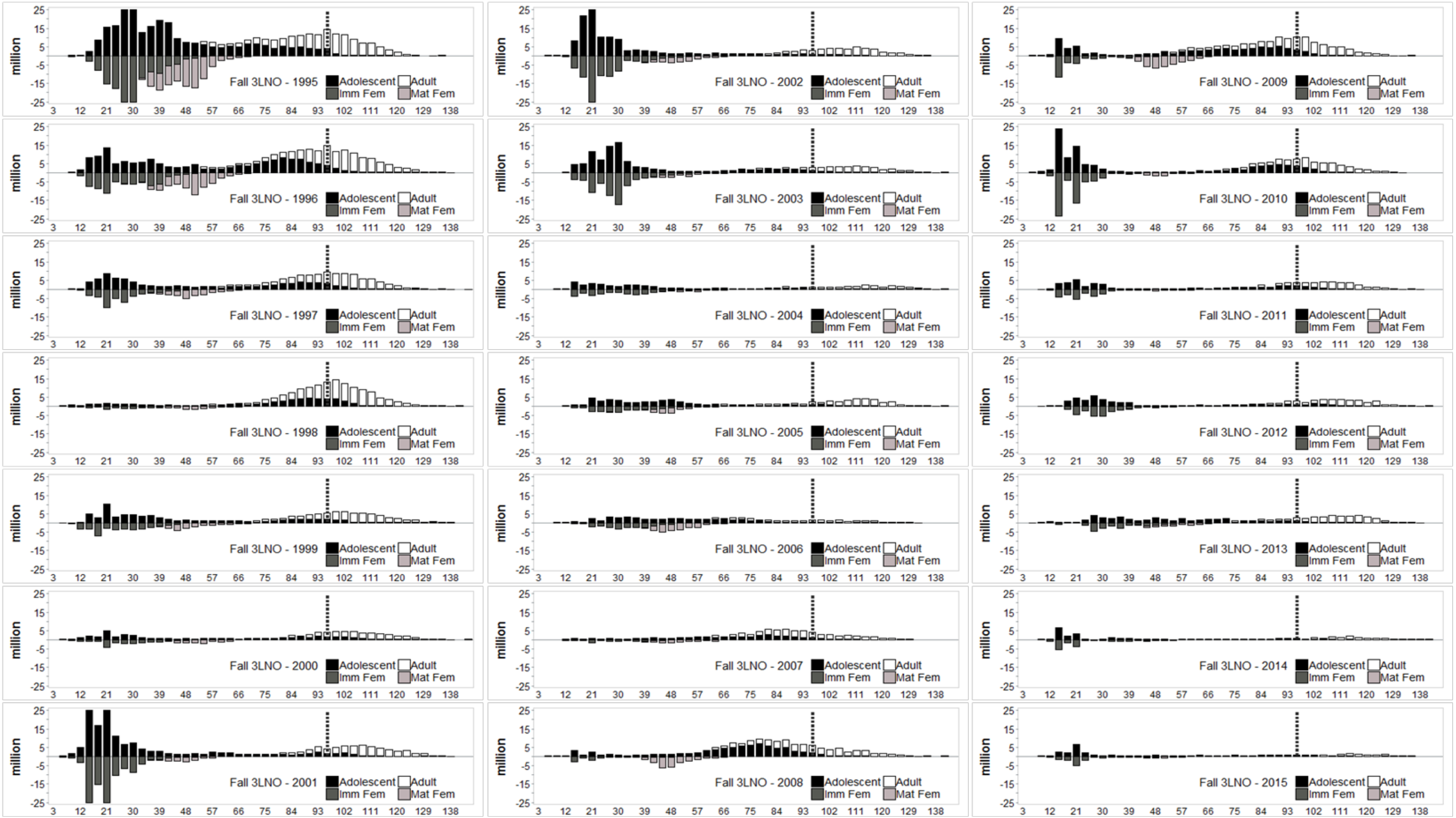

Figure 96. Abundance indices by carapace width for Divs. 3LNO offshore juveniles plus adolescent males (dark bars), adult males (white bars), immature females (dark grey bars), and mature females (light grey bars) from fall trawl surveys.

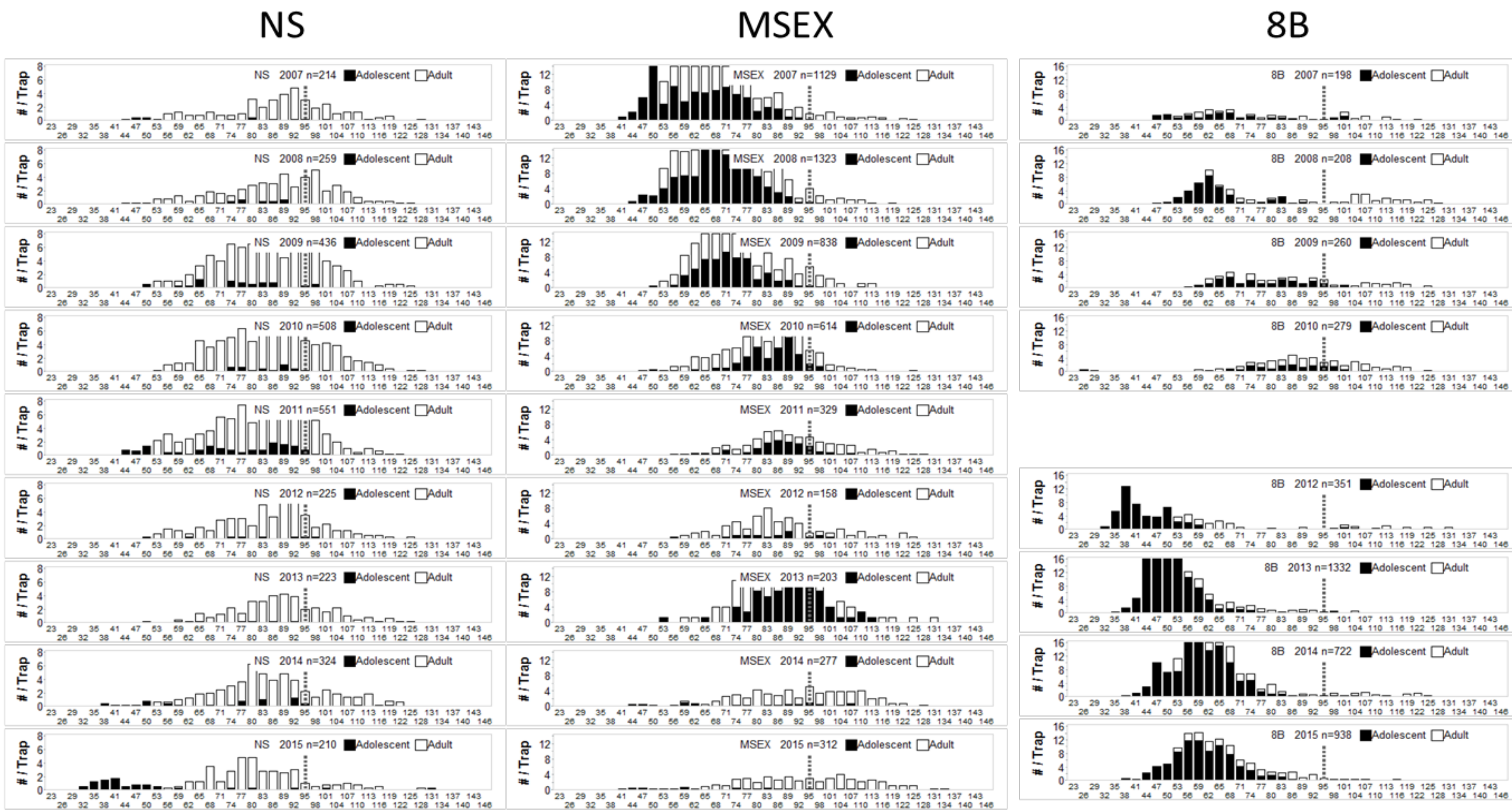

Figure 97. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Divs. 3LNO CPS trap survey. The vertical dashed line indicates the minimum legal size.

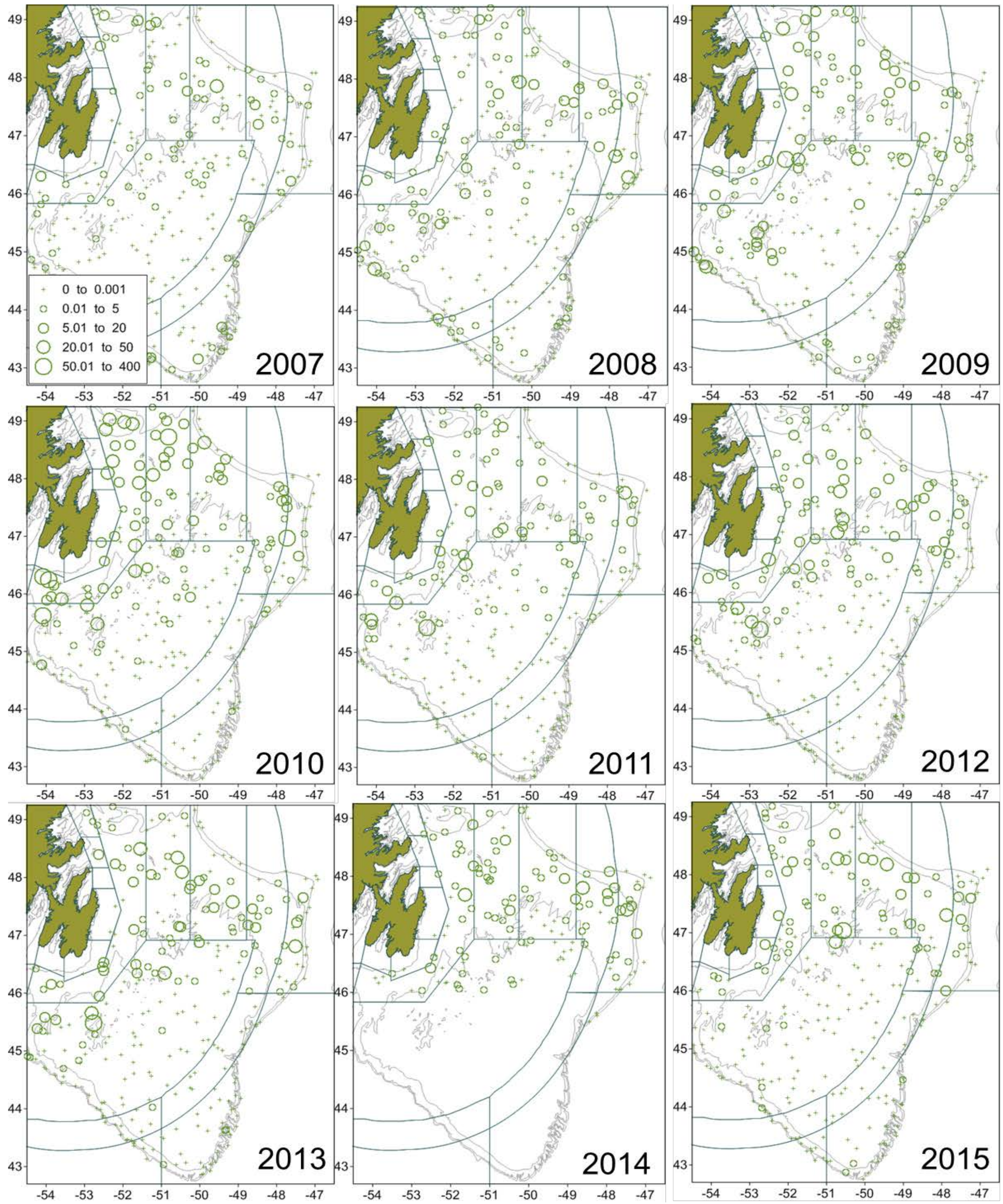

Figure 98. Distribution (#/tow) of small males (< 60 mm CW adolescents) in the Divs. 3LNO fall bottom trawl surveys from 2007-15.

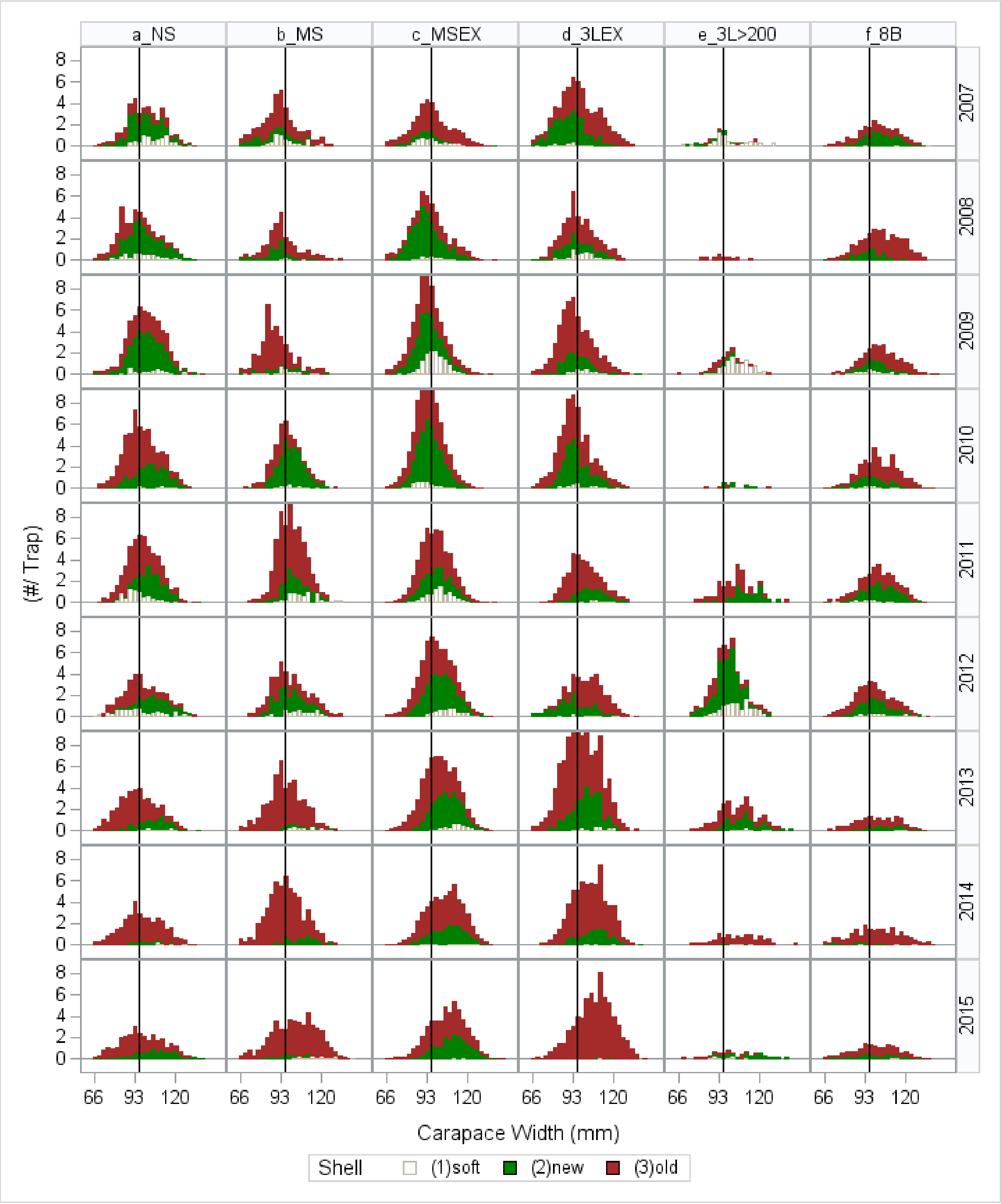

Figure 99. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Divs. 3LNO CPS trap survey. The vertical dashed line indicates the minimum legal size.

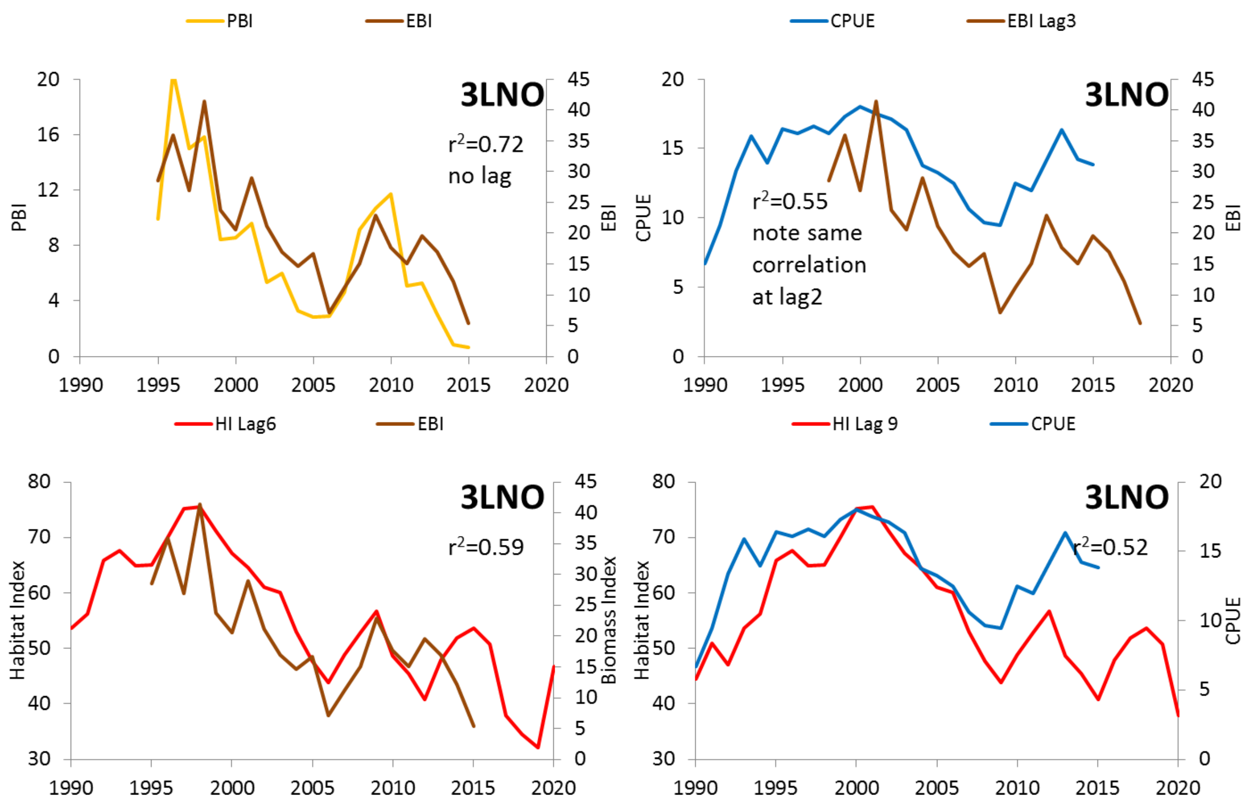

Figure 100. Summary of temporal relationships among key indices of resource status in Div. 3LNO. Best fit correlation lags shown. PBI is pre-recruit biomass index, EBI is exploitable biomass index, CPUE is fishery catch per unit of effort, and HI is habitat index.

