# ASSESSMENT OF NEWFOUNDLAND AND LABRADOR SNOW CRAB

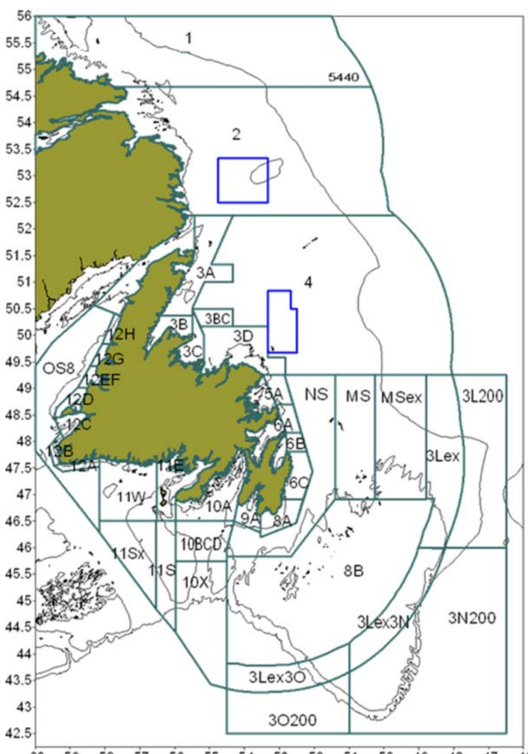


Figure 1. Newfoundland and Labrador Snow Crab Management Areas (CMAs). Blue boxes show trawling and gill-netting closures.

## Context

*The Snow Crab (Chionoecetes opilio) occurs over a broad depth range in the Northwest Atlantic from Greenland to the Gulf of Maine. Distribution in waters off Newfoundland and southern Labrador is widespread and continuous.*

*Crab harvesters use fleets of baited conical traps. The minimum legal size is 95 mm carapace width (CW). This regulation excludes females from the fishery while ensuring that a portion of the adult males in the population remains available for reproduction.*

*Total Allowable Catch (TAC) management was initiated in the late 1980s. This led to the development of multiple TAC-controlled management areas (Fig. 1) with about 2,700 license holders across several vessel fleets under enterprise allocation in 2013. All fleets have designated trap limits, quotas, trip limits, fishing areas within Divisions, and differing seasons. A vessel monitoring system (VMS) was fully implemented in the offshore fleets in 2004.*

*Stock status is assessed annually for inshore and offshore areas (where applicable) within each Northwest Atlantic Fisheries Organization (NAFO) Division. Resource status is evaluated based on trends in fishery catch per unit of effort (CPUE), exploitable biomass indices, recruitment prospects, and mortality indices. Data are derived from multi-species bottom trawl surveys in Divs. 2HJ3KLNOP4R, DFO inshore trap surveys in Divs. 3KLPs, fishery data from logbooks, observer catch-effort data, industry-DFO collaborative trap survey data, as well as biological sampling data from multiple sources.*

*A Regional Peer Review Process meeting was held February 24-26, 2015 in St. John's, NL to assess the status of the Snow Crab resource. Participants included DFO scientists, fisheries managers, and representatives from industry, the Provincial and Nunatsiavut governments, Aboriginal interests, and academia.*

## SUMMARY


- Total **landings** have remained at 50,000-53,000 t since 2007. However, Divs. 3LNO have accounted for a steadily increasing percentage in recent years, from about half in 2009 to 70% in 2014.
- The overall **exploitable biomass** has recently declined. Divs. 3LNO now account 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). **Recruitment** may improve soon thereafter.
- 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 6 to 8 years. However, a warm oceanographic regime suggests weak **recruitment** in the **longer term**.

## Divisions 2HJ

- **Landings** were at their lowest level in two decades in 2013 but increased by 25% to 1,740 t in 2014. **Effort** has been at its lowest level in two decades during the last two years.
- **Catch per unit of effort (CPUE)** has increased since 2012.
- **The exploitable biomass** has increased since 2011, as reflected by continued improvement in the post-season trawl survey index.
- **Recruitment** has increased since 2011.
- Short-term (2-3 year) recruitment prospects are uncertain due to variability in the pre-recruit biomass index.
- **The pre-recruit fishing mortality index** has increased over the past ten years to above the median level.
- The **exploitation rate index** increased steadily from 2007-12 but decreased to a moderate level in the past two years. Maintaining the current level of fishery removals would further reduce the exploitation rate in 2015.

## Division 3K Offshore

- **Landings** declined by half since 2009 to 6,100 t in 2014, their lowest level in two decades. Meanwhile **Effort** has declined by a third.
- **CPUE** declined by half from 2008 to 2011 and has since changed little, remaining near a historic low level.
- The post-season trawl and trap survey **exploitable biomass indices** have both declined steadily since 2008 to be at or near their lowest levels.
- **Recruitment** has been poor since 2009.
- **Recruitment** is expected to remain low in the short term (2-3) years. The post-season trawl and trap survey pre-recruit biomass indices have both declined since 2008 to their lowest levels.
- The **pre-recruit fishing mortality index** has varied at a moderate level since 2009.

- The **exploitation rate index** increased from 2008-10 and has since changed little.
- Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2015.

## Division 3K Inshore

- **Landings** declined from 2,900 t in 2009 to 1,750 t in 2014, due to declines in CMA 3D (Notre Dame Bay) and 3C (Green Bay) where TACs were not taken in most of the past 5 years. Overall, **effort** has declined since 2011.
- **CPUE** has remained low during the past four years in CMAs 3C and 3D, whereas it remained high in CMA 3B (White Bay).
- The CPS (Collaborative post-season) trap surveys indicate that the **exploitable biomass** has remained low in CMAs 3C and 3D in the past 4 years. The DFO trap survey indicates the **exploitable biomass** in CMA 3B has remained high.
- **Recruitment** has been low during the past 3-4 years in CMAs 3C and 3D. **Recruitment** peaked at its highest level in 2012 in CMA 3B but has since declined.
- **Recruitment** is expected to remain low in the short term in CMAs 3C and 3D and to continue to decline in CMA 3B.
- In the last two years, the post-season trap survey-based **exploitation rate index** has changed little in CMA 3D, has declined in 3B and has increased sharply in 3C.
- Data are insufficient to estimate **the pre-recruit fishing mortality index**.
- Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** overall in 2015 with continued high exploitation in CMA 3C.

## Divisions 3LNO Offshore

- **Landings** have remained near their highest level, at about 26,000 t, in the past 3 years. **Effort** declined considerably from 2011-13 but increased slightly in 2014.
- **CPUE** increased from 2009-13 and changed little in 2014.
- The indices of **exploitable biomass** from spring and fall trawl and trap surveys decreased, to differing degrees, in 2014.
- **Recruitment** has declined since 2012.
- **Recruitment** is expected to decline further in the short term (2-3 years). The pre-recruit biomass indices spring and fall trawl and trap surveys have declined since 2010.
- The **exploitation rate index** has changed little over the last four years. The **pre-recruit fishing mortality index** has remained relatively low since 2008.
- Maintaining the current level of fishery removals would likely increase the **exploitation rate** in 2015.

## Division 3L Inshore

- **Landings** have increased gradually since 2010 to a historical high of 8,000 t in 2014 while overall effort has declined.

- **CPUE** has been near its highest level for the past three years but there has been considerable variability among management areas.
- The post-season trap survey index suggests the overall **exploitable biomass** has increased steadily since 2008 to its highest level in the time series. Most management areas have experienced increases in recent years.
- Overall **recruitment** has declined gradually since 2010, although there is considerable variability among management areas.
- **Recruitment** is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in the past two years.
- The post-season trap survey-based **exploitation rate index** has changed little over the time series, with considerable variability among management areas.
- Data are insufficient to estimate a **pre-recruit fishing mortality index**.
- Maintaining the current level of fishery removals would likely decrease the exploitation rate in 2015.

## Subdivision 3Ps Offshore

- **Landings** declined from a peak of 4200 t in 2011 to 2700 t in 2014. Meanwhile, TACs have not been taken and effort has increased to a record high level.
- **CPUE** has steadily declined since 2009 to a record low in 2014.
- The **exploitable biomass**, as indicated by the spring trawl and fall trap survey indices, has been at its lowest level during the past two years.
- Both trap and trawl surveys indicate **recruitment** has declined since 2009.
- Recruitment is expected to remain low in the short term (2-3 years) as pre-recruit biomass indices from both trap and trawl surveys declined rapidly from 2009 to their lowest levels in 2013-14.
- The **exploitation rate index** has been at or near its highest level during the past two years. The **pre-recruit fishing mortality index** has increased steadily since 2010 to its highest level in 2014.
- Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2015.

## Subdivision 3Ps Inshore

- **Landings** remained at 2,500 t from 2011-13 but decreased to 2,200 t in 2014. Effort has increased steadily since 2010.
- **CPUE** remained at a high level from 2010-12 but has declined sharply in the past two years.
- The **exploitable biomass,** as indicated by the post-season trap survey index, declined since 2012 to its lowest level in eight years.
- **Recruitment** declined substantially in the past two years to its lowest level.
- **Recruitment** is expected to remain low for at least 2-3 years. The **pre-recruit biomass** index declined by more than half from 2007-11 and has since changed little.

- The post-season trap survey-based **exploitation rate index** changed little from 2008-13 but nearly doubled in 2014. Data are insufficient to estimate a **pre-recruit fishing mortality index.**
- Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2015.

## Division 4R Offshore

- Data are insufficient to assess resource status.

## Division 4R Inshore

- **Landings** have increased from a historical low of 155 t in 2010 to about 600 t in 2013-14. **Effort** has been stable for the last three years.
- **CPUE** has been near an all-time high for the last three years.
- The **exploitable biomass** index peaked in 2011 and has since declined to its previous level.
- **Recruitment** has declined since 2011 to its lowest level.
- **Recruitment** prospects are unfavourable in the short term (2-3 years). The trap survey index of **pre-recruit-sized males** peaked in 2009 and has since declined to its lowest level.
- The post-season trap survey-based **exploitation rate index** decreased in 2012 and has since changed little.
- Data are insufficient to estimate a **pre-recruit fishing mortality index**.
- Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2015.

# BACKGROUND

## Species Biology

The Snow Crab life cycle features a planktonic larval period, following spring hatching, involving several stages before settlement. Benthic juveniles of both sexes molt frequently, and at about 40 mm carapace width (CW) (~4 years of age) they may become sexually mature.

Crabs grow by molting, in spring. Females cease molting after sexual maturity is achieved at about 40-75 mm CW and do not contribute to the exploitable biomass. However, sexually mature (adolescent) males generally molt annually until their terminal molt, when they develop enlarged claws (adults), which enhances their mating ability. Males molt to adulthood within a size range of about 40-115 mm CW, and so only a portion of any cohort will recruit to the fishery at 95 mm CW. Age is not determined but Snow Crabs are believed to recruit to the fishery at about 10 years of age in warm areas (Divs. 2J3K4R) and at slightly older ages in cold areas (Divs. 3LNOPs), due to less frequent molting at low temperatures (Dawe et al. 2012).

Snow Crab is a highly stenothermal species and temperature has a profound effect on production, early survival, and subsequent recruitment to fisheries (Foyle et al. 1989; Dawe et al. 2008; Marcello et al. 2012). Cold conditions during early life history are associated with increased fishery catch per unit of effort (CPUE) and survey biomass indices 6-10 years later. Low temperature also promotes relatively small size at terminal molt (Dawe et al. 2012), resulting in an increased portion of crabs failing to recruit to the fishery. However, the positive effect of a cold thermal regime on early survival is clearly stronger than the negative effect on size-at-terminal molt.

Adult legal-sized males remain new-shelled with low meat yield throughout the remainder of the year of their terminal molt. They are considered to be pre-recruits until the following year when they begin to contribute to the exploitable biomass as older-shelled adults. Males may live about 6-8 years as adults after the terminal molt.

Snow Crabs undertake an ontogenetic migration from shallow cold areas with hard substrates to warmer deeper areas with soft substrates. Large males are most common on mud or mud/sand, while smaller crabs are common on harder substrates. The Snow Crab diet includes fish, clams, polychaete worms, brittle stars, shrimp, Snow Crab, and other crustaceans. Predators include various groundfish, other Snow Crabs, and seals.

## The Fishery

The fishery began in Trinity Bay (CMA 6A, Fig. 1) in 1967. Initially, crabs were taken as gillnet by-catch but within several years a directed trap fishery developed in inshore areas along the northeast coast of Divs. 3KL. The minimum legal mesh size of traps is 135 mm (5 ¼”), to allow small crabs to escape. Under-sized and new-shelled males that are retained in the traps are returned to the sea and an unknown proportion dies.

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 adjacent to where the license holder resided. During 1982-87 there were major declines in the resource in traditional areas in Divs. 3K and 3L while new fisheries started in Div. 2J, Subdiv. 3Ps, and offshore Div. 3K. A Snow Crab fishery began in Div. 4R in 1993.

Licences supplemental to groundfishing 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 feet (<10.7 m), introduced in 1995, were converted to licenses in 2003. There are now several fleet sectors and about 2,700 license holders.

In the late 1980s quota control was initiated in all management areas of each Division. Current management measures include trap limits, individual quotas, trip limits, fishing areas within divisions, and differing seasons. The fishery has started earlier in recent years and is now prosecuted predominately in spring, resulting in reduced incidence of soft-shelled crabs. A protocol was initiated in 2004 that results in closure of localized areas when the percent soft-shelled crabs within the legal-sized catch exceeds 20%. In Div. 3L, the closure threshold was reduced to 15% in 2009. Mandatory use of the electronic Vessel Monitoring System (VMS) was fully implemented in offshore fleets in 2004, to ensure compliance with regulations regarding area fished.