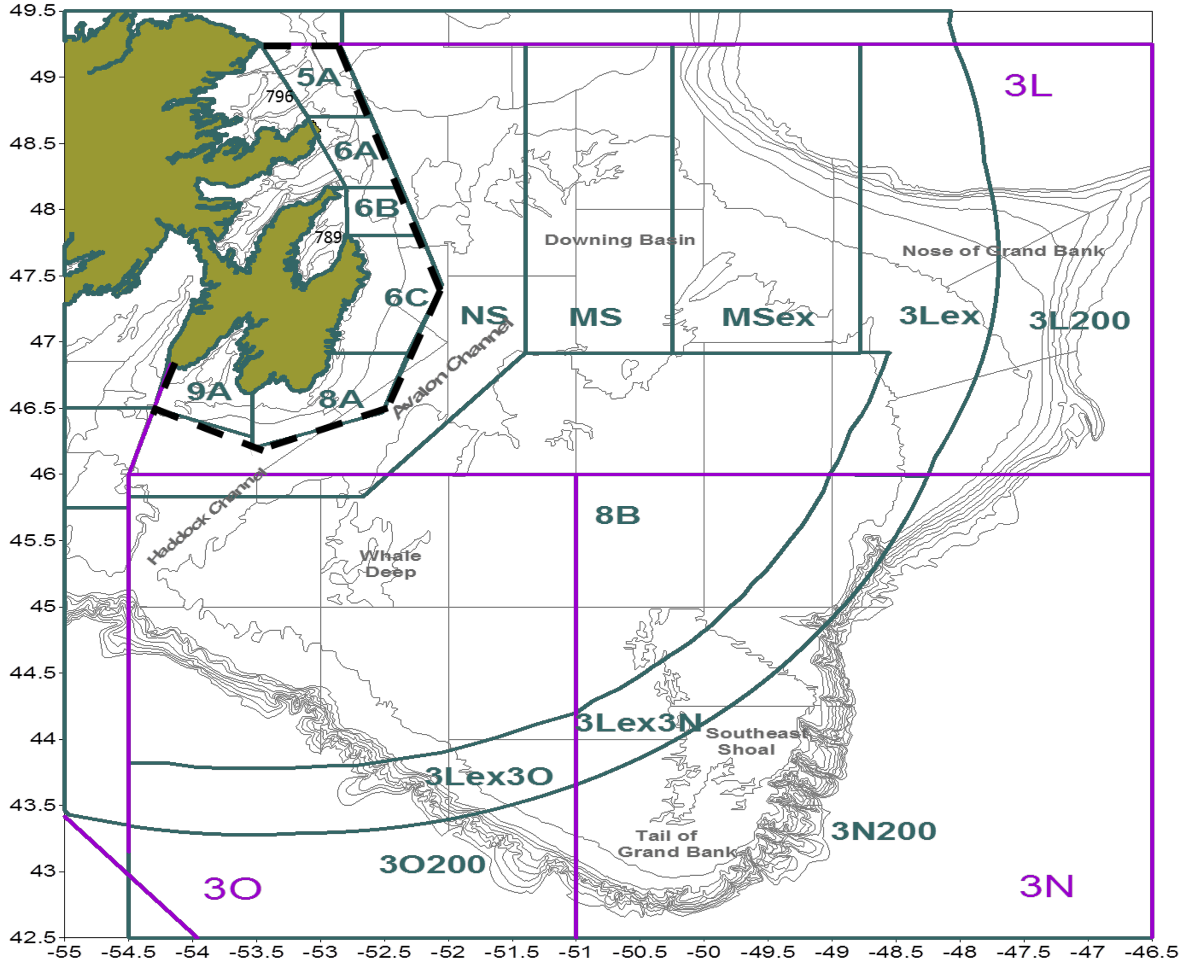

Figure 101. Map of Divs. 3LNO showing CMAs and important bathymetric features. Dashed perimeter indicates Div. 3L Inshore areas.

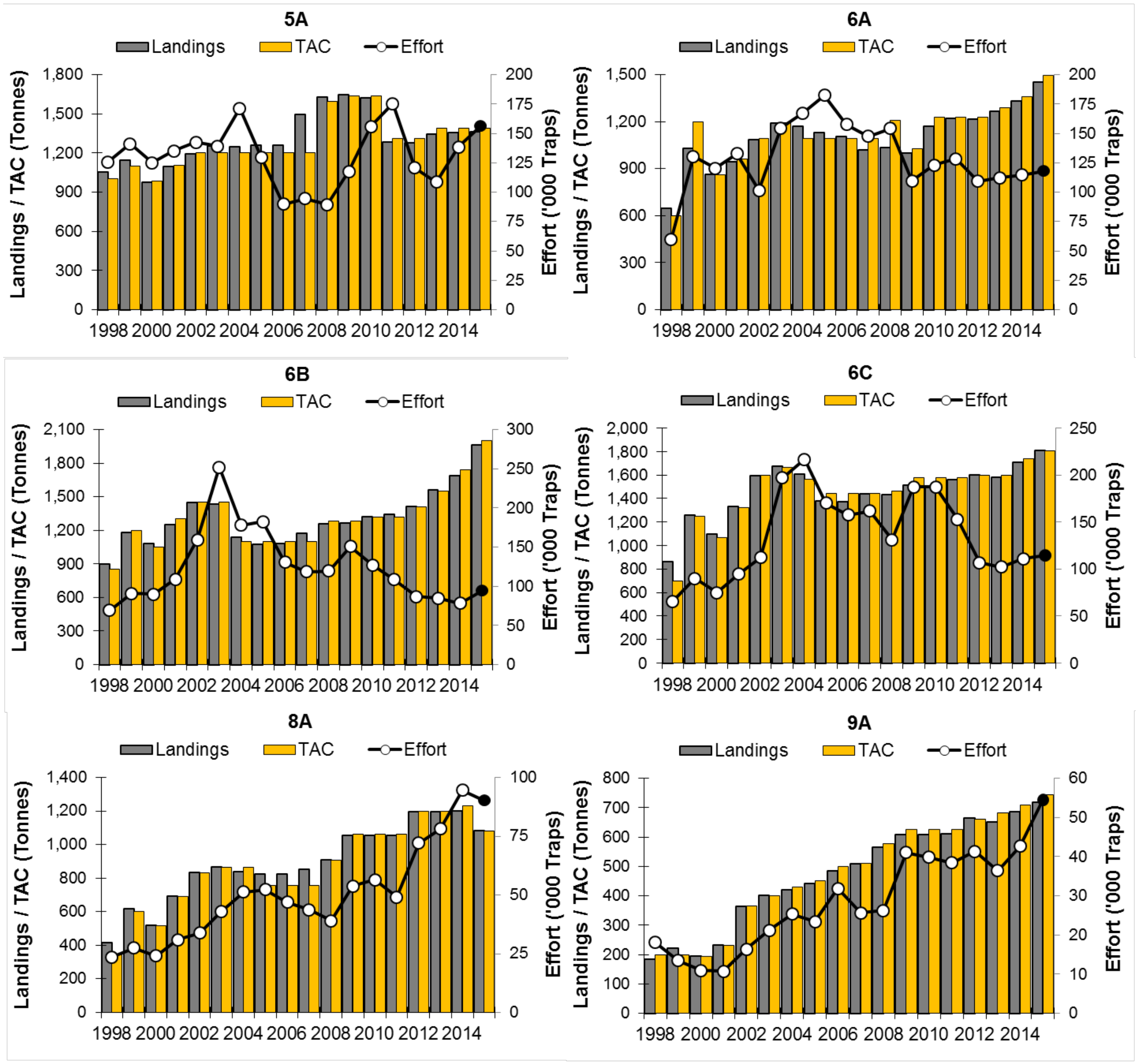

Figure 102. TAC, landings, and estimated effort for CMAs in Div. 3L Inshore. 2015 effort preliminary.

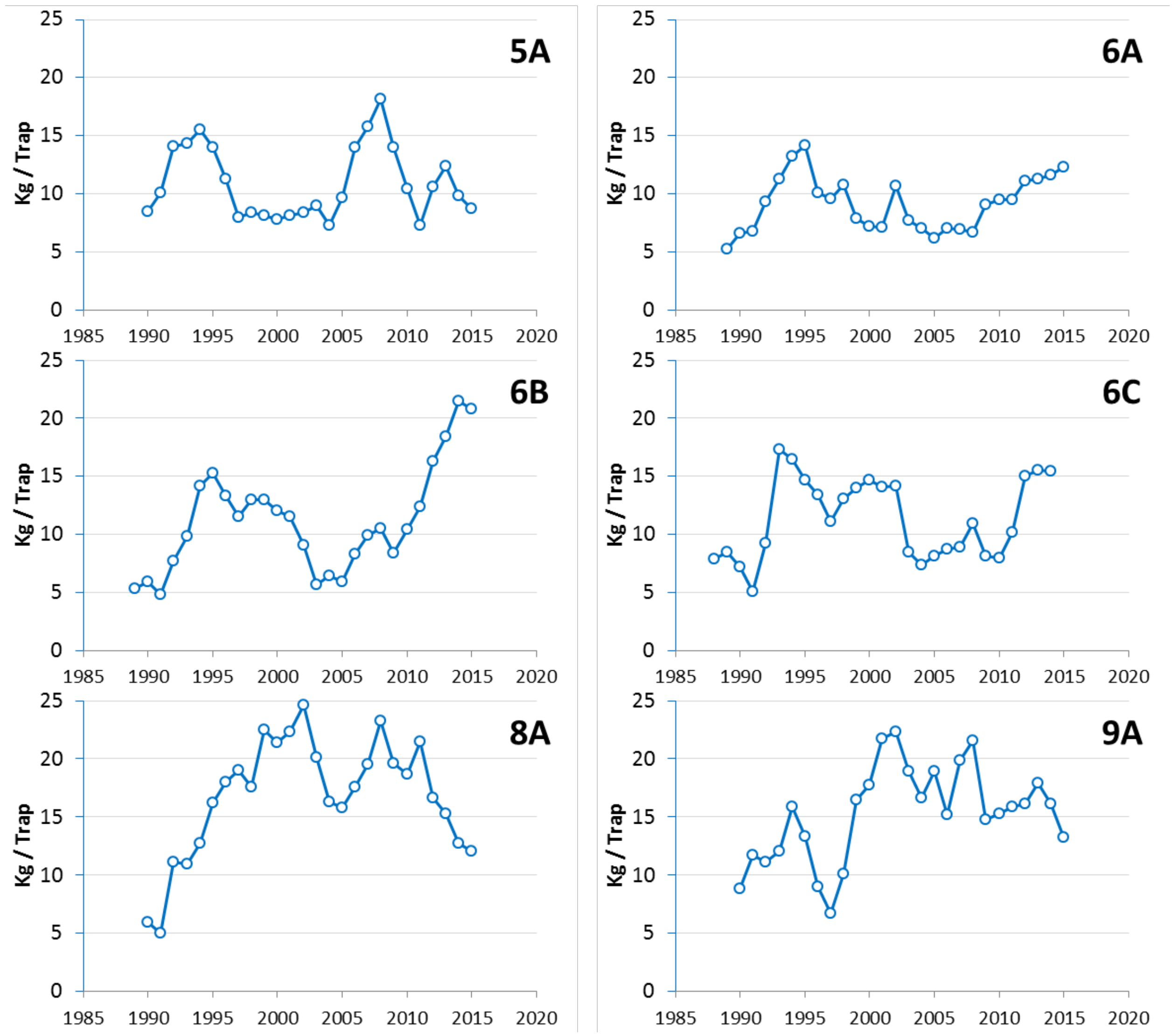

Figure 103. Trends in unstandardized CPUE by CMA in Div. 3L Inshore.

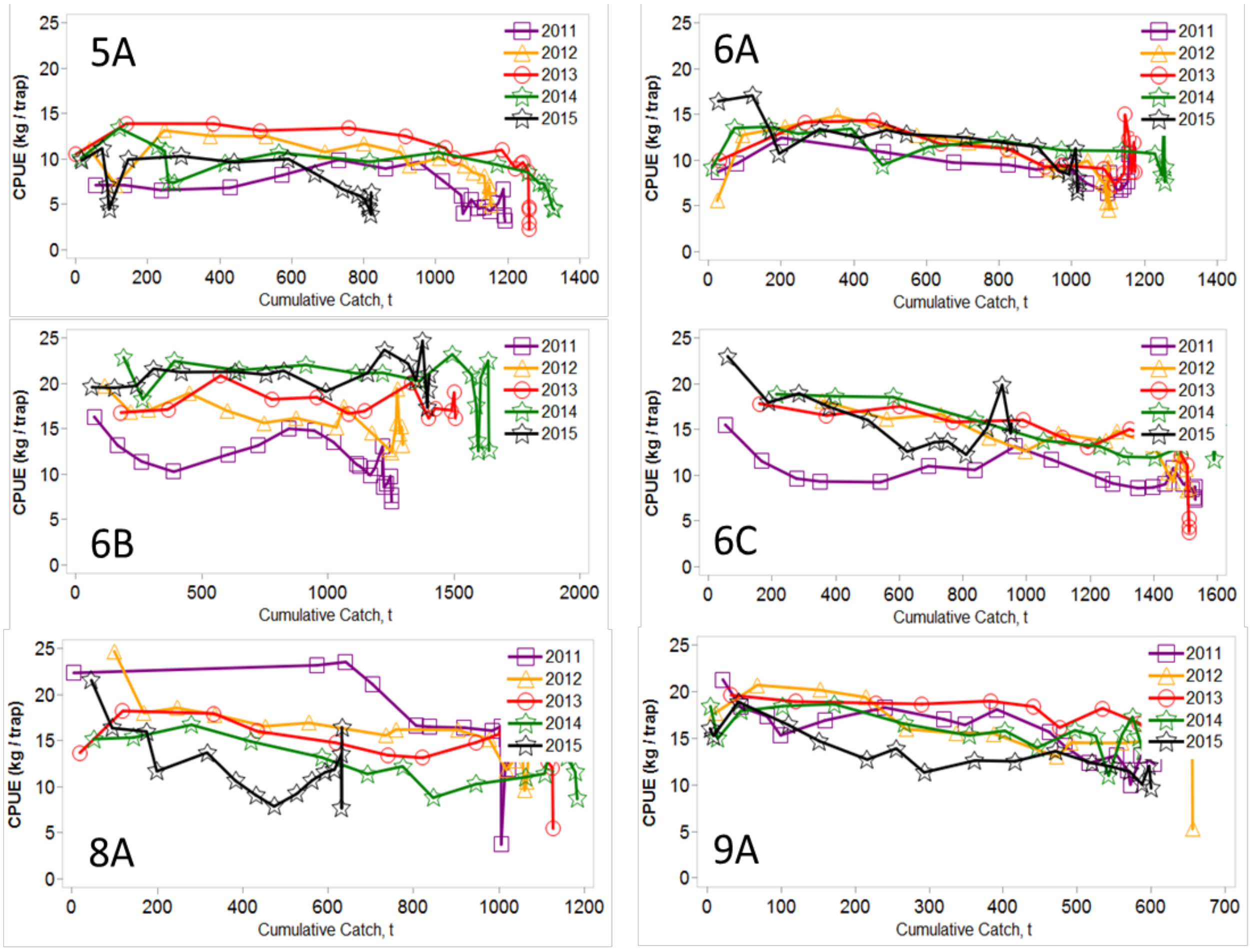

Figure 104. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Div. 3L Inshore.

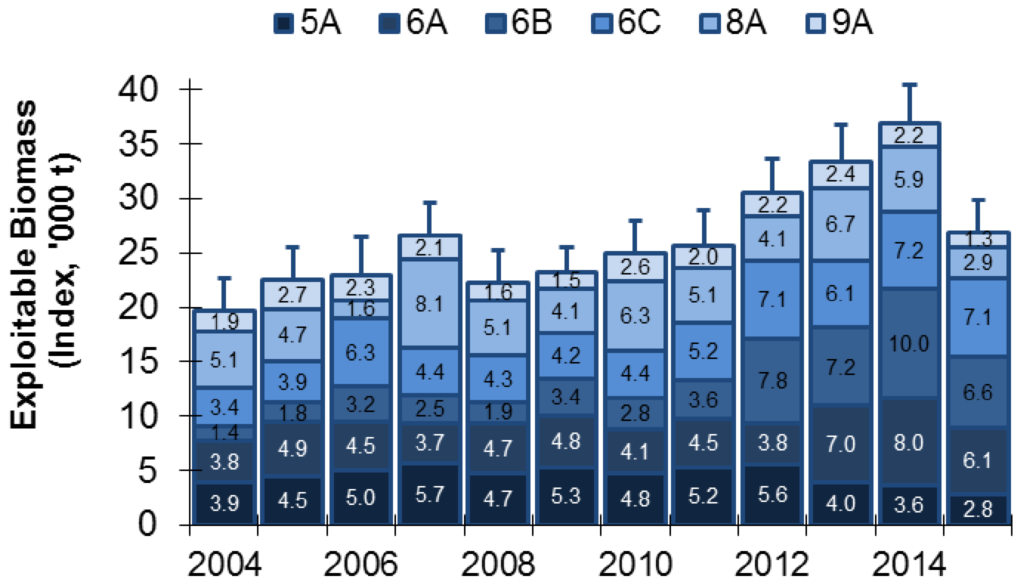

Figure 105. CPS trap survey exploitable biomass index from large-mesh traps for CMAs in Div. 3L Inshore.

Figure 106. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMAs in Div. 3L Inshore.

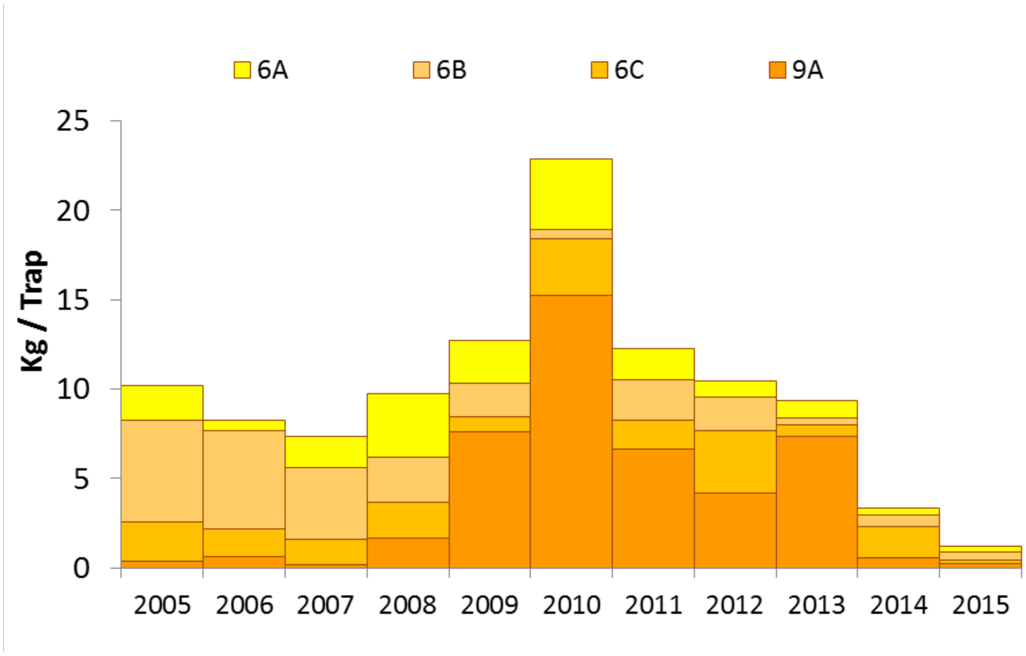

Figure 107. CPS trap survey pre-recruit biomass index from small-mesh traps for CMAs in Div. 3L Inshore. Index calculated as > 75 mm CW adolescent males.

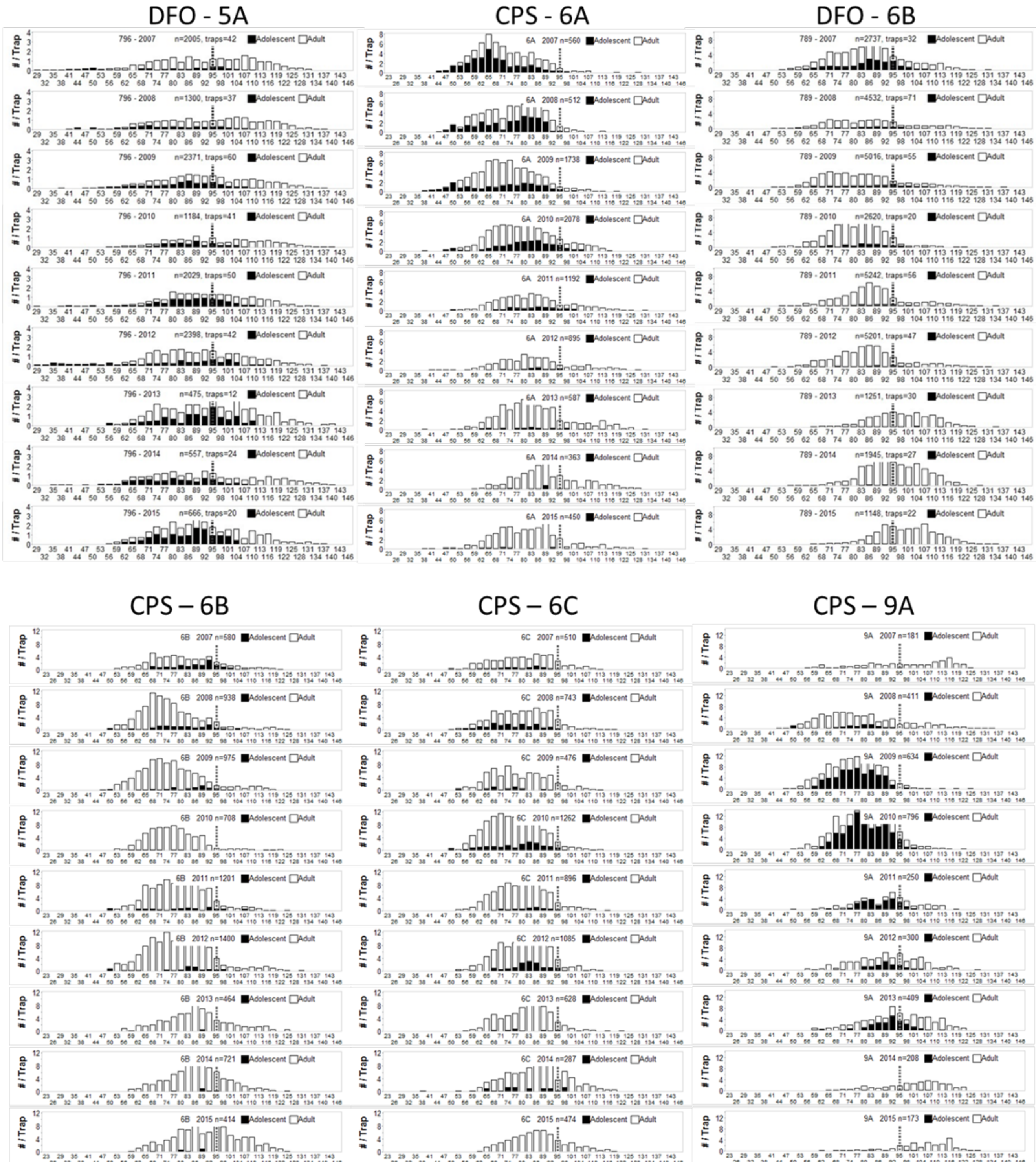

Figure 108. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Div. 3L Inshore CPS and DFO trap surveys. The vertical dashed line indicates the minimum legal size.

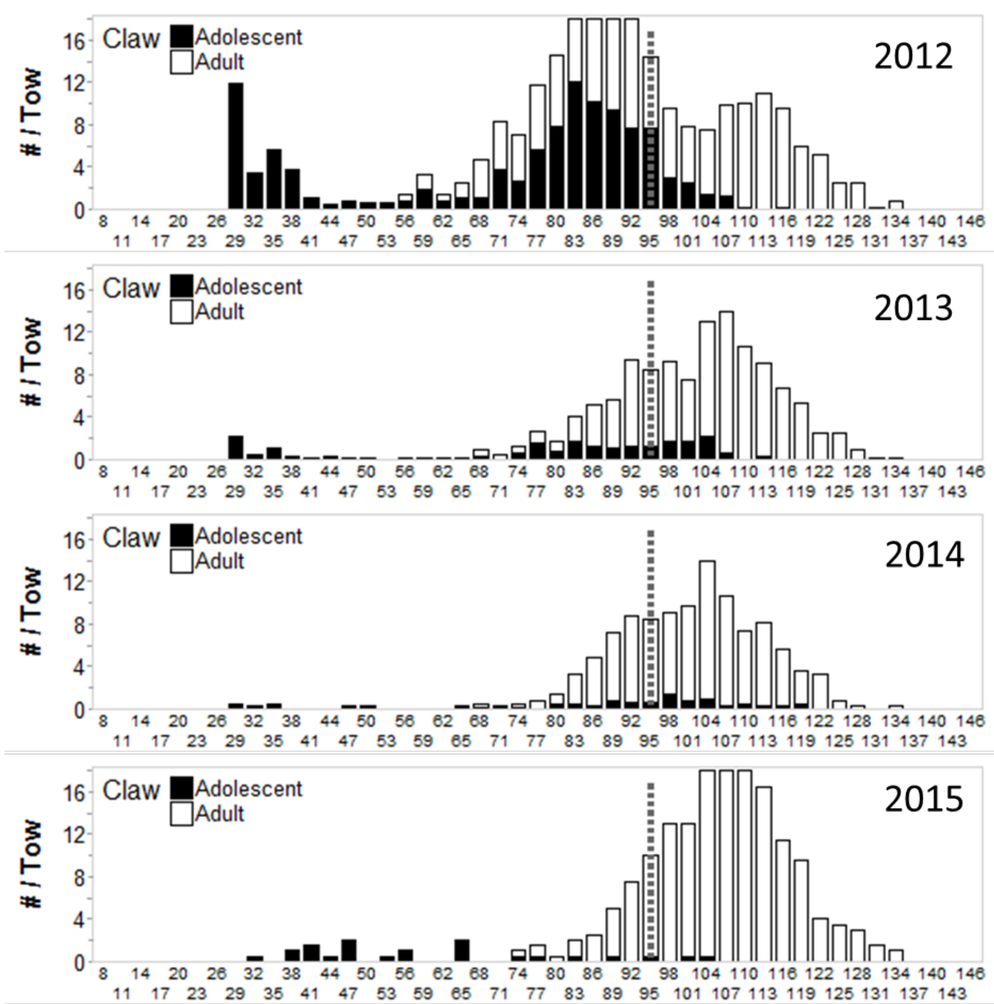

Figure 109. Trends in male carapace width distributions by maturity from trawling in CMA 6B (stratum 789) in the Div. 3L Inshore DFO surveys. The vertical dashed line indicates the minimum legal size. Note only 4 sets completed in 2015.

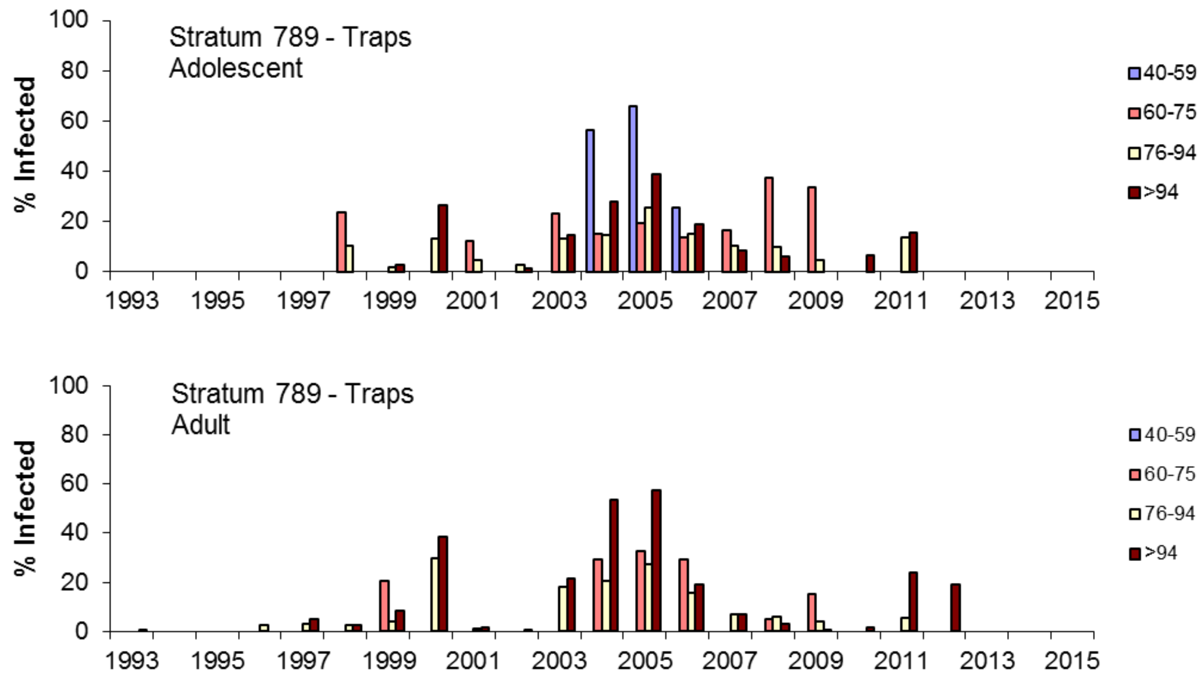

Figure 110. Trends in prevalence of BCD in new-shelled males by year and size group in stratum 789 from DFO trap surveys in Conception Bay; adolescents (above) and adults (below).

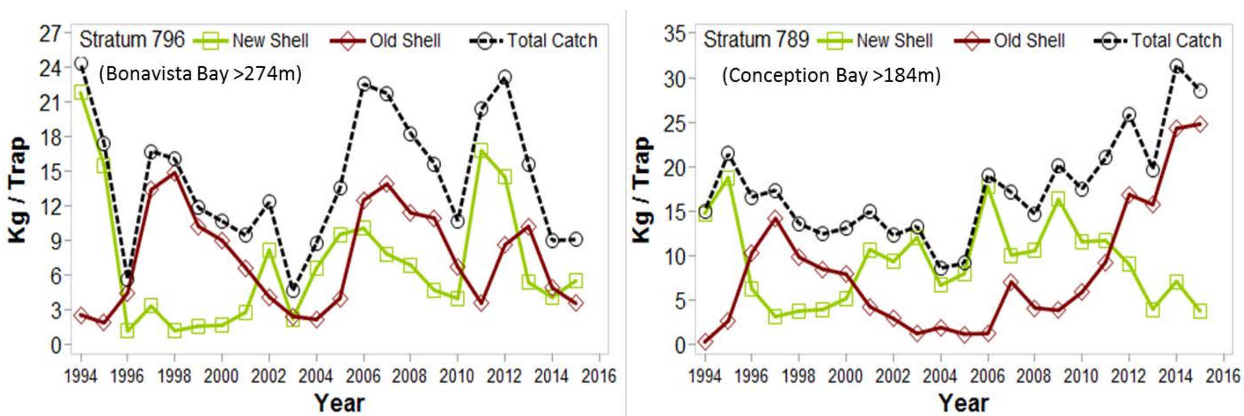

Figure 111. Trends in CPUE by shell condition for legal-sized crabs from the DFO trap survey in CMAs in Div. 3L Inshore. Data stratified by depth.

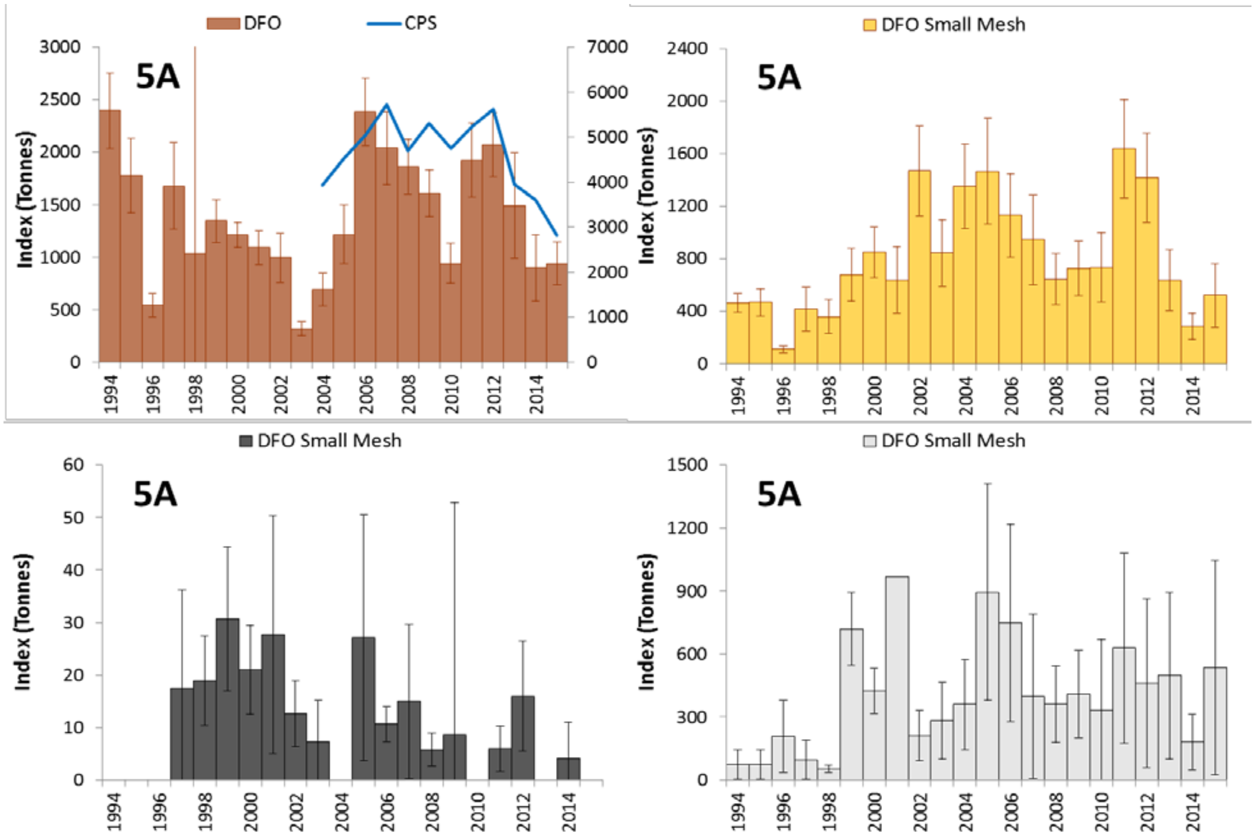

Figure 112. Indices from the DFO trap survey in CMA 5A. Exploitable biomass index from large-mesh traps (top left), pre-recruit biomass index from small-mesh traps (top right), < 50 mm CW crab biomass index from small-mesh traps (bottom left), and mature female biomass index from small-mesh traps (bottom right). All indices derived with STRAP.

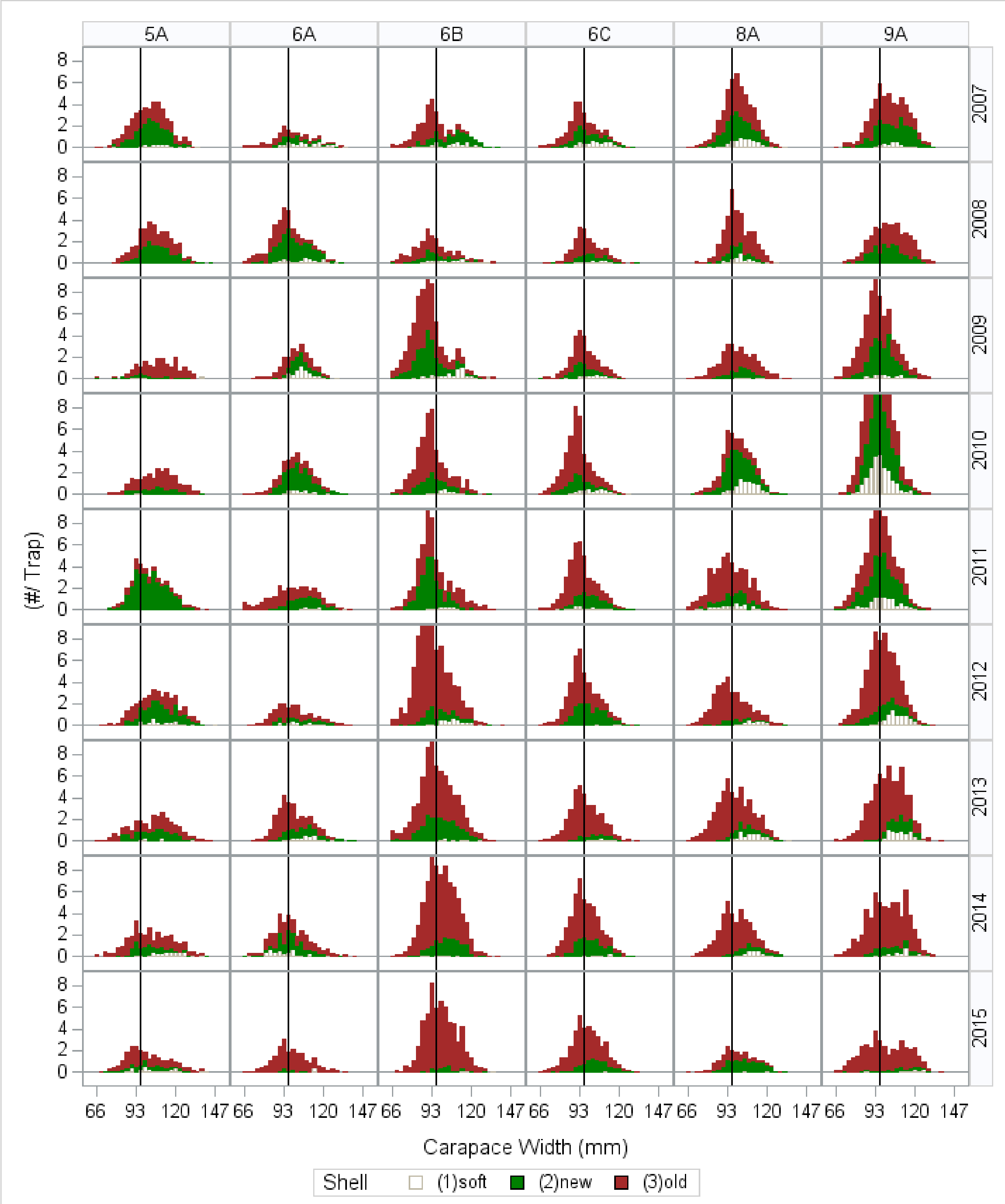

Figure 113. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Div. 3L Inshore CPS trap survey. The vertical dashed line indicates the minimum legal size.