**Landings** for Divs. 2HJ3KLNOP4R (Fig. 2) increased steadily from 1989 to peak at 69,100 t in 1999, largely due to expansion of the fishery to offshore areas. They decreased by 20% to 55,400 t in 2000 and changed little until they decreased to 44,000 t in 2005, primarily due to a sharp decrease in Div. 3K. Total landings have remained at 50,000 -53,000 t since 2007. However, Divs. 3LNO have accounted for a steadily increasing percentage in recent years, from about half in 2009 to 70% in 2014.

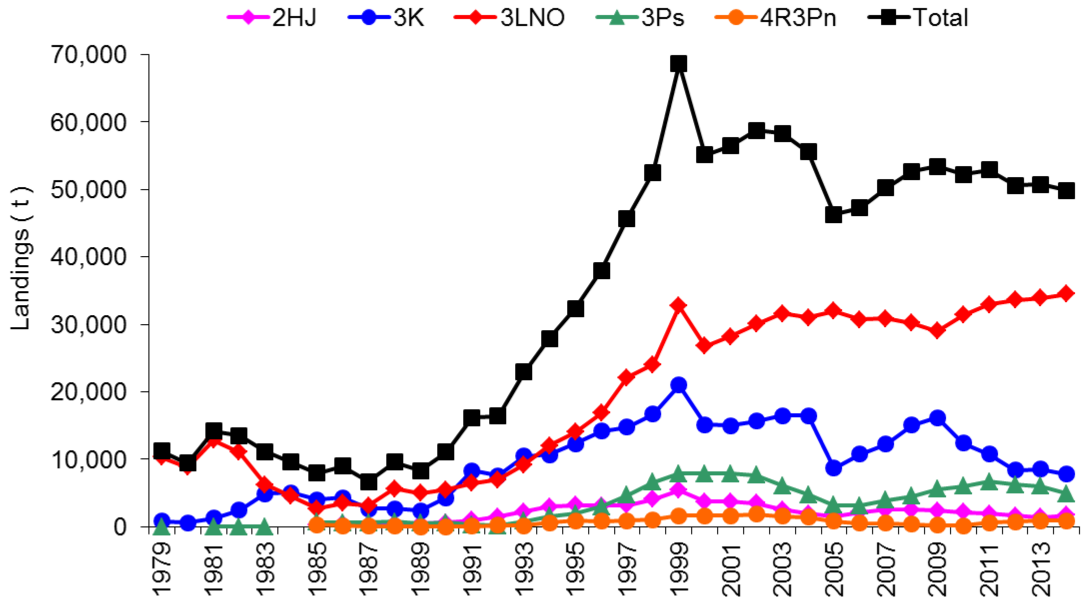


*Figure 2. Trends in landings (t) by NAFO Division and in total.*

Effort has increased since the 1980s and has been broadly distributed in recent years (Fig. 3).

The fishery is sometimes delayed in certain areas and years due to ice conditions (Divs. 2J and 3K) and price disputes. Late fishing seasons are believed to contribute to a high incidence of soft-shelled immediate pre-recruits in the catch. Severe ice conditions can affect the spatial distribution of fishing effort and fishery performance.

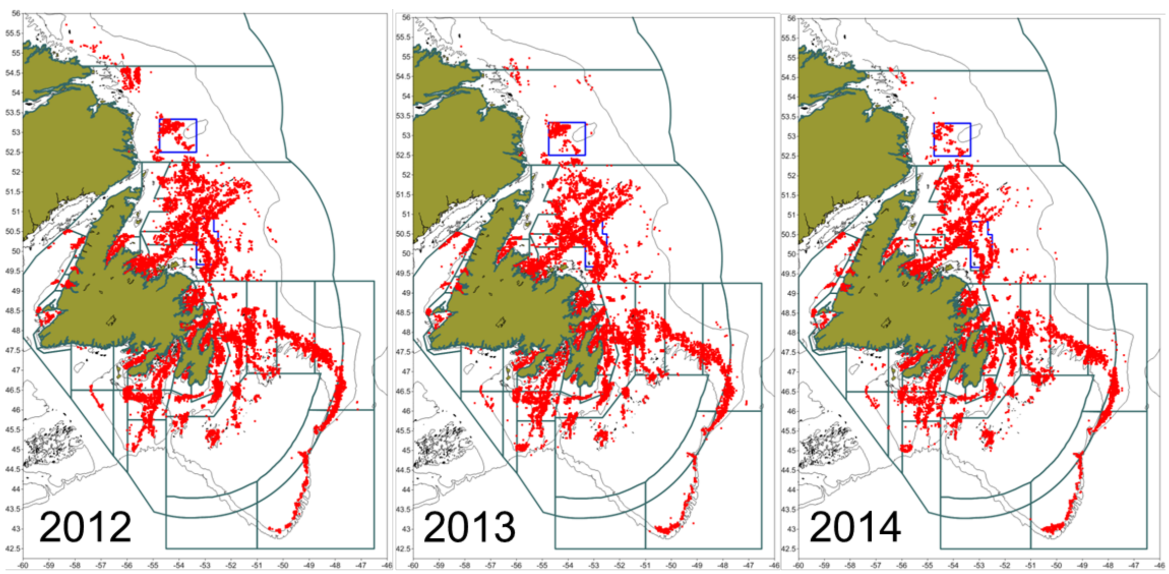


*Figure 3. Spatial distribution of commercial fishing effort during 2012-14.*

## ASSESSMENT

Resource status was evaluated based on trends in fishery **CPUE**, survey **exploitable biomass indices**, fishery **recruitment** prospects and **mortality indices**. Information was derived from multi-species bottom trawl surveys conducted during fall in Divs. 2HJ3KLNO and during spring in Divs. 3LNOPs. A Campelen shrimp trawl has been used in these multi-species surveys beginning in 1995 in Divs. 2HJ3KLNOPs. Fisheries have begun earlier since the mid-2000s and now overlap with the timing of the spring trawl surveys in Divs. 3LNOPs. Information was also available from a fall Industry-DFO collaborative post-season (CPS) trap survey initiated in 2003. Fall post-season surveys provide the most recent data available for the annual assessment. Information is also utilized from DFO inshore trap and trawl surveys in Divs. 3KLPs, fishery data from VMS, logbooks, and observer catch-effort data, as well as biological sampling data from multiple sources. There are multiple CPUE indices used in the assessment, but in offshore areas VMS-based CPUE is considered the most reliable due to complete coverage (excepting Divs. 2HJ) and little element of human error. Bottom temperature data from DFO trawl surveys were used to develop ocean climate indices toward inferring long-term recruitment prospects.

The resource is assessed separately for offshore and inshore areas of each division, where appropriate (Divs. 3KLPs4R); there is no distinction between inshore and offshore areas in Divs. 2HJ (Fig. 1). Divs. 3LNO offshore is assessed as a unit because the offshore fishery is managed at that spatial scale. More data are available for offshore than inshore areas in most Divisions. Trawl survey data are used only for offshore areas because these surveys have not consistently extended into inshore areas. Observer coverage and sampling has also been more extensive in offshore than inshore areas. Also, VMS is used only on offshore vessels.

Trawl survey abundance and biomass indices are calculated based on a set of “core strata” that was common to most years, especially recent years, and does not include inshore strata or deep (>730 m) slope strata that have not been regularly sampled.

The capture efficiency of Snow Crab by the survey trawl is unknown but low. Trawl efficiency is directly related to substrate type and crab size, and so varies considerably spatially. Efficiency is lower and more variable on hard substrates than on soft substrates. Efficiency also varies annually but annual and spatial variation also cannot be quantified.

Spring (Divs. 3LNOPs) and fall (Divs. 2HJ3KLNO) bottom trawl surveys provide data that are used to predict changes in biomass and recruitment for the upcoming fishery in the same year (spring Divs. 3LNOPs) or the following year (fall Divs. 2HJ3KLNO). These surveys, based on a stratified random sampling scheme, provide an index of the exploitable biomass that is expected to be available for the upcoming fishery. This exploitable biomass index is based on only adults of legal size (≥95 mm CW). It is used together with an exploitable biomass index (all legal-sized crabs) from the CPS trap survey in offshore areas to evaluate trends in the exploitable biomass. The inshore CPS trap survey exploitable biomass index is compared with commercial CPUE and catch rates from inshore DFO trap surveys, where available (Divs. 3KLPs).

Bottom trawl surveys also provide data on recruitment. Recent changes in recruitment are inferred from changes in survey biomass indices in relation to landings. Recruitment prospects for the upcoming fishery (in the next year) are inferred from biomass indices or catch rates of new-shelled legal-sized adults (immediate pre-recruits) from post-season or in-season trawl surveys. Trawl surveys also provide an index of pre-recruit biomass, based solely on adolescent (non-terminally-molted) males larger than 75 mm CW from spring and fall surveys. The adolescents of these groups would recruit in the short term (about 2-3 years) following the upcoming fishery. Short-term recruitment prospects are also inferred from biomass indices or catch rates of sub-legal-sized (‘under-sized’) males from observer at-sea sampling and post-season trap surveys. However, these males include an unknown portion of under-sized adults (terminally molted) that will never recruit. The portion of sub-legal-sized crabs in the CPS trap survey that are terminally molted is inferred from the percentage of these crabs that are old-shelled, since most old-shelled crabs are terminally molted adults as opposed to 'skip molted' adolescents.

Trawl surveys also provide abundance indices for males of all sizes. The abundance index for the smallest crabs consistently captured (12-30 mm CW) may indicate recruitment prospects about 6-7 years later, depending on NAFO Division. Longer-term recruitment prospects are inferred from the relationship of exploitable biomass indices (CPUE and survey) with ocean climate indices from 6-10 years earlier (Dawe et al. 2008, Marcello et al. 2012). The index used was the percentage of bottom area covered by cold water, representing small crab habitat. This 'habitat index' is derived using data from fall surveys based on temperatures <2°C in the deep warm northern areas (Divs. 2J and 3K), whereas they are derived using data from spring surveys in the shallower colder southern areas, based on temperatures <1°C (Divs. 3LNOPs). The relationships of habitat indices with the longer time series of CPUE are shown; relationships with survey biomass indices are similar. Trawl surveys also provide abundance indices of mature females. Females from survey catches are also sampled to determine the proportion carrying full clutches of viable eggs. Together these data may be used to infer changes in reproductive potential.

The CPS trap survey, based on a fixed-station grid design, is more spatially limited than the trawl survey as it targets only portions of commercial fishing grounds. A set of core stations was selected from this survey for calculating catch rates (number/trap) of legal-sized adults. These core stations represented those that were common to most years, especially recent years. A stratification scheme, developed for previous assessments, established core strata for estimating biomass indices. The survey also includes small-meshed traps, deployed on select stations, to provide data on long-term recruitment prospects.

Fishery-induced mortality is a function of the proportion of the exploitable population that is harvested and the proportion of the pre-recruit population that dies as a result of being caught, handled, and released. Trends in exploitation rate are inferred from changes in the exploitation rate index, defined as landings divided by the exploitable biomass index from the most recent trap or trawl survey.

The fraction of pre-recruits that are handled and released in the fishery, referred to as the pre-recruit fishing mortality index (PFMI), reflects an unknown mortality on released pre-recruits (adolescents). The total catch (T) of undersized crabs (adolescent plus adult) is estimated by multiplying the total landings of all crabs by the ratio of undersized to landed crabs in observed catches. The fraction (U) that is handled and released is estimated as T divided by the trawl survey estimate of undersized crabs in the previous survey. The fraction U is then considered the same as the corresponding fraction for adolescents only (i.e. the PFMI). U is probably greatly overestimated because the trawl misses many of the crabs, especially smaller crabs, in its path.

The percentage (by weight) of the total catch handled and released is a function of relative biomasses of pre-recruit and exploitable crabs. This implies a possible management strategy of maximizing yield-per-recruit. For example, reducing the catch (and associated effort) when the percentage released is high may result in greater yield-per-recruit and overall long-term yield if the numbers lost due to pre-recruit mortality exceeds the loss due to natural mortality of exploitable crabs.

## Overall Resource Status, Divisions 2HJ3KLNOP4R

Multi-species trawl surveys indicate that the exploitable biomass was highest at the start of the survey series (1995-98, Fig. 4). It declined from the late 1990s to 2003 and then increased to about 2009. The overall exploitable biomass has recently declined. However, both the trap and trawl surveys indicate that Divs. 3LNO have accounted for a steadily increasing percentage in recent years, such that Divs. 3LNO now account for most of the biomass.