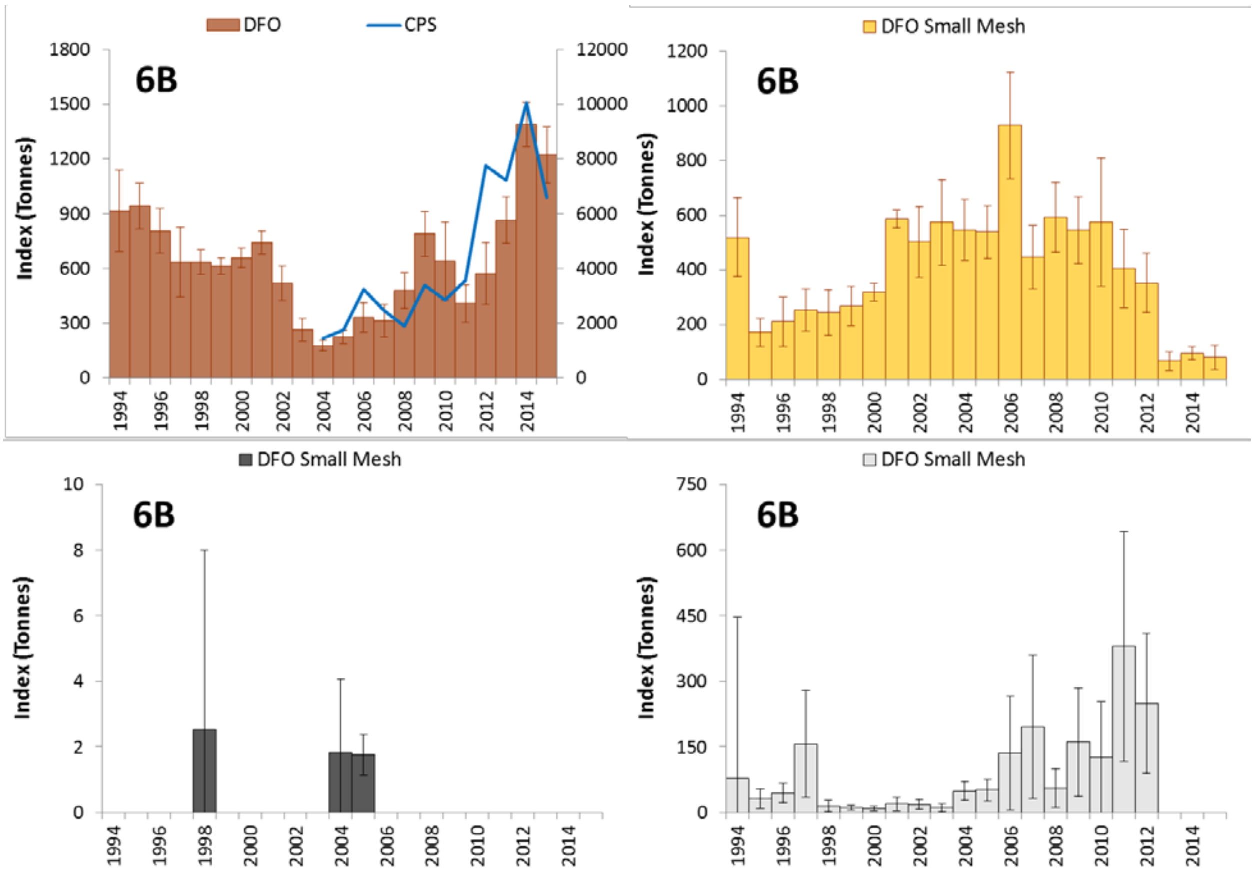

Figure 114. Indices from the DFO trap survey in CMA 6B. Exploitable biomass index from large-mesh traps (top left), pre-recruit biomass index from small-mesh traps (top right), < 50 mm CW crab biomass index from small-mesh traps (bottom left), and mature female biomass index from small-mesh traps (bottom right). All indices derived with STRAP.

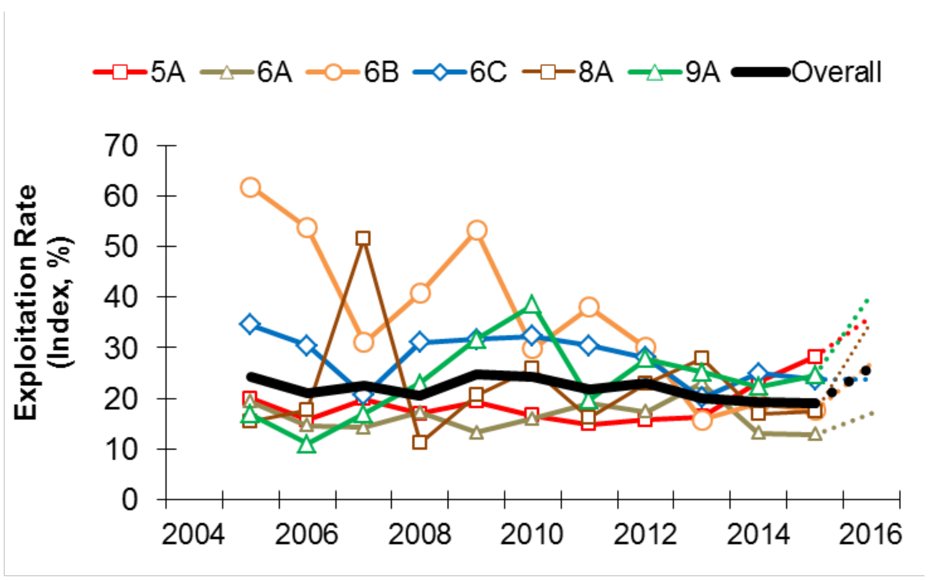

Figure 115. Exploitation rate indices by Crab Management Area as well as overall for Div. 3L inshore based on the CPS trap survey. Dashed lines represent 2016 estimates based on status quo landings.

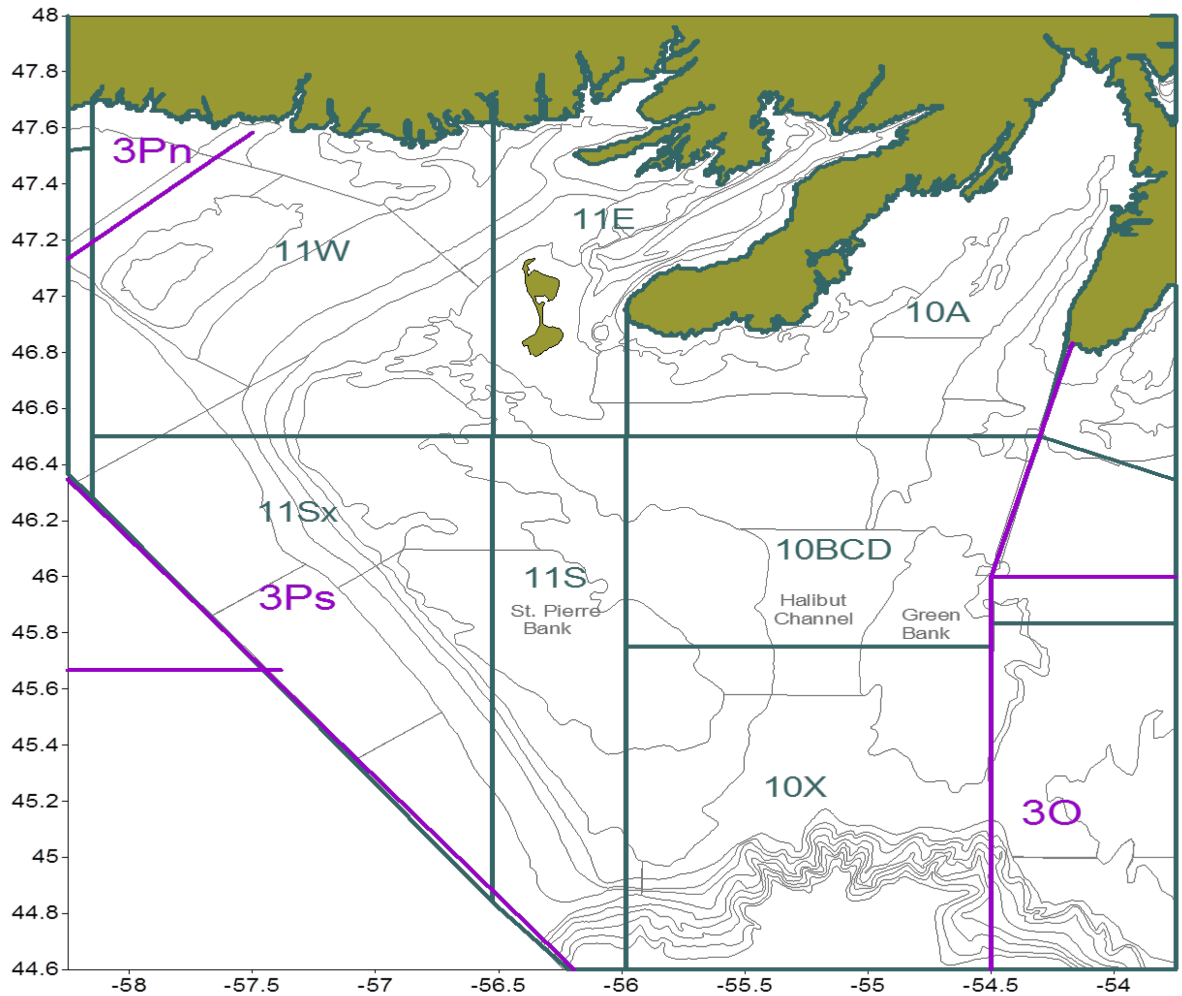

Figure 116. Map of Subdiv. 3Ps showing CMAs and important bathymetric features. Dashed perimeter indicates offshore areas. Note merger of CMAs 11Sx and 11S in 2015.

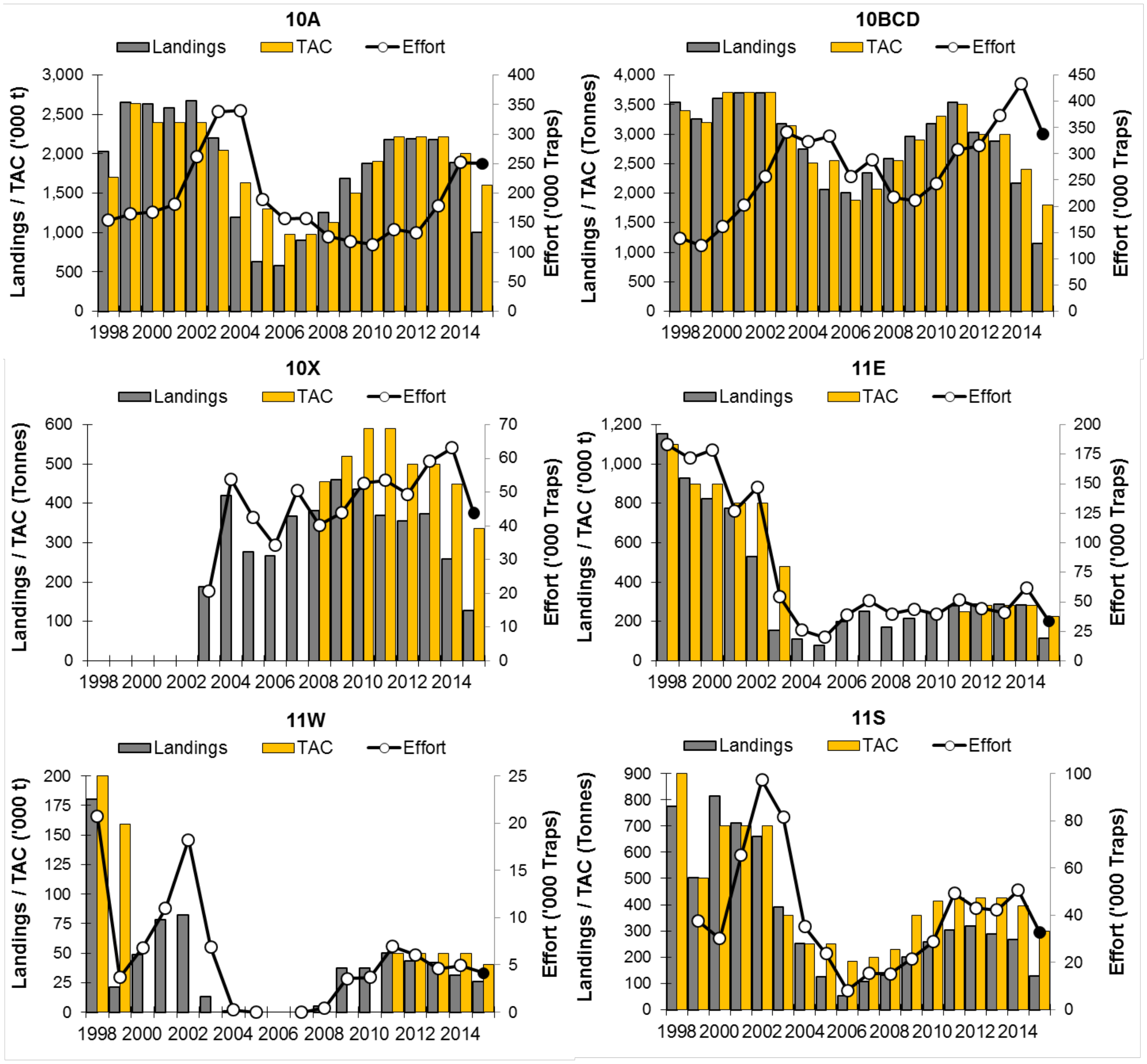

Figure 117. TAC, landings, and estimated effort for CMAs in Subdiv. 3Ps. 2015 effort preliminary.

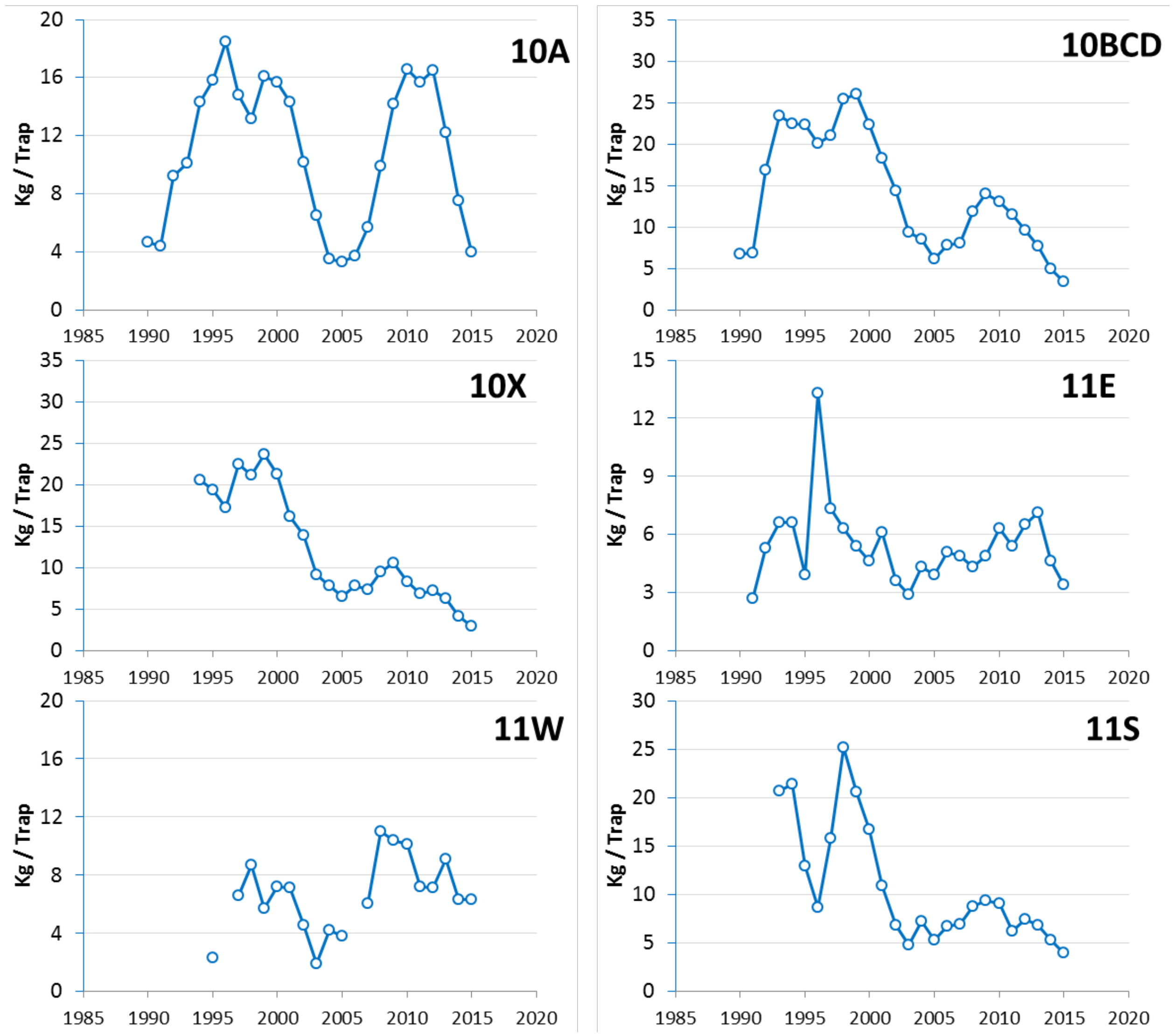

Figure 118. Trends in standardized CPUE for the entirety of Subdiv. 3Ps as well as by CMA.