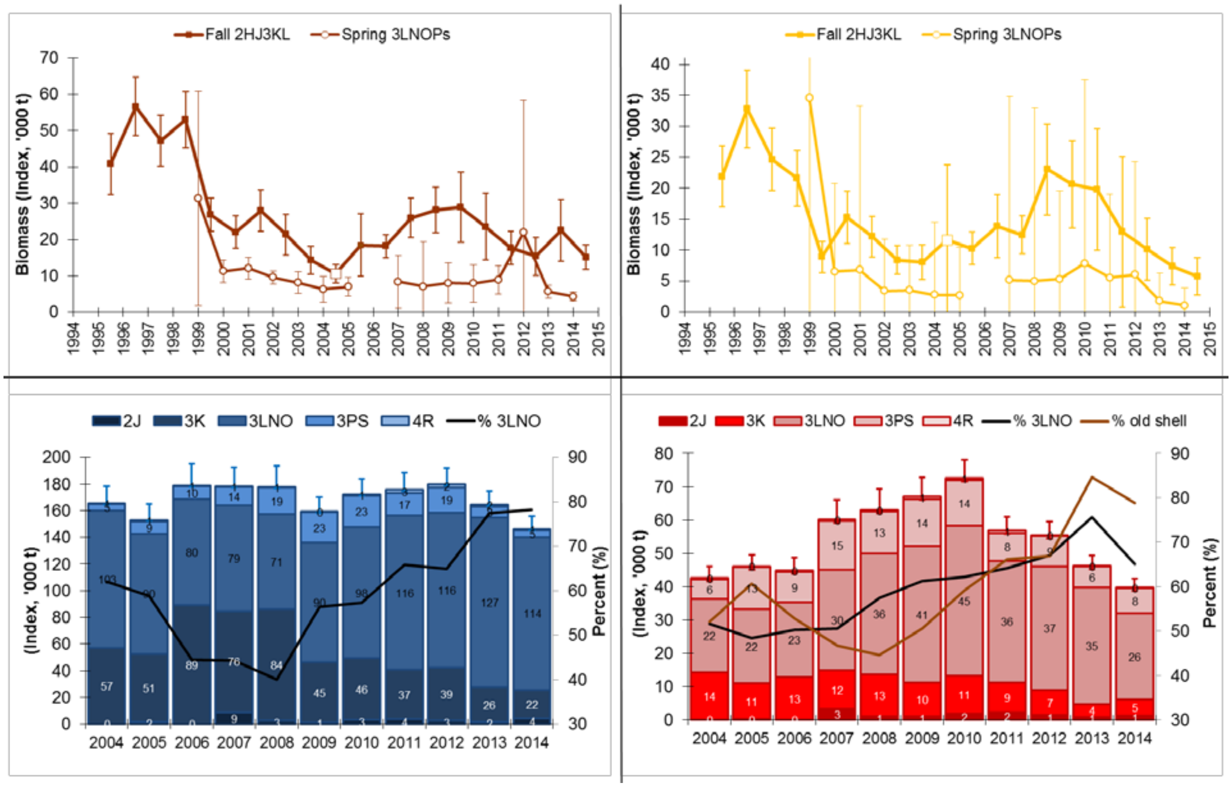


*Figure 4. Trends in exploitable biomass indices (left) and pre-recruit biomass indices (right) from multi-species offshore surveys during fall (Divs. 2HJ3KL) and spring (Divs. 3LNOPs) (above) and from fall post-season trap surveys throughout inshore and offshore Divs. 2J3KLNOPs4R (below). The heavy line overlain on the trap-based indices represents the percentage of the index derived from Divs. 3LNO whereas the lighter line represents the percentage of sub-legal-sized crabs that were old-shelled. Note that season-specific trawl survey indices are not additive due to differences in trawl efficiency and open symbols in the fall series and missing points in the spring series denote incomplete survey years.*

Overall, **recruitment** has declined in recent years and is expected to decline further in the short term (2-3 years) but it may improve soon thereafter. Trap and trawl survey biomass indices of pre-recruits (Fig. 4) increased from 2006-07 to 2009-10 due to increases in the South (Divs. 3LNOPs). Both the trap and trawl surveys indicate that Divs. 3LNO have accounted for an increased percentage in recent years. Survey biomass indices of pre-recruits have recently declined in all areas except Divs. 2HJ. However, the emergence of a pulse of small crabs, associated with cooling oceanographic conditions in the past three years, suggests a modest increase in recruitment within some NAFO Divisions (2J3KL) in about 6 to 8 years. A warm oceanographic regime suggests weak **recruitment** in the **longer term** (Fig. 5). The ocean climate indices have varied considerably over the past decade, introducing uncertainty beyond the short term. However, the overall trend is warming, with record warm conditions in 2011.

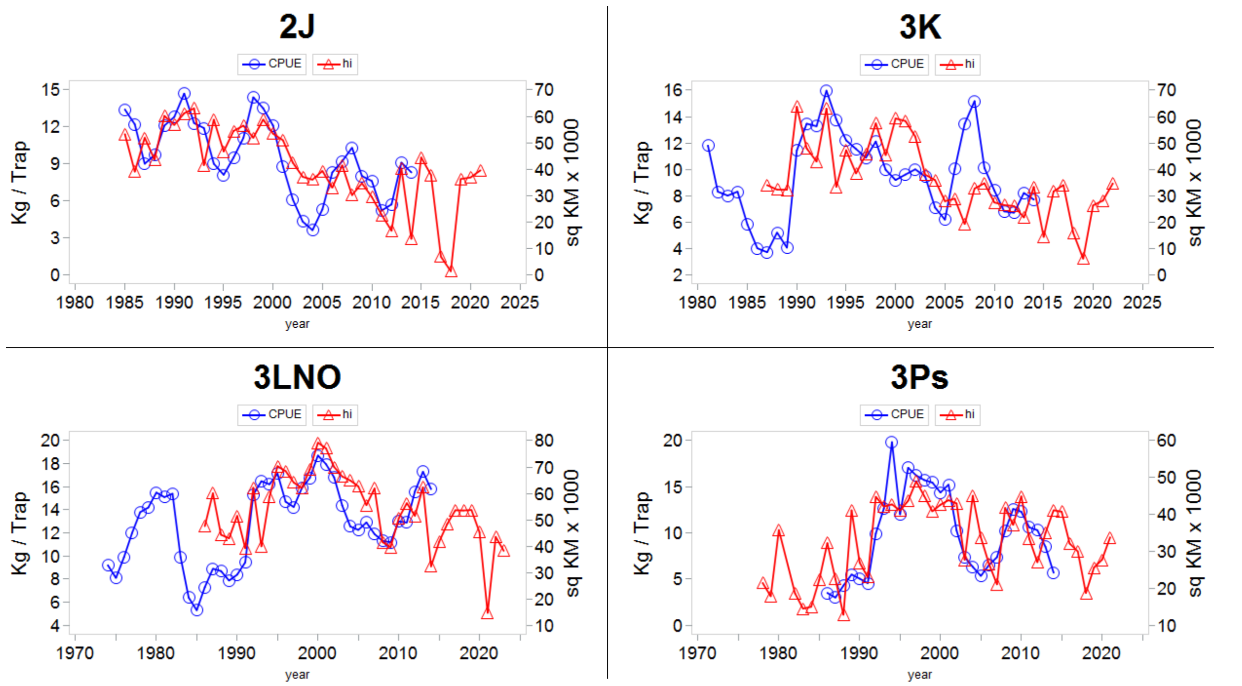


*Figure 5. Relationship of CPUE with habitat indices (HI) for Divs. 2J3KLNOPs at delays of 7-8 years for Divs. 2J3KPs and 10 years for Divs. 3LNO. Delay of best fit was determined by pairwise correlation analysis.*

# Resource Status, Divisions 2HJ (CMAs 1, 2)

## Commercial Fishery

**Landings** (Fig. 6) peaked in 1999 at 5,400 t, declined to 1,500 t in 2005, and increased by 60% to 2,400 t in 2008. They then declined to 1,380 t in 2013, their lowest level in two decades, but increased by 25% to 1,740 t in 2014. Effort has been at its lowest level in two decades during the last two years.

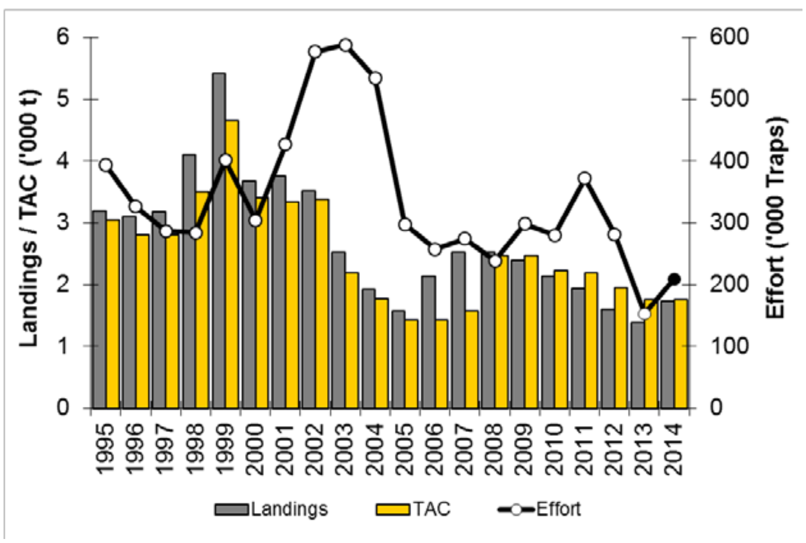


*Figure 6. Trends in TAC, landings, and fishing effort in Divs. 2HJ. The most recent estimate of effort is preliminary due to incomplete logbook data.*

Commercial catch rate (CPUE) is usually best reflected in the logbook index in this area because observer coverage is low and many vessels are not equipped with VMS. Logbook CPUE has oscillated over the time series (Fig. 7). CPUE has increased since 2012. However the change in 2014 is unclear because the three CPUE indices disagreed and 2014 logbook index is based on data from only about half of the fishery.

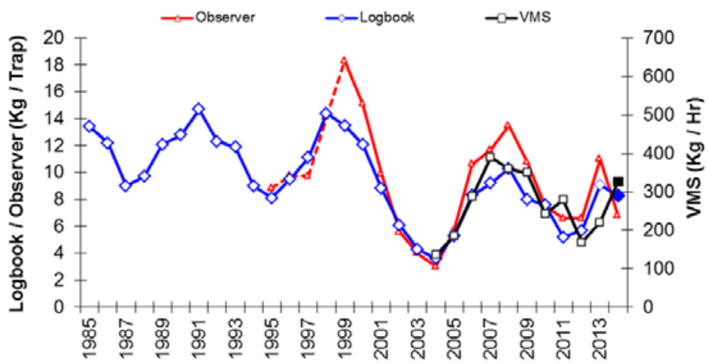


*Figure 7. Trends in Divs. 2HJ commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.*

### Biomass

The exploitable biomass, as reflected by the post-season trawl survey index, has increased from its recent low in 2011. The trawl survey indicates that the exploitable biomass has contracted southward in recent years with virtually none of the exploitable biomass in Div. 2H since 2011. The post-season trap survey index also increased in 2014 (Fig. 8), but this index is considered less reliable than the trawl survey index because of limited spatial coverage by the trap survey in this area.

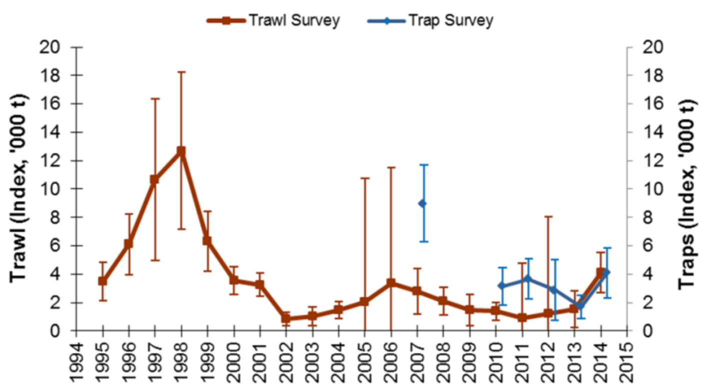


*Figure 8. Trends in the Divs. 2HJ exploitable biomass indices based on post season trawl and trap surveys. The trap survey was conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95 % confidence intervals.*

### Recruitment

The exploitable biomass (Fig. 8) is dominated by new-shelled recently recruited animals. **Recruitment** has increased since 2011, as reflected by an increase in the biomass index of new-shelled recruits in both surveys. Short-term (2-3 year) recruitment prospects are uncertain due to variability in the pre-recruit biomass indices from both surveys (Fig. 9).

The emergence of a modal group of small (12-30 mm CW) crabs suggests a modest increase in recruitment in about 6 years. The habitat index has varied considerably over the past 8 years (Fig. 5), introducing uncertainty. However, a warm oceanographic regime suggests low **recruitment** in the **longer term**.

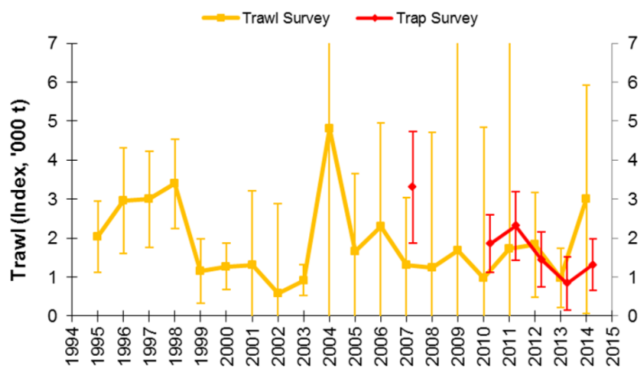


*Figure 9. Trends in Divs. 2HJ pre-recruit biomass indices from the post-season trawl survey and the CPS trap survey. The trap survey was conducted only in the southern portion of the Division (Hawke Channel) in 2008 and 2009. Error bars are 95% confidence intervals.*

### Mortality

The **exploitation rate index** declined from 2003 to 2007 (Fig. 10). It increased steadily from 2007-12 but decreased to a moderate level in the past two years. The **pre-recruit fishing mortality index** has increased over the past ten years to above the median level. The **percentage of the catch released** in the fishery decreased from 35% in 2012 to 20% in 2013 before increasing to almost 30% in 2014.

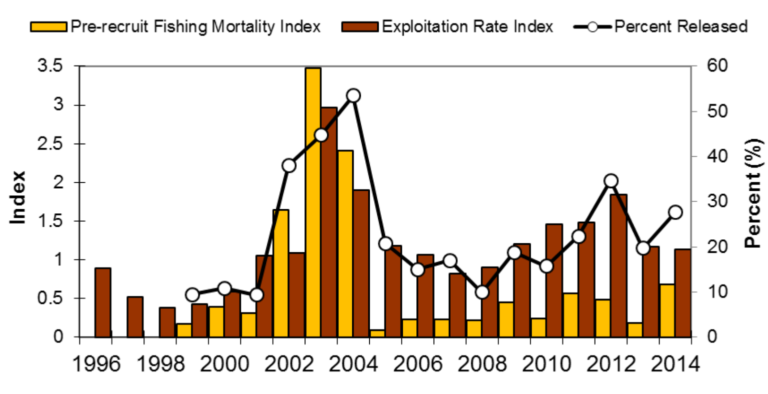


*Figure 10. Trends in the Divs. 2HJ exploitation rate and pre-recruit fishing mortality indices and percentage of the catch released in the fishery.*

## Resource Status, Division 3K Offshore (CMAs 3A, 3BC, 4)

### Commercial Fishery

**Landings** most recently peaked at 13,300 t in 2009 but since declined by half to 6,100 t in 2014, their lowest level in two decades. Meanwhile **effort** has declined by a third (Fig. 11).