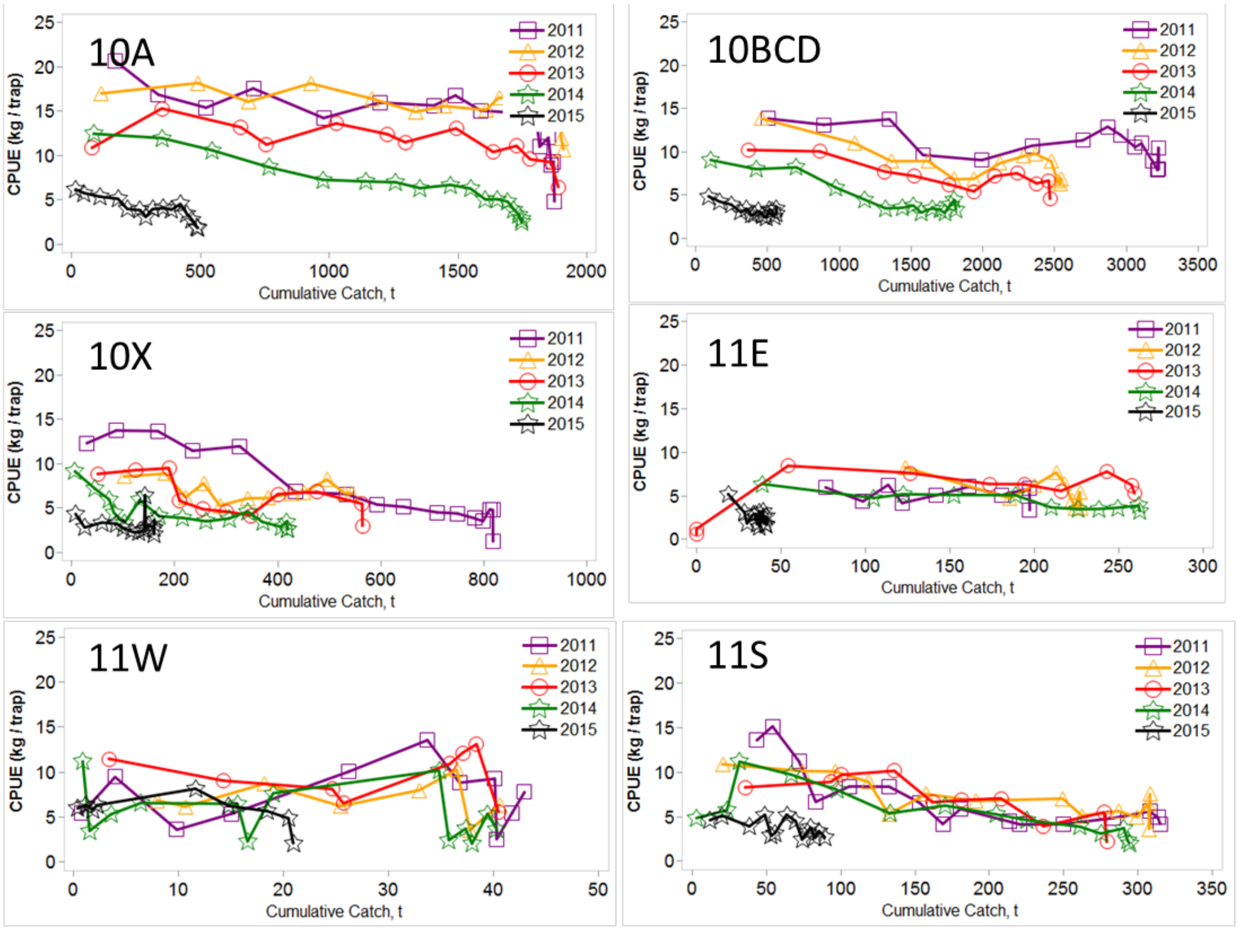

Figure 119. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Subdiv. 3Ps.

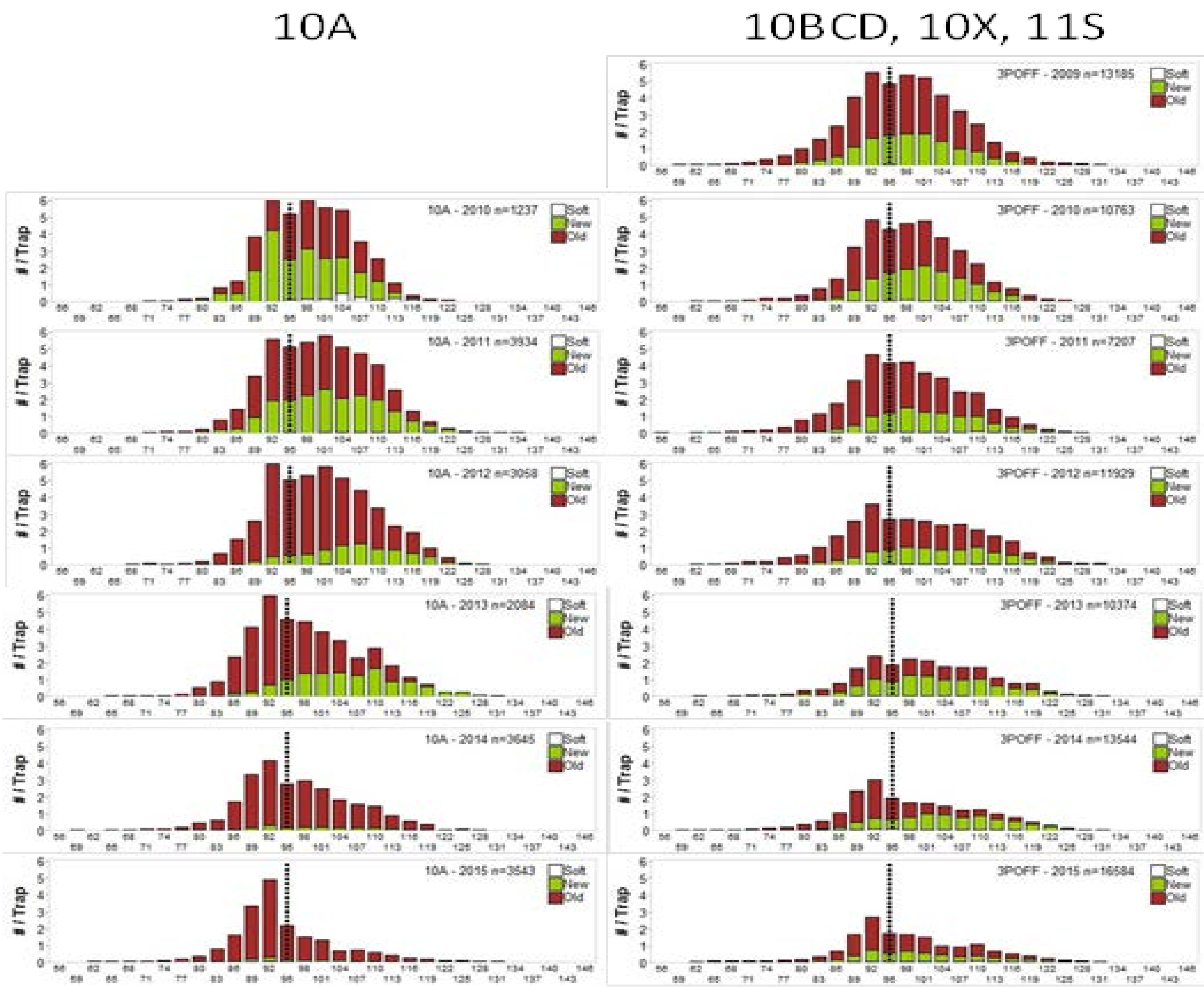

Figure 120. Trends in male carapace width distributions by shell condition from observer at-sea sampling for CMAs in Subdiv. 3Ps. The vertical dashed line indicates the minimum legal size.

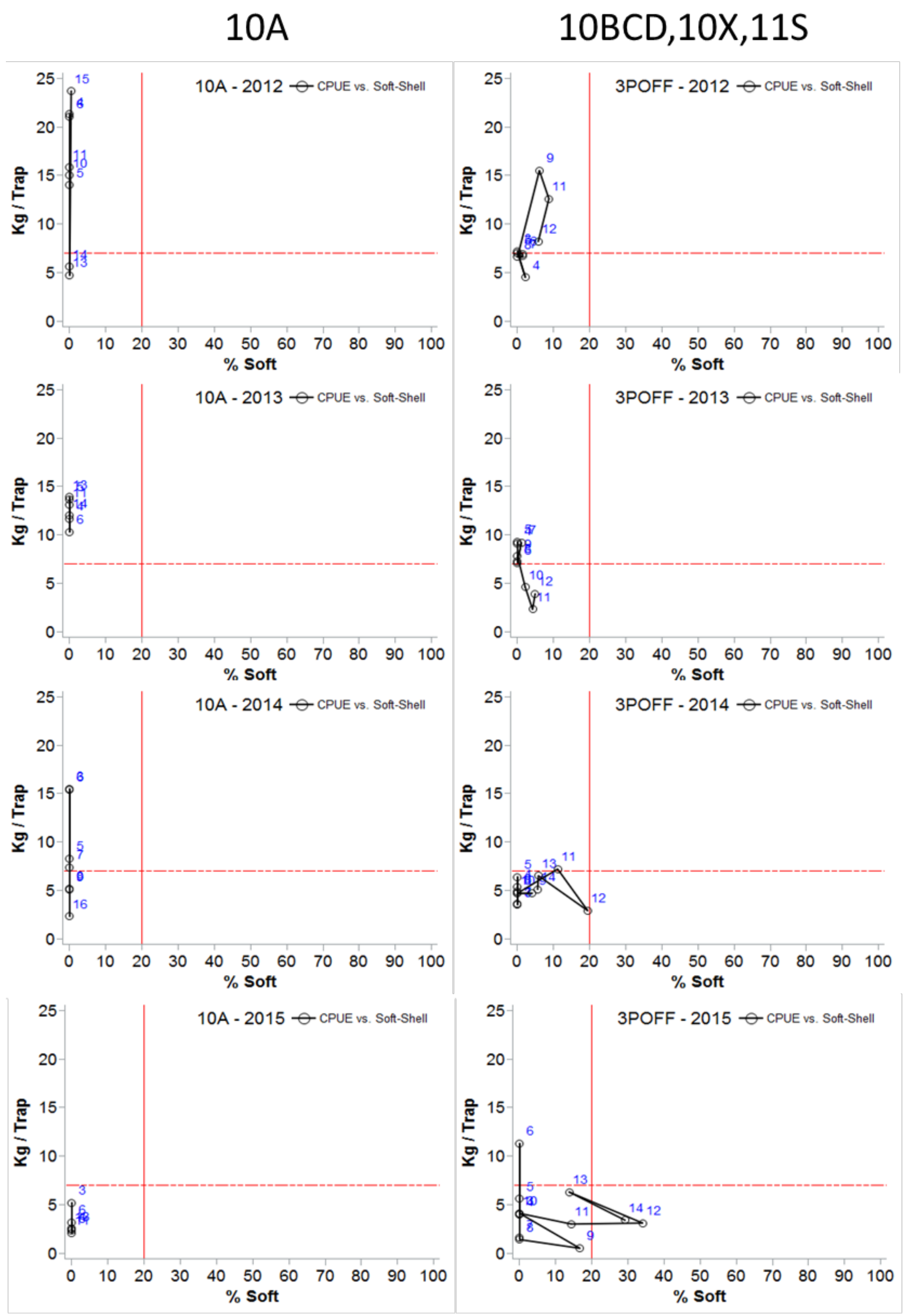

Figure 121. Trends in observed weekly catch rates versus the percentage of soft-shell crab in the catch for CMAs in Subdiv. 3Ps.

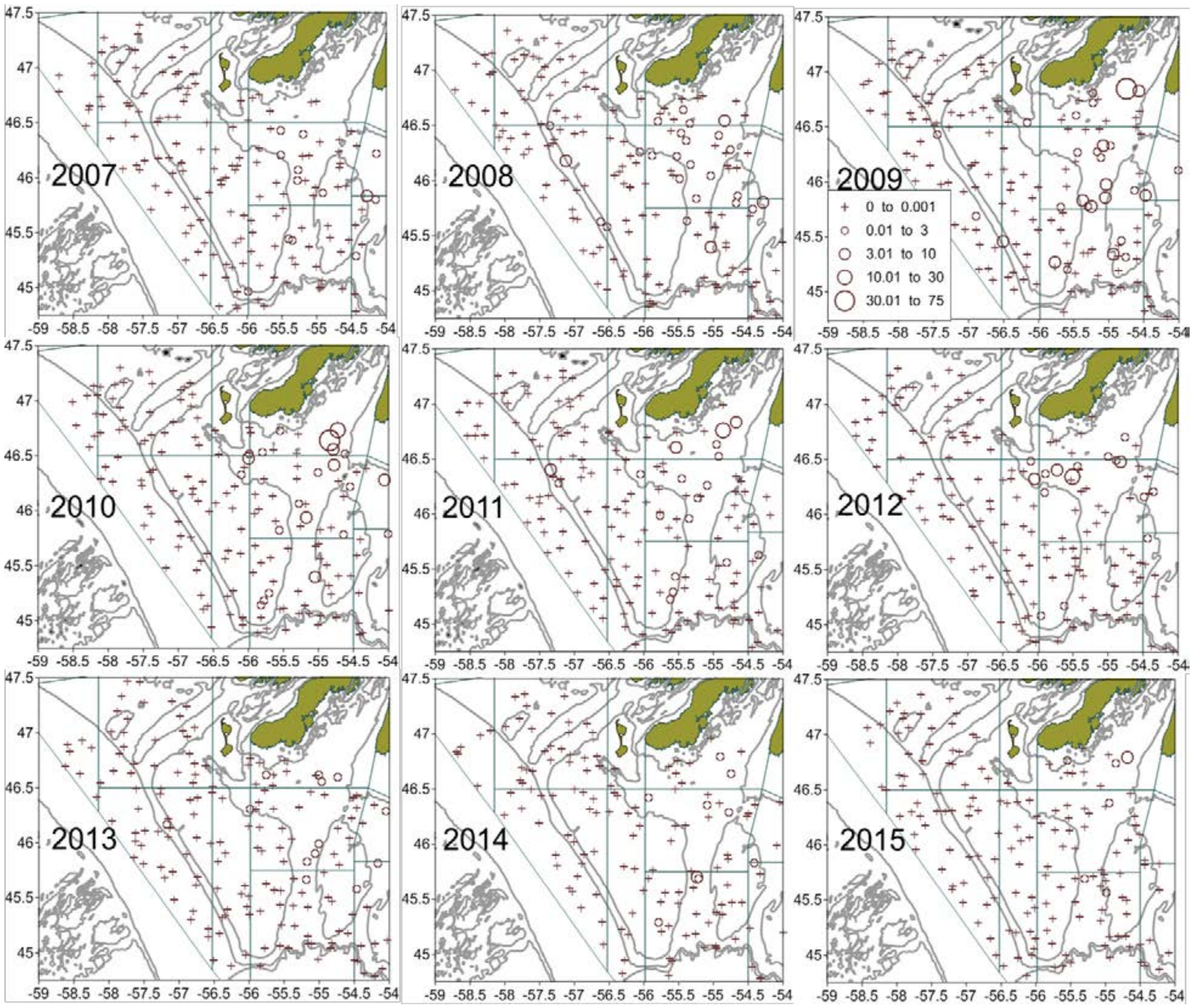

Figure 122. Distribution (#/tow) of exploitable males (> 94 mm CW adults) from Subdiv. 3Ps bottom trawl surveys from spring 2007-15.

Figure 123. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMAs in Subdiv. 3Ps.

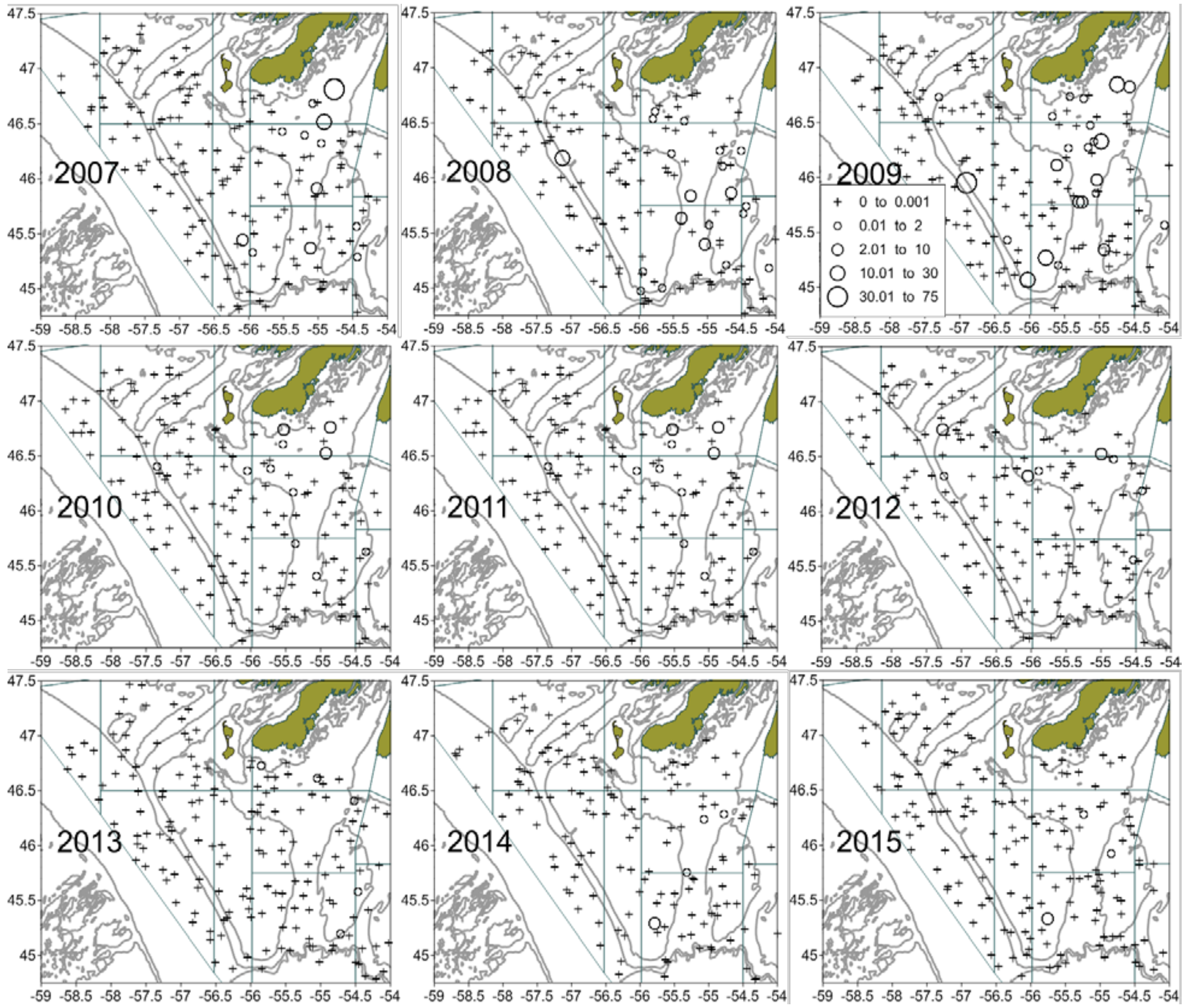

Figure 124. Distribution (#/tow) of pre-recruit males (> 75 mm CW adolescent) from Subdiv. 3Ps spring bottom trawl surveys from 2007-15.