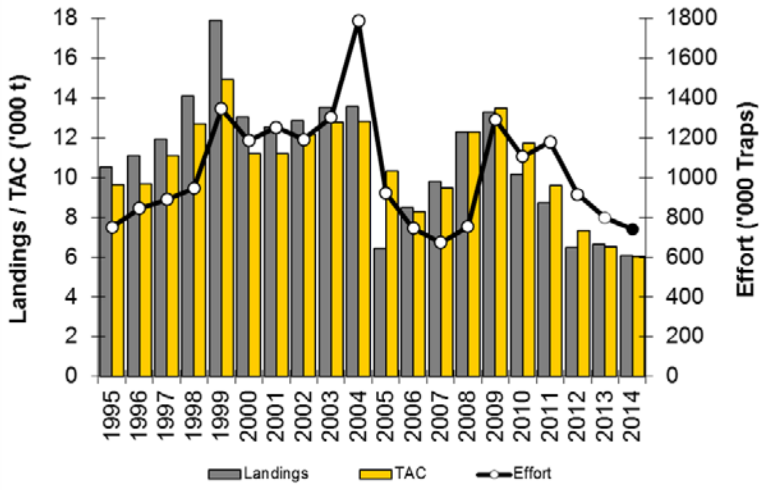


*Figure 11. Trends in TAC, landings, and fishing effort in Div. 3K offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

Commercial **CPUE** (Fig. 12) indicates substantial deterioration of fishery performance in recent years. It declined by half from 2008 to 2011 and has since changed little, remaining near a historic low level.

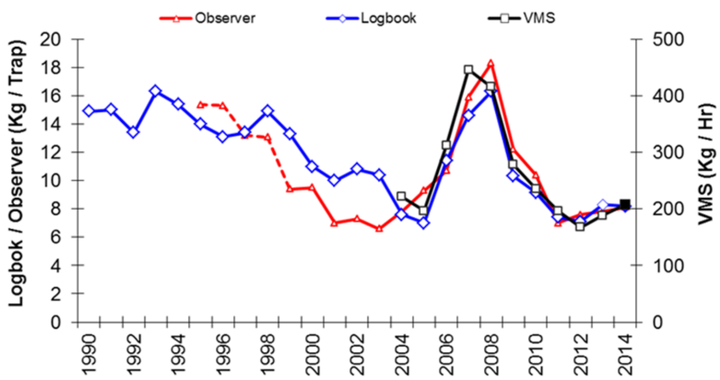


*Figure 12. Trends in Div. 3K offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.*

### Biomass

The exploitable biomass, as reflected by the post-season trawl and trap indices (Fig. 13), has declined steadily since 2008 to be at or near its lowest level.

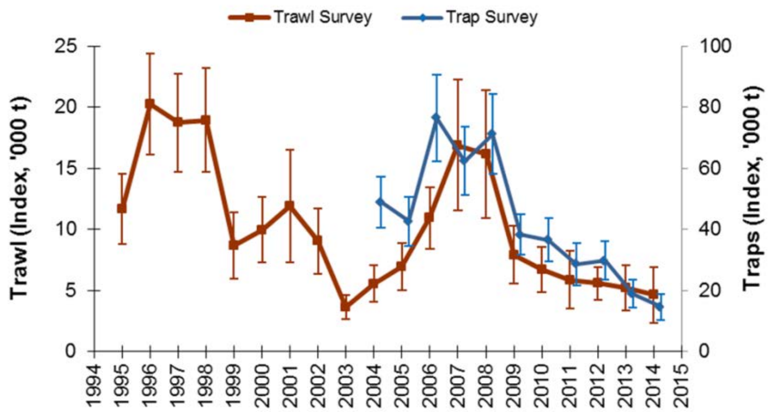


*Figure 13. Trends in the Div. 3K offshore exploitable biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.*

### Recruitment

**Recruitment** has been poor since 2009, as reflected by a declining exploitable biomass (Fig. 13) while landings have been decreasing (Fig. 11). The recent decrease in recruitment was potentially exacerbated by a high handling mortality on soft-shelled immediate pre-recruits in the fishery during recent years. However, in 2013 and 2014 there was little soft-shelled crab in the fishery, despite low catch rates, reflecting especially poor recruitment in the past 2 years.

Recruitment is expected to remain low in the short term (2-3) years. The post-season trawl and trap survey pre-recruit biomass indices have both declined since 2008 to their lowest levels (Fig. 14).

The emergence of a modal group of small (12 -30 mm CW) crabs suggests a modest increase in recruitment in about 7years. The habitat index has varied considerably over the past 8 years (Fig. 5), introducing uncertainty. However, a warm oceanographic regime suggests low **recruitment** in the **longer term**.

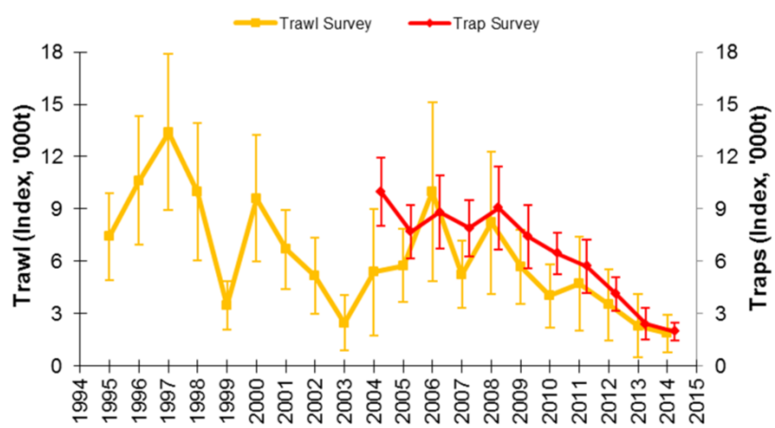


*Figure 14. Trends in Div. 3K offshore pre-recruit biomass indices based on post-season trawl and trap surveys. Error bars are 95 % confidence intervals.*

### Mortality

The **exploitation rate index** increased from 2008-10 and has since changed little (Fig. 15).

The **pre-recruit fishing mortality index** has varied at a moderate level since 2009. The **percentage of the catch released** in the fishery decreased from about 20% in 2012 to about 10% in 2014, while exploitable biomass declined.

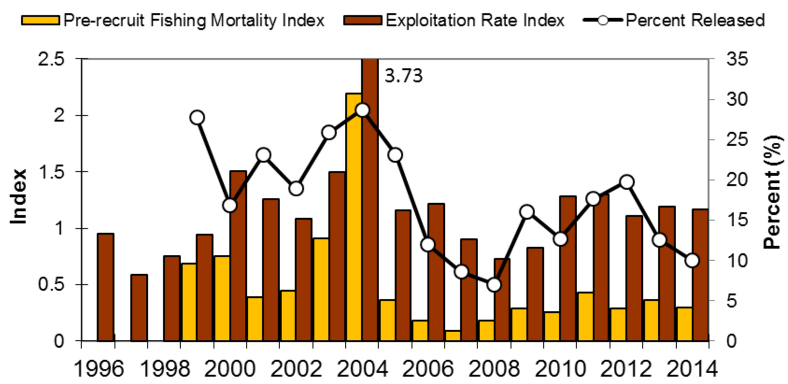


*Figure 15. Trends in the Div. 3K offshore exploitation rate and pre-recruit fishing mortality indices and percentage of the catch released in the fishery.*

## Resource Status, Division 3K Inshore (CMAs 3B, 3C, 3D)

### Commercial Fishery

**Landings** (Fig. 16) have oscillated since 1995. They have declined from their most recent peak in 2009 to 1,750 t in 2014 due to declines in CMA 3D (Notre Dame Bay) and 3C (Green Bay) where TACs were not taken in most of the past 5 years. Overall, **effort** has declined since 2011.

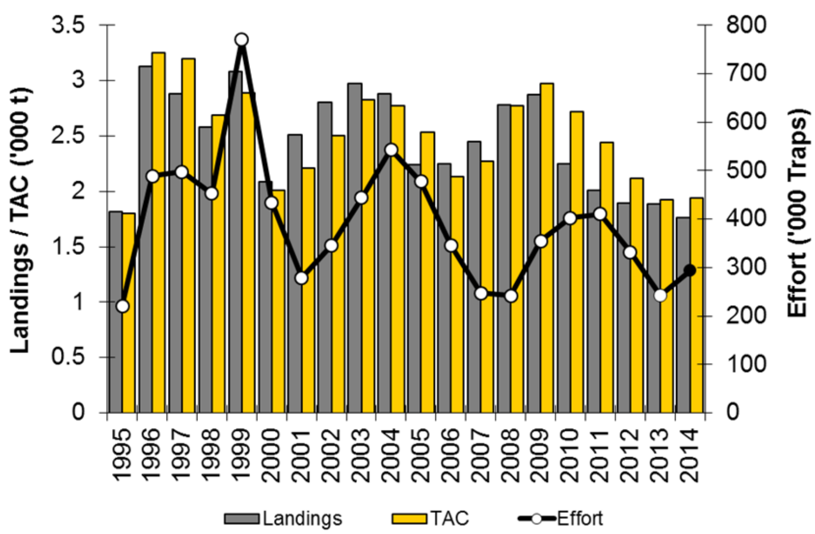


*Figure 16. Trends in TAC, landings, and fishing effort in Div. 3K inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

Commercial **CPUE** (Fig. 17) declined by more than half from 2008 to 2011. It has remained low during the past four years in CMAs 3C and 3D, as reflected in the overall index, whereas it remained high in CMA 3B.

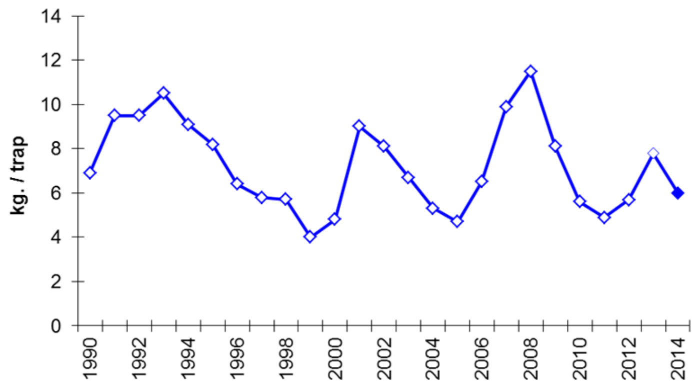


*Figure 17. Trend in Div. 3K inshore commercial logbook CPUE. The most recent logbook and VMS estimates are preliminary due to incomplete data.*

### Biomass

The overall **exploitable biomass**, as indicated by the CPS trap survey, decreased from 2007 to 2009 and has since fluctuated (Fig. 18). It indicates that the **exploitable biomass** has remained low in CMAs 3C and 3D in the past 4 years. The apparent low biomass in CMA 3B in 2014 is likely an underestimate; the DFO trap survey indicates the **exploitable biomass** in CMA 3B has remained high.

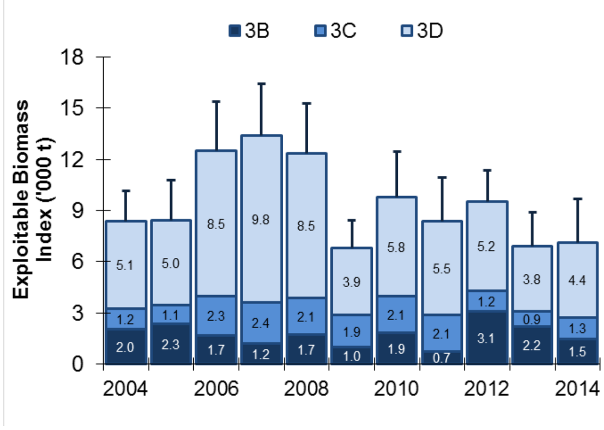


*Figure 18. Exploitable biomass index based on the CPS trap survey in inshore Div. 3K. Error bars are upper 97.5% confidence bounds.*

### Recruitment

The exploitable biomass (Fig. 18) is dominated by new-shelled recently recruited animals. **Recruitment** has been low during the past 3-4 years in CMAs 3C and 3D, as indicated by declining biomass of new-shelled recruits in those areas. It peaked at its highest level in 2012 in CMA 3B but has since declined. **Recruitment** is expected to remain low in the short term in CMAs 3C and 3D and to continue to decline in CMA 3B. The CPS post-season trap survey pre-recruit biomass index (Fig. 19) has been variable in CMAs 3C and 3D in recent years whereas it has declined since 2010 in CMA 3B. The overall percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, has changed little in the past four years (Fig. 19).

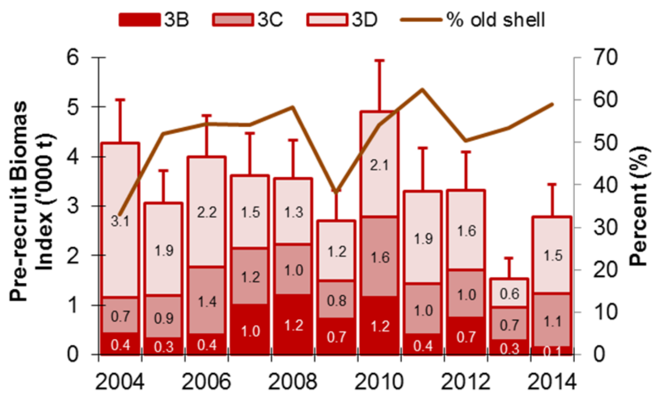


*Figure 19. Pre-recruit biomass index from the CPS trap survey in inshore Div. 3K with percentage of pre-recruit-sized crabs with old shells. Error bars are upper 97.5% confidence bounds.*

### Mortality

The CPS survey-based overall **exploitation rate index** has changed little throughout the time series (Fig. 20). However, there was considerable variability among management areas. In the last two years, it has changed little in CMA 3D, has declined in CMA 3B and has increased sharply in CMA 3C. Data are insufficient to estimate **the pre-recruit fishing mortality index**.

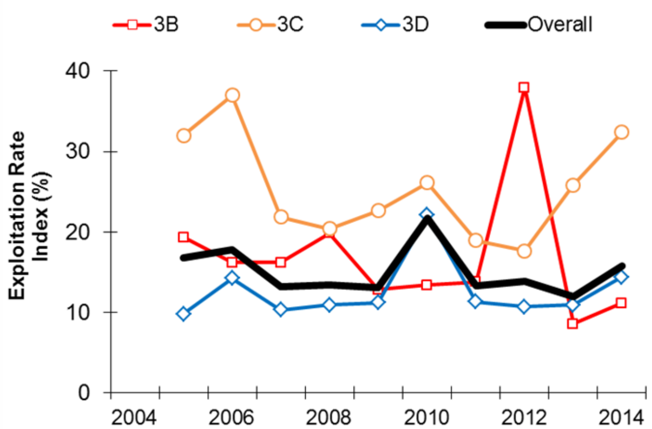


*Figure 20. Exploitation rate index from the CPS trap survey in inshore Div. 3K.*

## Resource Status, Divisions 3LNO Offshore (CMAs NS, MS, MSex, 3Lex, 3Lex3N, 3Lex3O, 3L200, 3N200, 3O200, 8B)

### Commercial Fishery

**Landings** (Fig. 21) have remained near their highest level, at about 26,000 t, in the past 3 years. **Effort** declined considerably from 2011-13 but increased slightly in 2014.

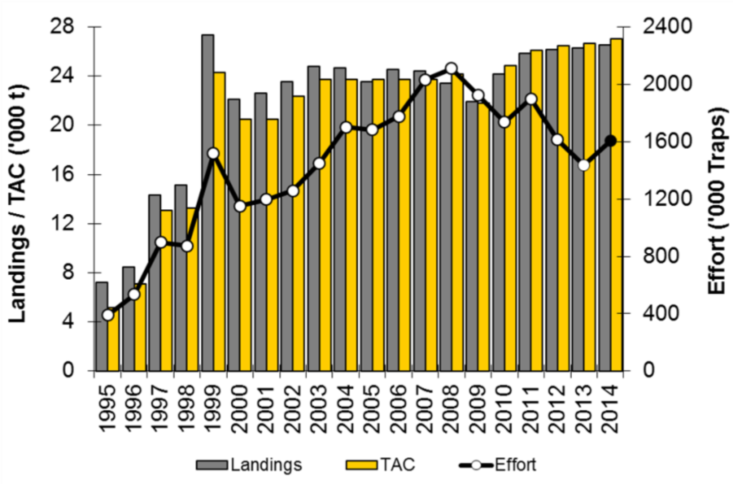


*Figure 21. Trends in TAC, landings, and fishing effort in Divs. 3LNO offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** declined to its lowest level in 2008 (Fig. 22). It increased from 2009-13 and changed little in 2014.

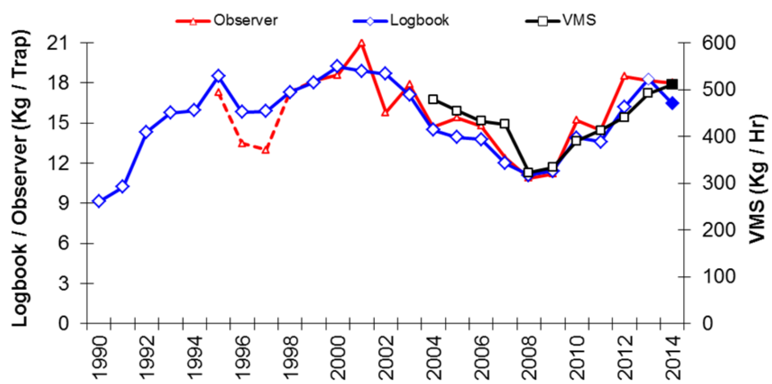


*Figure 22. Trends in Divs. 3LNO offshore commercial CPUE. The observer index is based on at-sea sampling since 1998 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.*

## Biomass

The indices of **exploitable biomass** from post-season trap and trawl surveys diverged during 2009 to 2011 with the trap index increasing and the trawl index declining (Fig. 23). It is believed that the trend in the trap survey index better reflects the trend in the exploitable biomass because it is supported by the increasing fishery performance during that time (Fig. 22). The indices of **exploitable biomass** from spring and fall trawl and trap surveys decreased, to differing degrees, in 2014. The fall trawl survey was complete in Div. 3L in 2014. It showed a decrease in the exploitable biomass index, indicating the sharp decrease in 2014 was not fully attributable to the omission of Divs. 3NO.

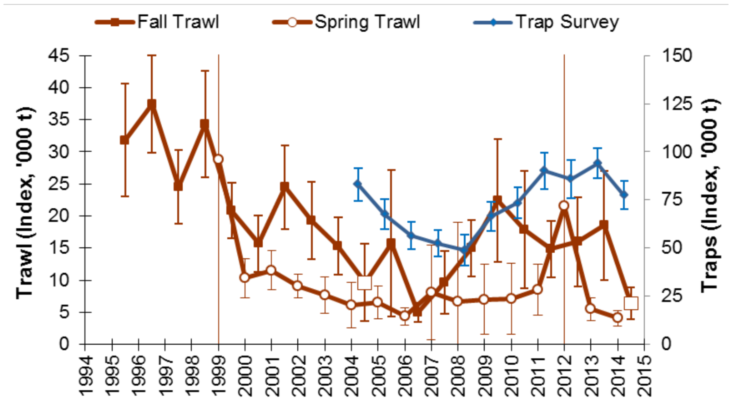


*Figure 23. Trends in the Divs. 3LNO offshore exploitable biomass indices based on spring and fall trawl and trap surveys; the fall trawl survey was incomplete in 2004 and 2014. Error bars are 95% confidence intervals.*

### Recruitment

**Recruitment** has declined since 2012. The biomass index of new-shelled recruits has declined since 2012 in both surveys. **Recruitment** is expected to decline further in the short term (2-3 years). The pre-recruit biomass indices spring and fall trawl and trap surveys have declined since 2010 (Fig. 24).

The emergence of a modal group of small (12-30 mm CW) crabs suggests a modest increase in recruitment in about 8 years. The habitat index has varied considerably over the past 8 years (Fig. 5), introducing uncertainty. However, a warm oceanographic regime suggests low **recruitment** in the **longer term**.

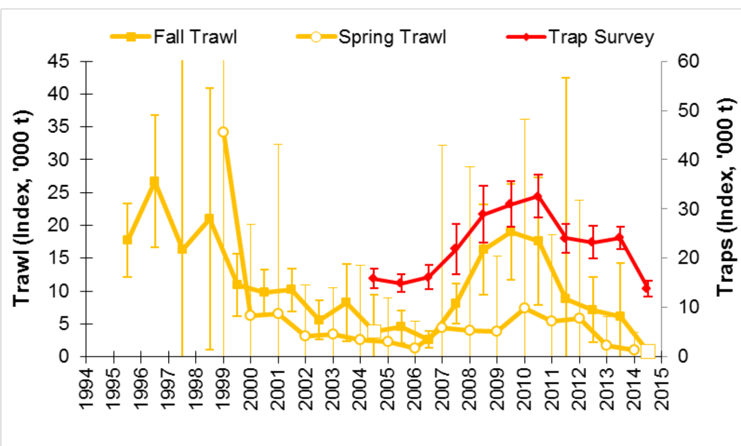


*Figure 24. Trends in Divs. 3LNO offshore pre-recruit biomass indices based on spring and fall trawl and trap surveys; the fall trawl survey was incomplete in 2004 and 2014. Error bars are 95% confidence intervals.*

### Mortality

The **exploitation rate index** has changed little over the last four years (Fig. 25). The **pre-recruit fishing mortality index** has remained relatively low since 2008. The **percentage of the catch released** in the fishery decreased from about 20% in 2008 to 10% in 2013 and 2014.

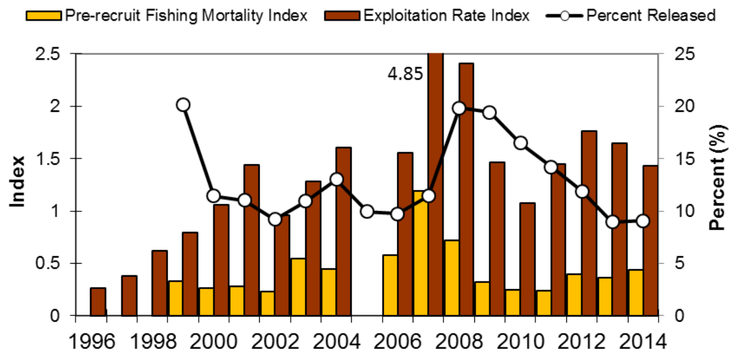


*Figure 25. Trends in the Divs. 3LNO offshore exploitation rate and pre-recruit fishing mortality indices and percentage of the catch released in the fishery. Mortality indices were not calculated for 2005 because the survey was incomplete in 2004.*

# Resource Status, Division 3L Inshore (CMAs 5A, 6A, 6B, 6C, 8A, 9A)

## Commercial Fishery

**Landings** have increased gradually since 2010 to a historical high of 8,000 t in 2014 while overall effort has declined. (Fig. 26).

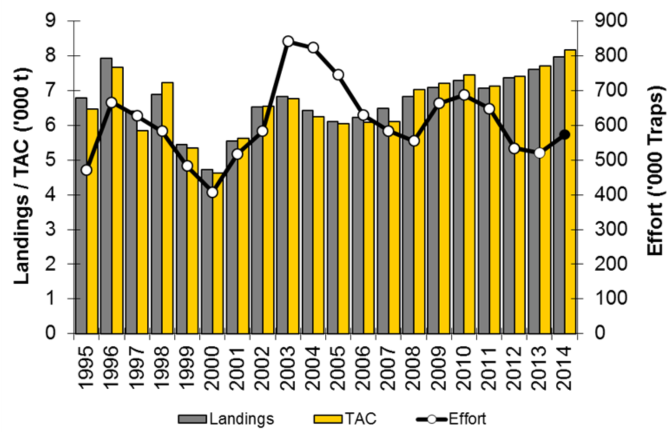


*Figure 26. Trends in TAC, landings, and fishing effort in Div. 3L inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** has been near its highest level for the past three years (Fig. 27) but there has been considerable variability among management areas.

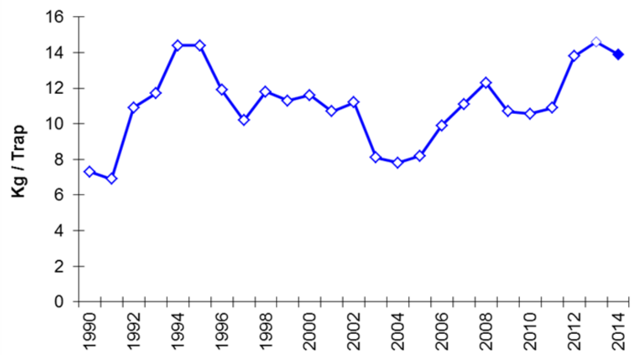


*Figure 27. Trend in Div. 3L inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.*

### Biomass

The post-season trap survey index suggests the overall **exploitable biomass** has increased steadily since 2008 to its highest level in the time series (Fig. 28). Most management areas have experienced increases in recent years.

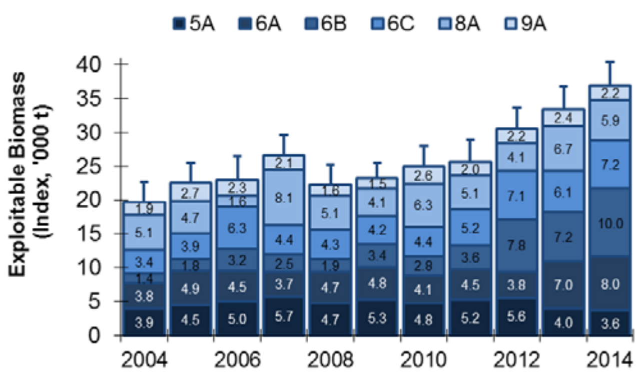


*Figure 28. Exploitable biomass index based on the CPS trap survey in inshore Div. 3L. Error bars are upper 97.5% confidence bounds.*

### Recruitment

**Recruitment** has declined gradually since 2010, although there is considerable variability among management areas. It is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in the past two years (Fig. 29). The **pre-recruit biomass index** in this area is dominated by old-shelled crabs and their proportion has increased in recent years (Fig. 29). It is believed that most of those are terminally-molted and will never contribute to the exploitable biomass.