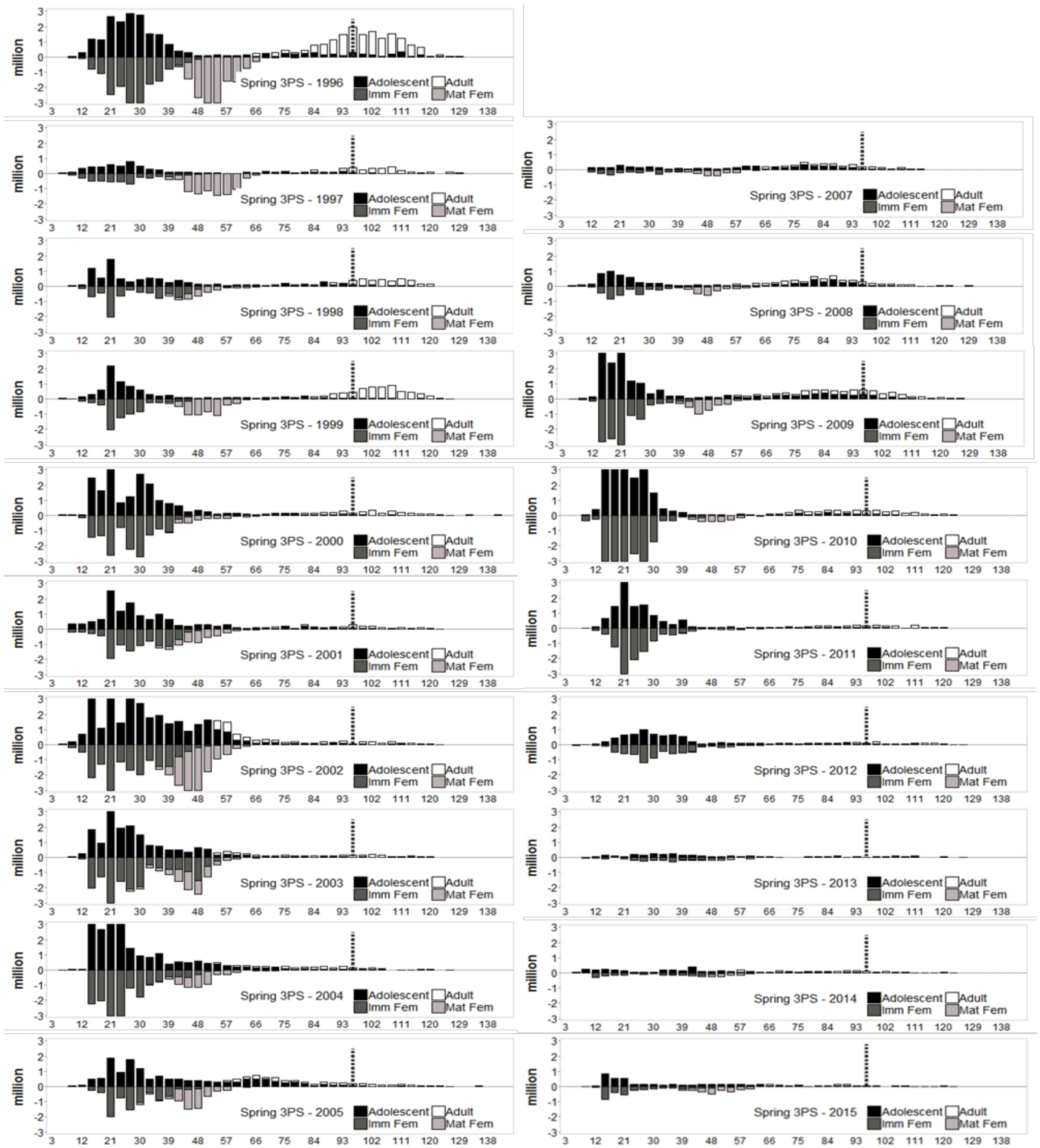

Figure 125. Abundance indices by carapace width for Subdiv. 3Ps juveniles plus adolescent males (dark bars), adult males (white bars), immature females (dark grey bars), and mature females (light grey bars) from fall trawl surveys.

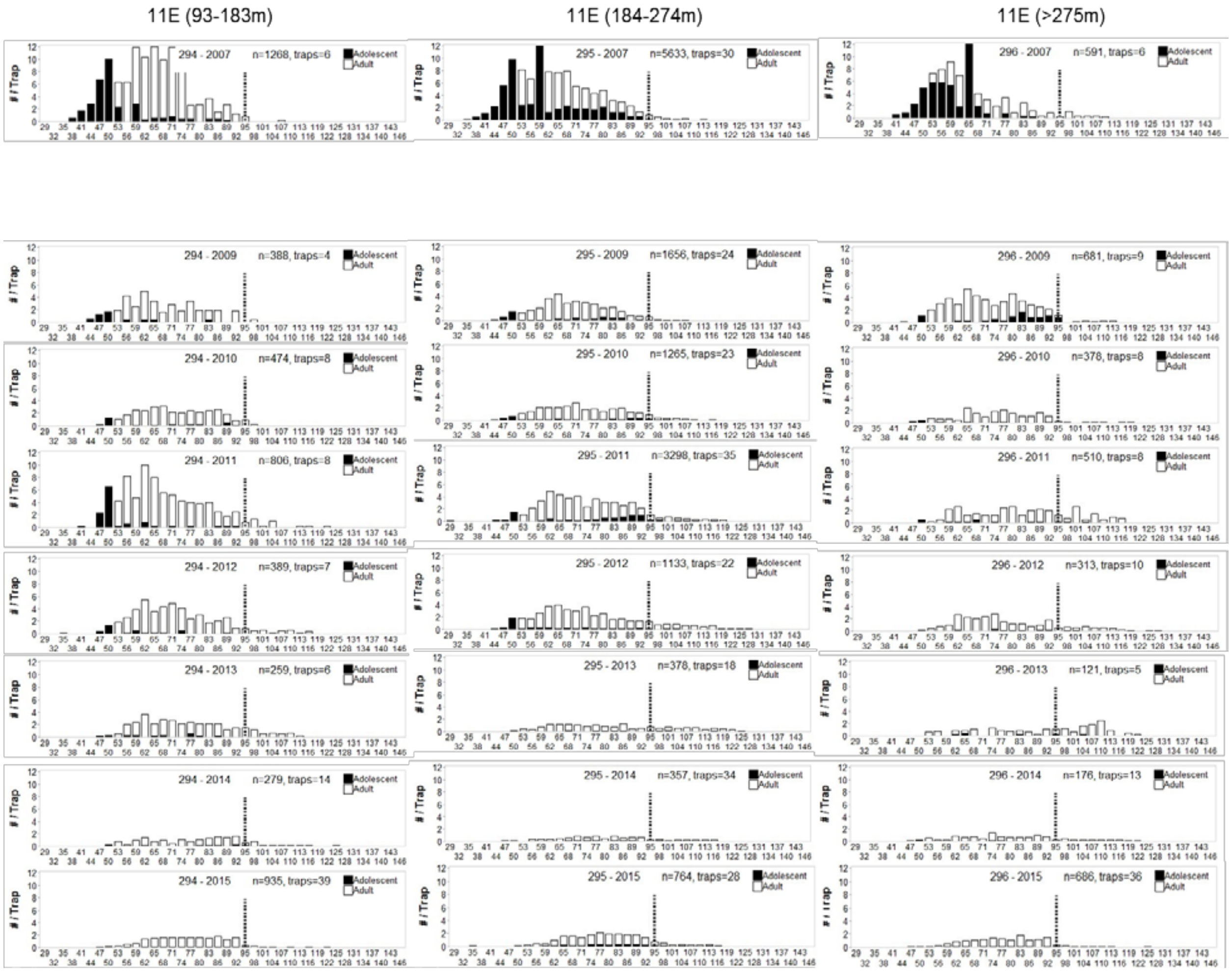

Figure 126. Trends in male carapace width distributions by maturity from small-mesh traps in CMA 11E DFO trap surveys. The vertical dashed line indicates the minimum legal size.

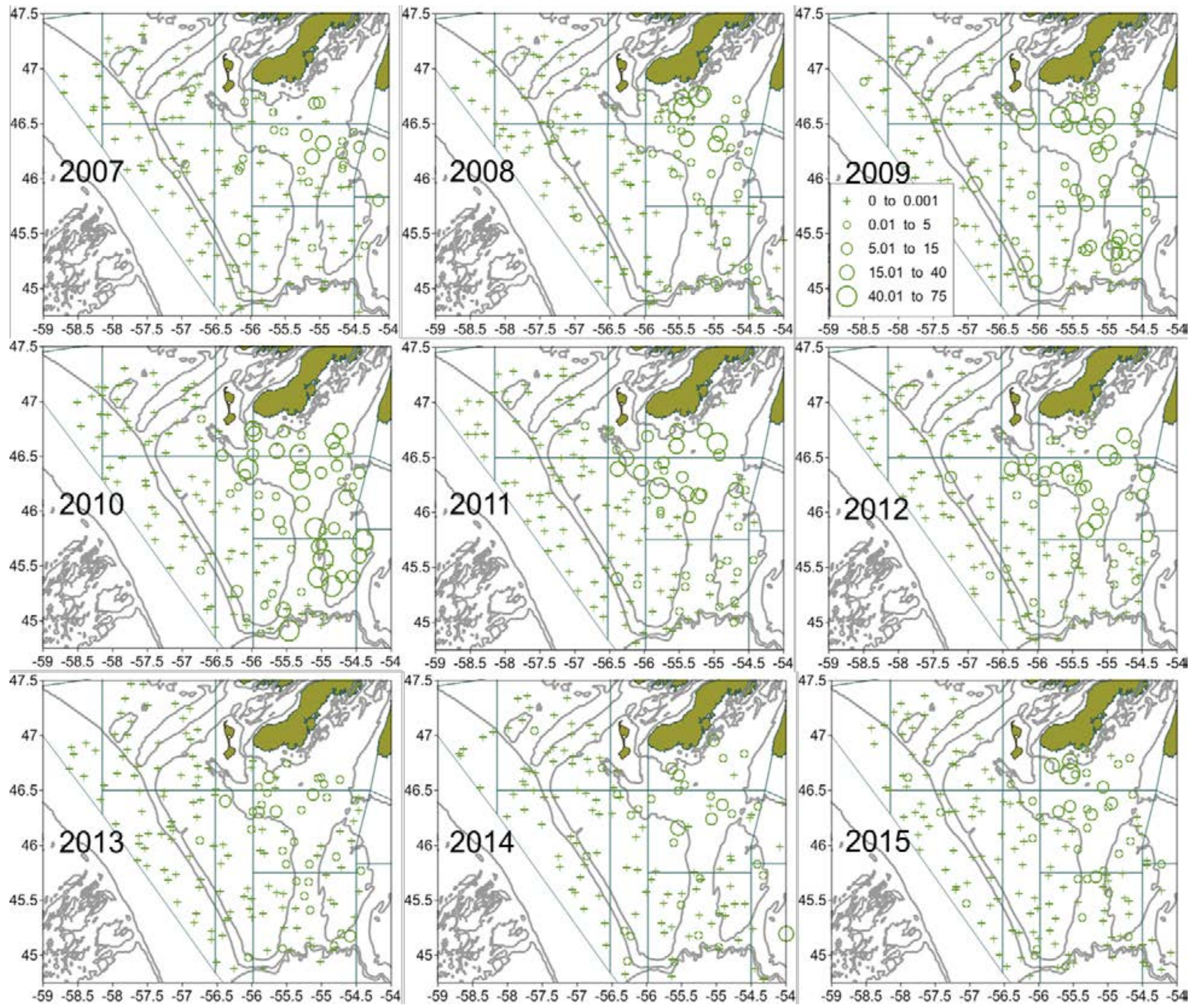

Figure 127. Distribution (#/tow) of small males (< 60 mm CW adolescents) in the Subdiv. 3Ps spring bottom trawl surveys from 2007-15.

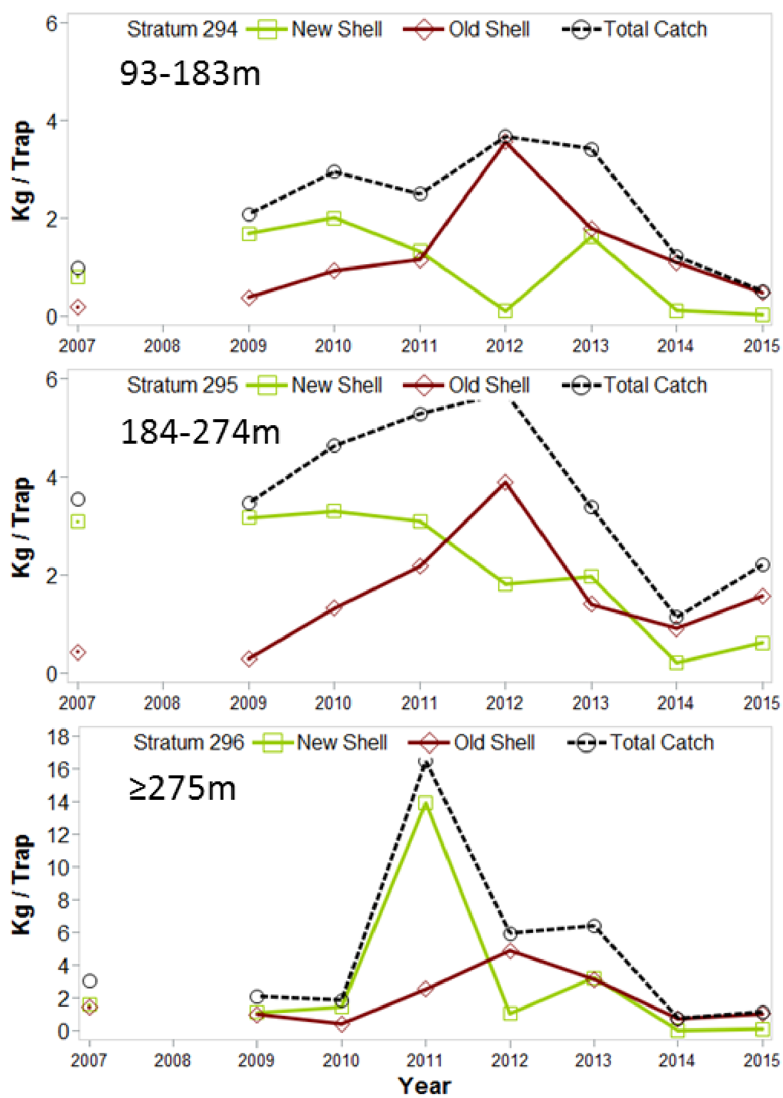

Figure 128. Trends in CPUE by shell condition for legal-sized crabs from the DFO trap survey in CMAs in Subdiv. 3Ps. Data stratified by depth.

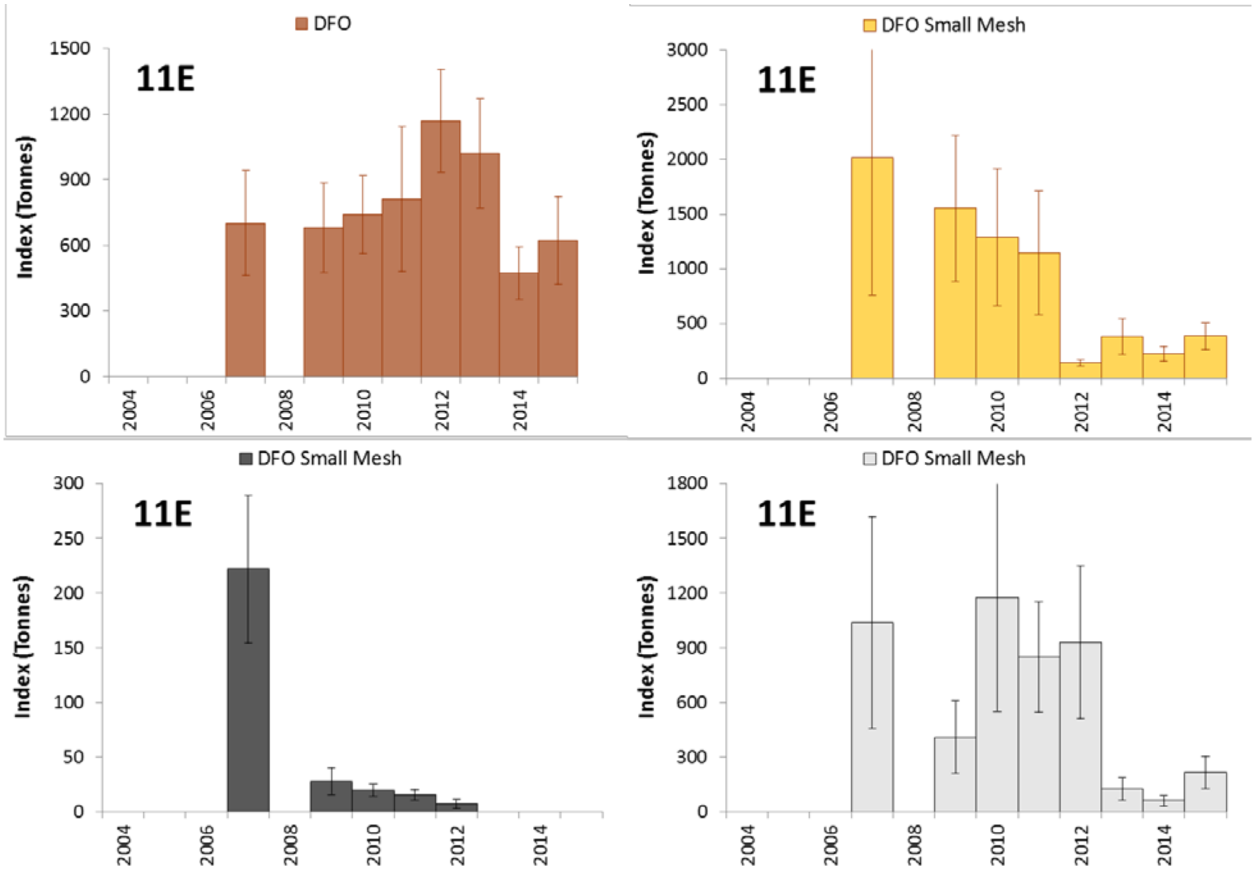

Figure 129. Indices from the DFO trap survey in CMA 11E. Exploitable biomass index from large-mesh traps (top left), pre-recruit biomass index from small-mesh traps (top right), < 50 mm CW crab biomass index from small-mesh traps (bottom left), and mature female biomass index from small-mesh traps (bottom right). All indices derived with STRAP.

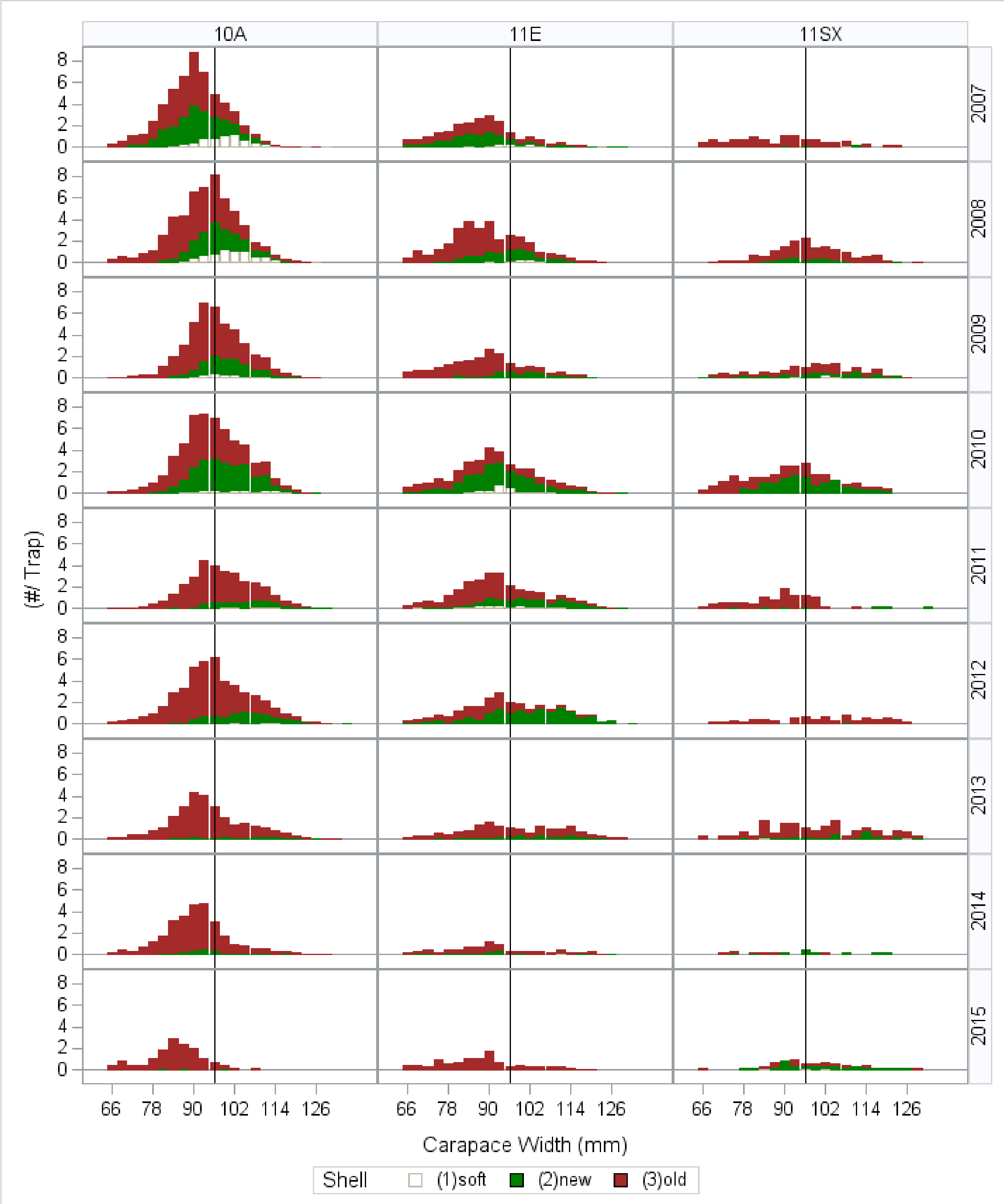

Figure 130. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Subdiv. 3Ps CPS trap survey. The vertical dashed line indicates the minimum legal size.

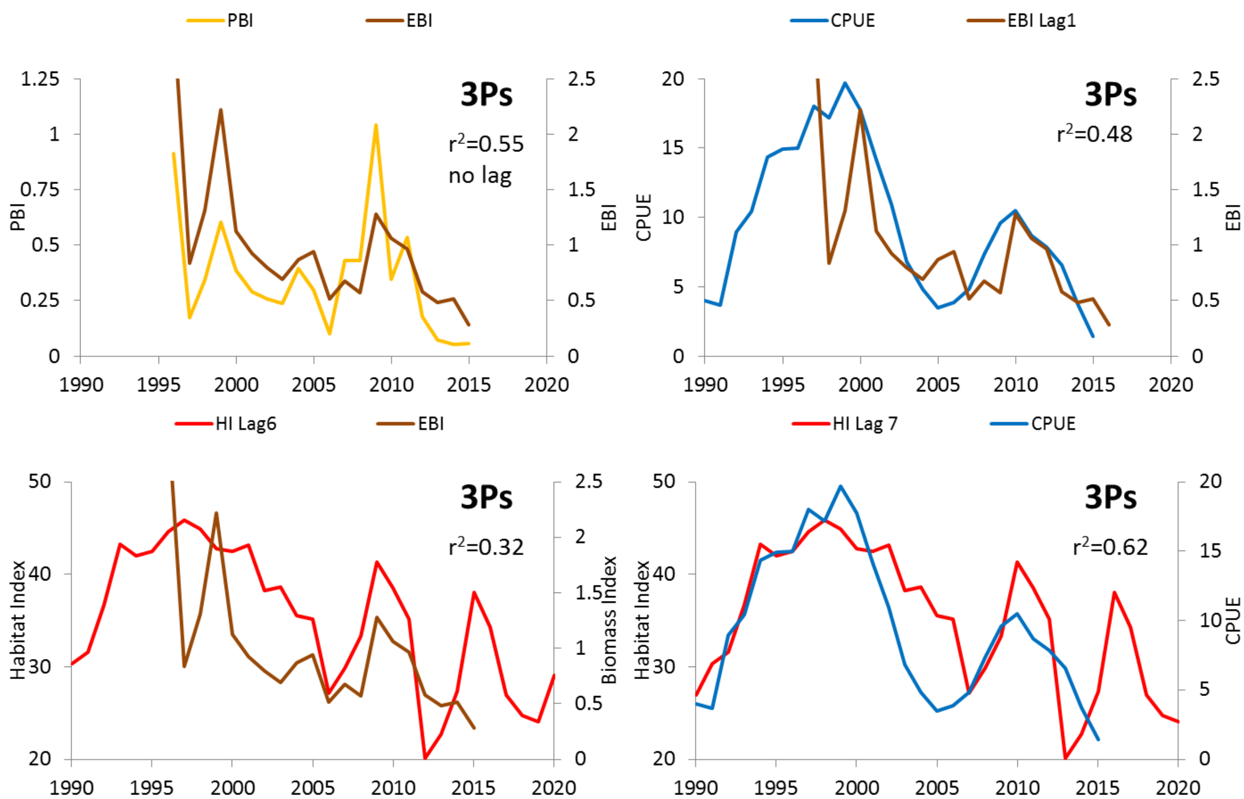

Figure 131. Summary of temporal relationships among key indices of resource status in Subdiv. 3Ps. Best fit correlation lags shown. PBI is pre-recruit biomass index, EBI is exploitable biomass index, CPUE is fishery catch per unit of effort, and HI is habitat index.

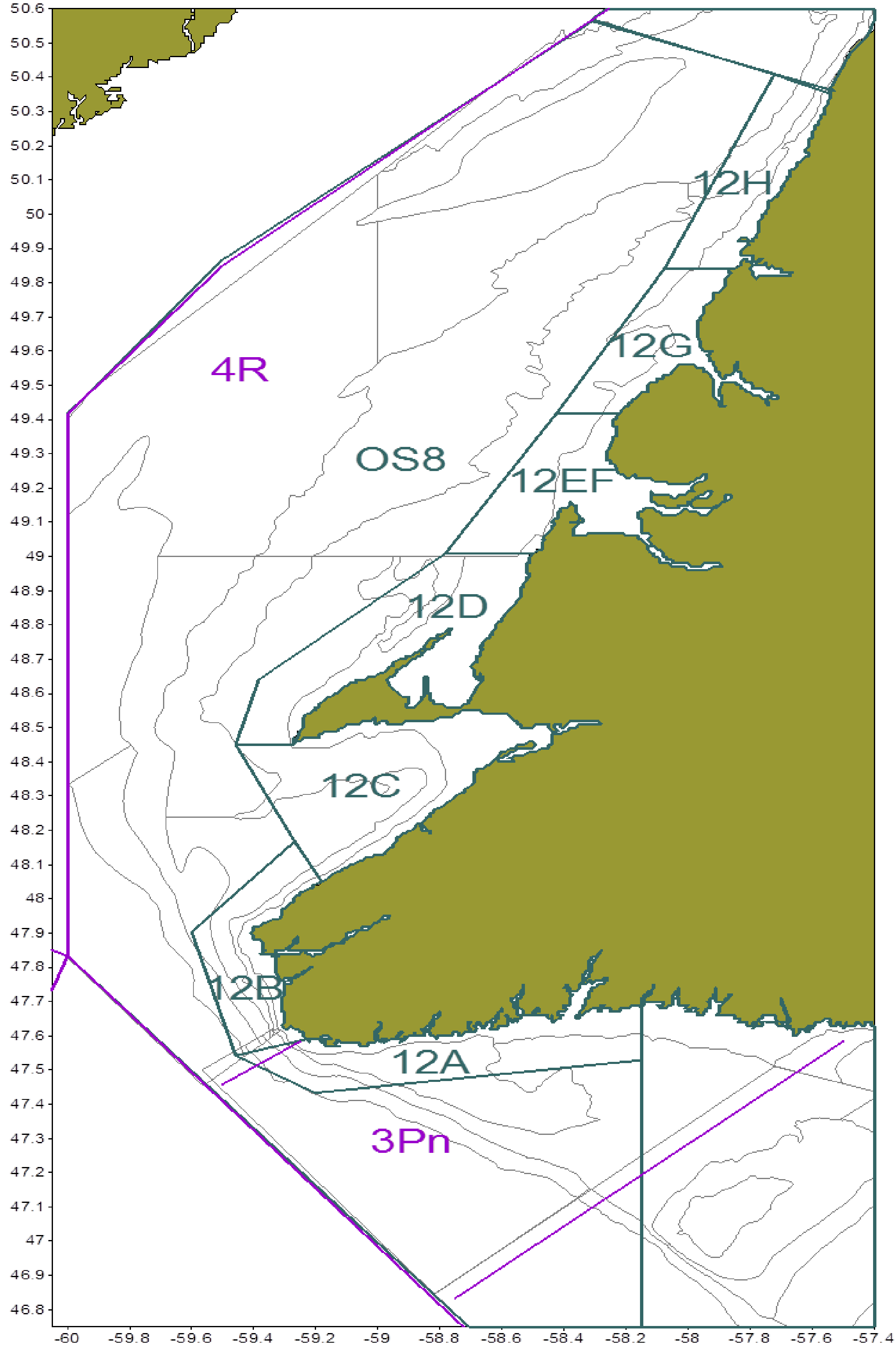

Figure 132. Map of Divs. 4R3Pn showing CMAs and important bathymetric features.

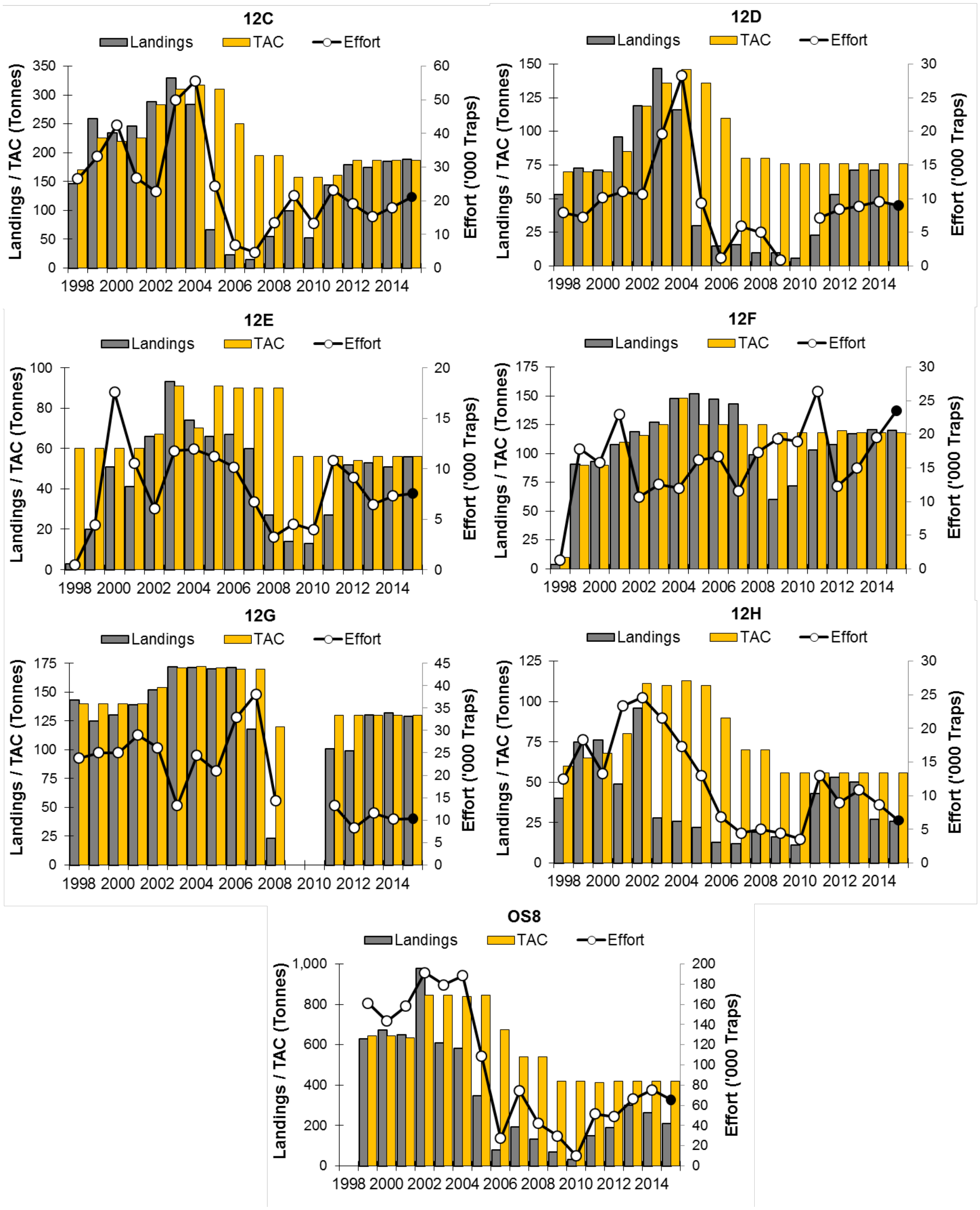

Figure 133. TAC, landings, and estimated effort for CMAs in Divs. 4R3Pn. 2015 effort preliminary.

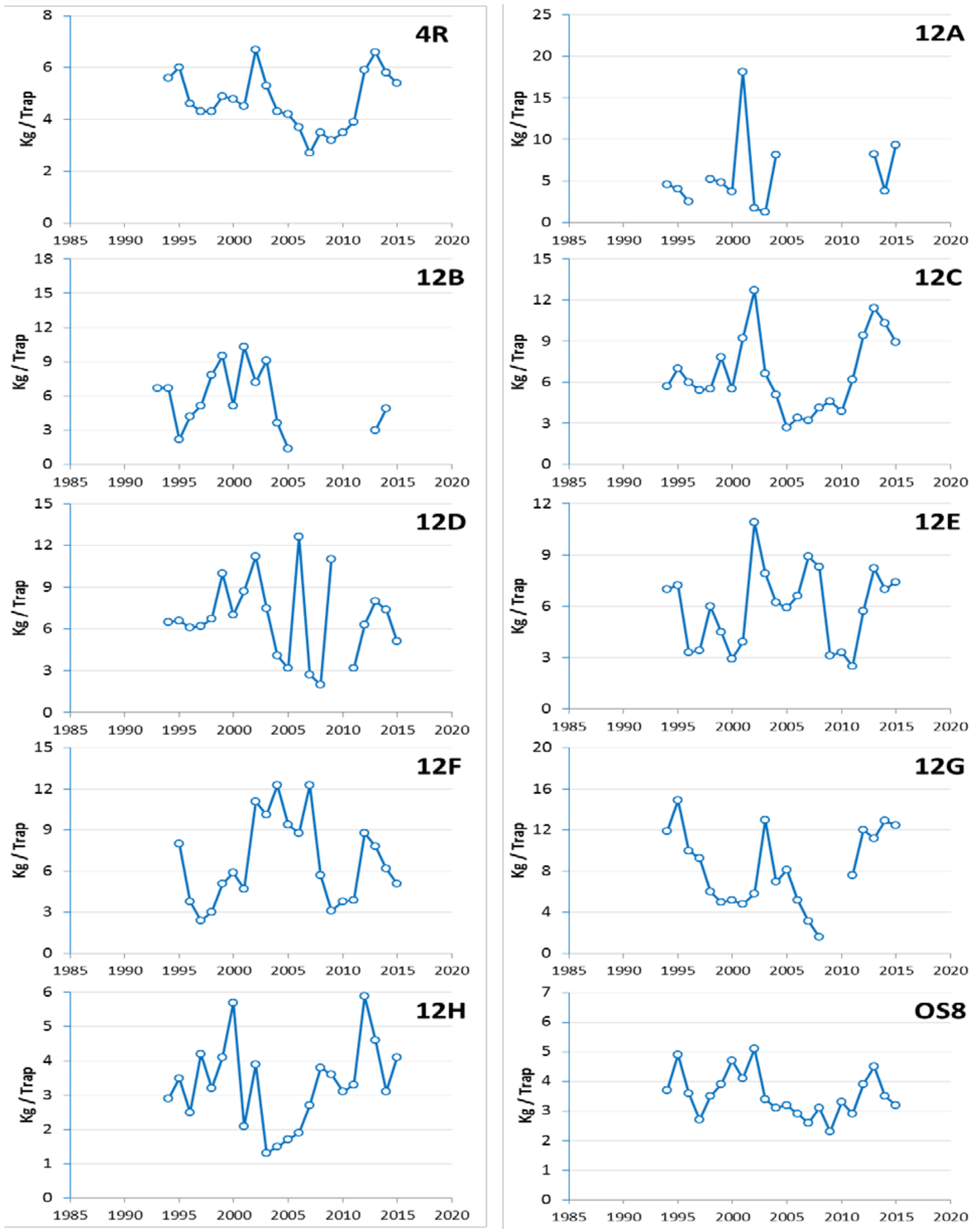

Figure 134. Trends in standardized CPUE for the entirety of Divs. 4R3Pn as well as by CMA.

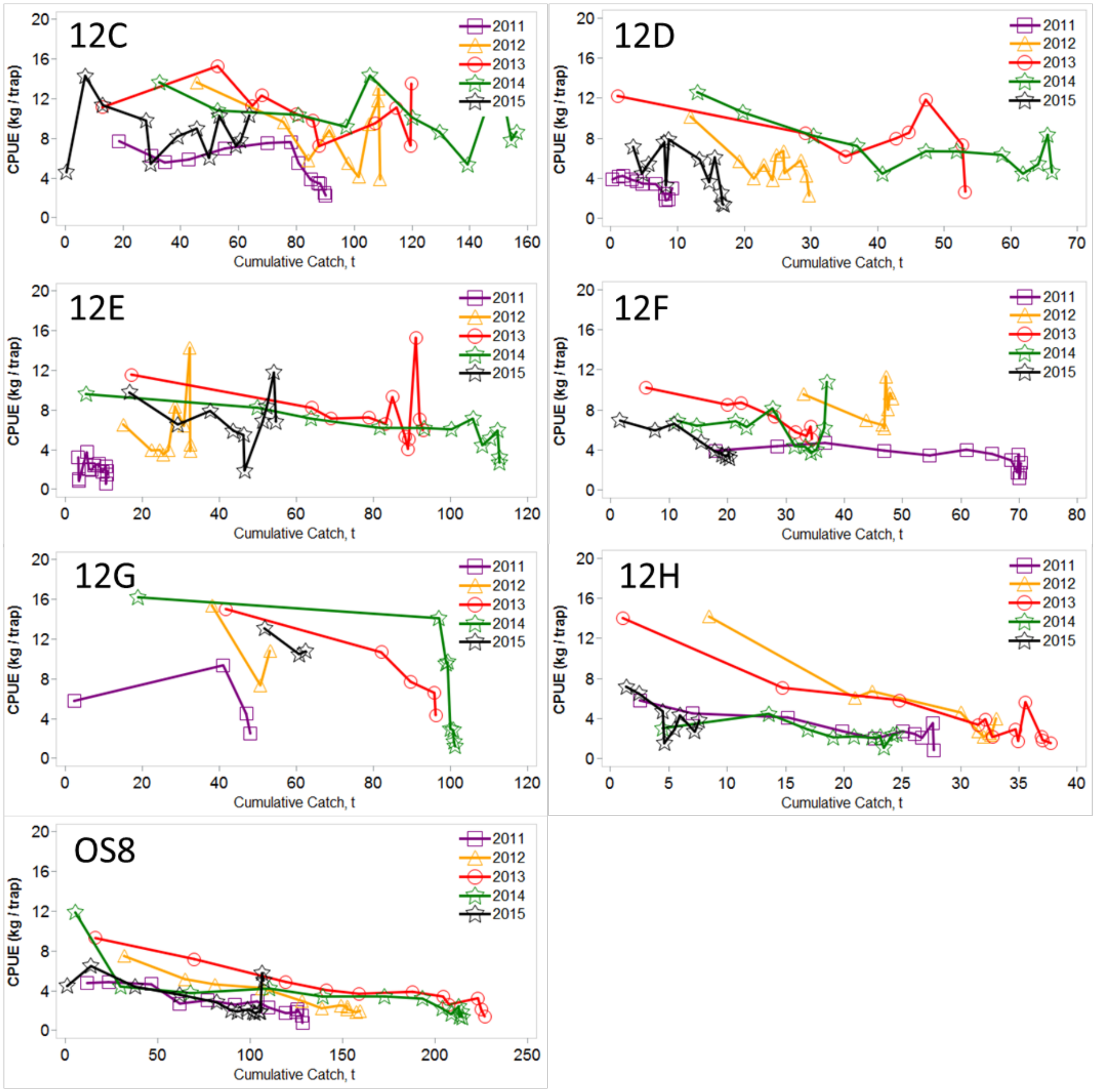

Figure 135. Trends in unstandardized CPUE versus cumulative catch in the fishery for CMAs in Div. 4R3Pn.