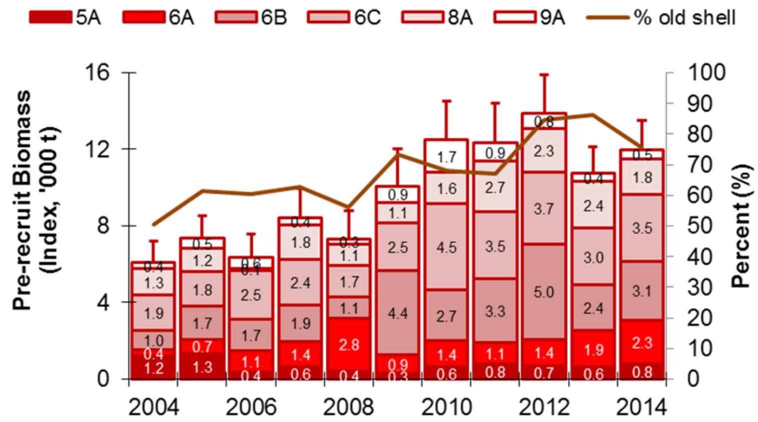


*Figure 29. Pre-recruit biomass index of under-sized crabs from the CPS trap survey in inshore Div. 3L with percentage of sub-legal sized crabs with old shells. Error bars are upper 97.5% confidence bounds.*

### Mortality

The post-season trap survey-based **exploitation rate index** has changed little over the time series, with considerable variability among management areas (Fig. 30). Data are insufficient to estimate a **pre-recruit fishing mortality index**.

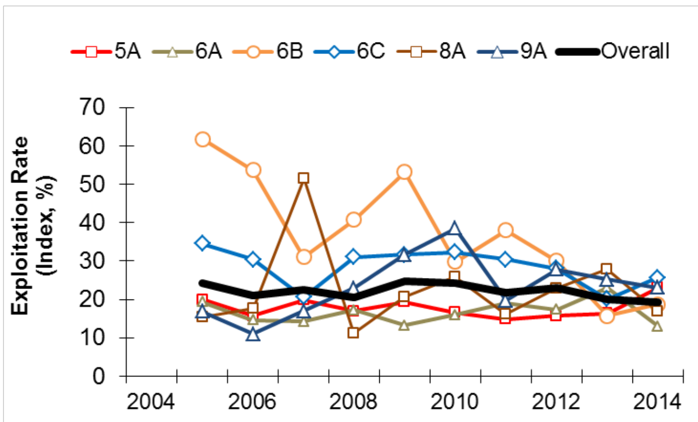


*Figure 30. Exploitation rate index from the CPS trap survey in inshore Div. 3L.*

## Resource Status, Subdivision 3Ps Offshore (CMAs 10BCD, 10X, 11S, 11Sx)

### Commercial Fishery

**Landings** declined from a peak of 4200 t in 2011 to 2700 t in 2014 (Fig. 31). Meanwhile, TACs have not been taken and effort has increased to a record high level.

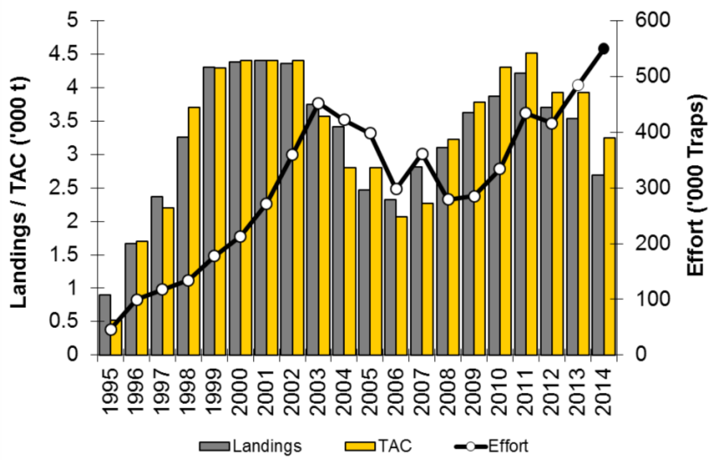


*Figure 31. Trends in TAC, landings, and fishing effort in Subdiv. 3Ps offshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** increased from 2005 to 2009 and has since steadily declined to a record low in 2014 (Fig. 32).

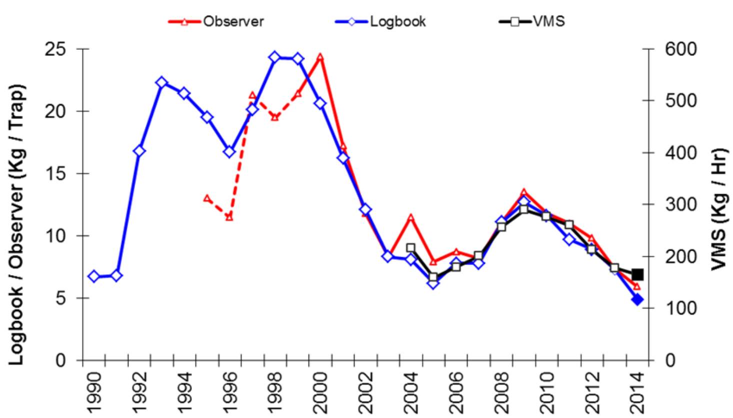


*Figure 32. Trends in Subdiv. 3Ps offshore commercial CPUE. The observer index is based on at-sea sampling since 1999 (solid line) and catch estimates in earlier years (dashed line). The most recent logbook and VMS estimates are preliminary due to incomplete data.*

### Biomass

The **exploitable biomass**, as indicated by the spring trawl and fall trap survey indices, has been at its lowest level during the past two years (Fig. 33).

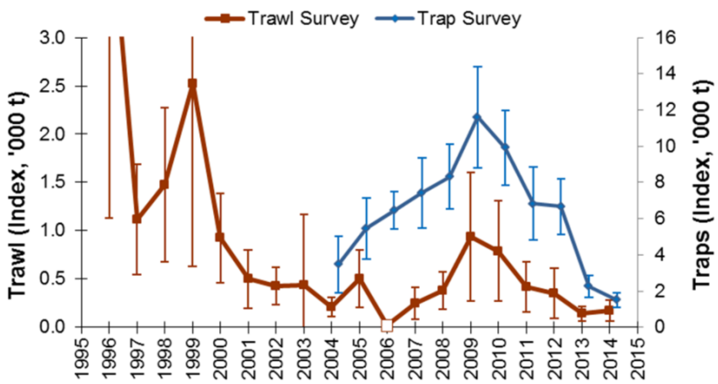


*Figure 33. Trends in the Subdiv. 3Ps offshore exploitable biomass indices from the pre-season trawl survey and the post-season trap survey; the trawl survey was incomplete in 2006. Error bars are 95% confidence intervals.*

## Recruitment

Both trap and trawl surveys indicate that **recruitment** has declined since 2009. Recruitment is expected to remain low in the short term (2-3 years) as pre-recruit biomass indices from both trap and trawl surveys declined rapidly from 2009 to their lowest levels in 2013-2014. (Fig. 34). However, an abundance index of intermediate-sized crabs (about 40-70 mm CW) from the post-season trap survey small-meshed traps suggests improved recruitment thereafter. The habitat index has been variable for the past two decades (Fig. 5); therefore, **longer-term recruitment** prospects are uncertain.

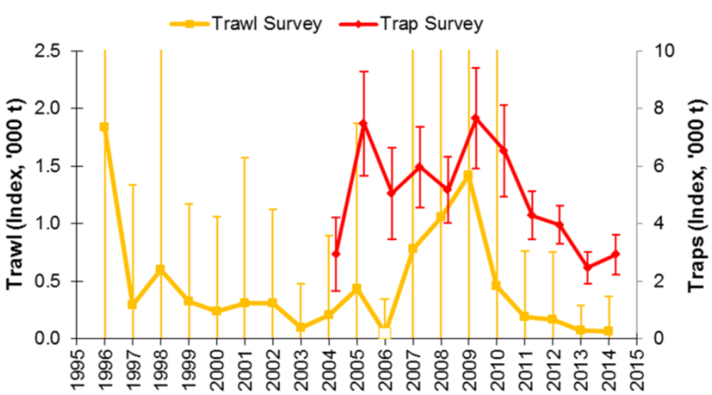


*Figure 34. Trends in the pre-recruit biomass indices from the pre-season trawl survey and the post-season trap survey in Subdiv. 3Ps offshore; the trawl survey was incomplete in 2006. Error bars are 95% confidence intervals.*

## Mortality

The spring trawl survey-based **exploitation rate index** has been at or near its highest level during the past two years. The **pre-recruit fishing mortality index** has increased steadily since 2010 to its highest level in 2014 (Fig. 35). The **percentage of the catch released** in the fishery has varied near 25% since 2008 (Fig. 35).

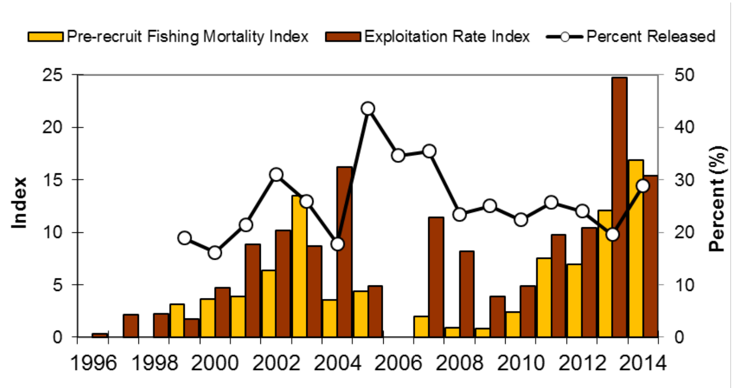


*Figure 35. Trends in the Subdiv. 3Ps offshore exploitation rate and pre-recruit fishing mortality indices and percentage of the catch released in the fishery. Mortality indices were not calculated for 2006 because the survey was incomplete in that year.*

# Resource Status, Subdivision 3Ps Inshore (CMAs 10A, 11E, 11W)

## Commercial Fishery

**Landings** remained at 2,500 t from 2011-13 but decreased to 2,200 t in 2014. Effort has increased steadily since 2010 (Fig. 36).

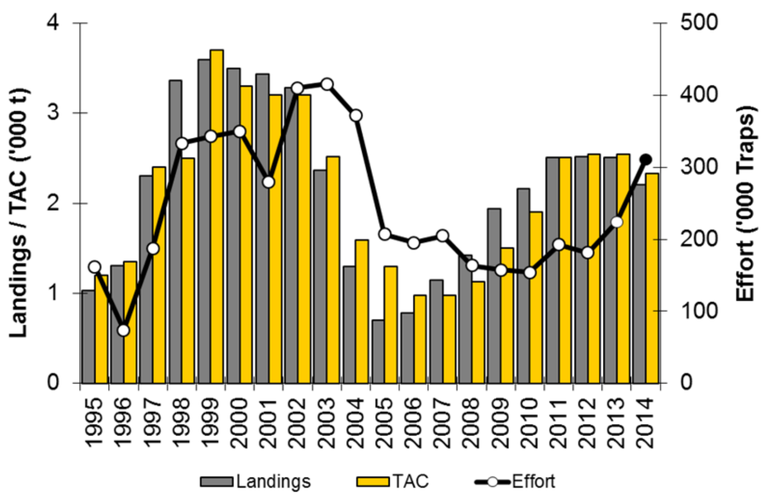


*Figure 36. Trends in TAC, landings, and fishing effort in Subdiv. 3Ps inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** remained at a high level from 2010-12 but has declined sharply in the past two years. (Fig. 37).

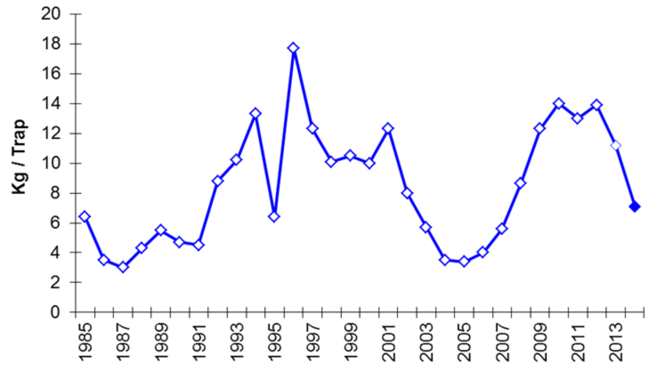


*Figure 37. Trend in Subdiv. 3Ps inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.*

## Biomass

The **exploitable biomass,** as indicated by the post-season trap survey index, declined since 2012 to its lowest level in eight years (Fig. 38). Most of the biomass is in Placentia Bay (CMA 10A).

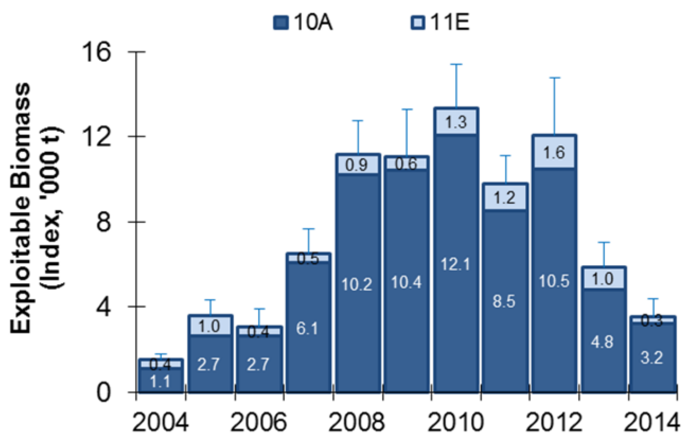


*Figure 38. Exploitable biomass index based on the CPS trap survey in inshore Subdiv. 3Ps. Error bars are upper 97.5% confidence bounds.*

## Recruitment

**Recruitment** declined substantially in the past two years to its lowest level and is expected to remain low for at least 2-3 years. The **pre-recruit biomass** index declined by more than half from 2007-11 and has since changed little (Fig. 39). The pre-recruit biomass index includes a high and increasing proportion of small adults in this area that will never recruit to the fishery.