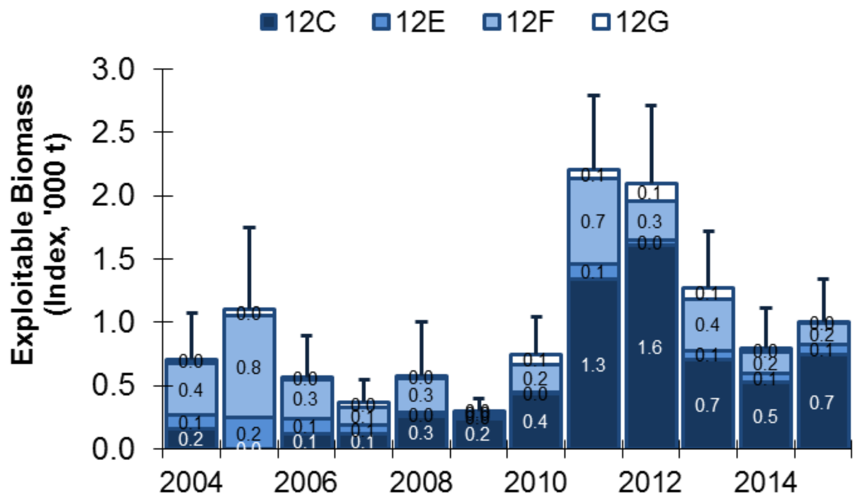

Figure 136. CPS trap survey exploitable biomass index from large-mesh traps for CMAs in Divs. 4R3Pn.

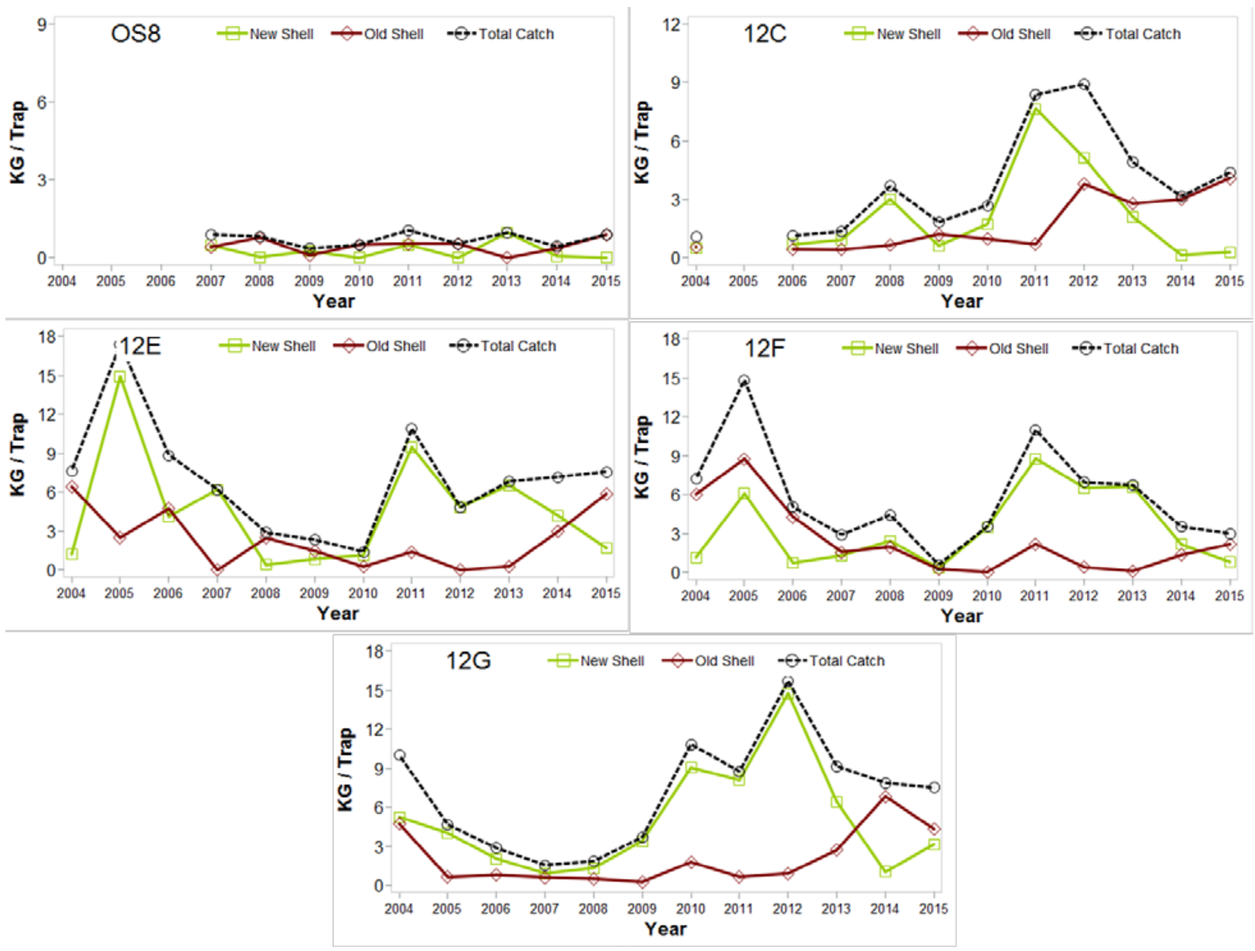

Figure 137. Trends in CPUE by shell condition for legal-sized crabs from core stations in the CPS trap survey in CMAs in Divs. 4R3Pn.

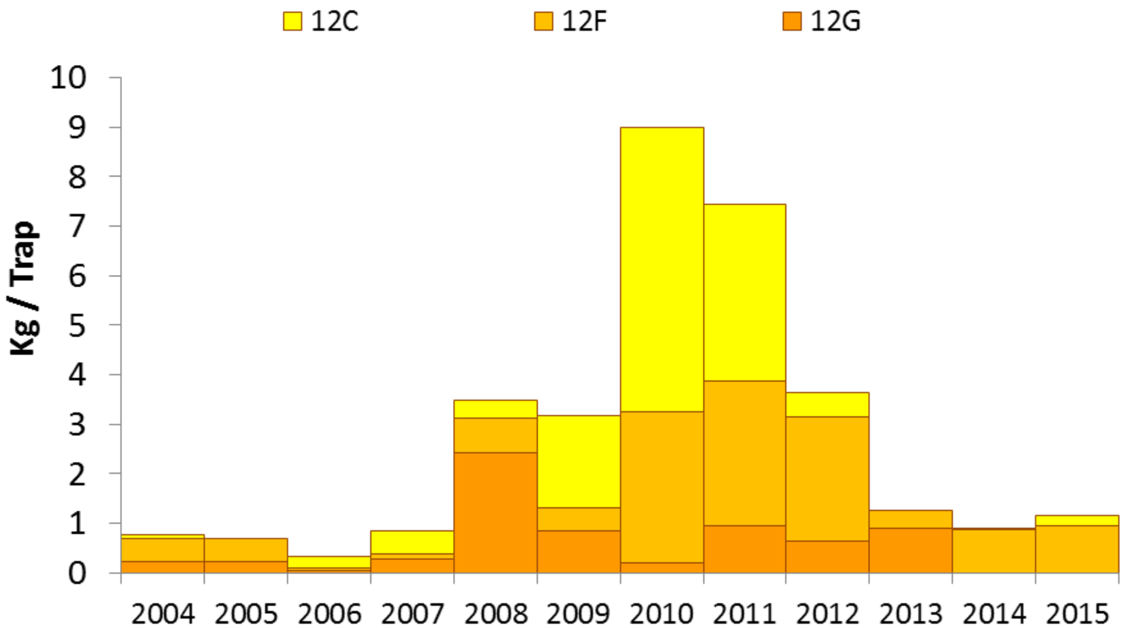

Figure 138. CPS trap survey pre-recruit biomass index from small-mesh traps for CMAs in Divs. 4R3Pn. Index calculated as > 75 mm CW adolescent males.

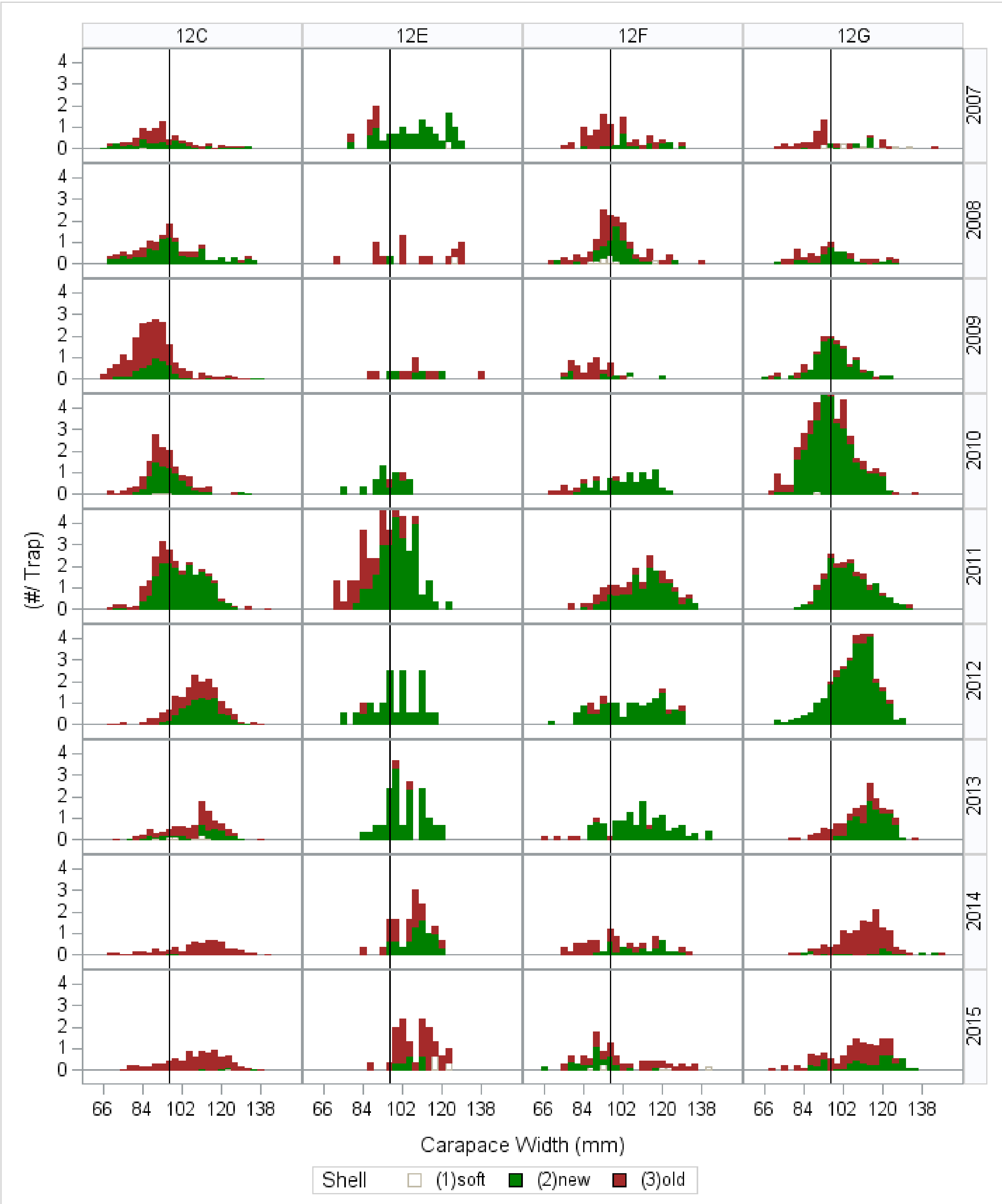

Figure 139. Trends in male carapace width distributions from large-mesh traps at core stations in CMAs in the Divs. 4R3Pn CPS trap survey. The vertical dashed line indicates the minimum legal size.

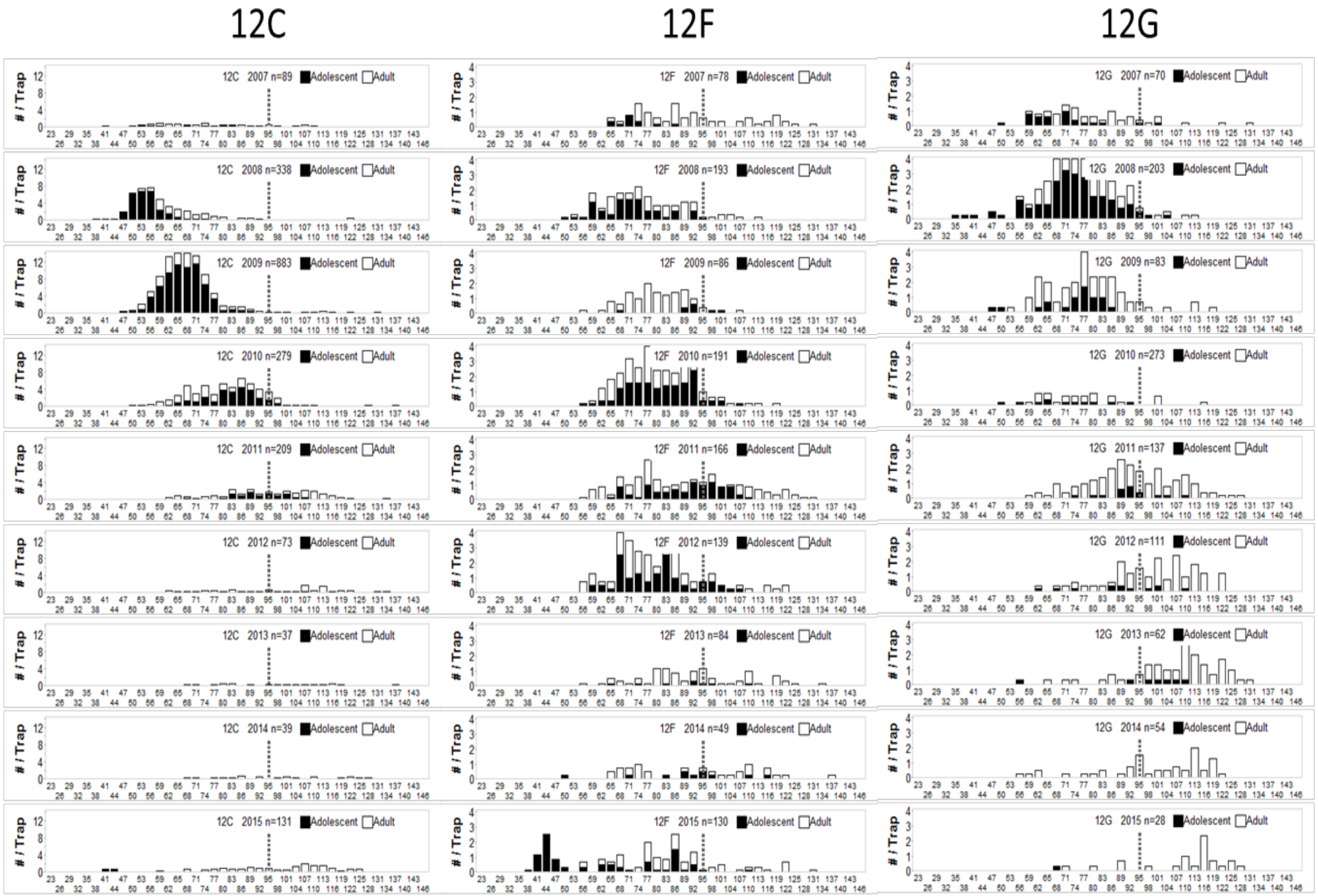

Figure 140. Trends in male carapace width distributions by maturity from small-mesh traps in CMAs in the Divs. 4R3Pn CPS trap survey. The vertical dashed line indicates the minimum legal size.

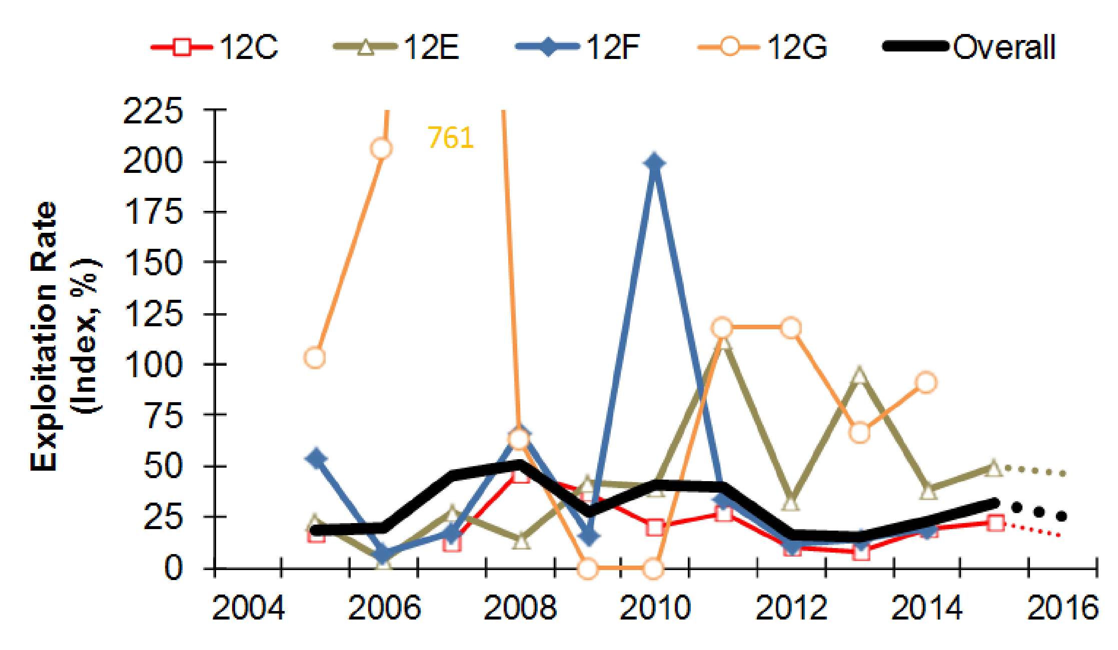

Figure 141. Exploitation rate indices by CMA as well as overall for Div. 4R based on the CPS trap survey. Dashed lines represent 2016 estimates based on status quo landings.