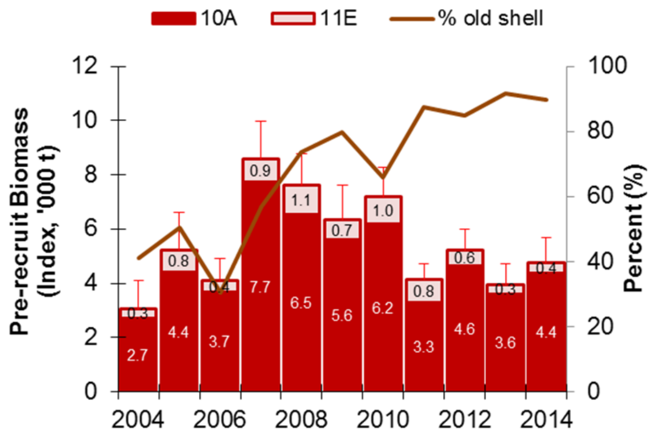


*Figure 39. Pre-recruit biomass index of under-sized crabs from the CPS trap survey in inshore Subdiv. 3Ps with percentage of sub-legal-sized crabs with old shells. Error bars are upper 97.5% confidence bounds.*

### Mortality

The post-season trap survey-based **exploitation rate index** changed little from 2008-13 but nearly doubled in 2014 (Fig. 40). Data are insufficient to estimate a **pre-recruit fishing mortality index**.

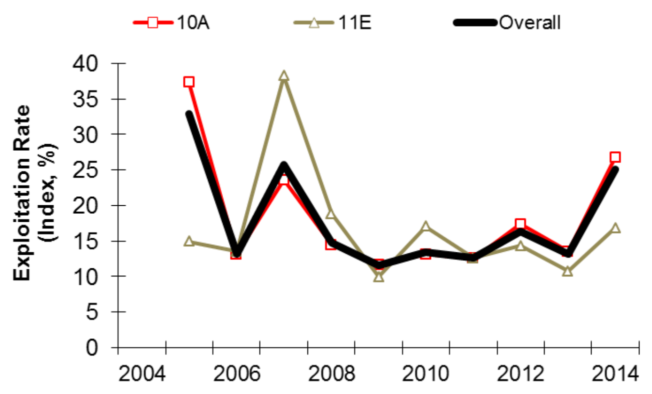


*Figure 40. Exploitation rate index from the CPS trap survey in inshore Subdiv. 3Ps.*

## Resource Status, Division 4R Offshore (CMA OS8)

### Commercial Fishery

**Landings** declined to a historical low of 30 t in 2010 and since increased. **Effort** increased by almost a factor of 7 since 2010 (Fig. 41). The TAC has not been taken since 2002.

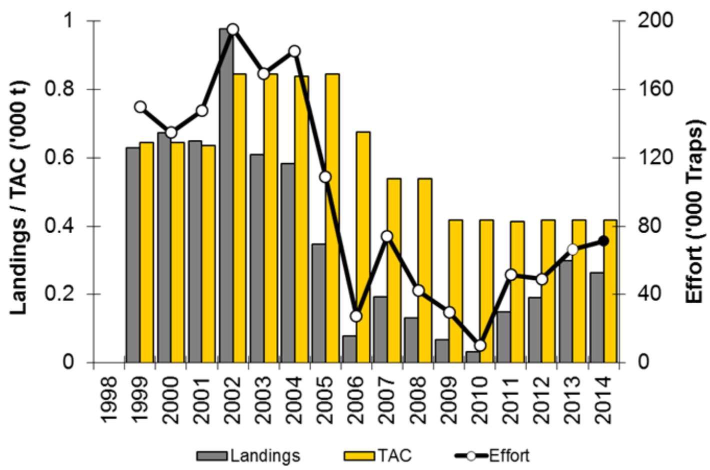


*Figure 41. Trends in TAC, landings, and fishing effort in Div. 4R.The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** has consistently been low relative to other divisions (Fig. 42).

Data are inadequate to assess the resource in this division.

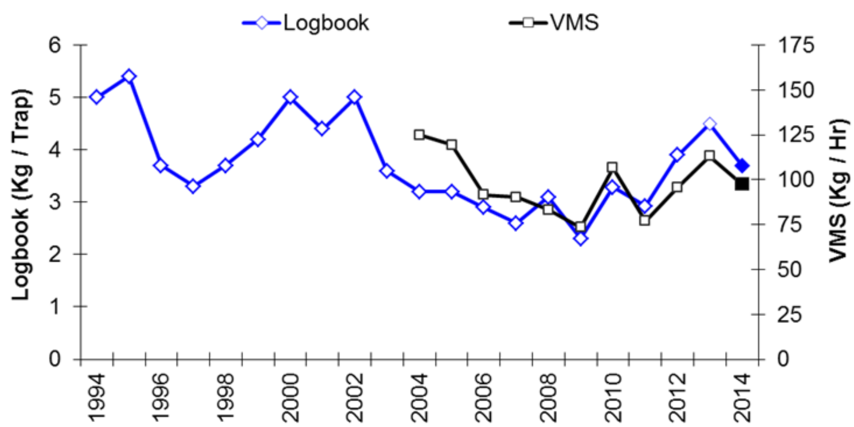


*Figure 42. Trends in Div. 4R offshore commercial CPUE. The most recent estimates are preliminary due to incomplete data.*

## Resource Status, Division 4R Inshore (CMAs 12A, 12B, 12C, 12D, 12E, 12F, 12G, 12H)

### Commercial Fishery

**Landings** have increased from a historical low of 155 t in 2010 to about 600 t in 2013-14. (Fig. 43). **Effort** has been stable for the last three years.

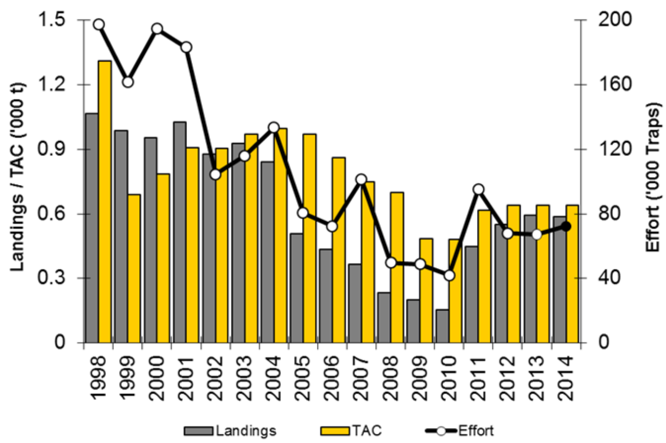


*Figure 43. Trends in TAC, landings, and fishing effort in Div. 4R inshore. The most recent estimate of effort is preliminary due to incomplete logbook data.*

**CPUE** has been near an all-time high for the last three years (Fig. 44).

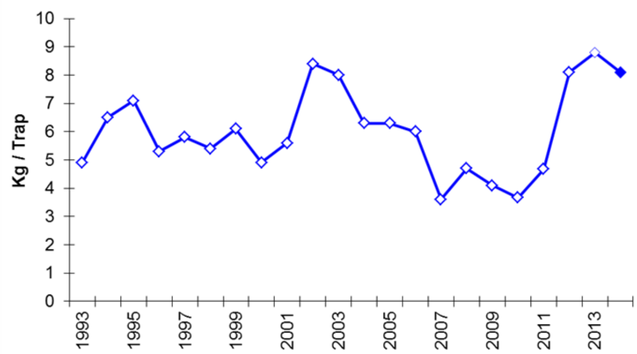


*Figure 44. Trend in Div. 4R inshore commercial logbook CPUE. The most recent estimate is preliminary due to incomplete data.*

The **exploitable biomass** index peaked in 2011 and has since declined to its previous level. (Fig. 45). Recent trends in biomass have been similar among management areas.

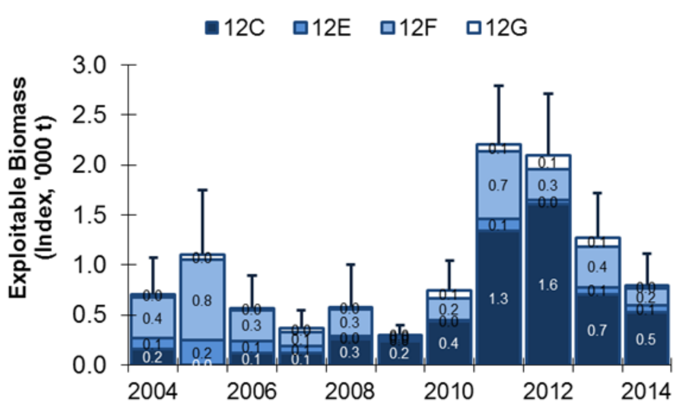


*Figure 45. Exploitable biomass index based on the CPS trap survey in inshore Div. 4R. Error bars are upper 97.5% confidence bounds.*

### Recruitment

**Recruitment** has declined since 2011 to its lowest level and prospects are unfavourable in the short term (2-3 years). The trap survey index of **pre-recruit-sized males** peaked in 2009 and has since declined to its lowest level (Fig. 46). The percentage of sub-legal sized crabs that are old-shelled, and therefore probably terminally molted, increased sharply in 2014.

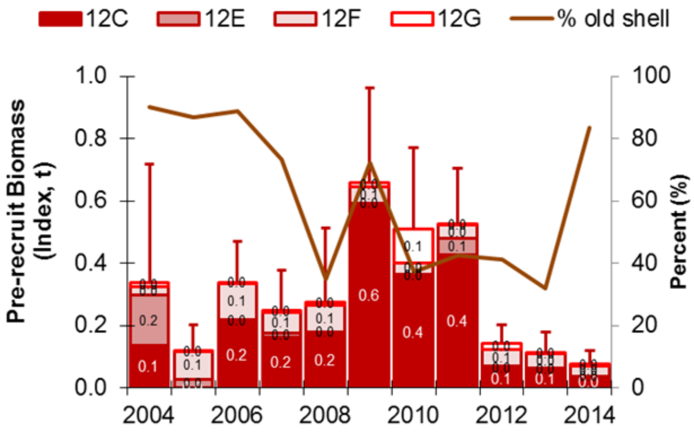


*Figure 46. Trends in the pre-recruit biomass index from the CPS trap survey in inshore Div. 4R, with percentage of sub-legal-sized crabs with old shells. Error bars are upper 97.5% confidence bounds.*

### Mortality

The post-season trap survey-based **exploitation rate index** decreased in 2012 and has since changed little (Fig. 47). However there has been considerable variation among management areas. Data are insufficient to estimate a **pre-recruit fishing mortality index**.

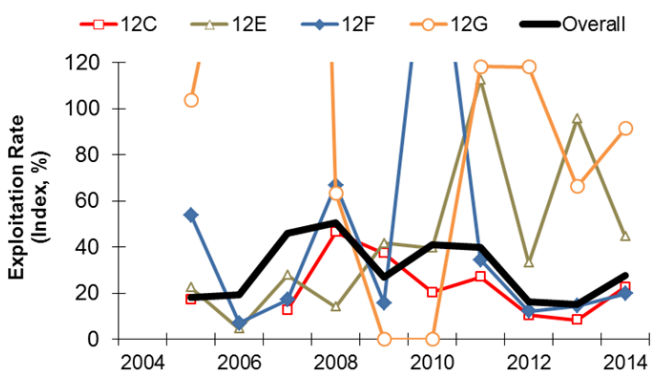


*Figure 47. Exploitation rate index from the CPS trap survey in inshore Div. 4R.*

## Sources of Uncertainty

There are several sources of uncertainty that affect the interpretation of trends in biomass, recruitment, and mortality that represent the basis for this assessment. Uncertainties that affect post-season survey indices are more important than those that affect indices based on fishery performance.

### Surveys

Interpretation of trends in exploitable and pre-recruit biomass indices from surveys is highly uncertain if the survey was incomplete. The multispecies trawl surveys commonly fail to sample inshore areas so they are used only for offshore areas. This introduces considerable uncertainty for all inshore areas because biomass and recruitment indices are available from only one source, the CPS trap survey.

It is difficult to predict recruitment from the trawl survey pre-recruit biomass index because it and the exploitable biomass index trend together rather than at some delay. This is thought to be largely due to annual variation in survey trawl efficiency which likely affects trends in both indices. Trawl efficiency is directly related to substrate type and crab size, and so varies considerably spatially. Efficiency is lower and more variable on hard substrates than on soft substrates. Interpretation of indices from the spring trawl survey in Divs. 3LNOPs is more uncertain than for those from the fall surveys because they occur after a variable fraction of fishery removals.

Exploitable and pre-recruit biomass indices from trap surveys are also affected by annual variation in catchability of crabs. There is uncertainty in interpreting trends in biomass indices from the CPS survey because there is limited spatial coverage. Also, catch rates in this survey may be affected by adverse weather and other factors that affect soak time and trap efficiency. There is concern in Divs. 3LPs where the proportion of males that have terminally molted below the legal size limit has increased in recent years. There is uncertainty in using shell condition as a proxy indicator of terminal-molt status because of great variation in expertise among observers sampling during these surveys and subjectivity in assignment of shell stages.

Small-meshed traps are included in sampling by the CPS trap survey on some stations in most areas to provide an index of future recruitment based on catch rates of sub-legal sized adolescents. However, there is uncertainty associated with very limited spatial coverage by small-meshed traps, especially in shallow-water small-crab habitat, and high variability in trap catchability. Small adolescents may be particularly susceptible to trap catchability effects due to competition with larger and adult males.

### Short-Term Recruitment

Predicting recruitment is complicated by variation in the proportion of pre-recruits that molt in any given year. Molt frequency is inversely related to body size and directly related to temperature such that growth is slower under cold regimes (eg. Divs. 3LNOPs) than under warm regimes (eg. Divs. 2J3K4R). There is increased uncertainty in predicting from the trap-based pre-recruit index because it includes an unknown portion of terminally molted adults. Inferring this portion from the percentage of these sub-legal-sized crabs that are old-shelled is also highly uncertain.

### Long-Term Recruitment Indices

There is high uncertainty in predicting annual biomass or fishery performance from lagged ocean climate indices due to large annual fluctuations in climate indices and demographic responses in the population. There is also uncertainty in the longer term regarding trends in the ocean climate. A trend of recent warming is clearer in the northern areas (Divs. 2J and 3K) than in the southern areas (Divs. 3LNO and Subdiv. 3Ps). Continued long-term warming in all areas is inferred from multi-decadal oscillations in the ocean climate of the entire Atlantic Ocean that, in recent years, are related to changes observed on the NL shelf (Colbourne et al. 2011). However, there is uncertainty regarding whether such long-term oscillations will persist as they have in the past. There is also concern that the biomass indices used for these relationships do not adequately reflect recruitment.

### Fishery Indices

Completion and timely return of logbooks is mandatory in this fishery. Data for the current year is typically incomplete and so the associated CPUE and effort values are potentially biased and considered preliminary. This created especially high uncertainty in the present assessment of Divs. 2HJ because only about half of the logbook data were available. The reliability of the logbook data is suspect with respect to effort (i.e. under-reporting) and areas fished. However, logbook data provide the best index in most inshore areas because VMS data are not available and observer coverage is commonly insufficient. There is uncertainty in interpreting trends from VMS-based CPUE in Div. 2H and Div. 2J because of incomplete coverage of the offshore fishery in those areas. There is further uncertainty regarding the reliability of logbook data in some areas (e.g. Div. 2H and inshore Div. 4R) because of consistently low levels of returns.

There is uncertainty regarding the effects of changes in some fishing practices (e.g. location, seasonality, soak time, trap mesh size, high-grading, and bait efficiency) on commercial catch rates (CPUE) and their interpretation as indicators of trends in exploitable biomass. Some of these changes (e.g. in mesh size and soak time) also affect catch rates of undersized crabs and so can compromise the utility of catch rate of undersized crabs as an index of future recruitment.

There are concerns regarding the utility of the observer data from at-sea sampling during the fishery due to low and spatiotemporally inconsistent coverage, especially in Div. 2H and Div. 4R and all inshore areas. These concerns introduce a strong bias in interpreting trends in catch rates at broad spatial scales; observer data are useful only for some inshore CMAs. Observer-based indices are also biased by inconsistent sampling methods and levels resulting from changing priorities. Inadequate sampling has limited the application of the soft-shell protocol. There are also concerns relating to variability in experience of observers in subjectively assigning shell stages. This introduces uncertainty in inferring recent recruitment trends and prospects based on catch rates of new-shelled crabs.

### Mortality Indices

Indices of fishery-induced mortality are subject to uncertainties associated with both survey and fishery data. Mortality indices are not estimated for years when the associated survey biomass index was not available or reliable. Trawl-based indices are not available for inshore areas. An exploitation rate index is estimated for inshore areas based on the post-season trap survey biomass index. However, this index may be biased by annual changes in the distribution of crabs or fishing effort inside versus outside the limited survey areas. The index of pre-recruit fishing mortality and percent of crabs handled and released are not estimated for inshore areas due to insufficient observer data.

Low and spatiotemporally variable observer coverage introduces high uncertainty in interpreting the effects of the fishery on pre-recruit mortality. There is particular concern that a low level of compliance by harvesters in accommodating observers may introduce bias in estimates of soft-shelled crab prevalence. This concern is especially relevant to areas of high soft-shelled crab prevalence in recent years (i.e. Divs. 2J3K) and it introduces high uncertainty regarding the level of fishery-induced mortality on soft-shelled immediate pre-recruits.

# CONCLUSIONS AND ADVICE

## Divisions 2HJ

**The exploitable biomass** has increased since 2011, as reflected by continued improvement in the post-season trawl survey index. **Recruitment** has increased since 2011. Short-term

(2-3 year) recruitment prospects are uncertain due to variability in the pre-recruit biomass index. **The pre-recruit fishing mortality index** has increased over the past ten years to above the median level. The **exploitation rate index** increased steadily from 2007-12 but decreased to a moderate level in the past two years.

Maintaining the current level of fishery removals would further reduce the exploitation rate in 2015.

## Division 3K Offshore

The post-season trawl and trap survey **exploitable biomass indices** have both declined steadily since 2008 to be at or near their lowest levels. **Recruitment** has been poor since 2009 and is expected to remain low in the short term (2-3) years. The post-season trawl and trap survey pre-recruit biomass indices have both declined since 2008 to their lowest levels. The **pre-recruit fishing mortality index** has varied at a moderate level since 2009.The **exploitation rate index** increased from 2008-10 and has since changed little.

Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2015.

## Division 3K Inshore

The CPS trap surveys indicate that the **exploitable biomass** has remained low in CMAs 3C and 3D in the past 4 years. The DFO trap survey indicates the **exploitable biomass** in CMA 3B has remained high. **Recruitment** has been low during the past 3-4 years in CMAs 3C and 3D. It peaked at its highest level in 2012 in CMA 3B but has since declined. **Recruitment** is expected to remain low in the short term in CMAs 3C and 3D and to continue to decline in CMA 3B. In the last two years, the post-season trap survey-based **exploitation rate index** has changed little in CMA 3D, has declined in 3B and has increased sharply in 3C. Data are insufficient to estimate **the pre-recruit fishing mortality index**.

Maintaining the current level of fishery removals would likely result in little change in the **exploitation rate** overall in 2015 with continued high exploitation in CMA 3C.

## Divisions 3LNO Offshore

The indices of **exploitable biomass** from spring and fall trawl and trap surveys decreased, to differing degrees, in 2014. **Recruitment** has declined since 2012 and is expected to decline further in the short term (2-3 years). The pre-recruit biomass indices spring and fall trawl and trap surveys have declined since 2010. The **exploitation rate index** has changed little over the last four years. The **pre-recruit fishing mortality index** has remained relatively low since 2008.

Maintaining the current level of fishery removals would likely increase the **exploitation rate** in 2015.

## Division 3L Inshore

The post-season trap survey index suggests the overall **exploitable biomass** has increased steadily since 2008 to its highest level in the time series. Most management areas have experienced increases in recent years. Overall **recruitment** has declined gradually since 2010, although there is considerable variability among management areas. **Recruitment** is expected to decline further in the short-term (2-3 years). The post-season trap survey pre-recruit biomass index decreased in the past two years. The post-season trap survey-based **exploitation rate**

**index** has changed little over the time series, with considerable variability among management areas. Data are insufficient to estimate a **pre-recruit fishing mortality index**.

Maintaining the current level of fishery removals would likely decrease the exploitation rate in 2015.

## Subdivision 3Ps Offshore

The **exploitable biomass**, as indicated by the spring trawl and fall trap survey indices, has been at its lowest level during the past two years. Both trap and trawl surveys indicate **recruitment** has declined since 2009. Recruitment is expected to remain low in the short term (2-3 years) as pre-recruit biomass indices from both trap and trawl surveys declined rapidly from 2009 to their lowest levels in 2013-14. However, a small crab abundance index from the post-season trap survey small-meshed traps suggests improved recruitment potential thereafter. **Longer-term recruitment** prospects are uncertain. The **exploitation rate index** has been at or near its highest level during the past two years. The **pre-recruit fishing mortality index** has increased steadily since 2010 to its highest level in 2014.

Maintaining the current level of fishery removals would result in a continued high **exploitation rate** in 2015.

## Subdivision 3Ps Inshore

The **exploitable biomass,** as indicated by the post-season trap survey index, declined since 2012 to its lowest level in eight years. **Recruitment** declined substantially in the past two years to its lowest level and is expected to remain low for at least 2-3 years. The **pre-recruit biomass** index declined by more than half from 2007-11 and has since changed little. The post-season trap survey-based **exploitation rate index** changed little from 2008-13 but nearly doubled in 2014. Data are insufficient to estimate a **pre-recruit fishing mortality index.**

Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2015.

## Division 4R Offshore

Data are insufficient to assess resource status.

The effect of maintaining the current level of removals on the exploitation rate in 2014 is unknown.

## Division 4R Inshore

The **exploitable biomass** index peaked in 2011 and has since declined to its previous level. **Recruitment** has declined since 2011 to its lowest level and prospects are unfavourable in the short term (2-3 years). The trap survey index of **pre-recruit-sized males** peaked in 2009 and has since declined to its lowest level. The post-season trap survey-based **exploitation rate index** decreased in 2012 and has since changed little. Data are insufficient to estimate a **pre-recruit fishing mortality index**.

Maintaining the current level of fishery removals would result in an increase in the **exploitation rate** in 2015.

# OTHER CONSIDERATIONS

## Reproductive Biology

The percentage of mature females carrying full clutches of viable eggs has generally remained high throughout the time series in most areas. However, the abundance of mature females has declined in all areas and have been at very low levels during the past 4 years in most areas. While this is a concern, the implications for Snow Crab production are uncertain. The threshold level of mature female abundance below which larval supply would become limiting is unknown.

Fishery-induced mortality on mature males (including undersized males) may adversely affect insemination of females, especially when abundance of larger adults is low.

## Bitter Crab Disease (BCD)

This disease, which is fatal to crabs, occurs in new-shelled crab of both sexes, appears to be acquired during molting, and can be detected visually during autumn. Fall surveys indicate that it has been most persistent, albeit at low levels, in Div. 3K. Prevalence in small males is directly related to density (Mullowney et al. 2011) and has been low in most recent years throughout Divs. 2J3KL.

## Management Considerations

The development of relationships between biomass indices and ocean climate indices provides the basis for some long-term recruitment prediction. 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 6 to 8 years. However, a warm oceanographic regime (Colbourne et al. 2011) suggests weak recruitment in the longer term.

Reproductive potential is largely protected by conservation measures that exclude females and males smaller than 95 mm CW, including a portion of the adult (large-clawed) males, from the fishery. Therefore, exploitation has been considered to have minimal impact on reproductive potential. However, fishery-induced mortality on small (<95 mm CW) males may adversely affect insemination of females, especially when abundance of larger adults is low. Another concern is that the abundance of mature females has declined to very low levels in most areas, but the implications for future recruitment are unknown.

Fishery-induced mortality on pre-recruits can impair future recruitment. Pre-recruit mortality is reduced by avoidance in the fishery and, when encountered, careful handling and quick release of pre-recruits. Mortality on sub-legal-sized males, including adolescent pre-recruits, can also be reduced by increasing trap mesh size and soak time, as well as trap modifications such as escape mechanisms. Such initiatives have reportedly been increasingly implemented in recent years.

Prevalence of soft-shelled legal-sized males in the fishery is affected by fishery timing and exploitable biomass level. Mortality on soft-shelled males can be minimized by fishing early in spring before recently-molted crabs are capable of climbing into traps. It may be further reduced by maintaining a relatively high exploitable biomass level, thereby maintaining strong competition for baited traps and low catchability of less-competitive soft-shelled immediate pre-recruits.

There is concern that the abundance of immediate pre-recruits appeared to be very low in most areas in 2013-14, as reflected by a low incidence of soft-shelled crabs in the fishery. This is especially concerning in areas where catch rates of crabs released were low despite low levels of exploitable biomass (i.e. Div. 3K).

There is concern for the fate of intermediate-sized adolescents that are expected to begin to recruit to the exploitable biomass in Subdiv. 3Ps in about three years. These crabs could first appear in the fishery as undersized adolescents as early as 2015, and subsequently as soft-shelled immediate pre-recruits. They would likely experience high handling mortality if the exploitable biomass remains low and fishing effort very high. Measures should be taken to minimize that pre-recruit mortality, including restoring the exploitable biomass and greatly reducing effort.

A protocol was introduced in 2005 to protect soft-shelled immediate pre-recruits from handling mortality by closing localized areas (70 sq. na. mi. grids) for the remainder of the season when a threshold level of 20% of the legal-sized catch is reached. It has become evident that this protocol, as implemented, is inappropriate and ineffectual in controlling handling mortality. This is largely due to very low observer coverage, together with the decision to treat unobserved grids as if they had no problem. In addition, failure to draw inferences from samples smaller than the minimum required has frequently resulted in failure to invoke the protocol even when it is clear that the level of soft-shelled crabs has exceeded the threshold. These shortcomings undermine the intent of the protocol. Also, when soft-shelled crab is widespread, grid closures can result in concentration of fishing effort in other areas with high but unobserved prevalence. Measures should be taken to ensure representative observer coverage and analysis so as to better quantify prevalence of soft-shelled crabs in the fishery.

The percentage (by weight) of the total catch handled and released is a function of relative biomasses of pre-recruit and exploitable crabs. This implies a possible management strategy of maximizing yield-per-recruit. For example, reducing the catch (and associated effort) when the percentage released is high may result in greater yield-per-recruit and overall long-term yield if the numbers lost due to pre-recruit mortality exceeds the loss due to natural mortality of exploitable crabs.

## Precautionary Approach

Any credible precautionary approach management system should include information about resource size and renewal rate, or whether a given level of harvest is sustainable. Further, it should be concerned with what might be adjusted to protect or enhance the reproductive potential and the renewal rate.

Total mature male biomass (MMB) may provide an appropriate basis for future reference points, assuming that insemination of females and larval production may be reduced at low MMB. However, there has to date been no such effect, with the percentage of females carrying full clutches of viable eggs remaining high throughout the survey time series. Therefore there is as yet no evidence of harm to reproductive potential and consequently no basis for quantifying reference points.

The Snow Crab fishery imposes virtually no mortality on females and the smallest adult males; one might argue that it is intrinsically conservative and avoids any deleterious effect of fishing on recruitment. ‘Caution’ can then focus on more nuanced considerations such as exploiting large incoming recruitment peaks economically efficiently (avoiding killing them as undersized or soft-shelled, for example).

# SOURCES OF INFORMATION

This Science Advisory Report is from the February 24-26, 2015 regional peer review process on the Newfoundland and Labrador Snow Crab Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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